LEAKAGE TESTING HANDBOOK

Revised Edition

July 1969

Prepared for

LIQUID PROPULSION SECTION
JET PROPULSION LABORATORY
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
PASADENA, CALIFORNIA

CONTRACT NAS 7-396

GENERAL ELECTRIC
RESEARCH AND DEVELOPMENT CENTER
SCHENECTADY, NEW YORK

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FOREWORD

This is a revised edition of the Leakage Testing Handbook originally written by J.W. Marr and issued as NASA Report No. CR-952 in June 1967. Both the original and revised editions have been prepared at the General Electric Company Research and Development Center under National Aeronautics and Space Administration Contract No. NAS7-396, between the Jet Propulsion Laboratory and the Missile and Space Division of the General Electric Company.

The work of revising and updating the Leakage Testing Handbook was performed by Dr. Philip H. Peters, Project Manager, and Mr. Everett E. Stone and Mr. A.J.Bialous, members of the engineering staff of the General Electric Research and Development Center.

The NASA Project Manager is Mr. F.E. Compitello, Code RPL, Liquid Propulsion Technology, Office of Advanced Research and Technology. The NASA Technical Manager is Mr. R.S. Weiner, Liquid Propulsion Section, Jet Propulsion Laboratory.

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Section 1

INTRODUCTION

Section 1

INTRODUCTION

1.1 BACKGROUND

Systems which contain liquid or gaseous fluids vary widely in size, complexity, function, and application. At some point in manufacture, there is concern about the degree to which a system is free of paths through which fluid leakage could occur. Methods and procedures must then be chosen or devised for testing for leakage, taking into account the amount of leakage that can be tolerated, the levels of working pressure which will prevail on the faces of container boundaries, and the means by which leaks may be located once they are sensed. Numerous methods are available for detecting, measuring, and locating fluid leakage across a containing boundary. Often only a few of these methods are applicable for testing an apparatus in a given situation after factors such as sensitivity of the test, time required to perform the test, and the cost, weight, and size of testing equipment are considered. It is desirable to specify in advance the maximum allowable leakage rate and the methods and procedures which should be followed in performing leakage testing.

Usually a manufacturer of equipment must develop standards and procedures for measuring fluid leakage which are appropriate to the particular type of equipment he manufactures and to the application in which the equipment is used. He may decide to include a listing of his specifications with the operating instructions for testing the system or unit before it is placed in use. Several military agencies and a few industrial groups have developed specific methods and procedures for performing leakage tests. Societies such as the American Society for Testing and Materials (ASTM), the Society for Nondestructive Testing (SNT), and the American Vacuum Society (AVS) either have established or are in the process of establishing standards for qualifying testing methods and procedures. More is said about this subject in Section 7, "Some Guidelines for Writing Specifications."

When a purchaser of an equipment places leakage test specifications in his requisition he may not be fully acquainted with the details of the method and procedures which he is in effect asking the supplier of the equipment to follow. As a result his specifications can easily be impracticable if not inordinately expensive to guarantee. To offset a high testing cost the purchaser can take advantage of statistical sampling techniques, where applicable,to reduce the number of units which actually need to be tested.

In any event, it is not uncommon to specify maximum allowable leakage rates which are unnecessarily low and require high test sensitivities. Subsequently the manufacturer is asked to prove that the specified sensitivity is in fact present in his test instruments. Serious problems can arise in obtaining acceptance of equipment by the purchaser under these circumstances. Programs may be slowed or brought to a halt until the specifications are met or until a new agreement is reached which reflects a more thorough appraisal of the level of allowable leakage and the sensitivity which is required to achieve an acceptable level of test accuracy. More importantly, if test sensitivity is inadequately prescribed, leakage of such magnitude may be found in a terminal test that the equipment must be scrapped or completely rebuilt. Potential hazards to personnel may also arise.

1.2 SCOPE

This handbook has been written to unify and consolidate information and, hopefully, to prevent discrepancies in understanding which can develop between the person preparing a specification and the one responsible for complying with it. It is expected to serve as a reference to persons who design equipment and write specifications, as well as to those who perform the leakage tests.

The book covers fundamental concepts of leakage testing, leakage phenomena often encountered during testing, and testing methods.

This handbook is divided into three parts:

- Part I (Sections 1 through 7) describes the fundamental concepts and theories of leakage testing.
- Part II (Sections 8 through 23) describes methods of leakage testing, their limitations, sensitivities, and use.
- Part III is a comprehensive review of leak detectors which are commercially available in the world market. Characteristics and sources of each equipment have been compiled and are presented in tabular form on individual data pages. Contributions from 128 vendors are included. Twenty-nine different principles of measurement are being used by these vendors. Several cross-indexing tables have been developed to serve as guides to information concerning specific types of leak detecting equipment and their manufacturers.

The reader desiring to become familiar with leakage testing can study Part I of the book to gain an understanding of the general subject, and can then select individual sections of Part II for the various methods which are appropriate to his application. He can refer to Part III to learn about equipment which is currently available for performing leakage tests.

1.3 LEAKAGE TEST CATEGORIES

Leakage testing can be divided into three categories:

- Leakage measurement
- Leak location
- Leakage monitoring

Leakage measurement is the measurement of the total leakage of a system or subsystem; it is the only method which reliably determines that a leak exists.

Leakage location is the procedure of pinpointing the precise locations of individual leaks.

It is extremely important that leakage measurement techniques and leak location techniques not be interchanged indiscriminately. In testing a system, the most reliable sequence is the measurement of total leakage and then, if necessary, the location of individual leaks.

Leakage monitoring is the continuous measurement of contaminants entering or leaving an enclosed system. The major distinction between leakage monitoring and the other two leakage testing techniques is that monitoring is usually performed over extremely long periods of time during system storage or operation. Leakage monitoring equipment differs from the equipment used for leak detection in that it usually consumes less power and is designed to operate stably over long periods of time. Many of the instruments used for leakage measurement may be adapted for continuous use.

Section 2

REASONS FOR LEAKAGE TESTING

Section 2

REASONS FOR LEAKAGE TESTING

Rapid, nondestructive methods for the detection of gas and liquid leakage in sealed systems are of great industrial and military importance. The operational reliability of such systems is greatly increased when considerable attention is paid to the leakage testing of individual components as well as that of the final assembly.

Leakage testing is performed for three basic reasons:

1. To prevent material loss by leakage.
2. To prevent contamination, creation of hazardous conditions, or disfigurement by leakage.
3. To detect faulty components and control the reliability of the product (Ref. 2-1).

2.1 MATERIAL LOSS

The first consideration in specifying the leak-tightness of a system is that the system must not leak sufficient material to cause system failure during its useful life. The allowable leakage rate is simply the allowable total leakage divided by the useful life of the system.

Material leakage can constitute a hazard to personnel during system operation. Tolerable concentrations must be known or established. These are often reported in the literature (Ref. 2-2). The maximum tolerable equipment leakage can be calculated from given allowable concentration, taking into account effects of dilution, ventilation, etc.

2.2 CONTAMINATION

Contamination of a system may be caused by material leaking either into or out of the system. For example, damage may be caused in the system of a liquid rocket motor when the oxidizer leaks out of the storage tank and reacts with parts of the motor. Electronic components may fail when air or water vapor enters a sealed protective container. Often very small amounts of material can cause contamination failure; it thus becomes difficult to predict accurately the conditions under which a failure may occur. In any event, if some decision can be made as to the amount of reaction product which may be allowed to develop between an oxidizer and part of a rocket engine, a total amount of leakage and an allowable leakage per unit time can be designated.

Again, failure of a sealed semiconductor component usually follows when a monolayer of water vapor, corresponding to 10^{15} molecules per square centimeter, has been absorbed on the surface of the semiconductor (p. 381, Ref. 2-3). An allowable leakage rate for such a component can be calculated in terms of the maximum life time which is required of the component for a given mission. If failure results from a pressure rise, then the maximum allowable pressure, the planned system operating time, and the system volume are all that are necessary for calculating the allowable leakage rate. Neilson (Ref. 2-4) has demonstrated such a method for calculating the allowable leakage into small sealed electronic components.

Appearance may often be a factor in setting a leakage specification, since leakage which spoils appearance eventually may lead to a failure of the equipment or otherwise render the equipment less acceptable for use. Rusting or corrosion of the external surfaces of valves, fittings, piping, panel-mounted switches, and nameplates are examples where loss of appearance affects utility and safety.

2.3 LEAKAGE AND RELIABILITY

Leakage testing may be employed to assess the reliability of a system by pinpointing sources of fluid leakage in the system and its components which may later affect the operation of the system deleteriously.

High values of leakage where none is expected can serve to identify errors of installation, such as the improper alignment or absence of a gasket. Such errors generally result in leakage rates of 10^{-2} to 10^{-5} atmosphere-cubic centimeters per second. Of course, the absence of high leakage does not necessarily indicate that a connection has been properly made. Leak-tightness can be obtained with misaligned parts as well; however, if parts are misaligned, leakage is likely to occur.

Many leaks are caused by material flaws such as cracks and fissures. Some of these flaws can be detected by leakage measurement. Even more can be detected by x-rays. But neither technique will detect all flaws. Leak detection is therefore complementary to other detection techniques in finding basic material flaws.

Occasionally it is desirable to locate very small leaks, below 10^{-7} atm-cc/sec. Such leaks, if they remain small, would not be objectionable in an equipment. However, operating stresses can cause the size of a leak path to increase with time, and leaks which are negligibly small at room temperature will enlarge if the component in which the leak path exists must eventually operate at a high temperature. Temperature cycling can cause permanent enlargement of a leak path which is initially very small.

The reliability of a system may be thought of in terms of the maximum rate of leakage which can be tolerated from or into that system. Test procedures are designed to determine that the leakage rate is in fact no greater than this maximum value. A system or component is deemed unreliable if testing shows that the leakage exceeds this level. The sensitivity of the test needs to be only high enough to measure leakage rates between one-fourth and one-half of the leakage reliability level.

2.4 SENSITIVITY

In specifying a leakage test, a procedure with an optimum sensitivity value in the correct leakage range should be chosen. Large deviations from this optimum value increase the time and the difficulty of performing the measurement. Any increase in the sensitivity specified for a particular test automatically increases the cost of testing. Therefore, a compromise has to be reached between testing cost and leakage tolerance.

For example, if a leakage rate of 10^{-4} atm-cc/sec is allowable in an equipment, it is unnecessary to perform a test sensitive to much less than that value, even though the actual leakage rate of the equipment is in fact well below 10^{-4} atm-cc/sec. The chief concern here is not with the actual leakage rate, but rather with meeting the requirements of the application. From this viewpoint testing costs may be minimized; design of the equipment also can be influenced resulting in the use of lighter weight materials, and in a reduction in weight, size, and cost of manufacture as well.

2.4.1 Optimum Sensitivity Value and Testing Difficulty

The procedure employed with a given method of testing for leakage has an optimum value of sensitivity at which it is most easily used. Deviation from this optimum value makes it more difficult to perform the measurement and decreases confidence in the results. Figure 2-1 is a diagram showing the influence of

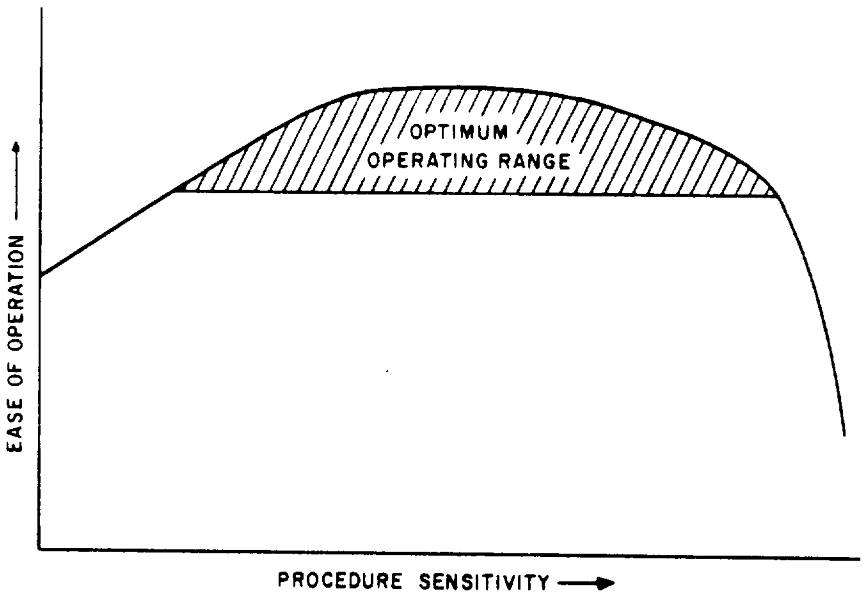


Figure 2-1. Ease of Operation Versus Procedure Sensitivity

increasing sensitivity on the ease of operation of the equipment. In most cases, after reaching a plateau, further increase of sensitivity rapidly decreases the ease of operation.

Bubble testing by immersion in water provides an example of how the optimum value of sensitivity affects the ease of performing the test. This testing method has a sensitivity range between 10^{-1} and 10^{-4} atm-cc/sec. In measuring for 10^{-1} atm-cc/sec leaks, a component may be placed in water and quickly removed. With immersion, bubbles will evolve from the pressurized component at such a rapid rate that there is no question of the existence of a leak. In checking for leaks in the range of 10^{-2} to 10^{-3} atm-cc/sec, care must be taken that the immersed component is submerged long enough for any bubbles coming from around crevices to collect and rise.

In the measurement of leaks near 10^{-4} atm-cc/sec, the component, after being immersed, has to be completely stripped of attached air bubbles so that the formation of bubbles of leaking gas may be detected. The 10^{-4} atm-cc/sec range is near the limit of detectability of this method, although higher sensitivity should result if longer waiting periods are used. If the rate of bubble evolution approaches the rate at which the gas dissolves in the testing fluid, no gas will be seen and the sensitivity will decrease rapidly as will the ease of operation. A somewhat higher sensitivity may be obtained by saturating the liquid with the gas.

Evidently bubble testing becomes exceedingly difficult to employ if a leakage rate much less than 10^{-4} atm-cc/sec is specified. It would be better to change to a test procedure which is more effective at that higher sensitivity. In the same manner, trying to check leaks larger than 10^{-1} atm-cc/sec becomes difficult because of rapid gas evolution and rapid decay of pressure in the system. However, the difficulties in the lower range of sensitivity are usually not so great as in the maximum sensitivity range of the method.

2.4.2 Cost Considerations

The cost of leakage testing increases as the required sensitivity increases. Figure 2-2 illustrates this increase in cost. The investment for a leakage determination of 10^{-3} atm-cc/sec is negligible, perhaps a few dollars for the apparatus involved in a bubble test. The investment for testing at 10^{-12} atm-cc/sec may well be in the order of $50,000. An increase in the sensitivity of a test with a given instrument will result in an increase in measurement cost. Such an increase is usually caused by the additional test complexity. This cost increases more rapidly when the level of sensitivity is located at the right of the sensitivity plateau of Figure 2-1.

2.4.3 Zero Leakage

Nothing made by man can be considered to be absolutely leak-tight. Even in the absence of minute porosity, the permeation of

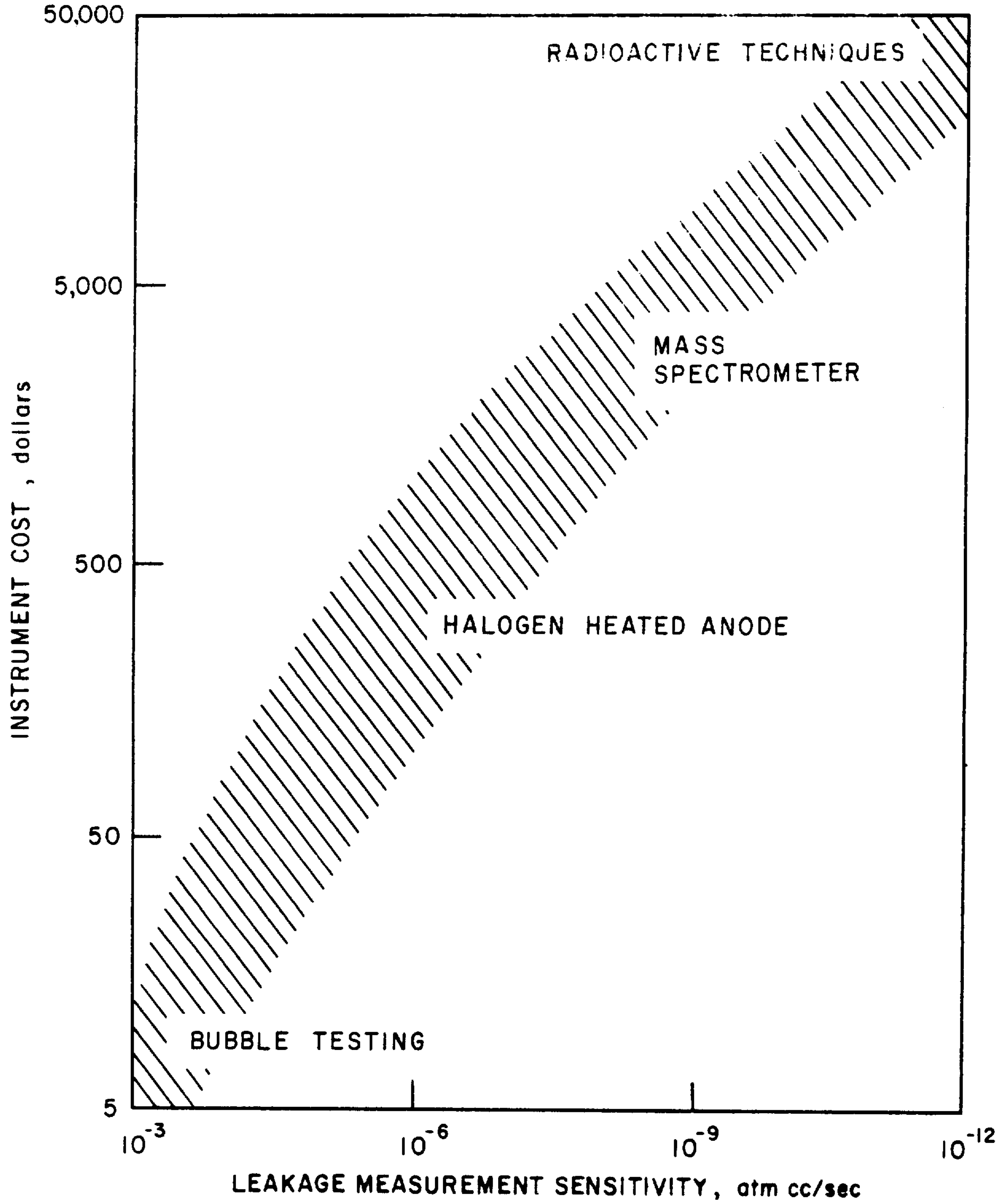


Figure 2-2. Effect of Required Sensitivity on Leak Detection Equipment Cost. (Reprinted from J.W. Marr, "Leakage Phenomenon," Valve Technology Seminar, Midwest Research Institute, Kansas City, Missouri, October 1965.)

certain gases through metals, crystals, polymers, and glasses still occurs. Leak-tightness is, therefore, a relative term. In setting the upper limit on allowable leakage, it is necessary to establish a practical leakage level for any given component under test below which the component may be considered to exhibit leak-tightness. The importance of leakage in the specific type of equipment or component may often be used as a practical guide. Increasing the sensitivity of a testing method brings with it an increase in the time required and the cost of performing a test. Cost reaches a maximum level when the specifications read in one of the following ways:

- No detectable leakage
- No measurable leakage
- No leakage
- Zero leakage

Such specifications are ambiguous and impose an unattainable standard on any type of equipment. Their use is to be avoided.

With specifications such as the above the operator will be continually forced to operate his equipment at maximum sensitivity and will always have to decide whether the signal output is due to system noise and drift or to actual leakage into the detector. In essence, if there is to be no leakage, there can be no signal to detect.

It is much easier to discriminate a leakage signal against a reference signal generated through a leak whose leakage rate is known than it is to discriminate against system noise.

It is therefore suggested that the term "zero leakage" be used only if it is defined as the measurable value of leakage below which the satisfactory operation of the system to be tested is in no way impaired. The Jet Propulsion Laboratory, for example, has used this concept in defining a level for zero <u>liquid</u> leakage into or out of a system in terms of a measurable level of tracer gas leakage (Ref. 2-6).

Section 3

CHOICE OF PROCEDURE FOR LEAKAGE TESTING

Section 3

CHOICE OF PROCEDURE FOR LEAKAGE TESTING

3.1 INTRODUCTION

The method to be used in conducting a leakage test must be chosen with considerable care. A correct choice of method will optimize sensitivity, cost, and reliability of the test.

One way to approach the problem of selecting a preferred method is to rank the various methods which are available for the test according to test sensitivity. Then, one has only to decide what degree is required and choose the method from those offering adequate sensitivity.

It is important to distinguish between the sensitivity associated with the instrument which is to be employed in measuring leakage and the sensitivity of the test procedure which is to be followed in using the instrument. The sensitivity of an instrument influences the sensitivity which can be attained in a specific test. The range of temperatures or pressures and the types of fluids involved influence both the choice of instrument and the choice of test procedure.

Each test procedure may have a different sensitivity. For example, a test utilizing a mass spectrometer leak detector will usually have a sensitivity of 10^{-10} atm-cc/sec when the procedure involves the measurement of a steady-state gas leakage rate. Under special conditions the sensitivity of the test may be increased to 10^{-14} atm-cc/sec by allowing an integration of the leakage to occur in a known volume before a measurement of the leakage is made. Thus, in the first case the sensitivity of the test equals the sensitivity of the instrument, whereas in the second case the sensitivity of the test is ten times greater than that of the instrument. On the other hand, if the test procedure utilizes a mass spectrometer operating in the detector-probe mode, the sensitivity of the test can be 10^2 to 10^4 smaller than that of the spectrometer alone.

Comparison of the sensitivities of any two instruments must be made with one particular type of test situation in mind. If the helium mass spectrometer leak detector is compared with the heated-anode halogen leak detector in detecting the presence of a leak into an evacuated vessel, it will be found that the mass spectrometer is at least 1000 times more sensitive. On the other hand, if these two instruments are both used for locating a leak from a pressurized environment into atmospheric air, the sensitivity of the heated-anode halogen detector is greater by at least a factor of ten. Thus, the manner in which an instrument is employed in a test affects its basic sensitivity and, thereby, the overall sensitivity of the test.

In view of these facts, the choice of the test method and procedure should be made by following a step-by-step process such as that outlined in the chart of Figure 3-1. Note that the numbers assigned to the headings of this section are repeated on the chart for reference purposes.

The chart is entered on the left at "Leakage" with the question: Should this test reveal the presence of a suspected leak (leakage measurement) or show the location of a known leak (leak location)? One then proceeds along the chart according to the features of the particular type of system to be tested in order to select an optimum testing method.

A number of the most commonly used leakage test methods are listed on the chart, showing the range of leakage sensitivity over which each method is applicable.

Any practical leakage testing program will utilize several different leakage test methods, progressing from those with little sensitivity to those of higher sensitivity as the leak-tightness of the object or system is proved. A systematic program must be employed for leakage testing in large complex systems (Ref. 3-2). In general, it is necessary to correct the large leaks before the small leaks can be evaluated. There are special cases, usually mass production items, where it is advantageous to make fine leakage tests prior to the gross leakage tests (Refs. 3-3, 3-4, and 3-5).

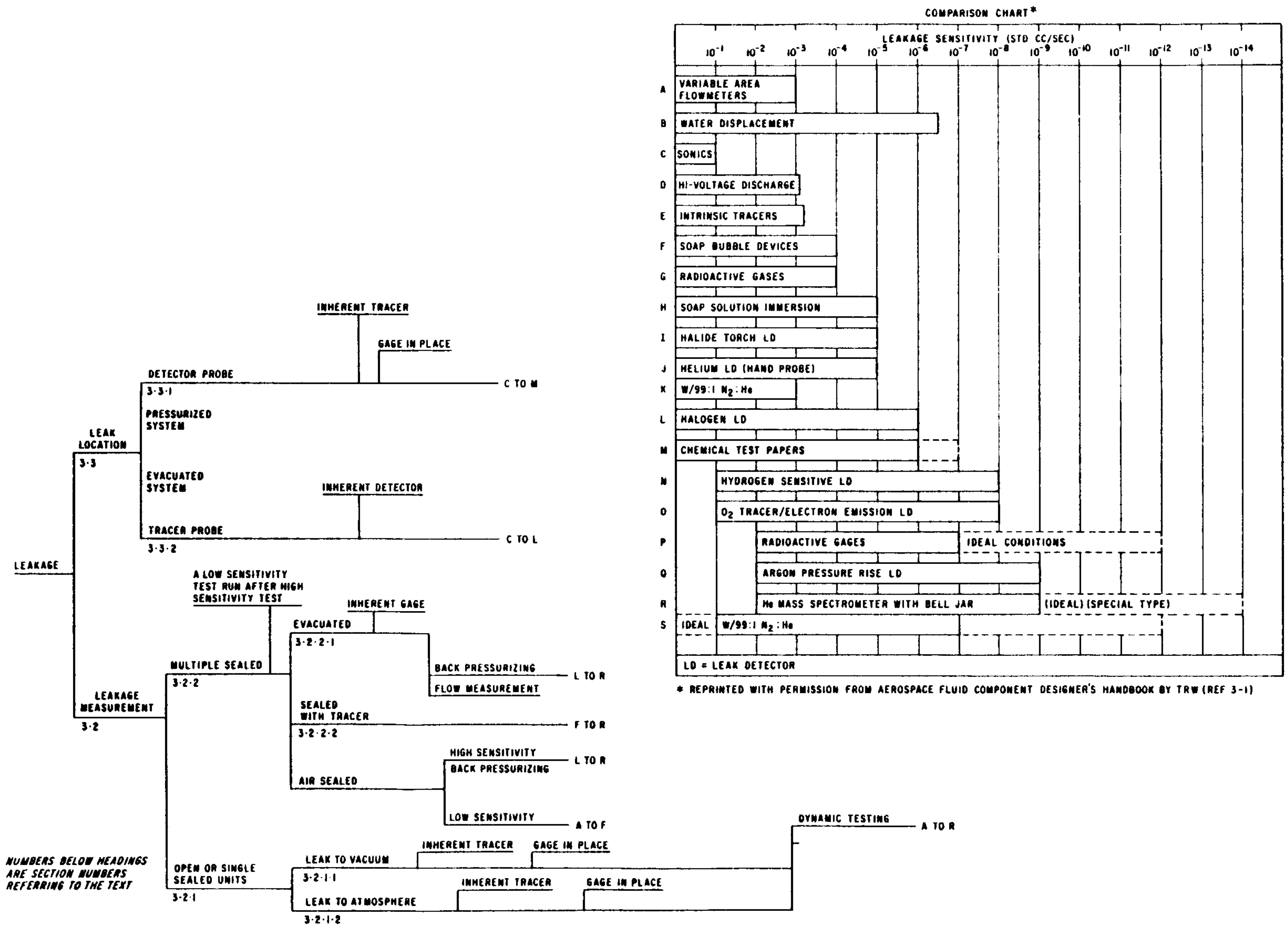
3.2 LEAKAGE MEASUREMENT

The leakage measurement procedure involves covering the whole of the suspected region with tracer gas, and establishing a pressure differential across the system by either pressurizing the tracer gas or evacuating the opposite side. The presence and concentration of tracer gas on the lower-pressure side of the system are then determined and measured.

The objects of leakage measurement fall into two categories: 1) open units which are accessible on both sides, and 2) units which are sealed. The second category usually consists of mass-produced items which are to be tested in large quantities. These include transistors, relays, ordnance units, and instruments.

3.2.1 Units Accessible on Both Sides

Either evacuation or pressurization of one side of a unit which is accessible on both sides may be employed to test for leakage across the unit. If one side is evacuated the tracer gas leakage into the vacuum will reach the detector quickly, since there is essentially no possibility of stratification. However, evacuation does not always allow the most sensitive and reliable measurement. If the evacuation system is extremely large, high pumping speeds will be involved and can often result in a substantial reduction of the amount of tracer gas which



* REPRINTED WITH PERMISSION FROM AEROSPACE FLUID COMPONENT DESIGNER'S HANDBOOK BY TRW (REF 3-1)

Figure 3-1. Typical Step-by-step Procedure for Choice of Leakage Test reaches the detector. Aside from sensitivity, evacuation of one side to low pressure may not be possible if the equipment is not strong enough to withstand the pressure differential.

3.2.1.1 Units Which May Be Evacuated. The first approach to testing units which may be evacuated is to determine whether there is an inherent tracer in the system. Perhaps during normal operation the system contains one of the tracer gases (e.g., helium or halogenated hydrocarbon). If so, the use of a testing method specifically for that gas might be preferred, since considerable savings can be realized if the system need not be filled with a tracer gas.

If no inherent tracer is available, the next approach should be to consider whether there is a gage already present in the system which might be used for leakage measurement. This gage might be simply an ionization gage or, in some fortunate circumstances, a mass spectrometer which is in the system as part of the analytical instrumentation. Not only gages which are normally used for leak detection should be considered: any equipment for detecting gas concentration which happens to be available may be used for leakage measurement. Even equipment not originally intended for pressure measurement may be used. For example, it is possible to detect the pressure rise in a leaking vacuum tube by operating the grid at a positive and the anode at a negative potential, and noting an increase in anode current with time.

If there is not an inherent tracer or gage within the system, then some testing method must be chosen which has the desired sensitivity. In the order of increasing sensitivity for testing an evacuated system, these include: flow measurement, pressure measurement, heated-anode halogen detector, and helium mass spectrometer leak detector.

In most cases, all the possible methods should be considered. A more sensitive procedure may represent a higher initial investment, but will usually provide test results of greater reliability.

Once the method has been chosen, it is necessary to decide on the testing procedure to be followed. Since it is usually preferable to perform the tests in the shortest possible time, a dynamic (steady-state) testing procedure should be tried initially. A static (accumulative) testing procedure of leakage testing yields a higher sensitivity but requires a much longer testing time. In some cases it will be necessary to resort to static testing if the dynamic test fails to reveal any leakage and the desired test sensitivity is above that provided by the dynamic test. For example, leaks in ceramic-to-metal seals may be so small that accumulative testing is required to detect them.

3.2.1.2 Systems Leaking to Atmospheric Pressure. The choice of testing method for systems leaking to atmospheric pressure should be made in the same pattern as suggested for evacuated systems. The first point to be considered is the possibility that there is an inherent tracer in the system. It should then be determined whether a gage exists in the system which may be used to measure pressure or tracer gas concentration. Again, this might not necessarily be the original purpose of the particular gage, but it may be adapted to this use for the leakage measurement.

If a tracer or a pressure monitoring device is not inherent in the unit being tested, then one of the standard methods of making leakage measurements must be employed. These are, in the order of increasing sensitivity: flow measurement, pressure measurement, bubble testing (immersion), and the use of a helium mass spectrometer, infrared analyzer, heated-anode halogen detector, or radioactive tracer. (Note that the helium mass spectrometer method is not the most sensitive when the measurement is to be made at atmospheric pressure.)

Whenever applicable, dynamic testing should be used. Static testing techniques will increase testing time, but they will also increase test sensitivity.

3.2.2 Simultaneous Testing of Sealed Units

Sealed units which are made in large quantities present several specific problems in testing. It is imperative that a large number of units be tested rapidly. It is also imperative that no defective units be allowed to pass.

Most of the testing procedures for sealed units involve partial evacuation. If the leak in the unit is exceptionally large, the tracer gas will escape rapidly from the unit during this partial evacuation. Consequently, high-sensitivity tests will be ineffective since they cannot be usefully employed if the tracer gas has already escaped from the system. It is therefore recommended that all parts be tested for large leaks after the high sensitivity tests that are described below have been conducted. This is because the standard way of performing large-leak testing is by the bubble-testing procedure; and since liquids are involved, smaller leaks can easily become clogged and may not be detected during a subsequent high-sensitivity test.

In the testing of sealed units, applicable testing methods are, in the order of increasing sensitivity: bubble testing, flow measurement, pressure measurement, infrared analyzer, heated-anode halogen detector, helium mass spectrometer, and radioactive tracer. The last four methods are applicable to a back-pressurizing testing procedure.

3.2.2.1 Testing Evacuated Units. With evacuated units the choice of testing procedure is relatively simple. If the system contains a gage which may be used to show the presence of gas contamination, it is the first testing method to be tried. If such a gage does not exist, a flow measurement procedure may be considered. Finally, if this is not sensitive enough, the back-pressurizing procedure must be used. The only other consideration in the choice of a procedure is that, after testing, the units should be passed through a bubble test to locate the exceptionally large leaks.

3.2.2.2 Testing Units Sealed with Tracer Gas. Units sealed with tracer gas may be tested for leakage of the gas out of the unit by dynamic or static precedures. Generally, the partial pressure of tracer gas inside a unit will be higher than it would be if the tracer gas were forced into an evacuated unit through a small leak, as is done in the back-pressurizing procedure. Thus presealing with tracer gas leads to a more sensitive, lower-cost leak test procedure involving fewer steps. As in the case with the other methods a final inspection must be conducted by means of a bubble test procedure to locate exceptionally large leaks.

3.3 LEAKAGE LOCATION

Leakage location can be subdivided into a tracer probe procedure and a detector probe procedure.

The tracer probe procedure is generally used when the system is evacuated and the tracer gas comes from the outside. The detector probe procedure is used when the system is pressurized with tracer gas and testing is done at atmospheric pressure. Usually the tracer probe technique is more rapid because the gas reaches the detector at a higher concentration than with a detector probe. In the detector probe procedure a pressure differential higher than one atmosphere across the system may be used, and therefore leaks of a smaller conductance can be found. In using either procedure it is important that leak location be attempted only after the presence of a leak has been ascertained.

3.3.1 Detector Probe Procedure

In testing a system which is leaking into atmosphere the first consideration is whether or not the leaking fluid may be used as a tracer. This will always be the procedure when using either the sonic method or the bubble-testing method. However, the tracer might be of a composition which will also prove satisfactory for use with the other testing methods. In order of increasing sensitivity these methods of leak location are: chemical testing, gage response, infrared gas analyzer, mass spectrometer, and heated-anode halogen detector.

3.3.2 Tracer Probe Procedure

In the location of leaks in evacuated systems the first item to consider is whether or not there is an inherent detector within the system. This may be a pressure gage of some type or, more desirably, a gage which is specific for a tracer gas which may be used. If such a gage does not exist, the methods to use in the order of increasing sensitivity are: sonic, pressure change gage response, high voltage discharge, heated-anode halogen detector, infrared detector, and mass spectrometer.

These methods must be individually examined to see if their limitations and advantages are suitable to the particular system being tested. Radioactive gases are not generally employed as a tracer for routine leak location because of the hazards associated with their use.

Section 4

TESTING FUNDAMENTALS

NOMENCLATURE FOR SECTION 4

a	Current
C	Conductance
C_A	Conductance of tracer gas
e	Base of natural logarithms
g	Standard gravity
h	Height
K	Multiplication factor
P	Pressure
P_E	Pressure of tracer gas
P_0	Atmospheric pressure
P_1	Upstream pressure
P_2	Downstream pressure
p_0	Initial partial pressure of tracer gas
Q	Leakage rate, pressure-volume per unit time
Q_E	Leakage rate, tracer gas
Q_i	Indicated leakage rate
R_B	Bubble radius
r	Capillary radius
S	Pumping speed, volume per unit time
S_E	Pumping speed, tracer gas
S_d	Pumping speed of detection instrument
t	Time
t_E	Time of exposure to tracer gas

t_R	Residence time after pressurizing
V	Volume
$\overset{\circ}{V}$	Leakage rate, volume per unit time
π	Ratio of length of circumference of a circle to its diameter
ρ	Density
σ	Surface tension
τ	Time constant, volume per unit time

Section 4

TESTING FUNDAMENTALS

The fundamental concepts involved in leakage testing with a tracer gas are presented in this section. These concepts govern the preparation for a particular leakage test and guide in the selection of the necessary testing equipment. For example, the effects on detector sensitivity and response time of the internal volume of a container relative to the internal volume of a leak detector used to measure leakage from that container can be evaluated from the principles set forth in this section.

4.1 DIMENSIONS OF LEAKAGE UNITS

The dimensions of the rate of gas leakage are

$$\frac{\text{Pressure} \times \text{Volume}}{\text{Time}}$$

sometimes written as $P\dot{V}$. The leakage rate is proportional to the mass flow of a given gas at constant temperature. If the nature of the leaking gas and the temperature are known, it is possible to use the formula for an ideal gas to determine the actual mass leakage.

A wide variety of units for leakage are in common use. The units always represent pressure multiplied by volume per unit time.

For example, an operator may have a gas tank whose volume is known in cubic feet. The tank is fitted with a pressure gage calibrated in pounds per square inch. If the gage is read daily, it is convenient for him to express the leakage as the product of the change in pressure which occurs during one day and the cylinder volume. He will then express the leakage as psi-cubic feet per day.

Suppose leakage occurs from the atmosphere into an evacuated chamber and increases the pressure in the chamber. The increase in pressure is determined by the number of molecules entering the chamber. The number of molecules entering the chamber depends not only on the volume flow rate of the gas but also on its pressure. The product of the volume flow rate and the external pressure is equal to the change in pressure inside the system times the system volume. Thus, it is not fully descriptive of the leakage rate to state that so many cubic centimeters per second of a gas are entering the chamber. Unless the entrance pressure is given, it will be assumed to be equal to one atmosphere. On the other hand, the volume of a given mass of liquid is invariant over a very wide range of pressure; hence, liquid leakage may be expressed in terms of volume flow. Considerable confusion can arise in performing calculations if the dimensions of gas and liquid leakage are not clearly set forth.

All equations used in this book express gas leakage rates in volume multiplied by pressure per unit time, and liquid leakage rates in volume per unit time.

4.2 CONVENTIONAL LEAKAGE UNITS

Lists of conventional sets of units used to express leakage rate and factors for converting from one set to another are given in Tables 4-1A and 4-1B. In leakage work, mass flow is usually expressed in atmosphere-cubic centimeters per second (atm-cc/sec) at 25 degrees C.

Sets of units for leakage rate are commonly employed as follows:

1. Military standards are written in atmosphere-cubic centimeters per second.
2. The Atomic Energy Commission specifies leakage rate in standard cubic centimeters per second, defining a standard cc as the volume of a gas at zero degrees centigrade and one atmosphere of pressure.
3. The George C. Marshall Space Flight Center of the National Aeronautics and Space Administration defines leakage rate in units known as SCIMs. A SCIM is a standard cubic inch per minute at one atmosphere pressure.
4. The English term lusec is another unit for leakage rate. A lusec is a micron-liter per second, a micron being defined as 1/1000 torr.
5. The torr-liter per second is in common use in America in preference to the less popular micron-liter per second.
6. Refrigeration servicemen define their leakage specifications in ounces per year of refrigerant. This standard is rational, since refrigeration systems are charged with several ounces of refrigerant and the systems must operate for years. A leakage of an ounce per year of refrigerant is equivalent to a helium leakage of 1.8×10^{-4} atm-cc/sec.

Attempts have been made to initiate a clear, concise and exact form of describing leaks for use in specifications and other documents (Ref. 4-1). Roberts (Ref. 4-2) suggested a nomenclature which eliminates the exponent and units. For example, the designation 2-8G 50-15/2 would signify the following:

2-8 Maximum leak size permitted is 2×10^{-8} atm-cc/sec

G Gas leakage (for liquid leakage: L followed by viscosity in centistokes. Example: L (80), 80 being viscosity of light oil at 20°C)

Table 4-1A

LEAKAGE CONVERSION FACTORS

Torr ℓ/sec	Micron ℓ/sec (lusec)	Atm cc/sec	Psi cc/sec	Torr cu in./sec	Micron cu in./sec	Atm cu in./sec	Psi cu in./sec
1	1×10^{3}	1.316	1.934×10^{1}	6.103×10^{1}	6.103×10^{4}	8.030×10^{-2}	1.180
1×10^{-3}	1	1.316×10^{-3}	1.934×10^{2}	6.103×10^{-2}	6.103×10^{1}	8.030×10^{-5}	1.180×10^{-3}
7.60×10^{-1}	7.600×10^{2}	1	1.470×10^{1}	4.638×10^{1}	4.638×10^{4}	6.103×10^{-2}	8.969×10^{1}
5.171×10^{-2}	5.171×10^{1}	6.805×10^{2}	1	3.156	3.156×10^{3}	4.153×10^{-3}	6.103×10^{-2}
1.638×10^{-2}	1.638×10^{1}	2.156×10^{2}	3.168×10^{1}	1	1×10^{3}	1.316×10^{-3}	1.934×10^{-2}
1.638×10^{-5}	1.638×10^{2}	2.156×10^{-5}	3.168×10^{4}	1×10^{3}	1	1.316×10^{6}	1.934×10^{-5}
1.245×10^{1}	1.245×10^{4}	1.638×10^{1}	2.408×10^{2}	7.60×10^{2}	7.60×10^{5}	1	1.470×10^{1}
8.474×10^{-1}	8.474×10^{2}	1.115	1.638×10^{1}	5.171×10^{1}	5.171×10^{4}	6.805×10^{-2}	1

To change the time base from seconds:

To	Multiply Value by
Minutes	60
Hours	3600
Days	8.640×10^{4}
Weeks	6.048×10^{5}
Months	2.417×10^{6}
Years	3.154×10^{7}

Table 4-1B

LEAKAGE CONVERSION FACTORS (WEIGHT)

Atm - cc	1	1.3	3.7×10^{-20}	2.2×10^{4}	2.2×10^{7}	6.4×10^{5}	1.0×10^{7}
Torr liters	0.76	1	2.8×10^{-20}	1.7×10^{4}	1.7×10^{7}	4.8×10^{5}	7.7×10^{6}
Molecules	2.7×10^{19}	3.5×10^{19}	1	6.0×10^{23}	6.0×10^{26}	$1.7 \quad 10^{25}$	2.7×10^{26}
Gram-moles	4.5×10^{-5}	5.9×10^{-5}	1.7×10^{-24}	1	10^{3}	28	4.5×10^{2}
Kilogram-moles	4.5×10^{-8}	5.9×10^{-8}	1.7×10^{-27}	10^{3}	1	2.8×10^{-2}	0.45
Ounce-moles	1.6×10^{-6}	2.1×10^{-6}	5.9×10^{-26}	3.5×10^{2}	35	1	16
Pound-moles	1.0×10^{-7}	1.3×10^{-7}	3.7×10^{27}	2.2×10^{-3}	2.2	6.3×10^{2}	1

The weight leakages are stated in weight-mole units; i.e., the number of moles of the material expressed in the stated weight units. To obtain the weight of material, multiply the weight-mole by the molecular weight of the material.

The conversions between volume and weight or molecular numbers are made for a gas temperature of 0°C. To convert volume to a weight at any other temperature, multiply result of calculation at 0°C by 273/(273 + T), where T is the temperature in degrees centigrade.

Example:

Convert 5×10^{-4} atm-cc of air at 100°C to grams:

$$(5 \times 10^{-4}) \times (4.5 \times 10^{-5}) \times 29 \times (273/373) = 4.78 \times 10^{-7} \text{Grams}$$

$$(\text{Atm-cc}) \times \frac{(\text{Gram-moles})}{(\text{Atm-cc})} \times (\text{Molecular Weight}) \times (\text{Temperature Correction}) = (\text{Grams})$$

50-15 High-side pressure, psia; and low-side pressure, psia

/2 Maximum accuracy factor of detection method. Here it is required that the demonstrable accuracy of the leak detector -- leak tracer -- leak standard system fall within the range of 1×10^{-8} to 4×10^{-8} atm-cc/sec.

4.3 LEAK CONDUCTANCE

In vacuum technology, a leak is a hole or porosity in the wall of an enclosure capable of passing gas from one side of the wall of the enclosure to the other when a pressure or concentration differential is established across the wall (Ref. 4-3).

Unless a leak is intentionally manufactured in an item, the dimensions of the leak will generally be unknown and indeterminate. As a result, it is not possible to calculate in advance the flow of a fluid through the leak under a given pressure differential. It becomes necessary, rather, to characterize the leak in terms of an extrinsic property known as conductance.

The conductance of a leak is determined by applying a measured differential pressure across the wall in which the leak is located, and measuring the rate at which fluid passes through the leak. The conductance is given by the following ratio between the two measured quantities:

$$C = \frac{Q}{P_1 - P_2} \qquad (4\text{-}1)$$

Thus conductance is the (volume flow rate) times (pressure) per (pressure difference). In a conventional set of units, conductance is measured in atm-cc/sec/atm. Conductance is also the ratio of the volume of a gas that enters a leak at one atmosphere of pressure and exits from that leak to vacuum per unit of time. In this case the dimensions of conductance are volume per unit time, or cubic centimeters per second in the units above.

The conductance is dependent upon the mode in which the fluid flows through the leak, and may often be found to be different at different levels of absolute pressure, especially when the average value of the inlet and outlet pressures in one situation is greatly different from that in another situation A large change in conductance can be observed when the average pressure is close to a transition region between two modes of flow. The transition from laminar to molecular flow with decreasing average pressure is a common instance of a mode change.

It is important to specify the average pressure at which the conductance is measured. In fact it is helpful to measure the flow rate versus differential pressure over the same range of absolute values of pressure which is expected to prevail in the equipment in which the leak is located. An average value of conductance can then be determined from data obtained in this way and any large changes in conductance observed. Changes in conductance due to a change in the area of the cross section of the leak with pressure will be taken into account. An abrupt increase in the cross section at high pressure would abruptly increase the conductance, and would reveal the presence of an incipient leak path which might not be noticed in a test at a lower pressure.

4.4 SENSITIVITY AND TESTING

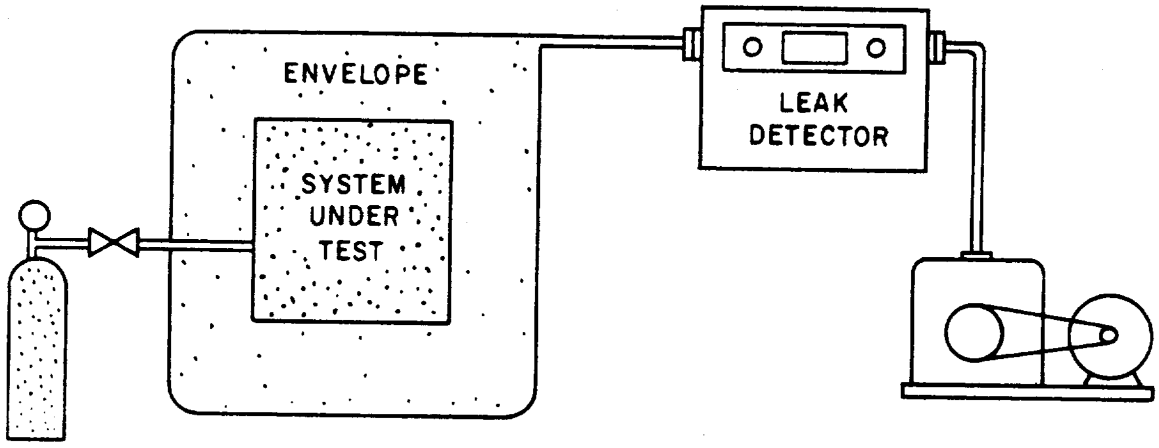
The sensitivity of a detector is determined by the minimum concentration of tracer gas which will produce a measurable signal at the detector. An increase in the pressure of tracer gas applied in the region of a leak will increase the flow of tracer gas through the leak and into the detector. The minimum level of leak conductance which can be detected with a detector of fixed sensitivity will decrease as the pressure of tracer gas at the entrance to the leak is increased. Thus, holes of smaller size can be found if a higher entrance pressure is employed. For example, a small increase in pressure on the detector side of the leak will not affect the sensitivity of a detector of the mass spectrometer type. Factors affecting detector sensitivity are presented in more detail in sections dealing with specific instruments, their operation, and use.

The above brief discussion shows how the sensitivity of a test can be increased by changing a parameter external to the detector. In dynamic (steady-state) testing a pressure increase is effective in increasing test sensitivity. In static (accumulation) testing an increase in testing time accomplishes a similar increase in test sensitivity. In both cases the detector or instrument sensitivity would remain the same.

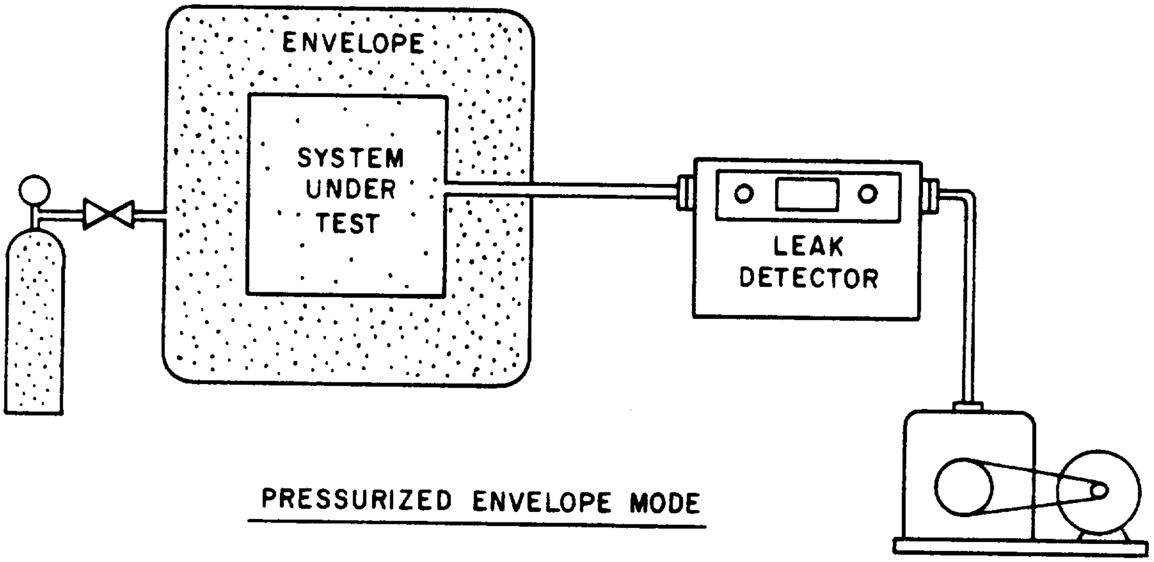
4.5 LEAKAGE MEASUREMENT TESTING

The leakage measurement technique involves a sampling of the total leakage from a closed system or from a region of a closed system which requires leakage testing. Use of the technique results in an indication of a leak if it is present, but not in the identification of particular locations where leakage occurs on the object being tested.

Tests using the leakage measurement technique can be conducted in two ways, as shown in Figure 4-1. By one method, the object to be tested is pressurized with tracer gas and placed inside a closed container, to which a leak detector is attached. The external container may be filled with normal air or any gas other than the tracer gas to which the detector is sensitive. The detector must be of a type operable at or near atmospheric pressure in this case. Alternatively, the container may be evacuated and a vacuum type of instrument employed. Evacuation of the container increases the differential pressure across any leakage path in the wall of the test object by one atmosphere for the same pressure of tracer gas that was used in the first instance



PRESSURIZED SYSTEM MODE



PRESSURIZED ENVELOPE MODE

Figure 4-1. Leakage Measurement Modes Using the Dynamic Testing Technique above. The sensitivity of the vacuum type of detector may be higher than that of the detector operating at atmospheric pressure, with the same differential pressure across the leak.

A second approach is to pressurize the container and evacuate the test object. In this situation a vacuum detector is located in the vacuum line to detect inward leakage from the pressurized container. The tracer gas flows to the detector, where its concentration is measured when equilibrium is established. The equation for the response of the detector is:

$$Q = PS \qquad (4\text{-}2)$$

Here it is assumed that the only gas in the detecting system is tracer gas.

The test sensitivity should be the same for either direction of flow through the leak paths, providing the same levels of absolute pressure and differential pressure of tracer gas are employed. The choice between the above two approaches might be based on the ability of the test object or the container to withstand pressure in one direction in preference to the other, or on the ease with which tracer gas may be applied to one side of the test object.

Some of the factors which affect the sensitivity and responses of the detector when the leakage measurement technique is employed are:

1. Physical properties of the particular tracer gas which is used. These govern the rate at which gas will traverse a leak path.
2. Speed at which tracer gas is removed by the vacuum pump in comparison with the volume of the test object.
3. Sensitivity of the detector for the particular tracer gas used.
4. Position of the tracer sensing element in the pumping system.

It is also possible to test and measure gas leakage from a pressurized test object by building a frame to support a plastic bag or tent which surrounds the test object. The bag is filled initially with atmospheric air (Refs. 4-4 and 4-5). The rate of change of tracer gas concentration is determined on a comparative basis against a known rate of tracer leakage into the bag. The method is especially useful in testing very large objects, perhaps ten to twenty feet high and several feet in diameter. References 4-4 and 4-5 discuss the accuracy of this method of measuring leakage. Measured values are within about 10 percent of the expected values on the basis of tests with calibrated leaks. The method does not appear to be useful for measuring leakage rates less than 10^{-3} atm-cc/sec, but may be entirely adequate in some testing situations. Certainly this level of test sensitivity is comparable with that attainable with bubble testing. The method has none of the disadvantages of bubble testing in that the test object is not wetted or contaminated and a large tank filled with heavy liquid is not required.

4.5.1 Magnitude of Response

The magnitude of the response in the dynamic (steady-state) method is dependent on the sensitivity of the detector to the tracer gas used and the speed at which the gas is removed by the pump. In most cases, where the tracer-gas partial pressure is converted by the instrument to a current which is proportional to pressure, Equation 4-2 can be expressed in the following form:

$$Q = S_d(Ka) \qquad (4\text{-}3)$$

In this form, the product Ka has dimensions of pressure. Instrument sensitivity can be affected by changing either K or a. The multiplication factor K can be increased to a limit generally imposed by electronic instrument noise; a can be increased by increasing the tracer-gas partial pressure within the system through a decreased pumping speed. Thus the sensitivity of the method increases with a decrease in pumping speed. Unfortunately, this increase in sensitivity brings with it a decrease in the speed of response.

There are times, however, when it becomes necessary to employ additional pumps in the evacuation system being used for testing. This is particularly the case when the detector must operate at a low pressure. The additional pumps are necessary to remove gas arising from both leakage and outgassing at a rate sufficient to keep the pressure at the detector at a suitably low level. The manner of connecting an additional pump to the detector system is shown in Figure 4-2. This pump increases the total

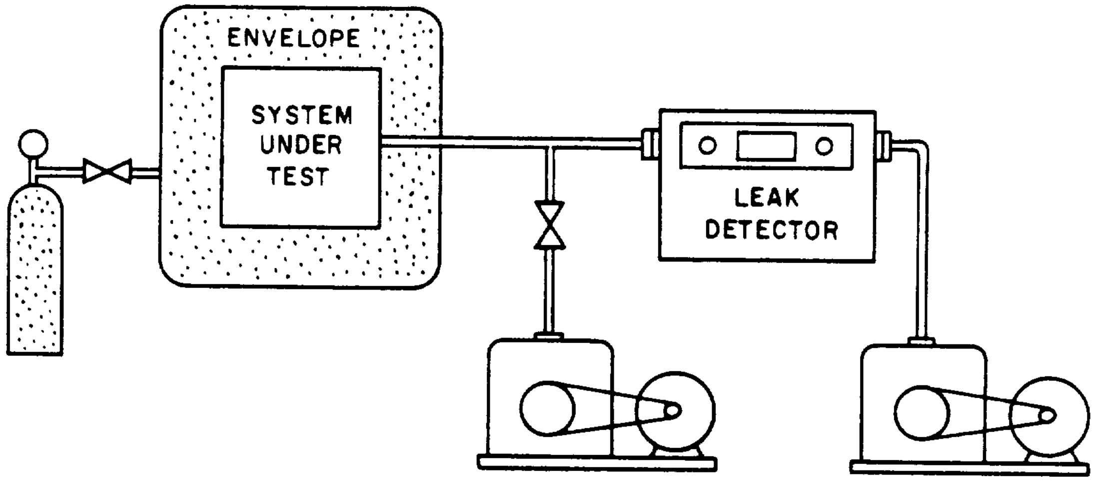


Figure 4-2. Leakage Measurement Involving the Use of an Auxiliary Pump

pumping speed of the system and reduces the partial pressure of the tracer gas at the detector. The sensitivity of the measurement is thereby reduced.

4.5.2 System Response Time

Although the pumping speed of a dynamic leak detecting system determines the magnitude of the response at equilibrium (Equation 4-2), several other factors influence the system response time. System volume is the most important of these factors. The complete subject is discussed in detail in several papers (Refs. 4-6, 4-7, 4-8, and 4-9). The discussion here shows the fundamental points involved.

The response time of a leak detection system may be determined by considering a system with leakage rate of tracer gas Q_E, an evacuated volume, V, and an internal partial pressure of tracer gas P_E. This system is evacuated by external pumps, and a portion of the tracer gas passes through the leak detector (see Figure 4-2). The pumping speed at the outlet of the volume to be tested is called S_E. A mass balance on the system at constant temperature requires that the rate of tracer gas accumulation within the system be equal to the rate of tracer gas leaking into the system, less the rate at which tracer gas is pumped out of the system, or:

$$V \frac{dP_2}{dt} = Q_E - P_E S_E \tag{4-4}$$

When this equation is integrated with the initial condition that at t = 0 the tracer gas partial pressure is p_0, there results:

$$\ell n \frac{Q_E - P_E S_E}{Q_E - p_0 S_E} = - \frac{S_E t}{V} \tag{4-5}$$

or,

$$\frac{Q_E - P_E S_E}{Q_E - p_0 S_E} = e^{-S_E t/V} \tag{4-6}$$

If the pumping speed S is the same for all gases, then $S = S_E$, and the subscript may be omitted.

Two special cases of Equation 4-6 are of interest. First is the case in which the system has been pumped for a long time and the partial pressure of the tracer gas in the system is initially zero ($p_0 = 0$). Equation 4-6 then becomes:

$$P_E = \frac{Q_E}{S} (1 - e^{-St/V}) \tag{4-7}$$

After a long exposure time the exponential term approaches zero, and

$$P_E = Q_E/S \tag{4-8}$$

For example, a leak detector may be pumping on a 10-liter system with a one-liter-per-second pump. The response of such a system is plotted as Curve 1 in Figure 4-3. In ten seconds, the detector responds with 63 percent of the ultimate signal. The equilibrium signal is attained in approximately one minute.

If the system to be pumped is 100 liters, the response time is considerably longer. As seen on Curve 2 of Figure 4-3, in 10 seconds only about 10 percent of the total response is observed. The equilibrium value is not reached for 10 minutes.

Such a response time might not be acceptable for leakage measurement, and is of dubious value for leak location. It is possible to decrease the response time by increasing the pumping speed of the system. In Curve 3 of Figure 4-3, the pumping speed for the 100-liter volume has been increased from one liter per second to five liters per second. This, however, decreases the magnitude of the signal. It may be observed that in this particular case the response rates for Curves 2 and 3 are similar at the beginning of the test.

The second special case of Equation 4-6 is that in which the pumps continue evacuation and gradually reduce the tracer gas concentration in the system. This condition corresponds to $Q_E = 0$ in Equation 4-6. The equation thus becomes:

$$P_E = p_0 e^{-St/V} \tag{4-9}$$

Curves 1 and 3 of Figure 4-3 indicate that the tracer gas is pumped rapidly from the system once it is removed from the vicinity of the leak. However, in Curve 2, the gas remains for a considerable period. The important factor in determining the shapes of these curves is the ratio S/V. The reciprocal quantity V/S, having the dimensions of time, is generally called the time constant of the system, τ. A long time constant results in a large indicated partial pressure change during the probing time. A short time constant permits rapid removal of search gas from the system when probing has ceased.

If the requirements of rapid response and clean-up times are not met, the leak-testing process is delayed to a large and sometimes intolerable extent. As an example, consider the case of a section of weld being probed at a constant rate. If the response is poor, the leakage indication will appear after the probe has moved well beyond the leak, and the path will have to be retraced slowly until a second signal is obtained. The second signal cannot be observed distinctly until the first signal has dropped to a low level. Therefore, the decay or clean-up time is equally as important as the response time.

Once the time constant V/S (volume/pumping speed) of the system has been calculated, and the equilibrium response is known,

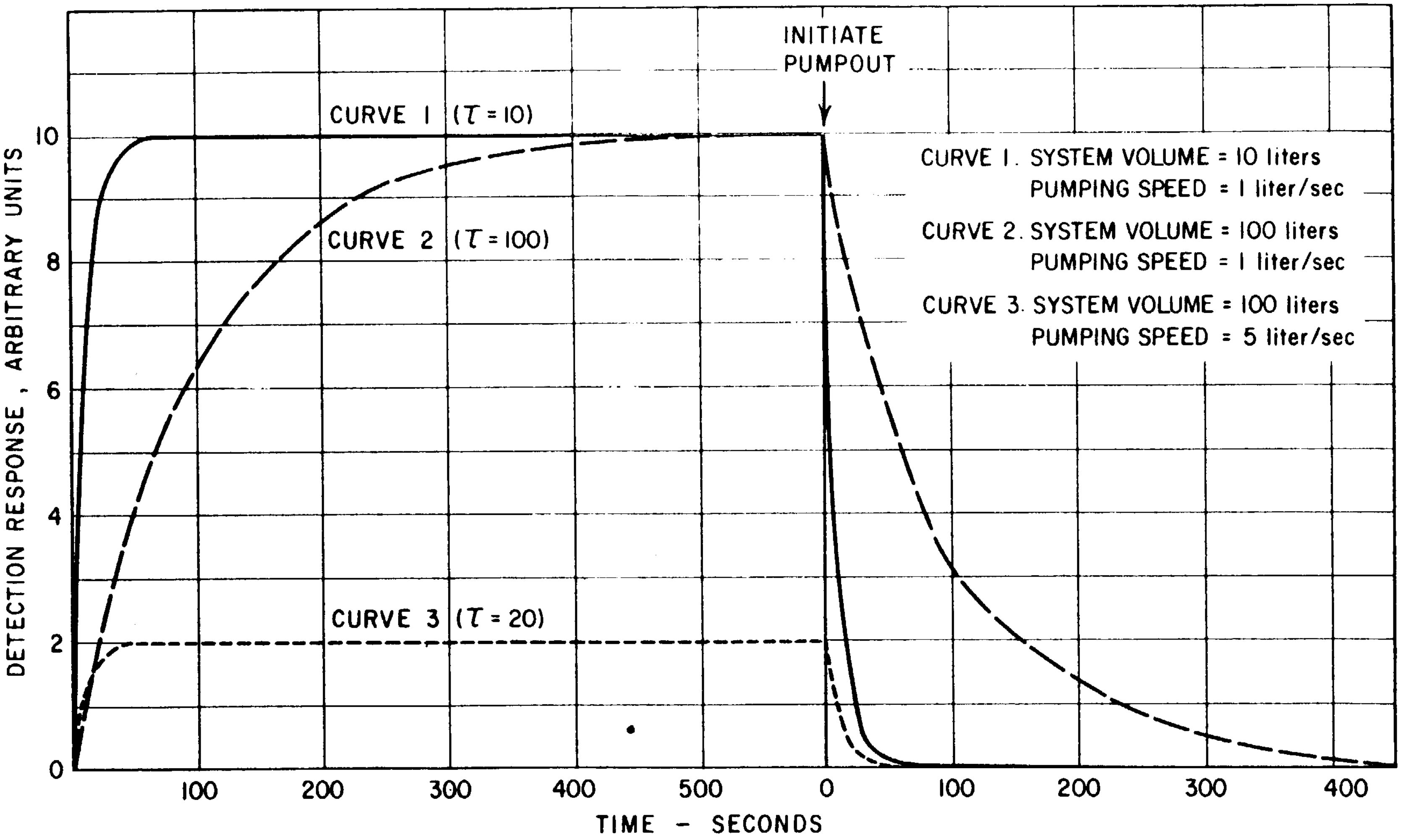


Figure 4-3. System Response Time

it is possible to construct response curves similar to those shown in Figure 4-3. Table 4-2 shows signal response as a percentage of final signal strength for several different time constants.

Table 4-2

SIGNAL RESPONSES AS A PERCENTAGE OF FINAL SIGNAL STRENGTH

	Percent of Final Signal	
Time Constant	Signal Increasing	Signal Decreasing
0.5	39.4	60.6
1	63.2	36.8
2	86.5	13.5
3	95.0	5.0
4	98.2	1.8

The response of the detector in a leak detecting system relative to the equilibrium response may be estimated with the aid of the nomograph shown in Figure 4-4. Pumping speed, system volume, and the time which has elapsed from the moment tracer gas was applied to or removed from the system must be known. The nomograph consists of the following parallel axes:

1. System volume, V
2. Pumping speed, S
3. Reference
4. Elapsed time, T
5. Relative response, Scales A, B, and C

A straight line is drawn connecting the two points representing values of S and T. This line intercepts the Reference axis. A line is then extended from the volume axis at the value of V, through the intercept on the Reference axis, and is terminated on the Response axis. Scale A on the Response axis represents the number of elapsed time constants before the signal is read. Scale B represents the response relative to the equilibrium signal after the tracer gas has been removed. Scale C represents the response relative to the equilibrium signal after the tracer gas has been applied. The utility of the nomograph can be extended to any range of values by multiplying only the V, S, and T values by ten raised to an appropriate power. The response axis need not be so modified.

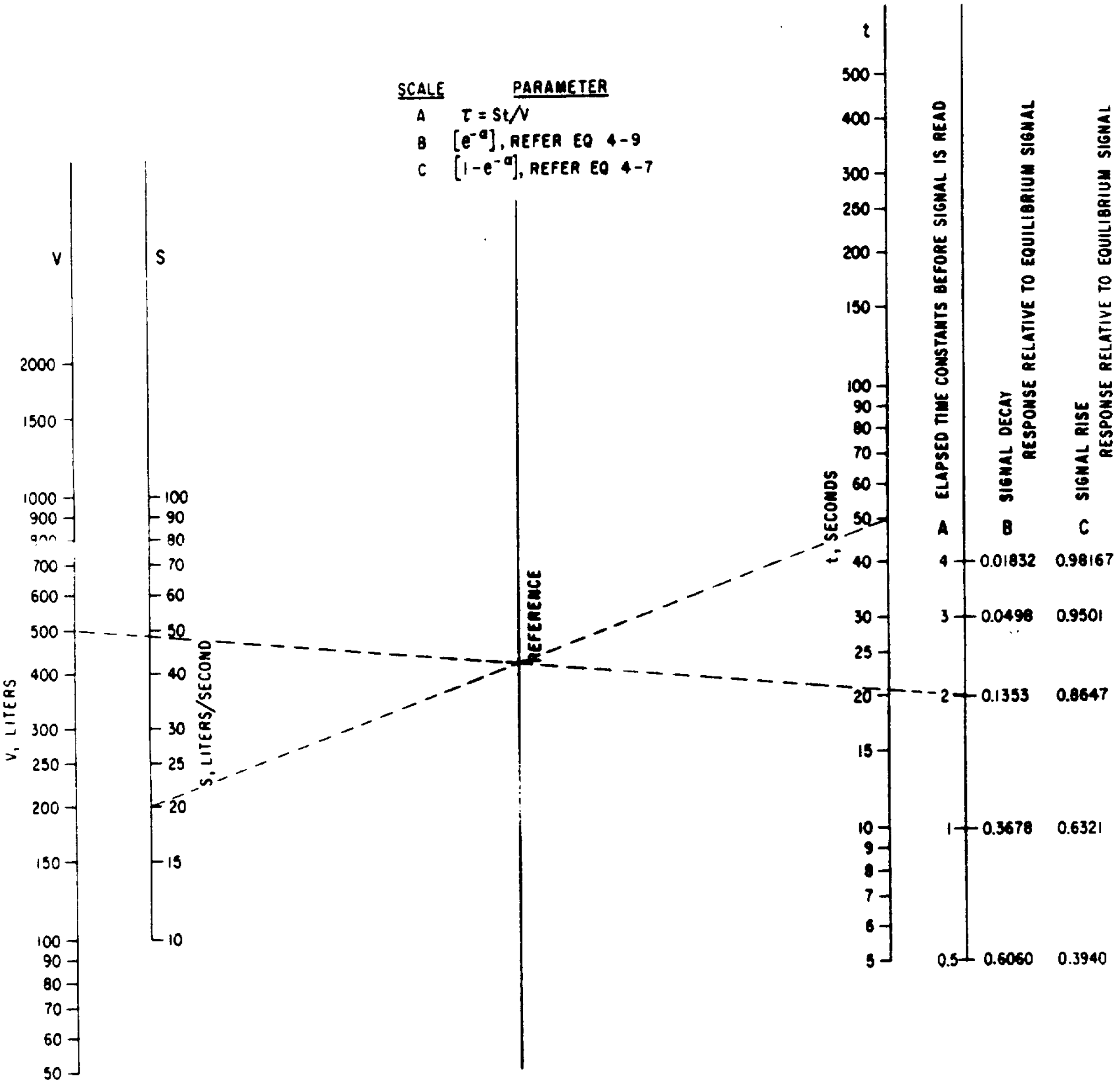


Figure 4-4. Response Nomograph for a Leakage Detection System

4.5.3 Detector Location

In recent years, many papers dealing with dynamic (steady-state) leakage measurement have been published. To increase the sensitivity of this method, it is often suggested that the detector be connected between the diffusion pump and the forepump (see Figure 4-5). While some authors conclude that such an arrangement does not show any improvement (Refs. 4-6 and 4-7), or that an improvement may be obtained under certain conditions (Ref. 4-8), others assert that by this procedure the change in probe pressure in the forepressure line can be considerably greater than in the test chamber (Refs. 4-9, 4-10, and 4-11). These differences in interpretation form the basis for extensive discussions in current technical periodicals (Refs. 4-7, 4-12, 4-13, 4-14, and 4-15).

D.J. Santeler (Ref. 4-16) summarizes these discussions by stating that whether or not an advantage is gained depends on the factor that is limiting the ultimate sensitivity of the test. In a clean system, the ultimate sensitivity may be limited by the partial-pressure sensitivity of the detector. In this event, the pressure amplification obtained on the forepressure side will result in a sensitivity gain. In a contaminated system, or in a search for extremely small leaks in the presence of large leaks, the sensitivity is frequently limited by the resolution of the detector in distinguishing tracer-gas partial pressure from the background. In this event, forepressure leak detection results in amplification of both tracer signal and background and unless selective pumping means are employed, no gain in the concentration ratio is realized.

When the leak detector is connected on the forepump side of the diffusion pump, the forepump removes gas from the system by a batch process and the pressure of its inlet side tends to fluctuate. These fluctuations contribute to the noise level of a sensitive detecting element if it is directly connected to the mechanical pump. The effect can be greatly attenuated by locating the detecting element in the line between two diffusion pumps connected in series. An alternative approach is to place a ballast tank or a throttling valve between the forepump and the detector (see Figure 4-5).

4.6 TRACER-ACCUMULATION TESTING

When the tracer-accumulation technique is used, the device to be tested is pressurized with the tracer gas and placed in a leak-tight chamber. The concentration of tracer gas in the chamber is then monitored as a function of time. Depending on the instrument being used for monitoring, the chamber can either be evacuated or remain at atmospheric pressure. The important characteristic which defines accumulation (static) testing is the concentration of the increased tracer gas in the test chamber during the testing period. In general, accumulation testing can be more sensitive than steady-state testing, since the sensitivity can be

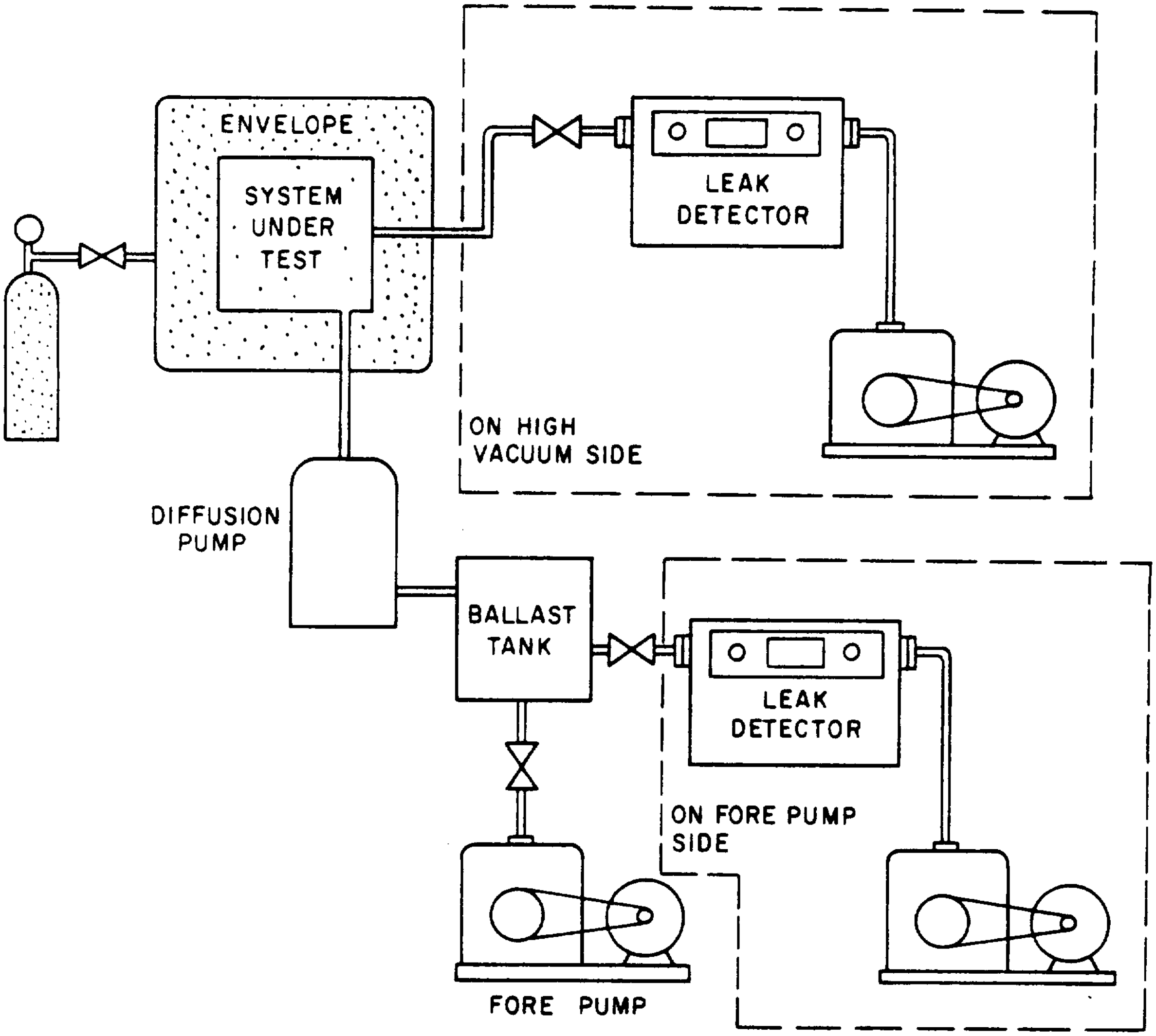


Figure 4-5. Alternate Sites for Leak Detector on Vacuum System

increased simply by increasing the accumulation time, assuming that outgassing and leakage into or out of the test chamber are negligible.

The governing equation for leakage measured by accumulation testing is

$$Q = V \frac{dP}{dt} \qquad (4\text{-}10)$$

Consider, then, a test object of volume V_1 at initial pressure $P_1 - P_{1_0}$, placed inside a chamber, with V_2 as the volume of the chamber not occupied by the test object. The chamber is evacuated and sealed off at an initial pressure $P_2 = P_{2_0} = 0$. A gage attached to the chamber measures the pressure P_2.

Applying Equation 4-10 to both volumes V_1 and V_2 results in

$$\left\{\begin{aligned} V_1 \frac{dP_1}{dt} &= -Q \qquad (4\text{-}11a) \\ V_2 \frac{dP_2}{dt} &= +Q \qquad (4\text{-}11b) \end{aligned}\right\}$$

From these can be written

$$V_1 \frac{dP}{dt} = -V_2 \frac{dP_2}{dt} \qquad (4\text{-}11c)$$

integrating

$$\int_{P_{1_0}}^{P_1} V_1 dP_1 = \int_{P_{2_0}}^{P_2} -V_2 dP_2 \qquad (4\text{-}11d)$$

so that

$$V_1 (P_1 - P_{1_0}) = -V_2 \ (P_2 - P_{2_0}) \qquad (4\text{-}11e)$$

For a leak having a conductance C and a flow rate Q,

$$Q = C(P_1 - P_{1_0}) = C(P_2 - P_{2_0}) \qquad (4\text{-}11f)$$

Combining Equations 4-11e and 4-11f,

$$Q = C \ [P_{1_0} - P_2 \ (1 + V_2/V_1) \ ] \qquad (4\text{-}11g)$$

But Q is also equal to $(V_2)\ dP_2/dt$ from Equation 4-11b.

Substituting Equation 4-11b in 4-11g and simplifying gives

$$\frac{dP_2}{dt} = \frac{C}{V_2} \left[P_{1_0} - P_2 \left(\frac{V_1+V_2}{V_1} \right) \right] \qquad (4\text{-}11h)$$

Rearranging and integrating with respect to P_2 and time t,

$$\ln \left[\frac{P_{1_0} - P_2 \left(\frac{V_1+V_2}{V_1} \right)}{P_{1_0} - \left(\frac{V_1+V_2}{V_1} \right) P_{2_0}} \right] = -Ct \left(\frac{V_1+V_2}{V_1} \right) \qquad (4\text{-}11i)$$

Now, since P_{2_0} is zero, the conductance of the leak can be calculated in terms of elapsed time T and the pressure P_2 in the outer chamber. (It is here assumed that P_{1_0} was known when the object was placed in the chamber and, therefore, that the change in P_{1_0} before testing began was negligible.) This calculation, of course, is based on the assumption that the total conductance of all leaks in the object is relatively small.

Equation 4-11i may be expressed in exponential form to show how P_2 varies with time for a given leak conductance and initial pressure. Thus,

$$P_2 = \left(\frac{V_1}{V_1+V_2}\right) \left(P_{1_0}\right) \left[1 - e^{-Ct\left(\frac{V_1 V_2}{V_1+V_2}\right)}\right] \qquad (4\text{-}11j)$$

P_2 approaches $(V_1/(V_1 + V_2))\ P_{1_0}$ with time.

The above analysis is also applicable when the outer chamber is not evacuated but contains an atmosphere in which there is no tracer gas. In this case, P_2 represents the partial pressure of tracer gas in the chamber.

The accumulation technique is useful when

1. A reading of total leakage is desired.
2. The leak to be measured is smaller than the maximum sensitivity of the leak detector in the steady-state mode.
3. The background contamination is severe, making it difficult to stabilize the leak detector for ordinary steady-state testing.
4. There are surfaces or a number of possible leak points not feasible or economical to check individually.

The accumulation chamber should be made reasonably tight to prevent loss of tracer gas by direct leakage. The accumulation chamber should also be made of nonpermeable material, to minimize losses by permeation. If the accumulation chamber has an unsymmetrical shape, some means should be provided to circulate the air within the chamber. This will tend to prevent an uneven concentration of tracer gas. Circulation is also necessary when the chamber is of a large volume or when a high-density tracer gas (that tends to stratify) is used.

A shortcoming of this method is that during the period of waiting for the tracer gas concentration to increase, it is also possible for adsorbed gases to be released. Frequently this outgassing will interfere with the detection of the tracer gas, resulting in biased leakage values. The use of a partial-pressure analyzer will identify the various gases present and allow virtual leaks to be distinguished from real leaks.

4.7 LEAK LOCATION TECHNIQUES

Although there are numerous techniques which can be used to locate leaks, bubble emission, tracer probe, and detector probe are the methods most frequently used. Techniques involving sonic energy, high potential discharge, and chemical reaction are useful under rather specific conditions.

4.7.1 Bubble Testing

The immersion or covering of a leaking part by a liquid leads to the formation of bubbles at the source of the leakage. Bubbles are emitted from a leak when the internal pressure exceeds the external liquid-head and surface-tension forces. Bubble size and frequency are functions of gas flow rate, leak size, and surface tension; these effects are discussed in References 4-17 and 4-18. In the simplest example, that of a single cylindrical capillary, the equilibrium bubble pressure is given by

$$P = P_0 + \rho g h + \frac{2\sigma}{r} \qquad (4\text{-}12)$$

representing the atmosphere pressure above the liquid, the gravitational head of the liquid, and the pressure due to surface tension of the bubble as it begins to form at the liquid end of the capillary.

As the gas flows through the capillary (leak), each bubble forms and expands, ultimately being attached to the rim of the leak by a neck, as illustrated in Figure 4-6 for the case of liquid wetting the leak channel.

Assuming that the bubble formed at the end of a tube is part of a sphere, then as the bubble is being generated, its radius R first decreases, as indicated by Figure 4-6(a), until it reaches its minimum value r, corresponding to the radius of the capillary as shown in Figure 4-6(b). Thereafter the radius R_B increases to form the expanding bubble shown in Figure 4-6(c). This variation implies that the term $2\sigma/R$ in Equation 4-12 has a maximum value, $2\sigma/r$, corresponding to the maximum value of excess pressure.

When the bubble buoyancy exceeds the surface tension restraint at the neck, the bubble is detached and rises to the surface. Bubble detachment occurs when

$$\frac{4\pi \ R_B^3 \rho g}{3} = 2\pi r \sigma \qquad (4\text{-}13)$$

Equations 4-12 and 4-13 present almost the total picture of bubble formation and growth. In more rigorous equations, viscosity affects the bubble size; however, this is considered negligible (Ref. 4-18) in most leaks. With an increase in viscosity there will be a small increase in bubble size.

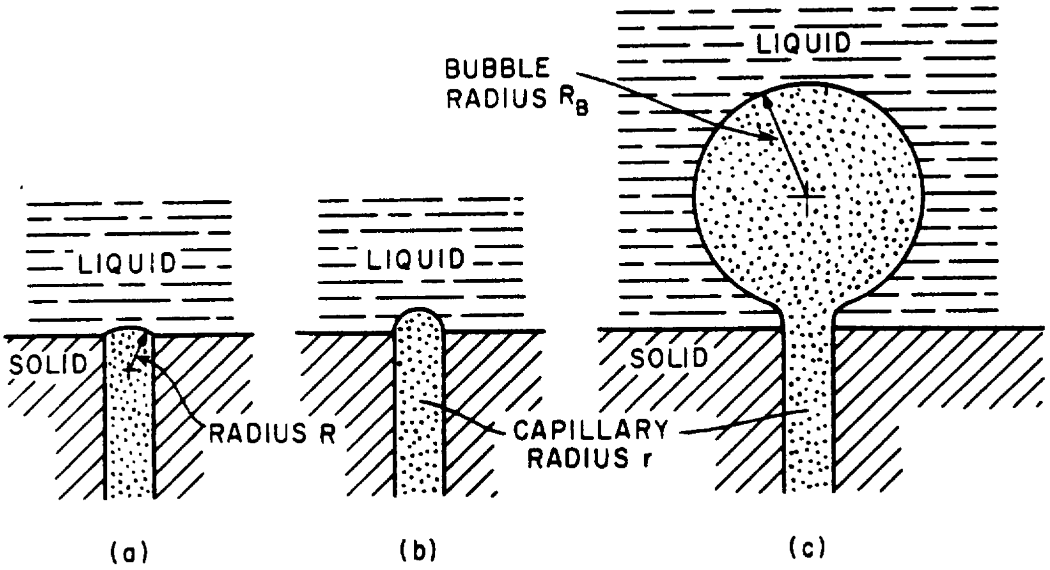


Figure 4-6. Bubble Formation at a Leak Site (Reprinted with permission from J.G.S. Biram and G. Burrows, "Bubble Tests for Gas Tightness," Vacuum, Vol. 14, June 1964, p. 223.)

The external pressure may be regarded as constant; therefore, there is a critical value of the pressure inside the bubble which must be reached if the bubble is to expand beyond the hemispherical stage. This condition imposes a limit on the application of bubble testing. For example, if the end of the capillary is just submerged in water, $\sigma = 73$ dynes per centimeter, and the capillary is supplied with gas at a differential pressure of one atmosphere (1.01×10^6 dynes per square centimeter), than

$$r = \frac{2 \times 73}{1.01 \times 10^6} = 1.45 \times 10^{-4} \text{ cm}$$

This is the smallest capillary radius that could be detected by means of a bubble for the given pressure difference.

If, however, a liquid of lower surface tension were used, such as methyl or ethyl alcohol, then the same differential pressure would allow a bubble to be formed at the end of a capillary of radius

$$\frac{2 \times 23}{1.01 \times 10^6} = 4.5 \times 10^{-5} \text{ cm.}$$

This radius is less than one-third of the smallest radius of a capillary which can be detected when water is used. With liquids having lower surface tensions, leakage rates 1/50 to 1/100 of the lowest rate detectable when the bubbles are formed in water can be detected.

Another factor which affects the sensitivity of bubble testing is the average size of the bubbles evolved. It may be seen by an examination of Equation 4-13 that the size of the bubble increases with an increase in surface tension. Therefore, the generation of a large number of bubbles requires the use of liquids having a small surface tension.

Bubble size is influenced by mechanically vibrating the test object. If the test object is vibrated, the bubble breaks off before it would if the test piece were stationary. This can be useful, as it increases the bubble rate for a given leak rate.

If the pressure over the liquid is reduced below atmospheric until bubbles just emerge from the end of the leakage path, limitations are imposed by the tendency of a liquid to degas and boil under conditions of reduced pressure. A comparatively high boiling point permits reasonably low pressures to be realized without boiling. To enable the smaller leaks to be detected it is desirable to use liquids having low values of surface tension; but such liquids also have correspondingly lower boiling points. These liquids may boil spontaneously before the pressure over the liquid can be reduced sufficiently to increase the rate of bubble formation significantly. Therefore, the choice of liquid for these tests must be very carefully made.

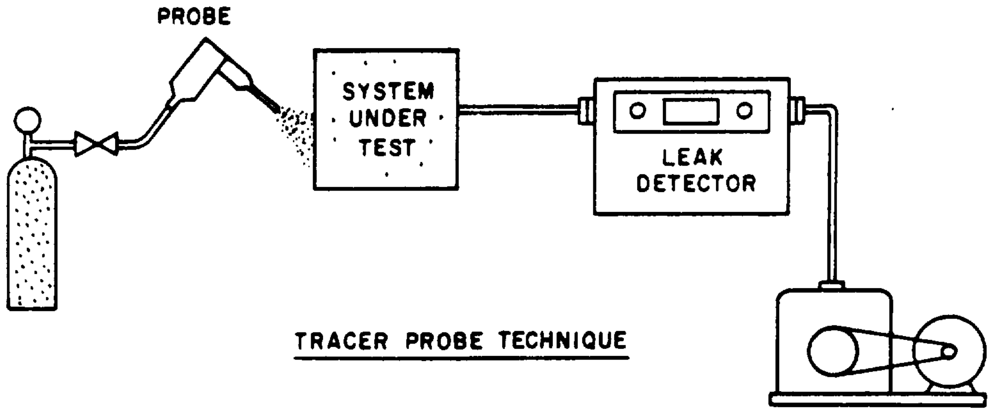
In summary, it is desirable to use a liquid of low surface tension and low viscosity. Pressure has to be higher with capillaries of small diameter. Finally, the use of a low-viscosity, low-molecular-weight gas will increase the flow rate through the capillary.

4.7.2 Probe Techniques

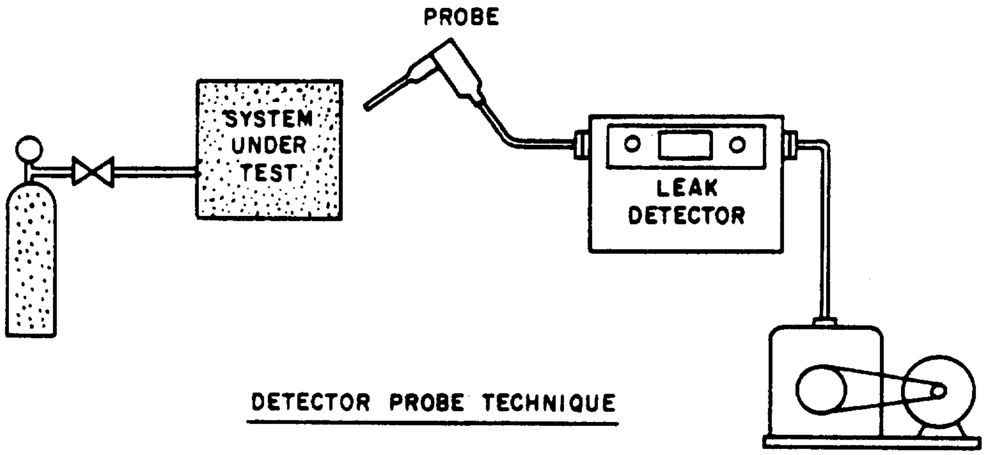
There are two distinct techniques for locating leaks with instrument probes. One employs a tracer probe and the other a detector probe, as shown in Figure 4-7. By the former technique, a fine stream of tracer gas from the tracer probe is played over the suspected leak area. Tracer gas is drawn into the interior of the test object if a leak is present, and is discovered by the leak detector.

For the detector probe, tracer gas blankets one side of the system being tested. The detector probe is then passed over the suspected area to determine if tracer gas is leaking through to the detector side of the system. The response equations given in Section 4.5 for steady-state testing apply to both probe techniques. (A detector probe is also known by such names as sniffer probe, pressure probe, sampling probe, and reverse probe.)

Selection of one or the other methods depends on several factors. For example, the detector probe technique of leak location should be used if the system must be tested in a pressurized condition, or the tracer gas is readily absorbed on the leak surfaces. If a tracer probe is used and the gas is absorbed in the leak, small leaks will go unnoticed since an equilibrium



TRACER PROBE TECHNIQUE



DETECTOR PROBE TECHNIQUE

Figure 4-7. Leak Location Techniques

is not quickly established between the leak surfaces and the tracer gas. (See Section 6.5 for details.) The detector probe technique may also be used if the detector has a sensing element that operates under atmospheric pressure.

Leak location by means of the tracer probe technique is usable on systems which can be evacuated or otherwise subjected to pressures below atmospheric. It is necessary that a port or aperture be available for attachment of the detector.

Other factors affect the choice of one technique over the other.

- It may be desirable to check for leakage in one specific direction where the existence of check valve leaks is suspected (see Section 6.5)

- The system might have long, narrow passages, so that it will be prefereable to pressurize rather than evacuate them. This is because the rate of travel of molecules in narrow evacuated passages is slow and a long time is required to reach the operating pressure of the leak detector.

4.8 SEALED UNIT TESTING

Two methods of testing sealed units are:

- Fill with tracer gas under pressure during manufacture. Test for gas leaks.
- Seal the unit, subject to high-pressure tracer gas, and remove tracer gas from the outside envelope. Test for gas leaking from the sealed unit. This technique is called "bombing" or "back-pressurizing".

4.8.1 Unit Sealed With Tracer Gas

For the first of these systems, the effect of leak size on detector signal may be represented in the generalized graph of Figure 4-8. Here the leak rate, derived from the signal of the detector, is plotted against the leak conductance. The curve represents the situation where the pressure of the tracer gas is initially atmospheric and where a fixed time elapses between manufacture and testing. Because of the time lapse, the curve departs from the line of unit slope, reaches a maximum, and falls for larger leak conductances. This is caused by the diffusive loss of gas from a leaking specimen. The minimum detectable leak is thus fixed by the detector, and the maximum detectable leak by the time lapse before testing (among other factors such as the internal geometry of the unit and the rate of release of absorbed tracer gas from the internal surfaces).

It follows from this description that extremely large leaks cannot be detected by this procedure. Some independent method of testing, such as immersion bubble testing, must be used to detect extremely large leaks. It also follows that this method will not be quantitative on large leaks. The leak size at which this method ceases to be quantitative may be calculated from the magnitude of tracer-gas loss prior to leakage measurement.

4.8.2 Back-pressurizing Technique

Back-pressurizing is a term coined by Howl and Mann (Ref. 4-19). Their article is the most comprehensive treatment of this technique.

The test unit is held for a period in a pressure vessel containing tracer gas at a high pressure. The gas enters the unit through any leak and is detected when the unit is taken out of the pressure vessel and the gas issues from the leak. The rate of the flow depends not only on the conductance of the leak but on how much gas has entered during the pressurizing period.

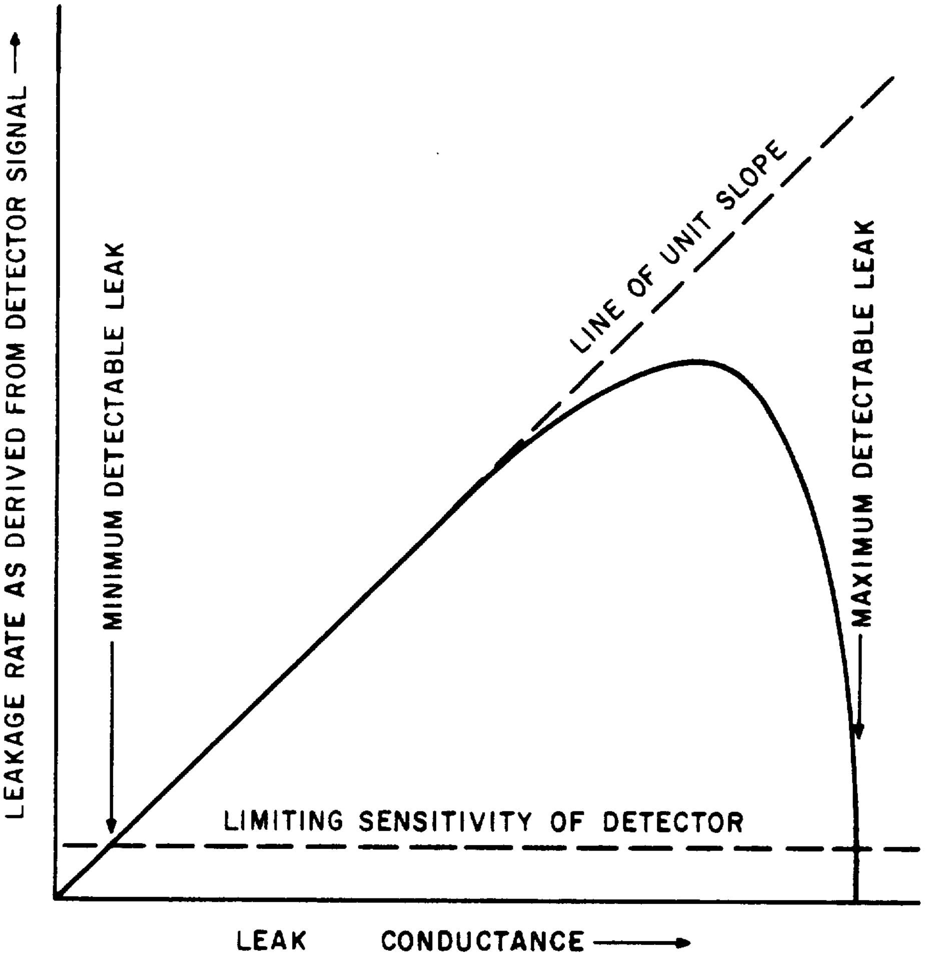


Figure 4-8. Detector Response for a Unit Sealed with Tracer Gas (Reprinted with permission from D.A. Howl and C.A. Mann, "The Back-pressurizing Technique of Leak-testing," Vacuum, Vol. 15, No. 7, 1965, pp. 347-52; Pergamon Press Copyright 1965 (Ref. 4-19).)

The leak-conductance signal-response curve for the back-pressurizing process is shown in Figure 4-9. For very small leaks, where the final signal is a function of the leak conductance and the partial pressure of the tracer after pressurizing, itself a function of leak conductance, the curve is concave and tangential to the x-axis. The curve crosses the line of unit slope where the leak conductance and pressurizing conditions are such as to raise the pressure of the tracer to one atmosphere. The curve remains above this line for a range determined by these two factors and, in addition, by the time lapse before testing. The physical significance of this curve being above the unit slope is that the pressure of the tracer in the specimen is above atmospheric at the time of test. The curve subsequently falls, as in Figure 4-8.

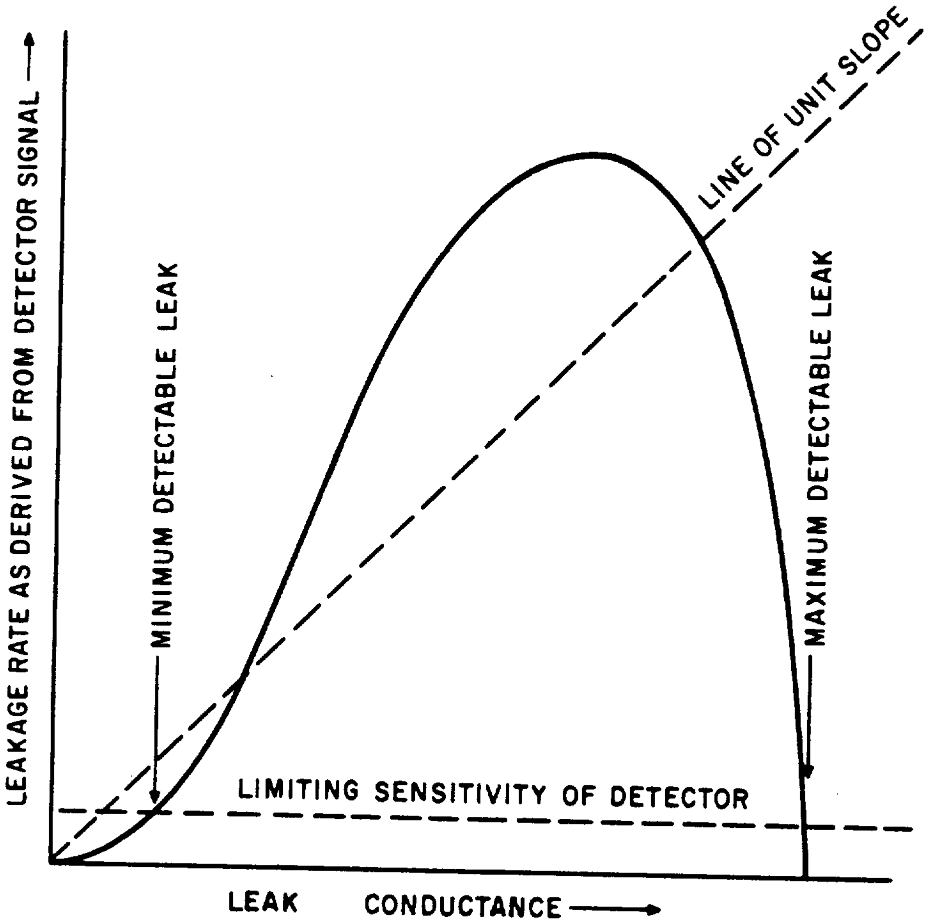


Figure 4-9. Relation of Leak-rate Signal to Leak Conductance for Back-pressurizing Technique (Reprinted with permission from D.A. Howl and C.A. Mann, "The Back-pressurizing of Technique of Leak-testing," Vacuum, Vol. 15, No. 7, 1965, pp. 347-52; Pergamon Press Copyright 1965 (Ref. 4-19).)

Although the minimum and maximum detectable leaks are shown as greater in Figure 4-9 than in Figure 4-8, this is not of general significance. Back-pressurizing may be more or less sensitive than a test with previous filling with tracer, depending on the pressurizing and test conditions.

The discussion which follows indicates how the sensitivity may be determined or the conditions specified for a given sensitivity. The discussion includes the effect of absorbed tracer gas on the outside of the test specimen, which can be one of the main practical disadvantages of the method.

The back-pressurizing technique of leak testing is carried out in three distinct steps:

1. A tracer gas at high pressure is applied to the external surface of the test specimen, causing inflow of the tracer gas through any leak.
2. A period ensues following the removal of the source of tracer gas during which some tracer gas is lost from the test specimen through the leak.
3. A test for leakage is performed on the test specimen.

Consider the application of the back-pressurizing technique to leaks through which the flow is either purely molecular or purely laminar (see Section 6). In leak-testing practice the leak with molecular flow is the more important, since it is necessary to detect leaks down to 10^{-7} torr liter per second or less, although leaks of 10^{-3} torr liter per second may still show molecular flow characteristics. For capillary leaks it can be shown that the leakage rate must be less than 10^{-6} atm-cc/sec for purely molecular flow and greater than 10^{-4} atm-cc/sec for purely laminar flow.

4.8.2.1 Molecular Flow Leaks. Assuming that the flow in and out of the system is molecular, the equation derived (Ref. 4-17) for the measured flow after performance of the three-steps described above is:

$$Q = C_A P_E \left[1 - \exp\left(-\frac{C_A t_E}{V}\right)\right] \exp\left(-\frac{C_A t_R}{V}\right) \qquad (4\text{-}14)$$

Figure 4-10 shows a plot of the measured leakage Q against leak conductance C_A for typical values of P_E, V, t_E, and t_R. Most leak detector systems using tracer gases are designed to detect leaks very much smaller than 10^{-5} torr liter per second. An assessment of the smallest detectable leak must therefore be based upon the molecular flow equation. Furthermore, for the very small leaks (less than 10^{-6} torr liter per second) it is possible to reduce this equation to a very simple form:

$$Q = \frac{P_E t_E}{V} C_A^2 \qquad (4\text{-}15)$$

This may be rewritten:

$$P_E t_E = \frac{QV}{C_A^2} \qquad (4\text{-}16)$$

The smallest detectable leak C_A depends upon the minimum leak rate Q, which gives a signal on the detector appreciably above the background. Equation 4-16 defines the value of the product $P_E t_E$ necessary to detect leaks as small as C_A on a system with a background signal appreciably smaller than Q.

Figure 4-11 shows the product of $P_E t_E$ plotted against C_A for various values of system volume, the minimum detectable signal being taken as 2.5 × 10^{-8} torr liters per second.

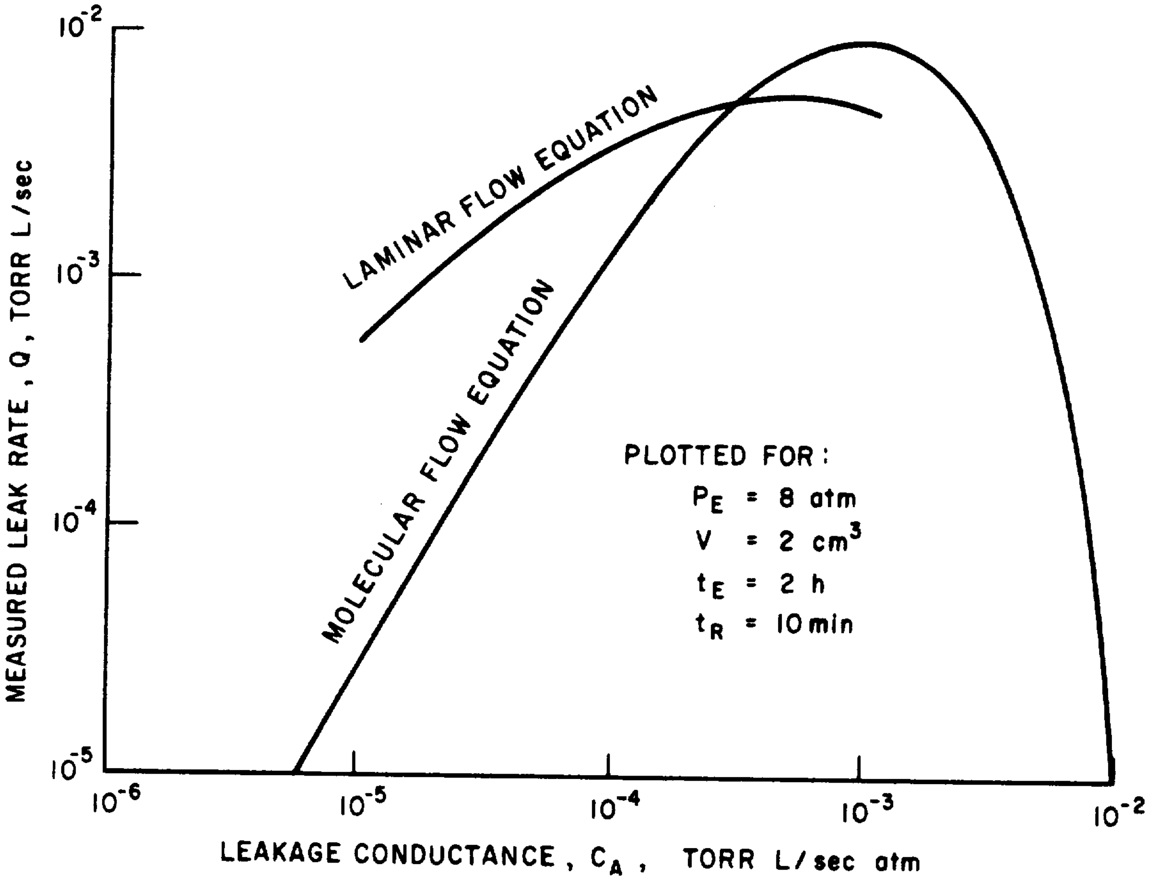


Figure 4-10. Computed Relation of Leak-rate Signal to Leak Conductance for a Particular Set of Conditions. (Reprinted with permission from D.A. Howl and C.A. Mann, "The Back-Pressurizing Technique of Leak-Testing", Vacuum, Vol. 15, No. 7, 1965, pp. 347-352; copyright 1965 Pergamon Press (Ref. 4-19).)

It is common for the noise level or background signal of the detector to result mainly from the presence of tracer gas which has been absorbed on the surface of the system during pressurizing. The amount of this absorption, and of the subsequent desorption during the leak test, is dependent on the gas used and on the material of the outer surface of the specimen and its finish. Generally, bright metal surfaces absorb least, oxidized metal surfaces absorb significantly, and such porous materials as graphite absorb excessively. As a first step in any back-pressurizing test, the signal from desorbed tracer gas should, if possible, be measured experimentally, using a specimen of the material which will be used.

The effect of significant absorption can be reduced by heating the specimen. This can be done either after pressurizing or, to minimize delay before testing, by heating while pressurizing. While hot, the tracer gas desorbs rapidly. In tests on nuclear fuel elements using helium (Ref. 4-19), temperatures in the range 200 - 400°C have been found satisfactory

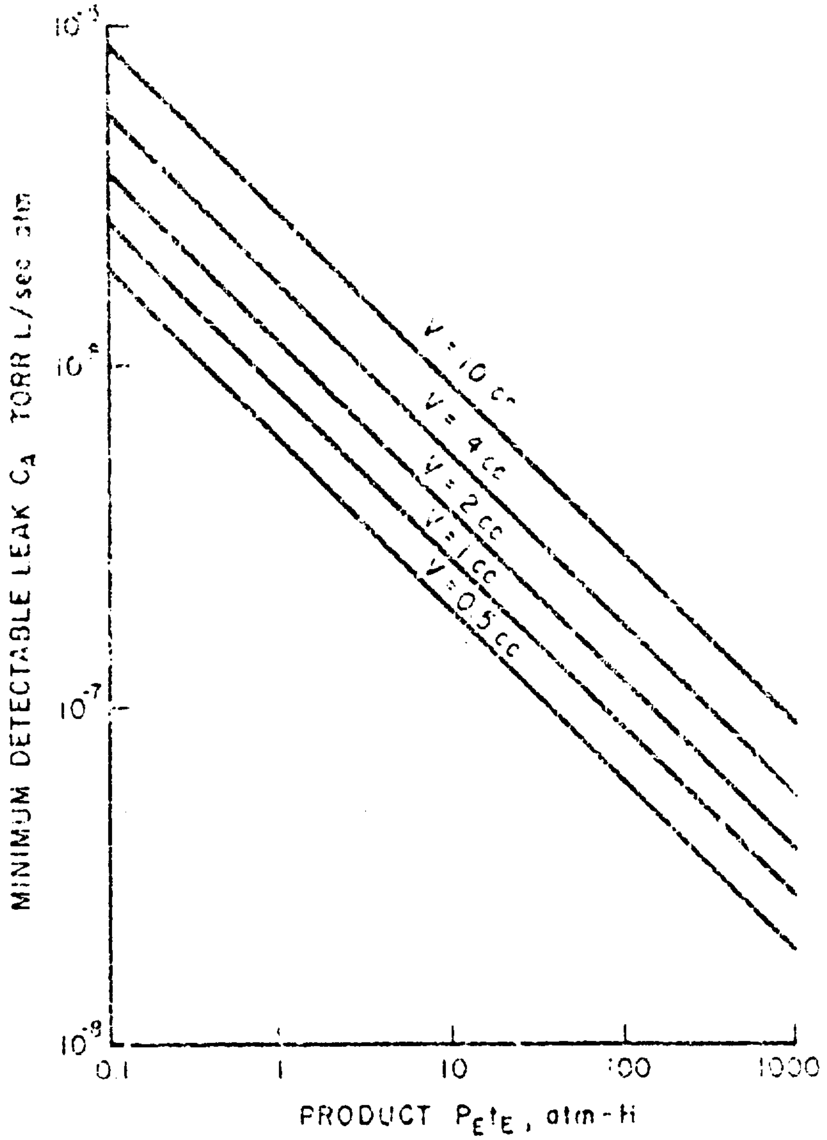


Figure 4-11. Required Values of $P_E t_E$ Calculated for $Q = 2.5 \times 10^{[illegible]}$ Torr Liter per Second. (Reprinted with permission from D.A. Howl and C.A. Mann, "The Back-pressurizing Technique of Leak-testing," Vacuum, Vol. 15, No. 7, 1965, pp. 347-352; Pergamon Press, Copyright 1965 (Ref. 4-19).)

NOT REPRODUCIBLE

in reducing background signals to negligible levels, i.e. to levels comparable to the noise level of the detector, below which no further gain in sensitivity would be achieved.

[illegible] *Laminar Flow Leaks.* If the flow in and out of the system is laminar, the equation for measured flow after performance of the three steps of back-pressurizing is:

$$Q = \left(\frac{P_E - P_0}{P_E}\right) C_A P_0 \left[\frac{1 + \dfrac{P_E - P_0}{P_E + P_0} \exp\left(\dfrac{-2C_A t_E}{V}\right)}{1 - \dfrac{P_E - P_0}{P_E + P_0} \exp\left(\dfrac{-C_A t_R}{V}\right)}\right]^2 \qquad (4\text{-}17)$$

The above is a simplified equation which assumes that:

$$2 \frac{C_A}{P_0} t_E P_E > 3 \qquad (4\text{-}18)$$

This implies that Equation 4-17 is valid for leaks greater than the range of 10^{-5} torr liters per second per atmosphere if the volume of the system is in the cubic centimeter range.

Equation 4-17 for laminar flow leaks breaks down when, in the second stage, with the test specimen in the atmosphere, the diffusion of air into the test specimen against the outflow of gas becomes appreciable. This is arbitrarily assumed to occur when the pressure in the system is less than twice atmospheric pressure.

Calculations using Equation 4-17 for laminar flow are compared with the results when using Equation 4-14 for molecular flow on Figure 4-10. Equation 4-17 is plotted only between 4×10^{-5} and 8×10^{-4} torr liters per second per atmosphere, the range in which it is applicable.

In general, the size of the leaks which may be detected depend on loss of gas during the second stage. The range of detectable leaks can only be extended appreciably by reducing t_R, the time between back-pressurizing and leak testing.

Section 5

PLANNING LEAKAGE TESTS

Section 5

PLANNING LEAKAGE TESTS

5.1 DESIGN FOR ACCESSIBILITY

If a system is to require leakage testing, such a requirement should be given consideration during the design period. Too often a system is completely constructed before any thought is given to the need for leak testing. At the end of construction, it may be impossible either to pressurize the system with tracer gas or to make connections to the system for evacuation. Therefore, if leakage testing is to be required, a system should be accessible by which it may be pressurized or evacuated.

Well-designed test connections should be used. Such connections can be a major source of difficulty on account of leakage, excessive tracer gas contamination, and dirt. Minimum amounts of elastomers and plastic should be used. Rubber and plastic tubing should be avoided because they will often absorb tracer gas which is difficult to remove by pumping. Only the shortest lengths of rubber tubing should be used. A light film of good, low-vapor-pressure grease should be applied to gaskets. Any excess should be removed since large quantities of grease act as a source of tracer-gas contamination and as a dirt catcher. The system may become so dirty because of excess grease that a good vacuum cannot be attained.

5.1.1 Leaks in Series

It has long been recognized (Ref. 5-1) that for a device which will require leak testing, no design which may develop voids in series with possible leak paths is acceptable. For example, if two heavy plates are to be welded together along mating edges, it is best to make either a full penetration weld or a partial penetration weld from only one side. It is undesirable to allow partial penetration welds from opposite sides since a void can be left between the welds. It would then be difficult to check and assure that there is not a leak through both welds because the speed of response to leakage from the void would be very slow.

The leak path (Figure 5-1) may consist of one or more small chambers connected by very fine capillaries. The pressure in a chamber (the intermediate volume) is atmospheric immediately after pressurization of the system, and the driving force (or pressure difference) between the chamber and the outside atmosphere is zero at this time. As the inner capillary (between the system and the chamber) conducts tracer gas to build up the pressure in the chamber, the pressure difference between the chamber and the outside atmosphere increases. With this increased pressure difference there is a slow increase in the flow rate to the outside. There will be a delay in time before atmospheric air is removed from the leak path and the path becomes filled with tracer gas. The presence of the leak will not be detected until tracer gas issues from the outside surface of the wall.

Thus, consideration of the time delay in leak detection is important when an intermediate volume is present in the total leak path, since a time lapse may prevent a leak from being detected. A review of leak-test procedures is necessary to establish the time lapse to be expected between component pressurization and measurable leakage. This can be accomplished by solving the derived equations for typical values of parameters associated with a particular configuration (Ref. 5-1).

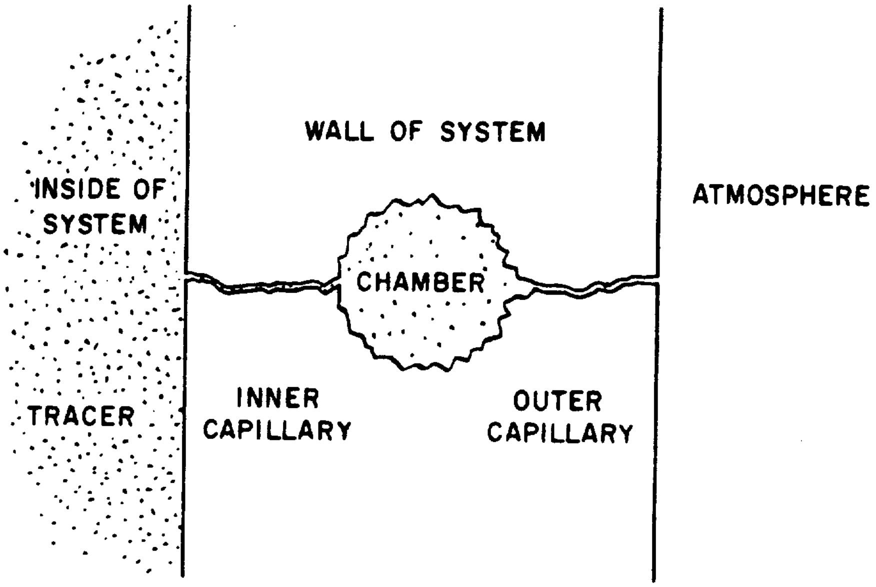


Figure 5-1. Sketch of Typical Series Leak Path

Testing of a fluid handling system will be greatly facilitated if the ports or gasketed openings which are provided for leakage testing are made large enough to permit rapid evacuation or pressurization. Large openings are especially desirable when the system is to be evacuated for leakage testing. Vacuum pumping of a vessel having a volume of several cubic feet through a valve having an orifice diameter of only one-eighth inch requires a pumpdown time which is not only excessive but also very costly.

Instructions for welding without enclosing sealed voids may be found in current publications (Refs. 5-2 and 5-3).

5.1.2 Component Testing

When a vacuum system is to be constructed, it is advisable to test each individual component for leakage prior to assembly. If this procedure is followed, any leaks indicated during a final test of the assembled system should be located only at the joints, unless a component has been damaged during assembly by the application of excessive torque or thermal stress, for example. As a further safeguard, the vacuum tightness of the system can be checked as each component is added and assembly proceeds.

It is always good practice in repairing leaks found during leak hunting to make permanent repairs whenever possible. Temporary repairs should be made only if the system must be operated, for a limited length of time, before permanent repairs can be made. A permanent repair means reworking the part involved or replacing the part. Some common sources of leaks and possible methods of repair are indicated below (reprinted with permission, from Vacuum Technology, by A. Guthrie; John Wiley and Sons, Inc., New York, 1963, pp. 500-501) (Ref. 5-4):

1. Static gasket seals
    - Tighten seal but not too much
    - If tightening does not work, shut down the system and examine the gasket and gasket surfaces.
    - Replace any damaged gasket and smooth rough surfaces (fine emery cloth).
    - When the gasket is not damaged, clean (acetone, etc.), coat with light film of good-quality vacuum grease (when permitted), and reassemble seal.
    - Do not use sealing materials such as Glyptal* to stop the leak. This procedure is temporary and the gasket cannot be used again.
2. Movable, gasketed seals (Wilson, chevron, etc.)
    - Add a small quantity of good-quality vacuum grease to the moving member and operate this member a few times through the seal.
    - If vacuum grease does not work, try tightening the retaining rings on the seal.
    - If tightening does not work, dismantle the seal and examine the component parts. Replace all damaged parts.
3. Flare fittings (and similar metal-to-metal seals)
    - Tighten the compression nut moderately. Too much tightening is likely to twist the tubing passing through the fitting.
    - If tightening does not work, take the joint apart.
    - Try annealing the copper flare.
    - If annealing does not work, use a thin coating of a suitable sealant (Glyptal*, etc.) on the surfaces that make contact.

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*Registered trademark of the General Electric Company.

4. Soldered, brazed, and welded joints

   - For temporary repair, use a cement. This method works for small leaks where the diffusion pumps are in their operating range. A "thin" cement (clear Glyptal, Eastman Kodak Resin 910, etc.) can be used for the smallest leak. For somewhat larger leaks use a more viscous cement, such as red Glyptal.
   - For permanent repair, rework the joint or replace the part.

5. Leaks through metal parts

   - For temporary repair use a cement, as in the case of soldered, brazed, and welded joints.
   - For permanent repair, rework the part involved (as appropriate) or replace the part.
   - Peening the leak is not reliable.

6. Glass-to-metal seals

   - A temporary seal can be made with a cement or wax.
   - Rework wax seals.
   - For permanent repair, replace the seal.

7. Glass-to-glass joints, cracks, and pinholes in a glass system

   - For small leaks, use a cement (at room temperature) or heat the glass and apply a suitable wax (picein, sealing wax, etc.).
   - For a large leak, rework the glass or replace the part of the system where the leak is located.

5.1.3 Safety Considerations

Potential hazards to personnel safety must be taken into account when designing the leakage test. These are: the flammability of the tracer gas, the possibility of asphyxiation or poisoning, and the danger of explosion or implosion of a pressurized system. As long as the designer is aware of these considerations from the beginning, it is possible to test with little inconvenience or danger. Included in Appendix A, along with physical properties of tracer gases, is a list of the safety precautions to be observed with the following gases: ammonia, argon, carbon dioxide, dichlorodifluoromethane, helium, hydrogen chloride, hydrogen, krypton, methane, neon, nitrogen, nitrous oxide, oxygen and sulfur dioxide.

5.1.3.1 Flammability. Hydrogen, methane, butane, and many of the liquids used in leakage testing are flammable. When these tracer fluids are used they are usually mixed to some extent with air. These potentially explosive mixtures are dangerous, and procedures should be taken to provide adequate ventilation and to prevent accidental ignition.

The precautions listed below will apply in all cases of flammable gases. Use of hydrogen enhances risk, and the precautions given are essential (Ref. 1-6).

1. Before hydrogen is admitted the system under test should be evacuated or purged with nitrogen. This will avoid an air-hydrogen mixture anywhere in the explosive range (4 percent to 74 percent of hydrogen in air, by volume). The same should be done with a rigid hood. With flexible hoods the volume between hood and vessel under test can usually be made very small - much less than the 10 cubic feet referred to below. If this is done, evacuation or purging is not essential.

   A hydrogen/nitrogen mixture is safer than pure hydrogen, if it can be used.

2. Testing should be done in a well-ventilated place, isolated as far as practicable from other processes. A room with a high roof, adequately vented at its apex, and with enough low-level air inlets is desirable. A small room with low roof and a minimum of openings for ventilation should not be used for testing with hydrogen.

   Special precautions will be necessary when the volume between the hood and system under test approaches 10 cubic feet, as there is then risk of a major explosion. Safety can then be insured only by testing the system in a blast enclosure, or cell. This should have strong walls and a light roof; persons should not be allowed to enter during a test. For safety, and to avoid having to provide a test cell unnecessarily, the volume between a hood and the enclosed system should be as small as possible.

3. Test areas, particularly test cells, should be free from obvious sources of ignition. Smoking must be prohibited, particularly when hydrogen is used. Electrical equipment may pose a hazard. If there is a possibility that, in the event of a leak, such equipment will be in an explosive atmosphere, then either the equipment must be repositioned outside the danger area or special equipment must be used. Such special equipment is either pressurized with inert gas or is intrinsically safe.

   A discharge of static electricity is a possible cause of ignition. Therefore all metal parts liable to become charged should be grounded, and any flexible nonmetallic hood should be made of "anti-static" material.

This would mean that the resistance of the leakage path from any point on the hood would not exceed 10^7 ohms. It is advisable for personnel, when testing with hydrogen, to avoid wearing clothing liable to produce static charges, and to wear shoes with conducting soles. Another precaution is to use tools which cannot produce sparks.

4. If possible, hydrogen cylinders should be in a storage area separate from any occupied building. The storage area should be well ventilated. Permanent piping should be provided to convey hydrogen to the test area.

The above precautions are also relevant where other flammable tracer gases are used, although hydrogen easily presents the greatest risk. Where a large system is being tested, or large volumes of hydrogen used, it may be advisable to provide monitoring equipment giving a continuous indication of the hydrogen-in-air content in the test area. Intrinsically safe detectors are available.

5.1.3.2 Asphyxiation. Most tracer gases are not toxic. However, if a question exists about the toxicity of any particular gas, a competent authority should be consulted (Ref. 2-2). Toxicity of some tracer gases is given in Appendix A.

None of the tracer gases will support human life. That is, if they replace oxygen in a volume, this volume cannot be entered without proper respiratory equipment. In this case, proper equipment is a gas mask which contains its own oxygen supply.

The oxygen required for breathing might be accidentally removed from an area. For example, if one of the halogenated hydrocarbons is used as a tracer gas, it will stagnate and settle to the lowest area in the system. If an operator is attempting to use a detector probe in this low area, the tracer gas which settles may eventually displace enough of the air to produce asphyxiation. In this case, adequate ventilation is necessary. Such ventilation, however, must be performed carefully. If the tracer gas is dispersed too rapidly from the place where it is escaping from the system, leak location will be difficult.

5.1.3.3 Explosion. If the system is pressurized with tracer gas, the rupture of its walls can produce considerable damage from release of the stored energy. It might seem that little precaution is necessary in pressurizing a small system; however, the damage from the rupture of a gas-filled volume results from the total mass of gas. Therefore, a small system at high pressure and a large system at low pressure may be equally dangerous.

Large systems need proof-testing prior to leakage measurement. The proof-test may be performed by pressurizing with gas to a high pressure while the test area is evacuated, or by a hydrostatic test using water. The disadvantage of the gas proof-test is that considerable damage can result if the system bursts during testing. On the other hand, should hydrostatic testing be performed, any small leaks in the system will become clogged with water. Therefore, if at all possible, hydrostatic testing should not be performed on systems where the allowable leakage must be less than 10^{-6} atm-cc/sec. The American Society of Mechanical Engineers code for unfired pressure vessels specifies that a hydrostatic test at 1.5 times the working pressure shall be performed on all code fabricated vessels (Ref. 5-5).

When a system is to be pressurized a pressure regulator fitted with a safety over-pressure device should be included, so that a pressure in excess of the design pressure can never be applied to the system.

Olson (Ref. 5-6) has related the hazard potential associated with a volume of compressed gas to its TNT equivalent. Figure 5-2 is a logarithmic plot of tank pressure versus the energy equivalent in pounds of TNT per cubic foot of tank volume. The explosion hazard can be readily seen. For example, a tank at 100 psia contains the energy equivalent of 0.023 pound of TNT per cubic foot of tank volume. A 10-cubic-foot tank under those conditions has the explosive potential of 0.23 pound of TNT.

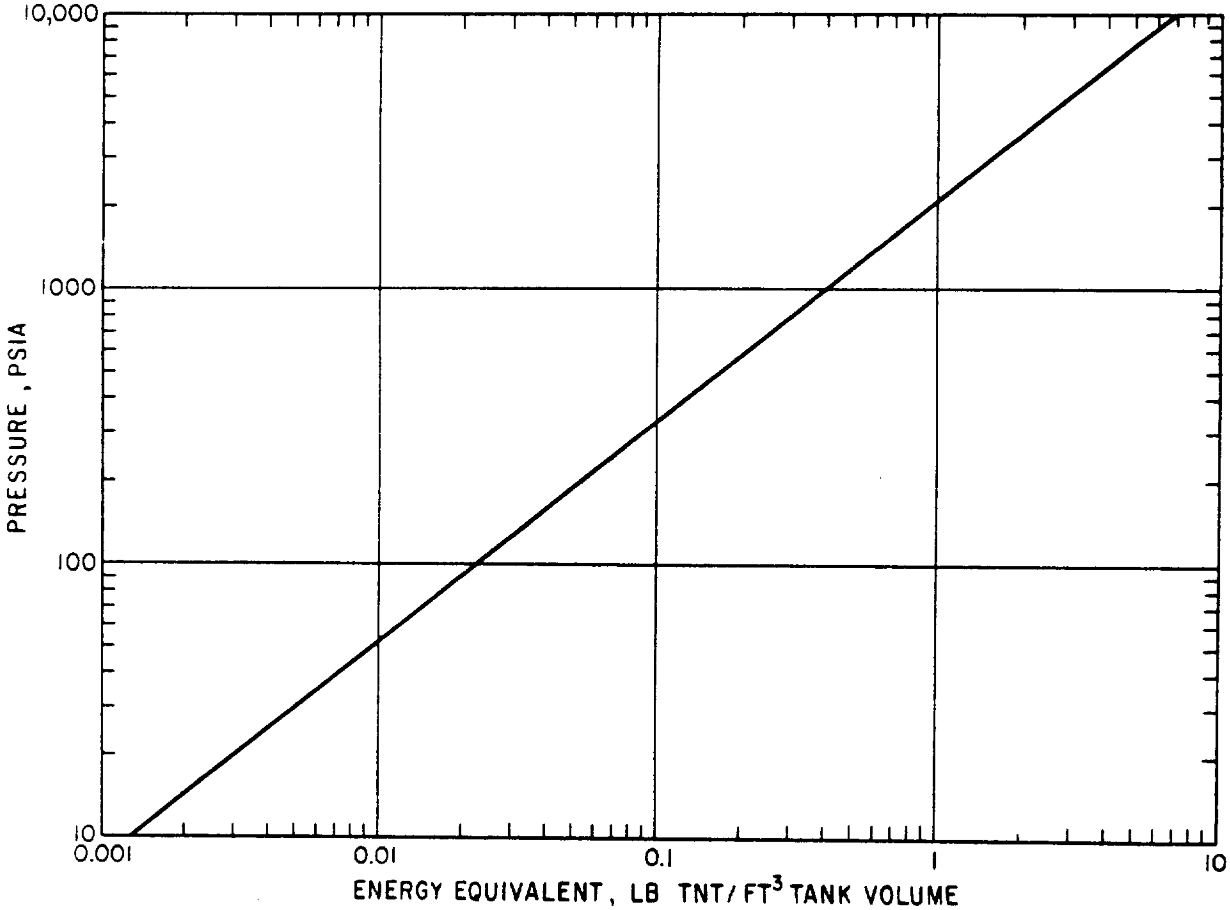

Figure 5-2. Tank Pressure Versus Energy Equivalent

5.1.3.4 Implosion. Although they are not pressurized, glass bell jars which are evacuated can be a dangerous source of flying glass from implosions. Should a crack occur in the bell jar, an unequal force distribution can shatter it. Pieces of flying glass, propelled by a pressure difference of approximately 15 pounds per square inch, will travel great distances unless they should happen to meet a safety shield or glass coming from the other direction. This is particularly serious when the capacity of the vessel exceeds approximately one cubic foot. For this reason all evacuated bell jars should be enclosed in some safety shield.

Safety shields should be used on bell jars under all conditions. One mistake often made is to omit them unless the system is to be evacuated to a high vacuum. The increase of the pressure on the bell jar from one torr to 10^{-3} torr is negligible. The major part of atmospheric pressure is exerted on the jar when rough evacuation takes place; the increase in pressure difference by evacuating the bell jar further is very small.

5.1.4 Effects of Gas Properties

Various properties of tracer gases affect the results of leakage testing. Gas density has an effect on the tendency of the tracer gas to stratify, or form layers, in the test volume, giving uneven readings for various leak locations. The diffusion rate of a tracer gas has an important effect on test results, particularly if there are restrictions or long, narrow, blind passages or crevices in the test volume. Variations in tracer-gas concentration can give varying leak indications.

5.1.4.1 Gas Concentration. In many leakage measurements, it is desirable or necessary to dilute the tracer gas used. Diluted tracer gas might be dictated by:

1. Expense involved in the use of pure gas.
2. More linear or more stable response obtained at lower gas concentration.
3. Pure gas producing a sensitivity much greater than needed.
4. Danger of fire or explosion with a flammable tracer gas (a dilute gas mixture reduces danger).
5. Inability to completely evacuate the system prior to filling with tracer gas, so that a dilute tracer is obtained during the pressurizing process.

Concentration of tracer gas in the system depends on its partial pressure. Total system pressure is the sum of the partial pressures of the gases in the system. Thus,

$$P = P_A + P_B + P_C + \dots \qquad (5\text{-}1)$$

Using Equation 5-1, the fractional concentration of gas A in the system is:

$$N_A = \frac{P_A}{P} = \frac{P_A}{P_A + P_B + P_C + \ldots} \qquad (5\text{-}2)$$

A special tracer-gas mixture is often prepared by combining volumes of different gases having equal partial pressures. A tracer gas such as helium is often mixed with nitrogen for use in leakage testing of large systems.

Most leak detectors are to some extent specific to a particular tracer gas. As a general and approximate rule, the response of a leak detector to a measured dilute tracer-gas concentration is proportional to the concentration of the tracer. For example, with a gas mixture containing one percent of a tracer which leaks at an actual rate of 1×10^{-6} atm-cc/sec^{-1}, the leak detector signal would indicate a leakage rate of only 1×10^{-8} atm-cc/sec^{-1}. The magnitude and direction of any deviation from this rule depends on the predominant flow mode for the tracer gas in the leak. The expected predominant flow modes are discussed in Section 6, "Flow Characteristics."

If the leakage is laminar, the flow will be inversely proportional to the viscosity of the gas mixture. The mixture will have a viscosity proportional to the viscosity of the individual species in a relation:

$$\eta_{\text{mixture}} = N_A \eta_A + N_B \eta_B + N_C \eta_C + \ldots \qquad (5\text{-}3)$$

The estimated leakage for pure tracer gas, Q_{est}, may be calculated from the relationship:

$$Q_{\text{est, pure tracer}} = \frac{Q_{\text{indicated tracer}}}{N_{\text{tracer}}} \; \frac{\eta_{\text{mixture}}}{\eta_{\text{tracer}}} \qquad (5\text{-}4)$$

The calculations are usually simplified by the fact that the viscosities of most gases are similar (Table 6-1, Section 6.1). Therefore, the measured leakage for laminar flow is approximately related to the total leakage by the equation:

$$Q_{\text{est, pure tracer}} = \frac{Q_{\text{indicated tracer}}}{N_{\text{tracer}}} \qquad (5\text{-}5)$$

If the flow in the leak is molecular, leakage of the tracer gas can be calculated from the measurement of leakage of the following mixture:

$$Q_{\text{est, pure tracer}} = \frac{Q_{\text{indicated tracer}}}{N_{\text{tracer}}} \left(\frac{M_{\text{mixture}}}{M_{\text{tracer}}} \right)^{1/2} \qquad (5\text{-}6)$$

5.1.4.2 Stratification. If a tracer gas is added to air already in the system, a uniform mixture is not readily achieved. The tracer gas will rise toward the top or settle toward the bottom of the system, according to its density. This stratification is more pronounced with high-molecular-weight gases and with gases of a low diffusion coefficient.

Precautions should be taken to mix the tracer with the diluent gas during pressurization of the system. This may be done by providing some means of circulating the gases within the system.

Alternatively, both the tracer and diluent gases may be added simultaneously through a rake or screened aperture. There should be no stratification problem inside the system providing precautions are taken to mix the tracer thoroughly with diluent gas in pressurizing the system. When the mixture is in equilibrium the concentration at height h above the bottom will vary as:

$$C_h/C_o = \exp(-Mhg/R_0T) \qquad (5\text{-}7)$$

5.1.4.3 Diffusion. A tracer gas of low diffusivity speeds leak location because the tracer gas remains close to the leak exit and allows accurate location of the leak with a detector probe. Scanning of the suspected area must be done thoroughly, however, to avoid passing over the leak.

A tracer gas of high diffusivity is necessary to fill *cul-de-sacs* or blind passages within a reasonable time. A low diffusion rate would not allow tracer gas to traverse a tortuous leak passage; hence would make leak detection unreliable. (Table 5-1 gives the diffusivity of certain gases used in leak detection work.)

The time required for a gas to diffuse into or out of a blind duct is given by:

$$t \sim \frac{L^2}{\pi^2 K} \ln\left[\frac{4}{\pi} \frac{1}{1-N_L/N_o}\right] \qquad (5\text{-}8)$$

Figure 5-3 is a plot of diffusion time in a blind duct for a number of tracer gases, using Equation 5-8.

Two procedures may be used to fill a duct with tracer gas. If the duct can be opened (perhaps by a valve) at the end remote from the gas source, filling the duct with tracer gas will be expedited. The other procedure, which is much more difficult, is to evacuate the system prior to admission of tracer gas.

5.2 EXAMPLES OF TYPICAL TEST AIDS AND FIXTURES

Two types of test procedure are discussed here: leakage measurement and leak location (by probe techniques). Although there are many similarities in principle, each procedure allows for individual equipment and operating peculiarities. Many of these are demonstrated on the following pages.

Table 5-1

DIFFUSIVITY OF TRACER GASES IN AIR
(1 atm, 0°C)

Gas	Chemical Formula	Molecular Weight	Diffusion Coefficient* (Sq ft per hr)
Acetylene	C_2H_2	26.0	0.55
Ammonia	NH_3	17.0	0.66
Argon	A	39.9	0.61
Benzene	C_6H_6	78.1	0.30
Butane	C_4H_{10}	58.1	0.33
Carbon dioxide	CO_2	44.0	0.52
Carbon disulfide	CS_2	76.1	0.36
Carbon monoxide	CO	28.0	0.67
Carbon tetrachloride	CCl_4	154.	0.28
Ethane	C_2H_6	30.1	0.49
Ethyl alcohol	C_2H_5OH	46.1	0.38
Ethylene	C_2H_4	28.0	0.52
Halogenated hydrocarbon F-11**	CCl_3F	137.	0.30
Halogenated hydrocarbon F-12**	CCl_2F_2	121.	0.32
Halogenated hydrocarbon F-21**	$CHCl_2F$	103	0.33
Halogenated hydrocarbon F-22**	$CHClF_2$	86.5	0.37
Halogenated hydrocarbon F-112**	$CCl_2F\text{-}CCl_2F$	204.	0.25
Halogenated hydrocarbon F-114**	$CClF_2\text{-}CClF_2$	171.	0.28
Helium	He	4.00	2.7
Hydrogen	H_2	2.02	2.6
Hydrogen Sulfide	H_2S	34.1	0.53
Krypton	Kr	83.8	0.51
Methane	CH_4	16.0	0.72
Neon	Ne	20.2	1.1
Nitric oxide	NO	30.0	0.70
Nitrogen	N_2	28.0	0.68
Nitrous oxide	N_2O	44.0	0.52
Oxygen	O_2	32.0	0.68
Propane	C_3H_8	44.1	0.39
Sulfur dioxide	SO_2	64.1	0.42
Water	H_2O	18.0	0.85
Xenon	Xe	13.1	0.42

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* Values calculated from empirical equation of J.C. Slattery and R.B. Bird (<u>AIChE Journal</u>, Vol. 4, No. 2, 1958, pp. 137-42.)

**ASHRAE Standard Designation

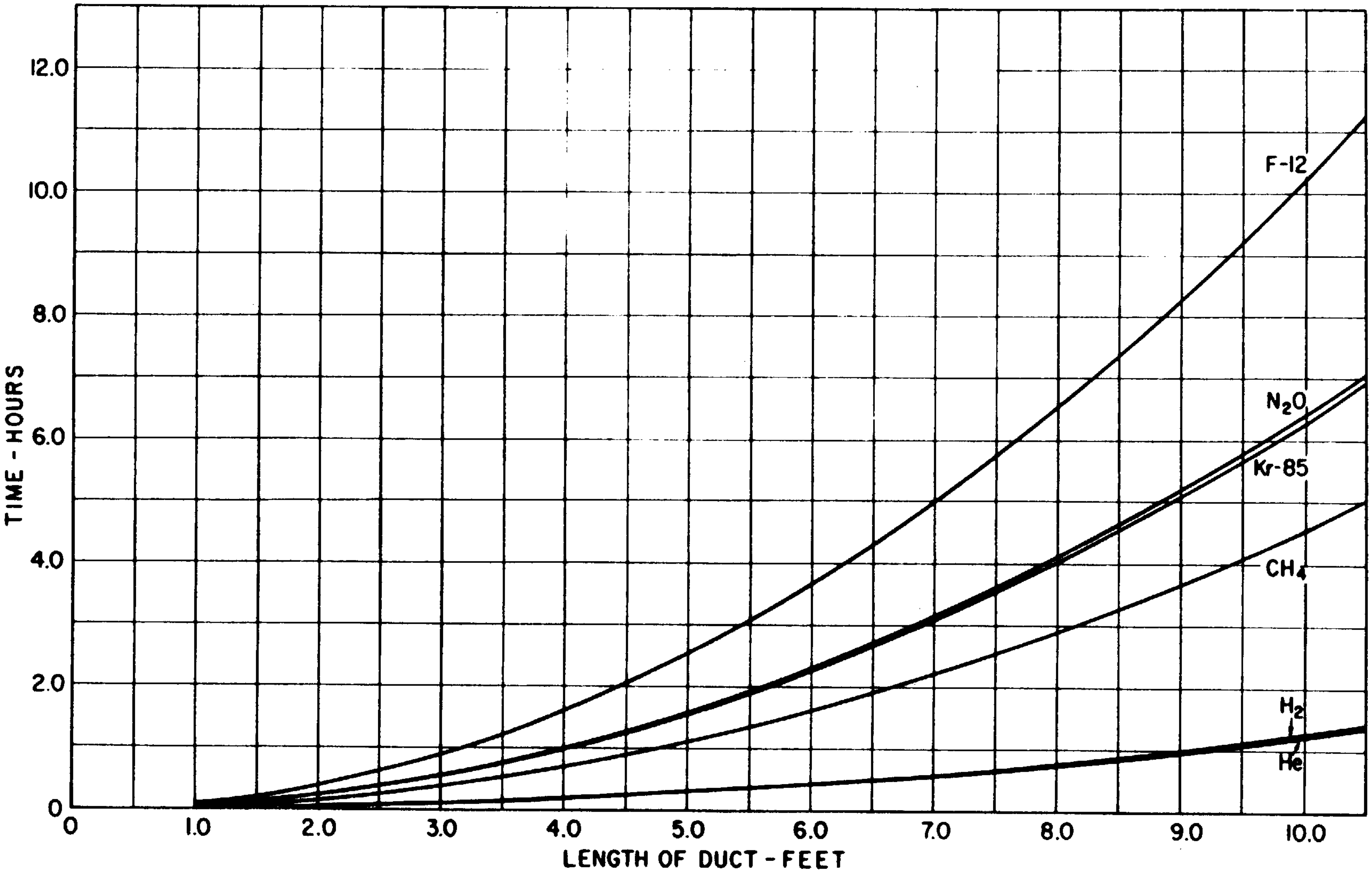

Figure 5-3. Diffusion of Tracer Gases in Blind Ducts. Time Required to Reach One-tenth the Original Tracer Gas Concentration at End of Duct.

5.2.1 Leakage Measurement

On large systems, where rapid testing of a large number of objects is required, testing time can be reduced by the use of a testing hood to surround the entire test object with an atmosphere of tracer gas. This eliminates probing time and gives a response proportional to the total leakage if several leaks exist; the possibility of missing leaks by careless probing is also removed. After the location of leaky test objects the hood may be removed and the leaks accurately located by probing with a small jet of tracer gas. A valuable adjunct to the testing hood is a thermal-conductivity gage, calibrated to read directly the concentration of tracer gas in the hood.

5.2.1.1 Hood Testing. In hood testing, the form of hood used depends on the task at hand. In a semipermanent assembly designed for routine overall testing of large numbers of components, the hood may be a metal chamber or bell jar. When testing one object of a type almost any item can be accommodated in a polyethylene bag. It can be dangerous, however, to use flammable or explosive tracer gases in conjunction with plastic hoods which can acquire an electrostatic charge.

A typical hood setup is shown in Figure 5-4. For small objects several manifolds are attached to one pump-leak detector combination; this allows the objects to be set up or taken down on one manifold while the units on another are under test. For larger equipment individual pump-leak detector combinations are required.

The test is made in the following manner:

- With the valve leading to the calibrated leak in an open position, tracer gas is forced into the hood until its concentration there is sufficient to give a reading on the leak detector. This reading (A) is proportional to the total leakage, which consists of unknown vessel leakage and known leakage from the calibrated leak.
- The valve leading to the calibrated leak is then closed, and a second reading (B) taken. This reading is, of course, proportional to the unknown leakage alone. The unknown leakage may be calculated from these two readings. Thus, unknown leakage =

$$\frac{\text{reading(B)}}{\text{reading(A)} - \text{reading(B)}} \times \begin{pmatrix}\text{conductance of} \\ \text{calibrated leak}\end{pmatrix} \times \begin{pmatrix}\text{pressure} \\ \text{difference}\end{pmatrix} \qquad (5\text{-}9)$$

- Equation 5-9 gives the unknown leakage in terms of the two readings and the leakage through the calibrated leak. Knowledge of tracer-gas concentration in the hood is not necessary. The only requirement is that

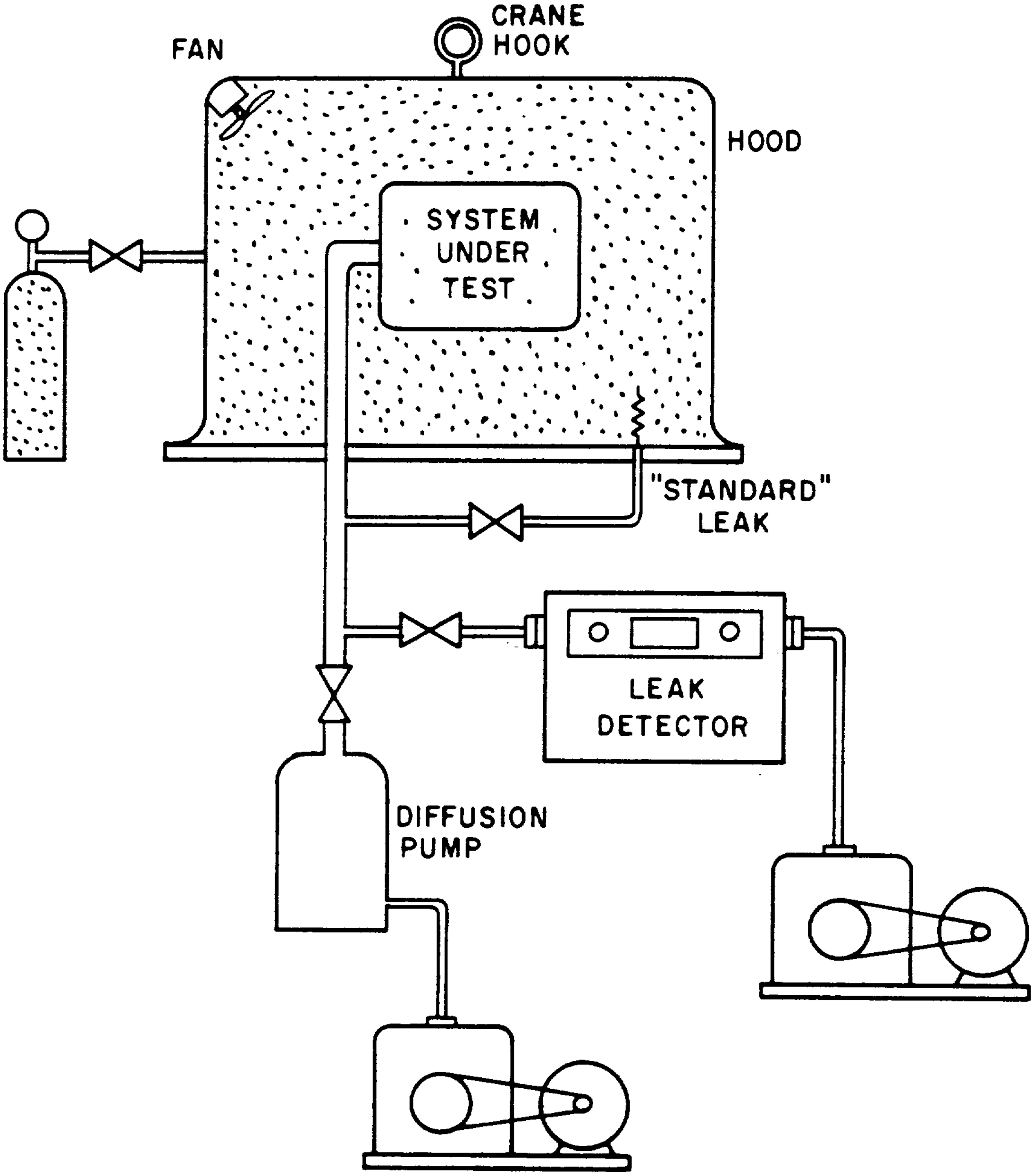

Figure 5-4. Typical Setup for Hood Testing

> this concentration remain substantially constant while the readings are taken. Normally, this requires from five to ten minutes. Well-constructed hoods show practically no decrease in tracer-gas concentration for considerably longer periods.

Figure 5-5 illustrates a type of manifold which allows continuous testing of a number of small vessels. The three testing lines make possible three simultaneous operations: loading and unloading, rough evacuation, and leakage measurement. Measurement of leakage can be performed individually on each vessel, or several vessels may be grouped in a single test. These measurements are made by the hood method. If rejected vessels are set aside for later attention, testing may be as rapid as the loading and unloading can be performed. The calibrated leaks shown serve both to test the effectiveness of the testing manifold and as a reference standard.

5.2.1.2 Small Component Testing. For rapid testing, components are sometimes leak-tested on a rubber pad on a base plate, by sealing the component to the pad (usually with the help of vacuum grease) and spraying some tracer gas around the component. If leakage is indicated, the experimenter must determine whether the component or the grease seal between pad and component or pad and fixture is leaking. Furthermore, vacuum grease absorbs and retains tracer gas. This produces a changing background signal due to tracer gas in the setup which must be compensated for in analyzing the test results.

Duxseal and Apiezon Q are putties which can be used for sealing in rapid testing. The component is sealed to a fixture with the putty and pumped down. The system is then allowed to stabilize at its maximum sensitivity. Tracer gas is passed over the entire surface of the part, and then lightly over the joint. If a leak is observed in the seal area, the setup is dismantled and reassembled, using new putty. Seal material is used only once and then discarded because the material may absorb tracer gas and allow permeation by tracer gas. The time constant for Duxseal exposed to helium has been determined as 20 minutes; hence, a test should be terminated within that period of time.

A good discussion of fixtures for leak testing is given by Smith in Reference 5-7. Every fixture has two sealing surfaces: where it is sealed to the detector and where the component to be tested is sealed to the fixture. Figure 5-6 is an example of such a test fixture. The seal between the envelope and the base plate does not have to be leak-tight.

Flexible gaskets made of elastomers and certain other materials should be used sparingly since they easily absorb helium. During the first few minutes that helium is entering one side of such a gasket, no helium leaves the other side. However, leakage starts after a few minutes and quickly builds up to a steady value. Because of permeability, the use of elastomers and similar materials is limited to the sealing of test setups for the measure-

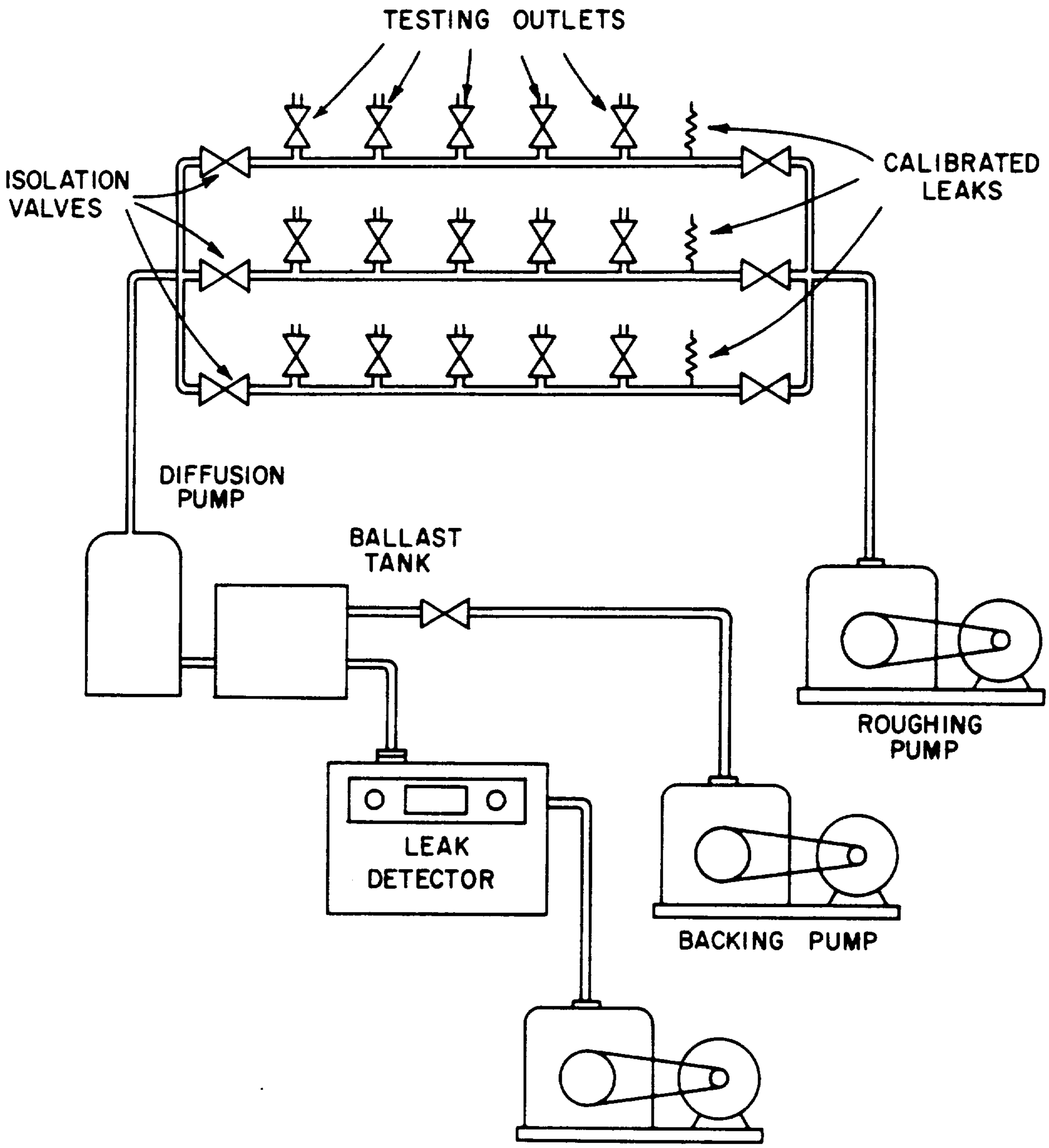

Figure 5-5. Typical Manifold for Rapid Testing of Small Parts

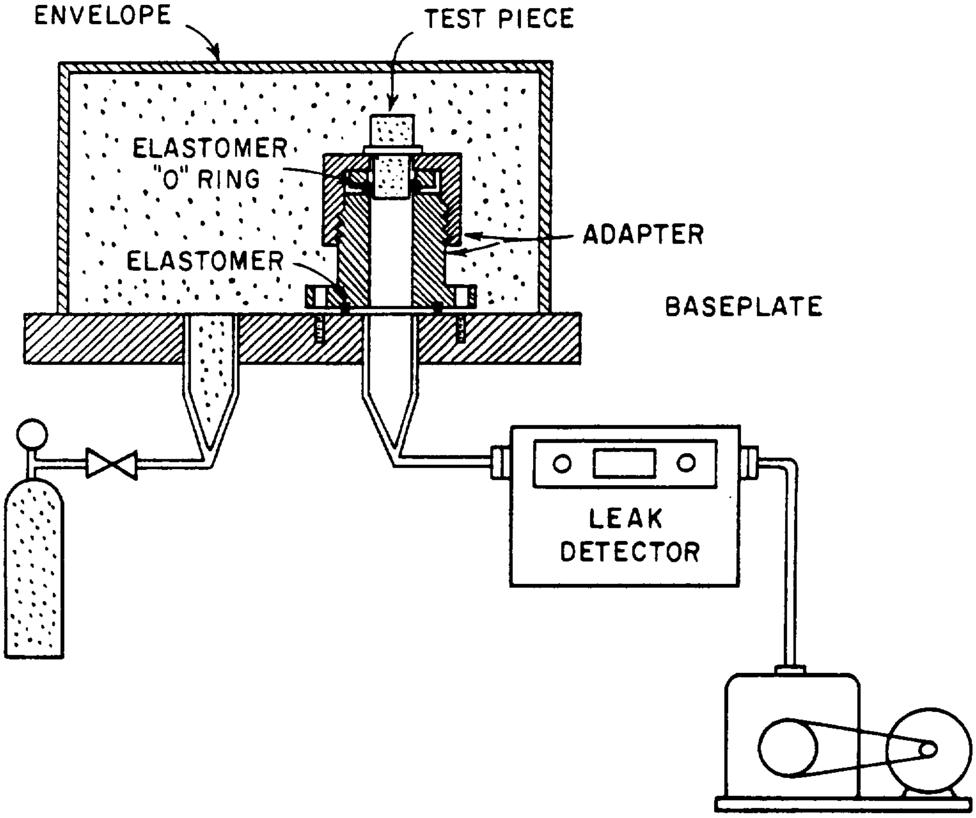

Figure 5-6. Reliable Test Fixture for Leakage Measurement (Reprinted with permission from G.C. Smith, ISA Journal, Vol. 10, November 1963, pp. 55-60; copyright 1963, Instrument Society of America, Pittsburgh, Pa. (Ref. 5-7).)

ment of leaks larger than 5×10^{-7} atm-cc/sec unless special fixturing and pumping techniques are used at the seal. If, however, rapid testing is essential and if long-term measurements are not required, elastomers can be used when detecting leaks as small as 1×10^{-9} atm-cc/sec. (Details on permeation are given in Section 6.2).

The size and type of leaks which must be detected are major considerations in the design of fixtures. In the region 10^{-4} atm-cc/sec to 5×10^{-7} atm-cc/sec, elastomers and flat gaskets are the easiest and most practical to use. Common elastomers used in O-ring configurations are made of viton or butyl rubber; flat gaskets are made of neoprene.

O-rings are mainly used for sealing between a base plate and a test fixture. When sealing around a circular part, the fixture must incorporate a means of holding the O-ring radially against the part. One way to accomplish this is to use a retainer ring in the fixture to hold the O-ring in place. Without the retainer, the O-ring tends to spread or roll away.

Sealing surfaces should be of good quality and have a 64 RMS minimum finish. Shaft surfaces should not have longitudinal marks or scratches. Tooling marks which are so oriented that they bridge the sealing interface are harder to seal than marks which are perpendicular to the shortest leak paths. To reduce the problem of sealing it is better to provide a good surface rather than to try to fill a rough surface with vacuum grease.

Metal gaskets are often used for sealing in tests for leaks smaller than 5×10^{-7} atm-cc/sec. These gaskets are usually made of copper or aluminum and heat-treated to a dead soft condition. Tests, lasting 24 hours, performed on these gaskets show their permeability rate for helium is far below the above leakage rate.

The big disadvantage in using metal gaskets is in the large forces required to assure sealing. Fixtures can be designed to withstand these forces, but many components do not have the physical strength to resist them. Therefore the dimensions of a component, and the mechanical properties of material used in it, must be known when designing fixtures.

The surfaces which metal gaskets seal against must be of much better quality than those used with elastomers. Surface finishes of 16 RMS or better are required for repeatable sealing.

The split-type fixture makes possible the use of elastomers and neoprene gaskets for leak testing in the realm of 5×10^{-9} atm-cc/sec. Design of the fixture is such that any leakage of tracer gas through seals will be to the atmosphere and will not be sensed by the detector. Detector seals (Figure 5-7) between the test piece and the detector base plate do not have to seal against the tracer gas since they are not in contact with it. Therefore any tracer gas entering the detector must come through leaks in the test piece. This method is generally more practical than metal-to-metal seals, and it does not impose severe mechanical loads on the test piece to secure good sealing. The shape of test pieces, however, sometimes prohibits its use.

Considerable test time can be saved by keeping the internal volume of the fixture as small as possible, and avoiding materials of construction which have high vapor pressures or high outgassing rates. This reduces the time required to evacuate the fixture to the operating pressure of the detector. Additional time can be saved by using a pump of ample capacity for evacuating the fixture and component.

The time required to perform the actual leak test is largely determined by the test specifications. Response time of a detector to tracer gas leakage in small parts, such as are considered here, is usually very rapid. The fixture designer should see that nothing impedes the flow of tracer gas to the detector tube and thereby adds to the testing time.

Fixtures should be small. This allows the use of a small envelope containing the tracer gas, and a saving in cost of the

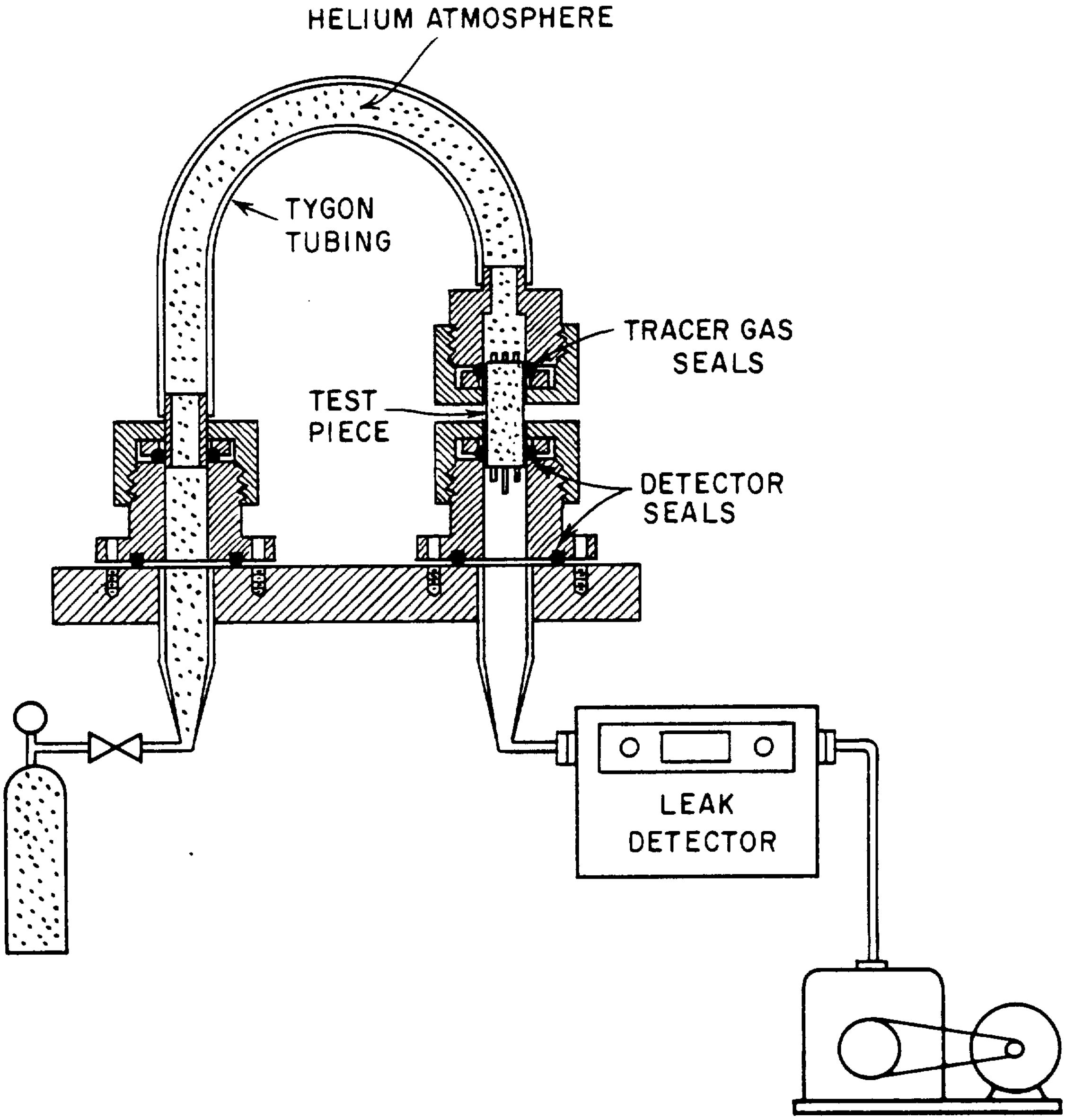

Figure 5-7. Split Fixture for Parts Testing. (Reprinted with permission from G.C. Smith, ISA Journal, Vol. 10, 1963, p. 56, Instrument Society of America, Pittsburgh, Pennsylvania., Copyright 1963.)

fixture, envelope, and tracer gas results. In addition to requiring less storage space, small fixtures save time during evacuating and backfilling.

Before a finished fixture is released for use, it should be thoroughly inspected visually, and leak-tested. Leak testing is done by substituting a solid metal replica for the component which will be used with the fixture. If any leaks are found, they will be in the fixture, providing the sealing surfaces are of good quality. If the fixture leaks, it can be repaired until the leakage is much smaller than the maximum allowable leakage for the component.

5.2.1.3 Weld Joint Testing. Testing of individual welds in large systems is discussed in Reference 4-10. The test method is illustrated schematically in Figure 5-8. A vacuum box which temporarily covers the section of weld under test is evacuated by a pump and also connected to the mass-spectrometer leak detector. Helium is maintained near atmospheric pressure on the opposite side of the weld under a cover of sheet polyethylene, fastened at its edges to the steel plate by suitable adhesive tape. If a leak is detected, it can be located by progressively reducing the surface enclosed by the plastic cover. The leak is finally isolated by means of a fine tracer probe.

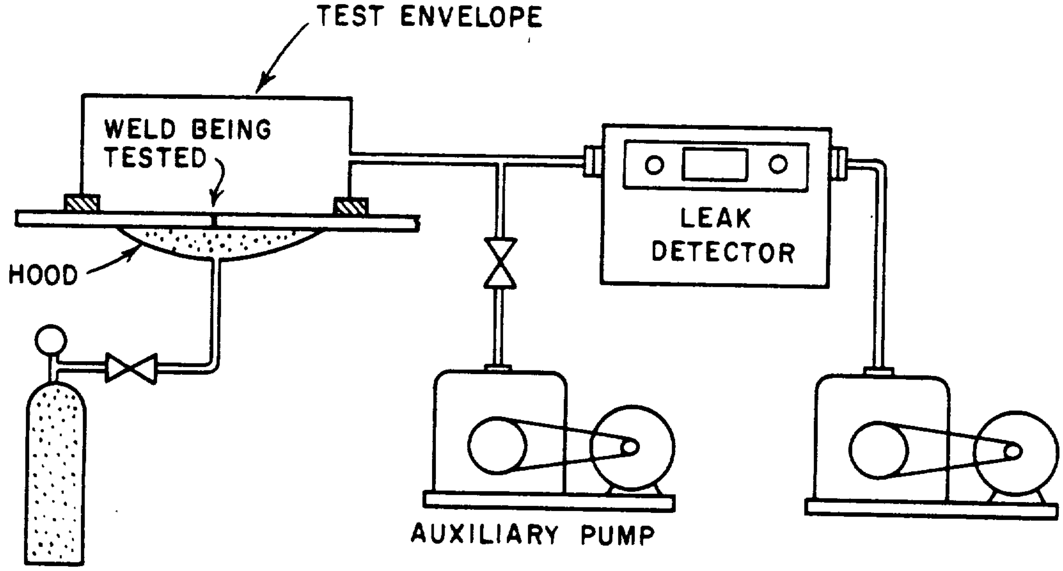

Figure 5-8. Vacuum Box for Weld Testing (Reprinted with permission from R.I. Garrod and J.F. Nankivell, Vacuum, Vol. 11, No. 3, 1961, pp. 139-145; copyright 1961, Pergamon Press, Inc. (Ref. 4-10).)

The major design requirements for the vacuum boxes may be summarized as follows:

1. Working pressure in a box should not exceed 10^{-1} torr.
2. Attachment of a box to any welded section should be an easy, reliable, and relatively rapid process.
3. Design should aim for a minimum number of different box types and sizes to cover all types of weld.

The principal difficulty in meeting these requirements is in making a satisfactory seal between the box and the section of the system under test. The surface of the steel plate is usually pitted, and generally has a poor finish compared with normal vacuum engineering standards. Furthermore, the welds often impose a relatively abrupt change in contour on the seal where the two ends of the box cross the weld.

The method adopted, which has proven satisfactory in operation, is illustrated schematically in Figure 5-9. The vacuum box consists of a flexible metal plate, to which are cemented two rectangular rubber gaskets. The gaskets are made from non-interconnecting cellular rubber. This material provides sufficient sponginess to effect a satisfactory seal with the steel plate and across the weld, but at the same time is nonporous. The section of the box inside the inner gasket is connected via flexible neoprene hose to the leak detector, which also contains the roughing pump for evacuating this volume. The annular space between the two gaskets is connected to a second rotary pump. By this means, leakage across the inner gasket is reduced sufficiently to allow the inner volume of the box to be maintained at a pressure, in most cases, of about 10^{-2} torr. Air is admitted to each section of the box, through driers and inlet valves to release the box from the welded plate after a leak test. For transportability and convenience in use, the rotary pump and the air inlet system may be mounted on a trolley.

5.2.1.4 Testing Pipe and Fittings. The vacuum box can take any convenient form that makes a reasonably tight seal to the pipework. The box or shroud case consists of two brass half-shells with silicone rubber seals molded to them. The offset clamp can have an over-center lock with adjustable tension similar to a pair of "vice-grip" pliers (Ref. 5-8). Different sizes and configurations would be needed for various fittings. Such a fitting may be used to hold the tracer gas or as the detector connector.

5.2.2 Leak Location

The location of leaks is usually accomplished by the detection of gas leakage. A hand-held probe is most frequently used to search for leakage which is first detected by chemical or other means. Where less sensitive detection methods can be tolerated it is possible to use audio or visual methods such as ultrasonics or bubble formation.

Probing is performed with either a detector or a tracer type probe. Certain precautions are necessary when using any probe.

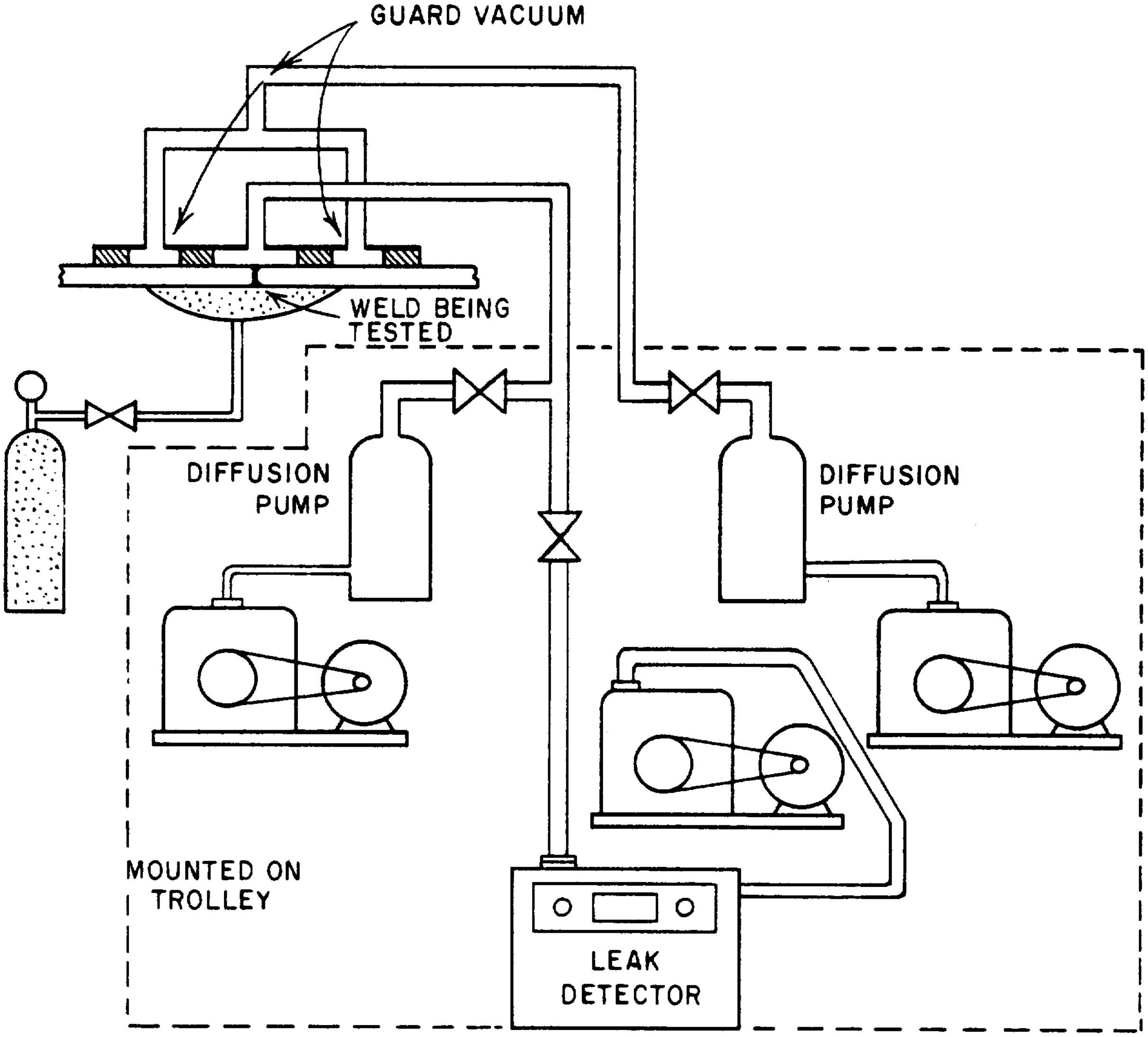

Figure 5-9. Use of Vacuum Box for Weld Testing. (Reprinted with permission from R.I. Garrod and J.F. Nankivell, Vacuum, Vol. 11, No. 3, 1961, pp. 139-145; Copyright 1961, Pergamon Press, Inc. (Ref. 4-10).)

Too rapid a search may miss very small leaks. If this risk is to be avoided, the speed at which the probe is moved must be in proportion to the minimum leak tolerance. In testing equipment for a leak specification of the order of 10^{-5} atm-cc/sec, the travel can be one to two inches per second; but probe speed should be reduced to one-half inch per second for smaller leaks.

If the tracer gas escapes into the room after the test has been completed and the test piece opened, sufficient time must be allowed to permit the ambient to again become free of tracer gas. If the waiting period cannot be tolerated, there are two alternatives that may be employed:

- The test piece can be removed to an outside area before the gas is permitted to escape.
- A vacuum system can be used to remove the gas before opening the test piece.

The use of the vacuum system has proved the more satisfactory. Although some gas usually remains in the test piece after evacuation, and therefore tends to contaminate the air, the time lost in reestablishing tracer-free air is relatively small.

If large volumes are to be tested, it is possible to recompress the tracer gas for reuse.

The degree of mechanization employed in a testing setup is dependent upon the production rate, the uniformity of test pieces, and the total time available for hand work by the operator.

It is usually not possible to depend on natural dissipation of escaping gas in a high-speed production test; it therefore becomes necessary to remove gas in the shortest possible time. The design must include adequate vacuum lines to remove the gas from the test piece after testing; and proper forced ventilation must be employed to clear the surrounding air. A hood has been found suitable for this purpose.

When sufficient incoming airflow is used to clear away leaking gas, steps must be taken to properly direct the air so that it does not remove the gas at the point of the leak, before the detector has had time to acquire a sample of tracer gas and indicate the leak.

It is suggested that due consideration be given to the following points.

1. If the tracer gas is lighter than air, the system should be probed from the upper parts of the test object to the lower. In this way the tracer gas, which rises, will flow back only over areas already tested. Of course, the reverse is true if the tracer gas is heavier than air.
2. For tracer probe testing of individual joints, time may be saved by using a generous flow of tracer gas

from a flexible rubber tubing (1/4 inch ID). When a leak is indicated, its exact location can be determined by means of a finer probe. On the other hand, with large leaks in the system, enough tracer gas may enter the system to saturate the leak detector for a while. With many small leaks, diffusion of tracer gas to these small leaks may make leak location difficult. The use of a fine probe will narrowly limit the area covered by tracer gas.

3. A very large leak will register on the detector, even when the probe is some distance from it. The leak should be located and repaired (permanently or temporarily). Vacuum putty may be used for temporary repairs.
4. When a point appears to leak but does not give a consistent response, a large leak in some other location is possible.
5. To distinguish between two possible points of leakage, close to one another, one of them can be covered (with tape, for example). A fine probe and a minimum flow of tracer gas will help.
6. If a liquid tracer is to be employed, there is less likelihood of blocking a leak if a pad of cotton is moistened (but not saturated) with the liquid and used rather than a liquid spray.
7. The probe should be moved over the test area at a speed consistent with the time constant of the system (see Section 4.5.2). When a detector probe is used, response and cleanup time constants depend on the length of tubing connecting the probe to the detector. As the length of tubing is increased, both response and cleanup time increase.
8. In detector probe testing, if large leaks are known to be present, it is wasteful of search gas to use a high pressure. Furthermore, the space outside the test vessel in the neighborhood of a large leak will become flooded with search gas, which will give confusing results when adjacent areas are probed. It is advisable, therefore, to pressurize the test vessel cautiously, watching the pressure gage for an indication of the presence of large leaks.

5.2.2.1 Design of Probes. The "sniffer", or detector probe, can be a simple device when it is to be connected to a leak detector with a pumping system, since the pumps provide the suction necessary for drawing a gas sample through the sniffer into the leak-detecting element. Figure 5-10 shows the Atlas-MAT "Schnuffelsonde" (Ref. 5-9) with a screw adjustment for controlling the gas throughput.

The important points in this design are that a sleeve on the end of the probe collects the gas which will travel to the detec-

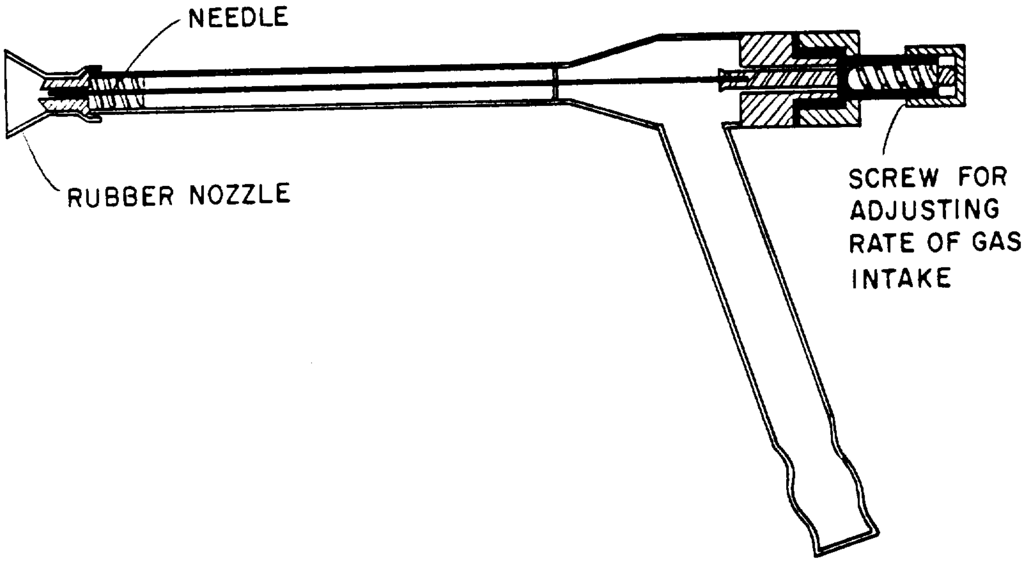

Figure 5-10. Detector Probe for Leak Location. (Reprinted with permission from H.W. Drawin and K. Kronenberger, Vakuum-Technik, Vol. 8, 1959, p. 128, Rudolf A. Long-Verlag, Wiesbaden, Germany (Ref. 5-9).)

tor; and that the flow is controlled at the entrance to the probe, i.e. there are no blind ducts at the entrance.

When tracer probe techniques are employed to locate the exact position of small leaks in equipment having re-entrant cavities, difficulties arise owing to the escape of search gas from the area under test. Under extreme conditions the whole region may become charged with search gas, which by its entry through neighboring leaks makes localization almost impossible. Fans which remove excess search gas from the region where the test is conducted effect only a partial improvement, and their installation is costly.

Pacey (Ref. 5-10) described a probe design which overcomes this difficulty. It consists of two coaxial stainless-steel tubes, search gas being supplied through the inner, and the excess being removed through the outer by means of a small vacuum pump which is vented outside the test region. The flow of search gas is adjusted to provide coverage of leaks without exceeding the capacity of the extraction pump.

Standard hypodermic needles provide a ready source of suitable tubes. Size 0 is used for the outer, and size G for the inner, both having Luer type fittings. The arrangement adopted is shown in Figure 5-11. The outer needle is softened by heating in a small gas-air flame; when cool it is bent through an angle of about 30 degrees, after the removal of most of the fitting to provide an attachment for the flexible tube leading to the vacuum pump at D. A hole is made at the bend to allow insertion of the inner tube. Concentricity at the probe end is brought about by winding a five-turn helix, shown at B, of 0.25-millimeter-diameter wire around the inner tube.

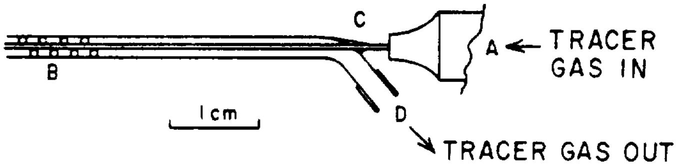

Figure 5-11. Self-extracting Tracer Gas Probe. (Reprinted with permission from D.J. Pacey, Journal of Scientific Instruments, Vol. 41, 1964, p. 398, Institute of Physics and The Physical Society, London (Ref. 5-10).)

After the helix is sprung into place in the outer tube, the inner is inserted through the hole already made and soft-soldered in position, using a zinc chloride flux. This allows a fillet of solder to form at C to provide adequate mechanical strength. The probe is attached to a suitable tubular holder by a taper engaging with the fitting of the smaller needle, through which search gas is supplied.

If a leak closes at atmospheric pressure, and thus does not exist under ordinary testing conditions, it is very difficult to locate. A device (Ref. 5-11) has been developed to locate such leaks by applying gas pressure to selected small portions of the surface. By application of this device to successive small portions of the system the leak is localized.

5.3 SYSTEM CLEANLINESS

The need for cleanliness of the system as a whole, including the test object, cannot be overemphasized. The larger the system the more important is cleanliness.

Tracer gas accumulation in surface dust and oil may cause false but large leak signals. Excessive amounts of rubber -- for example, gaskets and rubber tubing -- should not be used, since they absorb tracer gas. When a large leak is encountered, appreciable amounts of tracer gas are absorbed by the rubber and give false leak indications on succeeding tests.

Lubricants and vacuum greases should be minimized, since they, too, have an affinity for tracer gas. Good vacuum seals are obtainable without the use of greases. Greases are dirt catchers and, as such, will contaminate the vacuum system.

Outgassing properties of leak detection systems are described in numerous books on vacuum technology. A pressure rise in a sealed vacuum indicates a leak, but so does outgassing. Pressure rise caused by a leak will be a straight line when plotted against time. Outgassing will graph differently because it gradually decreases with time. The practical aspects of this are discussed in Section 11.4.

It is possible for a system to exhibit the symptoms of a leak when it is in fact vacuum-tight. Virtual leakage, as it is called, is often due to the presence of a condensable vapor in the system. For example, if water vapor is present in a system equipped with dry-ice traps, the system pressure will approach a limit of 10^{-3} torr, the vapor pressure of water at the temperature of solid carbon dioxide. This is the simplest form of virtual leak. In a liquid-nitrogen-cooled trap, the vapor pressure of water is about 10^{-15} torr, which is negligible by present-day standards. If, however, some of the water vapor has been condensed as ice just below the refrigerant level, then, as the liquid nitrogen evaporates and its level falls, the temperature of this ice will rise until it begins to sublime, producing a virtual leak. This effect will not occur, of course, in a trap in which the refrigerant level is automatically maintained.

In the presence of virtual leaks the system pressure is raised to a particular value which tends to be constant. When a virtual leak is indicated, volatile material may be present in the vacuum system.

The use of a dry-gas bleed in vacuum systems and leak detectors is a highly recommended procedure (Ref. 5-12). The purpose of the gas bleed is to create a laminar flow of gas through the entire system during those periods when the equipment is not in active use. This aids the outgassing of condensable materials, such as water vapor, by preventing readsorption. It also minimizes the back-migration of both hydrocarbons from the mechanical pump and condensables evaporating from the trap. In the case of mass-spectrometer leak detectors, the background signal will be lowered and maintenance reduced. A gas such as nitrogen is generally employed.

When installing a dry-gas bleed system, the point of connection is chosen so that the gas flows from the cleanest parts of the system, past any traps or baffles, and then through the vacuum pumps. In the case of the leak detector, locating the bleed between the spectrometer tube and the inlet cold trap, and leaving the inlet valve open to the manifold and its pump during the bleed operation, permits gas flow toward both pumps. In this way the inlet trap can be cleared of condensables without passing them through the spectrometer tube. Gas flow is adjusted to maintain the vacuum system pressure between 0.2 and 0.5 torr. This can best be accomplished by collapsing a piece of 1/4-inch copper tube until the vacuum pressure is in the proper range. A good vacuum valve between the vacuum system and the restriction can be used to turn the bleed off and on.

When the gas bleed procedure is employed on a vacuum system, the cold traps, if any, should not be maintained cold but allowed to warm to room temperature. Diffusion pumps should be shut down before the bleed gas is applied, leaving only the mechanical pump(s) operating, since the required system pressure for effective bleeding is above their normal operating pressures.

Section 6

FLOW CHARACTERISTICS

NOMENCLATURE FOR SECTION 6

A	Area
$\overset{\circ}{A}$	Avogadro's number (number of molecules per mole)
C_0	Coefficient of discharge, dimensionless
c	Specific heat (c_p, c_v, value at constant pressure and constant volume respectively)
d	Diameter
d_m	Molecular diameter
F	Average velocity in flow channel
f	Fanning friction factor, dimensionless
g	Standard gravity
K	Constant
K_p	Permeation coefficient or permeability
ℓ	Length
M	Molecular weight
m	Mass
N_K	Knudsen number, dimensionless
N_{Re}	Reynolds number, dimensionless
n	Number of molecules per unit volume
P	Pressure (P_1, P_2, upstream and downstream pressure respectively)
P_a	Average pressure
P_T	Pressure at throat of a nozzle or orifice
ΔP	Pressure differential
Q, Q_g	Leakage rate, pressure-volume per unit time
Q_ℓ, Q_v	Leakage rate, volume per unit time

q	Permeation rate, volume per unit time
R	Radius
R_0	Gas-law constant
r_c	Critical pressure ratio
T	Absolute temperature
V	Volume
V_a	Sonic velocity
W	Mass flow rate, weight per unit time
Z	Function given by the argument of Equation 5-13
γ	Specific heat ratio, c_p/c_v
η	Viscosity (η_g, η_ℓ, viscosity of gas and liquid respectively)
λ	Mean free path
ρ	Density
σ	Surface tension
ϕ	Contact angle, liquid to wall

Section 6

FLOW CHARACTERISTICS

6.1 GAS FLOW

Mass transfer due to gas leakage across a boundary proceeds in one or more of three basic modes of flow. These modes of flow are classified as

- Poiseuille, or laminar, flow
- Knudsen, or molecular, flow
- Transition flow, which is a mixture of laminar and Knudsen flow
- Turbulent and choked flow

The rate of transport in each mode is a function of several factors associated with the leak channel and the gas involved. The total pressure gradient is common to all modes of flow.

6.1.1 Poiseuille Flow

Isothermal streamline motion in round tubes under conditions such that the velocity distribution is parabolic with the maximum velocity at the axis characterizes the laminar type of flow. At sufficiently high values of velocity the motion becomes turbulent and is characterized by the existence of eddies or vortices in the flow channel. Turbulent flow is rarely encountered in leak-detection work. Streamline or laminar-flow leakage rate through a straight capillary of circular cross section can be calculated from Equation 6-1:

$$Q = \frac{\pi}{8} \left(\frac{d}{2}\right)^4 \frac{P_a}{\eta \ell} \left(P_1 - P_2\right) \qquad (6\text{-}1)$$

where $P_a = \frac{P_1 + P_2}{2}$

The equation is applicable where the length and diameter of the flow passage are known. The equation may be rewritten as follows:

$$Q = K \frac{P_a \left(P_1 - P_2\right)}{\eta} \qquad (6\text{-}2)$$

where K represents the constants in Equation 6-1. The constant K includes the two geometry factors of diameter and length, which are generally not known. Thus,

$$K = \frac{\pi}{8} \left(\frac{d}{2}\right)^4 \frac{1}{\ell} \qquad (6\text{-}3)$$

Laminar flow occurs under conditions determined by the average velocity of flow across a plane transverse to the leakage path, and by the density of the gas and its viscosity.* A dimensionless ratio called the Reynolds number may be used to express the conditions for laminar flow as well as other types of flow. The Reynolds number is the ratio of the inertial to the viscous forces in a flowing fluid. It is expressed as:

$$N_{Re} = \frac{\rho\ d\ F}{\eta} \qquad (6\text{-}4)$$

Substituting the value of the density in Equation 6-4, the ideal gas equation gives the following expression for the Reynolds number for an ideal gas:

$$N_{Re} = \frac{Q}{d}\ \frac{4M}{\pi\ \eta\ R_0 T} \qquad (6\text{-}5)$$

The critical value of the Reynolds number defining the region between laminar and turbulent flow has been shown to be dependent upon the entrance conditions, roughness of the walls, and the shape of the flow path. In general, for smooth tubes with well-rounded entrances, the critical value is about 1,200. For flow corrections necessitated by turns, constrictions, and surface roughness see Reference 6-1.

The two most important characteristics of laminar leaks are: 1) flow is proportional to the difference between the squares of the pressures upstream and downstream of the leak; and 2) leakage is inversely proportional to the leaking gas viscosity. Table 6-1 shows that the viscosities of many gases are similar. Therefore, a change of gas will not markedly increase the sensitivity of the leak-detection method unless this change of gas implies a change of instrument sensitivity. However, as shown in Figure 6-1, increasing the pressure difference across the leak by a factor of a little more than three will increase the flow rate through this leak by a factor of ten. Obviously, then, when the leaks to be measured are in the laminar flow range, the simplest method of increasing detection sensitivity is to increase the pressure across the leak.

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*From kinetic theory the viscosity of a gas is:

$$\eta = \frac{m\bar{F}}{3\ \sqrt{2}\pi d_m^2}$$

The average velocity $\bar{F}$ is $(8\ R_0 T/\pi M)^{1/2}$ and the mass of the individual molecules is $m = M/\mathring{A}$.

Thus,

$$\eta = \frac{2\ (MR_0T)^{1/2}}{3\pi^{3/2}\ \mathring{A}\ d_m^2}$$

This equation shows that the viscosity of a gas is independent of pressure and is proportional to the square root of temperature.

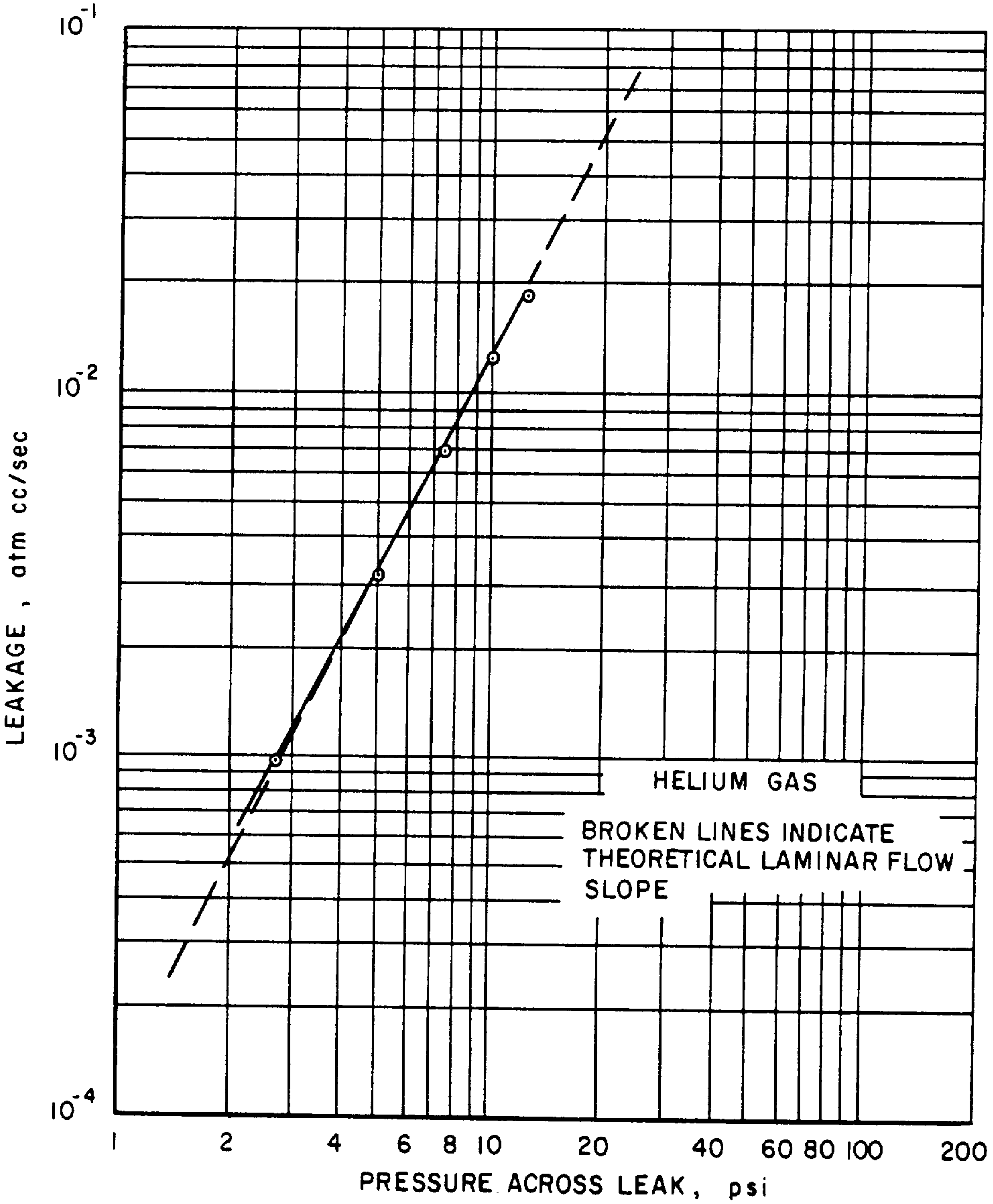

Figure 6-1. Laminar Flow in a Typical Hardware Leak. (Reprinted from J.W. Marr, Study of Dynamic and Static Seals for Liquid Rocket Engines, Final Report Phase II, Contract NAS 7-102 (Ref.6-2).)

Table 6-1

VISCOSITY OF GASES AT 0°C
(Ref. 6-1)

Gas	Viscosity, Centipoises
Acetylene	0.0092
Air	0.0169
Ammonia	0.0094
Argon	0.0208
Benzene	0.0069
Carbon dioxide	0.0135
Carbon disulfide	0.0089
Carbon monoxide	0.0171
Ethane	0.0085
Ethyl alcohol	0.0082
Ethylene	0.0093
Halogenated hydrocarbon F-11	0.0103
Halogenated hydrocarbon F-12	0.0118
Halogenated hydrocarbon F-21	0.0108
Halogenated hydrocarbon F-22	0.0120
Halogenated hydrocarbon F-113	0.0098
Helium	0.0178
Hydrogen	0.0083
Hydrogen sulfide	0.0118
Methane	0.0100
Nitric oxide	0.0178
Nitrogen	0.0168
Nitrous oxide	0.0133
Oxygen	0.0191
Propane	0.0077
Sulfur dioxide	0.0116
Water	0.0088
Xenon	0.0210

6.1.2 Knudsen or Molecular Flow

Molecular flow occurs in a duct when the mean free path is greater than the largest dimension of a transverse section of the duct (Ref. 6-1). In such flow, each atom moves independently and randomly. Net flow is in the direction of a concentration gradient.

The mean free path is the average distance that a molecule travels between successive collisions with the other molecules of an ensemble; it is given by the following equation:

$$\lambda = \frac{1}{\sqrt{2}\pi n d_m^2} \qquad (6\text{-}6)$$

If $n = (m\mathring{A})/(V \times M)$ and $V = m/M[(R_0T)/P]$ then Equation 6-6 becomes

$$\lambda = \frac{R_0T}{\sqrt{2}\pi P\mathring{A}d_m^2} \qquad (6\text{-}7)$$

In Equation 6-7, the mean free path at constant pressure is proportional to temperature. However, if the amount of gas in a volume is kept constant, the mean free path is independent of temperature (Equation 6-6).

The magnitude of molecular diameters and mean free paths is shown in Table 6-2. As a convenient calculation guide, the mean free path of air at room temperature is:

$$\lambda_{air} = \frac{5 \times 10^{-3}}{P} \text{ centimeters} \qquad (6\text{-}8)$$

when P is expressed in torr (about one millimeter of mercury).

Table 6-2

MEAN FREE PATHS AND MOLECULAR DIAMETERS FOR VARIOUS MOLECULES (Ref. 2-3)

Molecule	Mean Free Path ($cm \times 10^{+3}$ at 1 torr and 25°C)	Molecular Diameter ($cm \times 10^{+8}$)
Hydrogen	9.3	2.75
Helium	14.72	2.18
Neon	10.45	2.60
Argon	5.31	3.67
Oxygen	5.40	3.64
Carbon dioxide	3.34	4.65
Water	3.37	4.68
Benzene	1.34	7.65
Methane	4.15	4.19
Ethane	2.53	5.37
Propane	1.82	6.32
n-Butane	1.46	7.06
n-Pentane	1.19	7.82
n-Hexane	1.03	8.42

Knudsen or molecular flow exists when the expression $(\lambda/d)\ (8/\pi)^{1/2}$ is greater than 1. The flow rate in long circular tubes under these conditions can be calculated from:

$$Q = \frac{\sqrt{2\pi}}{6} \sqrt{\frac{R_0T}{M}} \frac{d^3}{\ell} (P_1 - P_2) \qquad (6\text{-}9)$$

In the case of an orifice or aperture in a flat plate the flow rate in torr-liters per second is:

$$Q = 3.638 \frac{\pi d^2}{4} \left(\frac{T}{M}\right)^{1/2} \Delta P \qquad (6\text{-}10)$$

These flow-rate equations include the terms of length and diameter of the flow channel. In most cases the leak channel is irregularly shaped and the values of length and diameter are not known. Using these equations, an estimate of leak size must be made to calculate leakage. Again, when experimental data on leakage rate are available a value of the ratio (d^3/ℓ) or of d^2 may be obtained if the other constants and conditions are known. Thus the equations can be used to evaluate effects on mass flow rate of other gases and other temperatures and pressures.

When the mean free path is large relative to the size of the effective leak diameter, the gas flow is limited by molecular collisions with the channel wall. There are comparatively few intermolecular collisions (the molecules act independently of each other), and the molecular momentum interchange with the wall causes molecules to travel in a direction opposite to that of the net mass flow. For example, when an ultra-high-vacuum system at 10^{-9} torr is leak-tested by a mass-spectrometer leak detector operating at 10^{-7} torr, some of the tracer gas will arrive at the leak detector because of migration in a direction opposite to the concentration gradient.

6.1.3 Transition Flow

The transition from laminar flow to molecular flow occurs over a pressure range of about two orders of magnitude, rather than at any set pressure value (see Section 6.4, "Correlation of Leakage Rates"). Transition flow can be described by an empirical equation formulated by Knudsen (Ref. 2-3):

$$Q = \frac{\pi R^4 P_a}{8\eta\ell} (P_1 - P_2) + Z \left[\frac{2\pi R^3}{3\ell} \left(\frac{8R_0T}{\pi M}\right)^{1/2} (P_1 - P_2) \right] \qquad (6\text{-}11)$$

where

$$Z = \frac{1 + \frac{2R}{\eta}\left(\frac{M}{R_0T}\right)^{1/2} P_a}{1 + \frac{2.47R}{\eta}\left(\frac{M}{R_0T}\right)^{1/2} P_a} \qquad (6\text{-}12)$$

Equation 6-11 is useful over a wide range of pressures for flow in long cylindrical tubes where the flow is laminar, molecular, or transitional.

Another empirical equation suitable for estimating purposes was derived by Burrows (Ref. 6-3) by assuming that the total flow rate can be represented by the sum of the laminar and molecular flows (Equations 6-1 plus 6-9). The following equation was obtained in this way for the flow of air at 20°C from atmospheric pressure to a high vacuum (zero pressure):

$$Q = 2.31 \times 10^4 \frac{R^3}{\ell} \left[3.55 \times 10^4 R + 3.18\right] \qquad (6\text{-}13)$$

where Q is in torr-liters per second, with R and ℓ in centimeters.

This equation is an adequate representation of the events occurring in the leak. Both laminar and molecular flow always occur together in a leak. However, laminar flow is insignificant at small values of R and the molecular flow mode contributes little to total flow at large values of R.

A simple graphical solution is described in Section 6.4.2 to calculate laminar flow through one section of a tube and molecular flow through another to approximate the behavior in the transition region.

6.1.4 Turbulent Flow

As mentioned, above a Reynolds number of about 2100 in the case of circular pipe, flow becomes unstable, resulting in the development of innumerable eddies or vortices. The laws for turbulent flow are quite different from the laws for laminar flow. The equation relating flow rate (Q) in units of pressure times volume/time may be written:

$$Q = \pi d^{5/2} \left[\frac{gR_0T(P_1{}^2 - P_2{}^2)}{64\ fM\ell}\right]^{1/2} \qquad (6\text{-}14)$$

where f, the fanning friction factor, is a function of the Reynolds number and depends on the roughness of the channel walls. The Reynolds number can be considered approximately constant in fully developed turbulent flow. Turbulent flow, because of its associated high velocity, occurs only in large leaks.

6.1.5 Choked Flow

Choked flow, or sonic flow, as it is sometimes called, occurs under special conditions of pressure. Assume a passage in the form of an orifice or a nozzle, and assume that the pressure upstream is kept constant. If the pressure downstream is gradually lowered, the fluid velocity through the throat of the orifice or nozzle will increase until it reaches the speed of sound in the fluid. If the downstream pressure is brought below this pressure, no further increase in fluid velocity will occur, and the mass flow rate will have reached a maximum or critical level. This is the condition known as choked, or sonic, flow. The ratio of the throat pressure to the upstream pressure when maximum flow occurs is called the critical pressure ratio (r_c); this is related to γ by the following equation:

$$r_c = \left(\frac{2}{\gamma+1}\right)^{\frac{\gamma}{\gamma-1}} \qquad (6\text{-}15)$$

The maximum, or sonic, velocity for an ideal gas is given by

$$V_a = \sqrt{\gamma g R_0 T} \qquad (6\text{-}16)$$

Based on knowledge of only upstream conditions of temperature and pressure, the maximum mass discharge under critical flow conditions is calculated as

$$W = \frac{\pi d^2}{4} C_0 P_1 \sqrt{\frac{g_c \gamma M}{R_0 T_1} \left(\frac{2}{\gamma+1}\right)^{(\gamma+1)/(\gamma-1)}} \qquad (6\text{-}17)$$

For an ideal monatomic gas, the value of γ is 1.67. For polyatomic molecules, the heat energy supplied is used for increasing not only the kinetic energy of translation but also the kinetic energy of rotation and vibration. Since the same amount of extra energy is required at both constant pressure and constant volume, γ decreases with molecular complexity. Characteristic values of γ are shown in Table 6-3. Additional values may be calculated (Ref. 6-4) or obtained from other references (Ref. 6-5).

Table 6-3

MOLAR HEAT CAPACITY OF GASES

Calories per Mole at 25°C and 1 Atm

Gas	C_p	C_v	$C_p/C_v-\gamma$
Argon	4.97	2.98	1.67
Helium	4.97	2.98	1.67
Hydrogen	6.90	4.91	1.41
Oxygen	7.05	5.05	1.40
Nitrogen	6.94	4.95	1.40
Carbon dioxide	8.96	6.92	1.29
Ammonia	8.63	6.57	1.31
Ethane	12.71	10.65	1.19
Propane	17.60	15.60	1.13

Because of the special conditions, choked flow is seldom encountered as the predominant flow mode, except in very large leaks.

6.1.6 Distinguishing Between Modes of Flow

Equations have been presented for the various possible modes of flow that can prevail in a leak. The following summary indicates the manner in which it is possible to determine the mode of flow in any situation.

The dimensionless ratio of mean free path to a characteristic lateral dimension of the flow channel is known as the Knudsen number:

$$N_K = \lambda/d \qquad (6\text{-}18)$$

Laminar flow exists for values of $N_K < 0.01$ and molecular flow exists for values of $N_K > 1.0$. The region of transition from one mode to the other lies between values of 0.01 and 1.0.

The Reynolds number (Equation 6-4) can be used to distinguish between turbulent and laminar flow. Turbulent flow exists at values of $N_{Re} > 2100$; laminar flow exists for values of $N_{Re} < 1200$. For values of $1200 < N_{Re} < 2100$ the flow mode can be either turbulent or laminar, depending upon the channel roughness.

As a rule of thumb, it is possible to predict the mode of flow through a leak channel from a knowledge of the rate at which a gas passes through the leak under a differential pressure in the order of one atmosphere (Refs. 5-4, 6-3, 6-6, and 6-7).

Mode	Leakage Rate (atm-cc/sec)
Turbulent	$> 10^{-2}$
Laminar	10^{-1} to 10^{-6}
Transition	10^{-4} to 10^{-7}
Molecular	$< 10^{-7}$

6.2 PERMEATION

Permeation is the passage of a fluid into, through, and out of a solid barrier having no holes large enough to permit more than a small fraction of the molecules to pass through any one hole. The process involves adsorption, diffusion, dissociation, solution, migration, and desorption.

The rate of flow by permeation is given by the following equation:

$$q = K_p A \frac{\Delta P}{\ell} \qquad (6\text{-}19)$$

The ΔP in this case represents the difference in the partial pressures of the leaking fluid on the two sides of the barrier.

The permeability coefficient, K_p, is defined as the product of the diffusion coefficient and the solubility coefficient of the permeating fluid in the barrier material. In a porous material in which the ratio of the volume of an average pore to the surface area of the pore is large, fluid transport from pore to pore is governed largely by diffusion processes.

Values of the permeability coefficient for a few polymeric and ceramic materials are shown in Table 6-4. The literature reference (Ref. 6-8) should be consulted for permeability values at other temperatures, or with other materials, or for different permeants.

If any system is to be relatively leak-tight, the materials of construction must have a very low permeability. For example, the permeation rate at room temperature of a natural rubber gasket 0.1 inch thick, 0.1 inch wide, and 5 inches in diameter with a one-atmosphere hydrogen pressure differential is 6×10^{-6} atm-cc/sec. In some uses, this permeation might represent an unacceptable leakage rate.

Permeation presents a problem to leakage checking equipment where the construction materials have a high permeability to the tracer gas. If a component containing a rubber diaphragm one millimeter thick and one square inch in surface area is leak-checked with helium gas, a leakage of approximately 2×10^{-5} atm-cc/sec will be measured across the diaphragm. This leakage is due to permeation of helium through the diaphragm; not to any actual holes. It represents the maximum sensitivity of helium leakage testing that can be performed on this component. However, if the component is to be used with another fluid, to which the membrane is impermeable, the leakage due to helium permeation measured during leakage testing is misleading.

Another example of this type of false reading is that obtained from a rubber O-ring. Depending on the particular material being tested, an O-ring will have a permeability of approximately 10^{-7} atm-cc/sec-atm per linear inch of exposed surface. Figure 6-2 illustrates the permeation rates of O-rings to helium; it also shows the time lag which depends upon the diffusion constant (Ref. 6-9). This permeability does not have to be taken into consideration during routine leakage checking if the leakage measurement can be performed before helium saturates the O-ring.

To eliminate permeability as a factor in leakage measurement, one of three possible procedures may be used.

1. The leakage measurement may be taken rapidly, not allowing the material to be saturated with gas. This is only possible if the material is relatively thick. For example, a very thin rubber diaphragm will rapidly saturate and almost immediate show leakage. On the other hand, O-rings are relatively thick and will not saturate rapidly enough to give a reading within a reasonable period of time (five minutes). If the diffusivity and solubility of the fluid in the material are known, it is possible to calculate the rate of increase of leakage (Ref. 6-10). However, in many cases (where the leakage path is long) this calculation is not necessary. An experimental check can be made to determine very quickly if leakage through a thick gasket is inconsequential for short-time periods.

Table 6-4

PERMEABILITY OF POLYMERIC MATERIALS TO VARIOUS GASES (Ref. 6-8)

$$\frac{\text{std cc cm}}{\text{sq cm sec bar}} \times 10^8 \text{ (Note: 1 bar} = 10^4 \text{ dynes per sq cm)}$$

Type or Trade Name		Carbon Dioxide	Helium	Hydrogen	Nitrogen	Oxygen	Propane	Water
Buna S		92.8	17.3	30.1	4.7	12.8		
Butadiene-acrylonitrite copolymer								
	Perbunan 18		12.7	18.9	1.89	6.12		
	German perbunan		9.20	11.3	0.84	3.0		
	Hycar - OR - 15		5.13	5.35	0.178	0.72		
	Hycar - OR - 25		7.40	8.85	0.45	1.76		
Cellulose acetate								
	Celanese P-912			6.6		0.81		
Cellulose acetate butyrate								
	Kodapak II		10.8	15.8	1.1	2.8	2.0/31c	
Cellulose nitrate			5.1			1.48	0.0057	4740.
Ethyl cellulose								
	Ethocel 610	31.6		22.4	5.5	17.9		9750
Hydropol		36.3	11.8		3.0	8.5	40.5	
Mipolam MP		3.95		4.3	0.2	0.69		
Neoprene G		19.2	3.38	10.2	0.88	3.0		
MEM-213 Polycarbonate*		713.	90.	150.	75.	128.	900.	750.
Nylon 6		0.92			0.0063	0.023		53
Polybutadiene		103.9		31.6	4.85	14.3		
Polychlorotrifluoroethylene								
	Kel-F			0.73	0.0025	0.02		0.22/30c
	Trithene		25.5/30c	0.73		0.0079/23c		
Polyethylene								
	Alathon 14	9.5	3.7	5.88	0.73	1.65		
Polyethylene terephthalate								
	Mylar A	0.888	0.73	0.44	0.0031	0.019		97.8
Polypropylene (0.907 g/cm^3)					0.33/30c	1.72/30c		36.8
Polystyrene								
	Dow 0641	5.63/20c		67.6	5.8	18.3		
Polyvinyl chloride-dioctyl phthalate								
	101-EP-100	0.765/30c		2.6/30c				
Polyvinylidene chloride								
	Saran 517	0.024	0.01	0.05		0.0018	0.00027	7.4
Rubber, butyl								
	Oppanol-B-200			4.8	0.22	0.89		
Rubber, hydrochloride								
	Pliofilm 140-N2	0.48		1.20				
	Pliofilm FM1	0.70			0.109	0.40		
Rubber, methyl		8.3	10.9	12.8	0.36	1.6		
Rubber, natural		105.	25.0	38.3	7.4	17.5	126.	2570
Rubber, polysulfide								
	Thiokol B	2.37		1.2		0.22		
Rubber, dimethyl silicone		2030.	263.	495.	210.	450.	3080	28500.
Teflon								
	FEP	7.51	30.1	9.89	1.44	3.37		
	TFE		523.	17.8	2.4	7.5		
Glass								
	Fused silica		0.75	0.00011				
	Vycor		1.13	0.00038				
	Pyrex		0.09					
	Soda lime		0.00056					
	X-ray shield		0.000 000 31					
Vitreosil			0.480					

*Information furnished by the Medical Development Operation of the General Electric Company's Chemical and Medical Division.

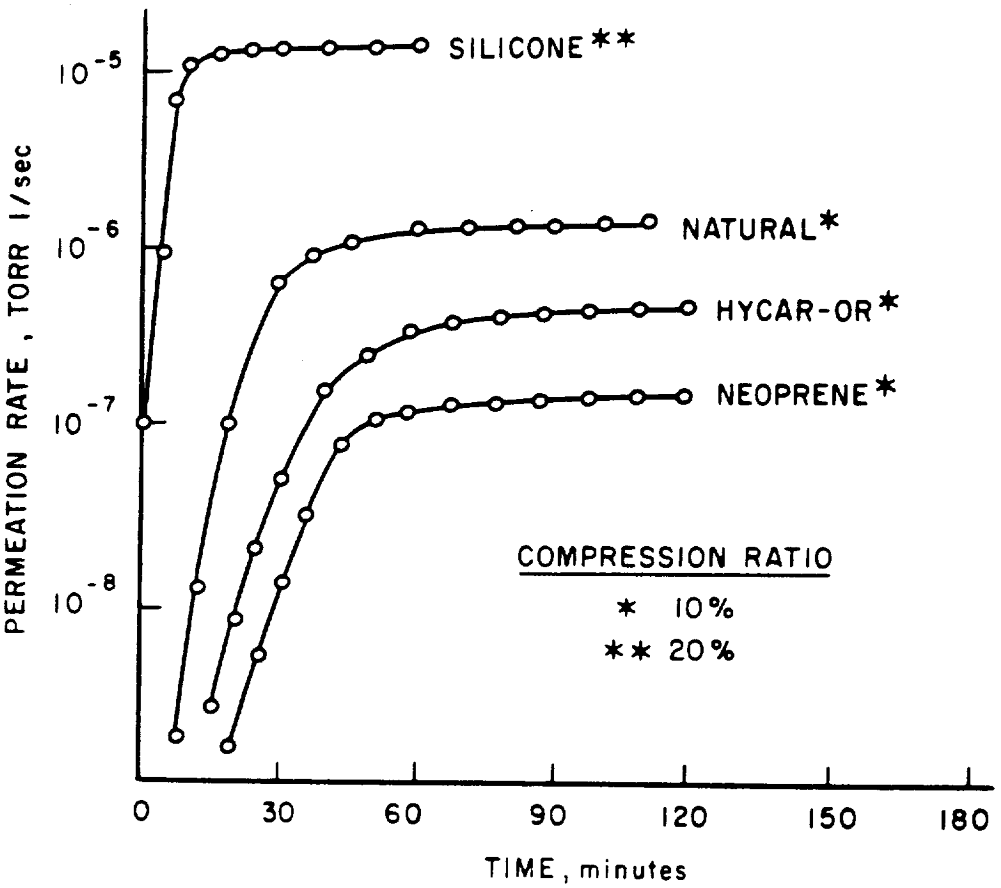

Figure 6-2. Permeation Rate Versus Time of Rubber Gasket for a 4 × 4 mm Cross Section. (Reprinted with permission from I. Kobayeshi and H. Yada, "Leak Test of Rubber Gaskets," Fundamental Problems in Vacuum Techniques, Vol. I, Pergamon Press, London, 1960, p.248 (Ref. 6-9).)

2. The maximum permeability of all components and the resulting mass transfer produced during leakage testing may be calculated by Equation 6-19. Then the difference between the total measured leakage and the permeation will be the actual gas leakage.

3. The last method and the most difficult one to perform, is to quantitatively measure the leakage at several pressure differentials. If the flow is solely due to permeation the leakage will be directly proportional to the difference in permeant concentration across the leak. A flow through a hole or a porous barrier will exhibit a leakage that is proportional to the difference in the squares of the pressures on each side of the barrier under laminar conditions. In this way, the presence of holes in the component can be differentiated from permeation.

6.3 LIQUID FLOW

The flow mode of a liquid through a leak or capillary channel at low flow rates will be laminar; at high flow rates the flow mode will be turbulent. The value of the dimensionless Reynolds number for the liquid is again the criterion for determining which mode prevails (see Section 6.1.1).

6.3.1 Laminar Flow

Poiseuille's equation for laminar liquid leakage flow is

$$Q_V = \frac{\pi}{8} \left(\frac{d}{2}\right)^4 \frac{P_1 - P_2}{\eta \ell} \qquad (6\text{-}20)$$

6.3.2 Turbulent Flow

The turbulent flow equation for liquids is

$$Q_V = \frac{\pi}{4} d^{5/2} \sqrt{\frac{(P_1 - P_2)g}{2\rho f \ell}} \qquad (6\text{-}21)$$

Turbulent flow occurs only in very large liquid leaks.

6.4 CORRELATION OF LEAKAGE RATES

It is often of interest to find the leakage rate of a gas or liquid through a given leak channel when the leakage rate for a particular gas through that channel is known from a previous measurement. Under certain conditions it is possible to correlate leakage values between different gases and between a gas and a liquid without a knowledge of the actual dimensions of the leak channel. Variations in the leakage rate with molecular weight, temperature, and pressure may also be calculated as long as the mode of flow remains the same. It does not appear possible to predict a leakage rate if the mode of flow changes or if, more specifically, a knowledge of the geometry of the leakage path must be known (Ref. 6-11).

6.4.1 Gas-to-gas Flow Correlation

If the flow is laminar, Equation 6-2 may be used to calculate a new flow rate relative to a known flow rate for two gases having different viscosities, or for different levels of inlet and outlet pressure for the same or two different gases. The geometrical factor K is common to the equations for the known and calculated flow rates. For the same levels of pressure, the flow rates for two gases of different viscosity are related:

$$\frac{Q_A}{Q_B} = \frac{\eta_B}{\eta_A} \qquad (6\text{-}22)$$

In general,

$$\frac{Q_A}{Q_B} = \left(\frac{\eta_B}{\eta_A}\right)\left(\frac{P_1{}^2 - P_2{}^2}{P_3{}^2 - P_4{}^2}\right) \qquad (6\text{-}23)$$

where (P_1, P_2) and (P_3, P_4) are two pairs of inlet and outlet pressures. The subscripts A and B represent two different gases. If a single gas is involved, the viscosity ratio is unity in Equation 6-23. A change in flow due to a difference in temperature is accounted for by the effect of temperature on viscosity. The footnote in Section 6.1.1 indicates that the viscosity of a gas varies as the square root of temperature. As shown in Table 6-1, the viscosity of gases at constant temperature varies by less than half an order of magnitude between the most viscous and the least viscous.

If the flow is molecular, and the leakage path is long compared to the length of its effective diameter, Equation 6-9 can be used to generate a similar proportionality:

$$\frac{Q_A}{Q_B} = \sqrt{\frac{T_A}{T_B}} \times \sqrt{\frac{M_B}{M_A}} \times \left(\frac{P_1 - P_2}{P_3 - P_4}\right) \qquad (6\text{-}24)$$

It is assumed in going from one set of pressures to the other that the flow mode remains unchanged in both laminar and molecular flow.

When there is reason to believe that the flow will change in going to a different level of pressure the following procedure is recommended:

- If pressure is increased, correlate as laminar.
- If pressure is decreased, correlate as molecular.
- If gas is changed, correlate as molecular.

6.4.2 Gas-to-liquid Correlation

It is possible to predict liquid leakage on the basis of leakage measured under other known conditions. This method is generally applicable to a leak or series of leaks which have a conductance between 1 and 10^{-5} atm-cc/sec-atm.

An equation which relates the laminar flow of a gas to the laminar flow of a liquid through the same leak is readily obtained by dividing Equation 6-1 by Equation 6-20. The equation is independent of the geometry of the leak and is

$$Q_\ell = \frac{\eta_g}{\eta_\ell}\,\frac{Q_g}{P_a} \qquad (6\text{-}25)$$

Solution of this equation is easily accomplished by use of the nomograph in Figure 6-3. One line connects the viscosity axes with a reference axis (I). A second line connecting the average

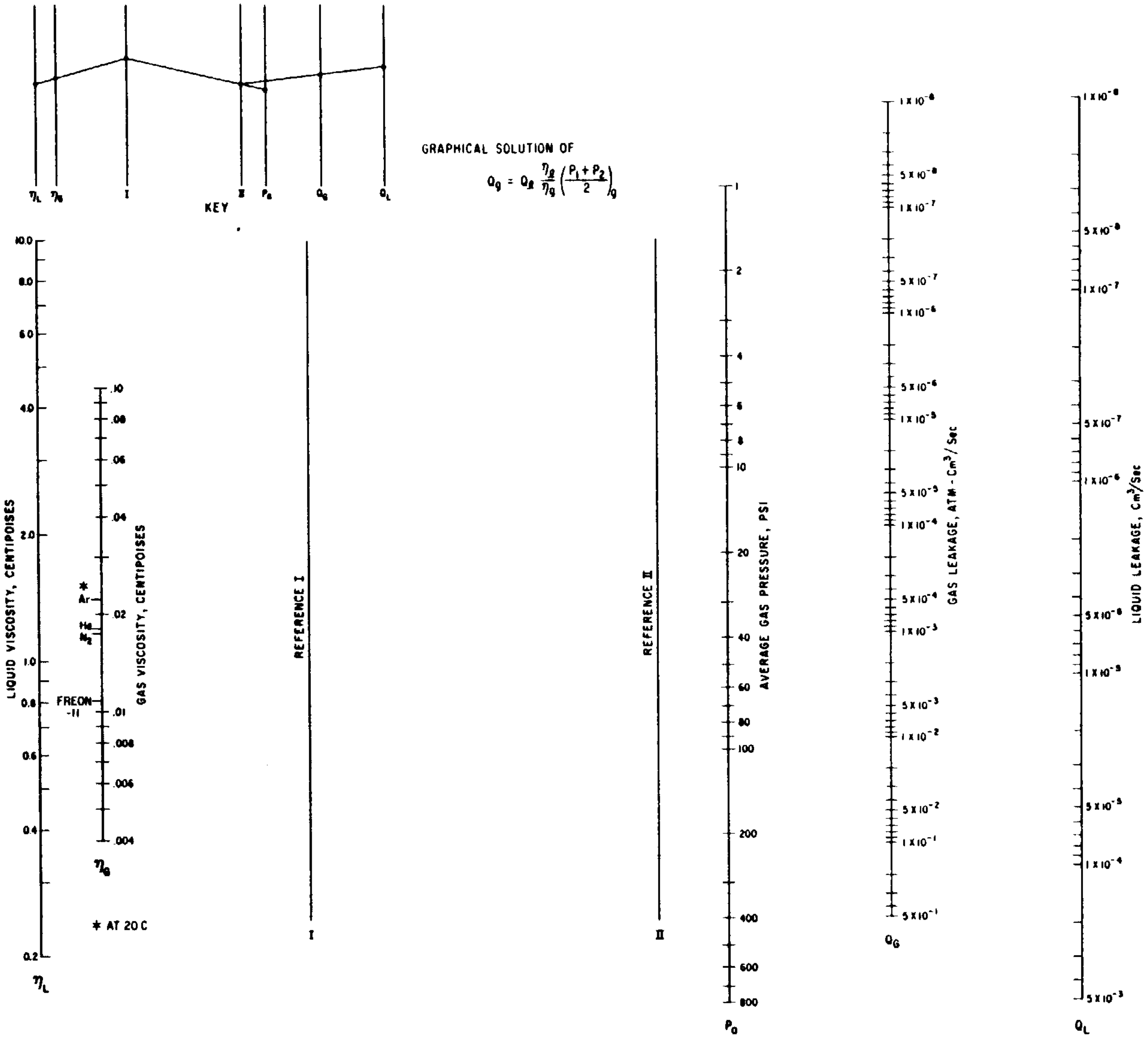

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Figure 6-3. Gas-liquid Leakage Nomograph pressure axis with axis (I) locates a point on axis (II). Thirdly, a line connecting the point on axis (II) with the gas leakage value also intersects the liquid leakage axis at a value which is the solution to Equation 6-25.

This correlation procedure is accurate only for laminar flow leaks. Should the measured leakage be molecular rather than laminar, the error introduced in the calculation will predict a greater liquid leakage than will actually be found. The equation may therefore be used with confidence, since any error will add a margin of safety to the results.

It is also necessary that:

- Leakage be the result of a finite hole or holes, and not of permeation.
- Gas flow be laminar; i.e. the flow through the leak is in the range of 1 to 10^{-5} atm-cc/sec or is made up of a number of leaks in that flow range.
- Calculations should at best be considered accurate to only a factor of two. Error in both the measurements and the deviations from the flow equations preclude a more accurate solution.

In experiments performed to check the validity of the above correlation (Ref. 6-12) liquid leakage was measured for leaks with previously measured gas leakage rates. It was found that leaks having a gas conductance in the 10^{-3} atm-cc/sec range had a liquid leakage approximately one-half that predicted by Equation 6-25. Leaks in the 10^{-4} atm-cc/sec range leaked liquid at a rate approximately one-tenth the rate predicted. Liquid leakage in leaks in the 10^{-5} atm-cc/sec-atm range were approximately one-twentieth of that predicted by the above equations.

It would appear that Equation 6-25 for correlation will produce conservative answers; i.e. the actual liquid leakage will always be smaller than that predicted by theory. It is believed that the liquid flow was lower than calculated for two reasons. First, no correction was made for any molecular flow component of the measured gas leakage. Secondly, the effective diameter of the leak channel was reduced in size by an immobile layer of liquid adjacent to the leak wall.

6.5 ANOMALOUS LEAKS

Some leaks which occur in practice exhibit a flow behavior quite unlike that of an ideal smooth-bore capillary. Such leaks are called anomalous leaks, and include check-valve leaks, geometry-change leaks, self-cleaning leaks, and surface-flow leaks.

6.5.1 Check-valve Leaks

Reference 6-2 contains examples of check-valve and geometry-change leaks found during a study of leakage phenomena.

Figure 6-4 is a plot of the leakage-pressure differential obtained on a damaged needle valve. It was observed that although the typical laminar flow curve was obtained at a high pressure differential, below this pressure the leakage abruptly stopped. With increase of the pressure, the leak reappeared. This phenomenon was repeatable.

This type of leak would be particularly hard to find, since it would not be detected below a critical pressure value.

6.5.2 Geometry Changes in Leaks

The shape of a leak may change with variations in temperature or pressure. Either a liquid or a gas under pressure can cause a change in leak size.

Change of leak size will affect a prediction of flow based on either Equation 6-23 or Equation 6-24. Each of these equations has been derived on the basis that the geometry factor remains invariant with changes in the other variables. Each of the equations correlates a new flow and a new pressure differential with an old flow and an old pressure differential. If the new pressure differential is higher than the old, the leak size may be caused to increase. If so, the actual leakage will be greater than that predicted by the correlation calculation.

The influence of temperature on leak size is somewhat unpredictable. For example, either an increase or a decrease in temperature can open up a leakage path, depending upon the stress distribution in the material near the leak wall.

6.5.3 Self-cleaning Leaks

Quantitative determination of the leakage of helium across gaskets under compression was observed to consist of a series of discrete laminar flow steps (Ref. 6-2). Figure 6-5 shows the data plotted in logarithmic form along with theoretical laminar flow lines.

Since the step-like increases in flow rate could result from a permanent deformation of the gasket, an experiment was run using an aluminum gasket too sturdy to be deformed. Figure 6-6 shows the data obtained from this experiment. During the original increase in pressure, the leakage increased at a rate greater than the square of the pressure increase. However, upon release of the pressure, the leakage decrease was proportional to the square of the pressure decrease. A second increase in pressure produced an increase which retraced the leakage encountered during the pressure decrease.

It is believed that the original pressure increase cleaned the leakage passages. Further pressure cycling did not effect the maximum leakage. This suggests that whenever possible leakage testing should be done at the proposed operating pressure, in order that potential leaks may be formed and observed.

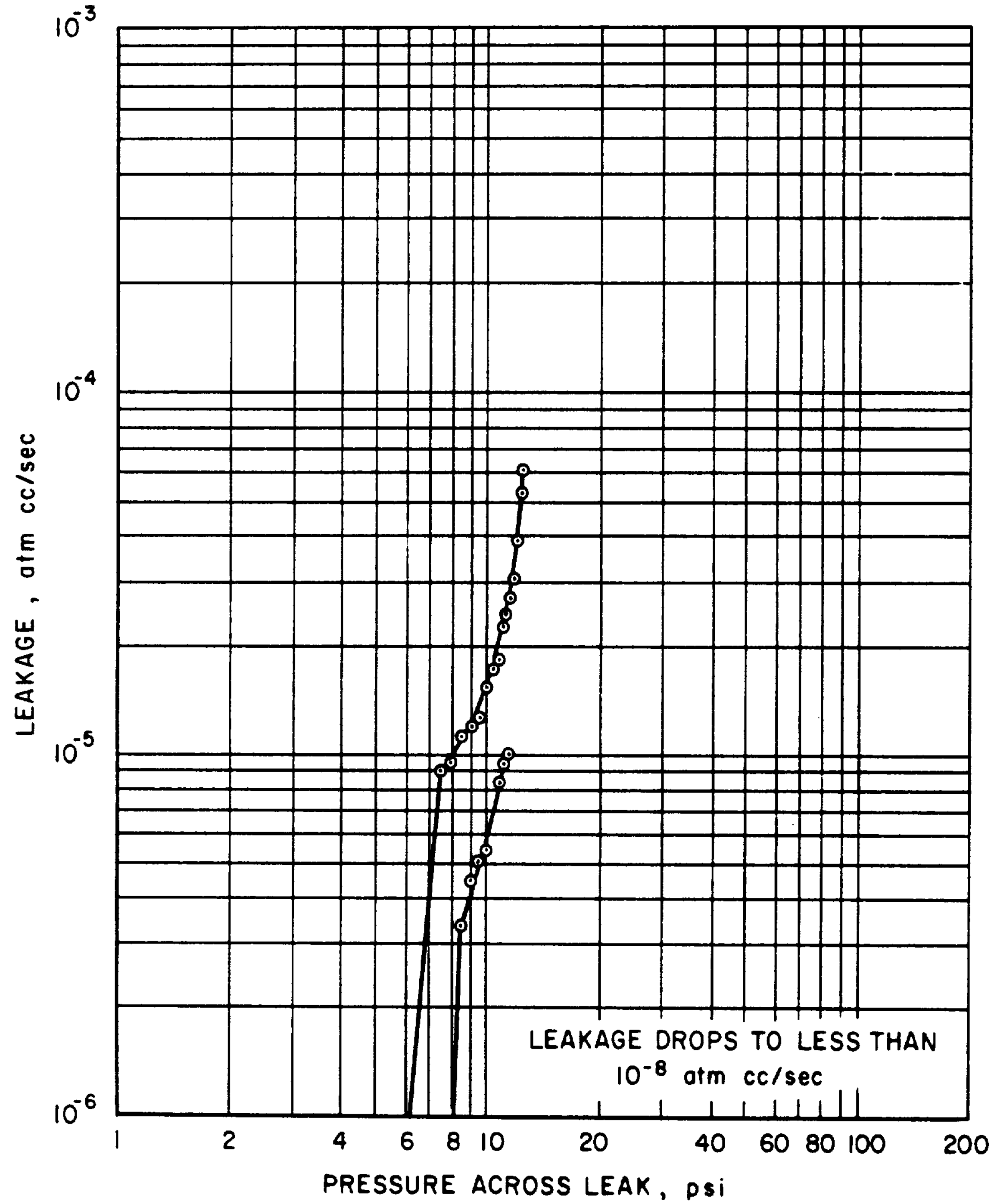


Figure 6-4. Check-valve Effect in a Hardware Leak. (Reprinted from J.W. Marr, Study of Dynamic and Static Seals for Liquid Rocket Engines, Final Report Phase II, Contract NAS 7-102 (Ref.6-2).)

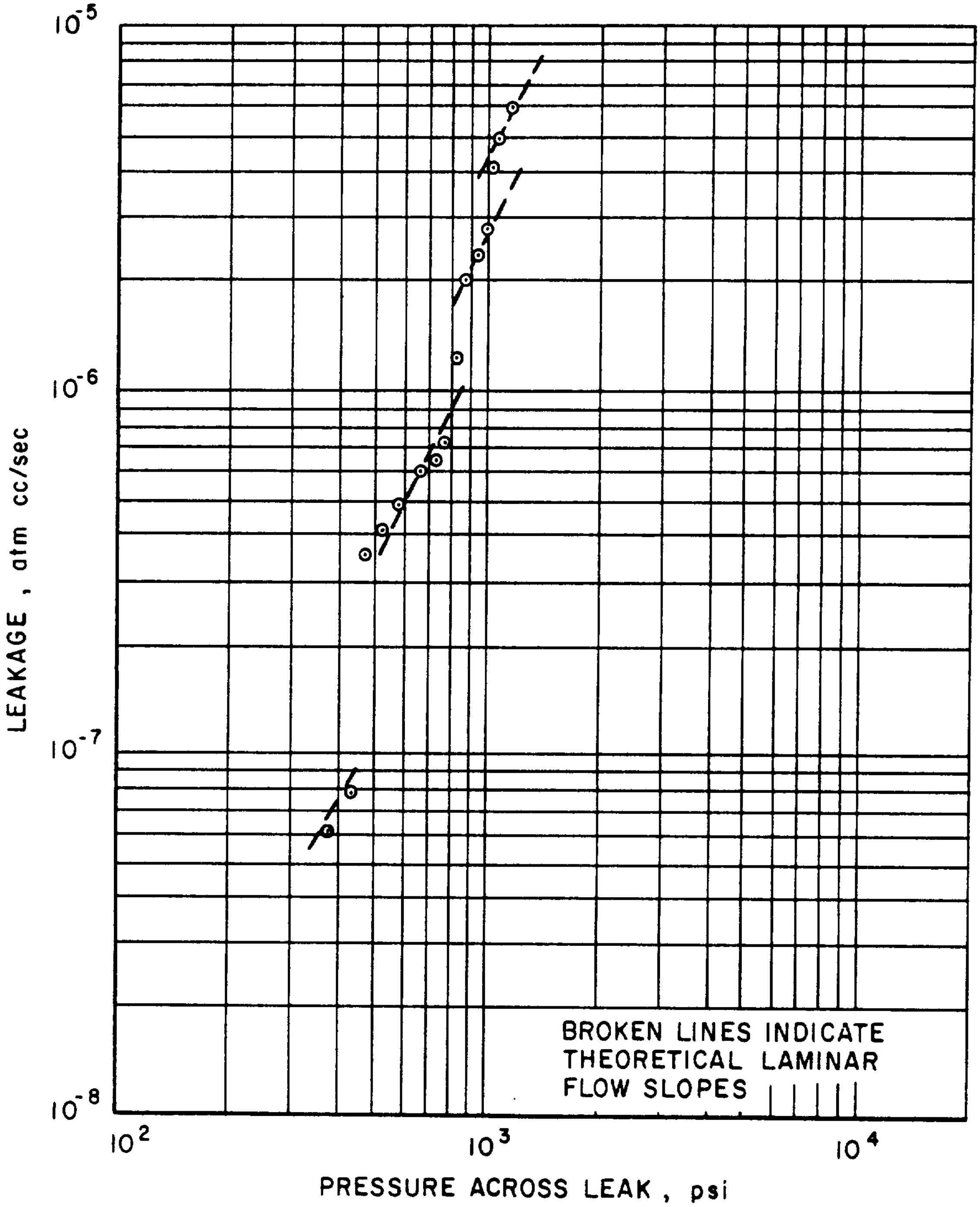


Figure 6-5. Geometry Change in a Gasket Leak (Reprinted from J.W. Marr, Study of Dynamic and Static Seals for Liquid Rocket Engines, Final Report Phase II, Contract NAS 7-102 (Ref. 6-2).)

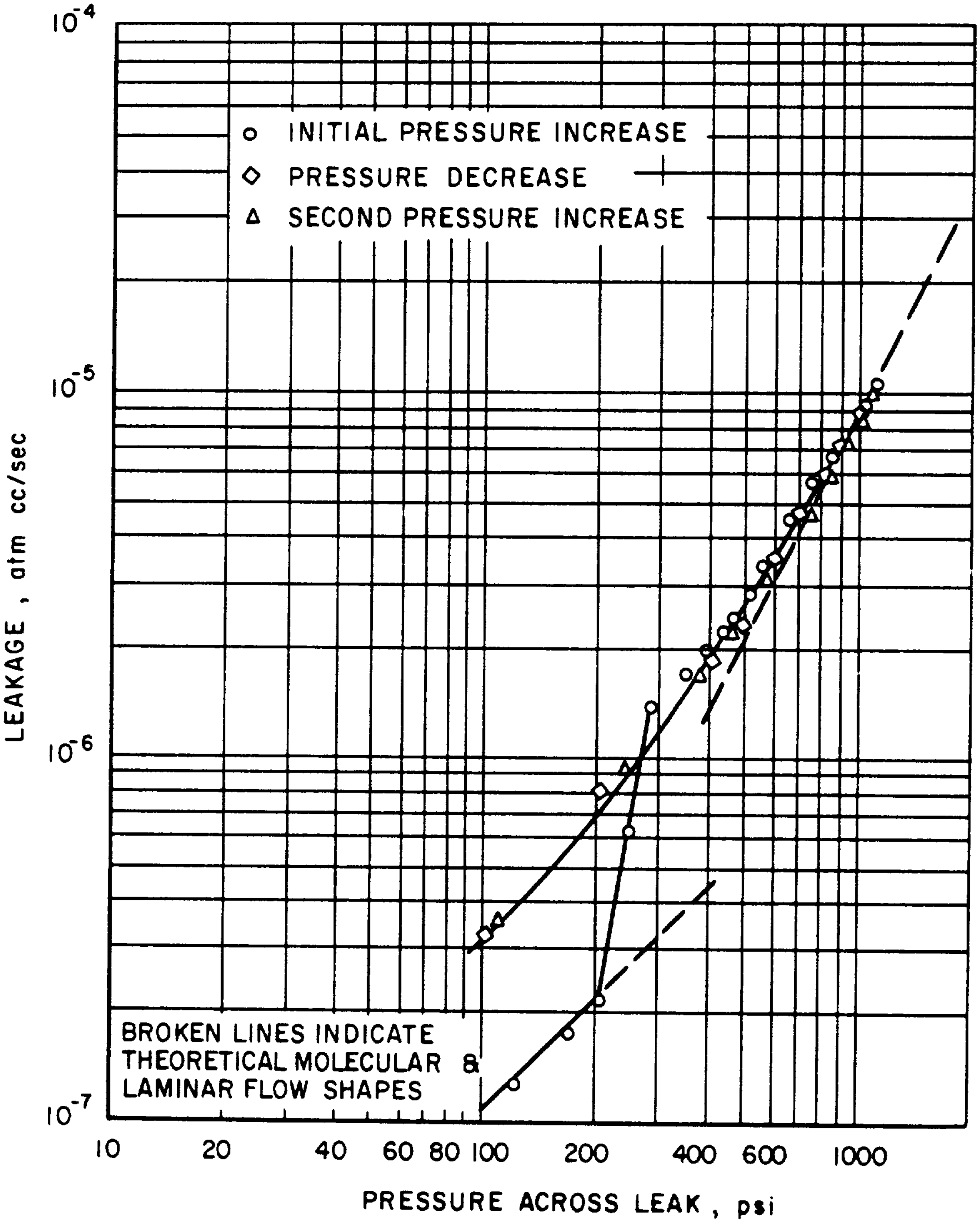


Figure 6-6. Self-cleaning Effect in Leaks. (Reprinted from J.W. Marr, Study of Dynamic and Static Seals for Liquid Rocket Engines, Final Report Phase II, Contract NAS 7-102 (Ref. 6-2).)

6.5.4 Surface Flow Leaks

The flow of gases and noncondensing vapors through fine capillaries and micropores cannot be dealt with by simple methods analogous to those applicable to molecular and laminar flow. Because of the narrow passages and large surface areas involved, surface adsorption and surface flow become important factors. The adsorption may be physical where only relatively weak van der Waals attractions are involved; or the adsorption may be regarded as chemical where the surface of the solid provides binding sites for the atoms, and the electronic structure of the solid permits the formation of a chemisorption bond. The nature of the binding sites, the bonds between the gas atoms, and the surface influence the degree of surface migration of the atoms.

The flow along a fine capillary or micropore is assumed to consist of two mechanisms working simultaneously:

1. Molecular flow along the bore of the capillary, whereby molecules are supposed to collide with the wall, rebound, and collide with the wall again without intermolecular collisions.
2. Surface flow along the wall of the capillary, whereby molecules are adsorbed and diffuse along the surface of the wall.

Both of these mechanisms promote gas flow from regions of higher gas concentrations to regions of lower gas concentrations.

For a given set of conditions, the proportion of molecules that follow the above mechanisms depends on a variety of factors. These factors include:

- Sticking probability (the probability that a molecule striking the surface will become adsorbed)
- Length of time the molecule remains adsorbed (the mean surface lifetime of the molecules)
- Coefficient of surface diffusion of the molecules

Such features are, in turn, influenced by other characteristics -- the number of sites occupied by the adsorbed molecules and whether a complete monolayer has been formed.

The nearer the properties of a gas approach those of a condensable vapor the greater the proportion of surface flow. Therefore, a reduction of temperature or an increase of pressure may sometimes promote a total flow in excess of that predicted by the laminar theory.

Although the final leak rate achieved with a condensable gas will be higher than predicted from flow theory, Hayashi (Ref. 6-13) showed that there will be an initial delay of flow due to condensation of the tracer gas on the leak surfaces. Consideration of this delay is important if a tracer probe technique is used for testing. For example, if butane, a readily condensable gas, is used in a tracer probe, some small leaks will be missed because of the time delay caused by the adsorption. Two remedies can be suggested to counter this problem:

1. Use of a noncondensable gas
2. Use of a detector probe where the gas is continually in contact with the leak and an equilibrium flow rate is established

6.6 LEAK CLOGGING

6.6.1 Surface Tension Effects

Very small holes that may give rise to appreciable leakage rates of gas under high vacuum conditions are sometimes partially or wholly blocked by solid particles having sizes in the micron range, or by liquids as a result of surface tension effects. The blockage may be of a temporary nature, and so give rise to misleading test results.

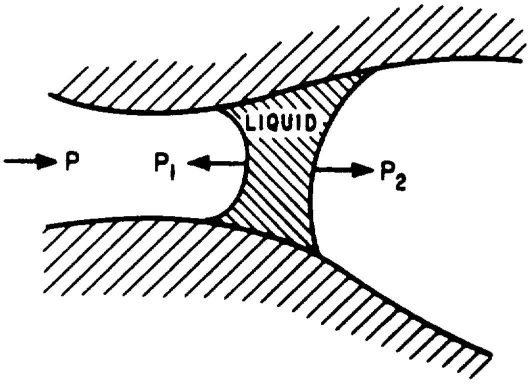
Until leakage testing has been performed, the system should be kept out of contact with atmospheric or other vapors and particulates that may cause blockage. However, this condition cannot always be met in practice. It is frequently observed that if a container to be tested for leaks has been in contact with a liquid at any time after manufacture, no leaks of small size (i.e., 10^{-7} atm-cc/sec or smaller) will be found. Small leaks are clogged with liquid because of surface tension. If water has entered a capillary tube, the pressure necessary to force it out of the tube is given by the following equation:

$$P = \frac{4\sigma \cos\phi}{d} \qquad (6\text{-}26)$$

A leak with a diameter of 1×10^{-4} centimeters will have a leakage rate for helium of approximately 1×10^{-6} atm-cc/sec. If water, with a surface tension of 72 dynes per centimeter, enters such a leak, the pressure required to force it out is approximately 2.8 atmospheres ($\cos \phi = 1$). Since the pressure differential during leakage testing is only one atmosphere, this leak is essentially clogged by the water. Clogging is more likely to take place under actual conditions than in the above example. Most leaks are neither circular nor regular in diameter; they usually contain constrictions and occasionally consist of slits.

Figure 6-7 shows an example of surface-tension clogging by a slug of liquid in the leak path. The cross section of the leak channel increases to the right. Gas pressure from the left has forced all liquid out of the leak but that in the slug. With no change in cross section, the adhesive forces acting at the liquid-wall interface would be equal and opposite in direction, and surface tension would not affect the ability of the applied pressure, P, to force the liquid out of the hole. However, the increase in cross section on the right reduces the force of surface tension directed to the right, so that the liquid resists any attempt to force it out. In some cases, pressures of many atmospheres are required to free a leak path of a liquid slug. This type of clogging effect will be greatest at the exit of a leak path, and the eventual removal of the slug may depend mainly on evaporation.

Conversely, if the gas pressure forces the slug to the left, the net surface-tension force will aid such flow, and the slug will pass all the more easily into the smaller cross-sectional region. If the cross section again increases on the left, the slug will remain locked in the constriction until it is removed by other means.



$$P > 2\sigma \left[\frac{1}{r_1} - \frac{1}{r_2} \right]$$

Figure 6-7
Liquid in Nonuniform Channel

If the liquid does not *wet* the wall, the curvature of the meniscus on each side of the slug is reversed, and the slug will be easily forced toward the larger cross section, but not as easily toward the smaller cross section.

Liquid clogging is not generally permanent in nature. If the temperature of the container is raised, the surface tension of the liquid will decrease or the liquid inside the leak will evaporate. However, if the entering vapor contains a dissolved salt, solid particles will remain after evaporation and cause permanent blockage.

Gas leakage much smaller than 10^{-8} atm-cc/sec is rarely seen, even though it is in the range of detectability. Such small leaks are found on new systems which have never been in contact with liquid. These leaks have to be carefully treated or they will clog during normal handling. It may be calculated that a leak 10^{-8} atm-cc/sec has a diameter in the order of 10^{-5} centimeters. To place this number in dimensions of atomic size, its diameter is about 1,000 Angstrom units.* Molecules of liquid contaminants (for example, either hand or machine oil) are in the order of 100 Angstroms in length. Should these molecules be held by surface tension, they could reduce the size of the hole and therefore reduce the leakage rate to a point of clogging. Molecular flow, which should predominate in this range, is proportional to the cube of the leak diameter. Therefore, a small decrease in leak diameter will produce a drastic decrease in gas leakage.

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*One centimeter = 10^8 Angstrom units.

6.6.2 Vapor Pressure, Viscosity, and Particulate Effects

A pressurizing test may suffer some restriction in its application to certain types of vacuum equipment, because the design may permit the use of only small overpressures. In these applications the presence of water may easily block a leakage path owing to its high surface tension. For example, when a particular capillary has absorbed water that wets its wall, this capillary can become completely blocked against a gas pressure difference of 1-1/2 atmospheres. A thin mineral oil in the capillary has a lower surface tension and would be more easily moved, requiring only about one-half atmosphere. Even though the applied pressure difference may be sufficient to move the oil, the viscosity of oils is relatively high. Therefore, in practice, the oil will usually permanently block a capillary of any appreciable length. This is due to the extremely slow rate of flow of oil. Oil is also difficult to remove thermally, and a deposit is generally left in any leak pore. Consequently, oil should not be used for pressure testing before leakage testing with a tracer gas.

Water will evaporate much more readily at reduced pressures than will a mineral oil, because of its higher vapor pressure. The rate of evaporation is accelerated if the temperature is raised. For leakage testing of evacuated systems, a number of points should be considered.

- A preliminary water-pressure test is permissible, but not recommended.
- Oil should never be used for overpressure test.
- A compressed-air test should never follow a water-pressure test before vacuum testing for leaks. This is because the residual water that is held in small capillaries may be forced back by the compressed air into larger voids. Under vacuum conditions, the liquid would evaporate slowly through the capillary restriction.
- Even a preliminary water-pressure test is inadvisable for an ultrahigh-vacuum system. In such a system detection of very small leaks through fine capillaries becomes essential and the time required to ensure clearance of such capillaries (by evaporation of the residual water) may be unduly prolonged.

To summarize, when a liquid is in a capillary, the liquid that has the lower surface tension is more readily moved by a gas-pressure difference, while a liquid that has a higher vapor pressure is more readily evaporated. As a consequence, capillaries that may be blocked by water under the conditions of an overpressure test may often be cleared by evaporation of the water into a vacuum. Moreover, apparatus which must undergo a rigorous check for leaks must be dried in a vacuum because small leaks are readily closed by the water adsorbed on the walls.

Following the general rule, it is preferable that the vessel or component to be tested should be kept out of contact with sources that may cause blockage, until after leakage testing and leak repair have been completed. Components should be kept in a dry box to prevent absorption of water vapor from the atmosphere.

Solid particles in the millimeter size range are not, in general, a source of trouble. But solid particles in the micron range may enter and temporarily block a capillary. They may subsequently be displaced, giving rise to an intermittent leak that is difficult to establish and locate. Blockage by solid particles may occur, for example, if the fluid used in connection with magnetic crack-detection work is applied before testing for leaks. Magnetic fluid contains iron particles, of which the greater proportion are usually in the 2 1/2-to-10-micron size range and are, therefore, comparable with the cross-sectional dimensions of small leaks.

One of the disadvantages of porosity will be understood by considering the effect of a hypothetical condition of a thousand capillaries, one-fourth inch long, situated close together in parallel, each having a radius of 10^{-5} centimeter. The total leakage rate through this assembly would be approximately 1.3×10^{-7} torr liters per second -- that is, about the same order of leakage as a single capillary of 10^{-4} centimeter radius. However, if water has access to the porous assembly, the pressure difference required to remove it from the capillaries would be (from Equation 6-26) 14 atmospheres, or 210 pounds per square inch. This is ten times the pressure difference needed to remove such blockage from a capillary of 10^{-4} centimeter radius.

Small holes in mild steel vessels or components may become permanently blocked by "rusting up" caused by moisture. In practice it is usually impossible to prevent atmospheric moisture from entering capillaries. Most metals are attacked to some extent by water in the presence of air; such an action gives rise to an oxide film that has a greater specific volume than the metal. This effect applies particularly to mild steel, where the oxide film has a specific volume about seven times greater than that of the parent metal. Consequently, the smaller capillaries, which have the greater tendency to retain water, readily rust up. Stainless steel is less likely to be affected in this way.

When a liquid blocks a capillary its removal from the capillary may be influenced by such factors as:

- Wetting combined with surface tension, which resists motion
- Viscosity, which controls the tendency to flow
- Vapor pressure, which controls the tendency to evaporate.

In addition, there are situations where factors such as soluble contaminants, polarization in the liquid, ionic solutions of the wall material, electrokinetic forces, and temperature can affect the leak rate. Reference 6-3 is an excellent article dealing with the flow of liquids and the effect of evaporation on fine capillary tubes.

Under certain special conditions it is possible for large leaks to become plugged. The expansion of liquids from below their triple-point pressures will result in freezing of the liquid to a solid. The buildup of a solid can temporarily plug leaks (Refs. 6-14, 6-15, and 6-16), and it is possible that such leaks might not be detected in the course of testing for leakage.

Section 7

SOME GUIDELINES FOR WRITING SPECIFICATIONS

Section 7

SOME GUIDELINES FOR WRITING SPECIFICATIONS

7.1 INTRODUCTION

This section discusses factors to be considered in specifying a *maximum allowable leakage rate* or a total level of leakage for a component or system. A leakage rate or leakage specification should be determined from an analysis of the effect of leakage on the system as well as on the mission or application in which it is to be used. At the outset, good design and fabrication techniques are requisite to assure proper and safe performance. Long-term storage of the system may be necessary; this should be taken into account. A leak-detection procedure requires careful planning in advance, with consideration of the test sensitivity and response time that will be required in testing the system for leakage.

It may be preferable to specify a level of *maximum tolerable leakage* rather than maximum allowable leakage *rate*. The maximum tolerable leakage usually can be obtained by multiplying the maximum allowable leakage rate by the length of time a system is expected to be usable, including the period during which it is to be in storage. However, if fluid is not to be introduced into the system until it becomes operational, the maximum tolerable leakage need be specified only for the duration of the mission. The level of the maximum tolerable leakage should be specified when the total amount of leakage is more important in its consequences than is the rate at which it is dispensed.

7.2 SPECIFYING MAXIMUM ALLOWABLE LEAKAGE RATE

One approach to the determination of maximum allowable leakage rate is to determine the leakage rates which apply to the following situations:

- System failure during the operational life of the system
- Hazard to either equipment or personnel
- Unacceptable appearance of the system
- Assurance of adequate design and good construction on the part of the manufacturer

The smallest leakage rate assigned to the above listing is taken to be the maximum allowable leakage rate on which specifications will be based. If the fluid in the system is to be a liquid, it is necessary to correlate the above maximum liquid leakage rate to the leakage rate of a tracer gas. Leak testing can then be conducted with a gas-sensitive leak detector of high sensitivity, using a calibrated gas leak as a standard.

The accuracy of calibration of a qualified or reference leak and the overall accuracy of the leakage test are such that it is advisable to specify a level of leakage rate which is at least a factor of two lower than the maximum allowable leakage rate as chosen above. It is much better to add the safety factor to the maximum allowable leakage rate than to require that measurement of the leakage rate be performed with high accuracy.

Setting the maximum allowable leakage rate should also include the following considerations:

- Is the cost involved in performing the leakage measurement reasonable? If the requirements are set so high that the unusual techniques and/or equipment are necessary to perform the measurement, it might be prudent to reevaluate the specified maximum allowable leakage and lower the requirements.
- Is the maximum tolerable leakage less than the inherent or otherwise unavoidable, leakage normal to the operation of the system? If this is the case, the leakage standard should be revised upward. For example, if the allowable leakage specified is less than the leakage expected from permeation there is not much point in assigning more stringent leakage specifications. If requirements are relaxed, reliable leakage measurements can be made more quickly and at less cost.

The allowable leakage rate should be specified for the gas used in the operation of the system. The value should be given in units of pressure multiplied by volume per unit time at a specified pressure differential across the leak. Gas leakage tests can be performed with gases other than the one designated if a formula is specified for correlation between the gases. A correlation which produces conservative values should be used.

It is very important to specify the pressure difference across the leak. This should be at the highest operating pressure of the system. Whenever possible, leakage measurements should not be performed at low pressures only. A test must be made at the maximum operating pressure to reveal any self-cleaning leaks, check-valve leaks, and leak expansion. The testing should be done both at maximum operating pressure and at one or several pressures below this maximum to completely eliminate the possibility of check-valve leaks. However, leakage at maximum operating pressure must be measured first.

The temperature for the leakage test should be specified as the operating temperature. Changes in the dimensions of the leak due to thermal expansion or contraction can affect measured levels of leakage.

7.3 INSTRUMENT QUALIFICATION

The sensitivity of a test instrument must be determined before it is used in testing equipment for compliance with a set of leakage-testing specifications. When this is done, it is suggested that the instrument should be said to have been *qualified* rather than calibrated.

The term *calibrated* implies that a given reading on the instrument corresponds to a leakage rate known to a certain accuracy. Actually, all that is known is that the indication bears a proportional relationship to the leakage issuing from the test leak. The calibration of the test leak is then a matter of comparing its conductance with that of one or more other leaks whose leakage rate is known, presumably with greater accuracy than is the conductance of the test leak.

The actual conductance or leakage rate must depend on the accuracy with which pressure, differential pressure, and volume flow rate can be measured. Alternatively, it is possible to measure and calibrate the mass flow rate by measuring the change in the buoyancy of a gas environment caused by leakage into that environment in a given period of time. A change in buoyancy involves units of mass, length, and time, each of which can be measured and defined with high accuracy.

The leakage through a "standard" leak used by one organization may be different from that through a "standard" leak used by another organization even though both groups claim that their respective leaks have the same value of conductance. These discrepancies arise because of errors in leak calibation, the calibration and stability of the instruments used, the purity of test gases, etc. They are troublesome and difficult to resolve, especially when specifications requiring high accuracy of leakage measurement have been accepted and must be met.

The accuracy with which leakage can be measured need not be made of prime importance however, in qualifying a testing instrument or system. Most practical situations require that some particular level of leakage not be exceeded. It need only be established that the leakage in the tested system is less than the allowable maximum. This can be done without requiring high accuracy of the testing instrument or of the test, simply by lowering the maximum allowable leakage rate and increasing the tolerance to which the rate needs to be measured.

An alternative and more certain approach is to specify that a set of leaks, all calibrated at the same time and under the same conditions, be supplied and used in all leak tests made on a system and its components. If the item is shipped to a distant location the leak used to test it should be shipped with it. This procedure will improve the consistency in the measurements made at the point of manufacture and at the point of use, although it is impractical to follow when many units are involved. Two leak detectors at two different locations can be calibrated against one another with better accuracy if the same test leak is employed. In any event, the accuracy with which the leakage rate of a test leak is known should be higher than the accuracy required for qualifying a piece of test equipment in terms of a given set of leakage specifications.

To qualify the instrument, the test leaks and their method of use should be carefully detailed. Test leaks may be supplied by the manufacturers of the leak detector or by the specifier's laboratory. If the leakage measurement is to be performed on several pieces of equipment in various locations, the test leaks used for the various equipments should be similar and procedures should be standardized. The leakage of the test leak should be in the range of the specified leakage.

A qualifying test shows that, under the conditions of leakage measurement, it is possible to determine that a certain leakage rate is not exceeded. It is important in detailing the procedure that the test is being qualified and not the instrument itself. For highest accuracy, the same gas should be used for qualifying the test leak that is used for measuring the leakage rate of the system. The gas should be introduced at the same pressure and in the same concentration into the qualifying leak as into the system being tested.

If leaks smaller than 10^{-6} atm-cc/sec are to be measured, it should be specified that the system should not be cleaned prior to leakage testing. Cleaning fluids will clog the smaller leaks in the system, and thus prevent their detection.

7.4 TESTING TECHNIQUE, SAFETY, AND DESIGN

Providing the allowable leakage is specified and an acceptable correlation is given between the various test gases, it should not be necessary to specify the exact equipment to be used in the test. However, it is necessary to state in some manner whether leakage measurement or location is required. Leakage measurement rather than location is the only reliable method of testing to determine the maximum leakage. It might be necessary to specify the use of an enclosure to ensure that all gas leaking from the system is collected by the leakage-measurement equipment. These specifications should be written to ensure that all of the gas which leaks out of the system is being measured.

Only under unusual circumstances should leakage-location techniques be used for leakage measurement. This method will drastically affect the credibility of the test. When a leakage-location technique is used, the sampling speed should be specified and extremely rigorous methods of qualifying the technique (not the equipment) should be used.

7.4.1 Safety Statement

Some statement must be made as to the safety precautions necessary while tests are being performed. If large pressurized vessels are being used, warning concerning proof-testing must be given. Decision must be made by the designer as to whether it is permissible to test at high pressure prior to proof-testing. Proof-testing using a hydrostatic test will clog most small leaks. It is, therefore, necessary to weigh the relative importance of leakage and the other factors that are involved in determining the overall safety of the system.

7.4.2 Design for Leakage Testing

Testing requirements should be considered early in the design of the system. System design should take into consideration such items as location of ports or connections for leakage measurement. The system must be capable of being tested quickly. It should not, for example, contain sealed voids which could greatly increase the testing time.

7.5 GENERAL LEAKAGE TEST SPECIFICATIONS

Several technical societies and certain Government agencies introduced approved leakage testing procedures for specific types of equipment. These tests provide both the equipment manufacturer and the user with uniform methods for conducting leakage measurement. For example, the tests detail the data to be recorded, calibration of the test, and the computation of leakage rate. Table 7-1 lists some of these tests and their originating societies, along with the number which identifies each document.

Table 7-1

LIST OF LEAKAGE TEST SPECIFICATIONS

Name	Society or Organization	Number	Reference	Remarks
Leakage Rate Testing of Containment Structures for Nuclear Reactors	American Nuclear Society	ANS 7.60	7-1	See Appendix B for a copy of this test.
Leak Detection and Leakage Measurement	American Society of Mechanical Engineers	PTC 19.21	7-2	
Detection of Leaks in a Large Aerospace Systems Environmental Chamber	Arnold Engineering Development Center	AEDC-TDR-64-237	7-3	Detailed test procedures for major components.
Test Methods for Electronic and Electrical Component Parts	U.S. Department of Defense	MIL-STD-202C	3-5	Method 112 details bubble, mass spectrometer, and radioactive tests.
Nondestructive Testing Requirements for Metals	U.S. Department of Defense	MIL-STD-271D	7-4	Subsection 6, "Leak Testing" covers primarily helium leakage tests.
Environmental Test Methods	U.S. Department of Defense	MIL-STD-810B	7-5	Method 512 describes a gross leakage test.
Test Methods and Procedures for Microelectronics	U.S. Department of Defense	MIL-STD-883	7-9	Method 1014 covers gross and fine leaks with three different procedures.
Iron-nickel Alloys for Sealing to Glasses and Ceramics	U.S. Department of Defense	MIL-I-23011B	7-6	Porosity determined by helium leakage test.
Standard for Welding of Reactor Coolant and Associated Systems and Components for Naval Nuclear Power Plants	U.S. Department of Defense	NAVSHIPS 250-1500	7-10	Helium leakage test is detailed.
Leak Rate Measurement, Mass Spectrometer Method	U.S. Atomic Energy Commission	Process Std 9956010	7-7	
Methods for Proving the Gas-Tightness of Vacuum or Pressurized Plant	British Standards Institution	B.S. 3636:1963		An excellent reference manual.
Pipeline Leakage		Water and Wastes Engineering Manual of Practice Number Two	7-8	General testing procedures for utility pipelines.

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Part II

TESTING METHODS

Section 8

MANUFACTURED LEAKS

Page

NOMENCLATURE

8.1.2 Porous Plug Leaks

Porous plug leaks are cited in the literature (Refs. 8-3, 8-4, 8-5, 8-6, and 8-7). A leak of this type consists of a metal, ceramic, or glass plug containing extremely fine pores. Flow through the plug is molecular. Therefore, the change of flow which will result from a change in the type of gas may be calculated from Equation 6-24. Such leaks can be made as reservoir or non-reservoir types, and can be calibrated against another reference leak or by absolute measurements of flow and differential pressure.

8.1.3 Capillary Leaks

Another type of leak which can be calibrated is made from fine capillary tubing of glass or metal, such as Pyrex and hydrogen-fired nickel. The capillary is constricted over a short region to the extent required to limit the flow of gas to a desired value. The capillary is mounted within and attached to one end of, a strong metal tube, to prevent breakage during normal handling.

Such leaks can be made with leakage rates from about 5×10^{-7} atm-cc/sec upward. Although smaller-sized leaks of this type can be made, they become extremely difficult to use because of clogging. These leaks can be calibrated with one or with a mixture of gases. They are normally made to be used with a separate supply of gas at a known differential pressure and are calibrated at the same pressure.

8.1.4 Variable-leakage Sources

A variable leakage source for a given gas may be made from a single capillary leak of fixed conductance by simply changing the differential pressure across the leak. If the leak is to supply gas at atmospheric or any other fixed pressure, the amount of leakage can be controlled by changing only the input pressure. A calibrated variable leakage source can be made by the use of a pressure gage on the input side of the capillary. The gage can be calibrated in leakage rate rather than in units of pressure.

A capillary leak may be connected to a small reservoir of tracer gas with a pressure gage, to form a calibrated variable leakage source. Figure 8-2 shows such a device, which is called a leak factor gage. Its scale is marked in multiples of the leakage rate of the capillary when measured from atmospheric pressure to vacuum. Provision is made for altering the pressure applied to the input side of the capillary.

The General Electric Type LS20, shown in Figure 8-3, is an example of another variable leakage source. Figure 8-4 is a schematic diagram of the system used. The unit includes a reservoir of halogenated hydrocarbon which is valved into a ballast tank in gaseous form. Also connected to the ballast tank is a glass capillary tube and pressure gage. The amount of leakage through the calibrated capillary is dependent on the amount of pressure in the ballast tank. Because the flow through the leak

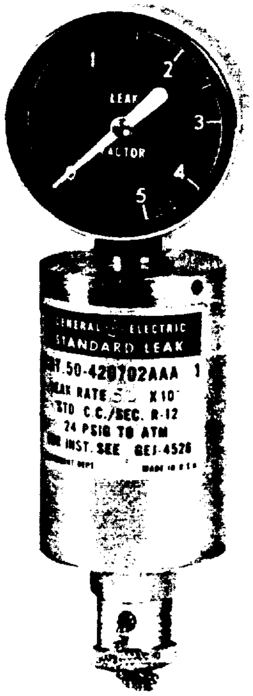


Figure 8-2

Reservoir Leak with Leak Factor Gage. (Reprinted with permission of the Instrument Department, General Electric Company. West Lynn, Massachusetts.)

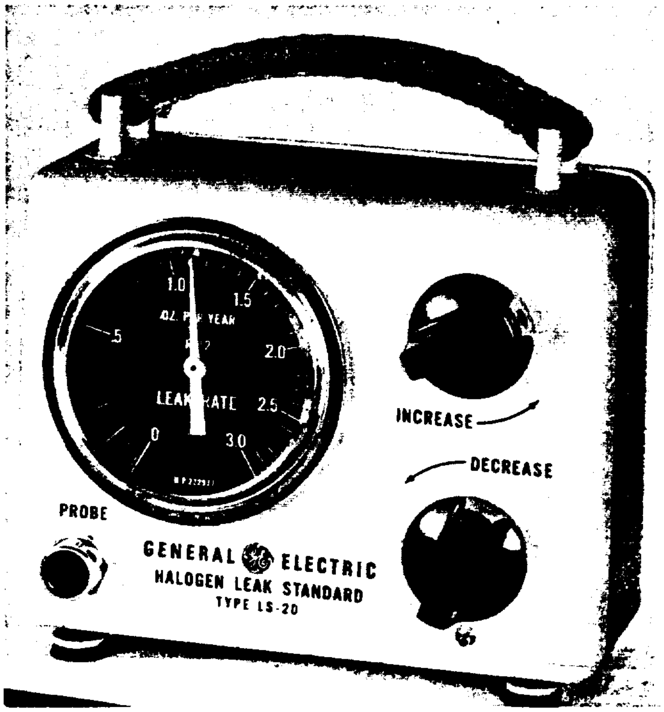


Figure 8-3

Variable Leakage Source Heated-anode Leak Detector. (Reprinted with permission of the Instrument Department, General Electric Company, West Lynn, Massachusetts.)

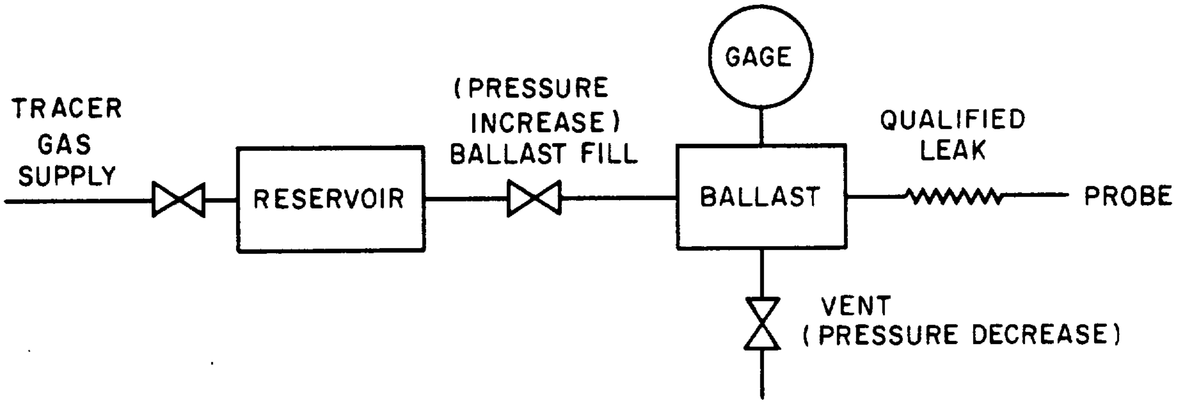


Figure 8-4. System for LS20 Variable Leakage Source

is laminar the gage is marked in units proportional to the square of the pressure drop. It is an excellent standard to use with probe-type instruments, such as the heated-anode halogen leak detector. The probe may be placed directly in the leak exit; the calibration approximates operating conditions.

8.1.5 Variable Conductance Leaks

A leak whose conductance can be changed is called a variable leak. It can be fashioned so that the conductance can be precisely set and reset many times. Such a leak takes the form of an elegant needle valve, or a mechanical means for flexing a piece of crushed metal tubing so as to slightly alter the size of the leak path. The accuracy with which the conductance can be set has been improved greatly over the past few years. Nevertheless, a variable conductance leak should not be used as a reference for calibrating a leak detector to be used in checking equipment-leakage specifications unless it is calibrated after each adjustment of its conductance.

8.2 ERRORS IN LEAKAGE MEASUREMENT

The principal errors contributing to the inaccuracy of leakage measurements are:

1. Inaccuracy in calibrating the leak
2. Nonlinearity of the leak-detection instrument
3. Variation in pressure differential applied across the leak
4. Impurity of gas applied to the leak
5. Variation in the amount of gas reaching the detector

Comparisons between leaks of various manufacturers (Ref. 6-2) have shown that their accuracies do not agree to more than plus or minus fifty percent of a mean value. This may be seen by the experimental plot of Figure 8-5, which shows the calibrated leakage readings as plotted to the response of a very linear mass spectrometer. The straight line drawn in the graph is the least-mean-square value of leakage versus spectrometer response. This line does not imply the correct value, but the general pattern around which the values of the leaks congregate.

Even the leaks of a single manufacturer vary by approximately ten percent. This is usually the guarantee which is presented upon purchase of the permeation-type calibrated leak. Leaks of a variable type -- for example, the General Electric LS20 -- are claimed to be accurate only to plus or minus twenty percent.

Most commercial leak detectors display the response to a detected leak as a current reading on a sensitive microammeter. It is usually assumed by the operator that a current reading twice the magnitude of a previously observable one represents a two-fold increase in leakage. This is not necessarily correct,

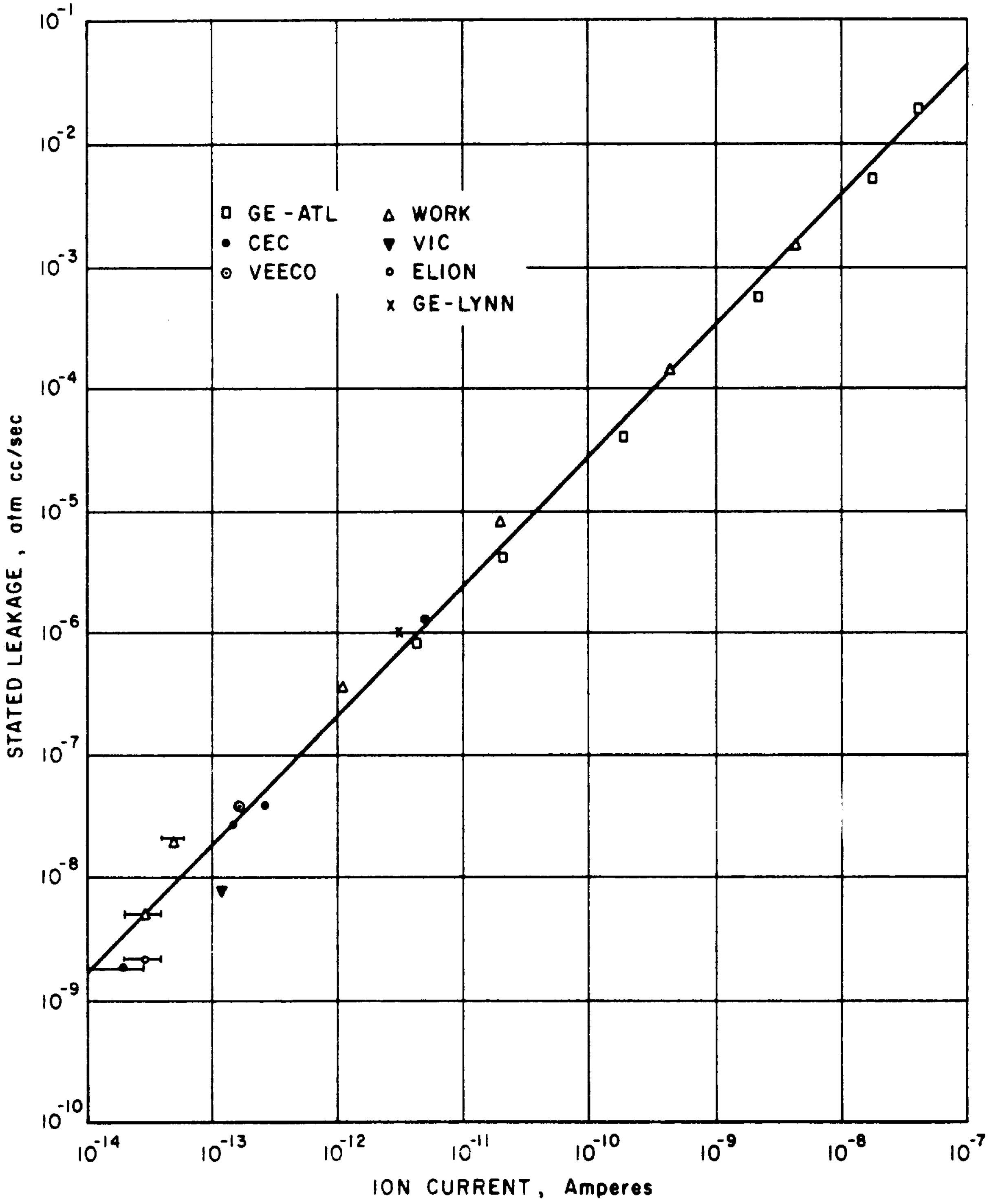


Figure 8-5. Comparison of Leakage Values for Leaks Supplied by Various Vendors (Ref. 6-2)

because of nonlinear properties associated with the structure of the pumping system or the electronic circuitry.

A typical correlation is shown in Figure 8-6. The confidence range is a fan-shaped area which converges on the mean values of actual and measured leakages. The tightest confidence range for a fixed amount of data is obtained when the points are grouped evenly at the extremes of the actual leakage range. Unless linearity of the correlation has been established it is best to have the data evenly distributed throughout the leakage range. Because such deviations exist it is recommended that when a leakage measurement is made to a closer tolerance a qualified leak of that specific value should be used.

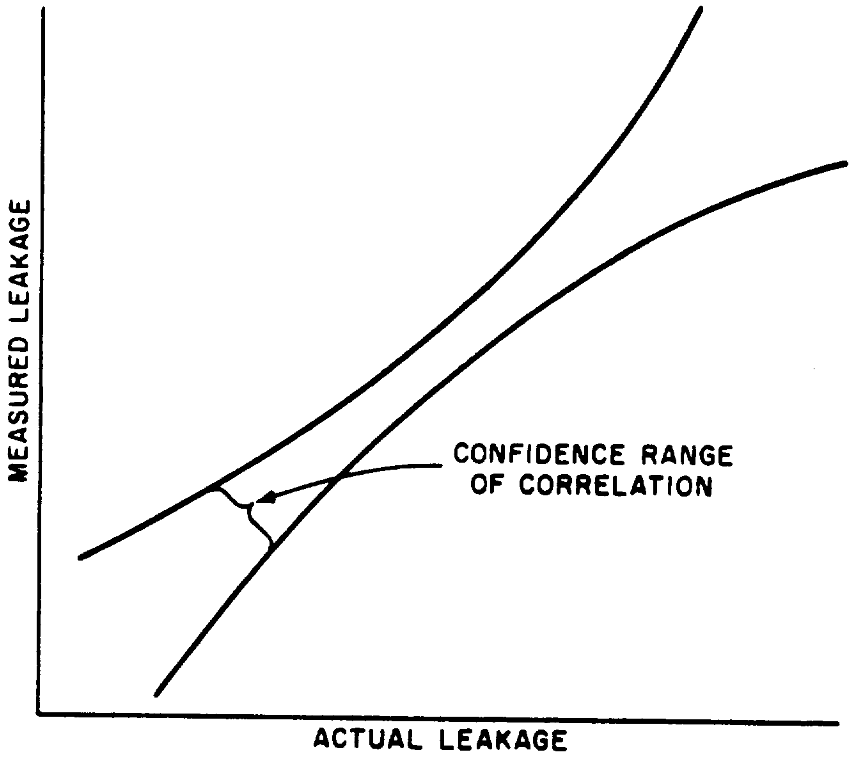


Figure 8-6. Correlation Between Actual and Measured Leakages

Leakage is dependent on the pressure differential across the leak. When leak detection is done by a tracer probe, the pressure differential is usually one atmosphere, the gas being sprayed over the suspected area without the aid of additional pressure. Should leak detection be performed at high altitudes, the atmospheric pressure is less than one standard atmosphere; the magnitude of this reduction is as much as twenty percent in such places as Boulder, Colorado. If the leaks which are being located are of a laminar nature, the flow through the leak is proportional to the square of the pressure differential. Therefore, a leak measured at atmospheric pressure in Boulder, Colorado, will be approximately forty percent lower than one in Cape Kennedy, Florida.

As has been mentioned, certain calibrated leaks contain their own gas supply, whereas others have the tracer gas sprayed on the leak at one-atmosphere pressure differential during use. Calibrated leaks with a self-contained gas supply always deliver to the detector a fixed amount of gas which is interpreted as the sensitivity of the leak detector. On the other hand, leaks where gas is added during use produce the calibrated amount of leakage only when a one-atmosphere pressure differential is supplied. The latter leaks, therefore, deliver less than the calibrated amount of leakage when used at high altitudes, where the atmospheric pressure is lower.

Another source of inaccuracy is the impurity of the tracer gas used for leakage measurement. If a tracer probe is used for leak detection, the gas is sprayed over the suspected area, in which case it is quite possible that the tracer gas is diluted with air as it approaches the leak. Therefore, the response of the leak detector will be reduced by the amount of air impurity entering the detector with the tracer gas. The use of a calibrated leak with a self-contained gas supply is thus undesirable, since it would not reproduce the leakage measurement method. In other words, the gas should be sprayed on the calibrated leak in the same manner as on the tested leak.

Tracer gas traveling to the detector may be absorbed on system surfaces. This would decrease the response of the detector. For accuracy, therefore, calibrated leaks should be positioned on the system as near as possible to suspected leak sites. Alternatively, they may be positioned as far away from the detector as possible to show minimum sensitivity.

Because of the variations discussed in this section, a measured leakage value is probably only within a factor of two from the true value. This implies that if a leak is measured as 1×10^{-5} atm-cc/sec, the actual value of that leak is between 2×10^{-5} and 0.5×10^{-5} atm-cc/sec. Therefore, if the maximum allowable leakage of a particular system is 2×10^{-5}, the specification may be written with a leakage not to exceed 1×10^{-5}, with the knowledge that the accuracy of this measurement is a factor of two. There is reasonable assurance that if the measured leakage is no higher than the one stated on the specification (1×10^{-5}), the actual system leakage will be no greater than the allowable one (2×10^{-5}). This method of specifying leakage is much more sensible than specifying a slightly higher leakage value with an unreasonable accuracy.

8.3 AVAILABILITY OF STANDARD LEAKS

Typical of the precision leaks commercially available are those shown in Table 8-1. Only a limited number of gases may be used with such leaks. Only one type of leak is designed to deliver gas at atmospheric pressure; that is the General Electric LS20 leak for the heated-anode halogen leak detector. Some manufacturers will produce precision leaks on request. One of these is Hastings-Raydist, Incorporated, formerly the R.H. Work Company.

Table 8-1

PRECISION LEAKS COMMERCIALLY AVAILABLE

Name	Type	Gas Supply	Gas	Leakage Range (atm-cc/sec)
Consolidated Electrodynamics Corporation Pasadena, California	Permeation	s.c.	Helium	10^{-6} to 10^{-10}
	Capillary-glass	s.c.	Argon	10^{-6} to 10^{-7}
	Capillary-glass	s.c.	Neon	10^{-6} to 10^{-7}
Edwards High Vacuum Incorporated Grand Island, New York	Capillary-glass	s.c.	Hydrogen	10^{-5} to 10^{-6}
General Electric Company - Vacuum Products Business Section Schenectady, New York	Capillary-metal	ind.	Air	10^{-6} to 10^{-7}
General Electric Company - Instrument Department West Lynn, Massachusetts	Capillary-glass	s.c. or ind.	Helium, Halogenated hydrocarbons	10^{-2} to 10^{-7}
Heraeus-Engelhard Vacuum, Incorporated Monroeville, Pennsylvania	Capillary	s.c.	Argon-Helium	10^{-6} to 10^{-8}
	Permeation	s.c.	Helium	10^{-8}
Veeco Instruments, Incorporated Plainview, Long Island, New York	Permeation	s.c.	Helium	10^{-9}
	Capillary-metal	ind.	Air	10^{-3} to 10^{-5}
Vacuum Instruments Corporation Huntington Station, New York	Permeation	s.c.	Helium	10^{-9}
Hastings-Raydist, Incorporated Hampton, Virgina	Permeation	s.c.	Helium	10^{-6} to 10^{-10}
	Capillary-glass	s.c.	Specified by purchaser	10^{-2} to 10^{-7}

s.c.: Self-contained tracer gas supply

ind.: Independent tracer gas supply

8.4 LEAK QUALIFICATION TECHNIQUES

Qualified precision leaks are available covering a range of eight decades of leakage values. Leakage rates are determined by methods such as the following, which are described in this subsection.

- Isobaric volume change
- Pressure rise method
- Pressure drop across a known conductance
- Pressure measurement at constant pumping speed
- Change in intensity of alpha radiation
- Mass leakage analysis

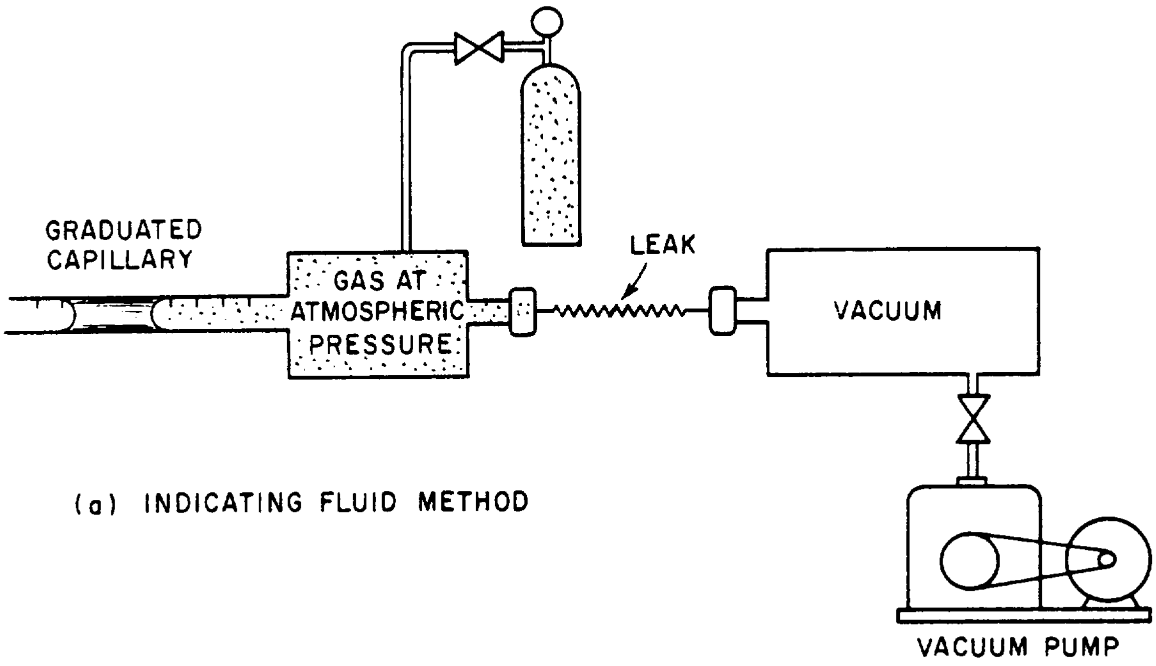
8.4.1 Isobaric Volume Change

A schematic diagram of the equipment used in the determination of leakage rates by isobaric volume change is shown in Figure 8-7. One side of the leak is attached to a vacuum system; the other side is attached to a gas reservoir at atmospheric pressure. To this reservoir is attached a capillary of known cross section, in which a slug of indicating fluid is placed. As gas leaks from the volume into the vacuum the slug of fluid travels down the capillary, to keep the pressure in the reservoir constant. As stated in Equation 8-1, the leakage rate is determined by measurement of the volume displaced by the travel of the slug down the capillary:

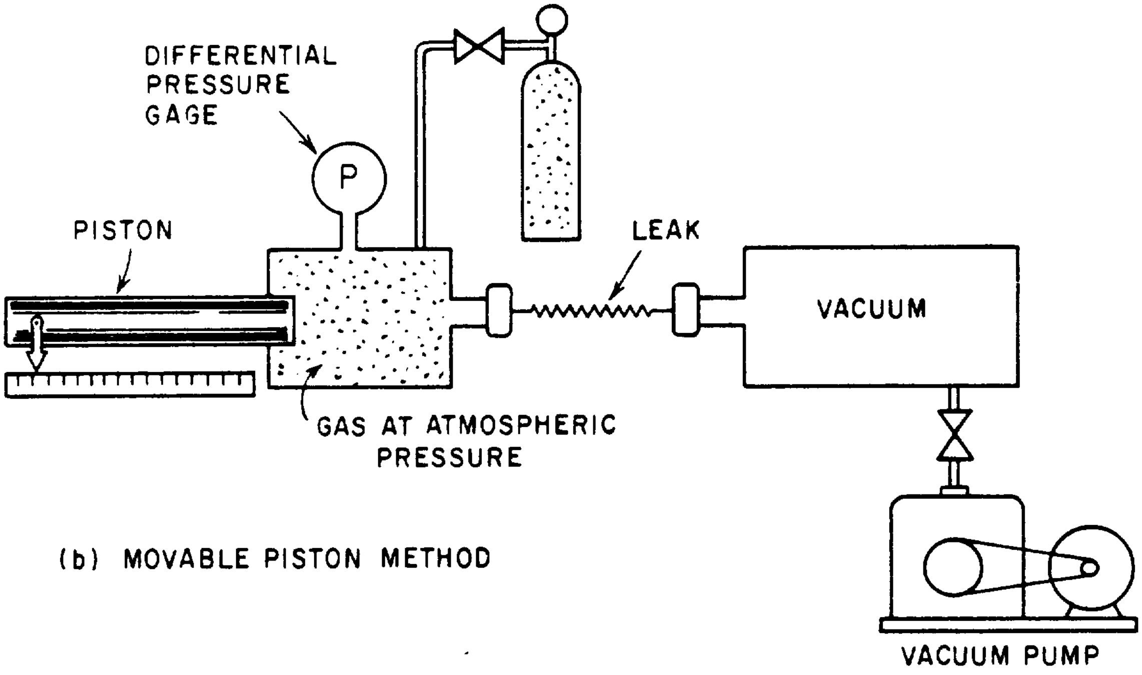
$$Q = \frac{P(V_2 - V_1)}{t} \qquad (8\text{-}1)$$

The primary limitation of this method is the size of the capillary involved. It is difficult to obtain a liquid which can be placed in one end of a small capillary tube and subsequently forced out the other end. For this reason, the practical limitation of such a method is in the range of 10^{-5} atm-cc/sec. It would be theoretically possible to use a slightly larger capillary, and to take longer periods of time between readings. However, the errors might arise from gas permeation through the liquid slug or through the walls. An error might also be introduced by a change in barometric pressure or a change in ambient temperature. This becomes particularly critical in the qualification of small leaks, since a slight temperature change might produce a volume change greater than that due to the efflux of the gas.

It is desirable to use a fluid with a low vapor pressure so that the leak is not contaminated by the vapor of the fluid. Unfortunately, most liquids of low vapor pressure are also of high viscosity, making it difficult to obtain an accurate measurement of the flow of liquid displaced in the capillary.



(a) INDICATING FLUID METHOD



(b) MOVABLE PISTON METHOD

Figure 8-7. Leak Qualification by Isobaric Volume Change. (Reprinted from J.W. Marr, Study of Static and Dynamic Seals in Liquid Rocket Engines, Final Report Phase II, Contract NAS 7-102 (Ref. 6-2).)

Such fluids also tend to form bubbles at the end of the capillary. The added pressure necessary to remove the bubble of liquid from the end of the capillary prevents the experiment from being isobaric.

Haywood (Ref. 8-8) overcame the need for an indicating fluid by the use of a piston to replace the effluxing gas. In this method, a differential pressure gage is used to measure the pressure in the gas volume, and the piston is pushed into the volume at a rate to keep the pressure constant. The pressure gage need not be calibrated. This method can readily measure leakage as low as 10^{-6} atm-cc/sec.

8.4.2 Pressure Rise Method

The second method of qualifying leaks is the pressure rise technique (Ref. 8-9). A leak and its gas supply are attached to an evacuated chamber of known volume (Figure 8-8). The leaking gas is allowed to accumulate in this volume, and the pressure rise is measured at various intervals. The leakage may then be computed by the equation:

$$Q = V\dot{P}$$

Laufer (Ref. 8-10) describes this procedure in detail, claiming an error of less than 10 percent. The major difficulty with

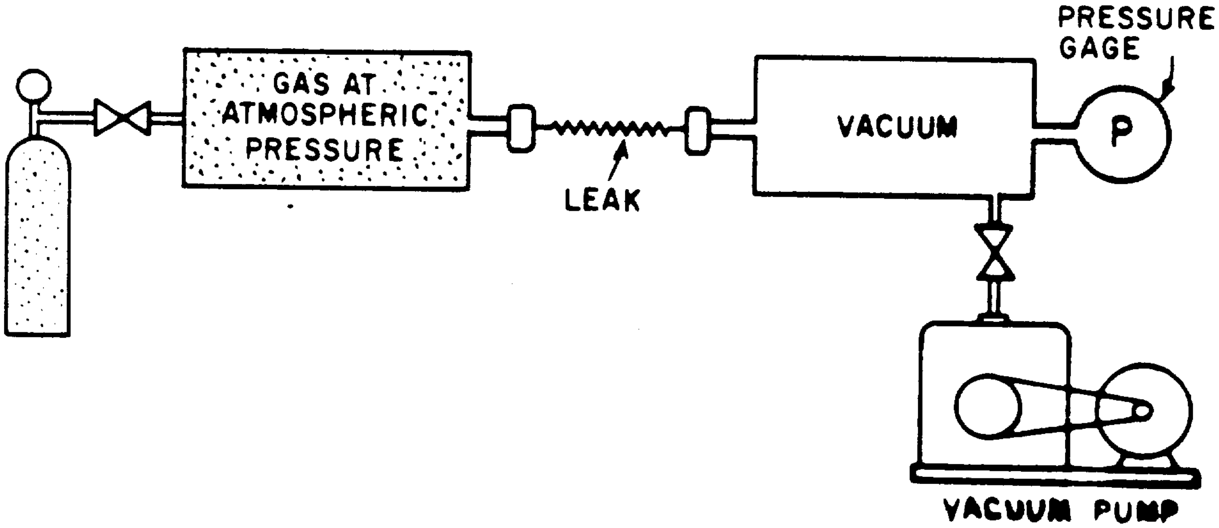


Figure 8-8. Leak Qualification by Pressure Rise Technique. (Reprinted from J.W. Marr, Study of Static and Dynamic Seals in Liquid Rocket Engines. Final Report Phase II, Contract NAS 7-102 (Ref. 6-2).)

this type of qualifying technique is in the measurement of pressure. The pressure in an evacuated system usually does not stay constant, but gradually increases because of outgassing of the walls of the chamber. The pressure rise due to this desorption must be taken into account in the calculations.

A second difficulty in pressure measurement is the lack of a suitable gage. A McLeod gage may be used, but is suitable only for the higher pressure ranges. If a long period is used to obtain a readable pressure change, outgassing becomes a particularly difficult problem. Ionization gages are difficult to use for this work, because of lack of adequate calibration and because of outgassing at the low pressures at which they work. Another alternative is the use of a mass spectrometer as the pressure gage (Ref. 8-11). In this case the effect of outgassing may be overlooked, since the desorbing gas is usually not the one being measured.

Fisher (Ref. 8-12) has described a "calibrated" leakage rate system suitable for use on large vacuum chambers which is not limited by the usual difficulties. Known leakage rates of a gas enter an evacuated chamber to which a mass spectrometer is coupled. Leakage rates of the actual substance are thereby determined, obviating the need for an inert tracer gas. An accuracy of plus or minus twenty percent is claimed for the method.

8.4.3 Pressure Drop Across a Known Conductance

A third method of determining leakage rates is measurement of the pressure drop across a known conductance. This technique is illustrated in Figure 8-9. The pressure drop across a known conductance is proportional to the flow. As previously stated,

$$Q = C(P_1 - P_2) \tag{8-3}$$

In molecular flow the conductance C may be determined from theory using known dimensions of the leak. Again, the major difficulty is in obtaining accurate measurements of pressure. Ionization gages have been used for pressure measurement, but their readings are often questionable. With the use of a previously qualified leak, this type of measurement can also be used to calibrate ionization gages (Ref. 8-13).

8.4.4 Pressure Measurement at Constant Pumping Speed

A fourth method of qualifying a leak is measurement of the pressure which results when a vacuum system is pumped at a known speed (Figure 8-10). The equation then used is:

$$Q = SP \tag{8-4}$$

The system is usually constructed so that the pumping speed is controlled by an orifice and may be rigorously calculated on theoretical grounds. The disadvantage of such a method is, again,

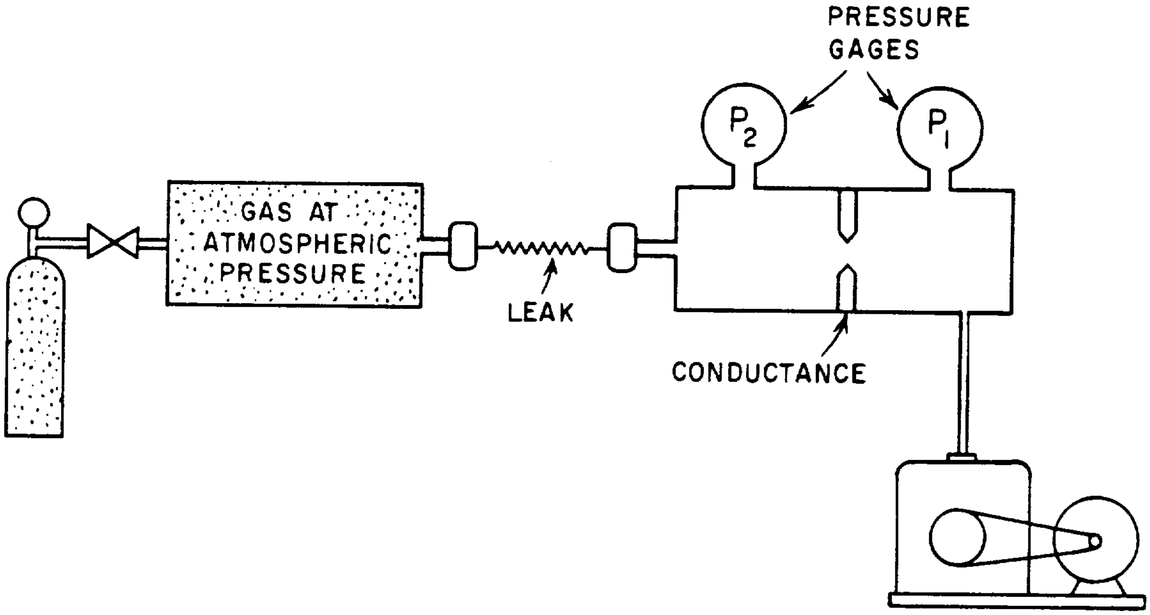


Figure 8-9. Leak Qualification By Pressure Drop Across a Known Conductance. (Reprinted from J.W. Marr, Study of Static and Dynamic Seals in Liquid Rocket Engines, Final Report Phase II, Contract NAS 7-102 (Ref. 6-2).)

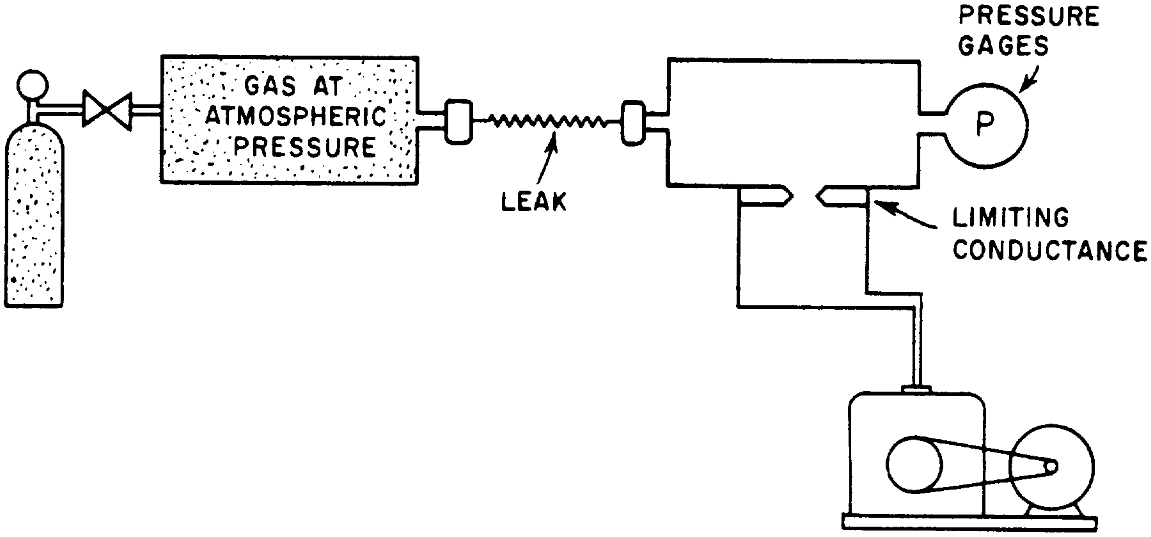


Figure 8-10. Leak Qualification By Pressure Measurement at Constant Pumping Speed. (Reprinted from J.W. Marr, Study of Static and Dynamic Seals in Liquid Rocket Engines, Final Report Phase II, Contract NAS 7-102 (Ref. 6-2).)

that the pressure of the system must be accurately measured. If the leakage Q and the pumping speed S are known, P can be derived using the above Equation 8-4. This type of system has also been used to calibrate pressure gages (Ref. 8-14). Some accuracy is gained if a mass spectrometer is used as the pressure gage since the error due to outgassing may be eliminated.

8.4.5 Change in Intensity of Alpha Radiation

A type of standard for leak qualification is described in Reference 8-15. Radioactive polonium is used as an alpha emitter (alpha particles are helium atoms stripped of their electrons). When alpha particles come in contact with other atoms, they acquire the necessary electrons to become helium molecules. Since the radioactivity of the polonium sample can be measured accurately, the number of alpha particles evolved is known. Therefore, the amount of helium gas formed is also known. In this way pressure-measuring instruments may be accurately calibrated. The only source of error is possible absorption or entrapment of the helium within the leak. This may be prevented by good design and/or the establishment of steady-state condiitions.

The above technique is limited to helium gas calibration. It can be used effectively only in the low-leakage ranges ($< 10^{-8}$ atm-cc/sec) because of the shielding that would be necessary in its use at higher concentrations of radioactive material. However, the technique is an excellent supplement to the other methods described, and it is most effective in the range which is difficult to measure by other techniques.

8.4.6 Mass Leakage Analysis

A novel method of measuring the mass of a gas in a chamber, as well as its rate of change with time, has been demonstrated at TRW Systems, Inc., by R.J. Salvinski (Ref. 8-16). The method has the advantage that measurement is theoretically independent of the type of gas, the ambient pressure in the chamber, and the gas temperature. However, these parameters do affect the accuracy of the measurement as they affect, for example, the sensitivity of the test and the size of the chamber. The method may be used to calibrate the conductance of a leak in terms of the fundamental units of mass, length, and time.

A sensitive electrobalance is placed within an evacuated chamber. A spherical glass ball of known volume V_B is attached to one end of the electrobalance and suitable counterbalancing weights to the other. An electrical signal is generated which is proportional to an unbalance in the force moments about the fulcrum of the electrobalance. This signal is fed back through an amplifier to an actuator which restrains any deflection of the arm of the electrobalance by applying a counter torque. A meter reads a voltage that is proportional to the countertorque.

The system can be used to measure a mass of gas admitted to the chamber through a leak. When the gas enters the chamber, the density of molecules in the chamber increases and causes the buoyant force F_B on the ball to increase. The arm becomes unbalanced and a countertorque is applied to compensate it.

The buoyant force is equal to $V_B \rho_A g$. The gas density ρ_A is equal to M_A/V_c, where M_A is the mass of the gas and V_c is the chamber volume less that of the ball. Thus:

$$F_B = M_A \cdot \frac{V_B}{V_c} \cdot g \qquad (8\text{-}5)$$

The meter reading will therefore be proportional to the mass of the gas, the known volumes, and the gravitational constant, g. The reading should be independent of the type of gas, its temperature, and its pressure. It is assumed that the measurement is made after leakage has been stopped, that there is no outgassing or absorption of gas; and that the sizes of the chamber and ball have not changed, because of a change in temperature, for example.

It appears that the conductance C of the leak can be found as follows. As leakage proceeds, the pressure P in the chamber increases toward the pressure P_1 as

$$P = P_1 \left[1 - e^{-\frac{Ct}{V_c}}\right] \qquad (8\text{-}6)$$

Since the mass in the chamber is proportional to the pressure P,

$$M_A = \frac{PV_c}{RT} \text{ (MW)} \qquad (8\text{-}7)$$

If the time constant of the electrobalance is short compared to that of the leak, V_c/C, it is now possible to determine the rate of change of the buoyant force with respect to time, from data on the variation of the force itself with time. Recall that F_B is proportional to the output reading of the electrobalance. A differentiator placed in series with the output will produce a reading directly proportional to $\dot{F}_B$.

As derived from the previous equations,

$$F_B = \left[\frac{P_1}{RT} V_B \text{ (MW) } g\right] \left[1 - e^{-\frac{Ct}{V_c}}\right] \qquad (8\text{-}8)$$

and the rate of change of buoyant force is:

$$\dot{F}_B = \left[C e^{-\frac{Ct}{V_c}}\right] \left[\frac{P_1}{RT} \text{ (MW) } \left(\frac{V_B}{V_c}\right) g\right] \qquad (8\text{-}9)$$

If P_1 and T are now constant, then:

$$\dot{F}_B = C \; e^{-\frac{Ct}{V_c}} \; (K_1) \qquad (8\text{-}10)$$

and

$$\ln \; (\dot{F}_B) = \ln K_1 \; C - \left(\frac{C}{V_c} \right) t \qquad (8\text{-}11)$$

A semilog plot of $\ln (\dot{F}_B)$ versus t is then a straight line of negative slope (C/V_c). Since V_c is known, the desired conductance of the leak may be calculated. The conductance has thus been determined from the data without a knowledge of the entrance pressure, the gas temperature, or the molecular weight.

The leakage rate Q_0 of the leak with a forepressure P_1 and and afterpressure of zero is simply $(C)(P_1)$. Here the type of gas and its temperature are the same as were used in determining the conductance, so as to account for the effects of these parameters on viscosity and the mode of flow.

The sensitivity of the mass leakage analyzer is determined by the ratio of the volumes and the sensitivity of the balance. In the first demonstration leakage rates of 10^{-2} atm-cc/sec could be measured. Leakage rates near 10^{-5} atm-cc/sec have been measured in improved models of the system.

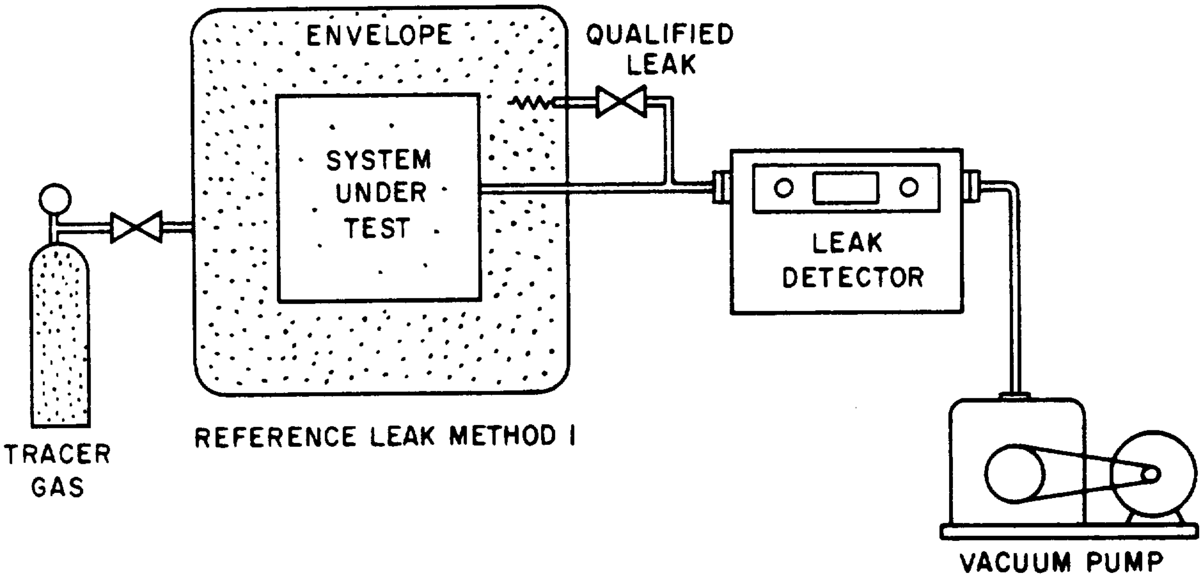
8.5 POSITIONING OF TEST LEAK

Since there are many variables which can affect the sensitivity of testing, it is necessary that leakage calibration or qualification be frequently performed. Locating a calibrated leak close to a suspected undesired leak will result in test measurements that most nearly reflect the actual leakage rates. Figure 8-11, for example, shows two methods which might be used for leakage measurement.

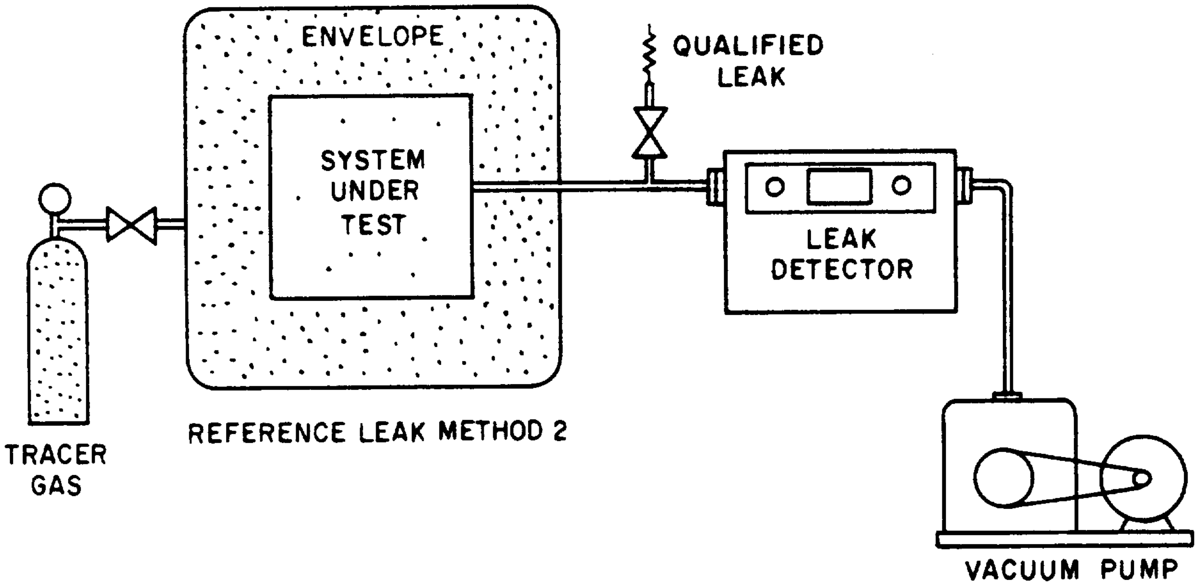
Method 1 gives better assurance that the concentration of tracer gas is the same in all phases of the test than does Method 2. These methods are only as accurate as the linearity of the detector response. Either method will show whether the system leakage rate is greater or less than the reference leak. In practice, Method 1 is easy to incorporate in a rigid hood in a permanent test position. It is not always easily arranged with a flexible hood.

It is extremely important when establishing sensitivity that the tracer gas be applied to the leak for the same period of time as it will be applied to each suspected area. This will take into account the effects of absorption on the walls and the effect on the time constant volume of the system.

For accurate results the unknown leak should be placed in the same port of the detector as the qualified leak, and under



REFERENCE LEAK METHOD 1



REFERENCE LEAK METHOD 2

Figure 8-11. Alternative Positions for a Qualified Leak on a System identical conditions. In calibrating, if the object to be tested is located immediately adjacent to the inlet of the detector, the known leak must be placed in that position. If the object to be tested is a vacuum chamber or an object to be located in a vacuum chamber, and the leak detector will be connected to the chamber foreline, the known leak must be located away from the foreline in the vacuum chamber. In this case, output versus time must be known.

When a glass qualified leak is placed inside a vacuum chamber, the helium permeation through the glass envelope of the qualified leak as well as that through the quartz membrane may be significant. The rate given by the manufacturer is for helium permeation through the quartz membrane only.

When a system is calibrated by using a pure helium leak with a one-atmosphere pressure differential across it, the rate obtained during an actual test must be that for pure helium across a one-atmosphere pressure differential. If, in the actual test, the helium is reduced in concentration by being mixed with another gas, the calibration must be adjusted accordingly.

The reference leak should have a leakage rate approximately equal to the permissible leakage rate, particularly if the response of the detector to leakage is not linear. The smaller the reference leakage rate the greater the difficulties associated with its use.

Two standards are available for the calibration of mass-spectrometer leak detectors. American Society for Testing and Materials standard F78-67T covers a procedure using qualified leaks (Ref. 8-17). American Vacuum Society standard AVS 2.1, which is reproduced in Appendix B, determines the significant performance characteristics in addition to the calibration (Ref. 8-18).

Section 9

MASS SPECTROMETERS AND LEAKAGE TESTING

9.1 INTRODUCTION

The mass spectrometer is a device which identifies atomic or molecular species by their mass-to-charge ratio. The operation consists of ionizing the sample, separating the different ion species, and detecting the separated species. A mass spectrometer that is built for leak detection is usually limited to the detection of helium. Other small mass spectrometers, called residual-gas analyzers, are built to scan over a range of masses and are useful in partial pressure measurements of residual gases in a vacuum.

Different schemes are employed for separating the ions according to their mass-to-charge ratios. A deflection type of mass spectrometer accelerates the ions and effects a separation by passing them through a magnetic or electrostatic field, or both. A time-of-flight mass spectrometer separates the ions by their different speeds over a fixed path. Several varieties of this latter type are available, namely the pulsed-beam, omegatron, and radio-frequency mass spectrometers. J.B. Farmer surveys the various types of mass spectrometers and discusses the outstanding properties of each type in Chapter Two of *Mass Spectrometry* (Ref. 9-1).

The deflection type of mass spectrometer is most commonly used in leak-detection work.

9.1.1 Application

Mass spectrometers for use in leak detection have been developed commercially by many firms throughout the world (see Part III). This type of instrument has proved to be highly versatile in its application to many different situations. It has gained wide acceptance, largely because of its high sensitivity and specificity to a single tracer gas helium, which has a very low concentration in earth's atmosphere.

Applications also cover a considerable range of size in electronic components. The same instrument can be adapted to test upwards of 1200 individual parts per hour or to test the integrity of large vessels such as are used for the storage of cryogenic liquids.

A residual-gas, or partial-pressure, analyzer can also be used to determine the leak-tightness of a system (Ref. 9-2). For example, it is possible to differentiate between outgassing, pump-oil backstreaming, and air leakage of an evacuated system from a scan of the first seventy mass numbers. When an air leak is indicated, by the presence of a nitrogen-oxygen signal, the instrument can be adjusted to respond only to helium. A helium probe is then used to locate the defect. Briefly, some of the responses and their diagnoses are:

Gas Present in System	Probable Cause
Oxygen, nitorgen and argon	Air leak
Nitrogen	Leak in liquid-nitrogen baffle
Water	Virtual leak, leak in coolant lines
Hydrocarbons	Ineffective baffling of pumps

9.2 SENSITIVITY

The sensitivity of a mass spectrometer depends upon several factors, some inherent in this instrument and others dependent upon the response to different gases. A helium leak detector will usually have a minimum-detectable concentration ratio of about one part of helium in ten million parts of air, or about 10^{-10} atm-cc/sec.

The method by which ions are detected has the greatest effect on the sensitivity of the instrument. There are two commonly used methods for detecting the ion current: 1) by an electrometer, and 2) by an electron multiplier. The electrometer collects the ion current directly on an electrostatically shielded plate. This current establishes a voltage across a resistor of very high resistance which then is amplified by a high-gain DC amplifier.

In the second method the ions are collected on the first of several dynodes of the electron multiplier. An ion striking the first dynode releases an electron, which travels to the next dynode; there a larger number of electrons are released. The process continues and the number of electrons is increased from stage to stage for as many times as there are stages in the device. The response of an electron multiplier which is exposed to a vacuum system (as opposed to one sealed in its own envelope) depends upon the condition and past history of the multiplier. For example, poisoning of the dynodes by some contaminant in the vacuum system will change the electron yield for tracer-gas ions. In fact the contaminant may be any gas other than the tracer, such as oxygen, hydrogen, or carbon monoxide. When using such a detector, it is advisable to calibrate frequently the output reading of the instrument, keeping a record of the sequence in which gases or vapors have been introduced and removed from the system being tested.

Sensitivity of a helium spectrometer is also a function of both total pressure and helium concentration. If excessive outgassing or leaks in the system under test raise the system pressure above approximately 10^{-2} torr, the sensitivity decreases rapidly. In this case, auxiliary pumping may be used to reduce system pressure. Such pumping, however, will also reduce sensivity; also, if too large an opening is used in the detector probe, sensitivity decreases rapidly because pressure within the mass-spectrometer detector will rise to the 10^{-2} torr region. A compromise must be sought between too large a probe opening, which reduces sensitivity, and too small an opening, which does not allow entry of enough helium for detection.

Present-day mass spectrometers actually have higher sensitivities to masses 30 - 50 than to mass 4 for helium. By the use of a tracer having a molecular weight in the above range, the sensitivity of a leakage test may be increased by about three orders of magnitude over that obtainable with helium (Ref. 9-2).

9.2.1 Ratings

Helium mass spectrometers are usually rated by their sensitivity. Sensitivity is determined by the level of gas flow which produces the minimum detectable signal. The American Vacuum Society has promulgated a procedure for making such measurements (Ref. 8-18). A copy of this standard (tentative), AVS 2.1, is included in Appendix B.

The sensitivities are usually expressed in terms of helium (atm-cc/sec), although a value for air will occasionally be used. For conditions of molecular flow the conversion to helium is obtained by multiplying the air value by 2.7.

9.3 CHARACTERIZATION OF AN ION-DEFLECTING MASS SPECTROMETER

Figure 9-1 shows schematically the basic elements of an ion-deflecting spectrometer. Singly ionized molecules or atoms are produced by a stream of electrons in a small ionizing chamber. The ions are drawn from the chamber and formed into a beam of constant velocity. This beam passes into a magnetic field in an electric field-free region. The beam interacts with the magnetic field and moves in a circular arc until it leaves the field. The beam then passes through a slit in a grounded electrode, to an ion collector. The radius of curvature of the beam while it is in the magnetic field is proportional to the function $\sqrt{M\ V}/B$, where M is the mass of the ion, V is the beam voltage, and B is the strength of the magnetic field. Only ions having masses lying within a particular, narrow range will reach the collector for a given setting of the voltage and magnetic field strength. Other ions are collected on the grounded electrode.

A mass spectrometer designed expressly for use in a leak detector that is operated with a single tracer gas does not have to be capable of scanning a mass spectrum. Beam optics and parameters such as the beam voltage and magnetic field are set to detect the mass of the particular tracer gas with the highest possible sensitivity. Provision is made for fine tuning of the response, by an adjustment of the electric field, for example.

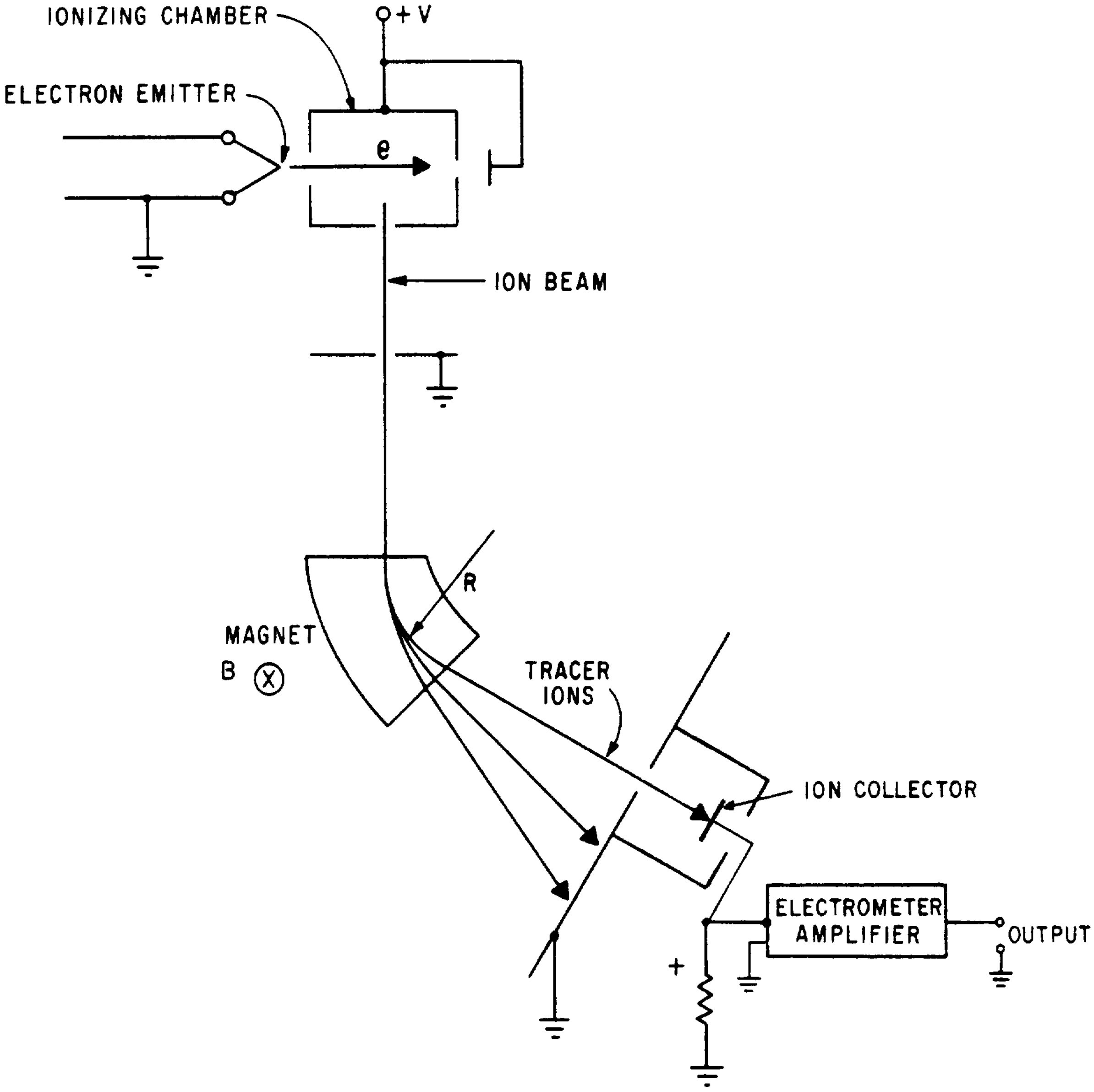


Figure 9-1. Schematic Diagram of an Ion-deflecting Mass Spectrometer

The electrometer stage of the DC amplifier is usually mounted inside the mass-spectrometer tube. This keeps the input resistor and other input connections dry, to minimize leakage currents. It also makes the leads as short as possible from the ion collector to the input element of the amplifier to prevent electrostatic pickup.

The random noise level at the output of the amplifier is determined largely by the resistance of the input resistor and the bandwidth of the input circuit of the amplifier. The output noise voltage varies as the square root of the product of the input resistance and bandwidth. The average value of this noise is zero. Superimposed on the noise will be small signal fluctuations which are the result of energetic ions in the collector chamber which strike the collector and are neutralized by electrons which flow through the resistor. This type of fluctuation can occur in the absence of the main ion beam. Lastly, there can be a DC drift in the balance of the amplifier's output circuit, which often results in a slow, monotonic change in the meter reading. Thus, in some instruments the zero balancing adjustment must be reset from time to time to keep the meter on scale. DC drift does not limit the sensitivity of the detector.

Drift and noise must be considered when quantitative values of a leakage rate are being sought. Frequent checking of the response with and without tracer gas is required when the magnitude of the leakage is very small. Flushing of the system with an inert gas other than helium is sometimes employed to remove memory effects, so that the leak signal will be as large as possible against the noise background.

In some instruments it is possible to use tracer gases other than helium. However, helium is most often chosen for the purpose because:

1. Helium diffuses through a leak more rapidly than any other gas except hydrogen.
2. Normal concentrations in the atmosphere are only one part in 200,000 parts of air (Ref. 9-4). In most cases the presence of tracer helium is clearly distinguishable from atmospheric helium. The latter is sometimes found to add to the background level when a spectrometer is operated at maximum sensitivity.
3. Except in systems which may contain deuterium gas, there is little possibility that another gas will give an indication that can be mistaken for helium.
4. Helium is inert and forms no compounds from which it can be released by dissociation.

Helium is absorbed by elastomers. O-ring gaskets can become saturated with helium and raise the background level in the mass spectrometer. Helium is pumped in Penning discharge gages by an ion burial process; since it forms no true compound it can be released by regurgitation mechanisms. Helium entrapment in ion pumps is also not permanent; in fact its use as a tracer gas in an ion-pumped system is to be avoided. (Fortunately, these effects are not present in a system pumped by an oil or mercury diffusion pump.) If a Penning gage is present in a mass-spectrometer leak detector, it should be cleaned and baked periodically to remove sorbed helium. The gage should be off when the spectrometer is operating at maximum sensitivity.

In principle, it should be possible to convert a commercial helium leak detector so that it will detect some other gas such as argon, hydrogen, or neon. In practice, however, this can prove to be expensive and unsatisfactory. The problems encountered stem from the higher concentrations of these other tracer gases in the atmosphere and from the difficulty in distinguishing the mass spectrum of the desired ion from the spectrum of an unwanted ion.

Hydrogen and argon have been used fairly extensively with mass spectrometers. However, their normal concentrations in air are about one part in 10,000 and one part in 100,respectively. Consequently, the background due to air seeping into the system is considerably higher with these gases. Suitable means must be used to compensate for this.

Hydrogen is more widely available and costs less than helium. It is more readily ionized than helium, yielding a higher sensitivity for leakage measurements. But it is also formed in the spectrometer ion source as a breakdown product of hydrocarbons and water vapor, especially when these come into contact with the spectrometer filament.

In a mass spectrometer for hydrogen special precautions must be taken in the construction of the ion source. Vapor contamination from the equipment under test is kept out of the spectrometer by a liquid-nitrogen trap in the inlet line to the ion source. The ion-source construction is "clean," in that organic materials are avoided and the demountable seals use metal foil gaskets. Finally, the mass spectrometer pumping system comprises a mercury diffusion pump with its own liquid-nitrogen trap. The result is a significantly lower hydrogen background.

Cossutta and Steckelmacher (Ref. 9-5) have attained a sensitivity of 4×10^{-10} atm-cc/sec on a lens mass spectrometer using hydrogen as the tracer gas. With helium the sensitivity was about half that for hydrogen. The background stability was greater in the mass-4 than in the mass-2 region. Therefore, the limiting sensitivity was about the same for both helium and hydrogen.

Argon can be used as a substitute for helium, but will reduce the sensitivity of the spectrometer. It retains many advantages such as high ionization efficiency, chemical inertness, and low cost. It has a relatively high background in air. The principal disadvantage is that argon at mass 40 is difficult to resolve from the background peaks. Both the nitrogen and oxygen peaks of air and hydrocarbons normally present in the vacuum system increase the general background in the mass-40 region. Thus argon is difficult to detect and measure. Some of these background difficulties may be overcome by use of the doubly ionized argon peak at mass 20, although this produces a lower sensitivity than measurements near mass 40. The mass-20 peak appears in a relatively clean region of the spectrum. Thus background ceases to be a problem. Slow diffusion of argon through leak passages limits to some extent its use for leak location.

The variable pressures and atmospheres associated with leak detectors are factors contributing to the unpredictable life of analyzer tube filaments. Occasional bursts of gas bring the system up to high pressures. Even with protective circuits to take care of these bursts, tungsten filaments will have a very short life. It is possible to increase filament life (Ref. 9-6) by coating it with thoria. Most commercial leak detectors are now sold with spectrometer tubes containing thoria-coated or iridium-tungsten filaments. Some leak detectors are built with dual filaments; if one filament burns out, the second can be quickly put into operation. Ionization of the tracer gas varies with electron-emission current. Therefore, the emission must be kept constant with an automatic regulator.

Contamination of the ion source can result in low sensitivity or unstable operation. One commercial helium leak detector contains a self-cleaning ion source in the mass spectrometer head. In that instrument, the ion repeller is a grid which runs red-hot, to burn off contamination deposits which try to form on the electrodes (Ref. 9-7). On other instruments, the ion repeller is platinum-clad and may be cleaned by immersion in a soft flame.

9.3.1 Some Other Ion Spectrometers

Ion mass-spectrometers other than the magnetic sector type may be used for leak detection. For example, Varadi (Ref. 9-8) describes a radio-frequency mass-spectrometer leak detector. In this type of analyzer tube ions are accelerated by a direct-current voltage, and then sent through a series of grids which have a radio-frequency (RF) voltage applied to them. If the transit time of the ions in going through the grid structure is in proper phase with the frequency of the applied RF voltage, the ion will gain energy. A repelling potential placed on a grid between the RF structure and the collector prevent all but those ions which have gained a maximum energy from reaching the collector. This type of tube does not require a magnetic field. It requires a large amount of electronic circuitry.

Barrington (Ref. 9-9) developed an inverted magnetron type of ion detector. In this tube, the anode is mounted centrally inside a grounded cylinder which acts as the cathode. A magnetic field of about 1000 gauss is applied axially. A discharge is initiated on application of a potential difference of about 1500 volts between the electrodes. The electrons, trapped by the magnetic field, circulate around the anode. Positive ions are accelerated radially towards the cathode and, because of their much larger mass-to-charge ratio, are deflected only slightly by the magnetic field.

A small exit hole is provided in the cathode. Ions emerge through the hole at angles and with velocities which vary according to the mass of each species. The ions continue to travel in the fringing magnetic field, and some spatial separation is achieved as a function of ion mass. The sensitivity of the device is in the order of 10^{-10} atm-cc/sec for helium. It does not appear to have sufficient resolution to be useful as a gas analyzer, however. Basically the magnetron interaction space may be thought of as an ion source. Collisional processes impair the formation of an ion beam at the exit hole where the angle is strictly a function of the mass of the ions contained in it, however.

An omegatron leak detector is described by Nicollian (Ref. 9-10). The omegatron is basically a small, compact cyclotron. The electron beam produces ions of the residual gases in the volume, and the magnetic field causes these ions to move in circular paths at their cyclotron frequency. When the applied radio-frequency voltage is in resonance with the cyclotron frequency of a particular ion, the ion will gain energy and move out in a spiral path, eventually striking the collector.

Any mass spectrometer may be used as a leak detector. However, those designed for leak detection are portable, rugged, and must have the ability to remain tuned to the tracer gas signal.

Reference 9-11 describes a mass spectrometer using two ion-deflecting analyzers in series. Those ions which are gas-scattered in the first analyzer, and which would produce a broadened peak in a single-stage instrument, are resolved into separate peaks by the second analyzer. With operating pressure in the spectrometer tube in the region of 10^{-5} to 10^{-6} torr, the background was three orders of magnitude less than in a commercial single-stage mass spectrometer. It was therefore possible to use an electron multiplier as an ion detector. A leak detector which employs this principle has recently been manufactured. The smallest detectable leak in this detector is in the range of 5×10^{-14} atm-cc/sec.

Unusual problems are encountered with higher mass-specrometer sensitivity. Residual background from atmospheric helium, diffusion of helium through glass, helium holdup from previous testing, and helium accumulation in the associated vacuum-measuring gages can present serious limitations. One of the most significant problems is the handling of the item to be tested. Leaks which a new machine would be capable of detecting can be easily - though temporarily - sealed by the grease and moisture from a fingerprint.

One approach to the problem of reducing background signals is embodied in an ion detector described by Daly in Reference 9-12. It can distinguish between helium ions and unwanted "air" ions. This detector is used with a conventional single-stage mass spectrometer. Its operation depends on the fact that the penetration of low-energy-charged particles in aluminum is proportional to the energy and inversely proportional to the square root of the atomic number of the ion. The metal thickness can be chosen so that the helium ion penetrates just to the back and releases there a secondary electron, which may be used to record the arrival of the helium ion in the foil. No signal will be obtained from the N^+ and N_2^+ ions because of their failure to penetrate a foil of this thickness. A great reduction of background can be achieved by this technique. This detector is not commercially available at present, however.

9.4 TYPICAL MASS-SPECTROMETER LEAK DETECTOR

A mass-spectrometer leak detector comprises the following major components:

1. High-vacuum pumping system for the analyzer system
2. Analyzer tube and its associated electrical circuits
3. Low-vacuum pumping system for roughing out the test item
4. Cold trap for removing condensable vapors
5. Appropriate couplings or flanges for the attachment of a test piece and qualified leak
6. Valves to control the flow of gases through the detector
7. Leak indicator, such as a meter or audible signal, or both
8. Vacuum gages

A typical vacuum system is shown in the functional diagram of Figure 9-2.

9.4.1 High-vacuum Pumping System

A forepump and a diffusion pump are used to maintain a vacuum of 10^{-4} torr or less in the analyzer tube.

Since hot organic diffusion-pump oils decompose near atmospheric pressure, the system must be exhausted to a pressure less than 10^{-1} torr before the diffusion pump is turned on. Similarly, it is important to shut off the diffusion pump first, and then allow the oil to cool before turning off the mechanical forepump or venting the diffusion pump to atmosphere.

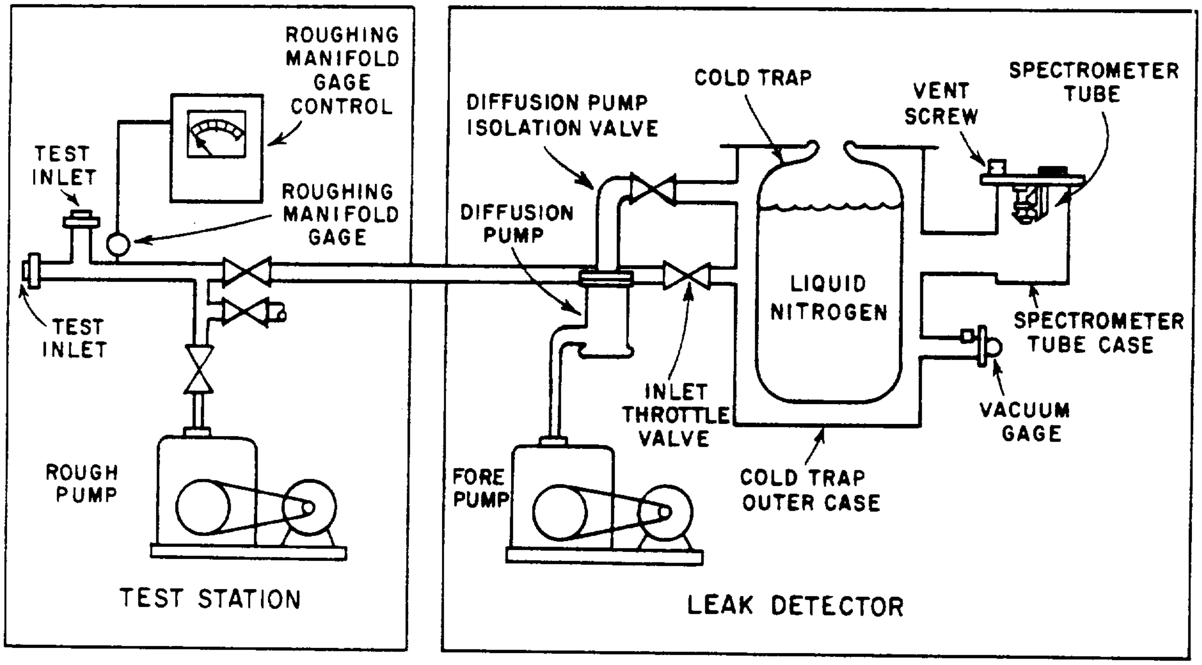


Figure 9-2. Mass Spectrometer Leak Detector Pumping System. (Reprinted with permission from Analytical Measurement Business Section, General Electric Company, Schenectady, New York.)

The forepump, diffusion pump, and blower should be interlocked for maximum protection of the diffusion-pump oil. The diffusion pump then cannot be turned on unless the forepump is started. A thermal, self-restoring circuit breaker should protect the forepump while providing intermittent operation to maintain vacuum in certain instances. The blower should be fused in conjunction with the diffusion pump so that a failure of the blower fuse will disrupt heating power to the diffusion pump.

One manufacturer uses a detector with a novel pumping system. Instead of a diffusion pump, chemical gettering is used. It is claimed that by the preferential chemical reaction of the residual gases, the concentration of helium in the analyzer tube is increased. This is supposed to increase the inherent sensitivity of this type of leak detector.

9.4.2 Analyzer Tube

The modern mass-spectrometer tube operates in a chamber connected to a cold trap. Usually, the entire tube and detector assembly is completely self-contained on a single, easily demountable flange (Figure 9-3). All elements of the tube, including magnets and filament, are self-aligning, eliminating critical alignment problems. The entire assembly can be lifted out for cleaning and parts replacement.

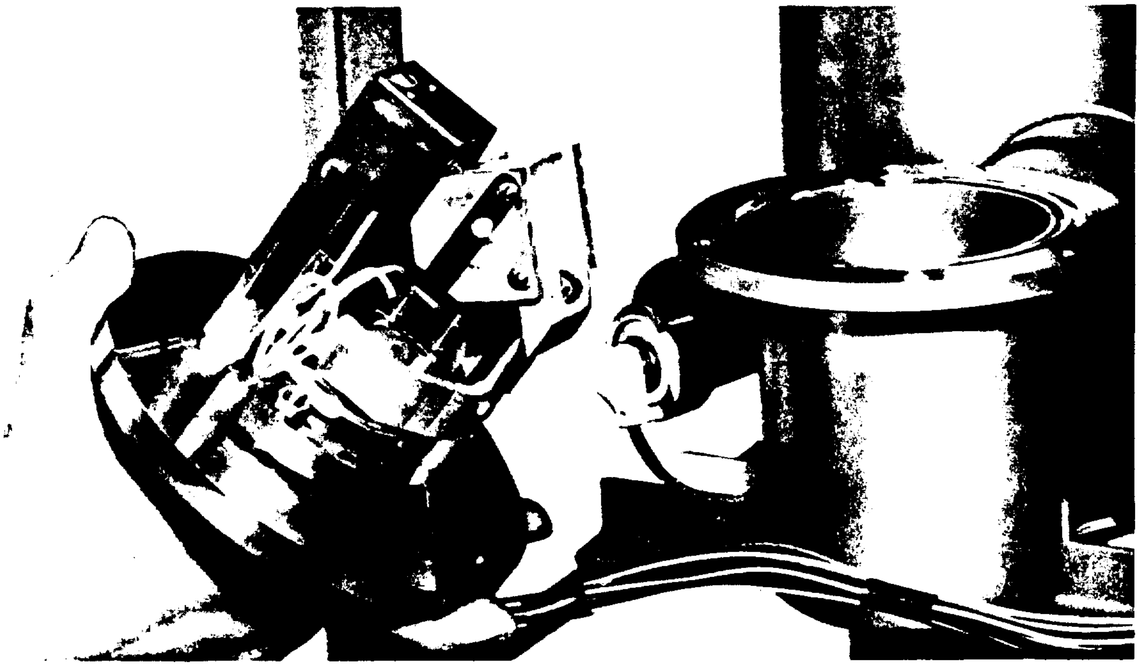


Figure 9-3. Analyzer Tube of a Modern Mass-spectrometer Leak Detector. (Reprinted with permission of the Analytical Measurement Business Section, General Electric Company, Schenectady, New York.)

Design of the tube is shown in Figure 9-4. A beam of electrons from a heated filament is attracted by a small potential difference toward an ionization chamber. The electrons pass through a hole into the chamber. Electrons hit gas molecules in the chamber and ionize them. The source magnet causes electrons to travel in a helical path and increase the probability of collision and ionization. An ion repeller ejects the positive ions out of the slit in the ionization chamber. An ion lens, consisting of two focusing half-plates which can be separately adjusted to the proper potentials, concentrates the ion beam at the center of the slit in the exit plate. Use of such an ion lens increases the intensity of the ion beam and the sensitivity to an input sample of tracer gas.

9.4.3 Low-vacuum Pumping System

A mechanical pump, or some similar device, must be provided for roughing the test item to low enough pressures to transfer it to the leak-detector system. Some mass-spectrometer leak detectors incorporate an automatic test station that changes valve positions at preset pressure levels. The test item is evacuated to some preset value; then the test valve opens automatically and the roughing valve closes. After completion of the leak test the test valve closes and the test item is automatically vented to the atmosphere.

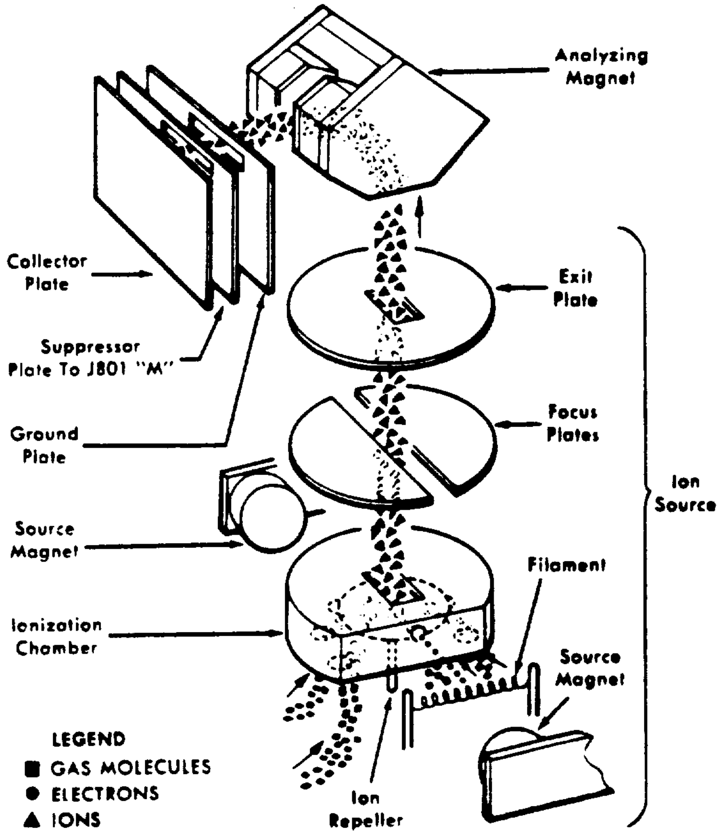


Figure 9-4. Operation of Modern Mass-spectrometer Analyzer Tube. (Reprinted with permission from the Analytical Measurement Business Section, General Electric Company, Schenectady, New York.)

9.4.4 Cold Trap

The purpose of a cold trap in a vacuum system is to remove gases and condensable vapors of water and oil. The vapor pressure of water at 20°C is 17.5 torr, but its vapor pressure at liquid-nitrogen temperature (-196°C) is approximately 10^{-15} torr. The lower the temperature of the trap the more effective it is in reducing pumping time and assuring a clean vacuum system. The recommended refrigerant is liquid nitrogen. Liquid air, though equally effective, may present an explosion hazard, because of its liquid-oxygen content. Good vacuum practice requires that the liquid in the cold trap be maintained at a reasonably constant level. If the trap is neglected and allowed to go dry, the operating efficiency of the leak detector will be impaired. A high background pressure will develop and will shorten the life of the filament.

If liquid nitrogen is not available, a slurry of dry ice and alcohol or an inflammable solvent such as trichlorethylene may be used. The boiling points of these materials are not so low as that of liquid nitrogen, and their trapping effectiveness is less.

A refrigeration unit manufactured specifically for leak-detector cold traps is available. This unit uses the adiabatic expansion of compressed air as the refrigeration principle, and may be operated from any clean compressed-air source.

The vacuum manifold connecting the test piece to the leak-detector system usually incorporates several vacuum compression-seal couplings. It is good practice to leave a standard leak in one of these inlets so that a rapid qualification may be performed before and after a leakage test.

9.4.5 Control Valves

Two high-vacuum, bellows-sealed control valves are usually incorporated in the vacuum system. These include an inlet throttle valve and a diffusion-pump isolation valve (see Figure 9-2).

The inlet throttle valve is especially designed with a throttling plate that varies the size of the valve opening as it changes from a fully closed to a fully open position. This valve is used to throttle a gas sample from a large vessel or from a test piece with large leaks so that the pressure in the leak-detector vacuum system does not exceed a safe upper limit.

The diffusion pump valve provides a means of isolating the diffusion pump from the vacuum chamber, cold trap, and mass-spectrometer tube for servicing and maintenance. The cold trap and mass-spectrometer tube can be removed for cleaning, the filament can be changed, and other maintenance functions can be performed without shutdown of the diffusion pump and forepump.

A valve is available which permits two discrete detector sensitivities while also allowing accumulation techniques of leak detection. The sensitivity choke on the valve provides a constant and fixed sensitivity increase, of a factor of about three times, by changing the pumping speed through the spectrometer tube. Opening the valve two to three turns from its closed position produces a fixed low pumping speed, which results in a higher sensitivity. For faster pumping, this valve may be fully opened and the choke lifted off its seat. The sensitivity and pumping speed can thus be changed without disassembly and with reproducible results. It is not necessary to recalibrate each time the valve position is changed. However, it is important that both calibration and operation be performed at the same valve setting. Figure 9-5 shows an exposed view of this valve.

As an alternative to the two-position valve, it is possible to use a permanent orifice to reduce pumping speed. Although such an orifice would increase the system sensitivity, it would also increase the system response time.

9.4.6 Leakage Indicator

The leakage indicator is usually a milliammeter which registers the amplified ion current. The detector usually has a multi-

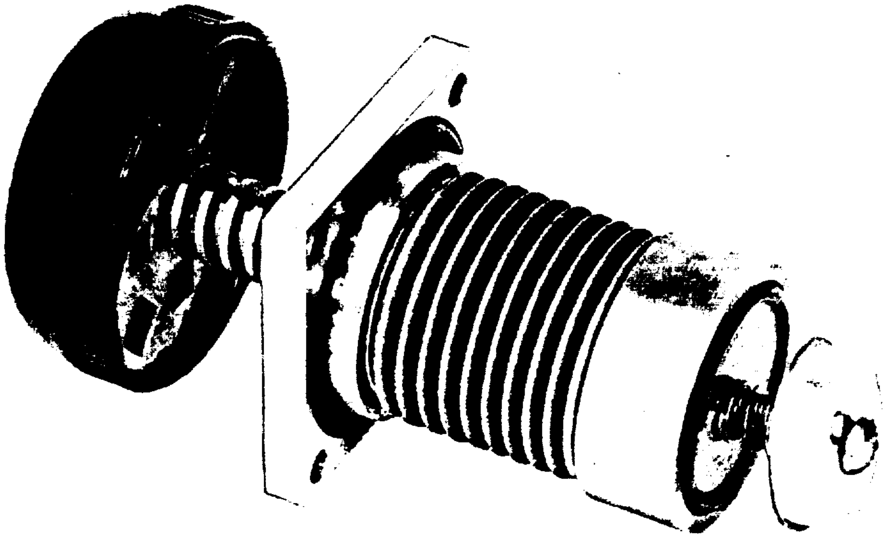


Figure 9-5. Exposed View of a Diffusion-pump Isolation Valve. (Reprinted with permission of the Analytical Measurement Business Section, General Electric Company, Schenectady, New York.)

position stepping switch so that the current range displayed on the meter may be changed.

For the convenience of the operator, who may be unable to see the output meter while he is probing the test system, a loudspeaker, audio oscillator, and amplifier can be installed on the equipment. An audible note is emitted whose pitch is related to the meter reading and hence to the magnitude of the ion current; that is, the pitch of the note rises when a leak is probed.

9.4.7 Vacuum Gages

Mass-spectrometer leak detectors usually employ two types of gages; Pirani, or thermocouple, gages for pressures greater than 10^{-3} torr, and ionization gages for pressures less than 10^{-4} torr. The Pirani, or thermocouple, gage indicates pressure in the fore-pump line and shows when the diffusion-pump line may be opened.

The ionization gage is usually of the cold-cathode or Phillips discharge type. This type of gage is more rugged and does not contain a hot filament which could burn out if accidentally exposed to atmosphere.

9.4.8 General Characteristics and Specifications of Commercial Detectors

Table 9-1 lists the general characteristics of commercially available mass-spectrometer leak detectors. Specific information regarding many of the available models will be found in Part III of this Handbook.

A performance specification for helium leak detectors has been issued by the Electronics Research Center of the National Aeronautics and Space Administration (Ref. 9-13). This specification details such items as sensitivity, response time, clean-up time, warm-up time, noise, and drift.

Table 9-1

COMMERCIAL MASS-SPECTROMETER LEAK DETECTORS

Characteristics	Average Values
Sensitivity	1×10^{-11} atm-cc/sec: 0.1 part per million helium in air
Tracer gas	Primarily helium; also hydrogen, argon, neon, butane
Output signal	Millivolt meter or microampere meter
Power requirement	1000 watts, 105/125 60 hertz AC; 220/250 60 hertz AC
Size	Width = 25 inches, Height = 40 inches, Depth = 20 inches
Weight	500 pounds
Price	$5000
Necessary accessory	Liquid nitrogen

9.5 LEAKAGE TESTING

The mass-spectrometer leak detector can be used in any of the following ways:

1. Leakage measurement
    - Steady-state
    - Tracer accumulation
2. Leak Location
    - Tracer probe
    - Detector probe

9.5.1 Steady-state Leakage Measurement

The steady-state method can be used on either evacuated or pressurized systems, as discussed in Section 4.5, "Leakage Measurement Testing."

The evacuated side should not contain volatile materials or materials sensitive to vacuum, because the test space will be at a pressure of 10^{-2} torr or less. The time required for this test is not much greater than the pumpdown time required for the evauation of the test item. The whole procedure can be highly automated.

The leakage measurement testing of pressurized items involves a time interval of about three hours per test plus a similar time for calibration of the test system. Continuous monitoring of the leak-detector signal is necessary with this method.

9.5.2 Leakage Measurement by Tracer Accumulation

Quantitative measurements using this method are subject to much greater error than those of the preceding subsection (9.5.1). Tracer gas is allowed to accumulate on the downstream side of the leak, and subsequently the concentration of the accumulated gas is determined. Section 4.6, "Tracer Accumulation Testing," discusses this method in detail.

With the helium leak detector, a note of caution is advisable because this method can give false readings as a result of outgassing from the test object (see Section 9.2, "Sensitivity"). When careful attention is given to detail it is possible to measure leakage rates smaller than 10^{-11} atm-cc/sec (Refs. 9-14 and 9-15).

9.5.3 Leak Location -- Tracer Probe

Detection time with this method includes the time to evacuate the test object and the time required to spray all areas with tracer gas. Location of individual leaks using a fine tracer gas stream can be very time consuming. Testing of a large object may be initiated by loosely fitting a hood of vinyl plastic around the object to retain the helium to determine if any leaks exist.

In systematic leak checking, gas is sprayed on the top of the component first, helium gas being lighter than air, and then gradually down over all other suspected areas. This is done so that the helium will not drift to an undetected leak and produce a leak indication at the wrong location. The detection procedure should be carried out in an area free from drafts and breezes.

9.5.4 Leak Location -- Detector Probe

Use of the detector probe (see 5.2.2.1) with the mass spectrometer results in a considerable loss in detection sensitivity (about a thousand times less) over that attainable with a tracer probe.

In the vicinity of a small leak, the rapid diffusion of helium into the air causes a steep helium concentration gradient to be established in the vicinity of the leak. When the probe approaches the leak area it samples the air-helium mixture. (It is important that the probe's orifice be close to its input end.) If the flow rate into the probe were high, it would sweep the helium in. However, the flow is usually very low and has little effect on the concentration gradient. If the probe misses the leak by as small a distance as one-fourth inch, the sensitivity will be reduced by approximately ten to one because of the steep gradient in concentration.

To overcome the effect of the gradient, a small rubber suction cup can be placed over the end of the probe. When the cup covers a leak during probing, the helium concentration begins to increase in the space and will soon reach a detectable level.

Both the probing speed and the distance from the test object to the detector probe are critical. Figure 9-6, reprinted from Reference 9-16, is an example of the effect of probing speed and distance on the sensitivity of the technique. The data represents one manufacturer's results obtained under ideal laboratory conditions. Such high sensitivity cannot be obtained under field conditions. At a probing speed of three feet per minute, even under ideal laboratory conditions, the probe must be within one-fourth inch of the leak to be able to detect and locate a 10^{-7} atm-cc/sec leak. If a weld which is wider than one-fourth inch is being checked for leaks, at least two parallel passes must be made to check the weld completely.

For best sensitivities the leak detector should be operated at about 1×10^{-4} torr detector pressure. Lower pressures result in low speed and longer time constants, while at higher pressures the inherent sensitivity of the leak detector begins to decrease. The use of long vacuum leads between the machine and the probe should be avoided if possible. The additional volume created by these leads adds to the time constant and, hence, reduces the apparent sensitivity. Sensitivity is not actually reduced, but slow response interferes with prompt detection of leaks as the probe is moved over the suspected area.

When pressure-testing large objects, it is preferable to use a short hose and to move the leak detector rather than to use a long hose and a stationary leak detector. Response time increases approximately linearly with probe length in the absence of adsorption and outgassing. That is, doubling the length should double the response time. Actually, doubling the length will probably double the outgassing rate and reduce the sensitivity.

Figure 9-7, also from Reference 9-16, is an example of the effect of tubing length on the clean-up and response time of the leak.

The most successful flexible hose to the probe is of the metal bellows type, although rubber tubing (preferably neoprene) is often used. The problem of sorption of helium can be ignored if metal lines are used. Rubber vacuum hose readily absorbs the

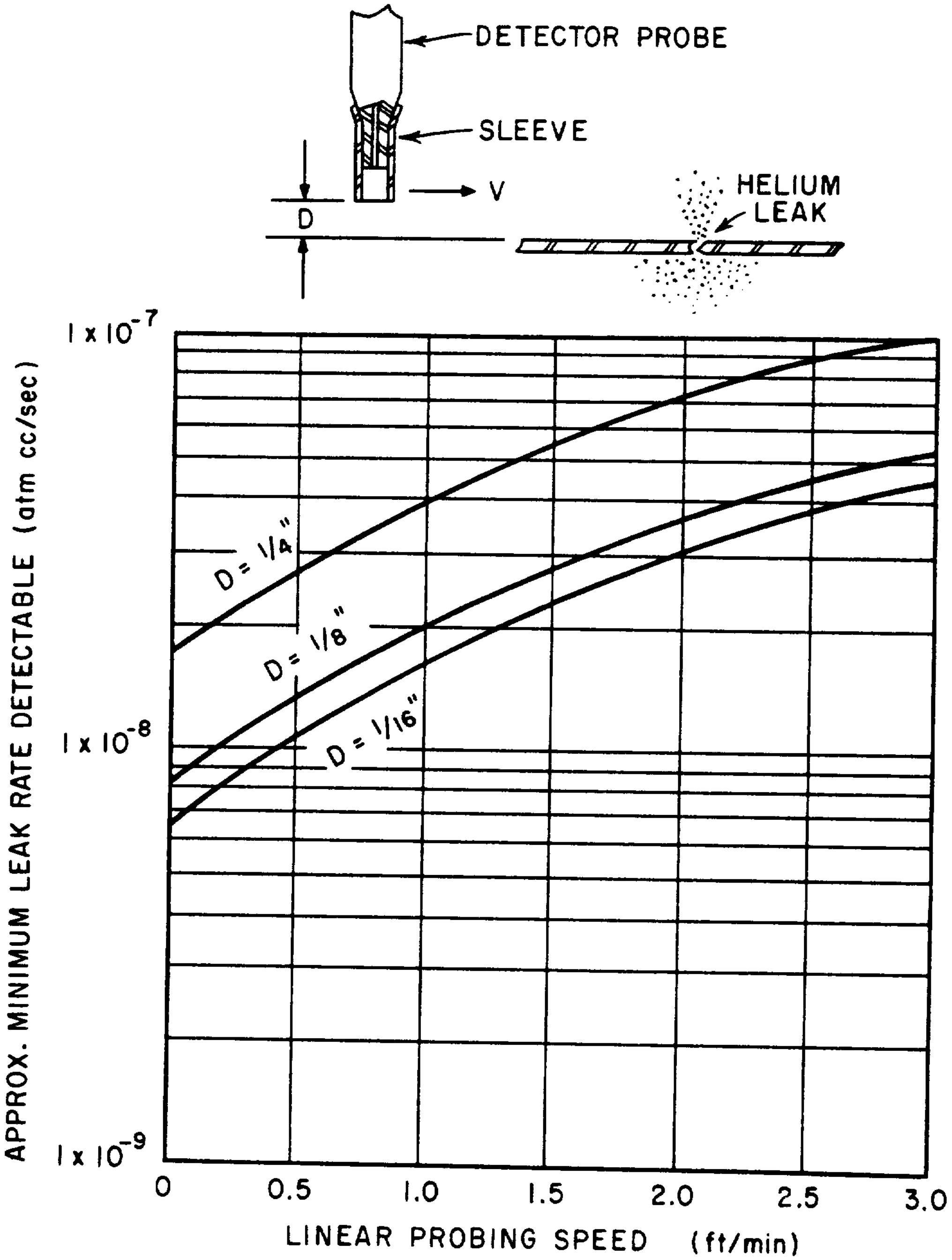


Figure 9-6. Effect of Probing Speed and Probe Distance on Sensitivity. (Reprinted with permission from Consolidated Electrodynamics Corporation, Pasadena, California.)

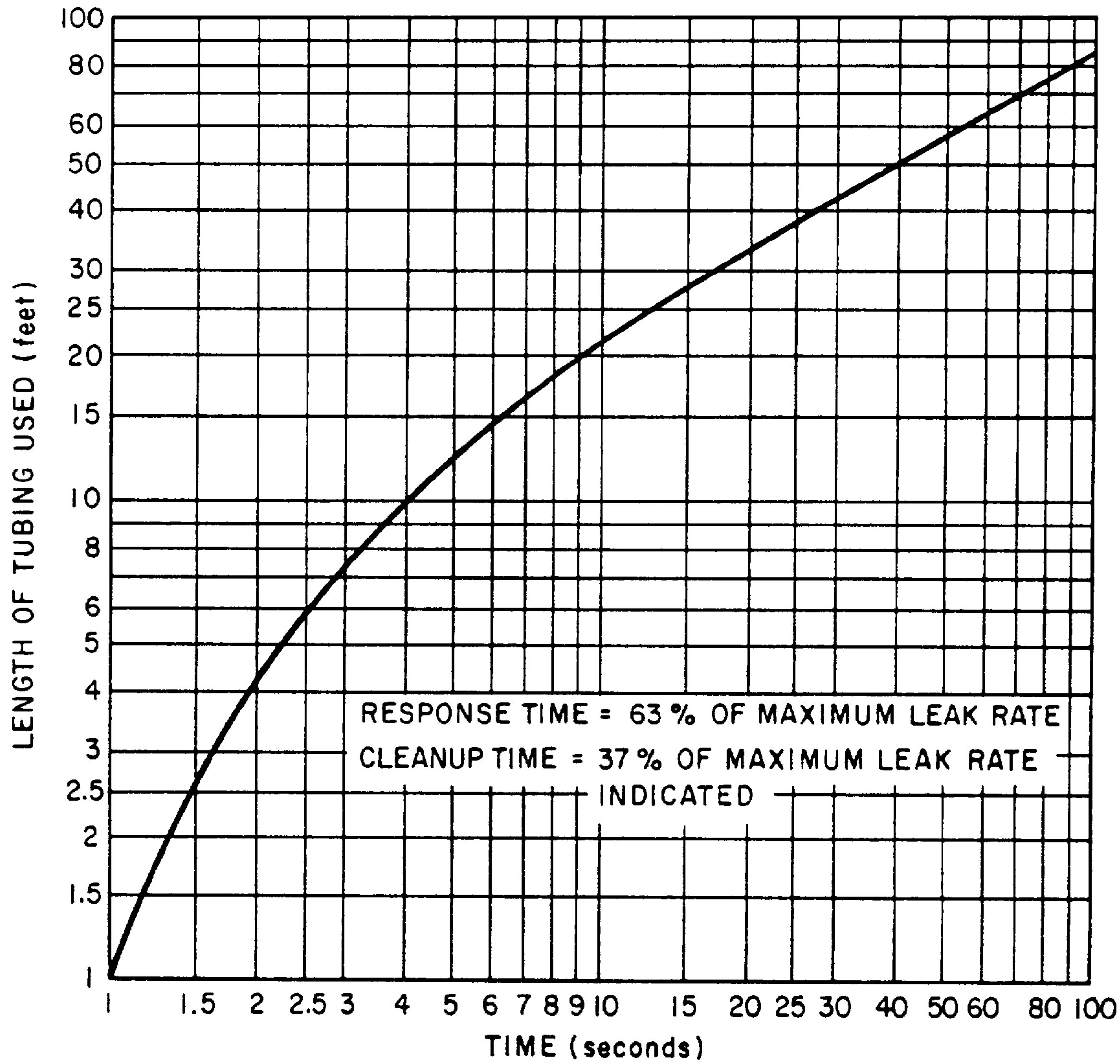


Figure 9-7. Response and Cleanup Time Versus Probe Length for a Mass Spectrometer Leak Detector. (Reprinted with permission from Consolidated Electrodynamics Corporation, Pasadena, California).

helium, removing it from the stream and reducing the sensitivity. Later released, this helium adds to the helium background. The complete removal of helium from a vacuum hose is a tedious process and frequently requires several hours. Clean-up rate can be improved by passing a dry gas through the line at a fraction of a torr of pressure.

When using a detector probe consider the following:

1. The use of a specially shaped probe is sometimes advantageous. For example, a simple probe made by attaching the flattened end of a piece of copper tubing to a needle valve varies the suction through the probe as described in Section 5.2.2.1.
2. The flow through the probe is sometimes too large to be handled by the pumping system of the leak detector. Then an auxiliary pump must be used, although this will reduce the detector sensitivity.
3. The sensitivity can be increased by placing a boot over the end of the probe.
4. After testing in one location, the probe may use up all the helium issuing from a leak there. The probe should be removed until a detectable concentration of helium has built up again around the leak.
5. The test object should be kept out of drafts to allow helium to build up in a concentration around a leak.
6. The minimum detectable conductance of a leak can be changed by pressurizing the vessel to be tested. If such an increase in pressure implies too great an expense in tracer gas, the gas may be diluted, but with some loss of sensitivity. For example, if a system pressure is increased by a factor of 10, the flow through the leak, providing it is laminar, will increase by a factor of 100. Decreasing the tracer-gas concentration by a factor of 10 will decrease the sensitivity only by a factor of 10.

The relative sensitivity of the probe technique may be established by placing the probe near a calibrated leak which has been pressurized, at a known pressure, with helium. The leakage indicator on the leak detector is read and the distance of the probe from the calibrated leak noted. Indicator readings are obtained for several spacings and a curve obtained of meter response versus spacing plotted. The curve is then extrapolated to find the meter indication that corresponds to zero spacing. This is the indication that would be obtained if the entire output of helium from the leak were to be accepted by the detector probe. The relative loss in sensitivity arising from moving the probe away from the leak varies as the ratio of the meter indication at a given distance to that at zero distance. The maximum sensitivity of the detector is reduced in this same ratio.

9.6 OPERATION AND MAINTENANCE

The specific steps involved in using a commercial leak detector will differ from model to model and from manufacturer to manufacturer. Details of operation for each model are usually spelled out carefully by the manufacturer. Maintenance problems are generally minimal. The openings for air circulation through the cabinet of the leak detector should not be blocked. Vibration of the unit should be avoided. A maintenance schedule should be set up for changing both the mechanical- and diffusion-pump oils. Gasketed joints that are disassembled periodically -- such as the flanges for connecting test objects, the liquid nitrogen trap, and the standard leak -- should be inspected on disassembly. Spare parts -- such as filaments, gaskets, and certain electronic parts -- should be kept on hand. The manufacturer can provide a list of parts that are most likely to be needed.

A great number of machine adjustments may be used to vary the sensitivity of the leak detector. Zero adjustment will change the sensitivity to some extent, as will internal pressure variation. Perhaps the greatest effect on sensitivity is the cleanliness level of the detector and the system being tested.

A philosophy needs to be developed for both personnel and equipment. Leak detection is no better than the operator. The following illustrate some of the established operator rules that have been known to minimize maintenance and increase efficiency. An operator should:

1. Refuse to test systems or parts which appear unclean or which visually appear to have contaminants on their surfaces -- i.e., oil, chips, lint, threads, water stains.
2. Use only jigs and fixtures developed for specific parts and standard setups.
3. Acquaint the supervisor or process control engineer with any parts which have been damaged or appear abnormal in any way prior to its test.
4. Determine that the apparatus has been checked out by the maintenance man before operating the detector at the start of each shift. The maintenance check should be recorded in a log book attached to each station.
5. Report all variations in machine performance to a maintenance man.
6. Maintain all cold traps diligently.

The cleanliness of the detector can be greatly enhanced by use of the nitrogen bleed technique described in Section 5.3. This technique should be used whenever the system is left overnight and use is anticipated the next day. Under no circumstances should the pumps of the leak detector be used for drying wet systems or evacuating dirty systems. Overnight use of the nitrogen bleed technique keeps the leak-detector pumping system unavailable to night-shift personnel who might not be knowledgeable in its proper use.

No matter what the circumstances of vacuum testing, a reliable, informed operator is needed. Although most commercial leak detectors are now almost completely automatic, some individual, responsible for the equipment, its operation, and use, should be familiar with the principles of vacuum technology. Helpful information will also be found in References 5-3 and 5-4. It is desirable to check sensitivity at the start and at the end of a work shift. It is also advisable when the detector is operational, to rapidly check after each testing task by admitting tracer gas into the detector through a calibrated leak.

The leak detector should be leak-tight when in use. It is possible to locate leaks in the detector system by a tracer probe technique, using the mass spectrometer itself to locate its own leaks. When the mass-spectrometer leak detector is checked, a leak may be indicated when helium is brought close to the exhaust of the mechanical pump. This is caused by the high diffusion rate of helium, which permits the gas to flow against the general gas flow. The operator of the equipment should be aware that such counter diffusion is a normal occurrence. False signals due to this counter diffusion may be avoided by preventing large amounts of helium gas from accidentally reaching the area near the mechical pump.

Section 10

HEATED-ANODE HALOGEN LEAK DETECTOR

Section 10

HEATED-ANODE HALOGEN LEAK DETECTOR

10.1 INTRODUCTION

In a halogen leak detector, minute quantities of halogen vapor enter a detector cell and are ionized catalytically on a heated platinum anode. Ions are collected on an adjacent cathode electrode at a potential which is negative with respect to the anode. A current proportional to the rate of ion formation flows in an external circuit to produce an indication on a meter. The rate at which ions are formed is proportional to the halogen concentration in the gas which passes into the detector cell. A unique feature of the detector cell is that the ionization process can be accomplished in air at atmospheric pressure.

The ionization process is specific to halogen vapors. The halogens are chlorine, iodine, bromine, and fluorine. Materials containing these elements are usually called halides. The most common halide materials used in leak detection are those containing chlorine.

10.2 SENSITIVITY

Sensitivity of this instrument to R-12 vapor, for example, can be as high as one part per billion of halogen in air, corresponding to a leakage rate near 1×10^{-9} atm-cc/sec. A vacuum-operated halogen detector works at a pressure of 10^{-1} to 10^{-3} torr and is capable of detecting halogen gas in concentrations as low as 0.2 part per million.

Sensitivity of the detector varies with the different halogen compounds. This variation is shown by Table 10-1, which is reprinted from Reference 10-1. The velocity with which a halogen-containing sample is passed through the detector cell also affects the production of ions and, therefore, the sensitivity of the cell.

The response of the sensing element changes markedly with temperature. Below approximately 850°C, the emission current is too small to be easily utilized. Above approximately 950°C it becomes unstable. Random fluctuations in ion production occur and can completely mask a leak signal.

The sensitivity of the detector unit will decrease as a result of prolonged exposure to pressures of less than 10^{-3} torr. Exposing the element to air for a while or bleeding a small amount of air into the system should restore sensitivity.

If, after the leak detector has been used for some time, there is a lack of sensitivity or there is erratic or off-scale indication, the sensitive element must be removed and cleaned or replaced.

Table 10-1

SENSITIVITY OF HEATED ANODE HALOGEN LEAK DETECTORS TO VARIOUS HALOGEN COMPOUND GASES

(Ref. 10-1)

Limited experimental data indicates that to give the same leak signal as R-12, the leak rate of another gas will be the R-12 leak rate multiplied by a factor as shown below.

Generic Name	Trade Designation	Chemical Formula	Approximate Multiplying Factor By Volume	By Weight
Dichlorodifluoromethane	R-12, F-12	CCl_2F_2	1	1
Trichlorofluoromethane	R-11, F-11	CCl_3F	1 1/4	3/4
Chlorotrifluoromethane	R-13, F-13	$CClF^3$	35	40
Chlorodifluoromethane	R-22, F-22	$CHClF^2$	1	3/4
Trichlorotrifluoroethane	R-113, F-113	CCl_3F_3	1/6	---
Dichlorotetrafluoroethane	R-114, F-114	$C_2Cl_2F_4$	1	1 1/4
	FC-43		131	---
	FC-75	C Cl F	30	100
Sulfurhexafluoride		SF_6	200	240
Methyl chloride		CH_3Cl	1 1/4	3
Perfluorocyclobutane	Freon C-318	C_4F_8	*	---
Perchloroethylene		C_2Cl_4	**	---
Trichloroethylene		C_2HCl_3	**	---
Carbon tetrachloride		CCl_4	**	---

---

* It is believed sensitivity to this gas is one percent of R-12 (multiplier 100), but supporting experimental data is not available.

** It is believed sensitivity to this gas is almost equal to sensitivity to R-12, but experimental supporting data is not available.

10.3 DESCRIPTION

Figure 10-1 is a photograph of a typical heated-anode halogen leak detector. This instrument includes:

- A two-element sensing structure, as shown in Figure 10-2 (see also Ref. 10-2). Vapor to be detected is passed between two closely spaced cylinders. The inner cylinder, or cathode, is kept red-hot by an internal wire heater. The outer cylinder, or anode, is operated at a negative potential with respect to the cathode.

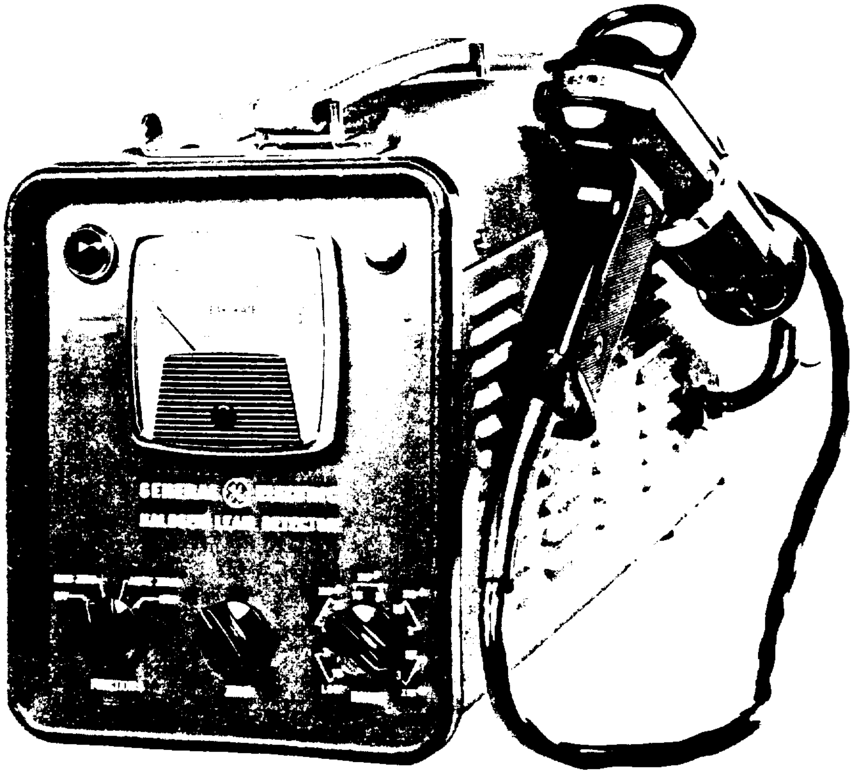


Figure 10-1. Heated-anode Halogen Leak Detector. (Reprinted with permission of the Instrument Department, General Electric Company, West Lynn, Massachusetts.)

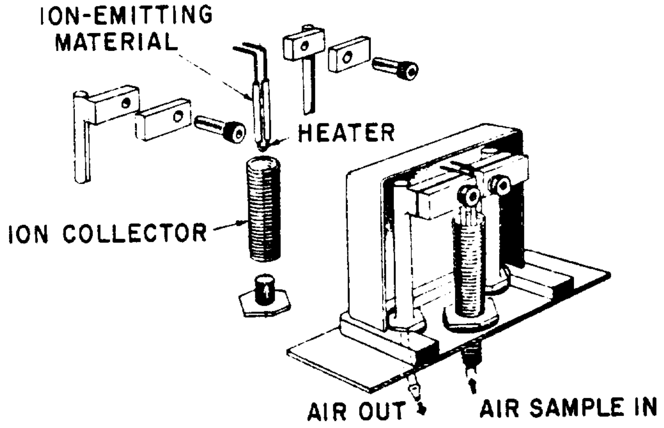


Figure 10-2. Detector Element of Heated-anode Halogen Leak Detector. (Reprinted with permission from W.E. Briggs, A.C. Jones, and J.A. Roberts, "Leak Detection Techniques," <u>1958 Fifth National Symposium on Vacuum Technology Transactions</u>, Symposium Publications Division, Pergamon Press, New York (Ref. 10-2).)

- Means of forcing a gas sample through the cylinders at a constant low velocity.
- A basic circuit (Figure 10-3) containing a low-voltage supply for the heater and a supply of a few hundred microamperes at 50 to 500 volts alternating or direct current for use as the interelectrode potential.

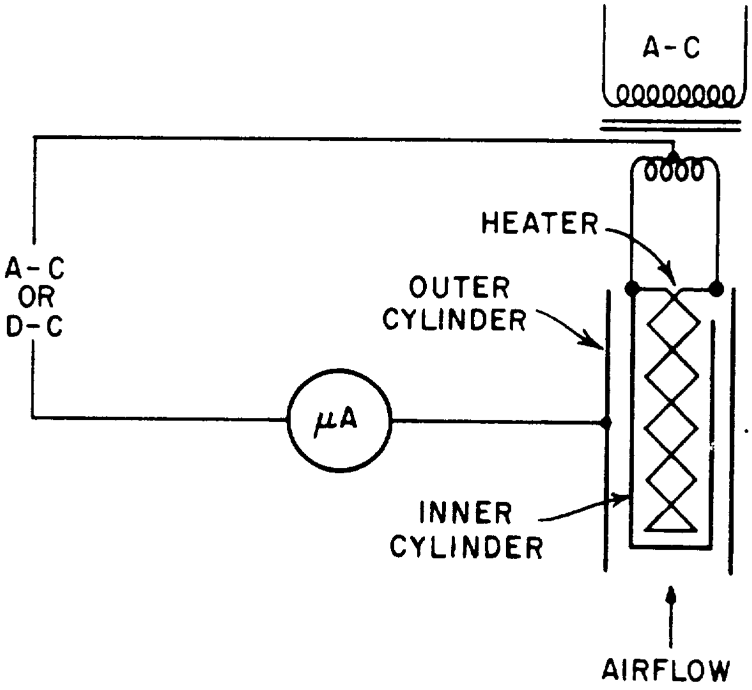


Figure 10-3. Basic Circuit of Heated-anode Halogen Leak Detector. (Reprinted with permission from W.C. White and J.S. Hickey, Electronics, Vol. 21, March 1948, McGraw-Hill Publications, New York.)

The ion current can be directly displayed on a microammeter or a galvanometer. By another method the change in voltage across a high resistance is utilized to operate an amplifier which, in turn, operates a suitable meter or relay.

An audible tone can be obtained by adding a relaxation-type circuit which incorporates a capacitor and glow-discharge tube with a loudspeaker as an indicating element. The current through the sensing element builds up a charge in the capacitor. When the voltage is sufficiently high, the glow-discharge tube fires. The pulse of current resulting from the discharge of the capacitor produces a click in the loudspeaker. The repetition rate of the clicks is an indication of the amount of current.

With any circuit used, it is desirable to include a protective resistor to prevent injury to the sensing element or indicating device which could result from an overdose of tracer gas or a short circuit between electrodes.

Equipment modifications provide adjustable sensitivity, automatic signal balancing, and special probe designs. An example of the latter is an air proportioning probe for use in areas where the background signal is unusually high. By the use of such a probe the sensitivity of the test can be increased and the signal stability improved. Use of the probe is described in Section 10.4. Specific information regarding the models which are available can be found in Part III of this Handbook.

10.4 GENERAL CHARACTERISTICS

The detector is designed specifically for halogen compounds. Although halogen contamination in the atmosphere will sometimes present a problem, the specificity leaves no doubt that only the tracer gas will be detected. The response of the instrument depends upon the halogen concentration. Up to one part per million the response is linear. Between one and 1000 ppm it is exponential, and above 1000 ppm the detector saturates.

The detector operates directly at ambient conditions, and can be used without complex pumping equipment. It is relatively cheap and portable, and can be used by inexperienced personnel without extensive instruction.

The detector can be exposed to mists of the halogens, providing exposure is limited to a relatively short time. If the sensing element is exposed to a halogen mist for too long a time, or to a highly concentrated vapor, it may lose its sensitivity. Prolonged operation at full temperature in a current of pure air and with voltage between electrodes will restore sensitivity if the contamination has not been excessive. The degree of contamination varies greatly from one compound to another; for example, carbon tetrachloride contaminates the electrodes more easily than the other halogenated hydrocarbons.

With proper maintenance and operation the elements used in industrial leak detectors can be expected to last 500 to 1000 hours. The element used in a serviceman's type of leak detector is much smaller and will not last as long. In general, little can be done to extend the life of these units. The element used in a serviceman's leak detector, however, is much lower in cost than is the general laboratory instrument.

The halogen detector also responds to solid particles of the iodides, chlorides, bromides, and fluorides. Therefore, it detects smoke from burning materials containing such compounds. The tobacco used in cigarettes must contain such a compound since the detector responds readily to cigarette (and to some extent cigar and pipe) smoke. A *No Smoking* rule should be enforced in the test area. The detector also responds to solder fluxes, cleaning compounds, and aerosol propellants. Such materials must be eliminated from the test area.

Rubber and plastic tubing must be avoided in any test system. Halogen gases are easily absorbed by these materials and may be released later to interfere with the test readings.

The inherent sensitivity of the halogen detector cannot be reached in practice if there is background contamination. A large leak near a small leak may completely obscure the signal from the small leak. In many factory test areas, a background level of halogen gas will build up because of leaks in the units being tested, leaks in the refrigerant supply tank, dumping of gas, and other sources that may allow halogens to enter the area.

The chief precaution in a test setup is to make certain that the testing is carried on in an ambient that is sufficiently free of halogen vapors. In many instances, an exploration of the available floor space will indicate a location that is free of these vapors. If such a location is not available, it may be necessary to partition off a testing area and provide proper ventilation to bring in halogen-free outside air. It should be understood that the presence of halogen vapors in proportions of ten parts per million may be sufficient to contaminate the air enough to cause a loss of sensitivity in the testing equipment.

With the automatic balance feature, the control unit will balance out a certain amount of halogen background, provided the concentration is constant or changing slowly. If this background level builds up to a point where normal air currents present in the room cause sudden changes in background concentration, leak signals may result even when the detector has not encountered a leak.

There are three methods of combating this condition:

1. Eliminate sources of background
2. Provide a controlled environment of fresh air in the testing area
3. Use a proportioning probe detector

For the first method, it should be possible to control indiscriminate dumping of refrigerant charges, leaky lines, degreasers using halogen solvents, paint fumes, etc.

Manufacturers of refrigerators and air conditioners have found it desirable to use the second method and construct a small room or booth for testing, since the background level of tracer gas is usually very high in their production areas because of the many sources of halogen gas. This room or booth is fed fresh air from the outdoors at a very low velocity to prevent excessive drafts and eddy currents of air within the room. The booth, in effect, isolates the leakage testing area and helps to keep background contamination from interfering. Fresh air is introduced through the roof so as to provide an air change once or twice a minute. A test booth is illustrated in Figure 10-4.

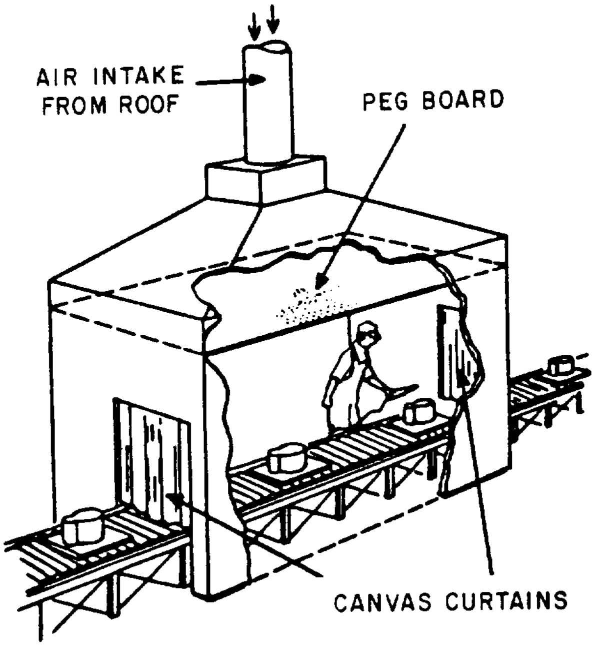


Figure 10-4. Controlled Atmosphere Test Booth. (Reprinted with permission from W.C. Hutchins, "Production Leak Testing of Appliances," Home Appliance Builder, October 1961, pp. 1-6 (Ref. 10-3).)

Some important facts should be kept in mind in constructing a booth:

1. Fresh air should be supplied to the booth from the out-of-doors. In some cases, this air should go through an activated-charcoal filter bed to remove any halogen gas that may be present.
2. The fresh air from the blower should be distributed as it enters the booth so as to prevent drafts or eddy currents of air within the booth. A false ceiling made of peg board is ideal to provide an even flow of air in the booth. When the booth is kept under this fixed positive air pressure, contaminated air will not come in from the shop or factory.
3. If a conveyor goes through the booth, canvas or rubber curtains help to maintain the booth's integrity.
4. An air conditioner in the booth will be helpful in providing comfort for the booth personnel and to clear the air. It will, of course, also help lower the humidity. Care should be taken to baffle the air conditioner so that the cool air is distributed as evenly as possible in the booth.
5. Construction techniques will vary. Some factories fabricate the booth out of wooden studding; sheathing

can be a type of hardboard or sheet rock. Others use the movable metal partitions commonly found in offices.

The chamber of the charcoal filter should be large enough to contain an ample amount of activated charcoal. The larger the chamber, the less often the charcoal will have to be changed. Thought should be given to the ease of changing the charcoal filter. One way to contain the charcoal is to use a drawer, the bottom of which can be a fine-mesh screen to allow air-flow through the charcoal.

In many areas where the background level is much lower it may not be necessary to use a special ventilating booth. A portable 16-inch or 20-inch fan placed in a window or doorway near the test area may be adequate. The fan will usually clear out the halogen background to the point where leakage testing can be accomplished satisfactorily.

Another method of overcoming the problem of high halogen backgrounds involves the use of a proportioning probe. This probe is so constructed that a supply of clean, halogen-free air from an external source can be mixed with the test sample of gas and passed through the detector. The proportion of clean air to test sample is adjusted by means of valves. Clean air can be obtained by filtering shop air through a bed of activated charcoal, or tank nitrogen may be used (see Figure 10-5).

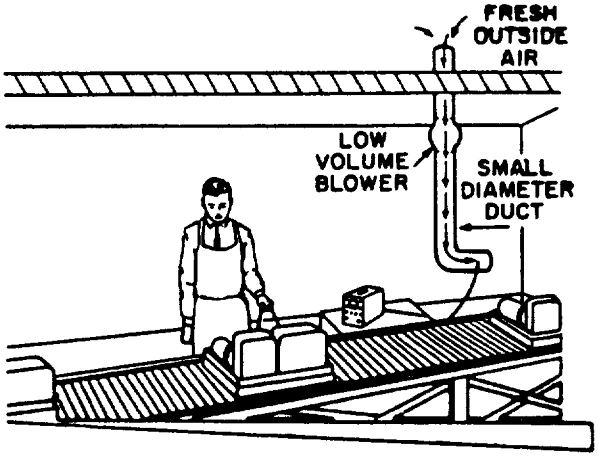


Figure 10-5. Fresh-air Ducting for a Proportioning Probe

10.5 LEAKAGE TESTS

It is possible to use the halogen detector to test for liquid leakage from sealed devices. The only requirement is that the leaking fluid contain a halogen compound with a high vapor pressure. In some cases it may be possible to add a halogen tracer to the liquid and, by application of heat, to increase the vapor pressure of the tracer.

Packaged refrigeration machines are given a warehouse leakage test by insertion of the probe of the detector through a hole punched near the bottom of the carton. The accumulation of tracer gas in the carton can be substantial, varying with the length of time that the unit has been sealed in the carton (Ref. 10-3).

The halogen leak detector may be used for leakage measurement or leak detection in a vacuum by inserting the detector head directly into equipment having integral pumping systems. The optimum pressure for vacuum operation is between 10^{-3} and 10^{-1} torr (Ref. 10-4). (In vacuum operation, the detector is somewhat sensitive to pressure variation.) The best sensitivity will be obtained if the valve to the diffusion pump is throttled. If the leakage is not large enough to maintain the optimum pressure, a small air bleed can be inserted to do so. For checking leakage in the forepump portion of the system, as well as in the high-vacuum chamber, the detector may be located just ahead of the forepump.

When vacuum leakage-testing small items on a short time cycle, the detector should be maintained in a ready condition in a small vacuum system of its own. This is desirable because of the large thermal inertia of the detecting diode. The system should maintain the element at about 5×10^{-3} torr pressure, and provide a small, steady flow of air through it to maintain sensitivity. The units to be tested should be evacuated to a pressure somewhat above that in the detector system, and a sampling valve opened between the two before starting the leakage-testing procedure. Great care should be taken to make all vacuum piping short in length and large in diameter, as the tracer gas moves primarily by diffusion.

Sensitivity multiplication can be obtained in vacuum leakage testing by using pressurized external tracer gas, or allowing accumulation in the system, or both. When the tracer probe is used for leak location, probing should be initiated at the bottom of the system. Movement should continue upward in a careful pattern. If probing is done above an undetected leak, tracer gas will drift down and provide a spurious signal.

Halogenated gases are about three times as dense as air. Tracer gas emerging from a relatively large leak will flow into all nearby nooks and crannies and remain for long periods of time. Its presence in confined spaces may give "ghost" readings up to twenty-four hours after the original leak has been repaired. The nature and persistence of these "ghost" signals are highly dependent upon the geometry of the stagnant pocket and the ventilation around it. Pure halogenated gas in an open beaker will be undetectable about fifteen minutes after it is filled. An open-mouth Erlenmeyer flask, on the other hand, will contain detectable amounts after sitting on a table top for twenty-four hours or more. If the same flask were placed in a light breeze near an open window the halogenated gas would vanish in a few minutes (Ref. 10-1).

The low diffusion coefficient of the dense halogenated tracer gases must be considered in preparing a test procedure. In order to produce a dependable signal at a leak,the tracer gas mixture with which the system is charged must have uniform composition. Any blind passages in the system must be flushed with well-mixed tracer gas; otherwise leaks in these *cul-de-sacs* will simply exude air and escape detection. Those not flushed will remain at low halogen concentration for long periods, because of the low diffusion rate of tracer gas in air (about 0.3 mole per square foot hour per unit molar concentration gradient).

The time required for a blind duct one yard long to reach fifty percent of full halogen concentration (Ref. 10-5) is on the order of three hours if diffusion alone is acting. Figure 10-6 shows the time required for various lengths of blind duct to reach ten percent and fifty percent of open-end halogen concentration. Settling out of heavier halogen gas from an initially well-mixed tracer gas is not significant.

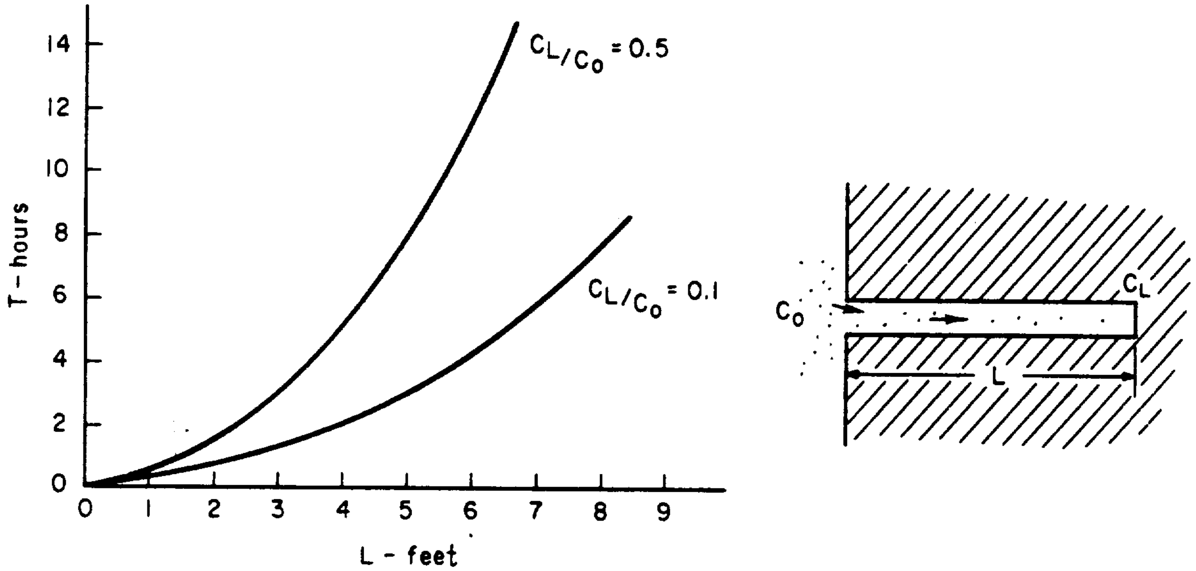


Figure 10-6. Diffusion of Halogenated Hydrocarbon R-12 in a Blind Duct. (Reprinted with permission from R.C. Quisenberry, Leak Detection Techniques Improvement Study for Space Vehicles, Second Formal Report, Ohio University, NASA Contract NAS8-2563, Athens, Ohio, June 1963.)

The halogen tracer gases are soluble in oil. Although small leaks are effectively plugged by oils, diffusion of the halogen material through the oil permits detection of the leak.

The most popular tracer gases for leak detection are the refrigerants R-12 (dichlorodifluoromethane - CCl_2F_2) and R-22 (monochlorodifluoromethane - $CHClF_2$). These gases are stored as liquids under pressure; at room temperature they exert vapor pressures of 70 psig and 122 psig. If the refrigerant in the cylinder is bled through a valve and introduced into a chamber, some or all of the liquid will vaporize to fill the chamber. Liquid from the cylinder will continue to vaporize until the pressure in the gas chamber is equal to the vapor pressure cited above or until no more liquid is left.

During the vaporization process these refrigerant gases cool considerably. If the gases are vented into a rather large chamber, the refrigerant cylinder may cool to the point where vaporization is extremely slow. Should this occur, it might be advisable to hasten vaporization by placing the cylinder in a tank of warm water. It is frequently desirable to dilute these tracer gases for the following reasons:

- Since R-12 and R-22 liquefy at 70 psig and 122 psig respectively at room temperature, a pressurized system being tested cannot have a refrigerant gas pressure greater than these pressures. If leakage testing is to be done at higher pressures, then pressurized air must be added on top of the refrigerant to obtain the desired test pressure in the system. This dilution with air reduces the sensitivity in proportion to the decrease in concentration; but a more than compensating increase in sensitivity is realized because it is proportional to the square of the pressure rise, assuming laminar flow governs the leakage.
- If it is desirable to measure the leakage quantitatively, the halogen concentration reaching the detector must be relatively low, less than one part per million, to stay within the linear range of the instrument.
- In testing large systems, the cost of the tracer gas may be considerable. If only large leaks are of interest, the dilution of the tracer gas will reduce the overall cost and, as an added feature, decrease the amount of background contamination by the leaks.

10.6 SAFETY

The detection element of the halogen leak detector operates at temperatures of about 980°C (1800°F) and with potentials of 300 volts. The following safety precautions must be observed:

- Never enter an area where there is an explosive vapor. If there is any question, first test the area with an explosion meter.
- Never test in enclosed spaces, such as bearing housings, oil tanks, or piping, without first testing with an explosion meter.
- Since voltages as high as 300 volts are present, the case should be kept at ground potential with a three-prong grounded receptacle or other suitable grounding lead.

SECTION II

PRESSURE CHANGE METHOD OF LEAKAGE TESTING

Section 11

PRESSURE CHANGE METHOD OF LEAKAGE TESTING

11.1 INTRODUCTION

Leakage testing by the pressure change method is accomplished by observing the change in pressure between the inside and the outside of the containment vessel or structure under test. The method is suitable only for leakage measurement and is used primarily in the testing of large systems.

The use of tracer gas is not required, and instrumentation is relatively simple. The pressure gages on the system will frequently be adequate; in other cases special differential gages designed for leakage testing may be necessary. This will depend upon the accuracy required. Testing times are long, especially when working near the limit of sensitivity of this method.

11.2 SENSITIVITY

In a pressurized system, sensitivity is dependent on the minimum detectable change of the pressure fluctuation. In an evacuated system sensitivity is dependent not only on the pressure change which may be observed, but also on the degree to which this pressure change is due to outgassing. Removal of the outgassing factor causing pressure change will increase the sensitivity of the technique. However, the evacuation mode is a more sensitive technique, because smaller changes in pressure can be detected. This is an accumulation leakage measurement procedure; therefore, sensitivity is largely dependent on the duration of the test. In all cases, care must be taken to ensure that the pressure indicating device is properly calibrated for the pressure range over which it will be used.

11.3 DESCRIPTION OF TEST EQUIPMENT

A suitable test device must be capable not only of withstanding the pressure differential applied during the test but also of indicating very small changes in pressure. The most sensitive equipment available detects pressure changes by the movement of a diaphragm which acts to unblance a capacitive bridge circuit. Table 11-1 summarizes the characteristics of the available pressure-change leak detectors. Specific information on this equipment may be found in Part III of this Handbook.

11.4 LEAKAGE TESTING METHODS

Measurement of leakage in either an evacuated or a pressurized device usually requires knowledge of the volume of the system under test. Change in pressure is noted after some elapsed time, and the system leakage calculated according to Equation 4-10, where V is the system volume.

Table 11-1

COMMERCIAL PRESSURE-CHANGE DETECTORS

General Characteristics	Average Values
Sensitivity	1×10^{-5} torr
Pressure range	3×10^{-4} torr to 10^{4} psi
Tracer gas	None
Output signal	Visual observation
Power source	115/230 volts, 50 to 400 hertz
Size	Sensor: 4 × 4 × 3 inches Electronic Unit: 8 × 8 × 12 inches
Weight	8 to 175 pounds
Price	Up to $6000

When the system is complex and the enclosed volume difficult to determine, the system leakage can be determined by the "additional-leakage" method of Hjerten, et al. (Ref. 11-1). In this method the results of a normal leakage test are compared with the measurements obtained with an additional known leakage which is connected to the system.

Where the duration of the test is more than a few hours it is possible that temperature variations may become significant. The resulting pressure changes would introduce large variations in the calculated leakage. The American Nuclear Society Standard 7.60, which is reproduced in Appendix B, describes a procedure for incorporating the temperature into the test method; this is known as the "absolute-temperature-pressure" method.

The error propagated by the temperature variations can be canceled by introducing a "reference system" in the test vessel. Keshock (Ref. 11-2) found this method had significantly less error than the absolute method. He cautions that the reference method as described in ANS 7.60 is not particularly useful, and shows how reliable results can be obtained.

11.4.1 Vacuum Leakage Test Considerations

When leakage measurements are made on an evacuated system the outgassing, or evolution, of absorbed gases may be expected to occur. In some instances the pressure achieved during pump-down may be limited by the outgassing. When an evacuated system is isolated from the vacuum pump, the system pressure will rise.

If only outgassing takes place, then the pressure will rise to a steady-state value, as shown in curve a of Figure 11-1. If the pressure rise is due solely to a leak, then the pressure

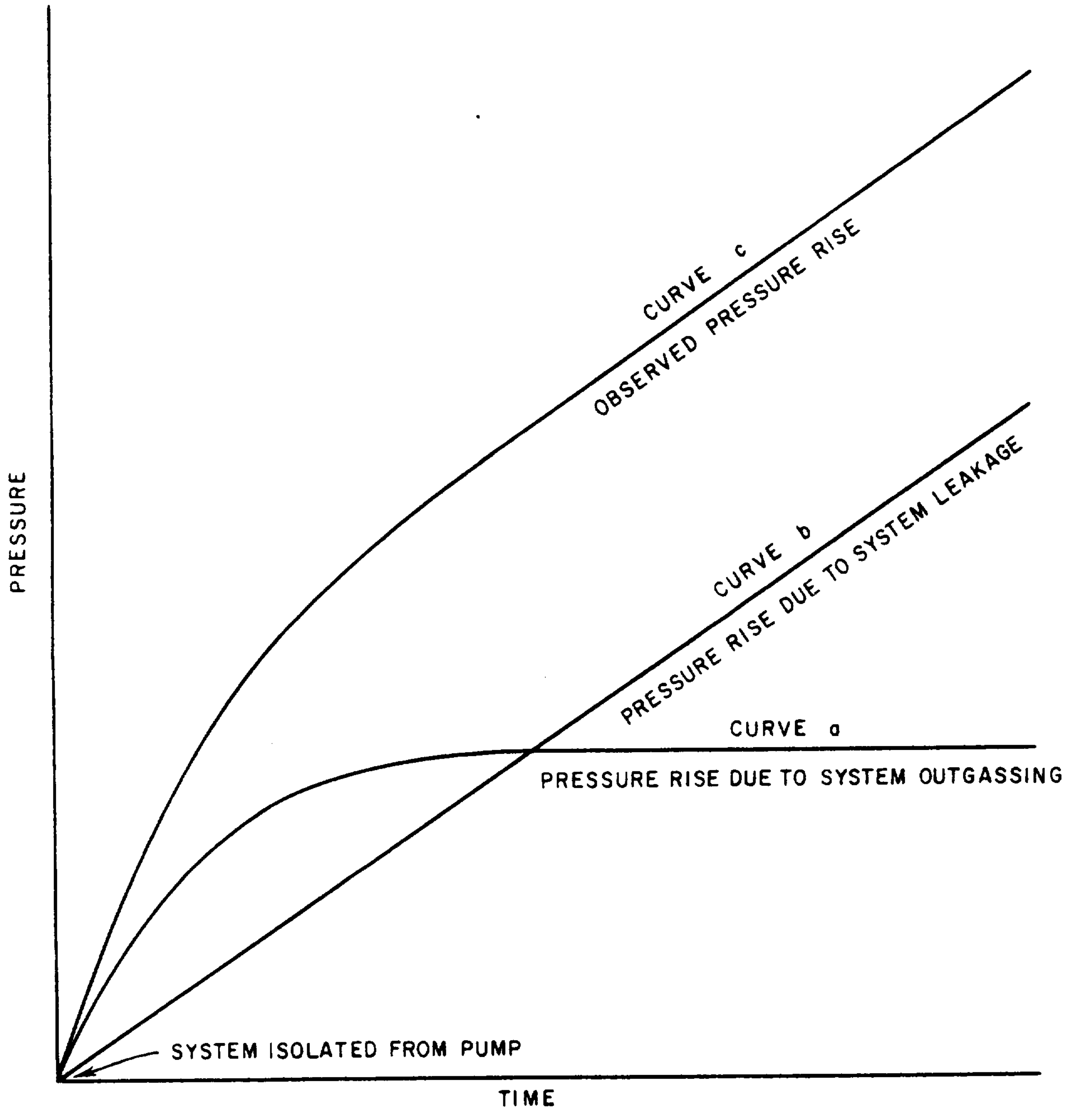


Figure 11-1. Effect of Leakage and Outgassing on a Pressure Versus Time Curve

change will behave in the manner illustrated by curve b. The combination of outgassing and leakage is illustrated by curve c. It is possible for outgassing to mask leakage. Therefore the adsorbed gases must be reduced below the level of the average deviation of the test.

To minimize outgassing, the system should be kept clean and dry. Any oil or grease on the inner surfaces of the system should be removed before testing. The system should not be exposed to water or water vapor. Liquids having a measurable vapor pressure should not be present in the system, since the system pressure will rise to that pressure value.

Two ways to reduce outgassing in a system are: 1) heating the system under vacuum, and 2) use of a dry gas bleed (see Section 5.3).

If the system being tested is isolated from the pumps, the pressure rise due to outgassing will cease when an equilibrium is established between the gases in the vacuum and those on the system surfaces as is illustrated in Figure 11-1. It is therefore necessary to wait until this equilibrium is established before taking leakage measurements. The pressure rise may be considered as due only to leakage when the rise in pressure during successive time increments is equal.

Many of the gases evolved during outgassing of a system are condensable. If a liquid-nitrogen trap is placed between the gage and the system wherein the pressure rise is being measured, the pressure rise observed will be due only to leakage (air is not a condensable gas under these conditions). Care must be taken that an equilibrium value of pressure rise is obtained when such a technique is employed. When the liquid-nitrogen trap is first cooled, system pressure will decrease because of the pumping effect on condensable gases by the trap. After these gases have been condensed, the leakage measurement can be started.

It is possible to discriminate between outgassing and leakage by means of an auxiliary vacuum hood, as illustrated by the schematic drawing in Figure 11-2.

The technique involves two sets of readings. The first is taken with the system under test evacuated in the normal manner, and measurements made of the pressure rise over a selected interval of time. The hood is then lowered over the component, and sealed on a suitable base. The hood is evacuated to approximately the same pressure as the system.

A second measurement of pressure rise is then made. The rise is now due to outgassing only, since there is no pressure difference between the inside and outside of the system. The arithmetical difference between the two rates gives the true leak rate. It will be appreciated from the brief description that this method is most suitable for repetitive testing of standard components, where the provision of a suitable hood and an additional pump station is justified by the saving in time. The same pumping system can also be used to evacuate both the hood and the system under test.

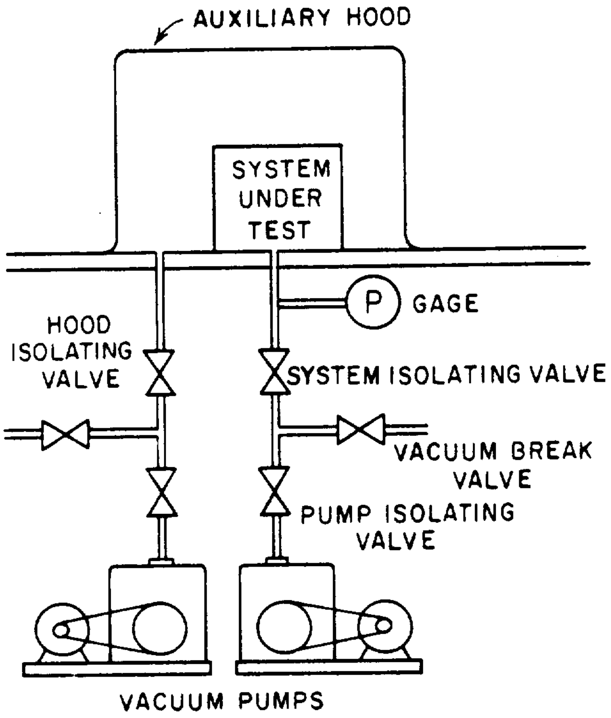


Figure 11-2. Test Setup for Pressure Change Testing, Using a Vacuum Hood

11.4.2 Volume Sharing Method

The volume sharing method of leakage testing is applicable to systems or parts of systems which do not contain their own pressure gages. The arrangement is illustrated in Figure 11-3.

A leak-tight container of known volume, V_2, is connected between the known volume to be tested, V_1, and a vacuum pump. Valve A is located between the two volumes and valve B between the container and the pump. A pressure gage, P, is located on the container. The procedure for testing for leakage into V_1 is as follows:

1. Pump both tanks to base pressure P_1.
2. Close valve A. Allow leakage to enter V_1.
3. After holding time, t_1, close valve B and open valve A.
4. Allow pressure to equalize in both chambers at a level P_2. (P_2 will be greater than P_1 if leakage has occurred.)

5. Calculate leakage rate Q where

$$Q = (V_1 + V_2)(P_2 - P_1)/t_1 \tag{11-1}$$

This method can be made highly sensitive since the holding time can be arbitrarily lengthened. Vacuum components are sometimes isolated for days by this means to test for small leaks.

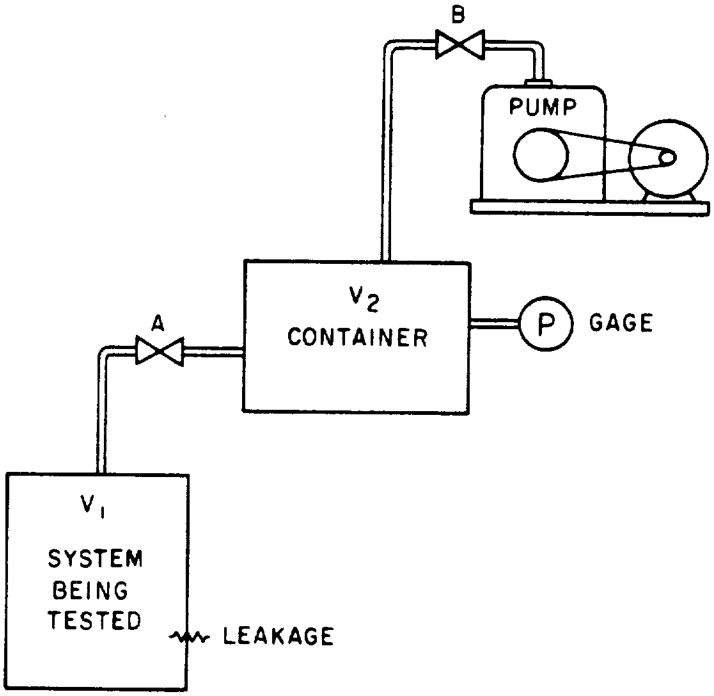


Figure 11-3. Volume Sharing Technique of Leakage Measurement

11.4.3 Automatic Leakage Testing Methods

The pressure rise technique has been used in an automated test setup (Ref. 11-3), where a carrousel-type vacuum lock was developed for expeditiously locking the specimens in and out of the test chamber (Figure 11-4).

The carrousel lock consists of an upper stationary steel plate and a lower rotating steel disc. The rotating steel disc contains eight pouches, connected with a small auxiliary pump which keeps the pressure below 0.7 torr. Thus, any possible leaking path to the high-vacuum chamber has only 1/1000 of the atmospheric pressure at its inlet. This reduces spurious leakage. With a test rate of 60 units per hour, all leakages of 2×10^{-8} torr liters per second and higher can be detected. The manometer, an ionization gage, is included in series with a liquid-nitrogen trap.

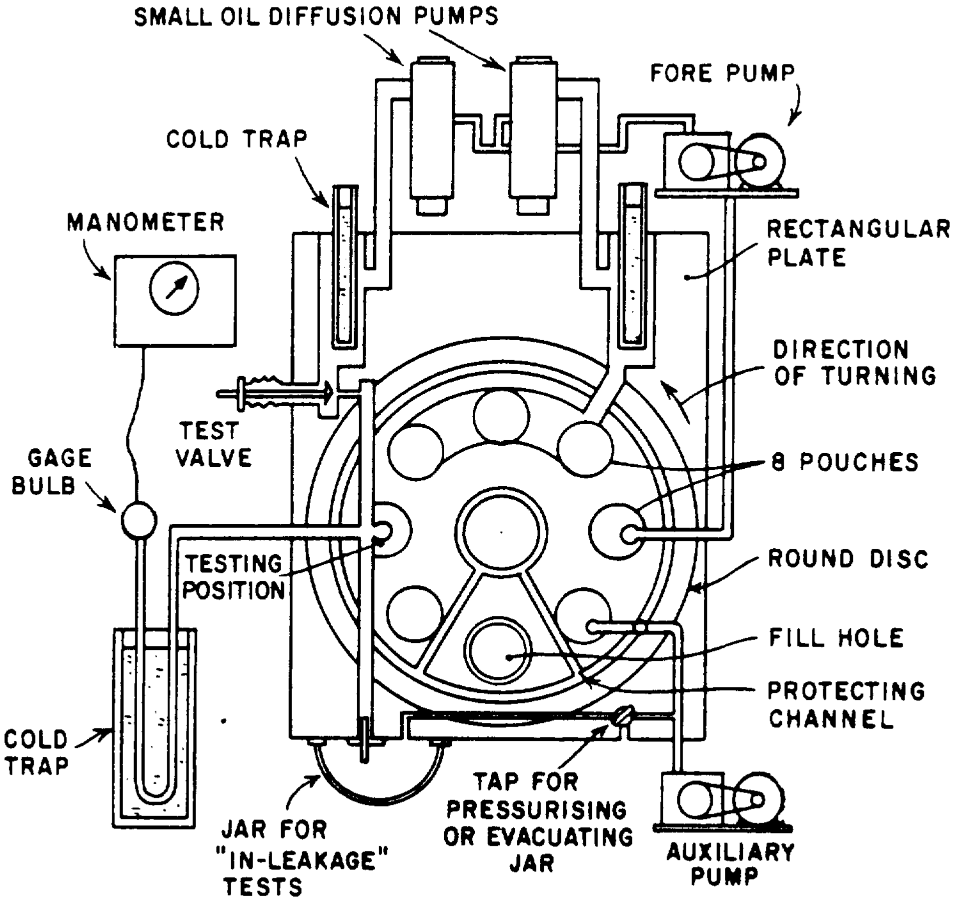


Figure 11-4. Pressure Change Procedure, Using a Carrousel Vacuum Lock. (Reprinted with permission from B.W. Schumacher, Transactions, 1956 National Symposium on Vacuum Technology, pp. 110-113. Copyright 1956, Symposium Publications Division, Pergamon Press.)

The samples are cleaned by washing in trichlorethylene. They are then warmed on a hot plate to 80 - 110°C in order to remove moisture. The cleaned units are put into the pouches through a filling hole in the upper stationary plate. A connection with the auxiliary pump is first made following the direction of turning in Figure 11-4, later with the forepump of two small oil diffusion pumps, then with the first of the oil diffusion pumps. This brings the pressure in the pouches down to about 1×10^{-5} torr. Then the pouch reaches the testing position, and is connected with the second of the oil diffusion pumps and the manometer.

If, in the testing position, a pressure of 2 to 5×10^{-6} torr is reached, usually after 15 to 20 seconds, a test valve is pressed down, interrupting the pumping. The manometer and pouch with the sample form one closed chamber, and the manometer is watched for a pressure increase.

A small amount of gas is usually given off by the walls of the chamber and the specimen, causing a pressure rise of 0.5 to 2 × 10^{-6} torr within the first few seconds, depending upon the length of time the pouch has been cleaned by pumping at 10^{-6} torr. After 15 seconds it can usually be decided whether a small leak is present or not. Larger leaks cause an immediate pressure increase to 10^{-5} or 10^{-4}; the test valve is released as soon as such a rapid rise occurs, so that the test chamber is not contaminated.

Before the test valve is released, the pressure in the test chamber will be determined by the equilibrium between leak rate and pumping rate. For large leaks, the equilibrium pressure is in the order of 10^{-4} to 10^{-3} torr. If a leaking unit is left in the test chamber long enough it will be emptied by the pumping. Calculations show, however, that more than an hour will be required to empty it so completely that it will no longer be seen in the test. Thus, the apparatus can be used to test for large leaks as well as small.

The limit of sensitivity is determined by outgassing. After a period of pumping, the outgassing background will be in the region of 1.5 × 10^{-10} torr liters per second.

Because all but one of the test chambers are under vacuum, not much gas is given off by the walls of the chamber. For a pouch left under atmospheric pressure overnight, the outgassing will be higher if the pouch is turned to the testing position without some time allowed (e.g., ten minutes) for outgassing. It is easy, however, to check the state of the pouches by a blank test.

Another automated test uses a differential pressure drop method in measuring leakage in sealed devices. (Figure 11-5 is

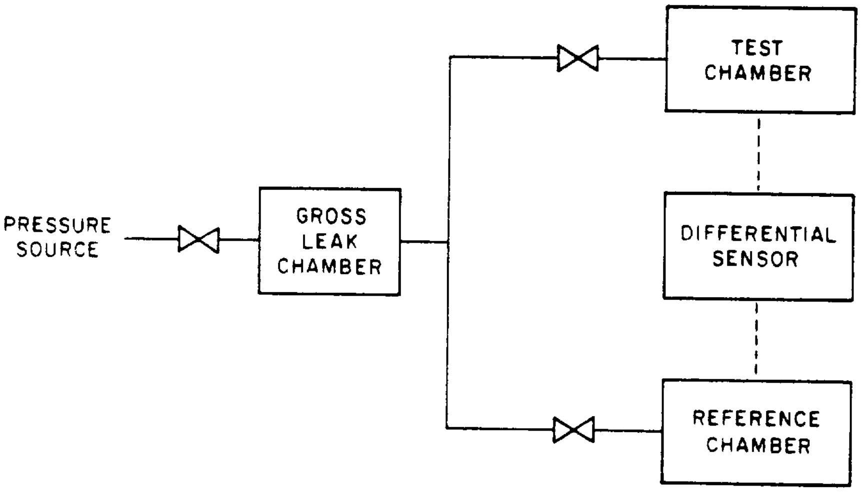


Figure 11-5. Differential Pressure Change Method of Leakage Measurement. (Courtesy of Picatinny Arsenal, Department of the Army (Ref. 11-4).)

a schematic of the system.) The unit to be tested is placed in the test chamber; the gross leak chamber is pressurized to test pressure and sealed. After pressure measurement, the valves leading to the test and reference chamber are opened. If the pressure drops below a predetermined value, gas has entered the unit being tested and the test is stopped. If the unit passes this gross leak test, the valves are closed and the pressure difference between the test chamber and reference chamber is measured. The leakage is determined from the pressure drop in the test chamber (Ref. 11-4).

This technique gives rapid (30-second) measurements of leakage in the full range from gross leaks to 1×10^{-4} atm-cc/sec. Since it can be fully automated, skilled test personnel are not required. Any test gas may be used, including air or nitrogen.

11.4.4 Leak Localizer

Gas companies use a modification of the pressurizing method of leakage measurement to localize leaks in gas mains (Ref. 11-5). The gas main is tested section by section, from the inside, with the leak locator. The leak locator consists of the following parts:

1. A flexible frame on which are spaced two rubber gas bags joined with a rubber tube.
2. A dual rubber tubing of sufficient length to reach from the bags to the control panel. One side of the dual tubing extends through the adjacent bag and is open to space between the two bags. This tube transmits the gas pressure to the control panel.
3. A control panel connected to the dual tubing with an inclined water gage is used to measure any variation in gas pressure; a spring gage is used to indicate the air pressure in the bags; connections are included for inflating and deflating the bags.
4. Two pumps are needed -- a pressure pump to inflate the bags and a suction pump to deflate the bags.
5. A steel rod is required to propel the bag frame and tubing along inside the main. The rod is connected mechanically to the bag frame; it is of sufficient flexibility to pass through a tap in the main, and of sufficient stiffness to avoid buckling when pushing the apparatus inside the main.

In testing for a leak, the bags are inserted in the pipe containing gas under pressure. They are spaced a set distance apart on the frame, so they seal off a portion of main when inflated. Inflated with a pressure tire pump, the bags make a seal with the inside of the pipe when under three to six pounds of pressure. The gas pressure between the bags is registered on the water gage as soon as the bags are in the main. When the main is sealed off completely by both bags and there is no leak in the main between the bags, the pressure between the bags will remain constant.

After a section has been tested, the bags are deflated with the suction pump and moved forward a distance to permit an overlapping of test lengths. This is important because a leak could be overlooked if a bag were to rest on the leak while making a test.

If a leak is isolated between the bags, the gage pressure drops as soon as the bags are inflated. To locate the leak more precisely, bags are deflated and moved together for half the original distance between them. If they still straddle the leak they are moved forward or backward by smaller increments until one of the bags just passes beyond the leak. The steel rod is marked and the measurement can be transferred to the pavement above.

Section 12

FLOW MEASUREMENT METHOD OF LEAKAGE TESTING

Section 12

FLOW MEASUREMENT METHOD OF LEAKAGE TESTING

12.1 INTRODUCTION

Flow measurement is a suitable method for leakage testing on a wide variety of devices or systems where high sensitivity is not required. The test consists of measuring the flow of air or gas into or out of a device or system. Tests can be performed by direct observation or by analyzing the pressure-time response of the system.

12.2 SENSITIVITY

The sensitivity of this method is relatively low. The sensitivity is dependent on the instrument used to measure the flow, and is independent of the system volume. For example, the minimum detectable flow out of a pressurized system is perhaps 10^{-2} to 10^{-4} atm-cc/sec, while the minimum value of flow from atmospheric pressure to vacuum may be about 10^{-1} atm-cc/sec.

12.3 DESCRIPTION OF EQUIPMENT

Conventional flow-rate measuring equipment is often suitable for conducting these tests, although several companies do offer special devices for flow-type leakage measurements. General characteristics of two such devices are summarized in Table 12-1. Specific details can be found in Part III.

Table 12-1

COMMERCIAL FLOW MEASUREMENT DETECTORS

General Characteristics	Type 1	Type 2
Principle	Volume displacement	Flow observation
Sensitivity	1×10^{-5} atm-cc/sec	1×10^{-2} atm-cc/sec
Tracer Gas	Nonspecific	Compressed air
Output Signal	Visual observation	Visual observation
Power Requirement	None	None
Size	Width = 3 inches; Height = 10 inches; Depth = 6 inches	Diameter = 10 inches; Height = 30 inches
Weight	5 pounds	20 pounds
Price	$ 350	$ 99

12.4 LEAKAGE TESTING METHODS

Of the many and varied applications of this method that are in use, only a few typical procedures have been selected for purposes of illustration.

12.4.1 Leakage of Sealed Devices

The flow measurement method can be applied to almost any sealed item which can be placed in a close-fitting test chamber. The chamber is sealed and a calibrated capillary is attached to it as illustrated in the schematic drawing of Figure 12-1.

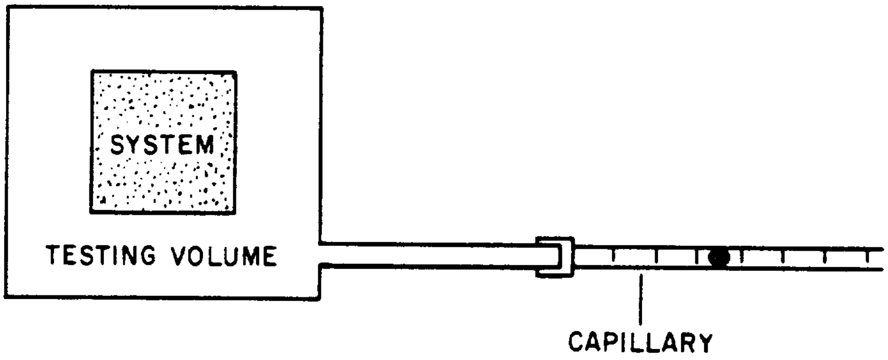


Figure 12-1. Flow Observation in Sealed-volume Leakage Measurement

Movement of a plug of indicating fluid in the capillary shows the presence of a leak. The leakage, Q, can be determined from the time required for the plug to move a measured distance, the diameter of the bore of the capillary, and the pressure in the testing volume. A 1.5 millimeter glass capillary can be used to measure leakage rates from 10^{-2} to 1 atm-cc/sec, and a 0.5 millimeter smaller rates, from 10^{-4} to 10^{-2}. The capillaries are scaled off in convenient units for computing leakage rates, and a stop watch is used for timing the movement of the plug. Pipettes used for liquid measurement are convenient calibrated capillaries.

The upper limit on leakage rate measurement is reached when the liquid plug moves so fast that timing is difficult. The lower limit is determined by the accuracy desired and errors introduced by the adhesive and inertial forces affecting the movement of the plug.

The errors due to starting inertia are minimized by the use of a water plug about one millimeter long, and by timing the liquid plug movement only after it reaches a constant velocity. The error due to the adhesive forces of surface tension can be minimized by coating the inside of the clean capillary tubing with an organosilicon compound. This effectively prevents the water from wetting the glass (Ref. 12-1).

The system being tested may be either evacuated or pressurized, and either sealed or connected to a pressure (vacuum) source. Of course, care must be taken that leakage, if observed, is not that from interconnections. This type of testing may be performed against a standard to compensate for temperature variations. In such a case, a second testing volume is placed on the other side of the capillary.

One advantage in the construction of this type of equipment is that there are no critical, leak-tight connections in the test volume. This is because the system is operating at atmospheric pressure. Even though a leak may exist between the testing volume and the atmosphere, leakage does not occur because there is no pressure differential; this is due to compensation by the liquid slug.

12.4.2 Leakage of Sealed Systems

For large leaks, a flow measuring device such as a wet-type gas meter or a rotameter may be used with accurate results. For measurement over a wide range of leaks, a Delta-Vee Meter (Ref. 12-2), can be employed. This instrument, designed primarily for determining leakage rates in hydraulic power systems, is schematically illustrated in Figure 12-2. Columns A, B, and C are capable of withstanding extremely high pressures. Tubes B and C are of different diameter; various leakage rates may be measured by selecting the proper tube. When all of the valves are open and the test component is pressurized, the level of the indicating fluid remains stationary. When the valve in the main line between Columns A and B is closed, leakage is indicated by the fluid moving up in Column B or C.

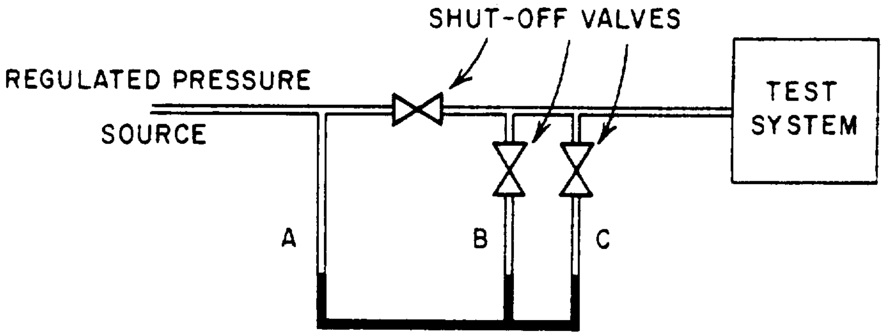


Figure 12-2. Delta-Vee Meter for Leakage Measurement. (Reprinted with permission from George C. Marshall Space Flight Center Conference on Leak-tight Separable Fluid Connectors, Huntsville, Alabama, March 1964; L.E. Grimes, "Laboratory Leakage Measurement Techniques on Separable Connectors.")

Another leakage test instrument for hydraulic systems (Ref. 12-3) provides automatic measurements. The meter is installed in the line between a test item and a source of high-pressure fluid, such as an accumulator which replenishes make-up fluid to the component. Flow in the line between meter and component represents leakage. Flow is measured by the displacement of a bellows, whose deflection is sensed by the change in resistance of a potentiometer. Leakage is read directly on the meter as cubic centimeters. Overall accuracy is claimed to be better than three percent.

It should be mentioned that the above instruments will work with gases as well as liquids, provided the indicating slug is immiscible in the fluid. This makes the described techniques extremely useful for testing under operational conditions.

Another variation of this method, which can be used to leak-test pipelines and other large volume units (Ref. 12-4), involves connecting the line to a pressure regulator and a bubbler. The line is plugged off at its end, and air pressure is passed through the bubbler to fill the line. If the line is tight, bubbling will cease.

In a similar procedure a public utility has developed an indicator for localizing gas leaks in gas-filled cables (Ref. 12-5). The instrument is essentially a U-tube manometer with appropriate valving. With the manometer installed in a segment of the line and the line pressurized, oil will rise in the glass tube toward the leak.

Leakage of an evacuated system can be measured by means of a flow meter. The system is evacuated through an isolation valve, with the exhaust of the pump going through a surge tank to a flow meter (see Figure 12-3). The isolation valve is first closed,

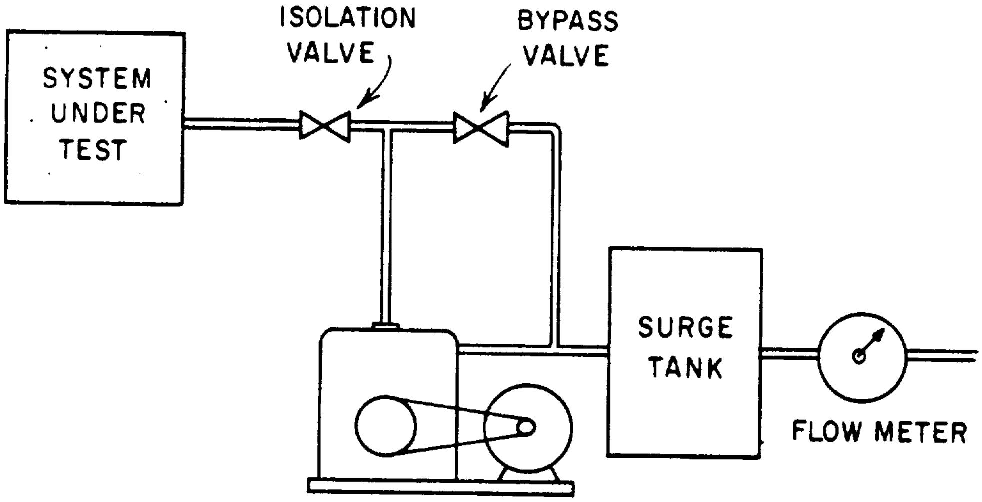


Figure 12-3. Pumping Technique of Leakage Measurement

and tightness of the pumping system is determined by measurement of flow through the flow meter. The isolation valve is then opened and the flow readings taken after an equilibrium has been achieved. The pressure in the system during test is adjusted to specified conditions by means of a bypass valve. The lower limit of pressure for which the pumping technique is useful is roughly 25 torr. The lower limit of sensitivity is approximately 8 atm-cc/sec, and is mainly dependent on the availability of suitable flow meters.

12.4.3 Leakage of Continuously Pressurized Systems

Leakage measurements have been obtained on a pressurized system by observing a change in the duty cycle of the compressor when it is set to maintain a specified pressure in the system (Ref. 11-1). If it is desired to measure the absolute value of leakage by this means, the capacity of the compressor should be known, or determined in a separate calibration test.

For this test technique, two stopwatches and a good pressure gage are required. The compressor is allowed to charge the system up to its normal delivery pressure. Then the compressor control valve is shut off and the compressor is left under no-load until the pressure in the vessel falls off to a suitable value below the initial delivery pressure. When this limit, P_0, is reached, one stopwatch is started and the compressor is put under load by manual operation of the control valve. The first watch is stopped when the pressure has risen to a predetermined value, P_1. The second watch is then started and the compressor output is cut off. When the pressure falls off to the original value, P_0, the compressor is again put under load; the first stopwatch is started again, and the other is stopped. In this way, a new cycle is initiated. The time intervals representing load and no-load conditions are recorded. Changes in these intervals with time indicate loss of fluid from the system.

Several cycles are carried out in succession to obtain good accuracy. Since no gas is added to or withdrawn from the system, only leakage will cause a change in pressure. Should the compressor be equipped with "dead-space regulation," provision must be made for the compressor to discharge to air during no-load periods.

This method has the advantage of requiring only very simple equipment. Its accuracy is less than that of more direct methods and it is subject to random errors, caused, for instance, by defective compressor valves.

The tests should be performed, if possible, on a compressor which gives charging times at least as long as the leakage times. It is not advisable to operate the compressor under part-load conditions, since its delivery capacity is rarely determined with the same accuracy for lower loads as for full load. Compressors with dead-space regulation have a part-load capacity which may differ in a compressor calibration test, and in a system leakage test, if the quantity and temperature of the cooling water are different in the two cases.

12.4.4 Pressure-time Response

Leakage of air into an evacuated system may be determined by either of the following methods:

- Pump the system down to an equilibrium pressure. Subtract from it the pressure due to outgassing determined in a leak-free system of the same kind (refer to Section 11.4).
- Derive an allowable pressure-time curve for the pump-down of a system. Systems deviating from this relationship are considered to be leakers.

In evacuating a system, the gas which is removed may come from the free air in the system, outgassing of the walls and other surfaces, or leakage. The change in pressure with time as the gas is removed can be expressed by Equation 4-10 where Q is the total gas flow from the system of volume V. Then Q/V is the rate of pressure change, dP/dt. Outgassing may be reduced to a negligible value by cooling the walls of the system with a refrigerant, or liquid nitrogen may be placed in a reservoir inside the system (Ref. 6-6). The value of Q will be the amount of the leakage, Q_ℓ, less the amount removed by the pump, S. Equation 4-10 takes the form $dP/dt = (Q_\ell - SP)/V$, which may be integrated to give:

$$\ell n \left(\frac{Q_\ell - SP_2}{Q_\ell - SP_1} \right) = - \frac{S}{V} (t_2 - t_1) \qquad (12\text{-}1)$$

When Q_ℓ is very small, as for a leak-free system, Equation 12-1 becomes

$$\ell n \left(\frac{P_2}{P_1} \right) = - \frac{S}{V} (t_2 - t_1) \qquad (12\text{-}2)$$

Pressure-time response is obtained by recording the time and pressure as the system is evacuated. A plot of $\ell n\,(P_2/P_1)$ versus time should be made. A straight line of slope $(-S/V)$ will be obtained for a leak-free system. A curved line asymptotic to a pressure value $P = Q_\ell/S$ results for a leaking system. The particular pressure value is a function of the time constant of the system (see subsection 4.5.2).

With either of these procedures, it is possible to set up an automated leakage test station such as the carrousel described in literature (Ref. 11-3). The chief difficulty with this type of test is the interference from the outgassing of dirty samples.

Section 13

BUBBLE EMISSION METHOD OF LEAKAGE TESTING

Section 13

BUBBLE EMISSION METHOD OF LEAKAGE TESTING

13.1 INTRODUCTION

Bubble emission from leaks is observed after pressurizing a device or system with a gas (such as air) and covering the suspected leak area with a liquid. The test object can be completely immersed or portions of the object can be covered with liquid. The method is simple to apply and requires little skill on the part of the operator.

Bubble emission is useful for locating leaks larger than 10^{-4} atm-cc/sec. Smaller leaks may be temporarily clogged by the liquid; some leaks are intermittent and may easily escape detection. The air which is dissolved in the liquid frequently forms bubbles on the test object, thereby interfering with the observation of leakage bubbles.

The size and appearance of the bubbles are critical in estimating leakage rate. For example, DeCastra and Wells (Ref. 13-1) establish three classes of bubble dimension and appearance. Class 1 appears as small, uniform, long persisting bubbles. This class implies a leakage range of 10^{-4} to 10^{-1} atm-cc/sec. Class 2 appears as a mixture of random-size bubbles that are moderately persistent. This class implies a leakage range of 10^{-1} to 1 atm-cc/sec. Large, fast forming bubbles of short persistence constitute Class 3. The implied leakage range is between 1 and 10 atm-cc/sec.

13.2 SENSITIVITY

Bubble-emission sensitivity increases with the pressure differential applied to the test device and with the care taken by the operator. The usual sensitivity of 10^{-4} atm-cc/sec may be improved to 10^{-}[illegible] atm-cc/sec by the use of special fluids, adequate illumination, and the use of optical magnification (Refs. 4-17 and 13-2).

13.3 DESCRIPTION OF EQUIPMENT

Equipment for bubble-emission leakage testing consists of suitable liquids and a source of compressed gas. While water alone can be used, the addition of a wetting agent makes bubble detection easier. Certain liquid fluorocarbons have the advantage of draining quickly; they are inert, and leave no residue. Table 13-1 lists the average characteristics of test liquids. For description of the individual liquids see Part III.

13.4 LEAKAGE TESTING METHODS

The formation of bubbles, resulting from leakage of gas into a liquid, is dependent not only on the pressure conditions but

Table 13-1

COMMERCIAL LIQUID-APPLICATION FLUIDS FOR BUBBLE TESTING

General Characeteristics	Average Values
Sensitivity	1×10^{-4} atm-cc/sec
Tracer Gas	Nonspecific, any compressed gas
Container Size	4 ounces to 55-gallon drum
Price	70 cents/4 ounces to $5 /gallon

also on the physical properties of the liquid and of the gas. Thus, by a suitable combination of liquid and gas, the size of the bubbles and their rate of formation can be modified. For purposes of leak detection and location it is desirable that the bubbles should be readily apparent. The sensitivity of the procedure is determined by the ability to observe bubbles formed at the outlet end of small holes and passages. It is possible to change the sensitivity of the test by changing the test gas. The rated leakage of the test gas may thereby be increased; this does not imply a change of the conductance of the leak.

When the liquid does not readily wet the solid surface around the orifice, the bubble rim tends to spread away from the orifice, resulting in larger bubbles. Larger bubbles are formed in the presence of any conditions which tend to inhibit wetting, such as traces of grease.

For a given gas flow rate, the production of larger bubbles reduces the bubble frequency, the frequency being inversely proportional to the cube of the bubble radius. For a given leak, the bubble frequency of a low surface tension organic liquid may be 100 times the frequency of bubble formation in water.

13.4.1 General Procedure

In one method a high-pressure gas line is connected to the component. Compressed air can be used, provided it is obtained from a cylinder. Compressed air from pipe lines is not recommended, since dirt and oil contamination is generally present and is likely to block small leaks. Pressure should be applied to the test unit before liquid application or immersion so that the liquid will not enter small leaks; much higher pressure is needed to detect a leak once it has been clogged with liquid (see Section 6.6).

Another method is to place the component in a container of liquid and to reduce the pressure on the liquid in the container. This method can give pressure differentials up to one atmosphere if the pressure inside the component is atmospheric.

From the standpoint of time and equipment, the results are superior to those obtained with the heated bath which is discussed below. Caution must be exercised in the performance of a vacuum-type test to ensure that the pressure above the bath does not fall too low, causing the bath to boil. When this happens, streams of bubbles rise from the surface and are difficult to distinguish from bubbles of leaking gas.

Still another method is to preheat the bath in which the component is to be placed. As the temperature within the component rises, the air inside will tend to expand and the internal pressure will rise. The pressure differential created in this manner will be in the range of a few pounds per square inch, as shown in Figure 13-1. From the standpoint of economy and rapidity of testing this is the best method to use with small components. Once the bath reaches the desired temperature, no further adjustments are necessary, except those minor ones that may be required to maintain a constant temperature. If the bath is large enough, samples to be tested may be mounted on a rack and all checked at the same time.

Although there are other ways of creating a pressure differential, these three are the most commonly used in bubble testing.

The liquid immersion procedure can be applied to a continuous manufacturing process. For example, as the component parts move along the production line toward final assembly, they can be pressurized with dry air and then immersed in clean, hot water baths. The water should be treated with a suitable softener to reduce surface tension and promote bubble growth, thus increasing the sensitivity of the test. Operators in front of large glass windows can detect leaks. The leaks can be tagged and the unit returned for repairs and recycling through the dip tank. One of the outstanding limitations of this test is the amount of entrained air carried into the tank on the surface of the units.

The side of the object being examined must be positioned in the test fluid so that the bubbles will rise directly to the surface. Obviously, the bottom side of any object being tested (i.e., the side facing the bottom of the test container) will tend to trap bubbles, decreasing the reliability of the test.

If the leak is small, the bubbles may be difficult to see until the eye is adapted. A reading glass will be found of great assistance (e.g., three-inch diameter giving a magnification of two or three times at four to five inches from the object). The glass will not reveal smaller bubbles, but will make it easier to see the source of the bubbles. Good lighting is essential and a dark background may be helpful. A small stream of bubbles may be more easily detectable from above than from the side.

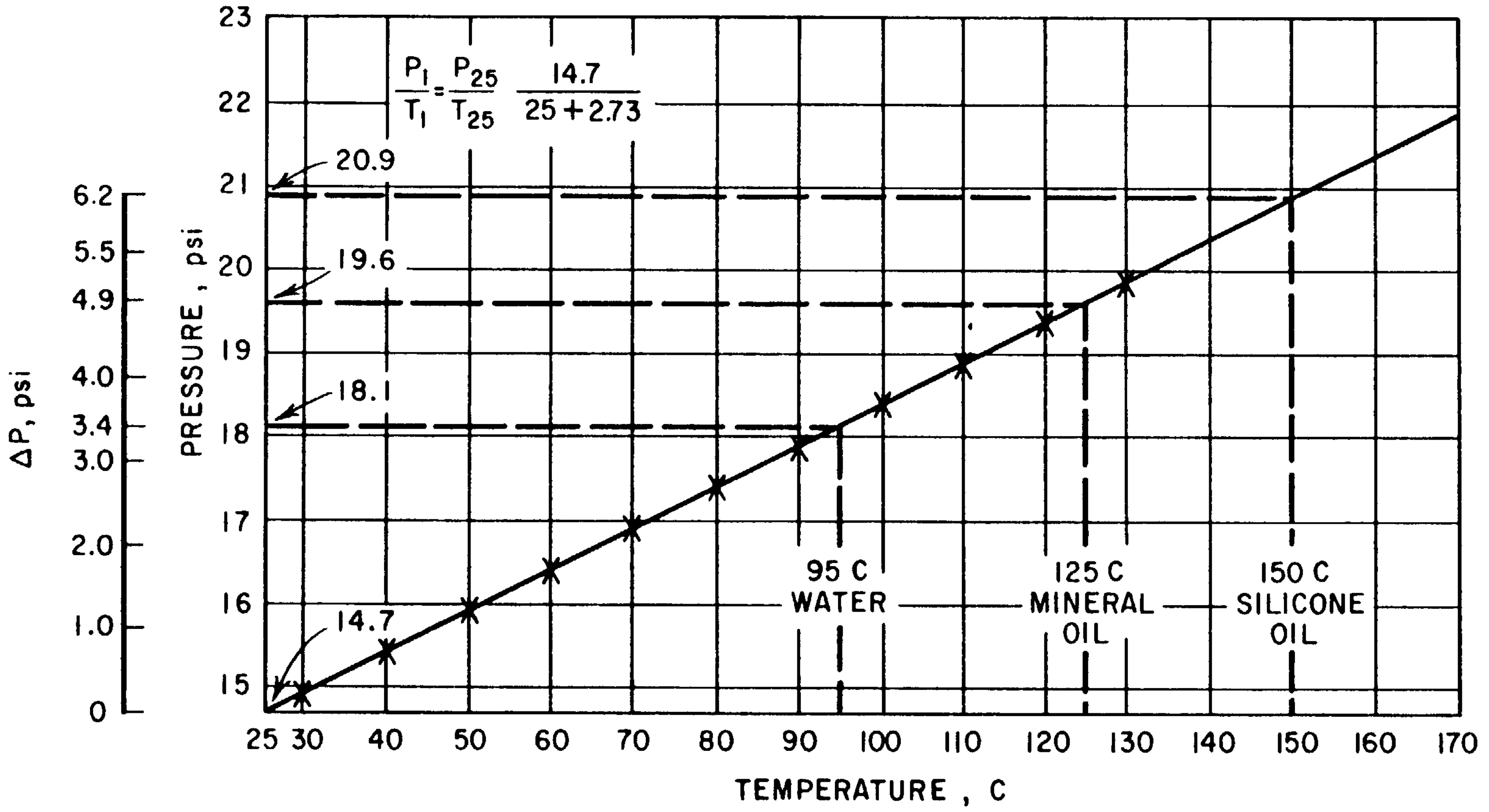


Figure 13-1. Pressure Versus Temperature for a Fixed Volume. (Reprinted with permission of U.S. Army Signal Equipment Support Agency, from Final Report on Task 511--Leak Detection by H.H. Scheffler, Battelle Memorial Institute, Contract DA-36-039-SC-73212, February 28, 1959).

If large vessels have to be tested, immersion may be impossible. Channels to contain the test fluid can often be built around suspected areas. The system or section being tested may be pressurized in numerous ways. Considerable ingenuity may have to be exercised in making up special clamps and fittings for sealing the component and attaching the air (or gas) hose. Rubber sheeting and C-clamps are useful in these respects.

When it is not possible to immerse the test object, a small quantity of soap solution may be applied directly to the suspected leak area. A bubble-free solution should be applied gently to preclude bubble formation during application. The solution should be flowed rather than sprayed or brushed onto the surface. The sensitivity of this technique is dependent on the time and care taken to observe bubble formation.

Two cautions are in order:

- When testing flanges, threads, or any joint which has a large exposure area, it is absolutely necessary that the solution bridge the entire joint. Gas will invariably slip out through the smallest pinhole which is not covered.
- The second caution is in the choice of a suitable solution. For high sensitivity it is necessary that the film does not break away from the joint and that the bubbles formed are not broken by air drying or low surface tension.

Guthrie and Wakerling (Ref. 13-3) propose an idea that is applicable to very large vacuum chambers. A volunteer equipped with an oxygen mask is requested to enter the chamber, which is pumped out to about three-fourths atmosphere. The man applies a soap solution to the inside surface of the system and looks for the formation of soap bubbles. Needless to say, the most careful precautions must be taken during this procedure. The man inside the vacuum system should be under observation at all times so that any signs of exhaustion or other difficulty will immediately be apparent. A continuous and uninterrupted source of oxygen must always be available. Also, every precaution must be taken to prevent any chance for the valve between the vacuum system and the pumps to be opened wide by mistake. The real value of the method lies in finding large leaks in parts of the surface of a large vacuum system that are not accessible from the outside. The method obviously has quite limited application.

13.4.2 Liquids for Bubble Tests

Water, fluorocarbon liquids, mineral oil, and a silicone oil are the liquids commonly used for immersion testing. A steady stream of extremely fine bubbles appears in an oil bath. If water is used, it must be treated to reduce the surface tension; this reduces the bubble size and the tendency of bubbles to cling to the surface of the component and build up to a relatively large size before breaking loose and rising to the surface. This means that in water small leaks would require a long period of time to produce a bubble that would be visible. A component would most probably be passed as acceptably sealed before time was allowed for a conclusive test.

A disadvantage common to tests using oil is the fact that the components, after being tested, must be degreased to remove the oil that adheres to the surfaces. A silicone oil bath is particularly expensive to use, because the oil clings to the component after immersion and cannot be completely recovered.

In addition to fluorocarbon liquids, methyl, ethyl, or isopropyl alcohols may also be used as test liquids. The one advantage in the use of these materials that is not found with the other fluids is their cleaning ability. Not only is the degreasing process eliminated, but they also clean foreign matter from the body of the component. After the component is removed from the bath, the rapid evaporation rate of these liquids leaves the surfaces clean and dry.

Alcohols should not be used in the heated bath procedure because of their toxicity and flammability. Adequate ventilation is required to prevent poisoning or eye damage from the vapors.

A soap solution for leak detection by topical application may be prepared from equal parts of corn syrup, liquid detergent, and glycerin (Ref. 7-1). The solution should not be prepared more than twenty-four hours before the test, and bubble formation properties should be checked with a sample leak every half hour during the test.

Section 14

USE OF RADIOACTIVE TRACERS IN LEAKAGE TESTS

Section 14

USE OF RADIOACTIVE TRACERS IN LEAKAGE TESTS

14.1 INTRODUCTION

Radioactive isotopes are used as tracers in the detection and measurement of leakage. Only a very small quantity of radioactive material is needed to load the system or item which is to be tested. The nuclear radiations from leakage of the radioactive material are detected by means of special electronic instruments. Uses of such radioactive leakage tests are varied, with the applications ranging from the production-line testing of small sealed components to the testing of pipeline systems.

14.2 SENSITIVITY

The sensitivity of this technique may be as high as 10^{-13} atm-cc/sec under ideal operating conditions. To attain these conditions, the soaking and counting time must be selected for high sensitivity, and the units being tested must be of a "clean" construction, with no possibility of adsorption of radioactive material on the outer surfaces. A practical value of 10^{-11} atm-cc/sec is the sensitivity to be expected under routine test conditions.

14.3 EQUIPMENT AND MATERIALS

For conducting leakage tests in the field, conventional scintillation counters or Geiger tubes are employed. When leakage tests are performed on a mass-produced item, the test procedure frequently used is that known as the "Radiflo" method.

The Radiflo equipment is automated and its operation is extremely simple. However, since the use of radioactive material presents a potential danger, the operators and supervisory personnel must take a course in instrument operation and health physics before they can be allowed to operate the equipment.

Although the initial cost of the detector is high, the maintenance and operation costs are low because almost all radioactive gas is recovered. The procedure is economical when the number of components to be tested range in the thousands per day. Radiflo can be calibrated for leakage rate. The manufacturer gives the following data for testing 5/16-inch transistors:

- Radioactive material costs $250 per 10,000 or 2-1/2 cents per transistor
- Activation labor is 15 minutes for 10,000 units
- Radiation check takes 0.16 minute per transistor

Inglis (Ref. 14-1) describes the 100-percent acceptance inspection of propellant items; inspection rates of 200 to 500 pieces per hour are claimed. Specific details regarding this type of equipment may be found in Part III.

Radioactive materials used are usually gamma-emitting isotopes with the following properties:

- They must emit gamma rays of sufficient intensity to be easily detected.
- They must be available at a low cost with a sufficiently high activity to permit the use of an inexpensive detector.

For example, radioactive krypton-85 is used in the Radiflo method of leakage testing. With a half-life of 10.3 years, this material can be used over and over again if it does not become too diluted with air or lost in the atmosphere. Only 0.7 percent of the disintegrations give 0.54 megavolt gamma rays. The primary usefulness of krypton-85 for leak detection is dependent on this small proportion of gamma-emitting disintegrations. The other 99 percent of the disintegrations are the less powerful beta rays.

The half-life of 10.3 years is equivalent to 3.25×10^8 seconds. One cubic centimeter of pure krypton-85 at normal pressure and temperature will contain 2.7×10^{16} atoms which will produce disintegrations at the rate of 5.78×10^{10} per second. Only 0.7 percent of these disintegrations, or 4×10^8 per second, yield gamma quanta. Krypton-85 received from Oak Ridge National Laboratory contains five percent of the radioactive isotope. In use this gas is further diluted with air or another gas for two reasons: 1) to give the gas the effective viscosity of air, and 2) to obtain a sufficient volume for filling dead spaces in pressurized containers.

Radioactive krypton-85, because of its chemical inertness, does not participate in any metabolic processes in the body if inhaled or ingested in any way. If accidentally inhaled for a short time, normal breathing of noncontaminated air will rapidly remove any krypton from the lungs and body tissue into which it might have diffused. With an adequate ventilating system, proper gamma-ray shielding of storage tanks and reasonable care, krypton-85 can be handled with negligible risk to the operators.

Many other radioactive materials are available for leakage testing. A few of these are listed in Table 14-1.

14.4 RADIFLO METHOD

In this method of leakage testing, the components to be tested are placed in a tank, which is then sealed and evacuated

Table 14-1

MATERIALS USED FOR RADIOACTIVE LEAKAGE TESTING

Element	Compound	Half-life	Energy (Megavolts)	
			Beta	Gamma
		Gas Leaks		
Br^{82}	CH_3Br	36 hours	0.46	1.31
Xe^{133}		5.3 days	0.35	0.08
Kr^{85}		10 years	0.70	0.54
A^{41}		1.8 hours	1.18	1.3
Rn^{222}		3.8 days	None*	None
C^{14}	CO_2	5600 years	0.16	None
		Liquid Leaks		
Na^{24}	$NaCl$, $NaHCO_3$	15 hours	1.39	2.75
As^{76}	$(NH_4)_3AsO_4$	27 hours	2.96	1.2
I^{131}	NaI	8 days	0.16	0.36
Sb^{122}	$(C_6H_5)_3Sb$	2.8 days	1.97	1.26

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*Alpha emitter

to about two torr. Diluted krypton-85 is then pumped into the tank under a pressure. The radioactive gas diffuses into existing leaks in the components. After a prescribed "soaking" period (a few minutes to a few hundred hours), the krypton is pumped out of the tank and stored for reuse. A suitable combination of krypton pressure and soaking time may be selected to give the desired sensitivity. After this, an air wash is circulated over the components to remove any residual krypton from the external surfaces. The components are then removed from the tank. Those with leaks will retain some radioactive atoms, which emit gamma radiation. This radiation is detected by a suitable radiation counter, the measured radiation being a function of the leak rate (Ref. 4-1).

Occasionally components with very large leaks (10^{-5} atm-cc/sec) tend to slip through the leak test as acceptable. This is due to rapid escape of the radioactive gas through the large opening during the final pump-down phase of the test cycle. This does not occur if the component contains any organic or other adsorptive material. In the absence of such internal adsorptive material, it is sometimes necessary to retain a slight partial pressure of krypton in the pressurizing tank before its removal for counting.

Alternatively, the components could be bubble-tested after the Radiflo test; the bubble tests will detect these gross leaks. Since the fluid used in bubble-testing will clog very small leaks, bubble-testing should be performed only after Radiflo has determined that no small leaks exist.

Disadvantages of the Radiflo technique are:

- Sample sizes limited to approximately one cubic foot
- Leaks cannot be localized
- Many organic materials will take up krypton-85 under pressure, and will hold it for various lengths of time after the pressure is released

Items to be leakage-tested frequently have adsorptive surfaces, such as organic coatings, or small areas of organic insulation or gasketing. The radioactive gas adsorbed by these surfaces could make the item appear to be a leaker when, in fact, it is not.

Radiflo is a classic use of the back-pressure testing described in subsection 4.8.2. As explained in that section, very large leaks may be overlooked because of rapid leakage out of the system during pump-down. However, if adsorbents are present inside the device, krypton-85 will remain inside the device.

Absolute leakage standards are not available because tests are performed on sealed systems. Standards are available to ascertain the activity of the test gas and the accuracy of the test instruments, but test leaks to qualify the procedure do not exist. There is even some question as to validity of the correlation between the measured flow of krypton-85 and the amount of air flow it represents. Clark, Jones, and Karoly (Ref. 14-2) found that because of difficulty in predicting the flow mode involved, leakage as measured by the Radiflo technique correlates to only one decade with flow measured by the mass-spectrometer leak detector.

Figure 14-1 is a schematic diagram of the Radiflo unit. Programmed electronic circuity is used to assure the protection of operating personnel from the radiation hazard. Both beta and gamma rays are detected by means of a thin wall Geiger-Muller counter. Krypton-85 adsorbed on surfaces will give readings of both beta and gamma rays. However, the walls of the device will adsorb any beta rays being emitted inside it. Therefore, it is possible to distinguish by the beta-to-gamma radiation ratio whether the radiation indication is due to adsorption or leakage. It goes without saying that if radiation due to adsorption on external surfaces is large, small amounts of leakage will go undetected. Precautions must be taken to assure that all surfaces are clean.

Routine checking of rejected parts by means of a thin-window Geiger-Muller tube consistently reveals surface-contaminated parts. Comparison of such rejected parts with acceptable parts of the same surface composition will determine the significance, if any, of the surface contamination. Those parts with significant contamination can often be decontaminated by a brief exposure to heat. Frequently, such a heating cycle is routinely incorporated into the testing procedure of certain parts having organic coatings.

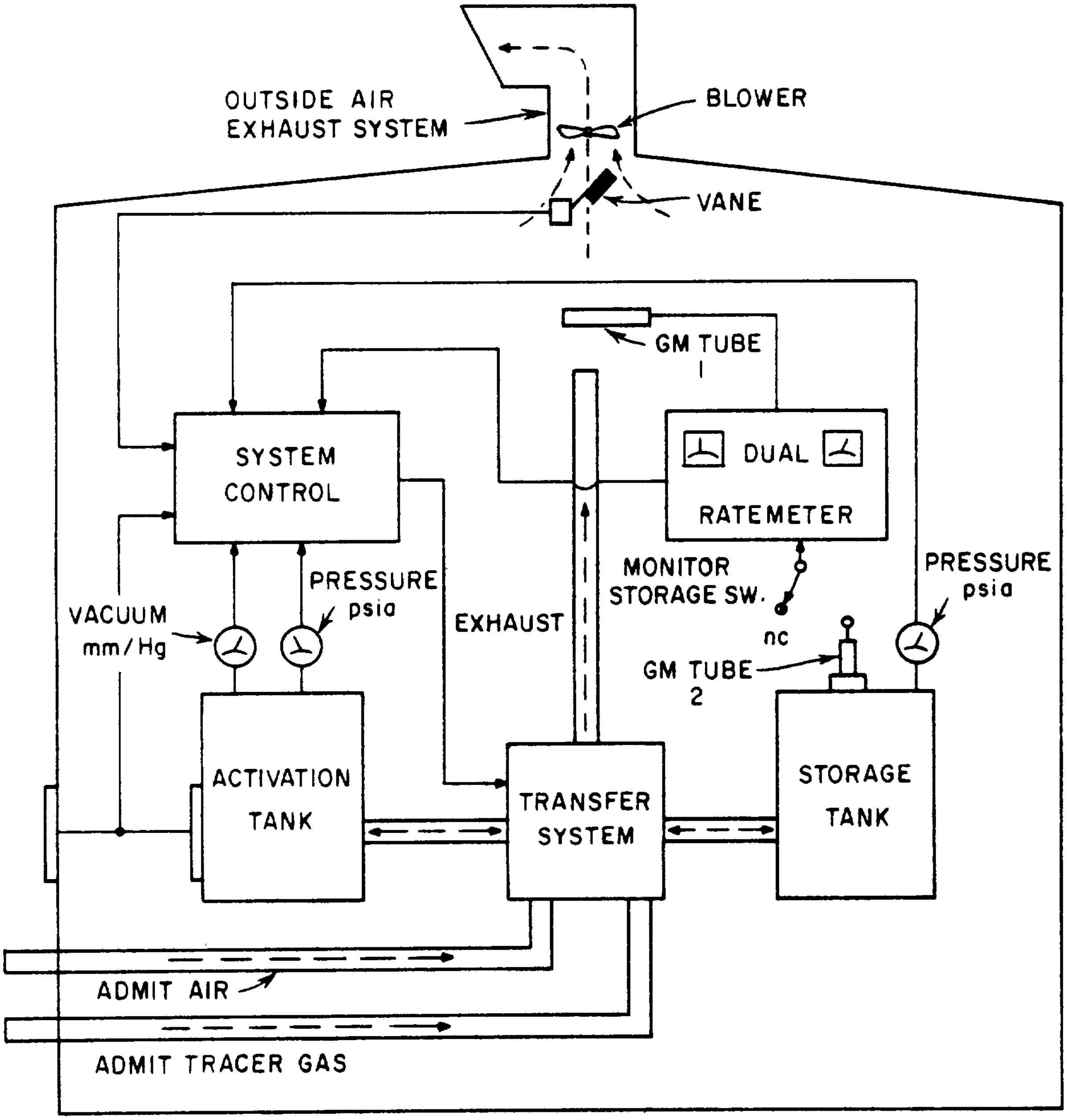

Figure 14-1. Unit for Radiflo Testing. (Reprinted with permission, W. Inglis, Materials Evaluation, Vol. 24, No. 3, p. 150, 1966, Copyright 1966, Society for Nondestructive Testing, Inc., Evanston, Ill.)

For mass-production testing, an automatic counting station will perform GO-NOGO testing functions at a rate from 600 to as high as 2000 units per hour, depending upon the size of the part being tested. Activated parts are placed in a shaker unit, automatically fed into cups on a continuously moving conveyor, and carried to a detector for analysis. A scaler measures and compares the activity against a preset rejection threshhold. The tested parts are then deposited in an appropriate "accept" or "reject" bin.

14.5 OTHER METHODS OF LEAKAGE TESTING

Radioisotopes are used in leak location on very large systems where the usual methods would be extremely difficult to apply. The advantages of radioisotope methods are their high sensitivity, compatibility with any gas or liquid being used in the system, and the fact that the tracer does not have to be removed from the leakage site to be detected.

However, these techniques require experienced personnel to handle radioisotopes, measure radioactivity, and interpret pertinent data. Moreover, the use of radioisotopes represents a potential health hazard, and disposal produces more handling problems than are encountered with other tracers.

Courtois and Gasnier (Ref. 14-3) have reviewed the procedures using radioactive liquids, gases, and capsules.

14.5.1 Pipeline Testing

Pipeline leakage is frequently detected by means of radioactive liquids or gases. A radioactive tracer is introduced into the system with the filling fluid. The fluid escapes through the leak, producing contamination in the vicinity of the leak. The tracer can be detected at the leak after flushing the system.

The three stages -- filling, contamination, and detection -- can be accomplished in various ways. The pipe may be filled with a homogeneous tracer or a slug (or puff) of tracer. With a homogeneous solution, the search can be carried out in a pipe under constant pressure and with no flow. It is necessary, however, to check the homogeneity of the product introduced and to remove a considerable volume of tracer-contaminated fluid.

Alternatively, a "puff" of a radioactive tracer is injected into the stationary liquid held between two scraper pistons, or go-devils, in the pipe. Only a relatively limited quantity of liquid is contaminated in this kind of tracing.

Detection may be at ground level, from the interior of the pipe, or by probing. At ground level, which is, of course, the simplest method, the detection team moves along the pipeline equipped with portable radiation detectors. Heavy activity of the radioelement is required because radiation must pass through a ground layer of considerable thickness, often including a layer of paving, cement, or other coverings. This method of detection requires the use of very sensitive detectors; for example, sodium iodide (thallium activated) crystal scintillation counters.

In the case of gas leaks, considerable diffusion of gas takes place toward the surface. Diffusion is largely determined by the nature of the ground as well as of the tracer gas. This reduces the accuracy of localization, but permits the use of a radioelement of lower activity by reducing the distance between the tracer and the detector.

It is possible to probe for the leak from inside the pipe, as described by Putman and Jefferson (Refs. 14-4 and 14-5). This procedure includes passing through the pipe a scraper piston, or go-devil, which contains the electronic detection system and a "memory." As this detecting scraper is moved along inside the pipe by the fluid flow it records any increase of activity in the ground where contamination by leakage has occurred.

The great advantage of the pipe probe method is that it requires only a low tracer activity at the leak because the radiation emitted need only pass through the pipe wall to reach the detector. The activities required are usually some 1,000 times less than those necessary for detection from ground level.

Some of the practical parameters which limit the use of this method are:

1. The pipe diameter must be sufficient to permit passage of the detection electronic device.
2. The bends of the pipe must be such that the scraper piston, the length of which is generally in the order of one and a half times the diameter of the pipe, may pass through.
3. After the passage of the tracer fluid, the pipe must be rinsed so as to be free from traces of activity.
4. The pipe must, insofar as possible, be free from elements likely to adsorb the tracer.
5. The suspension of the electronic detection equipment and its memory must be able to absorb the considerable shocks to which the scraper is subjected.
6. The detecting scraper must be absolutely impervious.
7. A number of small radioactive sources (e.g., Co^{60}) can be placed at certain distances along the pipeline. The presence of these sources is recorded to make easier the localization of the leak.

If detection from the inside of the pipe is impossible, the thickness of the ground layer between the source and the detector is reduced by digging holes and lowering the detection probe.

For systematic examination, the holes must be very close together. This kind of exploration would be possible only on very short pipelines. It is often sufficient to probe only suspicious points (connections, valves, etc.).

Various modifications of the methods described here have been used. In one instance, a slug of radioactivity was introduced suddenly and its rate of movement along the pipe followed. At a leak there was a discontinuity in the flow rate of the slug. This spotted the trouble. In another instance both ends of the main were closed, and the isotope was introduced at the center. The operator observed the direction the tracer flowed in the pipe, to the right or to the left. Then he bisected the offending section and tried again.

Still another modification involves the use of a sealed capsule that has been tagged radioactively. Leaks are found by placing a properly weighted radioactive capsule, or float, in the fluid of a sealed pipe and allowing it to be carried by the current. With normal exits closed, the only current is that of fluid escaping through the leak. The float moves with the current and stops at the leak. If the course of the piping has been marked beforehand, a man with a detector can easily follow the radioactive float.

When there are leaks of different sizes, the float often goes to a large leak and stops. It may slow down, however, as it passes a small leak, and an experienced observer can often recognize such a change of speed. If no speed changes are observed, the operator can locate and repair the largest leaks, then reexamine the line for smaller ones.

Use of sealed capsules for leak location is advantageous since smaller amounts of activity can be used and the active material does not mix with the pipe contents or contaminate surroundings. Further discussion of these methods may be found in Gemant (Ref. 14-6) and Black and Kerwick (Ref. 14-7).

Section 15

USE OF THE HALIDE TORCH IN LEAK LOCATION

Section 15

USE OF THE HALIDE TORCH IN LEAK LOCATION

15.1 INTRODUCTION

The halide torch is used to locate leaks in pressurized systems filled with a halogen-containing gas. The burner heats a copper plate with a flame that is a pale blue only if air is pulled into the burner. If small amounts of vapor containing halogen compounds come in contact with the plate, the flame turns green.

15.2 SENSITIVITY

The torch permits locating leakages of about eight to ten ounces of refrigerant gas per year, which is approximately one hundred parts per million. This makes the general optical sensitivity approximately 10^{-4} atm-cc/sec. When an electronic photometer is used to sense color changes, the sensitivity may be improved to about 10^{-5} atm-cc/sec.

15.3 DESCRIPTION OF EQUIPMENT

The halide torch (Type 1) consists of a burner connected to a tank of halide-free gas or alcohol. A portion of the combustion air is drawn into the flame (chimney fashion) through a tube near the base of the burner. A flexible extension of this tube is used as a probe to locate leaks (see Figure 15-1).

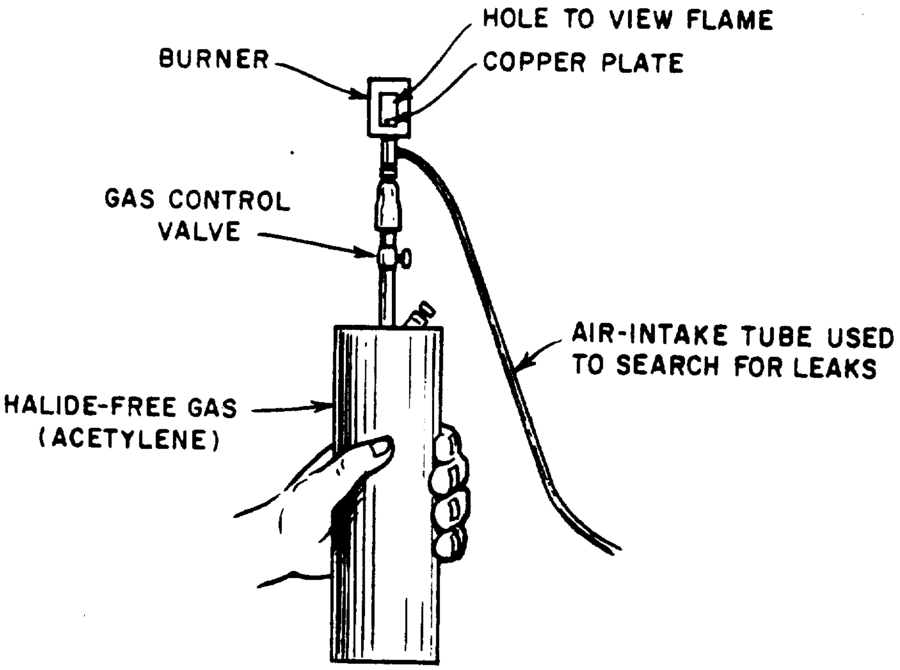

Figure 15-1. Halide Torch for Leak Location

The torch is available either as an attachment to portable gas cylinders or as a complete unit with an integral fuel supply.

A more sensitive instrument, with direct-reading dials (Type 2), can be obtained. Both devices are portable, easy to operate, and of relatively small size. Table 15-1 summarizes the characteristics of these items. A more complete description can be found in Part III.

Table 15-1

CHARACTERISTICS OF HALIDE TORCH DETECTORS

General Characteristics	Average Values	
	Type 1	Type 2
Sensitivity	10^{-4} atm-cc/sec	10 parts per million; 10^{-5} atm-cc/sec
Tracer gas	Halogen compounds	Halogen compounds
Output	Visual	Meter
Power requirement	Halide-free fuel	120 volts, 60 hertz AC
Size	15 inches × 4 inches diameter	15 inches × 16 inches × 9 1/2 inches
Weight	1 pound	35 pounds
Price	$10	$675

15.4 LEAKAGE TESTING METHOD

To probe for leaks, the torch is lighted and checked for proper operation by sucking in a trace of halogen gas from the tracer supply tank. The surface of the system being tested is then searched with the probe tube at the rate of a fraction of an inch per second. Since the tracer gas has four times the density of air, it is advisable to start work on the lower side of a possible leak. A small trace of halogen gas will show up as a green flame, a large quantity as a violet flame. Servicemen usually move the probe about one-fourth inch per second to locate leaks down to eight ounces per year. Although any halide gas could be used in this test, Freon (CCl_2F_2) is the best with respect to sensitivity, vapor pressure, inertness, and safety.

Depending on the size of the vessel and the sensitivity desired, the air may or may not be evacuated before the tracer gas is introduced. Evacuation takes longer and is not practicable for very small pipes; but if accomplished, it makes possible a pure tracer-gas atmosphere that can later be pumped back into the storage tank.

In general, the halide torch test is as sensitive and rapid as the soap-bubble test. In addition, the torch method permits location of leaks in places where soap bubbles could not be seen. There is no residue of water and soap to be removed before the tested apparatus can be used. Freon is nonflammable, and once a leak is found it can be soldered without fear of explosion.

The torch has no means of accurate calibration. It should be realized that it is difficult, in a contaminated atmosphere, to locate leaks smaller than eight or ten ounces per year even when the unit to be tested is filled with one hundred percent refrigerant gas.

A major drawback is the fact that the procedure consumes oxygen and may give off enough toxic gas to make it unsafe in confined areas that are not adequately ventilated. The open flame may be a serious hazard in certain atmospheres. Therefore, the torch should not be used in confined areas.

Carbon tetrachloride vapors are toxic; continued exposure to them is dangerous. This material should never be used without adequate ventilation. Persons using it should be carefully instructed beforehand to ensure safety in testing.

A single large leak may mask adjacent smaller leaks, necessitating prior location (and correction) of such larger leaks by separate test. This procedure uses halogenated hydrocarbons and is subject to diffusion and stratification problems.

Section 16

SONIC DETECTION OF LEAKAGE

Section 16

SONIC DETECTION OF LEAKAGE

16.1 INTRODUCTION

Leakage in either vacuum or pressurized systems may be detected by means of the sonic energy generated in the fluid vortices which accompany leakage flow. The only requirement is that the sonic signal be of sufficient intensity to be distinguished from the background noise. Special tracer fluids are not required.

Frequency of the leakage noise ranges from the audible to the ultrasonic. Detection is accomplished by any of several simple methods:

- Listening to the audible signal
- Electronic amplification of the audible signal
- Conversion of the ultrasonic signal to an electrical signal of lower frequency

The ultrasonic component of the leakage noise is broadly peaked at a frequency in the range of 30 to 50 kilohertz. Using the third method above, such sounds can be easily detected, even when the audible component is masked by a noisy background (Ref. 10-5).

Sometimes normal flow of fluids through a pipe will give an input to the instrument, making it useless except under static conditions. At other times the ultrasonic energy is reflected from hard surfaces, posing a problem in establishing the exact location of a source if the operator cannot get close to it. This requires some experience on the part of the operator to quickly recognize whether he is intercepting a direct wave or a reflection. The ability to recognize the direct and reflected waves can be readily acquired and is not a serious problem.

16.2 SENSITIVITY

This method has a sensitivity of approximately 10^{-3} atm-cc/sec -- a relatively large value of leakage -- under conditions of turbulent flow. Laminar flow will not produce a usable signal.

16.3 DESCRIPTION OF EQUIPMENT

To aid in the detection of audible signals an industrial stethoscope can be used. When these signals are too weak to be heard, an electronic stethoscope with an amplifier may make them audible.

Ultrasonic sound-detector probes are of two types: the directional probe, and the contact probe. The directional probe, or transducer, has a horn with which the operator scans an area and locates a leak, in much the same way that a radio direction finder is used to obtain radio bearings. One unit has a directional pattern that is 22 degrees wide at -3 decibel points. The short wavelengths of the ultrasonic frequencies make it possible to design highly directional horns that are small in size and convenient to use. Use of a parabolic dish permits a directivity pattern of a fraction of a degree.

The contact probe is used in the location of internal leaks in hydraulic systems and requires direct contact with the components of the system. The ultrasonic energy produced by the moving fluid is conducted through the valves, tubing, or vessel walls. Thus it is possible to detect leakage and changes in the flow conditions that are usually difficult to locate without disconnecting lines and partially disassembling the system. The detector is portable and can be used as a leakage locator with either the directional or contact probe. For production-line operation the detector units can be equipped with alarm or relay circuits (Ref. 16-1). Figure 16-1 is a functional diagram of a typical ultrasonic leak detector circuit.

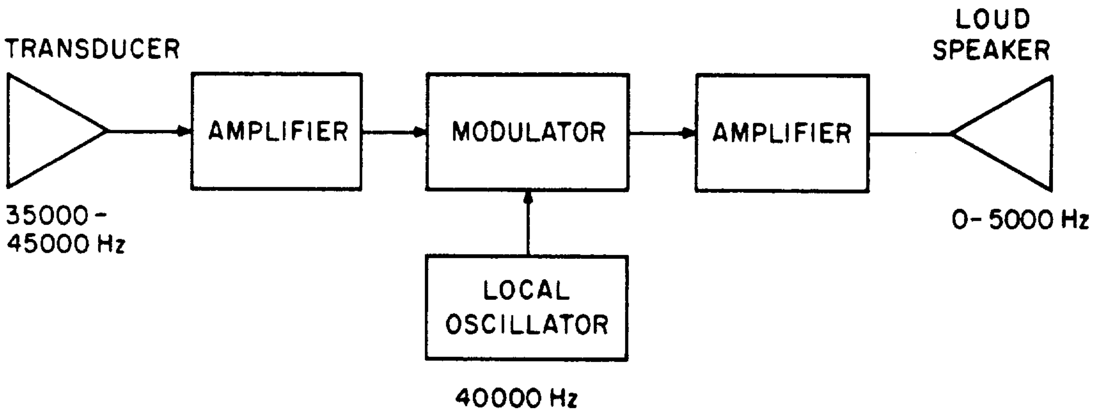

Figure 16-1. Block Diagram of an Ultrasonic Leak Detector. (Courtesy of Hewlett-Packard Company, Delcon Division.)

The electrical output produced by the ultrasonic transducer is amplified and then translated into the audible range in the modulator by the conventional mixing process commonly used in superheterodyne radio receivers. These converted ultrasonic signals exhibit audible sound characteristics that are very similar to their audible counterparts because of the same physical phenomena (e.g., a leak has the hissing sound that is characteristic of air escaping from a pressure vessel; friction has a scratching sound that is characteristic of two surfaces rubbing together).

Table 16-1 summarizes the characteristics of these instruments. Additional details may be found in Part III.

Table 16-1

CHARACTERISTICS OF SONIC LEAK DETECTORS

General Characteristics	Average Values		
	Ultrasonic	Sonic	Stethoscope
Output	Audible signal and meter	Audible signal and meter	Audible signal
Power requirement	Battery	Battery	None
Size	5 inches × 5 inches × 10 inches	5 inches × 3 inches × 3 inches	- - -
Weight	8 pounds	5 pounds	1 pound
Price	$300	$100	$20

16.4 LEAKAGE TESTING METHOD

McElwee and Scott (Ref. 16-2) describe the use of a stethoscope and a simple electrical amplifier to detect leaks by the sound they generate in the audible range. This method involved detection from the inside of pipes.

The injection of a sonic wave into a system was proposed by Quisenberry (Ref. 10-5). Sonic energy emerges with the leaking fluid and is detected by frequency shift and correlation methods.

With the aid of push rods and a protective tip for the transducer, it is possible to probe ducts for leakage by observing the signal level as the probe is pushed along the duct. For example, the leakage from underground transmission cables can easily be located and the spot to excavate pinpointed (Ref. 16-3).

Calibration of sonic leak detectors is done by giving a brisk squeeze to a small plastic "squeeze bottle." The sound may be detected over a distance of 50 feet.

Section 17

LEAKAGE DETECTION BY ABSORPTION OF ELECTROMAGNETIC ENERGY

background components. Almost all hydrocarbons can be used in a background of air and give results in the low ppm range of detection. Other gases which may be used are: carbon monoxide, sulfur dioxide, and the halogenated hydrocarbons.

17.2 SENSITIVITY

The infrared detector is in the same general class of applicability and sensitivity as the heated-anode halogen detector. These instruments are capable of a full-scale reading of 100 parts per million nitrous oxide in air. This implies a detectable limit of several parts per million. With an internal pumping speed of a few cubic centimeters per second, these instruments can detect leaks in the range of 10^{-6} atm-cc/sec.

However, the response time of the infrared detectors is twice that of the equivalent halogen system and they are at least one decade less sensitive. Their prices are at least twice those of a halogen detector.

17.3 DESCRIPTION OF EQUIPMENT

The available equipment is compact and rugged, suitable for field tests. Optional features include audio or visual alarm units which may be set for any point in the operating range of the instrument. The leakage test system may be automated for assembly-line operation.

An instrument as provided usually consists of a detector probe, filter, analyzer, flowmeter, metering valve, and pump. The valve adjusts the flow to the rate required for adequate sensitivity and response time. A neon light is provided at the end of the probe to indicate leakage conditions when the operator is in a noisy area and out of visual range of the indicator. The sampling system operates at slightly subatmospheric pressure; the pump can provide flow rates up to two liters per minute; auxiliary pumps can be used to increase pumping speed.

Table 17-1 summarizes the characteristics of light absorption leakage detectors. Descriptions of individual instruments may be found in Part III.

17.4 LEAKAGE TESTING METHOD

The absorption detector may be used for leak location or leakage measurement in a manner very similar to that discussed in Section 10, "Heated-anode Halogen Detector." Neither the ultraviolet nor the infrared detectors will be damaged by high concentrations of tracer gas. Nitrous oxide, the usual tracer gas, is not soluble to any large extent in rubber or plastic; hence, systems using these materials may be leak-checked with no difficulty. Because the molecular weight of this gas is only slightly higher than that of air, nitrous oxide does not stratify as much as do the heavier halogenated hydrocarbons.

Table 17-1

CHARACTERISTICS OF LIGHT ABSORPTION LEAKAGE DETECTORS

General Characteristics	Average Values Infrared	Ultraviolet
Sensitivity	1×10^{-6} atm-cc/sec 10 parts per million	5 parts per million
Tracer gas	Nitrous oxide, carbon dioxide	Chlorinated hydrocarbons; aromatic hydrocarbons
Output	Milliammeter	Milliammeter
Power requirement	115 volts 60 hertz or 190/260 volts 50 hertz	115 volts 60 hertz
Size	12 inches × 12 inches × 20 inches	Amplifier: 8 1/2 inches × 11 inches × 5 inches Detector: 6 inches × 6 inches × 19 inches
Weight	60 pounds	30 pounds
Price	$2000	$400

When used for leak location, the system has a response time of approximately three seconds. This, of course, can be changed by altering pumping speed or probe length. The response of the instrument is linear over the full scale, and calibration is accomplished by introducing tracer gas of a known concentration from a compressed-gas cylinder into the sample chamber of the detector. In this way, the instrument response is obtained in parts per million of tracer gas. The leakage rate is obtained by multiplying this response by the flow rate of gas through the sample chamber.

The detector may be either evacuated or at atmospheric pressure. If evacuated, the system pressure should not be allowed to vary by more than fifty times the pressure of the tracer gas, because of the outgassing products usually found in an evacuated system (water, carbon dioxide, and hydrocarbons) which also absorb infrared radiation.

Kaufman (Ref. 17-5) has shown that the infrared detector may be used in locating leaks in buried water lines. Water lines were injected with nitrous oxide to a ratio of 0.37 volume of N_2O to one volume of water. Leakage out of the lines was located by a detector probe as a result of the diffusion of gas to the surface of the ground.

passes through the reference cell as well as through the sample cell. The two radiation beams are admitted alternately into the detector by a chopper.

The radiation detector is a pneumatic device consisting of two chambers separated by a very thin membrane. These two chambers are filled with an infrared active gas, usually the same gas for which sensitivity is required. Hence, the name "selective detector." The membrane is metallized and mounted close to a fixed plate to form a small electric capacitor. Chopping of the radiation causes the gas in the detector to be alternately heated and cooled. The resulting pressure changes flex the membrane to cause a variation in the electrical capacitance. The capacitance variation modulates a sensitive radio-frequency oscillator whose signal is demodulated and rectified to drive an indicating meter.

Gases suitable for use in the absorption cell have absorption wavelengths in the range of two and ten microns (Ref. 17-1). Such gases have polyatomic molecules of dissimilar atoms. Other requirements of the tracer gas are that it must be:

- Noncorrosive to the system material
- No fire or explosion hazard
- Nontoxic
- Reasonably priced and readily available
- Producing good discrimination in normal atmospheric contaminants

Nitrous oxide (N_2O) is most often used as the tracer gas because it meets these requirements. Its major absorption band at 4.5 microns affords excellent discrimination ratios against atmospheric contaminants normally found in manufacturing plants.

It is completely nontoxic. With oxygen, it is a simple asphyxiant in the same class as nitrogen, helium, and hydrocarbons (Ref. 17-2). Nitrous oxide is an anesthetic, but a very weak one, since a concentration of more than 80 percent is necessary in order to produce deep anesthesia (Ref. 17-3). There is no evidence in the literature of any toxic effects due to ingestion or inhalation of nitrous oxide. The compound is noncorrosive and nonreactive with most materials (Ref. 17-4).

Nitrous oxide (N_2O) should not be confused with nitrogen oxide (NO), nitric oxide ($(NO)_2$), nitrogen dioxide (NO_2), nitrogen tetroxide (N_2O_4), or nitrous fumes (a mixture of NO and NO_2). With the exception of nitrous oxide (N_2O), all the oxides of nitrogen listed above are corrosive and poisonous. Unless the equipment is designed for their use, no attempt should be made to use any of these other nitrogen oxides for infrared leak detection.

Other gases besides nitrous oxide can be used as leak tracers. They must of course, be infrared-active, and their sensitivity will depend mostly on the discrimination ratios of the

Section 17

LEAKAGE DETECTION BY ABSORPTION OF ELECTROMAGNETIC ENERGY

17.1 INTRODUCTION

Leakage may be detected through the molecular absorption of radiant energy by the tracer gas. An absorption spectrum will not only identify the specific molecule involved but can also tell how much of that molecule is present in a given mixture. Energy wavelengths in the ultraviolet and infrared regions are most commonly used in commercial instruments.

The detection system consists of a radiation source, gas sample, reference sample, and radiation detector. Radiation passing through the sample is compared with that which passes through the reference gas. The difference in attenuation between the two absorptions is a measure of the concentration of the gas. Each instrument is specific for only one species of gas molecule and, by design, the possible interference by other gases is minimized.

Ultraviolet-type instruments are usually used for leakage monitoring. Infrared instruments are used for leak location and leakage measurements. The instruments are designed to be used at atmospheric pressure, but they can be modified for use under other conditions of pressure.

Figure 17-1 is a schematic diagram of a typical infrared detector. Two hot-wire sources provide the radiant energy which

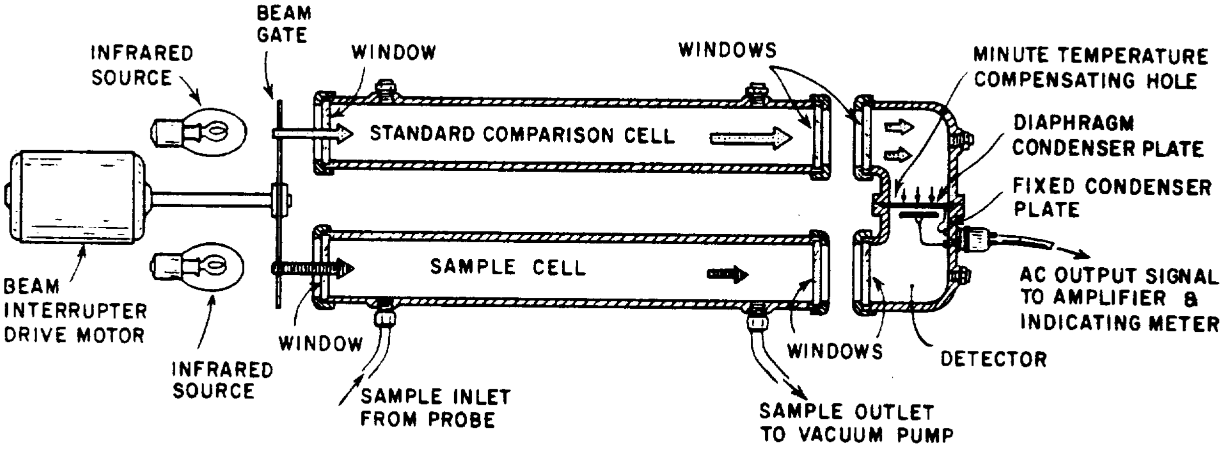

Figure 17-1. Infrared Leak Detector. (Reprinted with permission, from Neeley, A.H., Nitrous Oxide for Leak Detection, A: Chemical, Physical and Pharmacological Properties, with Results of Corrosion Tests (Ohio Chemical Technical Information Series: IA); Division of Air Reduction Company, Inc., Madison, Wisconsin, May 1957.)

Section 18

LEAK LOCATION BY MEANS OF CHEMICAL INDICATORS

Section 18

LEAK LOCATION BY MEANS OF CHEMICAL INDICATORS

18.1 INTRODUCTION

With the use of chemical indicators, leaks are located by the appearance of a liquid or the color change of a liquid. There are two different types of tests which may be employed:

- Chemical tests -- color indication is due to a reaction between the leaking tracer and a developer
- Penetrant tests -- color is inherent in the penetrant and is evident at the leak site because of migration to that point

Penetrant tests in addition to locating leaks, reveal cracks, surface imperfections, and poor welds.

The procedures are qualitative; thus the size of a leak cannot usually be determined. Each type of test (i.e., penetrant or chemical) must be considered individually since each has its own advantages and limitations.

For example, the major limitation of the chemical tests is the possibility that reactive chemicals might damage system parts. The penetrant tests can locate both leaks and surface imperfections; however, since penetrants are liquids, clogging of leaks can occur (see Section 6.6). This fact limits the utility of penetrants; they should not be used on systems which must subsequently be tested for very small ($< 10^{-6}$ atm-cc/sec atm) leakage rates.

18.2 SENSITIVITY

Chemical indicator tests are more sensitive at long exposure times. Unfortunately, the tests are not quantitative, because the indication of a leak is in the intensity of the color and area covered by the product of the reaction. However, the estimated sensitivity of the chemical reaction indicators is in the range of 10^{-3} atm-cc/sec.

The sensitivity of penetrants is thought to be several decades greater. Sensitivity of a penetrant is determined by knowledge of the time required for sufficient penetrant to flow through and be observed. When the physical properties of the penetrant are known, it is possible to calculate the sensitivity (Ref. 6-3).

18.3 MATERIALS AVAILABLE

Chemicals used for indicator tests are available from laboratory supply houses. Reagent grade chemicals should be used.

Penetrant materials are specially compounded dyes, oils, and solvents. These formulations are proprietary, but most of them depend upon a color-contrasting dye which is drawn into the defect. Sources of penetrants may be found in the listings of Part III.

18.4 LEAKAGE TESTING METHODS

These methods are easily performed, without the need for highly trained technicians or elaborate test equipment.

18.4.1 Penetrant Tests

The penetrant test consists in applying a liquid penetrant to the surface of a part where it can enter into any defects open to the surface. After the penetration period expires, excess material on the surface is removed and a developer is placed on the surface. The developer is a light-colored, powdered material (possibly in suspension), which adsorbs the penetrant that had previously seeped into surface openings. Development produces contrasting spots, much larger than the surface openings with which they are associated.

Penetrants are usually of two types: dye which fluoresces under ultraviolet light, or colored dye which is in high contrast to the metal or developer. The penetrant may be applied on the same surface as the developer, showing both leaks and surface imperfections, or the penetrant may be placed on one side of a surface and the developer on the other side. In this manner only leaks through the part will be seen.

Most commercial penetrants have properties of high wetting power, low surface tension, low viscosity, and high indicating ability. Complete details for conducting tests may be found in the *Nondestructive Testing Handbook* (Ref. 18-1).

Other fluids which will indicate the presence of a leak can be used, especially if they are inherent to the system. For example, many oils are fluorescent under ultraviolet light and their presence can be used as an indication of leaks.

Large systems can be tested under stress by filling the systems with a testing fluid under pressure and examining for leaks. A patent by Polito (Ref. 18-2) describes a water solution for such tests; it consists of 0.5 percent (by weight) monoethanolamine, 0.05 percent polyethylene glycol tert-dodecylthioether, and 50 parts per million fluorescein. The amine is used in this case as an antioxidant and a corrosion inhibitor. The thioether is used as a surfactant to reduce the surface tension of the solution and to better wet the walls of the leak. The indicator is fluorescein, which glows brightly in ultraviolet light. After pressurization with the test liquid, the suspected leak areas on the outside of the system are examined with a portable ultraviolet light.

18.4.2 Chemical Tests

Chemical test methods depend on a chemical reaction to produce a smoke or change in color at the leak site. A number of typical examples are described below.

18.4.2.1 Ammonia Gas. Ammonia gas makes an excellent tracer because it is chemically basic, is not highly toxic, and is only mildly corrosive. Its corrosive nature is strongly exhibited only on brass parts. Delafosse, Noé and Troadec (Ref. 18-3) describe a variety of possible tests using the gas. The ammonia tracer can be introduced as an anhydrous gas, or a cloth saturated with ammonia solution can be placed within the pressurized space. The sensitivity of the tests will be dependent upon the concentration of the gas.

Where leaks are present, the leakage of ammonia will be revealed by a white chemical fog which develops when the atmosphere is probed with a swab wetted with 0.1 N hydrochloric acid. Sulfur dioxide, such as from a sulfur candle, can also be used to reveal the presence of ammonia. Smoke has also been used to detect leaks (Ref. 18-4).

A variety of indicator solutions may be used to give a color change with ammonia. These all depend on a change of pH of the indicating solutions. Therefore, the pH of the solutions should be carefully adjusted so that they are at the threshold of color change prior to use.

A cloth dampened with a phenolphthalein solution and placed over the test area shows the location of leaks by a pink discoloration. The indicator consists of 1.0 percent phenolphthalein in a solution of equal amounts of water and ethyl alcohol. A better indicator is: five parts two-percent phenolphthalein in alcohol, two parts distilled water, ten parts glycerin, and sufficient titanium oxide powder to thicken the solution to the consistency of a thin paint. The titanium oxide powder serves the additional purpose of providing a white background against which the color change is contrasted.

For a yellow-to-purple color change (Ref. 18-5) 40 milligrams of bromocresol purple is dissolved in four milliliters of 0.02 N sodium hydroxide. This is diluted to 100 milliliters. In a separate container, ten grams of starch is added to 500 milliliters of boiling water and stirred to form a slurry. The dye solution is added to the starch slurry. To this mixture is added five milliliters of Tween 40 wetting agent, and the pH is adjusted to 5.0 with dilute hydrochloric acid. To test, a small portion of the indicating agent is put on a piece of paper and the paper is moved rapidly through the air, horizontally, about 12 inches away from the open top of a bottle of standard ammonia reagent. Immediate appearance of purplish color on the paper shows the agent is ready for trial application. Otherwise, slight additional pH adjustment may be necessary.

It is possible to use alizarin between a pH of 5.5 and 6.8 or methyl red between a pH of 4.4 and 6.0 as an indicator (Ref. 18-3). These show a color change better if a trace of methelene blue is added to the solution. The addition of calcium chloride to the indicator solution to complex the ammonia increases color retention as well as increasing the sensitivity of the test.

18.4.2.2 Carbon Dioxide Gas. Carbon dioxide can be used as a tracer gas. It is not as sensitive as ammonia but is noncorrosive. The system should be filled with the gas and the outside sprayed with an agar-agar solution of an indicator (Ref. 18-6). Agar-agar solutions can be "loaded" with sodium carbonate and phenolphthalein, yielding a bright cherry red solution which turns white upon contact with carbon dioxide. This solution can be sprayed onto the surface to form a stable red film. Carbon dioxide causes a white spot to be produced in the agar-agar film at points of leakage. Studies indicate that the volume of agar-agar film which is discolored is directly proportional to the amount of carbon dioxide that enters the film. Therefore, the area of discoloration is directly proportional to the amount of carbon dioxide which has escaped.

The spray solution consists of (parts by weight): agar-agar, 1.0; distilled water, 40.0; anhydrous sodium carbonate, 0.10; and phenolphthalein, 0.15. It is important to obtain the proper viscosity of agar-agar solution, which should be between eight and ten millipoises at the spraying temperature.

When the spray solution is prepared, the dry powders (agar-agar, sodium carbonate, and phenolphthalein) should be blended thoroughly in proper proportions. To the dried powders boiling distilled water should be added, with stirring to disperse the solid constituents. The resulting mixture should be heated with constant stirring, to between 96 and 98°C, on either a hot plate or a steam bath. When the solid is completely dissolved and a clear solution is obtained, it should be allowed to cool to between 65 and 70°C. At this temperature it may be stored in a closed container and sealed to exclude air and small quantities of carbon dioxide.

To perform the test, the hot agar-agar solution from the storage container (at 65 to 70°C) is poured into the preheated sprayer bottle. The compressed air supply should be preheated in a heat exchanger to the spraying temperature. The spray nozzle should be held approximately two feet from the test piece. A single coating should be applied, in one pass. Multiple coatings should be avoided. Spraying should always be done in a horizontal direction, never vertically.

After testing, the agar-agar film can be removed completely with a jet of high-velocity air from an air nozzle. This leaves the surface of the device clean and dry.

18.4.2.3 Miscellaneous Chemical Tests. Hydrogen sulfide has been used as a tracer gas to locate leaks (Ref. 18-7) with an indicator of a five-percent solution of stannous chloride. The leak location is shown by a brown stain of stannous sulfide. Because of the poisonous nature of hydrogen sulfide, this is not a very popular method.

A variety of other chemical reactions may be used for leak location. For example, precipitates may be formed by hydrogen sulfide with silver or lead salts (Ref. 18-5). Leaks in gas pipelines have been located by the reaction of silver salt solutions with acetylene gas (Ref. 18-8). Water has been used as a penetrant (Ref. 18-9), with anhydrous copper sulfate as a developer. Anhydrous copper sulfate turns blue in the presence of water.

Leak-indicating paints have been reported by Griffith (Ref. 18-10). An immediate color change occurs upon contact with liquid hydrazine or its derivatives. Exposure to oxidizers containing nitric acid or halogens (bromine pentafluoride and chlorine trifluoride) immediately bleaches the paint. However, exposure of the paint to direct sunlight destroys the indicating ability within two weeks.

Section 19

LEAK LOCATION BY HIGH-POTENTIAL DISCHARGE

Section 19

LEAK LOCATION BY HIGH-POTENTIAL DISCHARGE

19.1 INTRODUCTION

Leaks in evacuated systems can be located with the aid of a high-potential discharge. There are two different ways by which this method may be applied (the choice will depend upon the particular system to be tested):

1. The exterior of the system is probed with an electrode. Leaks are detected by the appearance of a spark between the electrode and the system.
2. The color of a corona discharge within the system is observed as the exterior is probed with a tracer material.

The first method is limited to glass systems or to the glass parts of metal systems; while the second method does not have these limitations, it does require the presence of a window for viewing the nature of the discharge.

19.2 SENSITIVITY

These methods are qualitative and are useful only from a few torr to about 10^{-2} torr. They will probably detect leakages of about 10^{-4} atm-cc/sec. Pirani and Yarwood (Ref. 5-3) claim to have detected a leakage of 10^{-12} atm-cc/sec; however, an elapsed time of six months was required while the pressure in the test device increased from 1.0 to 1.01 torr.

19.3 DESCRIPTION OF EQUIPMENT

A hand-held high-potential probe is available from laboratory supply houses as a "spark-coil detector," or Tesla coil. An auxiliary glow-discharge tube (Geissler tube) can be attached or built into the system with electrodes sealed into the ends, to which a source of high voltage (DC or AC) can be connected.

Both of these devices operate at potentials of several kilovolts. The output should be provided with a circuit to limit the current to a few microamperes.

The glow-discharge tube may be converted to an audible detector by letting the tube be the variable factor in a relaxation oscillator circuit. Figure 19-1 is a schematic diagram of such a circuit, suggested by Lloyd (Ref. 19-1). He observed the amplitude of the oscillations to peak at 4×10^{-1} torr (2.5 kilohertz). On either side of this pressure the oscillations fell off to zero at pressures of 5×10^{-2} torr and 10 torr.

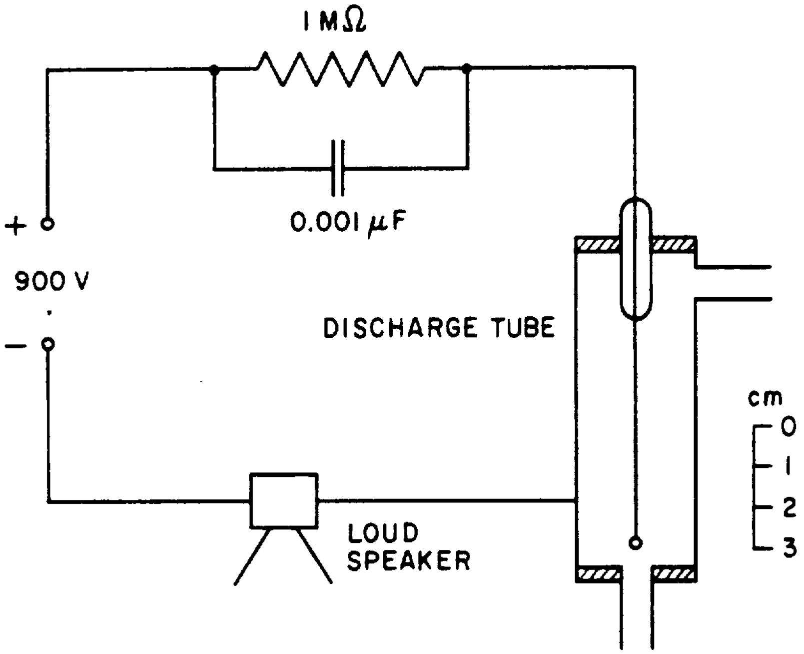

Figure 19-1. Discharge Tube Audible Leak Locator. (Reprinted with permission from J.T. Lloyd, Journal of Scientific Instruments, Vol. 27, 1950, p. 76; The Institute of Physics and The Physical Society, London.)

19.4 LEAK TESTING - SPARK DISCHARGE

With the system evacuated to a pressure between 10 and 10^{-2} torr, the exterior is probed with the spark coil. The probe tip should be held about 0.5 to 1.0 centimeter from the surface which is to be tested and the probe moved slowly over the suspected leak. Continual application of the probe to one spot may puncture the glass wall of the system, score the barrel of a Teflon stopcock, or rupture gaskets. The probe cannot be brought closer than several centimeters from metal parts, as the spark will ground through the metal.

The presence of a leak is shown by the appearance of a spark from the electrode through the leak which will then appear as a white spot. The reliability of this method depends upon operator skill in probing the complete system.

19.5 LEAK TESTING - CORONA DISCHARGE

This test method is quite similar to that of the spark-discharge test. The pressure in the test system must be in the same range as that for the spark discharge, and a suitable glass viewing window or tube must be available for observing the color of the discharge.

If the system has a glass section, then a spark coil can be used to excite the discharge. Guthrie (Ref. 5-4) recommends that a spark gap of about 0.5 to 1.0 centimeter be connected in parallel with the high-voltage electrode and grounded to eliminate the possibility of puncturing the glass.

A corona-discharge tube can be attached to the system, preferably near the forepump, where the pressure will be sufficiently high for a glow to occur. A leak is located by applying a tracer material to the suspected leak and observing the color change in the corona glow.

The nature of this discharge will depend on the pressure and on the gases in the system. The color is characteristic of the gases present. For air, the color tends toward red or purple. The exact color (as for other gases) depends to some extent on the glass used in the system. Pyrex or soda glass will show a yellow-green fluorescence, while lead glass shows a blue fluorescence. The tracer material can be a gas or a liquid. Some materials commonly used are: illuminating gas, ether, and carbon dioxide. With the first two materials the discharge takes on a grayish-blue appearance. This is similar to the characteristic color of carbon dioxide but, possibly because of fluorescence of the glass, the color is often reported as bluish-green.

Volatile liquid such as benzene, acetone, or methanol are frequently used. In fact, any material whose discharge color contrasts with the background could be used as tracer material. However, gasoline, benezene, pyridine and solutions containing nitrogen compounds should not be used because they adhere to glass. Table 19-1 shows the glow-discharge colors which are associated with a number of different tracer materials.

The problem of two leaks of more or less equal size occurs rarely but must be considered with complicated apparatus. It is fortunately solved by the fact that in a mixture of more or less equal parts of carbon dioxide and air the color of the positive column tends toward that of carbon dioxide. So if there is carbon dioxide on either of the leaks, that leak is located and can be stopped, and the other can be found later.

Although the sensitivity and reliability of leak location by high-potential discharge are dependent upon operator skill, recognition of a leak is relatively easy. The operator must be knowledgeable in the probing of all possible leakage areas and able to recognize the indication of a leak. Probing of the system may proceed at a rate of approximately one foot per minute. Because of the high molecular weights of some of the tracers, considerable delay may occur between the time the tracer enters the vacuum system and the time it passes into the discharge area. (The entire system may be checked for leakage by hooding with tracer gas as described in Section 5.2.)

Table 19-1

DISCHARGE COLORS IN GASES AND VAPORS AT LOW PRESSURES*

Gas	Negative Glow	Positive Column
Air	Blue	(Reddish)
Nitrogen	Blue	Yellow (red gold)
Oxygen	Yellowish white	Lemon
Hydrogen	Bluish pink (bright blue)	Pink (rose)
Helium	Pale green	Violet-red
Argon	Bluish	Deep red (violet)
Neon	Red-orange	Red-orange (blood red)
Krypton	Green	- - -
Xenon	Bluish white	- - -
Carbon monoxide	Greenish white	(White)
Carbon dioxide	Blue	(White)
Methane	Reddish violet	- - -
Ammonia	Yellow-green	- - -
Chlorine	Greenish	Light green
Bromine	Yellowish green	Reddish
Iodine	Orange-yellow	Peach-blossom colored
Lithium	Bright red	- - -
Sodium	Yellowish green (whitish)	Yellow
Potassium	Green	Green
Mercury	Green (goldish white)	Greenish blue (greenish)

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*Reprinted with permission from Vacuum Technology, by A. Guthrie, John Wiley and Sons, Inc., New York, 1963, p. 456.

\- - - Indicates no distinctive color given.

This testing method may be applied to sealed systems which contain a suitable indicating gas; for example, neon. The color of the induced glow discharge is compared with a standard whose pressure is known. Pirani and Yarwood (Ref. 5-3) suggest such a test for quality control tests where extensive experience in production is lacking.

For the smallest leaks, a discharge tube and a stopcock should be connected to the line between the forepump and the diffusion pump. When the stopcock is closed, gas coming through the diffusion pump accumulates in the discharge tube. If the discharge tube is clean, it is possible to distinguish between tracer gas and air in the accumulated gas. Traces of gas on the walls of the discharge tube will interfere seriously with the test if they are freed. So, if it takes longer than a few minutes to make a test, the discharge should not be started until it is time to test it. With this precaution, however, one may make conclusive tests and locate a leak definitely, even when it takes hours to accumulate enough gas.

Section 20

IONIZATION-GAGE LEAKAGE TESTING

Section 20

IONIZATION-GAGE LEAKAGE TESTING

20.1 INTRODUCTION

An ionization gage may be used as a sensitive indicator of gas or vapor leakage either into or out of an evacuated system.

In this gage a stream of electrons is provided to ionize gaseous components in the vicinity of the gage electrodes. As the ions approach a negatively charged collecting electrode, they cause a current to flow in an external metering circuit. This current is dependent on the product of the electron current, the density of the gas in the gage, and a sensitivity factor which is characteristic mainly of the type of gas involved. The ion current of a gage may be calibrated in terms of pressure if the type of gas, the temperature, the electron current, and the gage sensitivity factor are known. The sensitivity factor depends on the probability of ionization, which is in turn dependent on applied voltage and the total number of electrons per molecule.

A change in ion current will occur when there is a change in gas composition such as may be brought about by leakage of a gas tracer into a chamber in which a gage is located. Leakage identification and leak location with an ion gage depend upon a change in response to a change in gas composition. Testing by ionization gage is not normally made specific to any particular tracer gas, and changes in gage response can arise as a result of changes in parameters other than gas composition -- such as changes in the pumping speed and outgassing rates.

Electrons required to generate ions in an ionization gage may be supplied from a thermionic emitter, or from a high-voltage gas discharge which is sustained at low gas pressures by a static magnetic field. The emitter in a hot-cathode ionization gage is sensitive to loss of emission by oxidation, deposition, or alloying of a nonemitting layer on the hot surface of the emitter. Loss of emission can be irreversible unless the operating pressure is kept below approximately 5×10^{-4} torr.

The ion-discharge (Penning) type of gage may be employed to monitor pressures at levels higher by three orders of magnitude without causing permanent harm to the gage. The ion-discharge type of gage may also be constructed to monitor changes in gas density at extremely low pressures. Cold-cathode gages having the geometry of an inverted magnetron have been built to measure pressures between 10^{-3} and 10^{-12} torr (Ref. 2-3, pp. 334-336). They are, of course, adaptable for monitoring minute changes in gas pressure or gas composition in that pressure range.

It is more common to find a hot-cathode triode ionization gage as part of a vacuum system. This type of gage is most likely to be available for use in detecting system leakage in the range of 10^{-4} to 10^{-8} torr.

20.2 GAGE RESPONSE IN LEAK SENSING

A procedure for using an ionization gage in leak sensing and location is described below. An expression is derived for the change in response which may be expected when a tracer gas is used.

Figure 20-1 shows how an evacuated chamber which is being continuously pumped may be tested with an ionization gage. The surfaces of the chamber are exposed to tracer gas from a tracer probe (or they can be flooded with tracer gas by enclosing the chamber with a hood). If a leak is present, both air and tracer gas enter the chamber and pass to the vicinity of the gage. The change in gage response may be derived as follows:

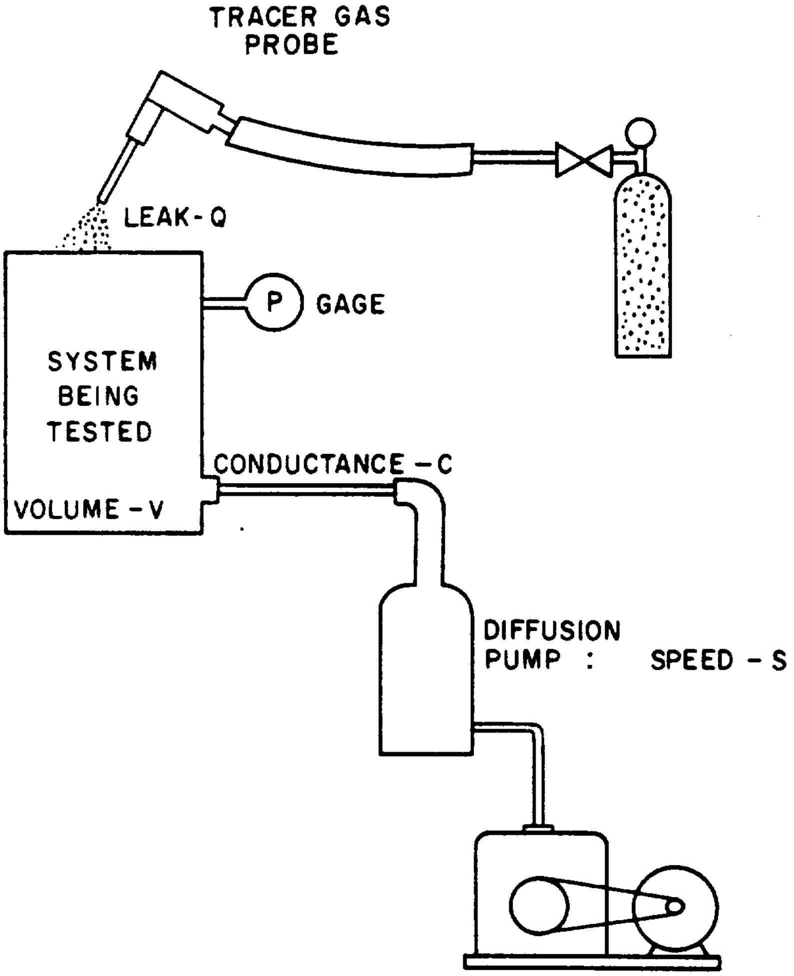

Figure 20-1. Idealized System for Vacuum Gage Response Testing

Assume that the base pressure in the chamber is constant at a value P_2 with an outflow of gas to the pumps Q. C is the molecular flow conductance of the tubing leading to the pumps from the chamber, and is assumed to be the effective pumping speed at the site of the gage. Thus:

$$Q = P_2 C \tag{20-1}$$

If leakage is governed by laminar flow it will be related to pressure, leak conductance for laminar flow, and viscosity. If P_1 is the total pressure of incoming leakage,

$$Q_L = \frac{C_L}{\eta} (P_1^2 - P_2^2) \tag{20-2}$$

Since $P_1 >> P_2$,

$$Q_L = \frac{C_L P_1^2}{\eta} \tag{20-3}$$

Suppose the relative concentration of tracer gas is X. The relative concentration of air is then 1-X. The leakage will be removed from the chamber at a rate Q such that:

$$Q = C_a P_{2a} + C_t P_{2t} \tag{20-4}$$

At the same time leakage into the chamber will consist of two terms like that of Equation 20-4. The exiting rate of a given gas component will be equal to the rate of entrance of that component when equilibrium of the system is reached. Thus:

$$\frac{C_L P_1^2}{\eta_t} (X) = C_t P_{2t} \tag{20-5}$$

$$\frac{C_L P_1^2}{\eta_a} (1-X) = C_a P_{2a} \tag{20-6}$$

The total pressure in the chamber is obtained from the above two equations:

$$P_2 = P_{2t} + P_{2a} = C_L P_1^2 \left[\frac{X}{\eta_t C_t} + \frac{(1-X)}{\eta_a C_a}\right] \tag{20-7}$$

When no tracer gas is present the equilibrium equation is:

$$\frac{C_L P_1^2}{\eta_a} = C_a P_{2a}\Big|_{X=0} \tag{20-8}$$

The change in total pressure which occurs when tracer gas appears at the leak entrance is obtained by subtracting Equation 20-8 from Equation 20-7. Thus:

$$\Delta P_2 = C_L P_1^2 \left[\frac{X}{\eta_t C_t} + \frac{1-X}{\eta_a C_a} - \frac{1}{\eta_a C_a}\right] \tag{20-9}$$

If the leak is assumed to be flooded with tracer, $X = 1$, and

$$\Delta P = C_L P_1^2 \left[\frac{1}{\eta_t C_t} - \frac{1}{\eta_a C_a} \right] \qquad (20\text{-}10)$$

If the sensitivity of the ion gage to air is K_a and to the tracer gas K_t, the change in gage reading, ΔG, on applying the tracer is:

$$\Delta G = C_L P_1^2 \left[\frac{K_t}{\eta_t C_t} - \frac{K_a}{\eta_a C_a} \right] \qquad (20\text{-}11)$$

It can be seen that the maximum change in gage reading will be obtained when there is:

1. Complete coverage of the leak by the tracer gas
2. High sensitivity of the gage for the tracer gas
3. Low viscosity of the tracer gas
4. A small value of C_t, the effective pumping speed for tracer gas

The tracer gas should have a high molecular weight, since the conductance of the tubing leading to the pump, C_t, is inversely proportional to the square root of the molecular weight of the gas involved.

The above derivation of gage response assumes that flow through the leak is laminar. In small leaks ($< 10^{-6}$ atm-cc/sec) the flow will be molecular. If the leakage into the system is molecular, and the pumping speed is determined by the tubulation leading to the pump, the change in gage response can be expressed as:

$$\Delta G = P_1 \quad (X) \left[K_t \frac{C_{Lt}}{C_t} - K_a \frac{C_{La}}{C_a} \right] \qquad (20\text{-}12)$$

where C_{Lt} and C_{La} are the molecular-flow conductances of the leak for tracer gas and air respectively.

Quite evidently the leak conductances are not generally known in advance. However, the equation does show the desirable conditions for obtaining a maximum response to tracer gas:

1. Tracer gas should flood the leak area; $X \rightarrow 1$.
2. Pumping conductance for tracer gas, C_t, should be low.
3. Gage sensitivity for tracer gas should be higher than that for air.
4, Pressurizing the outside of a container will increase the change in gage response. Response will increase linearly with pressure if the flow is molecular.
5. Gage response will be independent of the viscosity of the tracer gas.

Since there are a variety of factors involved in choosing a proper combination of gas and gage, it is often easier to determine the sensitivity factor experimentally. Blears and Leck define this factor as:

$$\phi = \frac{\text{pressure caused by tracer gas on the leak}}{\text{pressure on system with air on leak}}$$

The experimental values of this factor are shown in Table 20-1 for both a hot-cathode gage and a thermal-conductivity (Pirani) gage. The minimum detectable leak can be determined by:

$$Q_{min} = \frac{\Delta P_{2a} C_a}{\phi} \qquad (20\text{-}13)$$

where

ΔP_{2a} = smallest measurable air pressure variation

Q_{min} = smallest measurable leakage

C_a = pumping speed for air at the gage

Table 20-1

LEAKAGE TESTING SUBSTITUTION FACTORS ϕ
(Ref. 4-6)*

Tracer Gas	Hot-cathode Ionization Gage	Pirani Gage
Butane	10	1
Diethyl ether	5	0.7
Carbon dioxide	1	0.3
Carbon tetrachloride	1	0.05
Benzine	0.3	0.1
Hydrogen	0.4	0.4
Coal gas	0.25	0.25

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It is apparent from the above discussion that the minimum measurable leakage will be within a decade of the minimum measurable pressure change multiplied by the pumping speed at the pressure measurement site. In the design of this type of leakage measurement, the response time of the system must also be taken into account. The pumping speed used is the pumping speed at the site of the gage. Thus the location of the gage affects the sensitivity. If the gage is connected by way of a restriction, it will be difficult to detect small leaks anywhere except near the gage itself.

In the testing of an evacuated system it is important that pressure fluctuations (such as those which arise from the backing and the diffusion pumps) be reduced to deviations not exceeding 0.2 percent. This can be accomplished by reducing the cross section of the pumping port or by constricting the gage tubulation. In the latter case the gage response then becomes slower and a longer time is required to achieve high sensitivity.

It is desirable that the tracer gas have as different an ionization efficiency from the background gas (air) as possible. In general, gage sensitivity increases with the number of electrons in the molecule (Ref. 2-3, p. 321). It is possible for the change in gage response to decrease in the presence of tracer gas rather than increase (Ref. 19-1). Examination of ion gage sensitivities suggests that the best materials for this procedure are either those of low molecular weight (hydrogen, helium, neon) or those of high molecular weight (acetone, ether or alcohol).

In using liquids, care must be taken that they do not plug the leak. Response may be delayed by adsorption on the leak surface.

As long as the leaks being located are the ones that limit the system pressure, this method may be applicable to very low pressures and/or very low leak rates. It has been shown to be a more sensitive method than the use of the mass-spectrometer leak detector (Ref. 20-1).

The sensitivity of the ionization-gage method of leak sensing is greatly dependent on the stability and sensitivity of the electrometer used to measure the ion current as well as upon gage, tracer-gas, and pumping parameters. For routine testing with a conventional triode gage and current monitor, the detection of leakage rates between 10^{-4} and 10^{-6} atm-cc/sec can be expected. Modified gages permit extension of the sensitivity to 10^{-10} atm-cc/sec (Ref. 20-2).

20.3. IMPROVING SENSITIVITY

In order to improve the sensitivity of this method, the background ionization current may be nulled by means of a sensitive difference amplifier or a galvanometer with backing-off voltage control, so that very small changes in ionization current may be detected. An example of a circuit for such testing is shown in Figure 20-2. The indicating instrument has been replaced with a potentiometer and the null balance instrument is a galvanometer or a sensitive microammeter, either of which is provided with a suitable shunting circuit. In a stable vacuum a constant current flows through the gage tube and the potentiometer, creating a steady voltage drop across the potentiometer. The battery provides a reference voltage and the potentiometer can be adjusted to give a null indication on the galvanometer. The shunting switch is left closed until this adjustment is made.

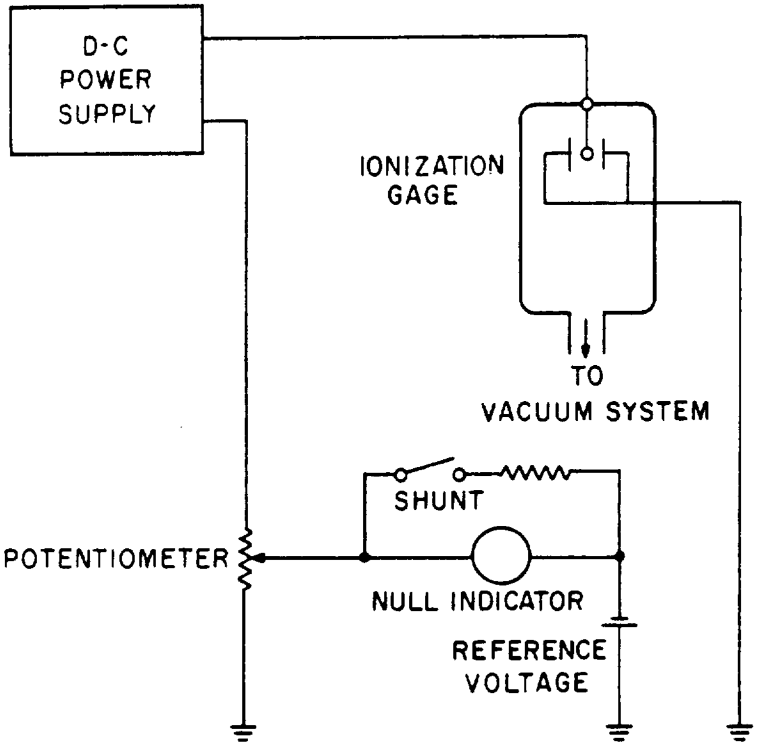

Figure 20-2. Null Balance Circuit for Leak Location. (Reprinted with permission from W.E. Briggs, A.C. Jones, and J.A. Roberts, "Leak Detection Techniques", 1958 Fifth National Symposium on Vacuum Technology Transactions, Symposium Publications Division, Pergamon Press, New York (Ref. 10-2).)

Care must be taken that the tracer gas does not permanently react and change the gage sensitivity. For example, Varicak (Ref. 20-3) found that after carbon dioxide had been applied for some time, the sensitivity of a Penning gage changed. The discharge current decreased about 30 to 40 percent, probably because of a film of carbonates on the electrodes.

The sensitivity of an ionization gage to tracer gas can also be increased if the gas is brought selectively to the gage, by the use of a selective membrane or a cryogenic trap in front of the gage. For example, if an ionization gage is separated from the test system by means of a palladium membrane, and if the membrane is heated to about 700°C, the presence of hydrogen can be easily detected by the gage because of the rapid and selective permeation of hydrogen through hot palladium.

When the palladium barrier gage is used and maximum sensitivity is desired ($\Delta P \sim 2 \times 10^{-8}$ torr) it is necessary to place a liquid nitrogen trap between the gage and the rest of the system; this excludes hydrocarbons and water vapor from the gage.

Such vapors dissociate at the hot palladium surface to give hydrogen, which produces a spurious response. In addition, the cracked hydrocarbons build up a carbon layer on the palladium which reduces its permeability.

It is also desirable to use a mercury rather than an oil diffusion pump in the vacuum system since the hydrogen which results from the decomposition of diffusion-pump oil gives rise to an unstable background ion current in the gage. In a system containing multiple leaks, oxygen in the air entering the undetected leaks combines at the hot palladium surface with the hydrogen entering through a leak which is being probed. If there is an excess of oxygen all hydrogen will react with the oxygen before it can pass through the barrier, and will therefore be undetected. Under these circumstances, Ochert and Steckelmacher (Ref. 6-7) have suggested that a controlled leak of hydrogen should be admitted to the system to take up the oxygen. To obtain maximum leak-detection sensitivity in the presence of oil vapor it has sometimes been found necessary to maintain a hydrogen partial pressure in the system of about 3×10^{-7} torr by the addition of a glowing tungsten filament at about 800°C (Ref. 20-4).

If air is admitted to the ion gage, the palladium becomes oxidized even if it is cold. Whenever this occurs, two to three hours of run-in time are required to obtain reproducible results on duplicate runs. Therefore, even if the gage is not in use the forepumps should be operated continuously to prevent air contact with the palladium. If the gage is left exposed to the atmosphere, several warm-up runs should be made, allowing hydrogen to pass through the calibrated leaks and pumping down between successive runs.

As another example, it is possible to use an absorbent bed which will pass the tracer gas and block air. Silica gel, outgassed at 300°C and then cooled to liquid nitrogen temperatures, is commonly used for this purpose. Under these circumstances, silica gel readily passes hydrogen and the noble gases (helium, neon, argon) but not air. A system using a silica gel bed with a cold cathode gage and hydrogen has been described by van Leeuwen and Oskam (Ref. 20-5). Further refinements of this gage separated it from the system by a liquid nitrogen cold trap filled with silica gel (Ref. 20-6).

Van Leeuwen and Oskam claimed this system to be about a hundred times more sensitive than the palladium-hydrogen system. However, several hours were required to measure leaks of the order of 10^{-12} atm-cc/sec, and careful degassing of the leak detector and the tube to be tested was necessary. One advantage claimed for silica gel is a long usage time before it has to be degassed. The increased sensitivity of silica gel is claimed to be due to less gas evolution from the gel than from heated palladium; this results in lower pressures. This detector, although very sensitive, is limited by long pump-down times.

A dual magnetron leak detector is described by Beck and King (Ref. 20-7). Two magnetron ionization gages are connected in series, with a cryogenic trap between them. The outputs of these two gages are balanced on a bridge. Tracer gas changes the current of the first gage, but is condensed in the trap and therefore does not affect the second gage. With two gages, background pressure variations do not affect the detector. The sensitivity of this detector is reported to be 10^{-10} atm-cc/sec.

The inverted magnetron can be converted to an extremely sensitive helium leak detector (Ref. 9-9). It operates without a hot filament, is inexpensive, small, rugged, and bakeable, and the electronic circuitry is simple. Leakages of 10^{-13} atm-cc/sec are readily detected, while with selective pumping the minimum detectable leak is claimed to be 10^{-13} atm-cc/sec.

Negative-ion forming tracer gas (such as refrigerant F-12) can be detected in a modified ionization gage described by Perkins and Robinson (Ref. 20-8). Because refrigerant gases are uncommon in vacuum systems it is possible to use them to probe for leaks. At a system pressure of 10^{-4} torr a negative-ion partial pressure of 10^{-11} torr can be detected.

One very sensitive means of locating leaks in vacuum systems is to observe the temperature-limited emission of a tungsten filament in a vacuum. Lawton (Ref. 20-9) found that when a stream of oxygen is blown over the outside of a leak, the resulting increase in oxygen pressure in the vacuum system causes the emission of the filament to drop. Although the principle has been known for a long time, and various circuits developed for its use (Ref. 20-10), this technique has not been extensively used.

Leger (Ref. 20-11) developed an instrument using this technique. Barton (Ref. 20-12) describes experiments in which the grid of a triode ionization gage was connected externally to the collector to form a diode. This was used to detect oxygen admitted to the apparatus under controlled conditions. He reports that an air leak which gave rise to a partial pressure of 10^{-7} torr was readily detected when probed with oxygen.

The detection circuit used was a modified ionization-gage control unit. The filament was heated by a regulated power supply but was not emission-regulated. The emission current was read on a 0 to 10 microammeter in series with a 4.5-volt battery and a resistor. In this way, it was possible to read a change of a microampere at an emission of more than ten microamperes.

Bloomer and Brooks (Ref. 20-13) examined the requirements for stable operation of this type of detector, using thoria-coated tungsten filaments. They found it best to reduce the thoria to thorium at the beginning of the test by heating for a few seconds to a temperature of 2400°K. The greatest sensitivity is at an operation temperature just below 1900°K, when the tungsten surface is partly covered with thorium. This can be obtained only when leaks of 10^{-9} torr-liters per second or less are remaining in a well-baked system pumped at a speed of 0.1 liter per second.

The filament can become desensitized when it is carburized. Because of the danger that this could happen in the presence of hydrocarbon vapors, and because of the influence of residual water vapor upon the emission of electrons from the thoriated tungsten, the detector is not very suitable for use in an unbaked apparatus. If a filament accidentally becomes carburized it must be replaced; no thermal treatment cycle will bring it back to a sensitive state. But in a well-baked system thoriated filaments can, if necessary, always be restored to a desired state of sensitivity by a short period of running at a temperature of about 2400°K.

20.4 DISCHARGE GAGES AND ION PUMPS IN LEAK SENSING

Cold-cathode, gas-discharge ion pumps are convenient instruments for leak location. An ion pump acts not only as a pump but also as an effective pressure gage, since the pump current is proportional to the number of molecules being pumped. Pump current is also dependent on the ionization efficiency. Pumping speed is dependent on the chemical reactivity of the gas molecules being pumped rather than on their molecular weight. Therefore, the response of an ion pump to a tracer gas will be different from that of a triode ionization gage.

Figure 20-3 shows the response of ion-pump current to leakage as a function of time for five typical trace gases (Ref. 20-2). The short-term response is generally quite different from the long-term time response. To make full use of the procedure the tracer gas must be applied to suspected leak areas for a time period which is about five times the ratio of the pumping speed to system volume.

The best gases for use in leak location by ion pump are argon, oxygen, and carbon dioxide. Estimates of the minimum detectable leakage that can be located with an ion pump are about 10^{-11} torr-liters per second. This is a conservative estimate of the sensitivity. The current changes being measured are several orders of magnitude greater than the corresponding mass-spectrometer ion currents (Refs. 20-2, 20-4).

A novel leak detector has been described by J.R. Young (Ref. 20-15). Using the system shown in Figure 20-4, the procedure is to evacuate an ion pump and keep it operating at low pressure with the valve V_1 closed. The system to be leakage-tested is first evacuated by a mechanical pump to a pressure of $1\text{-}10 \times 10^{-3}$ torr. Valve V_1 is then opened and V_2 closed. An equilibrium pressure is reached in a few minutes. When the leak is probed with argon, the ion pump current increases rapidly, presumably because of the low speed of the pump for argon. Probing with hydrogen and oxygen causes a reduction in pressure,

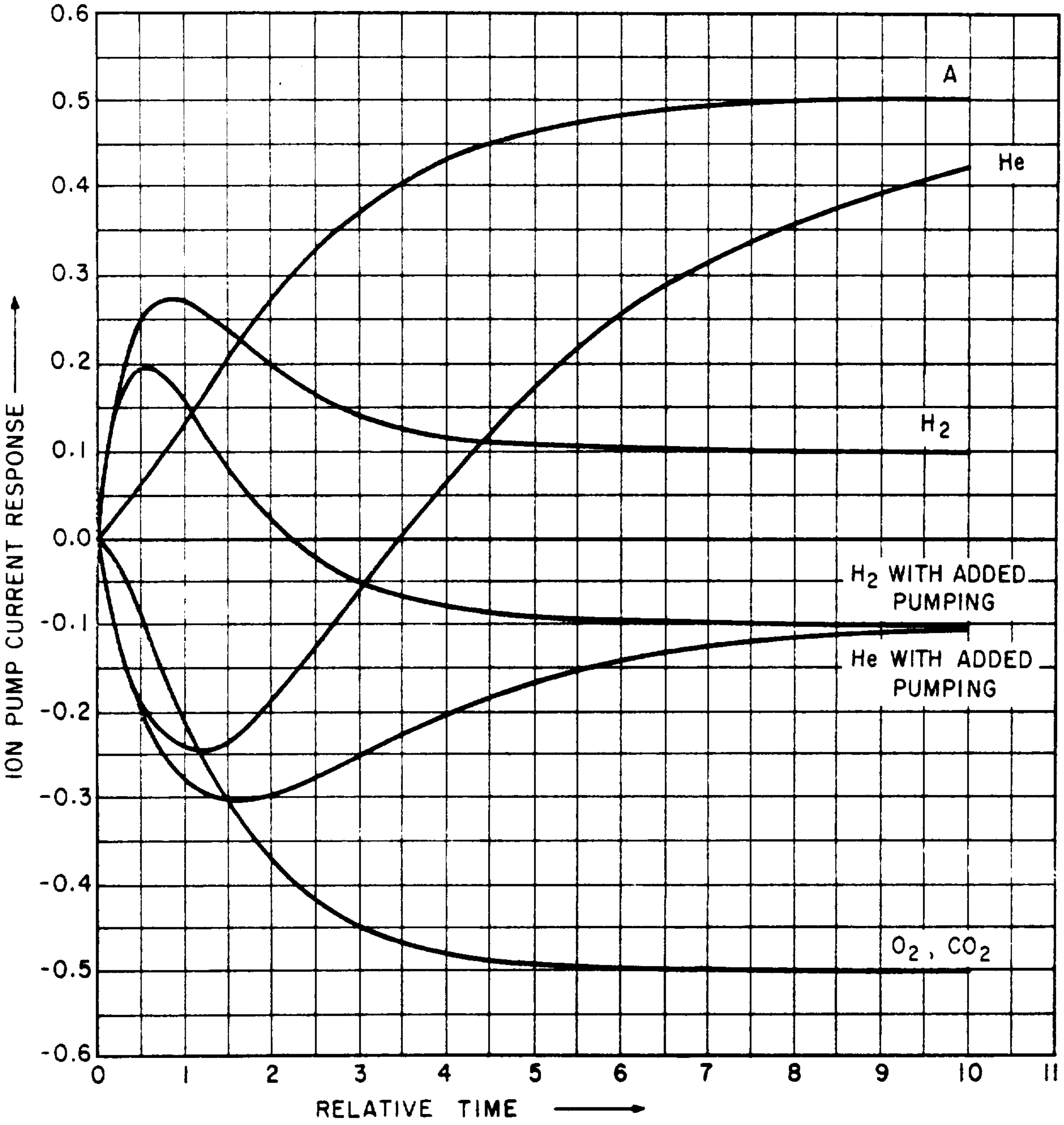

Figure 20-3. Response of Ion Pump Current to Various Gases. (Reprinted with permission from <u>1962 Transactions, Ninth National Vacuum Symposium of the American Vacuum Society</u>, J.W. Ackley and others pp. 380-383, Copyright 1962, American Vacuum Society.)

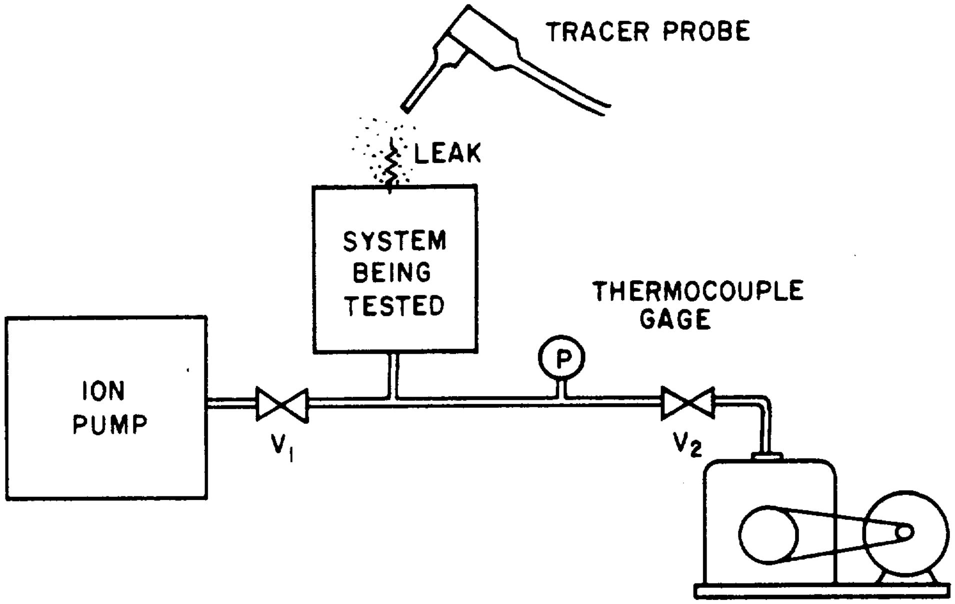

Figure 20-4. Ion Pump Leak Detector. (Reprinted with permission from J.R.Young, Review of Scientific Instruments, Vol. 32, 1961, p. 85; Copyright 1961, American Institute of Physics.)

since these gases are pumped more rapidly than air. Helium is also used as the search gas, but the sensitivity is lower than for argon.

Leaks as small as 10^{-10} torr-liters per second can be located by this technique. Leaks between 10^{-3} and 10^{-5} torr-liters per second can be located by partially opening V_1 and having V_2 opened sufficiently to avoid a pressure increase in the system during the testing procedure. Leaks of 10^{-5} to 10^{-8} torr-liters per second can be determined a few minutes after opening V_1 and closing V_2. Leaks smaller than 10^{-8} torr-liters per second require a longer time, depending on the volume and outgassing properties of the item under test.

20.5 APPLICABILITY OF METHOD

In general, when testing evacuated systems by means of ionization gages little additional equipment is necessary. Leak location can be performed with gages already on the system and with a variety of tracer gases. The method is inexpensive and requires no highly trained personnel.

The method is dependent upon maintaining a constant pressure in the system. If the system pressure varies for reasons unrelated to testing, leak location by this procedure is not practical.

The method cannot be used in a contaminated atmosphere, because the gages will respond to the other gases present in the air. Therefore, they are not used in areas where welding (inert gases), cleaning (solvent fumes), brazing (combustion products), or painting (paint solvents) operations are performed.

Section 21

LEAK DETECTION WITH THERMAL CONDUCTIVITY GAGES

Section 21

LEAK DETECTION WITH THERMAL CONDUCTIVITY GAGES

21.1 INTRODUCTION

Gages which sense a change in the thermal conductivity of a gas at low pressure can be employed to indicate leakage into or out of a chamber. Such gages are commonly attached to vacuum systems to indicate pressure in the range of a few torr to perhaps 5×10^{-4} torr. These gages do not detect pressure directly and must be calibrated in terms of pressure. When a small wire, or similar element, is heated electrically, the temperature attained by the wire depends upon the rate at which heat is removed by the surrounding gas. At high gas pressure the mean free path of the gas molecules is much shorter than the distance between the heated wire and the nearest cold wall; hence, the thermal conductivity of the gas is independent of pressure. However, as this mean free path becomes comparatively long, as at low pressures, the heat that is conducted away by the gas is linearly proportonal to the gas pressure.

In fact, the rate of heat removal per unit area of heated surface is proportional to the product of the pressure, the molecular heat conductivity of the gas, and the difference in absolute temperatures of the hot and cold surfaces (Ref. 2-3, p. 281). Heat loss by radiation is kept very small by operating the heated wire at a relatively low temperature, in the range of 100 to possibly 200°C.

When a constant current is fed through the wire, the temperature of the wire will increase proportionally as the gas pressure decreases. The temperature change in the wire will cause a change in its resistance which can be sensed by connecting the wire as one arm of an electrical bridge circuit, as is done in a Pirani-type gage. Greater sensitivity to changes in gas pressure can be obtained by using higher impedance circuits and semiconductor thermistor elements to detect small changes in temperature. Stability of the bridge circuit against changes in ambient temperature can be improved by using a matched pair of thermistors, one element being located in the vacuum chamber and the other in a sealed chamber at the same ambient temperature as the chamber in which the sampling thermistor is located. In a thermistor form of thermal conductivity gage the bridge output current is linearly proportional to pressure over three decades of pressure from 2×10^{-4} torr upward.

The temperature of the element heated with a constant current in a low-pressure environment can be monitored directly with a thermocouple rather than indirectly by measuring a change in the resistance of the element. Thermocouple gages of the thermal conductivity type are preferred for monitoring foreline pressure on present-day vacuum systems, since only an approximate indication of pressure signifies that a diffusion or ion pump can be turned on without harm to the pump oil.

The relatively low operating temperature of the sensing elements makes these detectors quite safe to use under most industrial conditions. The functional life and long-term stability of the sensing elements are good. The only ill effect which has been noted after long periods of operation under industrial conditions has been the accumulation of a dust deposit in the intake line which is easily removed.

21.2 APPLICATION TO LEAK DETECTION

The response of a low-pressure thermal conductivity gage depends in part upon the composition of the gas in the chamber in which the gage is located. When there is leakage of a tracer gas into the chamber the gas composition and its thermal conductivity change. As a result, the gage responds to the presence of the tracer gas.

For example, a change in response of perhaps 25 percent will take place when a noble gas is substituted for air in the chamber. In a thermocouple gage the response varies with junction temperature and increases with the molecular weight of the gas. In gages involving a resistance bridge the response may be made to increase or decrease, according to the location of the sensing element in the circuit. In any event, leakage detection depends upon there being a difference in the molecular conductivity of the ambient gas and the tracer gas.

21.3 SENSITIVITY

The maximum sensitivity of thermal conductivity gages for the sensing of leakage is in the range of 10^{-4} to 10^{-6} atm-cc/sec. For field-testing the sensitivity may be only 10^{-3} atm-cc/sec, while the ultimate sensitivity is obtained only by using special temperature compensation and control procedures.

21.4 OPERATING AT ATMOSPHERIC PRESSURE

Gages in which heat is removed from a sensing element by convection can be used for leak location at atmospheric pressure. Changes in gas composition due to the presence of a tracer gas cause a change in resistance or temperature of the element. This type of gage is relatively insensitive to pressure.

A typical example of a detector probe employs a hot-wire resistance bridge having a resistance element in each of two arms of a bridge network. One element is exposed to air containing tracer gas, while the other is exposed only to air and serves as a reference to compensate for changes in ambient conditions (Ref. 21-1).

As shown in Figure 21-1, the sensing elements are mounted in a metal block inside a hand-held probe unit. Gas samples are drawn up through a narrow bore tube by the action of a small fan which can be run at two speeds: a fast speed for maximum response, and a slower speed to provide increased detection sensitivity at some sacrifice in response time.

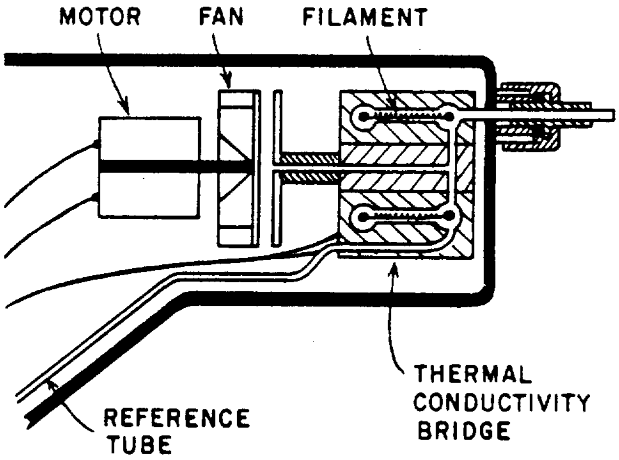

Figure 21-1. Thermal Conductivity Leak Detector. (Reprinted with permission from W. Steckelmacher and D.M. Tinsley, Vacuum, Vol. 12, No. 3, 1962, pp. 153-159; Copyright 1962, Pergamon Press, Inc., New York.)

To obtain a good response, the sensing elements must be small enough to fit into chambers of small volume. Since this detector is intended to discover changes in gas concentration rather than rates of flow, the gas should be made to flow past the entrance of the element chambers rather than through them. The sensing elements are coils of thin tungsten wire mounted on glass-metal seals in a compact assembly. In more recent designs, thermistors have replaced the tungsten wires (Refs. 21-2 and 21-3).

The electronic circuitry can be transistorized, and thereby made compact enough so the unit can be hand-held. The components consist mainly of a stabilized power supply for the thermal conductivity bridge, an amplifier to increase the amount of bridge unbalance, and a meter or signaling device. The electrical power source can be either batteries or line current. An attenuator makes it possible to vary the sensitivity of the instrument.

21.5 LEAKAGE TEST METHODS

21.5.1 Evacuated Systems

When the system pressure is in the range of the thermocouple gage the suspected leak area is simply probed with a suitable tracer. Best results will be obtained if the pumping speed is relatively low. A suitable location for the gage is the line between the diffusion pump and the forepump.

In principle, any tracer gas having a thermal conductivity different from that of air can be used. The sensitivity depends upon relative differences in thermal conductivities of the gases. It is apparent in Table 21-1 that both hydrogen and helium show large relative differences, and are therefore the most sensitive tracer gases for this method. For special applications, it is sometimes desirable to employ one of the other tracer gases. The table, based on data from Reference 21-4, gives some indication of the results to be expected. It is clear that those gases with a thermal conductivity greater than air (such as hydrogen, helium, neon, methane) or those with thermal conductivities less than air (such as halogenated hydrocarbons, argon, carbon dioxide) would be suitable.

The resistance bridge used in this detector does not actually measure thermal conductivity. Because of its structure, the readings obtained are dependent not only on thermal conductivity but on density, accommodation coefficient, and viscosity. Therefore, the values of thermal conductivity merely give an indication of the trend to be expected in behavior.

While the use of liquids to probe for leaks is not recommended, Minter (Ref. 21-5) reported a 20:1 improvement in signal strength with water, compared to that obtained with hydrogen as a tracer material. When probing with hydrogen an increase of tracer-gas partial pressure can be obtained by reducing the diffusion-pump heater voltage (Ref. 21-6). This decrease of hydrogen-gas pumping speed is obtained without materially reducing the pumping speed for other gases.

Modifications of the simple leak location technique are similar to those described in Section 20 for ionization gages. For example, Kent (Ref. 21-7) describes a Pirani leak detector using hydrogen gas; the gage is isolated from the system by a cooled charcoal trap. With this device it is possible to locate leaks as small as 10^{-6} atm-cc/sec.

Ishii (Ref. 21-8) developed a differential leak detector using butane gas. It has two Pirani gages in a Wheatstone bridge circuit. One of the gages is in series with a charcoal trap. This arrangement has stability because any random pressure changes will be detected by both gages, while the butane tracer gas will be absorbed by the charcoal. The charcoal does not have to be heated during detection. The sensitivity of this system is reported to be 10^{-6} atm-cc/sec.

Table 21-1

THERMAL CONDUCTIVITIES OF TRACER GASES*

Gas	Chemical Formula	Molecular Weight	Thermal Conductivity**
Air	(Mixture)	29.9	0.01478
Acetylene	C_2H_2	26	0.01128
Ammonia	NH_3	17	0.01333
Argon	A	39.9	0.01016
Benzene	C_6H_6	78	0.00538
Butane	C_4H_{10}	58	0.00822
Carbon dioxide	CO_2	44	0.00873
Carbon disulfide	CS_2	76	0.00410
Carbon monoxide	CO	28	0.01360
Ethane	C_2H_6	30	0.01102
Ethylene	C_2H_4	28	0.01025
Halogenated hydrocarbon F-11	CCl_3F	137.4	0.00470
Halogenated hydrocarbon F-12	CCl_2F_2	120.9	0.00542
Halogenated hydrocarbon F-21	$CHCl_2F$	102.9	0.00554
Halogenated hydrocarbon F-22	$CHClF_2$	86.5	0.00660
Halogenated hydrocarbon F-113	$CCl_2F\text{-}CClF_2$	187.4	0.00438
Halogenated hydrocarbon F-114	$CClF_2\text{-}CClF_2$	170.9	0.00629
Helium	He	4	0.08740
Hydrogen	H_2	2	0.10770
Hydrogen sulfide	H_2S	34	0.00770
Krypton	Kr	83.8	0.00540
Methane	CH_4	16	0.01872
Neon	Ne	20.2	0.02660
Nitric oxide	NO	30	0.01180
Nitrogen	N_2	28	0.01462
Nitrous oxide	N_2O	44	0.00925
Oxygen	O_2	32	0.01490
Propane	C_3H_8	44	0.00925
Sulfur dioxide	SO_2	64	0.00514
Water vapor	H_2O	18	0.01087
Xenon	Xe	131.3	0.03000

---

* Data from Reference 21-4.

**Thermal conductivity values for a temperature of 20°C in units of BTU/(hr)(sq ft)(°F/ft).

Measurement of the total leakage can be obtained by the methods suggested in Sections 11 and 12.

21.5.2 Pressurized Systems

The minimum leak discernible by a detector probe, in terms of quantity of tracer gas per unit time, depends upon the rate of flow of the gas through the leak detector and the minimum concentration to which the detector will respond. With reduction of the rate of flow, smaller leaks can be detected. However, there is a practical limit, since it is important in leak location that the detector should respond quickly when the probe traverses the position of the leak. Reducing the rate of flow lengthens the response time, and beyond a certain point the indications from the leak detector become meaningless.

For tests with the thermal conductivity detector the atmosphere must be free from tracer gas. If a system with a very large leak is being tested, the local atmosphere may become contaminated with tracer gas. While this will be inherently balanced out by the reference circuit, ultimate sensitivity is bound to decline. This shortcoming has been overcome by the use of a reference gas in a four-element thermistor bridge circuit (Ref. 21-9). The reference, or ambient, gas is passed over two of the bridge elements and the sample is passed over the other two elements. Leakages of 3×10^{-4} atm-cc/sec of refrigerant F-12 were easily detected in confined conditions.

Section 22

LEAK DETECTION BY GAS-TO-PARTICLE CONVERSION

Section 22

LEAK DETECTION BY GAS-TO-PARTICLE CONVERSION

22.1 INTRODUCTION

A relatively novel approach to the detection of gas leakage makes use of instruments developed primarily for the detection of submicron particles in the atmosphere. These instruments are known as condensation nuclei, or CN, counters. In such instruments water vapor is caused to condense on small particles in an incoming stream of carrier gas to form droplets which are much larger than any of the particles. The droplets scatter visible light and are easily detected (Ref. 22-1).

In order to detect a gas, it is necessary to convert gas molecules to solid particles. This is done by reacting the gas, chemically or otherwise, with another substance.

22.2 TYPICAL PARTICLE COUNTER

Figure 22-1 is a schematic diagram of a typical CN counter, showing the arrangement of the basic components. In the diagram submicron particles in a sample of air are drawn into a humidifier and then into an expansion chamber. The left valve closes and the right opens, to allow a rapid evacuation of the chamber to a pressure near 10 torr. The relative humidity rises rapidly from 100 percent to as high as 400 percent during this expansion. Water condenses on the tracer nuclei and droplets grow to a size

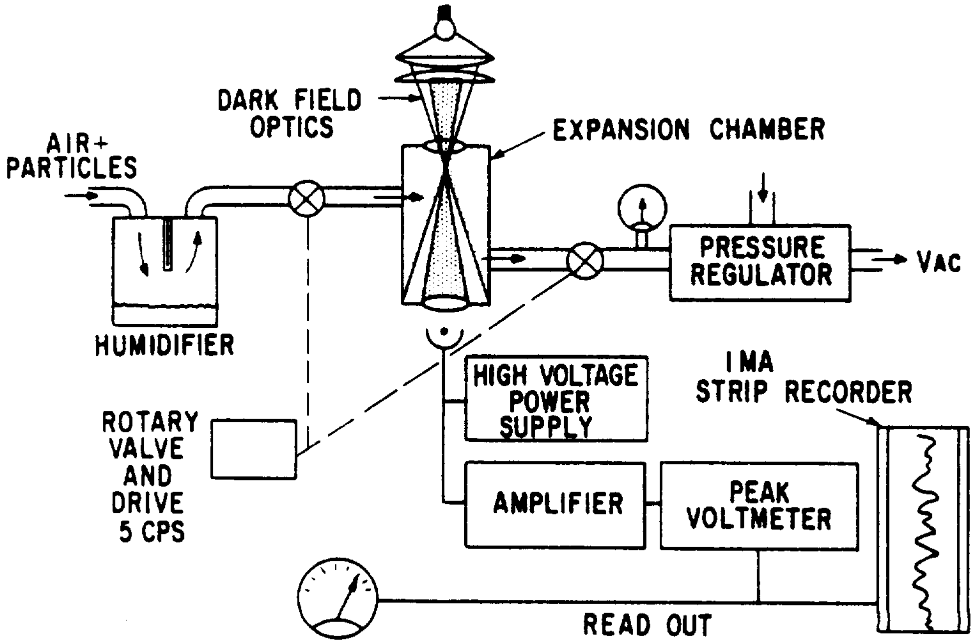

Figure 22-1. Condensation Nuclei Counter

of about five microns in a time of about twenty-five milliseconds. All droplets attain the same size, regardless of the initial sizes of the entering nuclei.

A beam of light shining into the chamber and a dark-field optical system are employed to view the vapor cloud. Only light which is scattered by the water droplets is registered on a detecting photo tube. The intensity of the scattered light is a measure of the number of droplets present in the chamber, and therefore of the number of nuclei particles which entered the chamber. After a measure of the scattered light has been taken, the chamber is emptied and flushed with a new gas sample, and the cycle repeated at a rate of about five hertz.

22.2.1 Particle Sensitivity

This type instrument will easily detect particles as small as 10^{-3} microns or 10^{-7} centimeters in diameter, and will count as few as 10 to as many as 10^{7} particles per cubic centimeter. The sensitivity is as high as one part in 10^{14} by mass. The response is linear up to 10^{5} particles per cubic centimeter. Sample flow rates of 100 cubic centimeters per second are normally involved, at atmospheric pressure.

22.3 GAS-TO-PARTICLE VERSION

Figure 22-2 shows how the particle detector can be employed to detect gases. The tracer gas sample and carrier gas are first fed through a filter to reduce the particle background to a negligibly low level, and then are fed to a converter. There a reaction with the tracer gas occurs, resulting in the formation of condensation nuclei particles; a fixed number of tracer gas mole-

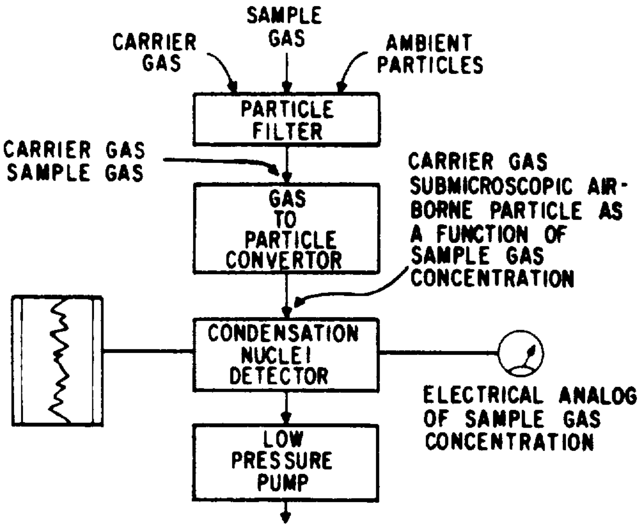

Figure 22-2. Gas-to-particle Conversion Concept

cules are involved in the creation of each particle. The particles then are passed to the expansion chamber to be counted as before.

22.3.1 Gas or Vapor Sensitivity

Table 22-1 is a list of gases and vapors which have been detected by means of a gas-to-particle conversion process. Some nine different conversion processes are involved in this listing. In a photochemical converter, for example, the incoming gas is simply irradiated by a small ultraviolet lamp. Chemical conversion for unsymmetrical-dimethylhydrazine (UDMH) involves an acid-base reaction with dilute nitric acid vapor.

Propellants and oxidizers such as UDMH and inhibited red fuming nitric acid (IRFNA) can be detected directly with high sensitivities of at least 0.1 and 0.5 ppm respectively (Ref. 22-2). The sensitivities for sulfur dioxide and ammonia gases are in the parts-per-billion range, exceeding the sensitivity of the helium mass spectrometer by several orders of magnitude when operating in a detector-probe or "sniffer" mode.

Many of the gases which readily form nucleation sites are chemically reactive. Their use as tracers should be evaluated in terms of the hazards that might arise.

Helium and argon cannot be converted to particles, and so cannot be used as tracer gases. The sensitivity to halogenated hydrocarbons is not high when pyrolysis is used for conversion.

22.3.2 Stability and Response Time

When calibrated for a specific gas the CN counter will operate stably within plus or minus five percent for days at a time. The response time of the counter is about one and one-half seconds and is the same for all particle concentrations. This is unlike many instruments, whose response time increases with sensitivity.

More information is needed about factors affecting quantitative measurement of a gas leakage rate with this type of instrument. There is little doubt, however, that the CN counter can be readily adapted to sensing, locating, and monitoring system leakage, and that very sensitive and easily used leakage testing techniques can be developed around this type of instrument.

In addition to detecting gas leakage, the condensation nuclei counter can be used to locate leaks in HEPA (high-efficiency particulate air) filter installations (Ref. 22-3).

Table 22-1

SOME GASES DETECTED BY GAS-TO-PARTICLE CONVERSION

Substance	Type Conversion	Concentrations Utilized PPM
Aluminum iodide	Hydrolysis	0.01
Ammonia	Acid base	0.005
Benzene	Photochemical	2
Carbon dioxide	Electrochemical	5
Carbon monoxide	Chemical	1
Chlorine	Chemical	1
Ethyl alcohol	Reversed photochemical	5
Freon 12-21	Pyrolysis	2
Fuming nitric acid	Hydrolysis	0.5
Hydrochloric acid	Hydrolysis	0.5
Hydrocarbons	Photochemical	0.1
Methyl mercaptan	Oxidation	0.01
Monoethylamine	Chemical	0.5
Mercury	Photochemical	0.001
Metallic carbonyl	Hydrolysis	0.001
Nitrogen dioxide	Hydrolysis	0.5
Naptha	Reverse photochemical	5
Octane	Photochemical	2
Sulfur dioxide	Photochemical	0.001
Sulfur hexafluoride	Pyrolysis	1
Sulfuric acid	Hydrolysis	1
Solvesso No. 100	Reverse photochemical	1
Toluene	Reverse photochemical	1
Unsymmetrical-dimethylhydrazine	Chemical	0.1

Section 23

MISCELLANEOUS LEAKAGE TESTING METHODS

Section 23

MISCELLANEOUS LEAKAGE TESTING METHODS

23.1 INTRODUCTION

This section is a collection of leakage testing procedures which are unusual, or have application only under specific conditions. Although the selection has been arbitrary it is hoped that it will give some idea of the variety of leakage procedures which may be employed.

Almost any detector which will show a change of gas concentration or composition may be used for leakage measurement. The sensitivity and practicality will depend on the ingenuity with which the detector is employed. For example, a dental mirror can be used to detect refrigerant leakage. A spot of condensed moisture clouds the mirror where the leaking refrigerant, cooled by expansion through the leak, strikes the surface of the mirror. The list of similar possibilities is amost limitless.

23.2 COMBUSTIBLE GAS DETECTORS

Combustible gas detectors are manufactured by several companies (Table 23-1). Details of this type of test equipment may be found in Part III under the heading "Catalytic Combustion." These detectors are designed for leak location by the detector probe technique on systems filled with combustible gases.

Table 23-1

CHARACTERISTICS OF COMBUSTIBLE GAS DETECTORS

General Characteristics	Average Values
Sensitivity	1 cu.ft/hr., 10 ppm hydrogen, 1% lower explosive limit
Tracer gas	Combustible mixtures
Output	Meter, tone, and light
Power requirement	115 volts, 60 hertz, battery
Size	From 4 × 8 × 10 inches to 15 × 17 × 10 inches
Weight	2 to 60 pounds
Price	$75 to $600

Each detector is a hand-held unit, usually with its own pump and power supply. As in the thermal conductivity detector, the tracer gas is passed over a thermocouple or other temperature sensor. In the combustible gas detector, however, the heat sensing element is in contact with a combustion catalyst. When a combustible tracer gas comes in contact with the catalyst, the heat of combustion raises the catalyst temperature and produces a response of the heat-sensing element.

23.3 ANALYTICAL MASS SPECTROMETER

A mass spectrometer is sometimes a part of the analytical equipment present on a vacuum system. This instrument is more versatile than the mass-spectrometer leak detector described in Section 9. It can quantitatively measure the concentration of any gas. Such an instrument can be used to diagnose problems with a vacuum system, and occasionally locate the source of a leak.

The use of the analytical mass spectrometer is essentially the same as that outlined for the residual gas analyzer discussed in subsection 9.1.1.

23.4 GAS CHROMATOGRAPH

A gas chromatograph separates a mixture of gases and measures their individual concentrations. The separation is by means of the differences in their residence times in a column of sorbent material. This instrument has been used to measure the permeability of polymers (Ref. 23-1). The same basic equipment design can be used for leakage measurement. The system is pressurized with tracer gas and placed in a chamber which is at atmospheric pressure. An inert carrier gas, passed through the chamber, sweeps across the system. The concentration of tracer gas in the carrier is measured.

Three advantages of the chromatograph in leak detection are:

- The chromatograph measures leakage at atmospheric pressure.
- The leakage measurement can be calibrated by measurments traceable to the Bureau of Standards.
- Leakage of the contents of a container may be one of a variety of vapors or gases which can be detected directly with a gas chromatograph. Thus no tracer would be needed to detect a leak in the container.

23.5 GAS CAPACITANCE LEAKAGE TEST

Integrated circuit modules which have already been mounted on printed circuit boards can be tested for leakage by measuring the change in capacitance of the module as gas composition changes (Ref. 23-2). A back-pressurizing technique which utilizes a gas whose dielectric constant is one to two percent different from that of the original filling gas makes it possible to detect leakages of less than 10^{-7} atm-cc/sec.

Several hours are required to make such a test. Care must be taken in interpreting the data, to separate the mechanical changes from the gas-concentration changes.

23.6 PROPELLANT LEAK DETECTOR

It is possible to detect the leakage of propellants by sensing the temperature drop caused by evaporation of the leaking propellant. Juran (Ref. 23-3) found that the cooling effect was between 0.01 and 0.3 watt for each cubic centimeter per hour of leakage, and that changes in temperatures could easily be detected. For example, at a leakage of 5×10^{-2} atm-cc/sec the temperature change recorded was 2°F.

23.7 HYDROGEN LEAK DETECTORS

An activated oxide film has been shown to be sensitive to small amounts of hydrogen or other reducing gases (Ref. 23-4). Changes in resistivity of these films are rapid in ambient air; the response time amounts to only a few seconds and recovery is nearly as rapid. Sensitivity is reported to be about 10^{-1} to 10^{-2} atm-cc/sec.

Another hydrogen detector is a "stick-on" sensor that turns color in the presence of hydrogen (Ref. 23-5). Less than 1 atm-cc/sec will cause the reaction. The detector consists of powdered palladium oxide and a reaction-quenching material, all enclosed in a porous packet on the outside of which is a heat-sensitive paint. In use these detectors are mounted on flanges and other connections where hydrogen leakage may occur.

23.8 OIL LEAK DETECTOR

Leakage of fuel oil, hydraulic fluids, and organic solvents from flanges or other joints can be detected by the use of a wrap-on tape which turns red in the presence of oil leakage. The tape does not burn and is nontoxic. It can be applied by hand to any surface configuration (Ref. 23-6).

23.9 BIOLOGICAL TECHNIQUES ADAPTED FOR LEAKAGE TESTING

It has often been suggested that one simple method of leak location is to fill a system with honey, release ants, and watch where they enter the system. Although this dubious technique is related in jest, attempts have been seriously made to develop a leak location technique using a sex hormone of a butterfly (Ref. 23-7). This hormone was injected into pipelines, and the location of the leaks was clearly established by the congregation of a large number of butterflies. Presumably, it was felt that the sensitivity of the technique could be increased by using a drive greater than hunger.

Biological techniques are not always used in such a sophisticated fashion. Gas companies routinely place an odor-producing compound in natural gas. This odor-producing compound serves as a leakage monitor, indicating the existence of a leak. To a certain extent, a leak can be localized by the use of such olfactory techniques.

The sensitivity of the nose as a leakage testing instrument should not be underrated. It has been estimated that a concentration of propyl or butyl mercaptan as low as one part per billion in the atmosphere can be detected. This fact is regarded with envy by manufacturers of mass-spectrometer leak detectors, whose standard instruments can detect helium at a concentration of only one part per ten million. Fortunately for these manufacturers, olfactory response is neither quantitative nor very directional. However, specially trained dogs have been used to detect leakage from buried pipes.

Vegetation response can be used for leak location. The growth of many plants is affected by the presence of natural gas. Gas companies frequently locate leaks in pipelines by traveling the route of the line and observing adjacent plant growth (Ref. 11-5). Leaks in the line will produce stunted plant growth in the vicinity of the leak. This will be exhibited by a preseasonal color change or a slowdown on the growth rate. Such changes can be readily detected by trained personnel.

Part III

CHARACTERISTICS AND SOURCES OF COMMERCIALLY AVAILABLE LEAK DETECTORS

Section 24

Section 25

Section 26

Section 27

Section 28

Section 29

Section 30

Section 24

COMMERCIAL LEAK DETECTORS

Section 24

COMMERCIAL LEAK DETECTORS

Part III of this Handbook presents the characteristics of the various types of commercial leak-detecting equipment and their sources. To this end, a survey and review was performed of all known leak detectors, their characteristics and specifications. The descriptive information is presented in condensed form, and is intended to serve as a general guide and aid in the selection of leak-detecting equipment suited for specific applications.

To obtain factual and current information, letters of inquiry were sent to more than three hundred manufacturers in the United States, Belgium, England, France, Germany, Holland, Italy, Japan, Sweden, and Switzerland. In the interests of uniformity and of obtaining more specific performance data and physical descriptions, each of these firms was asked to complete and return "information fill-in" forms for its units. One hundred and twenty-eight vendors submitted useful information. Twenty-nine different principles are used in the leak-detecting equipment being offered.

Vendor replies were received in various degrees of completeness. Information extracted from these replies has been arranged in tabular form for each leak-detecting equipment. A scrupulous effort has been made to avoid any interpretation or extrapolation of the vendor-submitted information. Monitoring types of equipment have not been generally included. However, the classification of leak-detecting and leak-monitoring types of equipment is not always clear-cut.

The commercial field of leak-detecting equipment is highly competitive and is in a continuing state of change. Despite this, much of the submitted information should continue to be useful as a general guide to leak-detecting equipment, its characteristics, specifications, and sources, for several years to come.

24.1 ARRANGEMENT OF TABLES

The data have been arranged in five different tables to facilitate the retrieval of information regarding specific types of leakage-testing equipment and their sources. The order of listing is alphabetical in each of the tables.

Section 25

MANUFACTURERS OF LEAK DETECTING EQUIPMENT - MAILING ADDRESSES

MANUFACTURERS OF LEAK DETECTING EQUIPMENT - MAILING ADDRESSES

1. Accessory Controls & Equipment Corp.
815 Bloomfield Avenue
Windsor, Connecticut

2. Aerojet-General Corporation
Aerometrics Division
Box 216
San Ramon, California 94583

3. Aero Vac Corporation
Box 448
Troy, New York 12181

4. Alamo Specialty Company
Dist: Alamo Mill Supply Co.
702 Culebra Avenue
San Antonio, Texas

5. American Design, Inc.
37116 Second Street South
Box 31169
Birmingham, Alabama

6. American Gas & Chemicals, Inc.
Leak Tech Division
511 East 72nd Street
New York, New York 10021

7. Andar Corporation
185 East Evelyn Avenue
Mountain View, California 94041

8. Associated Electrical Industries
Distributed & Maintained by
Picker Nuclear
1275 Mamaroneck Avenue
White Plains, New York 10605

9. Automation Industries, Inc.
Sperry Products Division
1000 Shelter Rock Road
Danbury, Connecticut 06810

10. Bacharach Instrument Company
Division of American Bosch
Arma Corporation
200 North Braddock Avenue
Pittsburgh, Pennsylvania 15208

11. Beckman Instruments, Inc.
Scientific & Process Instruments
Division
2500 Harbor Boulevard
Fullerton, California 92634

12. Bendix Corporation
Scientific Instruments Division
3625 Hauck Road
Cincinnati, Ohio 45241

13. Bernzomatic Corporation
740 Driving Park Avenue
Rochester, New York 14613

14. Burnett Electronics Lab., Inc.
P.O. Box 23015
San Diego, California 92123

15. Canal Industrial Corporation
5635 Fisher Lane
Rockville, Maryland 20852

16. Cargille Scientific, Inc.
R.P. Cargille Laboratories, Inc.
33 Village Park Road
Cedar Grove, New Jersey 07009

17. Century Geophysical Corporation
Century Electronics & Instr., Div.
P.O. Box C Admiral Station
6540 E. Apache Street
Tulsa, Oklahoma 74115

18. Consolidated Electrodynamics Corp.
Subsidiary of Bell & Howell
1400 South Shamrock Avenue
Monrovia, California

19. Datametrics, Inc.
87 Beaver Street
Waltham, Massachusetts 02154

20. Davis Emergency Equipment Co, Inc.
Instrument Division
45 Halleck Street
Newark, New Jersey 07104

21. Dawe Instruments Ltd.
Western Avenue
Acton, London W.3
England

22. The Decker Corporation
45 Monument Road
Bela Cynwyd, Pennsylvania 19004

23. Devco Engineering, Inc.
37 Pier Lane West
Fairfield, New Jersey

24. Dragerwerk Lubeck (West Germany)
Agents: Scott Aviation Corp.
225 Erie Street
Lancaster, New York 14086

25. Eastern Laboratories, Inc.
1229-31 Washington Avenue
Vineland, New Jersey 08360

26. Edwards High Vacuum, Inc.
3279 Grand Island Blvd.
Grand Island, New York 14072

27. Electronic Associates, Inc.
4151 Middlefield Road
Palo Alto, California 94303

28. Erdco Engineering Corporation
136 Official Road
Addison, Illinois 60101

29. Euphonics Industries, Inc.
1634 West 33rd Place
Hialeah, Florida 33012
Distributor: The Elwood Corp.
2180 Elmwood Ave.
Buffalo, N.Y. 14216

30. Excelsior Varnish, Inc.
1219-43 West 74th Street
Cleveland, Ohio 44102

31. Fisher Research Laboratory, Inc.
1975 University Avenue
Palo Alto, California 94302

32. Flamort Chemical Company
746 Natoma Street
San Francisco, California

33. Flow Technology, Inc.
401 South Hayden Road
Tempe, Arizona 85281

34. Fluid Data, Inc.
651-661 Calebs Path
Hauppauge, New York 11787

35. The Fredericks Company
Anne Street
Bethayres, Pennsylvania

36. Galaxie Products
Box 3412
South El Monte, Calif. 91733

37. Gas Analysis Systems, Inc.
P.O. Box 146
Basking Ridge, New Jersey 07920

38. Gas Purifying Materials, Inc.
Instrument & Equipment Division
3-15 26th Avenue
Long Island City, N.Y. 11102

39. General Air Products Corporation
5345 North Kedzie Avenue
Chicago, Illinois

40. George W. Gates & Co., Inc.
P.O. Box 216
Hempstead Turnpike & Lucille Ave.
Franklin Square
Long Island, New York 11010

41. General Electric Company
Instrument Department
40 Federal Street
West Lynn, Massachusetts

42. General Electric Company
Materials Engineering Laboratory
Research & Development Center
P.O. Box 43
Schenectady, New York 12301

43. General Electric Company
Vacuum Products, Business Section
1 River Road
Schenectady, New York 12301

44. General Monitors, Inc.
3019 Enterprise Street
Costa Mesa, California 92626

45. Goldak Company, Inc.
1544 W. Glenoaks Blvd.
Glendale, California 91201

46. Gow-Mac Instrument Company
100 Kings Road
Madison, New Jersey 07940

47. Granville-Phillips Company
5675 East Arapahoe Avenue
Boulder, Colorado 80302

48. Hastings-Raydist, Inc.
Hampton, Virginia 23361

49. Hays Corporation
742 East Eight Street
Michigan City, Indiana

50. Heckerman Corporation
814 West Hyde Park Blvd.
Inglewood, California 90302

51. Hewlett-Packard Company
Delcon Division
333 Logue Avenue
Mountain View, California 94040

52. Highside Chemicals, Inc.
10 Colfax Avenue
Clifton, New Jersey 07013

53. Hilger & Watts, Ltd.
Hilger - I.R.D. Ltd.
98 St. Pancras Way
Camden Road
London, N.W. 1 England
Agent: Calibrated Instruments, Inc.
17 West 60th Street
New York, New York 10023

54. Hoke, Inc.
1 Tenakill Park
Cresskill, New Jersey

55. Honeywell, Inc.
Apparatus Controls Division
2701 Fourth Avenue
Minneapolis, Minnesota 55408

56. Houston Atlas, Inc.
Box 19035
Houston, Texas 77024

57. Johnson-Williams, Inc.
2300 Leghorn Avenue
Mountain View, California 94040

58. Japan Vacuum Engineering Co., Ltd.
1, 1-Chome, Kyobashi Chuo-Ku
Tokyo, Japan

59. Justrite Manufacturing Company
2061 N. Southport Avenue
Chicago, Ill. 60614

60. Kelite Chemicals Corp.
1250 North Main St.
Los Angeles, California 90012

61. Kobbe-McCawley Corporation
530 Columbus Avenue
P.O. Box 1437
Melbourne, Florida 32901

62. Lenk Manufacturing Company
P.O. Box 324
Franklin, Kentucky 42134

63. Lion Research Corporation
60 Bridge Street
Newton, Massachusetts 02195

64. Loenco, Inc.
2092 N. Lincoln Avenue
Altadena, California 91001

65. Lumidor Products Corporation
P.O. Bcx 357
2500 W. 6th Avenue
Hialeah, Florida

66. Magnaflux Corporation
7300 W. Lawrence Avenue
Chicago, Illinois 60656

67. Marcol, S.A.
Brussels, Belgium
Agent: M. Paquet & Co., Inc.
17 Battery Place
New York, New York

68. Mast Development Company
2212 E. 12th Street
Davenport, Iowa 52803

69. The Matheson Company, Inc.
P.O. Box 85
E. Rutherford, New Jersey 07073

70. Met-L-Check Company
11919 S. Western Avenue
Los Angeles, California 90047

71. Mine Safety Appliances Company
201 North Braddock Avenue
Pittsburgh, Pennsylvania 15208

72. Minear Scientific Instruments
P.O. Box 6187
San Diego, California 92106

73. Minnesota Mining & Manufacturing Co.
Chemical Division
2501 Hudson Road
St. Paul, Minnesota 55101

74. MKS Instruments, Inc.
P.O. Box 215
Lexington, Massachusetts 02173

75. Moak Machine & Foundry Co.
Port Huron, Michigan 48060

76. Modern Engineering Company, Inc.
P.O. Box 8159
St. Louis, Missouri 63103

77. National Research Corp.
Equipment Division
Subsidiary of Norton Company
160 Charlemont Street
Newton, Massachusetts 02161

78. Newark Controls Company
15 Ward Street
Bloomfield, New Jersey 07003

79. Nuclear Products Company
N.U.P.R.O. Company
15635 Saranac Road
Cleveland, Ohio 44110

80. Perkin-Elmer Corporation
Ultek Division
P.O. Box 10920
Palo Alto, California 94303

81. Phoenix Precision Instrument Co, Inc.
3803-05 North 5th Street
Philadelphia, Pennsylvania 19140

82. Joseph G. Pollard Co., Inc.
New Hyde Park
L.I., New York 11040

83. Quantum Dynamics, Inc.
19458 Ventura Blvd.
Tarzana, California 91356

84. Riken Keiki Fine Instrument Co., Ltd.
2-7-6 Azusawa Itabashiku
Tokyo, Japan

85. Ruska Instrument Corporation
P.O. Box 36010
6121 Hillcroft Avenue
Houston, Texas 77036

86. Salen & Wicander, AB
Box Sundbyberg 3.
Sweeden

87. Schneider Manufacturing Co.
Reading, Massachusetts
Distributor: The Grisby Company
1204 "K" Street
Washington, D.C.

88. Shannon Luminous Materials Co.
Tracer-Tech Division
7356 Santa Monica Blvd.
Los Angeles, California 90046

89. Sherwin, Inc.
Belmont Chemicals Division
5007 East Washington Blvd.
Los Angeles, California 90022

90. J. and S. Sieger Ltd.
Poole - Dorset
England

91. Sierra Engineering
Materials Research Division
6220 San Fernando Road
Glendale, California 91201

92. Sloan Instruments Corporation
535 East Montecito Street
Box 4608
Santa Barbara, California

93. Spectronics Corporation
Black Light Eastern Division
24 Kinkel Street
Westbury, L.I., New York 11590

94. Sprague Devices, Inc.
Huron Street
Michigan, Indiana 46360

95. Starr-Kapp Engineering Co.
15115 Diversey Street
Dearborn, Michigan 48126

96. Superior Signal Company, Inc.
W. Greystone Road
Spotsworth, New Jersey 08884

97. Technicon Inc.
Saw Mill River Road
Ardsley (Chaucey), New York 10502

98. Technology/Versatronics, Inc.
Division Technology Corporation
506 South High Street
Yellow Springs, Ohio 45387

99. Techsonics Inc.
Santa Fe Road
Taos, New Mexico 87571

100. Tel Air Products Corporation
7010 N.W., 37th Court
Box 814
Miami, Florida

101. Teledyne, Inc.
Analytical Instrument Div.
370 South Fair Oaks Avenue
Pasadena, California 91101

102. Tenvac, Incorporated
Pembroke, Massachusetts 02359

103. Tescom Corporation
Smith Welding Equipment Div.
2633 S.E. 4th Street
Minneapolis, Minn. 55414

104. Testing Systems, Inc.
2826 Mt. Carmel Avenue
Glenside, Pennsylvania 19038

105. Texas Instruments, Inc.
Apparatus Division IPG
P.O. Box 66027
3609 Buffalo Speedway
Houston, Texas 77006

106. Thermal Industries of Florida, Inc.
3655 N.W. 74th Street
Miami, Florida 33147

107. Thermal Instrument Company
Box 72
Cheltenham, Pennsylvania 19012

108. Tinker and Rasor
Detectron Division
P.O. Box 243
San Gabriel, California

109. Trans-Sonics, Inc.
P.O. Box 326
Lexington, Massachusetts 02173

110. Turco Products, Inc.
Div. of Purex Corp., Ltd.
24600 South Main Street
Wilmington, California

111. 20th Century Electronics Ltd.
King Henrys Drive
New Addington Croydon Suffrey
England

112. Union Carbide Corporation
Linde Division
P.O. Box 6000
Florence, South Carolina 29501

113. Union Industrial Equipment Corp.
150 Cove Street
Fall River, Massachusetts 02720

114. United States Gulf Corporation
609 Saw Mill River Road
Ardsley, New York 10502

115. U.S. Safety Service Company
Division M
1535 Walnut Street
Kansas City, Mo. 64108

116. Uson Corporation
2120 South Postoak
Houston, Texas 77027

117. Universal Controls Corp.
P.O. Box 20276
Dallas, Texas 75220

118. Varian Associates
Vacuum Division
611 Hansen Way
Palo Alto, California

119. Varian Mess Analysen Technik
GmBH Heraeus-Engelhard, Inc.
Seco Road
Monroeville, Pa. 15146

120. Veeco Instruments Inc.
Terminal Drive
Plainview, New York 11803

121. Volumetrics
1025 Arbor Vitae
Inglewood, California 90301

122. Vacuum Instrument Corporation
6 Stepar Place
Huntington Station
Long Island, New York 11746

123. Wallace and Tiernan, Inc.
25 Main Street
Belleville, New Jersey 07109

124. Watsco, Inc.
1800 West 4th Avenue
Hialeah, Florida 33010

125. The Welch Scientific Company
7300 North Linder Avenue
Skokie, Illinois 60076

126. Whittaker Corporation
Pace-Wiancko Division
12838 Saticoy Street
North Hollywood, California 91605

127. Winton Products Co., Inc.
Box 3332
Charlotte, North Carolina 28203

128. Yellow Springs Instrument Co., Inc.
Box 279
Yellow Springs, Ohio 45387

Section 26

CODE SYMBOLS FOR TYPES OF LEAK DETECTING EQUIPMENT

CODE SYMBOLS FOR TYPES OF LEAK DETECTING EQUIPMENT

	Detector Principle	Code Symbol
1.	Bubble (Liquid Applicant)	B
2.	Catalytic Combustion	C
3.	Chemical Indicator - Dye	D
4.	Chemical Indicator - Dye - Pressurized	DP
5.	Chemical Indicator - Reagent	R
6.	Electrochemical Cell	EC
7.	Flame Ionization	FI
8.	Flow	FL
9.	Gas Density	GD
10.	Halide Torch - Flame Color	FC
11.	Immersion	IM
12.	Infrared Absorption	IR
13.	Interferometer	IN
14.	Ion Gauge	IG
15.	Mass Spectrometer	M
16.	Particle Detector	PD
17.	Pressurized CO_2	CP
18.	Pressure Change - Gas	GP
19.	Pressure Change - Liquid	LP
20.	Pressure - Water	WP
21.	Sonic - Sonic Range	S
22.	Sonic - Ultrasonic Range	US
23.	Spark Coil (High Frequency)	SC
24.	Thermal Conductivity	TC
25.	Tracer - Halogen	TRH
26.	Tracer - Radioactive	TRR
27.	Tracer - Smoke	TRS
28.	Ultraviolet Absorption	UV
29.	Volumetric Displacement	V

Section 27

MANUFACTURERS OF LEAK DETECTING EQUIPMENT - PRINCIPLES USED

LEAK DETECTING EQUIPMENT MANUFACTURERS - PRINCIPLE USED

	Manufacturer	Detector Principle
1.	Accessory Controls & Equipment Corp.	GP
2.	Aero Vac Corporation	M
3.	Aerojet-General Corp. (Aerometrics Division)	V
4.	Alamo Mill Supply Co. (Exclusive Agent: Alamo Specialty Co.)	B
5.	American Design, Inc.	WP
6.	American Gas & Chemicals, Inc.	B & R
7.	Andar Corporation	M & IG
8.	Associated Electrical Industries (Distributed & Maintained by Picker Nuclear)	M
9.	Automation Industries, Inc. (Sperry Products Division)	D
10.	Bacharach Instrument Division of American Bosch Arma Corporation	R & C & TC & TRH & EC
11.	Beckman Instruments, Inc. (Process Instruments Division)	IR & TC & UV
12.	The Bendix Corporation (Scientific Instruments Division)	M
13.	Bernz-O-Matic Corporation	FC
14.	Burnett Electronics Lab, Inc.	US
15.	Canal Industrial Corporation	IG
16.	Cargille Scientific, Inc.	B
17.	Century Geophysical Corp. (Century Electronics and Instruments Division)	FI
18.	Consolidated Electrodynamics Corp. (Subsidiary of Bell and Howell)	GP & M
19.	Datametrics, Incorporated	GP & LP
20.	Davis Emergency Equipment Co., Inc. (Instrument Division)	TC & FI & FC & C
21.	Dawe Instruments	US
22.	The Decker Corporation	GP
23.	Devco Engineering, Inc.	TRH & TC

	Manufacturer	Detector Principle
24.	Dragerwerk-Lubeck (West Germany) Scott Aviation, Lancaster, Pa. (US distributor)	R
25.	Eastern Laboratories, Inc.	B
26.	Edwards High Vacuum, Inc.	M & TC & IG
27.	Electronic Associates, Inc.	M
28.	Erdco Engineering Corporation	C
29.	Euphonics Industries, Inc. (The Elwood Corporation is the sole distributor)	US
30.	Excelsior Varnish, Inc.	B
31.	Fisher Research Laboratory, Inc.	S & US
32.	Flamort Chemical Company	B
33.	Flow Technology, Inc.	FL
34.	Fluid Data, Inc.	US
35.	The Fredericks Company	IG
36.	Galaxie Products	B
37.	Gas Analysis Systems, Inc.	TC
38.	Gas Purifying Materials Company, Inc.	TC & C
39.	George W. Gates & Co., Inc.	D
40.	General Air Products Corporation	CP
41.	General Electric Company (Instrument Department)	TRH
42.G	General Electric Co., Materials Engineering Laboratory Research and Development Center	PD
43.	General Electric Company - Vacuum Products Business Section	M & IG
44.	General Monitors, Inc.	EC & C
45.	Goldak Company, Inc.	S & US
46.	Gow-Mac Instrument Company	TC
47.	Granville-Phillips Company	GP & IG & M
48.	Hastings-Raydist, Inc.	FL
49.	The Hays Corporation	EC

	Manufacturer	Detector Principle
50.	The Heckerman Corporation	B
51.	Hewlett-Packard Company (Delcon Division)	US
52.	Highside Chemicals, Inc.	DP & B
53.	Hilger & Watts, Ltd. (Hilger-I.R.D. Ltd., Division) Calibration Instruments, Inc.	IR
54.	Hoke, Inc.	B
55.	Honeywell, Inc. (Apparatus Controls Division)	UV
56.	Houston-Atlas, Inc.	C
57.	Japan Vacuum Engineering Co., Ltd.	M
58.	Johnson Williams Products - Bacharach Instrument Co., Div. American Bosch Arma Corporation	C
59.	Justrite Manufacturing Company	FC
60.	Kelite Chemicals Corporation	B
61.	Kobbe-McCawley Corporation	R
62.	Lenk Manufacturing Company	FC
63.	Lion Research Corporation	FL
64.	Loenco, Inc.	TC
65.	Lumidor Products, Corp.	US
66.	Magnaflux Corporation	D
67.	Marcol, S. A. (M. Paquet & Company, Inc. distributor)	S
68.	Mast Development Company	EC
69.	Matheson Company, Inc.	C & TC & R
70.	Met-L-Chek Company, Inc.	D
71.	Mine Safety Appliances Company	C & TC & IR & IG
72.	Minear Scientific Instruments	S
73.	Minnesota Mining & Manufacturing Co. - Chemical Division	IM
74.	MKS, Instruments, Inc.	GP

	Manufacturer	Detector Principle
75.	Moak Machine & Foundry Company	WP & IM & GP
76.	Modern Engineering Company, Inc.	FC
77.	National Research Corp. (Equipment Division) Subsidiary of Norton Company	M
78.	Newark Controls Company	GD
79.	Nuclear Products Company (NUPRO Co.)	B
80.	Perkin-Elmer Corporation - Ultek Division	M & IG
81.	Phoenix Precision Instrument Company, Inc.	PD
82.	Joseph G. Pollard Company, Inc.	S
83.	Quantum Dynamics, Inc.	FL
84.	Riken Keiki Fine Instrument Company, Inc.	IN & C
85.	Ruska Instrument Corporation	GP
86.	Salen & Wicander, AB	C
87.	Schneider Manufacturing Company	S
88.	Shannon Luminous Materials Company (Tracer-Tech Division)	D
89.	Sherwin, Incorporated	D
90.	J. & S. Sieger, Ltd. (Poole-Dorset - England) Agent: Smith-Jeese, Inc.	C
91.	Sierra Engineering Company (Materials Research Division)	TRR
92.	Sloan Instruments Corporation	M
93.	Spectronics Corporation (Black Light Eastern Division)	D
94.	Sprague Devices, Inc.	B
95.	Starr-Kap Engineering Co.	GP & LP
96.	Superior Signal Company, Inc.	TRS
97.	Technicon Corporation	R
98.	Technology/Versatronics, Inc.	FL & EC
99.	Techsonics, Inc.	US

	Manufacturer	Detector Principle
100.	Tel Air Products Corporation	US
101.	Teledyne, Inc. (Analytical Systems Co., Teledyne Analytical Instruments Division)	C & IR & TC & FI & EC & UV
102.	Tenvac, Inc.	M
103.	Tescom Corporation - Smith Welding Equipment Division	FI
104.	Testing Systems, Inc.	D
105.	Texas Instruments, Inc.	GP
106.	Thermal Industries of Florida, Inc.	TRH
107.	Thermal Instrument Company	FL
108.	Tinker & Rasor (Detectron Division)	S
109.	Trans-Sonics, Inc.	GP
110.	Turco Products, Inc. (Division of Purex Corp., Ltd.)	D
111.	20th Century Electronics, Ltd.	M
112.	Union Carbide Corporation (Linde Division)	FI
113.	Union Industrial Equipment Corp.	IN & R & C
114.	United States Gulf Corporation	B
115.	United States Safety Service Company	R
116.	Universal Controls Corp.	FL
117.	Uson Corporation	TC
118.	Vacuum Instrument Corporation	M
119.	Varian Associates (Vacuum Division)	M
120.	Varian Mess Analysen Technik (Hereaus-Engelhard Vacuum, Inc. distributor)	M
121.	Veeco Instruments, Inc.	M
122.	Volumetrics	V
123.	Wallace & Tiernan, Inc.	GP
124.	Watsco, Inc.	B
125.	The Welch Scientific Company	SC

	Manufacturer	Detector Principle
126.	Whittaker Corporation (Pace-Wiancko Division)	GP
127.	Winton Products Company, Inc.	B
128.	Yellow Springs Instrument Company, Inc.	EC

Section 28

TYPES OF LEAK DETECTING EQUIPMENT MANUFACTURERS AND TRADE NAMES

TYPES OF LEAK DETECTING EQUIPMENT - MANUFACTURERS AND TRADE NAME

Bubble - (Liquid Applicant)

Manufacturer	Trade Name
Alamo Mill Supply Company (Exclusive Agent: Alamo Specialty Co.)	Alspec
American Gas & Chemicals, Inc.	FM Inert & Leak-Tec
Cargille Scientific, Inc.	Sho-Gas
Eastern Laboratories, Inc.	Bubble-Coat
Excelsior Varnish, Inc.	Leak Finding Compound
Flamort Chemical Company	Detect-A-Leak
Galaxie Products	I-Spy Leak Detector
Heckerman Corporation	Heck-Check
Highside Chemicals, Inc.	Leak Finder Foam
Hoke, Incorporated	Chek-Seal
Kelite Chemicals Corporation	Bubble-Fluid
Nuclear Products Company (NUPRO Co.)	Snoop & Real Cool Snoop
Sprague Devices, Inc.	Air Push
United States Gulf Corp.	Detek
Watsco, Inc.	Search
Winton Products Co., Inc.	Sherlock

Catalytic Combustion

Bacharach Instrument Division of American Bosch Arma Corp.	Bacharach Gastron
Davis Emergency Equipment Co., Inc. (Instrument Div.)	Vapotester Gastester
Erdco Engineering Corporation	Tox-Ex
Gas Purifying Materials Co., Inc. (Instrument & Equipment Div.)	Vaporgraph Odorgraph

Catalytic Combustion

Manufacturer	Trade Name
General Monitors, Inc.	
Houston Atlas, Inc.	Duotector
Johnson-Williams Products - Bacharach Instr. Co. Division American Bosch Arma Corp.	
The Matheson Company	
Mine Safety Appliance Co.	Gascope Explosimeter
Riken Keiki Fine Instrument Co., Ltd.	
Salen & Wicander, AB	Salwico
J. S. Sieger, Ltd. (Poole-Dorset-England) Agent: Smith-Jeese, Inc.	
Teledyne, Inc. (Analytical Instrument Division)	
Union Industrial Equipment Corp.	

Chemical Indicators - Dye

Automation Industries, Inc. (Sperry Products Division)	
George W. Gates & Co., Inc.	
Magnaflux Corp.	Zyglo
Met-L-Chek Co., Inc.	Met-L-Chek Flaw Findr
Shannon Luminous Material Co. (Tracer-Tech Div.)	Tracer-Tech
Sherwin, Inc.	Dubl-Chek
Spectronics Corp. (Black Light Eastern Division)	
Testing Systems, Inc.	Fluoro Finder
Turco Products, Inc. Division: Purex Corp., Ltd.	Fluor Chek & Dy Chek

Chemical Indicator-Dye-Pressurized

Highside Chemicals, Inc.	Trace

Chemical Indicator (Reagent)

Manufacturer	Trade Name
American Gas & Chemicals, Inc.	Bug-It & Jet/Tec
Bacharach Instrument Division of American Bosch Arma Corp.	
Dragerwerk-Lubeck (West Germany) Scott Aviation, Lancaster (US Distributor)	
Kobbe-McCawley Corporation	
The Matheson Company, Inc.	
Technicon, Inc.	Auto-Analyzer
Union Industrial Equipment Corp.	Kitagawa Detector
United States Safety Service Company	Saf-Co-Meter

Electrochemical Cell

Bacharach Instrument Division of American Bosch
Arma Corp.

General Monitors, Inc.

The Hays Corporation

Mast Development Co.

Technology/Versatronics, Inc.

Teledyne, Inc.
(Analytical Instrument Division)

Yellow Springs Instrument Co., Inc.

Flame Ionization

Century Geophysical Corp.
(Century Electronics & Instr. Div.)

Davis Emergency Equipment Co., Inc.
(Instrument Division)

Teledyne, Inc.
(Analytical Instrument Division)

Flow

Manufacturer	Trade Name
Flow Technology, Inc.	
Hastings-Raydist, Inc.	
Lion Research Corporation	
Quantum Dynamics, Inc.	
Technology/Versatronics, Inc.	Linurmass
Thermal Instrument Company	
Universal Controls Corporation	Dragnet

Gas Density

Newark Controls Company	

Halide Torch-Flame Color

Bernz-O-Matic Corp.	
Davis Emergency Equipment Company, Inc. (Instrument Division)	
Justrite Manufacturing Company	
Lenk Manufacturing Company	
Modern Engineering Company, Inc.	Jiffy
Tescom Corporation (Smith Welding Equipment Division)	
Union Carbide Corporation (Linde Division)	

Immersion

Moak Machine & Foundry Company	
Minnesota Minning & Manufacturing Company (Chemical Division)	

Infrared Absorption

Manufacturer	Trade Name
Beckman Instruments, Inc. (Process Instruments Division)	
Hilger & Watts, Ltd. (Hilger-I.R.D. Ltd., Div.) Calibrated Instruments, Inc.	
Mine Safety Appliances Company	Lira
Teledyne, Inc. (Analytical Instrument Division)	

Interferometer

Riken Keiki Fine Instrument Co., Ltd.	
Union Industrial Equipment Corp.	

Ion Gauge

Andar Corporation	
Canal Industrial Corporation	
Edwards High Vacuum, Inc.	
Fredericks Company	Televac
General Electric Company (Vacuum Product Business Section)	
Granville-Phillips Company	
Mine Safety Appliances Company	Billion-Aire
Perkin-Elmer Corporation Ultek Division	

Mass Spectrometer

Aero Vac Corporation	
Andar Corporation	
Associated Electrical Industries Distributed and Maintained by Picker-Nuclear	Minimass

Mass Spectrometer

Manufacturer	Trade Name
The Bendix Corporation Scientific Instruments Division	
Consolidated Electrodynamics Corp. Subsidiary of Bell & Howell	
Edwards High Vacuum, Inc.	
Electronic Associates, Inc.	
General Electric Company (Vacuum Products Business Section)	
Granville-Phillips Company	Spectrascan
Japan Vacuum Engineering Co., Ltd.	
National Research Corporation, Subsidiary of Norton Company (EquipmentDivision)	Manumatic
Perkin-Elmer Corporation Ultek Division	
Sloan Instruments Corporation	
Tenvac, Incorporated	
20th Century Electronics, Ltd.	Centronic
Vacuum Instrument Corporation	
Varian Associates Vacuum Division	
Varian Mess Analysen Technik GmbH (Heraeus-Engelhard Vacuum, Inc. distributor)	
Veeco Instruments, Inc.	

Particle Detector

General Electric Company, Materials Engineering Laboratory, Research and Development Center	
Phoenix Precision Instruments Co., Inc.	

Pressurized CO_2

General Air Products Corporation	Test-King

Pressure Change (Gas)

Manufacturer	Trade Name
Accessory Controls & Equipment Corp.	
Consolidated Electrodynamics Corp. (Subsidiary of Bell & Howell)	
Datametrics, Inc.	Barocel
Decker Corporation	
Granville-Phillips Company	
Moak Machine and Foundry Company	
MKS Instruments, Incorporated	Baratron
Ruska Instrument Corporation	
Starr-Kap Engineering Company	Air-Chek
Texas Instruments, Inc.	
Trans-Sonics, Inc.	
Wallace & Tiernan, Inc.	
Whittaker Corporation Pace-Wiancko Division	

Pressure Change (Liquid)

Datametrics, Inc.	Barocel
Starr-Kap Engineering Company	Leak Chek

Pressure - Water

American Design, Inc.

Moak Machine & Foundry Company

Sonic - Sonic Range

Fisher Research Laboratory	Audio-Scope & Master Electronic Witch
Goldak Company, Inc.	Dual-tronic

Sonic - Sonic Range

Manufacturer	Trade Name
Marcol, S. A. (M. Paquet & Co., Inc. - distributors)	Airsonic
Minear Scientific Instruments	Leakscope
Joseph G. Pollard Company, Inc.	
Schneider Manufacturing Company	Globe Geophone
Tinker & Rasor (Detectron Division)	

Sonic - Ultrasonic Range

Burnett Electronics Lab, Inc.	
Dawe Instruments	
Euphonics Industries, Inc. (The Elwood Corporation is the sole distributor)	
Fisher Research Laboratory	
Fluid Data, Inc.	Leakdata
Goldak Company, Inc.	Hunter
Hewlett Packard Company Delcon Division	
Lumidor Products Corporation	Detec-tor
Techsonics, Inc.	Son-Tector
Tel Air Products Corp.	Tel-A-Leak

Spark Coil

The Welch Scientific Company

Thermal Conductivity

Bacharach Instrument Divison of
American Bosch Arma Corp.

Thermal Conductivity

Manufacturer	Trade Name
Beckman Instruments, Inc.	Therma Bridge
Devco Engineering, Inc.	
Edwards High Vacuum, Inc.	
Gas Analysis Systems, Inc.	
Gas Purifying Materials Co., Inc.	Analograph
Gow-Mac Instrument Company	
Loenco, Incorporated	Loenco
The Matheson Company, Inc.	
Teledyne, Inc. (Analytical Instruments Division)	
Uson Corporation	

Tracer - Halogen

Bacharach Instrument Division of American Bosch Arma Corp.	Leakator
Devco Engineering, Inc.	
General Electric Company (Instrument Department)	
Thermal Industries of Florida, Inc.	

Tracer - Radioactive

Sierra Engineering Company Materials - Research Division	Radioflo

Tracer - Smoke

Superior Signal Company, Inc.

Ultraviolet Absorption

Beckman Instruments, Inc.

Ultraviolet Absorption

Manufacturer	Trade Name
Honeywell, Inc. (Apparatus Control Division)	
Teledyne, Inc. (Analytical Instruments Division)	

Volumetric Displacement

Manufacturer	Trade Name
Aerojet-General Corporation (Aerometrics Division)	
Volumetrics	

Section 29

GENERAL SUMMARY OF CHARACTERISTICS FOR LEAK DETECTORS

GENERAL SUMMARY

LEAK DETECTOR CHARACTERISTICS

OPERATING PRINCIPLE: Bubble (Liquid Applicant)

MANUFACTURERS: 16 firms

OUTPUT SIGNAL IMPEDANCE: Visual - Liquid will bubble.

RANGES: Does not apply

SENSITIVITY: Maximum claimed 1×10^{-5} cc/sec.

REPEATABILITY: Good

RESPONSE TIME: Almost instantly to 1 minute.

ENVIRONMENT EFFECTS: Min. -65°F Max. 212°F

DOES IT FAIL SAFE: Does not apply

LIFE EXPECTANCY: Shelf life one year generally

PORTABILITY: Hand carry

SIZE: 4 oz. to 55 gallon drums

WEIGHT: Usually 4 oz. bottles. Also available up to 500 lbs.

TIME ON MARKET: Max. 26 years

PRICE: .70¢/4 oz. to $5/gal.

DELIVERY TIME: Stock approx. 1 week

REMARKS: Usually is non-inflammable, non-toxic, leaves no residue, and can be obtained to meet military specifications.

Can be formulated to be compatible with particular fluids or gases.

Solutions are available which are stable up to approximately 750°F.

GENERAL SUMMARY

LEAK DETECTOR CHARACTERISTICS

OPERATING PRINCIPLE:	Catalytic Combustion
MANUFACTURERS:	14 firms
SPECIFICITY:	One unit is specific for hydrogen. 31 units for combustible gases and vapors.
EXCITATION:	9 units 115v 60 Hz 23 units battery operated, some rechargeable.
OUTPUT SIGNAL IMPEDANCE:	Various combinations of visual sign audible signal, panel meter and output for recorder.
RANGES:	0 - 1.0% concentration to 0 to 100% LEL combustible gases.
SENSITIVITY:	1.0 cu. ft./hr., 1 ppm, 1% full range (0-1.0 L.E.L.)
REPEATABILITY:	±1% to 5% of full scale
RESPONSE TIME:	One to 30 seconds
ENVIRONMENT EFFECTS:	Normal environment does not affect performance of most units. One unit sensitivie. To 10 G's vibration.
DOES IT FAIL SAFE:	No
MAINTENANCE:	Replace or recharge batteries periodically.
LIFE EXPECTANCY:	Sensor - one year. Instrument - 5 to 20 years.
PORTABILITY:	8 units hand carry
SIZE:	4" x 8" x 10" to 15" x 17" x 10"
WEIGHT:	1 3/4 lbs. to 60 lbs.
TIME ON MARKET:	1 year to 20 years
PRICE:	$75 to $1200
DELIVERY TIME:	Stock (1 week) to 3-6 months
REMARKS:	Units are available with accessories for special applications.

GENERAL SUMMARY

LEAK DETECTOR CHARACTERISTICS

OPERATING PRINCIPLE:	Chemical Indicators - Dye	Visible Dye Penetrant Fluorescent Penetrant
MANUFACTURERS:	9 firms	
EXCITATION:	Variety of ultraviolet lamps for use with fluorescnet penetrants. Requirements are from 90 v dc to 115v ac.	
OUTPUT SIGNAL IMPEDANCE:	Visible or dye fluorescent. Photocell readout systems available.	
SENSITIVITY:	Smallest flaw detectable is 75 millimicrons and leaks down to 1×10^{-7} std. cc/sec.	
REPEATABILITY:	Good	
RESPONSE TIME:	Dwell time for penetrant 2-15 minutes for developer an additional 5-15 minutes.	
ENVIRONMENT EFFECTS:	Greater sensitivity is obtained when dyes are used with ultraviolet lamp. Temperature range 60°F to 212°F.	
MAINTENANCE:	None	
LIFE EXPECTANCY:	Shelf life - 1 year to indefinite	
PORTABILITY:	Penetrants are usually in kit form - hand carry	
SIZE:	Penetrant kits are usually packaged 3 or 4-12 ounce spray cans.	
TIME ON MARKET:	Up to 16 years	
PRICE:	Penetrants kits are $22.50 to $150.	
DELIVERY TIME:	Usually from stock - 1 week.	
REMARKS:	Liquid and fluorescent penetrants detect cracks, flaws and porosity in ceramics, plastic and metals. Process requires application of penetrant, then emulsifier, and then a developer solution. Some preparation qualify under MIL-I-25135C, MIL-I-6866B, and NAVSHIPS 250-1500-1 specifications.	

GENERAL SUMMARY

LEAK DETECTOR CHARACTERISTICS

OPERATING PRINCIPLE:	Chemical Indicator - Dye - Pressurized
MANUFACTURERS:	1 firm
SPECIFICITY:	None
RANGES:	0-5000 psi
SENSITIVITY:	Varies with time and pressure applied
OUTPUT SIGNAL IMPEDANCE:	Colored fluid penetrates surface.
RESPONSE TIME:	Varies inversely with size of leak
LIFE EXPECTANCY:	Indefinite
SIZE:	2" x 2" x 5" container
WEIGHT:	4 ounces, plastic bottle
PORTABILITY:	Yes
TIME ON MARKET:	20 years
PRICE:	$1.15 for 4 ounces to $18.40 for one gallon
DELIVERY TIME:	Stock
REMARKS:	An intensely colored oil is circulated through the system. Leaks are detected by colored spots appearing on the outside of the system at the location of the leak.

GENERAL SUMMARY

LEAK DETECTOR CHARACTERISTICS

OPERATING PRINCIPLE:	Chemical Indicators - Reagents
MANUFACTURERS:	8 firms
SPECIFICITY:	Gases
EXCITATION:	120v ac
OUTPUT SIGNAL IMPEDANCE:	One type of detection tube requires visual inspection. Other units provide an electrical output.
RANGES:	1 ppm to 30% by volume
SENSITIVITY:	0.1 ppm is maximum
RESPONSE TIME:	2 minutes to 5 hours - varies inversely with concentration.
ENVIRONMENT EFFECTS:	Compensation for temperature and humidity is usually built into the equipment.
MAINTENANCE:	As needed
LIFE EXPECTANCY:	Single test per unit to indefinite
PORTABILITY:	Hand carry
WEIGHT:	1 to 70 lbs.
TIME ON MARKET:	Up to 25 years
PRICE:	$100 to $5000 with pump and case. Tubes $6.50 per 10
DELIVERY TIME:	1 week to 3-6 months
REMARKS:	Some products consist of a detector tube that is used for a single test, others are colorimetric sensors and still others are photoelectric devices that detect color change.

GENERAL SUMMARY

LEAK DETECTOR CHARACTERISTICS

OPERATING PRINCIPLE:	Electrochemical Cell
MANUFACTURERS:	7 firms
SPECIFICITY:	Strong oxidents (ozone, chlorine, etc.) Oxygen N_2O_4, UDMH and hydrazines, depending on model.
EXCITATION:	Three units are galvanic cells, others require 120v 60 Hz or battery power.
OUTPUT SIGNAL IMPEDANCE:	Panel instrument and dc voltage
RANGES:	0-5% to 0-50%. Oxygen or 0-5 ppm to 0-100 pphm by volume (oxidants)
SENSITIVITY:	0.05% O_2; 1 pphm by volume of ozone, chlorine and iodine; 1/2 ppm for oxidizers.
REPEATABILITY:	1% to 5% full scale
RESPONSE TIME:	5 to 50 seconds
ENVIRONMENT EFFECTS:	30°F to 125°F
DOES IT FAIL SAFE:	No
MAINTENANCE:	Recharge cells periodically (20 days to 3 months)- replace cell annually.
LIFE EXPECTANCY:	8 to 12 months
PORTABILITY:	Yes
SIZE:	3" x 4 1/2" x 5 3/4" to 16" x 18" x 10"
WEIGHT:	2.5 to 67 lbs.
TIME ON MARKET:	1 1/2 to 4 years
PRICE:	$245 to $3000
DELIVERY TIME:	2 weeks to 4 months

GENERAL SUMMARY

LEAK DETECTOR CHARACTERISTICS

OPERATING PRINCIPLE:	Flame Ionization (Hydro-carbon gases are ionized in a hydrogen flame, carbon ion current is measured with an electrometer circuit.)
MANUFACTURERS:	3 firms
SPECIFICITY:	Hydrocarbon gases and vapors in air.
RANGES:	Multi-ranges 3 to 8
EXCITATION:	115v 60 Hz
OUTPUT SIGNAL IMPEDANCE:	Indicating panel instrument - 5 and 25 mv dc.
SENSITIVITY:	Varies with composition. Typical maximum sensitivity = 2 ppm methane in air; 25 ppm propane in air
REPEATABILITY:	1% to 2% of full range
RESPONSE TIME:	2 to 4 seconds
ENVIRONMENT EFFECTS:	Sample in air, requires 18% oxygen
DOES IT FAIL SAFE:	No
MAINTENANCE:	Maintain hydrogen supply
PORTABILITY:	Both portable and stationary models.
SIZE:	Portable unit 15" x 16" x 9 3/4"
WEIGHT:	Portable unit 30 lbs.
TIME ON MARKET:	1 to 3 years
PRICE:	$1445 to $11,000
DELIVERY TIME:	2 weeks to 6 months
REMARKS:	Useful for measuring hydrocarbons in trace concentrations.

GENERAL SUMMARY

LEAK DETECTOR CHARACTERISTICS

OPERATING PRINCIPLE:	Flow
MANUFACTURER:	7 firms
SPECIFICITY:	Units are available for either gases or liquids
EXCITATION:	28v dc - Hand pump
OUTPUT SIGNAL IMPEDANCE:	Audible - visual (Frosting at leak) - Meter - Digital.
RANGES:	0.001 std. cc/sec. to 3×10^5 std cc/min. Air - 0.001 to 0.1 gpm liquid
SENSITIVITY:	1×10^{-2} cc/sec. (air) and 30 std. cc/min. Oxygen
REPEATABILITY:	Best is 0.1% of full scale
RESPONSE TIME:	0.1 second to 10 seconds
ENVIRONMENT EFFECTS:	Accuracy is affected by environmental temperature
PORTABILITY:	Usually yes. Some larger units are not.
SIZE:	10" diam. x 30" to 4" x 4" x 5" (sensor)
WEIGHT:	28 oz. to 300 lbs.
TIME ON MARKET:	Up to 15 years
PRICE:	$99 to $1295
REMARKS:	Many modifications are available to meet application requirements.

GENERAL SUMMARY

LEAK DETECTOR CHARACTERISTICS

OPERATING PRINCIPLE: Gas Density (A gas density switch - temperature compensation achieved by a trapped volume in a reference bellows).

MANUFACTURER: 1 firm

EXCITATION: Provides electrical contacts only

OUTPUT SIGNAL IMPEDANCE: Switch action

RESPONSE TIME: .001 second

ENVIRONMENT EFFECTS: Designs available for use at environmental temperatures of -85° to + 400°F

DOES IT FAIL SAFE: Yes

MAINTENANCE: None

LIFE EXPECTANCY: 3 to 5 years

PORTABILITY: Yes

SIZE: 1" diam. x 2"

WEIGHT: 2 ounces

TIME ON MARKET: 6 years

PRICE: $60 to $200

DELIVERY TIME: 4 to 8 weeks

GENERAL SUMMARY

LEAK DETECTOR CHARACTERISTICS

OPERATING PRINCIPLE:	Halide Torch - Flame Color (Flame color change in presence of halides)
MANUFACTURERS:	7 firms
SPECIFICITY:	Non-combustible refrigerant gases or vapors - Halides, halogenated hydrocarbons.
RANGES:	Largest is 15 to 1,000,000 ppm in air
SENSITIVITY:	Maximum is 15 ppm
EXCITATION:	Photocell type units require 115v, 60 Hz. Torch type require no power.
OUTPUT SIGNAL IMPEDANCE:	Change in color of flame - Panel meter for photocell type units.
RESPONSE TIME:	2 seconds
ENVIRONMENT EFFECTS:	Useful over temperature range from -65° to +150°F
MAINTENANCE:	Change gas cylinders as needed
PORTABILITY:	Hand carry
TIME ON MARKET:	Longest is 23 years
SIZE:	Max. 15" x 16" x 9 3/4" to 1 1/4" diam. x 6" long
WEIGHT:	1/4 to 35 lbs.
PRICE:	$8 to $16 for visual type; $715 for photocell type
REMARKS:	One Unit uses an electric arc instead of flame, another unit burns alcohol and other units burn compressed gas.

GENERAL SUMMARY

LEAK DETECTOR CHARACTERISTICS

OPERATING PRINCIPLE:	Immersion
MANUFACTURERS:	2 firms
SPECIFICITY:	None
SENSITIVITY:	Leaks as small as 1 x 10^{-7} std. cc/sec.
EXCITATION:	None required
OUTPUT SIGNAL IMPEDANCE:	Gas bubbles
PORTABILITY:	Usually not portable
REMARKS:	Leak detection systems are often designed for specific components in production lines. Immersion fluids can be water or higher boiling-point liquids. Components being tested can be pressurized with a gas or heated to increase pressure of sealed-in gas.

GENERAL SUMMARY

LEAK DETECTOR CHARACTERISTICS

OPERATING PRINCIPLE:	Infrared Absorption
MANUFACTURERS:	5 firms
SPECIFICITY:	Generally specific to nitrous oxide gases. Selectivity can be obtained by various filters of the infrared beam.
RANGES:	Set to customers requirements. Typical full ranges: 100 ppm N_2O, 50 ppm CO
SENSITIVITY:	Locates leaks to 10^{-2} lusec (1.28×10^{-5} std. cc/sec.)
EXCITATION:	115v 60 Hz or 50 Hz. Others available.
OUTPUT SIGNAL IMPEDANCE:	Panel meter (milliameter or millivoltmeter)
REPEATABILITY:	±1% full scale
RESPONSE TIME:	5 to 30 seconds (full response).
ENVIRONMENT EFFECTS:	Temperature range: 30 to 120°F No effect from normal humidity
DOES IT FAIL SAFE:	Not usually but can be made so.
MAINTENANCE:	6 month interval. Check span and zero daily.
LIFE EXPECTANCY:	10 years
SIZE:	12" x 12"x 19" to 37" x 38" x 35"
WEIGHT:	50 to 200 lbs.
PORTABILITY:	Some units are portable
TIME ON MARKET:	10 to 15 years
PRICE:	\$2400 to \$5400
DELIVERY TIME:	60 to 120 days
REMARKS:	Used as leak detector with nitrous oxide tracer gas. Can detect cyanogen, hydrazine, hydrogen cynide, nitric oxide, H_2S, CO, CO_2 and hydrocarbons. Variations and modifications are available to conform with customers requirements.

GENERAL SUMMARY

LEAK DETECTOR CHARACTERISTICS

OPERATING PRINCIPLE: Interferometer

MANUFACTURERS: 2 firms

SPECIFICITY: For gases. Unwanted background gases can be filtered out.

RANGES: As low as 0 to 2% hydrogen, methane, propane, etc.

SENSITIVITY: As low as 0.02% by volume.

EXCITATION: 115v, 60 Hz or battery

OUTPUT SIGNAL IMPEDANCE: Panel meter and audible and visual alarm.

REPEATABILITY: ±5% full scale

RESPONSE TIME: 3 seconds

ENVIRONMENT EFFECTS: Designed for use at ambient temperature of -30 to +45°C

DOES IT FAIL SAFE: No

MAINTENANCE: Nominal

LIFE EXPECTANCY: 10 years

SIZE: 2 1/2" x 3 1/2" x 7 1/2" to 8 5/8" x 7 1/8" x 11 7/8"

WEIGHT: 3 1/2 to 15 lbs.

PORTABILITY: Yes

TIME ON MARKET: 10 years

PRICE: $1500

DELIVERY TIME: 3 to 4 weeks

REMARKS: The displacement of interference light fringes produced by the optical path difference between the sample gas and an air reference, is measured by a photo-electric circuit.

GENERAL SUMMARY

LEAK DETECTOR CHARACTERISTICS

OPERATING PRINCIPLE: Ion Gauge

MANUFACTURERS: 6 firms offer gauges and 2 firms offer accessories.

SPECIFICITY: For gases. Can be made to respond to a specific gas.

RANGES: 10 to 10^{-11} torr in decade steps; 0-3 ppm to 0-50 ppm of Hydrazine and UDMH.

SENSITIVITY: 0.5 ppm Hydrazine, 0.15 ppm UDMH.

EXCITATION: 115v 60 Hz; batteries (some rechargeable)

OUTPUT SIGNAL IMPEDANCE: Panel meter, voltage output, signal lamp

REPEATABILITY: Best is ±1% full scale

RESPONSE TIME: 15 seconds

ENVIRONMENT EFFECTS: Designed for normal ambient temperatures and humidity.

DOES IT FAIL SAFE: Most do not but one unit is fail safe.

MAINTENANCE: Replace batteries or recharge periodically.

LIFE EXPECTANCY: 5 years to indefinite

SIZE: 4 1/2" x 3" x 2" to 19" x 7" x 9"

WEIGHT: 1 1/2 to 45 lbs.

PORTABILITY: Most units are portable

TIME ON MARKET: 3 to 8 years

PRICE: $350 to $1495

DELIVERY TIME: Stock to 60 days.

REMARKS: Probe gas is detected within an evacuated test system.

GENERAL SUMMARY

LEAK DETECTOR CHARACTERISTICS

OPERATING PRINCIPLE:	Mass Spectrometer
MANUFACTURER:	19 firms
SPECIFICITY:	All gases, mass 1 - 600. Varies between units.
RANGES:	Multirange taps up to 11 per unit.
SENSITIVITY:	Abundance - 0.02 PPM Partial Pressure - 10^{-15} torr (N_2) Helium 5 x 10^{-13} std. cc/sec. 10 amps per torr for N_2
EXCITATION:	105/125v, 220/240v
OUTPUT SIGNAL IMPEDANCE:	Panel meter; audible signal; 1 microamp to 1 ma; 10 mv to 10v dc
REPEATABILITY:	Short term: ±1% to ±5%; Long term: ±5% to ±10%
RESPONSE TIME:	0.1 to 1.0 sec.
ENVIRONMENT EFFECTS:	Suited for normal factory environments - Analyzer tubes useable to 200°C and bakeable to 400°C
DOES IT FAIL SAFE:	20 units - yes; 6 units - no; 1 unit - can be
MAINTENANCE:	Units vary from once every 2, to once every 12 months
LIFE EXPECTANCY:	Vary from 5 to 15 years
SIZE:	Minimum - W = 11 inches - H = 7 inches - Depth = 10 inches Maximum - W = 7 feet - H = 5 feet - Depth = 3 feet
WEIGHT:	From 12 lbs. (less magnet) to 1450 lbs.
PORTABILITY:	Movable
TIME ON MARKET:	From 1 to 10 years
PRICE:	From $1975 to $27,000
DELIVERY TIME:	From stock to 4 months
REMARKS:	Many accessories are available. Some units are specifically for one gas.

GENERAL SUMMARY

LEAK DETECTOR CHARACTERISTICS

OPERATING PRINCIPLE:	Particle Detector Gases and vapors converted to particles and counted in chamber or forward scattering of light is detected.
MANUFACTURERS:	2 firms
SPECIFICITY:	Usually not specific but it is possible to detect specific gases with use of special chemical converters.
EXCITATION:	115v 60 Hz
OUTPUT SIGNAL IMPEDANCE:	Panel instrument
RANGES:	100 to .001μ grams/liter of 0.3 micron particles.
SENSITIVITY:	Examples: Halocarbon refrigerant - 2 PPM; sulphur dioxide -.001 PPM unsymmetrical dymethyhydrazine - 0.1 PPM
RESPONSE TIME:	1 to 5 seconds
DOES IT FAIL SAFE:	No
MAINTENANCE:	Detector chamber must be clean - valve requires lubrication every 2000 hours.
PORTABILITY:	Movable on roller table
SIZE:	Approximately 22" x 10" x 20"
WEIGHT:	90 to 127 lbs.
TIME ON MARKET:	6 to 13 years
PRICE:	$2213 to $4800
DELIVERY TIME:	4 to 10 weeks
REMARKS:	Useful for detection of clean room seals and noxious gas leaks. Can detect phosgene, unsymmetrical dimethyl hydrazine, chlorine and nitrogen dioxide.

GENERAL SUMMARY

LEAK DETECTOR CHARACTERISTICS

OPERATING PRINCIPLE:	Pressurized (CO_2) - Frosting of atmospheric moisture
MANUFACTURER:	One firm
MODEL NO. & TRADENAME:	Test-King
OUTPUT SIGNAL IMPEDANCE:	Pressure gage, audible signal and visual observation of frosting of moisture in the area of a leak.
DOES IT FAIL SAFE:	Yes
MAINTENANCE:	Tank requires periodic recharge with CO_2
DOES IT FAIL SAFE:	Yes
MAINTENANCE:	Tank requires periodic recharge with CO_2
LIFE EXPECTANCY:	20 to 30 years
SIZE:	25" x 6 3/4"
WEIGHT:	40 lbs.
PORTABILITY:	Can be hand carried
TIME ON MARKET:	15 years
PRICE	$90
DELIVERY TIME:	2 weeks
REMARKS:	Test system is connected to the regulator of a pressurized CO_2 tank. Tank may be removed for recharging or for use elsewhere while leaving system being tested under pressure. Detects leaks by frosting of atmospheric moisture, provides an audible leak signal and a system pressure gage. Meets all Interstate Commerce Commission regulations.

GENERAL SUMMARY

LEAK DETECTOR CHARACTERISTICS

OPERATING PRINCIPLE:	Pressure Change - Gas
MANUFACTURERS:	13 firms
SPECIFICITY:	None
RANGES:	0-0.0001 torr to 0 -10,000 psi differential 0 - 1 torr to 0 - 100 psi absolute
SENSITIVITY:	0.00001 torr, maximum
EXCITATION:	Some units require only fluid pressure sources, others require 105-125v, 50 to 400 Hz and 220-240v, 50-60 Hz.
OUTPUT SIGNAL IMPEDANCE:	Varies with unit: Dial gage, panel meter (analog and digital), voltages to 10v dc and 10v ac FM.
REPEATABILITY:	Maximum is 0.002% FS
RESPONSE TIME:	3 milliseconds to 2 minutes
ENVIRONMENT EFFECTS:	Most units are temperature sensitive
DOES IT FAIL SAFE:	No
MAINTENANCE:	Some manufacturers offer maintenance contracts. Normally; zero check and periodic calibration.
LIFE EXPECTANCY:	Up to 20 years
SIZE:	From 6" x 11" x 7" to 25" x 22" x 19" - some are in two parts.
WEIGHT:	From 8 lbs. to 175 lbs.
PORTABILITY:	Most are portable
TIME ON MARKET:	Units vary from 1 to 20 years
PRICE:	From $670 to $6000
DELIVERY TIME:	From stock item to 12 weeks
REMARKS:	Most designs have a pressure sensing cell and a remote electronic unit.

GENERAL SUMMARY

LEAK DETECTOR CHARACTERISTICS

OPERATING PRINCIPLE:	Pressure Change - Liquid
MANUFACTURER:	2 firms
SPECIFICITY:	None
RANGES:	Basic ranges from 0-1 torr to 0-100 psi differential with a 9 position pressure range selector switch which scales sensitivity from X1 to X0.0001.
SENSITIVITY:	1×10^{-5} torr, maximum
EXCITATION:	115v, 5 to 400 Hz
OUTPUT SIGNAL IMPEDANCE:	Digital panel indicator and analog output ±5 or ±10v dc
RESPONSE TIME:	3 milliseconds at 760 torr
ENVIRONMENT EFFECTS:	Pressure transducer: 0 - 150°F Electronic system: 0 - 110°F
DOES IT FAIL SAFE:	No
SIZE:	Electronic System: 8 3/8" x 14" x 9 1/2" Pressure Transducer: 3 1/4" x 3" x 3 3/4"
WEIGHT:	25 lbs.
PORTABILITY:	Yes
PRICE:	Electronic System: $1050 to $2050 Pressure Transducer: $890 to $1200 Complete System: $2750
REMARKS:	For some units the system liquid must be electrically non-conducting. Pressure transducers and leak testing systems require vacuum back-filling with appropriate system liquids.

GENERAL SUMMARY

LEAK DETECTOR CHARACTERISTICS

OPERATING PRINCIPLE: Pressure - Water

MANUFACTURERS: 2 firms

SPECIFICITY: None

EXCITATION: Requires pressurized hydraulic systems.

SIZE: Tape is 2" wide

TIME ON MARKET: (Tape) - Less than one year

REMARKS: Water leaks are observed visually in one model and by electrical continuity of a water soluble tape in another.

Use of rust inhibitors in water are advocated.

GENERAL SUMMARY

LEAK DETECTOR CHARACTERISTICS

OPERATING PRINCIPLE:	Sonic - Sonic Range
MANUFACTURERS:	7 firms
SPECIFICITY:	None
RANGES:	Up to 17 kHz. Some have multiple ranges.
SENSITIVITY:	Unit can detect air escaping through a hole 0.0005" in diameter at a system pressure of 80 torr.
EXCITATION:	Self contained battery. Some units
OUTPUT SIGNAL IMPEDANCE:	Visual and audible signals
RESPONSE TIME:	Up to the speed of sound
ENVIRONMENT EFFECTS:	Normal atmospheric humidity and temperature will not affect performance.
DOES IT FAIL SAFE:	No
MAINTENANCE:	Battery replacement
LIFE EXPECTANCY:	5 to 25 years
SIZE:	From 3" diam. x 5" long to 15" x 10" x 11"
WEIGHT:	From 5 oz. to 20 lbs.
PORTABILITY:	Yes
TIME ON MARKET:	From 1 to 50 years
PRICE:	From \$6.50 to \$395
DELIVERY TIME:	Maximum is 2 weeks
REMARKS:	Some units are simple stethoscope types while others are much more sophisticated and provide means for amplification and tuning to frequency of interest.

GENERAL SUMMARY

LEAK DETECTOR CHARACTERISTICS

OPERATING PRINCIPLE:	Sonic - Ultrasonic Range (36 to 44 kHg).
MANUFACTURERS:	10 firms
SPECIFICITY:	None
SENSITIVITY:	Can detect leaks down to 0.001" diameter, pressurized at 2 psi at a distance of one foot.
EXCITATION:	Self contained battery
OUTPUT SIGNAL IMPEDANCE:	Indicating meter and audio signal (headphones)
RESPONSE TIME:	Speed of sound
ENVIRONMENT EFFECTS:	Designed for use in normal ambient atmosphere.
DOES IT FAIL SAFE:	No
MAINTENANCE:	Replace internal batteries after 150 to 1000 hours of use.
SIZE:	From 1 1/2" diameter x 9" long to 12" x 8" x 5"
WEIGHT:	From 12 oz. to 11 lbs.
PORTABILITY:	Yes
TIME ON MARKET:	From 1 to 30 years
PRICE:	From $130 to $850
DELIVERY TIME:	Maximum time is 3 weeks
REMARKS:	All audible sounds are filtered out and the ultrasonic sound made by a fluid leak through an irregular orifice is detected and converted into audible sound.

GENERAL SUMMARY

LEAK DETECTOR CHARACTERISTICS

OPERATING PRINCIPLE:	Spark Coil (Telsa Type)
MANUFACTURER:	1 firm
SPECIFICITY:	For detecting leaks in glass vacuum systems.
EXCITATION:	115 v ac or dc
OUTPUT SIGNAL IMPEDANCE:	A glow appears in a vacuum system when the coil probe approaches a system leak.
SIZE:	2" diam. x 12" long
PORTABILITY:	Hand held probe
PRICE:	$16.75
REMARKS:	Not recommended for thin wall systems.

GENERAL SUMMARY

LEAK DETECTOR CHARACTERISTICS

OPERATING PRINCIPLE:	Thermal Conductivity
MANUFACTURERS:	10 Firms
SPECIFICITY:	Selectivity to specific gases can be achieved with suitable filters.
RANGES:	1/2 to 10 oz/yr. of R12 gas - 10 ppm H_2S and others to 100% of gas of interest.
SENSITIVITY:	Maximum is 1 x 10^{-5} std cc/sec helium and 1 ppm.
EXCITATION	115v, 60 Hz or internal batteries (some rechargeable)
OUTPUT SIGNAL IMPEDANCE:	Panel instrument, signal lamp, tone, dc signal
REPEATABILITY:	Vary from 1/2% to 25% Full Scale
RESPONSE TIME:	Vary from 1/2 sec. to several minutes
ENVIRONMENT EFFECTS:	Designed for use in normal ambient environment.
DOES IT FAIL SAFE:	Some units do
MAINTENANCE:	Replace batteries periodically. Span check monthly for high sensitivity units.
LIFE EXPECTANCY:	Vary from 5 to 20 years.
SIZE:	From 3" x 4" x 9" to 15" x 7" x 10"
WEIGHT:	From 4 to 110 lbs.
PORTABILITY:	Most units are portable
TIME ON MARKET:	From 1 to 15 years
PRICE:	From $165 to $5,000
DELIVERY TIME:	From 1 week to 4 months
REMARKS:	Usually for use in measuring concentrations in by-gaseous mixtures.

GENERAL SUMMARY

LEAK DETECTOR CHARACTERISTICS

OPERATING PRINCIPLE:	Tracer - Halogen
MANUFACTURERS:	4 firms
SPECIFICITY:	Halogen gases
RANGES:	From 1 to 10 ranges
SENSITIVITY:	Maximum is 1 x 10^{-9} std. cc/sec. (6 x 10^{-6} oz./year) R-12
EXCITATION:	115 or 230v, 60 Hz or internal batteries
OUTPUT SIGNAL IMPEDANCE:	Lamp, panel meter or audible signal
RESPONSE TIME:	Approximately 1 second
ENVIRONMENT EFFECTS:	Suited for use in a temperature environment from 0 to 55°C (avoid areas with high concentrations of halogen gases and corrosive vapors and salt spray.)
DOES IT FAIL SAFE:	Most do not.
MAINTENANCE:	Replace batteries periodically. Replace sensing element when required.
LIFE EXPECTANCY:	Depends on exposure time of element to desensitizing agents.
SIZE:	From 6" x 3" x 2" to 20" x 14" x 11"
WEIGHT:	From 1 1/2 to 20 lbs.
PORTABILITY:	Yes
TIME ON MARKET:	From 1 to 15 years
PRICE:	From $90 to $1115
DELIVERY TIME:	From 1 to 6 weeks
REMARKS:	Leak standards are available which permit quantitative calibrations. Detectors must not be used in the presence of flammable vapors.

GENERAL SUMMARY

LEAK DETECTOR CHARACTERISTICS

OPERATING PRINCIPLE:	Tracer - Radioactive
MANUFACTURER:	1 firm
SPECIFICITY:	Krypton 85 (Krypton-85 and Nitrogen mixture)
MODEL NO. & TRADENAME:	Radioflo Model 44-462
SENSITIVITY:	1×10^{-11} std. cc/sec.
EXCITATION:	115v, 25 amps, 60 Hz (50 Hz available)
OUTPUT SIGNAL IMPEDANCE:	Scintillation Crystal Counting Station
DOES IT FAIL SAFE:	Yes
SIZE:	56 1/4" x 54 7/8" x 44"
WEIGHT:	Complete system: 3640 lbs. (5 gallon Activation Tank)
PORTABILITY:	No
TIME ON MARKET:	12 years
PRICE:	Price on request

GENERAL SUMMARY

LEAK DETECTOR CHARACTERISTICS

OPERATING PRINCIPLE:	Tracer - Smoke
MANUFACTURER:	1 firm
MODEL NO. & TRADENAME:	Superior Smoke Candles and Superior Smoke Bombs
EXCITATION:	None required. Flame manually applied to fuse.
OUTPUT SIGNAL IMPEDANCE:	Visual observation and odor of escaping smoke through leak.
RESPONSE TIME:	Approximately 5 minutes
ENVIRONMENT EFFECTS:	Should be stored below 65° humidity and 85°F
DOES IT FAIL SAFE:	Yes
LIFE EXPECTANCY:	18 months
SIZE:	Four sizes from 1/2" x 1 3/8" OD to 14" x 1 3/8" OD with burning time of 30 seconds, 60 seconds, three minutes or five minutes.
WEIGHT:	1 1/2 oz. to 1 lb. each
PORTABILITY:	Yes
TIME ON MARKET:	14 years
PRICE:	$4.50 to $25.80 per dozen
DELIVERY TIME:	2 weeks
REMARKS:	After the smoke device is started a blower injects the non-toxic smoke into the system to be leak tested. Smoke will be observed escaping from leaks. This method can be used on large systems such as sewer lines. On smaller systems a blower may not be necessary and merely insertion of the smoke device is sufficient. Smoke volume normally should be sufficient to fill an area 5 or 6 times that of the test system. Various types of smoke devices available. Smoke will not stain clothing nor corrode metal.

GENERAL SUMMARY

LEAK DETECTOR CHARACTERISTICS

OPERATING PRINCIPLE:	Ultraviolet Absorption
MANUFACTURERS:	3 Firms
SPECIFICITY:	Not usually designed for specific gases but this can be achieved by selecting specific light sources and filter elements.
RANGES:	From ppm to 100% concentration
SENSITIVITY:	± 1% Full Scale
EXCITATION:	115v, 50 or 60 Hz.
OUTPUT SIGNAL IMPEDANCE:	Voltage or current signal; panel instrument
REPEATABILITY:	± 1% to ± 15%
RESPONSE TIME:	1 to 30 seconds
ENVIRONMENT EFFECTS:	Designed for use over environmental temperature range of 40-110°F.
DOES IT FAIL SAFE:	No
MAINTENANCE:	Annual check of electronic tubes and standard cell in one unit.
LIFE EXPECTANCY:	5 years
SIZE:	Amplifier 8" x 11" x 5" to 9" x 8" x 18" Analyzer 6" x 6" x 19" to 29" x 8" x 10"
WEIGHT:	30 lbs for portable unit
PORTABILITY:	One unit is portable
TIME ON MARKET:	2 years for portable unit
PRICE:	$600 for the portable unit
DELIVERY TIME:	4 weeks for portable unit

GENERAL SUMMARY

LEAK DETECTOR CHARACTERISTICS

OPERATING PRINCIPLE:	Volumetric Displacement
MANUFACTURER:	2 firms
SPECIFICITY:	None
SENSITIVITY:	1 x 10^{-5} std. cc/sec. is maximum
OUTPUT SIGNAL IMPEDANCE:	Liquid level in a calibrated sight glass in one unit and a digital indicator in the other.
ENVIRONMENT EFFECTS:	Units are sensitive to environmental temperature.
DOES IT FAIL SAFE:	No
MAINTENANCE:	None required
LIFE EXPECTANCY:	250,000 cycles
SIZE:	Approximately 6" x 10" x 3"
WEIGHT:	4.8 and 12 lbs.
PORTABILITY:	Yes
TIME ON MARKET:	2 years for digital unit
PRICE:	$395 for digital unit
DELIVERY TIME:	Digital unit is in stock

Section 30

LEAK DETECTORS - THEIR CHARACTERISTICS

MANUFACTURER:	Accessory Controls & Equipment Corporation
OPERATING PRINCIPLE:	Pressure Change-Gas (detects pressure difference between test system and a trapped supply)
MODEL NO. & TRADENAME:	ACE-234
RANGES:	-20 to +20 inches of water differential pressure
EXCITATION:	0-300 psi - compressed gas
OUTPUT SIGNAL IMPEDANCE:	Reading on pressure gage (mechanical)
ENVIRONMENT EFFECTS:	Temperature sensitive - large air currents should be prevented from passing over system or leakage detector.
MAINTENANCE:	As required
LIFE EXPECTANCY:	Depends on care and useage
PORTABILITY:	Can be hand carried
TIME ON MARKET:	10 years
PRICE:	$670
DELIVERY TIME:	6 - 8 weeks
REMARKS:	Temperature of test system and detector must not vary during test.

MANUFACTURER:	Aero Vac Corporation
OPERATING PRINCIPLE:	Mass Spectrometer
SPECIFICITY:	All gases, mass 2 to 200
MODEL NO. & TRADENAME:	Model 370, Process Control Analyzer
SENSITIVITY:	10^{-12} torr (10 ppm)
EXCITATION:	105 to 125 volts ac, 15 amps
OUTPUT SIGNAL IMPEDANCE:	X Axis 0-10v dc; Y Axis 0-100mv dc
RESPONSE TIME:	Less than 1 second
DOES IT FAIL SAFE:	Yes
MAINTENANCE:	Approximately once every three months
LIFE EXPECTANCY:	Ten years
SIZE:	24" x 24" x 60" (WDH)
WEIGHT:	450 lbs.
PORTABILITY	On casters
TIME ON MARKET:	18 months
PRICE:	$12,400
DELIVERY TIME:	One month

MANUFACTURER:	Aero Vac Corporation
OPERATING PRINCIPLE:	Mass Spectrometer
SPECIFICITY:	All gases, mass 2 to 300
MODEL NO. & TRADENAME:	Model No. 685
RANGES:	Mass 2 to 300
SENSITIVITY:	10^{-13} torr (1.0 ppm)
EXCITATION:	105-125v ac
OUTPUT SIGNAL IMPEDANCE:	X Axis 0-10v dc; Y Axis 0-100mv dc
RESPONSE TIME:	Less than 1 second
DOES IT FAIL SAFE:	Yes
MAINTENANCE:	Approximately once every 3 months
LIFE EXPECTANCY:	10 years
SIZE:	WDH 48" x 24" x 60"
WEIGHT:	600 lb.
PORTABILITY:	On casters
TIME ON MARKET:	2 years
PRICE:	$16,000
DELIVERY TIME:	4 months

MANUFACTURER:	Aero Vac Corporation
OPERATING PRINCIPLE:	Mass Spectrometer
SPECIFICITY:	All gases, mass 1 to 500
MODEL NO. & TRADENAME:	Model No. 686
RANGES:	Mass 1 to 500
SENSITIVITY:	10^{-13} torr (0.02 ppm)
EXCITATION:	105-125v ac
OUTPUT SIGNAL IMPEDANCE:	X Axis 0-10v dc; Y Axis 0-100mv dc
RESPONSE TIME:	Less than 1 second
DOES IT FAIL SAFE:	Yes
MAINTENANCE:	Approximately once every 3 months
LIFE EXPECTANCY:	10 years
SIZE:	WDH 60" x 24" x 60"
WEIGHT:	1000 lb.
PORTABILITY:	On casters
TIME ON MARKET:	2 years
PRICE:	$27,000
DELIVERY TIME:	4 months

MANUFACTURER:	Aero Vac Corporation
OPERATING PRINCIPLE:	Mass Spectrometer
SPECIFICITY:	All gases, mass 2 to 70
MODEL NO. & TRADENAME:	M270
RANGES:	Mass 2 to 70
SENSITIVITY:	10^{-10} torr (20 ppm)
EXCITATION:	105-125v ac 15 amps
OUTPUT SIGNAL IMPEDANCE:	X Axis 0-10v dc; Y Axis 0-10mv dc
RESPONSE TIME:	Less than 1 second
DOES IT FAIL SAFE:	Yes
MAINTENANCE:	Approximately once every 3 months
LIFE EXPECTANCY:	10 years
SIZE:	WDH 24" x 24" x 60"
WEIGHT:	450 lbs.
PORTABILITY:	On casters
TIME ON MARKET:	4 years
PRICE:	$8900
DELIVERY TIME:	Stock
REMARKS:	Versatile. Simple conversion from leak testing of pressurized or evacuated systems to high vacuum gas analysis and vice versa.

MANUFACTURER:	Aero Vac Corporation
OPERATING PRINCIPLE:	Mass Spectrometer
MODEL NO. & TRADENAME:	Model AVA1 Residual Gas Analyzer
RANGES:	Mass numbers 2 to 70 standard; option of extending to 1 and to 200.
SENSITIVITY:	Sensitivity range for Nitrogen: 10^{-10} torr
OUTPUT SIGNAL IMPEDANCE:	Meter indication of pressure, mass scan, and emission. Recorder output: 10 MVF.S.; pressure: 10 VF.S. mass.
RESPONSE TIME:	30 secs. and 2 min. per range
SIZE:	Cabinet 21" x 23" x 13" Rack Panel 19" x 8 3/4"
PRICE:	$2940
REMARKS:	Spectrometer tube is bakeable to 400°C. Maximum operating pressure: 10^{-3} torr. Total pressure measurement range: 10^{-3} to 10^{-10} torr.

MANUFACTURER:	Aero Vac Corporation
OPERATING PRINCIPLE:	Mass Spectrometer
MODEL NO. & TRADENAME:	Model AVA1-100 Residual Gas Analyzer
RANGES:	Mass range from 2 to 200
SENSITIVITY:	Sensitivity range for Nitrogen: 10^{-12} torr
OUTPUT SIGNAL IMPEDANCE:	Meter indication of pressure, mass scan, and emission. Recorder outputs: 10 mv FS pressure; 10 VFS mass.
RESPONSE TIME:	8 min. per range
SIZE:	Cabinet: 21" x 23" x 16 1/2" Rack Panel: 19" x 12 1/2"
PRICE:	$4900
REMARKS:	Spectrometer tube is bakeable to 400°C

MANUFACTURER:	Aerojet-General Corporation- Aerometrics Division
OPERATING PRINCIPLE:	Volumetric Displacement
SPECIFICITY:	None
MODEL NO. & TRADENAME:	Displacement Leak Meter
SENSITIVITY:	0.008 std cc/min.
OUTPUT SIGNAL IMPEDANCE:	Displacement of a liquid in a calibrated sight glass.
ENVIRONMENT EFFECTS:	+ 40 to + 110°F
DOES IT FAIL SAFE:	No
SIZE:	4" x 6" x 8"
WEIGHT:	12 lbs.
PORTABILITY:	Yes
REMARKS:	The detector design incorporates a back pressure balancing principle which practically eliminates back pressure to the leakage source. It can be used to measure leakage rates in air or any inert gas system. In use the detector is connected to a sealed cavity formed around the area of a pressurized system being leak tested (seals, assemblies etc.).

MANUFACTURER:	Alamo Mill Supply Company Exclusive Agent: Alamo Specialty Company
OPERATING PRINCIPLE:	Bubble (Liquid Applicant)
MODEL NO. & TRADENAME:	KA-OX-10, ALSPEC (Federal Stock List No. 6810-286-6019, MIL-25567A)
OUTPUT SIGNAL IMPEDANCE:	Visual - White bubble formation in leaking area
ENVIRONMENT EFFECTS:	Type I: +33°F to +180°, Type II: -65° to +32°
DOES IT FAIL SAFE:	Yes
LIFE EXPECTANCY:	Indefinite
SIZE:	4 ounce polyethylene squeeze bottle. 5 gallon polyethylene container.
WEIGHT:	4 oz. and 40 lbs.
PORTABILITY:	Yes
TIME ON MARKET:	5 years
PRICE:	$2.50 per 4 oz. polyethylene bottle, $35.00 per gallon standard pack 25-4 oz. bottles per case.
DELIVERY TIME:	Stock
REMARKS:	This product is an inert compound developed for fast, safe positive detecting of leaks in pressurized gas systems. Above formula is for use with oxygen system and most other gases. Other formulas are available for specific systems such as chlorine, air conditioning, telephone cables and LP gases.

MANUFACTURER: American Design, Inc.

OPERATING PRINCIPLE: Pressurized - Water -(Conducting Tape)

SPECIFICITY: Tape is water soluble

MODEL NO. & TRADENAME: Leak Detection Tape

SIZE: Tape is 2" wide

TIME ON MARKET: 3 months

REMARKS: Tape is multilayered. A strip of aluminum foil is electrically insulated from the test system by a strip of water - soluble paper. A wider strip of adhesive tape permits adhereing the assembly to the surface being leak tested. An electrical continuity circuit is required for detecting a loss of the water soluble paper. The tape has been developed by the Boeing Company on a NASA program.

MANUFACTURER: American Gas & Chemicals, Inc.

OPERATING PRINCIPLE: Bubble (liquid applicant)

MODEL NO. & TRADENAME: "Leak-Tec"

SENSITIVITY: 1×10^{-5} STD. cc/sec or 0.013 cubic feet/year

OUTPUT SIGNAL IMPEDANCE: Bubble

RESPONSE TIME: Almost instantly

ENVIRONMENT EFFECTS: Formulae available to -65°F. See "REMARKS"

SIZE: 4 ounce plastic container

PORTABILITY: Can be hand carried

PRICE: Approximately $1.50 each

REMARKS:

non-explosive
non-flammable
non-injurious
non-corrosive

For detection of gas and air leaks in pressurized systems. Special formula available for vacuum testing. Leave no residue.

Typical formulas available -

#OX-65-C for oxygen (+35 to -65°F) - MIL-L-25567A(ASG) (-65°) Type II

#16-OX for oxygen (regular) - MIL-L-25567A(ASG) (STD) Type I

#577-V for vacuum testing

#177 for refrigeration, air conditioning (not for ammonia) eleven other chemical formula available.

MANUFACTURER:	American Gas & Chemicals, Inc.
OPERATING PRINCIPLE:	Bubble (Leak Detection Liquid)
MODEL NO. & TRADENAME:	FM Inert
SENSITIVITY:	Will detect leakage rates down to 10^{-5} standard cc/sec.
OUTPUT SIGNAL IMPEDANCE:	Visual (Bubble)
ENVIRONMENT EFFECTS:	Thermal stability: approximately 750°F
REMARKS:	For testing handling and storage equipment for missile fuels and oxidizers when the equipment is pressurized with air or other gas before filling with fuel. Liquid and residue are inert to the following reagents: Commercial concentrated nitric acid White fuming nitric acid (cold and hot) 90% hydrogen peroxide Commercial concentrated sulfuric acid (cold or hot) Commercial hydrazine and UDMH Liquid oxygen

MANUFACTURER:	American Gas & Chemicals, Inc.
OPERATING PRINCIPLE:	Chemical Indicator (Reagent)
SPECIFICITY:	Water
MODEL NO. & TRADENAME:	BUG·IT W-15
SENSITIVITY:	Visible detection to 1/10,000 of 1 cc. Black light inspection increases sensitivity to 2/100,000 of 1 cc.
OUTPUT SIGNAL IMPEDANCE:	Visual - Water is indicated by the appearance of a red pattern on the white surface. See remarks.
RESPONSE TIME:	Immediate
REMARKS:	BUG·IT is supplied in sheet form. It should be wrapped around the area of suspected leakage, securing it with the pressure sensitive adheshive. The color change is immediate and irreversible. With experience, the red pattern size can be interpreted quantitatively.

MANUFACTURER:	American Gas & Chemicals, Inc.
OPERATING PRINCIPLE:	Chemical Indicator (Reagent)
SPECIFICITY:	Freon
MODEL NO. & TRADENAME:	BUG·IT FR-20
SENSITIVITY:	Visible detection to 4/10,000 of 1 cc.
OUTPUT SIGNAL IMPEDANCE:	Visual - Freon is indicated by the appearance of a blue pattern on the surface. See remarks.
RESPONSE TIME:	Immediate
REMARKS:	BUG·IT is supplied in sheet form. It should be wrapped around the area of suspected leakage, securing it with the pressure sensitive adhesive. The color change is immediate and irreversible. With experience, the pattern size can be interpreted quantitatively.

MANUFACTURER:	American Gas & Chemicals, Inc.
OPERATING PRINCIPLE:	Chemical Indicator (Reagent)
SPECIFICITY:	Hydrazine and other nitrogen containing compounds such as hydroxylamine also to components of tobacco smoke.
MODEL NO. & TRADENAME:	BUG·IT H-25
SENSITIVITY:	Indicates presence of 5 PPM of hydrazine in the atmosphere by color change in five minutes. An actual leak of hydrazine vapor of 1.6×10^{-4} cc/sec is indicated after several minutes. Smaller leaks down to 1×10^{-6} cc/sec require proportionately longer testing time.
OUTPUT SIGNAL IMPEDANCE:	Visual - see note above.
RESPONSE TIME:	5 minutes
REMARKS:	BUG·IT H-25 paper is supplied in 4" x 5 1/2" sheets with "band-aid type adhesive ends which can be cut to required size. Develops an irreversible orange pattern on contact with hydrazine vapors. (Color changes to yellow at high vapor concentrations and on contact with liquid hydrazine). It is deactivated by ammonia and amine vapors.

MANUFACTURER: American Gas & Chemicals, Inc.

OPERATING PRINCIPLE: Chemical Indicator (Reagent)

SPECIFICITY: Fuel, oil, hydraulic fluids and organic solvents.

MODEL NO. & TRADENAME: BUG·IT F105

SENSITIVITY: Develops an irreversible blue pattern on contact with even a fraction of a drop (approx. 0.001 cc) of engine fuel, oil, hydraulic fluids or any of a number of different solvents. This response occurs most rapidly with light hydrocarbons, but becomes more intensive with heavy oils.

OUTPUT SIGNAL IMPEDANCE: Visual - blue coloring, see note above

ENVIRONMENT EFFECTS: Operational temperature: -65°F to 250°F

REMARKS: BUG·IT is supplied in 4" x 5 1/2" sheets with a pressure sensitive backing and can be cut to desired size. Can be left in place indefinitely.

MANUFACTURER:	American Gas & Chemicals, Inc.
OPERATING PRINCIPLE:	Chemical Indicator (Reagent)
SPECIFICITY:	Engine fuels, hydraulic fluids, oils and organic solvents
MODEL NO. & TRADENAME:	JET/TEC, type A perforated
SENSITIVITY:	0.05 cc
OUTPUT SIGNAL IMPEDANCE:	Visual - develops an irreversible red pattern at the leak source.
ENVIRONMENT EFFECTS:	Temperature: -65°F to 380°F
SIZE:	2 1/2 inch x 4 feet strips (20 per package). Some special sizes available.
PORTABILITY:	Easily by hand
TIME ON MARKET:	3 years
PRICE:	$38.50 (20 strips 2 1/2 in. x 4 1/2 ft.)
DELIVERY TIME:	Stock
REMARKS:	JET/TEC is a wrap-on foil backed asbestos leak detection tape that locates leaks instantly. Supplied in strips 2 1/2" x 4 1/2". Non-toxic; non-corrosive and non-staining. The package priced above contains the required heat resistance tape for fastening the strips.

MANUFACTURER:	Andar Corporation
OPERATING PRINCIPLE:	Mass Spectrometer
SPECIFICITY:	Helium
MODEL NO. & TRADENAME:	Series LD-300
SENSITIVITY:	2.6×10^{-11} std. cc/sec. of helium
EXCITATION:	115/230 v., 3 amp, 50/60 Hz.
REPEATABILITY:	± 1%
RESPONSE TIME:	Instantaneous
ENVIRONMENT EFFECTS:	Practically no influence
DOES IT FAIL SAFE:	Yes
MAINTENANCE:	6 months intervals. (No oil, no liquid nitrogen, getter ion pumped)
LIFE EXPECTANCY:	15 years
SIZE:	Cabinet 24" x 24" x 38"
WEIGHT:	300 lbs.
PORTABILITY:	Mounted on casters
TIME ON MARKET:	1 month
PRICE:	$4600 and up
DELIVERY TIME:	45 days
REMARKS:	Is also able to detect gross leaks. Optional equipment and accessories available.

MANUFACTURER:	Andar Corporation
OPERATING PRINCIPLE:	Ion Gauge - Amplifier
MODEL NO. & TRADENAME:	LD-100
RANGES:	2 (high, low)
SENSITIVITY:	1 x 10^{-9} std. cc/sec.
OUTPUT SIGNAL IMPEDANCE:	Reading on microammeter
REPEATABILITY:	±0.1%
RESPONSE TIME:	Instantaneous
ENVIRONMENT EFFECTS:	Not affected except by extreme temperature and humidity.
DOES IT FAIL SAFE:	No
MAINTENANCE:	Replace batteries every 6 months
LIFE EXPECTANCY:	Basic unit - 5 years exclusive of battery change.
SIZE:	1 3/4" x 3" x 4"
WEIGHT:	14 oz.
PORTABILITY:	Can be hand carried
TIME ON MARKET:	6 months
PRICE:	$250
DELIVERY TIME:	From stock
REMARKS:	Used for locating leaks in vacuum systems. Unit is designed for use with ion gauge or ion pump control unit. Detector amplifiers and displays differential input voltage.

MANUFACTURER:	Associated Electrical Industries Distributed and maintained by Picker Nuclear
OPERATING PRINCIPLE:	Mass Spectrometer (Residual Gas Analyzer)
SPECIFICITY:	Preferably helium, but can be used with all gases in mass range 2-200.
MODEL NO. & TRADENAME:	MS10
RANGES:	1000:1 in seven ranges. High test range gives sensitivity quoted below. Range extension accessories available.
SENSITIVITY:	5×10^{-13} std. cc per sec.
EXCITATION:	100 to 260 volts, 50/60 Hz - 150 watts
OUTPUT SIGNAL IMPEDANCE:	3" meter indication. 10 mV recorder at 100 ohm source.
REPEATABILITY:	±2 1/2%
RESPONSE TIME:	0.6 secs. Faster response with pro-rata sensitivity reduction.
ENVIRONMENT EFFECTS:	Unaffected by 6% line voltage fluctuations. Unaffected by humidity. Analyzer tube useable to 150°C and bakeable at 400°C.
DOES IT FAIL SAFE:	Yes
MAINTENANCE:	Annual service recommended.
SIZE:	17"W x 18"D x 10 1/2"H
WEIGHT:	Basic Instrument - 112 lbs.
PORTABILITY:	Yes. Needs vacuum connection to test chamber or system.
TIME ON MARKET:	6 years
PRICE:	$5290 f.o.b. New York
DELIVERY TIME:	30 days
REMARKS:	Above specification refers to basic instrument. A wide range of vacuum and inlet systems and special purpose accessories are available.

MANUFACTURER:	Associated Electrical Industries Distributed and maintained by Picker Nuclear
OPERATING PRINCIPLE:	Mass Spectrometer (Partial Pressure Gauge)
SPECIFICITY:	Preferably helium. Can be used with all gases in mass range 2-240.
MODEL NO. & TRADENAME:	Minimass
RANGES:	100000:1 in 9 ranges and decade multiplier.
SENSITIVITY:	10^{-11} std. cc/sec for nitrogen
EXCITATION:	115-120 and 220-240v, 50/60 Hz, ac 120 v amp
OUTPUT SIGNAL IMPEDANCE:	3" meter indication - 10mV recorder output
REPEATABILITY:	±3%
RESPONSE TIME:	1 second
ENVIRONMENT EFFECTS:	Unaffected by humidity. Analyzer tube useable to 200°C bakeable to 400°C
DOES IT FAIL SAFE:	Yes
MAINTENANCE:	Annual service recommended
SIZE:	7 13/16"H x 19 3/4"W x 16 11/16"D
WEIGHT:	74 lbs.
PORTABILITY:	Yes. Needs vacuum connection to test chamber or system.
TIME ON MARKET:	1 year
PRICE:	$2650 f.o.b. New York
DELIVERY TIME:	30 days
REMARKS:	Instrument available in glass and metal analyzer configurations.

MANUFACTURER:	Automation Industries, Incorporated Sperry Products Division
OPERATING PRINCIPLE:	Chemical Indicators - Dye
MODEL NO. & TRADENAME:	Sperry Penetrants - DP-400 Penetrant, DW-525 Developer
RESPONSE TIME:	2 minutes to 10 minutes depending on material tested and nature of defect.
ENVIRONMENT EFFECTS:	Material should be at least 68°F and clean for best results. Must be thoroughly dry before application of penetrant.
SIZE:	Single 16 oz. spray can to 55 gallon drum
PORTABILITY:	Can be hand carried
PRICE:	DP-400 Penetrant, single spray can - $5.00 or $11.00/gallon DW-525 Developer, single spray can - $5.00 or $7.90/gallon
DELIVERY TIME:	From stock
REMARKS:	Requires spray, brush, or dip of red dye. Dye is then wiped off, developer is applied, and imperfections show up as red marks. Depth of defects indicated by richness of color and speed of bleed out. Is non-toxic. One gallon covers 3000 sq. ft.

MANUFACTURER:	Bacharach Instrument Division of American Bosch Arma Corporation
OPERATING PRINCIPLE:	Catalytic Combustion
SPECIFICITY:	Combustible gases and vapors
MODEL NO. & TRADENAME:	Bacharach Gastron: Model 282 (Code 23-7059) for combustibles, and Model 310 (Code 23-7060) for H2 and combustibles.
RANGES:	Model 282: 50 ppm to 25% natural gas Model 310: 50 ppm to 5% hydrogen
SENSITIVITY:	Model 282: Better than 50 ppm Model 310: Approximately 10 ppm
EXCITATION:	5v, 4.0 amp.-hr. rechargeable nickel cadmium battery
OUTPUT SIGNAL IMPEDANCE:	Audio earphone and meter. DC meter is 0-50 micro-amps.
REPEATABILITY:	± 25%
RESPONSE TIME:	2 seconds or less
ENVIRONMENT EFFECTS:	Can be operated satisfactorily between -30°F and +130°F. Storage limits between -60°F to 150°F.
DOES IT FAIL SAFE:	Calibration kit provided to check overall operation.
MAINTENANCE:	Recharge battery after 10 hours continuous operation. Replace detector cell after 40 hours normal use.
LIFE EXPECTANCY:	10 years normal use
SIZE:	Main housing: 3 1/2" x 3" x 6 1/2". Does not include probe and pistol grip.
WEIGHT:	2 lbs. 6 oz. (instrument only) 4 lbs. 10 oz. (complete with battery)
PORTABILITY:	Designed to be carried by hand
TIME ON MARKET:	5 years
PRICE:	Model 282: $695.00 list, complete with accessories. Model 310: $745.00 list, complete with accessories.
DELIVERY TIME:	21 days
REMARKS:	Designed to detect leakage from buried natural gas distribution lines without need to sink "bar holes". Also useful for hydrogen leak testing applications where extreme sensitivity required.

MANUFACTURER:	Bacharach Instrument Division of American Bosch Arma Corporation
OPERATING PRINCIPLE:	Chemical Indicator-Reagent
SPECIFICITY:	Oxygen
MODEL NO. & TRADENAME:	#10-5054; #10-5011: #10-5046 Fyrite Gas Analyzers
RANGES:	0-7.6%; 0-21%; 0-60%
OUTPUT SIGNAL IMPEDANCE:	Visual - liquid in a column
ENVIRONMENT EFFECTS:	Ambient temperature from -30° to 150°F. Gases up to 850°F may be tested.
MAINTENANCE:	Change fluid after approximately 100 samplings
LIFE EXPECTANCY:	See maintenance
PORTABILITY:	Yes
PRICE:	$61.00
DELIVERY TIME:	2 weeks

MANUFACTURER:	Bacharach Instrument Division of American Bosch Arma Corporation
OPERATING PRINCIPLE:	Thermal Conductivity
MODEL NO. & TRADENAME:	Model SA65A Gas Leak Detector (Code 23-7027)
RANGES:	Range selector incorporates X1, X2, X4, X10, X20 and X100 positions.
SENSITIVITY:	6.8×10^{-5} std. cc/sec. Helium.
EXCITATION:	6.3 volt rechargeable sealed lead acid battery rated at 2.6 ampere-hours.
OUTPUT SIGNAL IMPEDANCE:	Audible (earphone) and visual (meter). Meter is 0-50 microamp.
REPEATABILITY:	± 25%
RESPONSE TIME:	1 to 2 seconds
ENVIRONMENT EFFECTS:	Satisfactory performance in ambient range of 0 to 140°F. Not affected by humidity. Non-nutrient materials used. MIL-I-26600 RFI tested.
DOES IT FAIL SAFE:	Yes, operator's check list provided
MAINTENANCE:	Battery recharge required after 8-9 hours continuous operation.
LIFE EXPECTANCY:	Estimate 10 years, depending on duty cycle.
SIZE:	3 1/4" x 9 1/4" x 9 3/4"
WEIGHT:	8 1/2 lbs. including battery and charger
PORTABILITY:	Can be hand carried
TIME ON MARKET:	2 years
PRICE:	$750 list
DELIVERY TIME:	21 days after receipt of order
REMARKS:	The SA65A Leak Detector has been tested and approved Intrinsically Safe by Factory Mutual for use in Class I, Division 1, Group A, B, C, and D hazardous atmospheres. FM Report available on request.

MANUFACTURER:	Bacharach Instrument Division of American Bosch Arma Corporation
OPERATING PRINCIPLE:	Thermal Conductivity
MODEL NO. & TRADENAME:	Model SA63 Gas Leak Detector (Code 23-7001)
RANGES:	In terms of R-12 gas: 1/2, 1, 2, 5 and 10 oz./yr.
SENSITIVITY:	4.4×10^{-5} std. cc/sec., Hydrogen
EXCITATION:	Six size D dry cells
OUTPUT SIGNAL IMPEDANCE:	Signal light and tone
REPEATABILITY:	± 25%
RESPONSE TIME:	3 seconds
ENVIRONMENT EFFECTS:	Satisfactory performance in ambient range of 32° to 110°F. Not affected by humidity.
DOES IT FAIL SAFE:	Yes, operator's check list provided
MAINTENANCE:	Batteries require replacement after 40 hours continuous service. Use alkaline maganese type.
LIFE EXPECTANCY:	5-10 years, depending on duty cycle
SIZE:	3 1/4" x 7 3/4" x 9 3/4"
WEIGHT:	7 1/2 lbs. with batteries
PORTABILITY:	Can be hand carried
TIME ON MARKET:	4 years
PRICE:	$250 list
DELIVERY TIME:	21 days after receipt of order

MANUFACTURER:	Bacharach Instrument Division of American Bosch Arma Corporation
OPERATING PRINCIPLE:	Tracer - Halogen (TRH)
SPECIFICITY:	R11, R12, R22 and similar refrigerants
MODEL NO. & TRADENAME:	"Leakator" (Bach Code #23-7023)
SENSITIVITY:	1/2 ounce per year of R12
EXCITATION:	2 size D batteries
OUTPUT SIGNAL IMPEDANCE:	Visual - light goes out when leak is detected
RESPONSE TIME:	1 second
ENVIRONMENT EFFECTS:	Operates: 0-120°F; not affected by high humidity Stored: 0-140°F
DOES IT FAIL SAFE:	Yes
MAINTENANCE:	Replace batteries periodically (30 hours life)
SIZE:	4 1/2" x 2" x 7 1/2"
WEIGHT:	1 1/2 lbs.
PORTABILITY:	Yes
PRICE:	$97.50
DELIVERY TIME:	Stock

MANUFACTURER:	Bacharach Instrument Division of American Bosch Arma Corporation
OPERATING PRINCIPLE:	Electrochemical Cell
SPECIFICITY:	Oxygen
MODEL NO. & TRADENAME:	Model K Oxygen Indicator
RANGES:	0-5% and 0-25% oxygen (#23-7049)
EXCITATION:	None required. Unit is a self generating electrolytic cell.
OUTPUT SIGNAL IMPEDANCE:	Visual - indicating panel instrument
ENVIRONMENT EFFECTS:	Under normal operating conditions, the instrument is not affected by position, temperature and altitude.
MAINTENANCE:	Reactivate cell at six month intervals
SIZE:	3" x 4 3/8" x 5 3/4"
WEIGHT:	2.5 lbs.
PORTABILITY:	Yes
PRICE:	$295
REMARKS:	Gas sample is drawn into the instrument with an aspirator bulb. Sample passes through a teflon membrane permeable to oxygen and into an electrolytic cell. Also available in range 0-25% oxygen (#23-7047) $195, and 0-25% and 0-100% oxygen (#23-7048) $225.

MANUFACTURER:	Beckman Instruments, Inc. (Process Instruments Division)
OPERATING PRINCIPLE:	Infrared
SPECIFICITY:	Nitrous oxide (N_2O)
MODEL NO. & TRADENAME:	#15A
RANGES:	100 ppm N_2O full scale
SENSITIVITY:	1.0 cu. in./hr. (6 x 10^{-5} std. cc/sec.) with 10% N_2O in system being checked. For systems containing 100% N_2O, leaks of 0.1 cu. in./hr. (6 x 10^{-6} std. cc/sec.) may be detected.
EXCITATION:	115v, 600w either 50 or 60 Hz models
OUTPUT SIGNAL IMPEDANCE:	Visual on indicating instrument and changing frequency (audio) at earphones.
RESPONSE TIME:	3 seconds from time probe draws in sample to initial meter response.
SIZE:	38 1/2" x 37" x 35"
PORTABILITY:	Mounted on four 12 inch pneumatic tires. Fitted with probe and 50 ft. cables.
REMARKS:	If system to be leak checked normally carries a gas that has good infrared absorption, the leak detector may be sensitized to that gas, and it is not necessary to evacuate the system. In this case, the leak detector can be used during actual working conditions.

MANUFACTURER:	Beckman Instruments, Inc. (Process Instruments Division)
OPERATING PRINCIPLE:	Infrared Absorption
SPECIFICITY:	Sensitized at time of manufacture for nitrous oxide (N_2O), unless another gas is specified.
MODEL NO. & TRADENAME:	W 138220 Mobile Infrared N_2O Leak Detector
RANGES:	100 ppm N_2O full scale
SENSITIVITY:	1.0 cu. in./hr. (4.5 x 10^{-3} std. cc/sec.) with 10% N_2O in system being checked or 0.1 cu. in./hr. (4.5 x 10^{-4} std. cc/sec. with systems containing 100% N_2O.
EXCITATION:	115v, 600w either 50 or 60 Hz models
OUTPUT SIGNAL IMPEDANCE:	Visual or indicating instrument and charging frequency (audio) at earphones.
REPEATABILITY:	±0.5% full scale
RESPONSE TIME:	Three seconds from time probe draws in sample to initial meter response.
ENVIRONMENT EFFECTS:	115v, ±15v, 60 ±0.5 Hz, -20 to 120°F
DOES IT FAIL SAFE:	No
MAINTENANCE:	Check zero and span daily; no specific servicing interval.
LIFE EXPECTANCY:	Indefinite with normal maintenance
SIZE:	38 1/2" x 37" x 35"
WEIGHT:	200 lbs.
PORTABILITY:	Mounted on four 12 inch pneumatic tires; fitted with probe and 50 ft. cables
TIME ON MARKET:	10 years
PRICE:	$5400
DELIVERY TIME:	90-120 days
REMARKS:	The model 315A NDIR analyzer, used as the detector, features all solid state electronics. If system to be leak checked normally carries a gas that has good infrared absorption, the leak detector may be sensitized to that gas and it is not necessary to evacuate the system. In this case, the leak detector can be used during actual working conditions.

MANUFACTURER:	Beckman Instruments, Incorporated
OPERATING PRINCIPLE:	Thermal conductivity
MODEL NO. & TRADENAME:	Model TBA-2100 "Therma Bridge" Analyzer
RANGES:	0-100 divisions on a 4" long scale
EXCITATION:	115v, 60 Hz, 35w
OUTPUT SIGNAL IMPEDANCE:	Panel Instrument
REPEATABILITY:	±1% of full scale
RESPONSE TIME:	30 seconds or less at 1 SCFH for 90% of change
SIZE:	8" x 13 1/2" x 12 1/2"
WEIGHT:	17 lbs.
PORTABILITY:	Yes
PRICE:	$350
REMARKS:	Some available accessories - A 0-10mv dc output for continuous recording of all analyses. Alarm contact (meter operated) to provide warning of high or low concentrations of the gas of interest.

MANUFACTURER:	Beckman Instruments, Incorporated
OPERATING PRINCIPLE:	Ultraviolet Absorption
SPECIFICITY:	Detects gases which absorb energy in the 400 mμ region.
MODEL NO. & TRADENAME:	Model 255 (Ultraviolet Filter Photometer)
RANGES:	From ppm to 100% concentration, dependent on application.
SENSITIVITY:	Accuracy ±1% full scale
EXCITATION:	115v, ±15v, 60 Hz, or 115v, ±15v, 50 Hz
OUTPUT SIGNAL IMPEDANCE:	Choice of: Current - 0 to 5ma, 500 ohms maximum Voltage - adjustable to any potentiometric recorder (spans of 1 through 100mv)
REPEATABILITY:	±1% of reading
RESPONSE TIME:	Electronic - 0.5 sec. for 90% of full scale Sample flushing - dependent on volume of cell
ENVIRONMENT EFFECTS:	Ambient temperature range: 30°F to 120°F
SIZE:	Analyzer: 29" x 8" x 9 5/8"; Amplifier: 8 3/4" x 8 3/16" x 18 9/16" Transformer: 9" x 12" x 4 1/4"
REMARKS:	Maximum zero drift: 1% of span in 8 hours Maximum span drift: ±1% of full scale in 24 hours

MANUFACTURER:	The Bendix Corporation (Scientific Instruments Divison)
OPERATING PRINCIPLE:	Mass Spectrometer
SPECIFICITY:	Mass range 1 to 500 AMU
MODEL NO. & TRADENAME:	Model MA-1
SENSITIVITY:	1 PPM; 10^{-13} torr for N_2; 100 amps/torr; 10^{-12} gram
EXCITATION:	115v - 60 Hz - 15 amp circuit
OUTPUT SIGNAL IMPEDANCE:	Simultaneous 4 mode scope and recorder readout
ENVIRONMENT EFFECTS:	The ion source may be operated from normal ambient to 300°C. The analyzer, including the magnetic electron multiplier is bakeable to 300°C.
DOES IT FAIL SAFE:	Yes
SIZE:	Table top cabinet - 19" x 18" x 26" Analyzer console - 27" x 27" x 35"
WEIGHT:	Table top cabinet - 100 lbs. Analyzer console - 150 lbs.
PORTABILITY:	Analyzer console is on casters.
PRICE:	As residual gas analyzer - approximately $8000
REMARKS:	The analyzer tube with or without its pumping system can be remote, up to 100 feet from the control console.

MANUFACTURER:	Bernz-O-Matic Corporation
OPERATING PRINCIPLE:	Halide Torch - Flame Color
SPECIFICITY:	Non combustible refrigerant gas or vapor (R-11,R-12, R-22,R-113,R-114 and carrine).
MODEL NO. & TRADENAME:	Tx-12M Leak Detector Unit
EXCITATION:	Propane flame
OUTPUT SIGNAL IMPEDANCE:	Color change in flame
REPEATABILITY:	Operator ability to detect flame color change.
ENVIRONMENT Effects:	Performs from -20°F to + 130°F
DOES IT FAIL SAFE:	No
MAINTENANCE:	Replacement of disposable propane cylinder every 10-15 hours of use.
LIFE EXPECTANCY:	Indefinite (except for changing cylinder)
SIZE:	Shipping size 10" x 6" x 3"
WEIGHT:	4 lbs.
PORTABILITY:	Designed as completely portable, self-contained unit
TIME ON MARKET:	10 years
PRICE:	$15.70 retail with cylinder
DELIVERY TIME:	From stock
REMARKS:	Color of propane flame in contact with reactor plate turns from pale blue to yellow in presence of a halide gas.

MANUFACTURER:	Burnett Electronics Lab, Inc.
OPERATING PRINCIPLE:	Sonic-Ultrasonic Range
SPECIFICITY:	Air
MODEL NO. & TRADENAME:	Burnett Model 609 Ultrasonic Listener
RANGES:	Variable uncalibrated gain control
SENSITIVITY:	A 0.001" diameter hole can be detected in a system pressurized to 2 psi, at a distance of one foot.
EXCITATION:	Batteries 1.5 volt.
OUTPUT SIGNAL IMPEDANCE:	Audio signal and indicating meter
RESPONSE TIME:	Speed of sound
MAINTENANCE:	Replace batteries 400 to 500 hours of use
LIFE EXPECTANCY:	5 years
SIZE:	Approximately 8" x 10" x 3"
WEIGHT:	11 lbs.
PORTABILITY:	Yes
TIME ON MARKET:	2 Years
PRICE:	$295.00
DELIVERY TIME:	Shelf item
REMARKS:	Has speaker mounted in amplifier or can be used with special headset to screen out background noise. Probe is directional and hand held.

MANUFACTURER:	Canal Industrial Corporation
OPERATING PRINCIPLE:	Ion Gauge
SPECIFICITY:	Freon, Helium
MODEL NO. & TRADENAME:	Model 100B Photometric Leak Detector and Vacuum Gauge.
RANGES:	Uncalibrated (responds 1 std. cc/sec. to 3 x 10^{-8} std. cc/sec.)
SENSITIVITY:	3 x 10^{-8} std. cc.sec. at 10^{-5} mm Hg; 1 x 10^{-7} std. cc/sec. at 10μ .
EXCITATION:	110-120v ac, 50-60 Hz.
OUTPUT SIGNAL IMPEDANCE:	Visual reading on indicating instrument
REPEATABILITY:	Sensitive to vacuum level, otherwise within 10%.
RESPONSE TIME:	Less than 15 seconds after gas enters chamber.
ENVIRONMENT EFFECTS:	Voltage range: 110-125v, 50-60$\sim$ - no effects under normal temperature and humidity.
DOES IT FAIL SAFE:	Yes
MAINTENANCE:	Photocell window requires cleaning. Frequency depends on vacuum.
LIFE EXPECTANCY:	Indefinite
SIZE:	8 1/2" x 7" x 14"
WEIGHT:	15 lbs.
PORTABILITY:	Can be hand carried
TIME ON MARKET:	3 years
PRICE:	$1240
DELIVERY TIME:	Stock item.
REMARKS:	Photodetector senses color or brightness of ionized tracer gas.

MANUFACTURER:	Cargille Scientific, Inc.
OPERATING PRINCIPLE:	Bubble-(Liquid Applicant)
MODEL NO. & TRADENAME:	Sho-Gas
SENSITIVITY:	0.25 std cc/hr
LIFE EXPECTANCY:	Determined by use
SIZE:	Varies (quart plastic bottle to 5 gallon can)
WEIGHT:	Depends on container purchased.
PORTABILITY:	Can be hand carried
PRICE:	From \$2.60 to \$25.00 depending on amount purchased. (\$2.60/quart-5 gallon container at \$5.00/gallon)
DELIVERY TIME:	Stock
REMARKS:	Conforms to MIL-L-25567A (ASG) except 4.5.6 skin toxicity is not known.

MANUFACTURER:	Century Geophysical Corporation Century Electronics & Instruments Division
OPERATING PRINCIPLE:	Flame Ionization
SPECIFICITY:	Methane
MODEL NO. & TRADENAME:	Detector cell manufactured by Perkin-Elmer (213B), modified by Century.
RANGES:	X1, X3, X10, X30, X100, X300, X1000, X3000
SENSITIVITY:	1 ppm
EXCITATION:	1-300 v battery, 4-6 v lantern batteries, 1-115 v 60 cycle inverter powered from 12 v truck battery.
OUTPUT SIGNAL IMPEDANCE:	200 ohms: Indicating instrument and audible signal.
REPEATABILITY:	1 % of full/scale
RESPONSE TIME:	4 sec. from sample intake to indication on pen recorder.
ENVIRONMENT EFFECTS:	Range cell temperature is thermostatically controlled. Inverter frequency must be ± 0 cps ± 3 cps.
DOES IT FAIL SAFE:	No
MAINTENANCE:	Calibrate. Check zero and span daily. Check compressor and blowers weekly.
LIFE EXPECTANCY:	With proper maintenance - indefinite.
SIZE:	Console size 35" wide X 24" deep X 30-1/4" high
WEIGHT:	Approx. 125 lbs. - console only
PORTABILITY:	Mounted in 3/4 ton "personnel carrier" type truck.
TIME ON MARKET:	1 year
PRICE:	$11,000.00
DELIVERY TIME:	6 months
REMARKS:	Air tank, hydrogen tank and calibration gas tank mounted externally to the console. This firm features leak detection service.

MANUFACTURER:	Consolidated Electrodynamics Corporation (Subsidiary of Bell and Howell)
OPERATING PRINCIPLE:	Mass Spectrometer - Quadrupole
SPECIFICITY:	Yes, all gases, mass/to 300
MODEL NO. & TRADENAME:	Type 21-440
RANGES:	1 to 300 AMU, continuous
SENSITIVITY:	10 amps per torr for N_2 Minimum detectable partial pressure is 5×10^{-14} torr N_2
EXCITATION:	115v, 60 Hz, 15 amperes
OUTPUT SIGNAL IMPEDANCE:	10v dc into oscilloscope or high impedance recorder (50K ohms)
REPEATABILITY:	3% of reading, short range; 10% long range
RESPONSE TIME:	30 milliseconds to 30 minutes per scan as desired.
ENVIRONMENT EFFECTS:	Tube bakeable 400°C operable to 200°C. Electronics for 70 R.H. and 110°F operation (ambient)
LIFE EXPECTANCY:	10-15 years
SIZE:	Tube 24" long 4" diameter Electronics 21" W. X 12" H. X 18" D.
WEIGHT:	125 Lbs. total
PORTABILITY:	Yes
TIME ON MARKET:	May 1968
PRICE:	$5300 - with oscilloscope is $6200.
DELIVERY TIME:	4 weeks

MANUFACTURER:	Consolidated Electrodynamics Corporation (Subsidiary of Bell and Howell)
OPERATING PRINCIPLE:	Pressure change (gas) (force balance system)
MODEL NO. & TRADENAME:	Force Balance Pressure Transducer, Type 4-333-0001 Servo Amplifier, Type 1-156-0001
RANGES:	± 1.5 to ± 500 psid, other units to 0-10,000 psid
SENSITIVITY:	0.001% full scale
EXCITATION:	105 to 125v, 60 to 400 Hz, 35 watts maximum.
OUTPUT SIGNAL IMPEDANCE	± 10 volts full scale
REPEATABILITY:	0.05% full scale
RESPONSE TIME:	0.1 second for 99% full scale pressure step.
ENVIRONMENT EFFECTS:	Operating ambient temperature range: Transducer; 40°F to 165°F, Servo Amplifier; 32°F to 120°F - 0.025% full scale shift per degree F change. Humidity; meets MIL-E-5272B, Procedure 1.
SIZE:	Type 4-333-0001: 4" X 3" X 2 1/2" Type 156: 4 1/2" W X 9 3/16" D X 5 1/8" H
WEIGHT:	Type 4-333-0001: 2.6 Lbs. Type 156: 6.5 Lbs.
PORTABILITY:	Yes
TIME ON MARKET:	Since 1960
PRICE:	Pressure Transducer: $995 Servo Amplifier: $1950
DELIVERY TIME:	30 days
REMARKS:	Must supply your own analog output voltage indicator.

MANUFACTURER:	Consolidated Electrodynamics Corporation (Subsidiary of Bell & Howell)
OPERATING PRINCIPLE:	Pressure change (gas) (diaphragm/variable capacitor)
MODEL NO. & TRADENAME:	Type 23-105 - Micromanometer
RANGES:	1 to 150 X 10^{-3} torr Absolute
SENSITIVITY:	0.1 X 10^{-3} torr
EXCITATION:	115v, 60 Hz, 30 watts
OUTPUT SIGNAL IMPEDANCE:	Capacitance bridge balanced by driving diaphragm back to null by electrostatic force and reading voltage on the duodial control.
REPEATABILITY:	$\pm$ 0.5 X 10^{-3} torr
ENVIRONMENT EFFECTS:	Ambient temperature range: 20 to 40°C
MAINTENANCE:	Contract maintenance service is available
LIFE EXPECTANCY:	20 years
SIZE:	Gage: 6" X 6" X 3 1/2" - Bridge/Amplifier: 4" X 2" X 4 1/2" Control unit: 19 1/2" X 8 1/2" X 7 1/2"
WEIGHT:	40 Lbs. total
PORTABILITY:	Yes
TIME ON MARKET:	20 years
PRICE:	$2600
DELIVERY TIME:	4 weeks
REMARKS:	System volume on sampling side is 50 cc.

MANUFACTURER:	Consolidated Electrodynamics Corporation (Subsidiary of Bell & Howell)
OPERATING PRINCIPLE:	Mass Spectrometer (less vacuum system) - Cycloidal Residual Gas Analyzer
SPECIFICITY:	Yes: mass range 2 to 200
MODEL NO. & TRADENAME:	Type 21-614
RANGES:	m/e 2 to 11 and m/e 12 to 200
SENSITIVITY:	Partial pressure of N_2 of 5 x 10^{-12} torr
EXCITATION:	115v, 60 Hz, 3 amps
OUTPUT SIGNAL IMPEDANCE:	Panel Meter and 0-10 mv dc output signal for high impedance recorder (50K ohms)
REPEATABILITY:	1% of reading
RESPONSE TIME:	7 min. per octave to 10 sec. per octave as desired.
ENVIRONMENT EFFECTS:	Electronics: up to 70% R.H. and 110°F (ambient) Tube bakeable to 250°C
MAINTENANCE:	Contract maintenance service available.
LIVE EXPECTANCY:	10 to 15 years
SIZE:	Control unit: 21" x 18" x 21 3/4" Analyzer: 17" x 17" x 12 1/2"
WEIGHT:	Control unit: 150 lbs. - Analyzer Assembly: 90 lbs.
PORTABILITY:	Movable
TIME ON MARKET:	6 years
PRICE:	$7700
DELIVERY TIME:	4 weeks
REMARKS:	Cycloid tube and envelope are bakeable to 250°C.

MANUFACTURER:	Consolidated Electrodynamics Corp. (Subsidiary of Bell & Howell)
OPERATING PRINCIPLE:	Mass Spectrometer (Helium Leak Detector)
SPECIFICITY:	Helium; standard modifications available for Argon, Neon Hydrogen.
MODEL NO. & TRADENAME:	Type 24-120B
RANGES:	9 ranges (X1 to X10000 range multiplier switch; 10 positions)
SENSITIVITY:	5×10^{-11} atm cc/s - He
EXCITATION:	105 to 125v, 60 Hz, 800 watts (50 Hz available)
OUTPUT SIGNAL IMPEDANCE:	Linear output, 0-100 meter scale divisions
REPEATABILITY:	± 5%
RESPONSE TIME:	Less than 1 sec. required to produce 50% full scale deflection on X1 scale.
ENVIRONMENT EFFECTS:	Temp: +40°F to 110°F (ambient) Humidity: up to 95%
DOES IT FAIL SAFE:	Yes
MAINTENANCE:	6 months - clean manifold and change oil
LIFE EXPECTANCY:	At least 10 years.
SIZE:	30" wide X 20" deep X 22" high
WEIGHT:	200 Lbs. (shipping weight 275 Lbs.)
PORTABILITY:	4 carrying handles on unit. May be mounted on an accessory mobile workstand for mobility.
TIME ON MARKET:	24-120 series - 9 years.
PRICE:	$3,700
DELIVERY TIME:	Stock item
REMARKS:	1. Remote Control Unit is included with basic instrument. 2. Several standard accessory Semi-automatic Test Port Stations are available for use with basic instrument. 3. Other accessories available are: Spray Probe Standard Leaks Sniffer Probes Port Adapters Audio Alarm Bell Jars & Plate 2 & 3 Valve Inlet Manifold Mechanical pumps Auxiliary Cold Trap

MANUFACTURER:	Consolidated Electrodynamics Corporation (Subsidiary of Bell & Howell)
OPERATING PRINCIPLE:	Mass Spectrometer - (less vacuum system) - Residual Gas Analyzer
SPECIFICITY:	Yes - mass range 2 to 100 AMU
MODEL NO. & TRADENAME:	Type 21-615
RANGE:	Mass range 2 to 100
SENSITIVITY:	N_2 partial pressure to 2 x 10^{-12} torr/division
EXCITATION:	105 - 125v, 60 Hz, 2 amperes
OUTPUT SIGNAL IMPEDANCE:	Panel Meter and output to high impedance recorder (50,000 ohms).
REPEATABILITY:	3% short term; 5% long term.
RESPONSE TIME:	Scan rate is 60 seconds per octave.
ENVIRONMENT EFFECTS:	Electronics up to 70% R.H. and 110°F (ambient) Analyzer - bakeable to 400°C.
MAINTENANCE:	Contract maintenance service available
LIFE EXPECTANCY:	10 to 15 years
SIZE:	Control unit: 12" x 22" x 16" Analyzer: 15" x 11" x 11"
WEIGHT:	Control unit: 50 lbs. - Analyzer: 40 lbs.
PORTABILITY:	Easily moved
TIME ON MARKET:	2 1/2 years
PRICE:	$3500
DELIVERY TIME:	2 weeks
REMARKS:	Cycloid tube and envelope are bakeable to 450°C.

MANUFACTURER:	Datametrics Inc.
OPERATING PRINCIPLE:	Pressure Change (Gas or Liquid)
SPECIFICITY:	Electrically nonconducting gases and liquids
MODEL NO. & TRADENAME:	Type 1014 Electronic Manometer - "BAROCEL"
RANGES:	Basic ranges are from 0-1 torr to 0-100 psi differential, each with a 9 position pressure range selector switch which scales sensitivity from x 1 to x 0.0001.
SENSITIVITY:	1×10^{-5} torr, maximum
EXCITATION:	115 volts; 50 to 400 Hz; 60 watts
OUTPUT SIGNAL IMPEDANCE:	±5 volts at full scale on 7 ranges (±10 volts on special models)
RESPONSE TIME:	To 3 milliseconds at 760 torr
ENVIRONMENT EFFECTS:	Sensor type 511 - 0 to 150°F Electronic manometer type 1014 - 0 - 110°F
SIZE:	Type 1014: 8 3/8" x 14" x 9 1/2" (Electronic Manometer) Type 511: 3 1/4" x 3" x 3 3/4" (Pressure Sensor)
WEIGHT:	Shipping weight is approximately 25 lbs.
PORTABILITY:	Yes - Hand Carry
PRICE:	Type 1014 - $1050 (Electronic Manometer) Type 511 - $890 (Pressure Cell for use with the 1014)
REMARKS:	Provided with 9 position range selector switch from x .0001 to x 1 of full range. The type 521 pressure sensor with all hermetic seals can also be used with the 1014. The type 531 pressure sensor with bake out temperatures up to 300°C can also be used with the 1014. Pressure transducers for liquid systems require vacuum back-filling with the appropriate system liquid after connecting the pressure transducer into the system. Pressure differences measured between the pressurized test system and a static reservoir indicate the existance of leaks.

MANUFACTURER:	Datametrics Inc .
OPERATING PRINCIPLE:	Pressure Change (Gas or Liquid)
SPECIFICITY:	Electrically nonconducting gases and liquids
MODEL NO. & TRADENAME:	Type 1018 - Electronic system for type #511 "BAROCEL" pressure sensor
RANGES:	0-10, 0-100, 0-1000 torr and 0-1, 0-10 psi - Full range - varies with model.
SENSITIVITY:	0.01% full scale
EXCITATION:	115 volts; 50 to 75 Hz
OUTPUT SIGNAL IMPEDANCE:	Digital Panel Indicator - Also analog output: 0 to ±10v dc Source impedance 50Ω
ENVIRONMENT EFFECTS:	Type 511 - pressure transducer - 0 to 150°F Type 1018 - Electronics system - 40 to 110°F
SIZE:	Type 1018: 8 3/8" x 14" x 9 1/2" - Electronic System Type 511: 3 1/4" x 3" x 3 3/4" - Pressure Sensor
WEIGHT:	Shipping weight approximately 25 lbs.
PORTABILITY:	Yes - Hand Carry
PRICE:	Type 1018 - $2050 Type 511 - $890; Type 521 - $1200
REMARKS:	Can be used with pressure sensor types 511 or 521. Panel is provided with a 4 position range switch x1, x0.1, x 0.01, x 0.001. Pressure trandsucers for liquid systems require vacuum back-filling with system liquid after connecting the pressure transducer into the system. Pressure differences measured between the pressurized test system and a static reservoir, indicate the existance of leaks.

MANUFACTURER:	Davis Emergency Equipment Co., Inc. (Instrument Division)
OPERATING PRINCIPLE:	Catalytic Combustion
SPECIFICITY:	Combustible gases and vapors.
MODEL NO. & TRADENAME:	D-6 Vapotester #11-660
RANGES:	2 scale instrument 0-100% LEL of Hexane in air, 0-10% LEL
EXCITATION:	Battery operated (8 size D cells)
OUTPUT SIGNAL IMPEDANCE:	Reading on panel indicating instrument
ENVIRONMENT EFFECTS:	Must not be used on pure oxygen
DOES IT FAIL SAFE:	No
MAINTENANCE:	Replacement of batteries and/or filaments when necessary
WEIGHT:	Slightly over 4 lbs.
PORTABILITY:	Portable unit
PRICE:	$157
DELIVERY TIME:	1 - 2 weeks
REMARKS:	Unit calibrated on Hexane. Many different calibration curves are available for interpreting readings of various combustibles in terms of PPM. Accessories available include: various type probe assemblies, sample dryer, liquid trap, cotton filters, fixed and variable dilution valves, calibration kit, etc. Spare filaments placed in case compartment.

MANUFACTURER:	Davis Emergency Equipment Co., Inc. (Instrument Division)
OPERATING PRINCIPLE:	Catalytic Combustion
SPECIFICITY:	Combustible gases or vapors
MODEL NO. & TRADENAME:	D-2 Vapotester #11-410
RANGES:	One - 0-100% of LEL of Hexane in air
EXCITATION:	Zero adjuster simultaneously sets operating voltage. Battery operated (8 size d cells)
OUTPUT SIGNAL IMPEDANCE:	Reading on panel indicating instrument
ENVIRONMENT EFFECTS:	Must not be used on pure oxygen
DOES IT FAIL SAFE:	No
MAINTENANCE:	Replacement of batteries and/or filament when necessary.
WEIGHT:	Slightly over 4 lbs.
PORTABILITY:	Portable unit
PRICE:	$100
DELIVERY TIME:	1 - 2 weeks
REMARKS:	Unit is calibrated on Hexane. Is single filament, single control unit designed for general use. One control knob permits adjustment of meter pointer to zero and simultaneously sets fixed operating voltage across the bridge. Spare filament mounted on filament block. Accessories available include: various type probe assemblies, sample dryer, liquid trap, cotton filters, fixed and variable dilution valves, calibration kit, etc. Model #11-470 can be calibrated for customer's specific gas.

MANUFACTURER: Davis Emergency Equipment Co., Inc. (Instrument Division)

OPERATING PRINCIPLE: Catalytic Combustion

SPECIFICITY: Combustible gas or vapors

MODEL NO. & TRADENAME: D-1 Vapotester #11-325

RANGES: One, 0-100% LEL of Hexane in air

EXCITATION: Separate zero and operating voltage adjustments. Battery operated (8 size D cells)

OUTPUT SIGNAL IMPEDANCE: Reading on panel indicating instrument

ENVIRONMENT EFFECTS: Must not be used on pure oxygen

DOES IT FAIL SAFE: No

MAINTENANCE: Replacement of batteries and/or filaments when necessary.

WEIGHT: Slightly over 4 lbs.

PORTABILITY: Portable unit

PRICE: $105

DELIVERY TIME: 1 to 2 weeks

REMARKS: Model #11-326 is calibrated on natural gas.
Model #11-327 is calibrated on customer's specified gas.
Model #11-325 is calibrated on Hexane.
One active and one reference filament are connected in bridge circuit. Zero stability maintained even as the battery voltage decreases.

Bridge voltage can be periodically checked and adjusted during long tests, without disturbing instrument zero.

Spare filaments in carrying case.

Accessories available include: various type probe assemblies, sample dryer, liquid trap, cotton filters, fixed and variable dilution valves, calibration kit, etc.

MANUFACTURER:	Davis Emergency Equipment Co., Inc. (Instrument Division)
OPERATING PRINCIPLE:	Catalytic Combustion and Thermal Conductivity (dual cell instrument)
SPECIFICITY:	Combustible gases and vapors
MODEL NO. & TRADENAME:	D-5 Gastester #11-575
RANGES:	Catalytic - 0 to LEL natural gas Thermal conductivity - 0-100% gas concentration - natural gas
EXCITATION:	Battery operated (8 size D cells)
OUTPUT SIGNAL IMPEDANCE:	Reading on panel indicating instrument
ENVIRONMENT EFFECTS:	Must not be used on pure oxygen - combustible mixtures.
DOES IT FAIL SAFE:	No
MAINTENANCE:	Replacement of batteries and/or filaments when necessary.
WEIGHT:	Slightly over 4 lbs.
PORTABILITY:	Portable unit
PRICE:	$157
DELIVERY TIME:	2-4 weeks
REMARKS:	Unit is calibrated on natural gas. Scales calibrated on other true gases can be supplied on request. O-LEL scale uses catalytic filaments. 0-100% gas scale operates on thermal conductivity principle. Flashback arrester is built into filament block. Approved by Factory Mutual Laboratories. Unit used for detection and measurement of a true gas in air. Accessories available include: various type probe assemblies, sample dryer, liquid trap, cotton filters, fixed and variable dilution valves. Calibration kit, special calibrations on true gases. Spare filaments in case.

MANUFACTURER:	Davis Emergency Equipment Co., Inc. (Instrument Division)
OPERATION PRINCIPLE:	Flame Ionization
SPECIFICITY:	Hydrocarbons in air
MODEL NO. & TRADENAME:	#11-654
RANGES:	Six range factors: 1, 10, 25, 100, 250, 1000
SENSITIVITY:	Typical full scale maximum sensitivities are: 5 ppm Benzene in air; 20 ppm methane in air; 25 ppm propane in air, 35 ppm Halocarbon Refrigerant 12
EXCITATION:	115v, 50/60 Hz
OUTPUT SIGNAL IMPEDANCE:	Reading on panel indicating instrument 25mv dc for external recorder.
REPEATABILITY:	2% of full scale
RESPONSE TIME:	Varies directly with sample flow rate. 2-3 seconds, exclusive of external sample transport.
ENVIRONMENT EFFECTS:	Sample requirement: sample in air or with a minimum of 18%. 0_2 (for exceptions, contact factory)
DOES IT FAIL SAFE:	No
MAINTENANCE:	Lecture fuel bottle must be replaced when necessary
SIZE:	15" x 16" x 9 3/4"
WEIGHT:	30 lbs.
PORTABILITY:	Portable unit
PRICE:	$1445 --- $1700 with audible alarm
DELIVERY TIME:	2 - 4 weeks
REMARKS:	Output signal is function of specific hydrocarbon being detected and rate of combustion of the hydrogen fuel mixture. Hydrogen flame ionizes hydrocarbon molecules. Sample flow is obtained by internal diaphragm type pump. Sample is drawn directly through the analyzing cell. Has rotameter with needle valve to set sample flow rate through cell. Positive sample pressures of up to 3000 psig can be measured by means of optional pressure regulator accessories. Audible alarm is optional. Contains integral flame arrestors for added safety.

MANUFACTURER:	Davis Emergency Equipment Co., Inc. (Instrument Division)
OPERATING PRINCIPLE:	Halide Torch - Flame Color (Electric Arc Halide detector) (Blue lines of copper spectrum in electric arc produced in presence of a halide vapor phototube detects intensity).
SPECIFICITY:	Halogenated hydrocarbons
MODEL NO. & TRADENAME:	#11-9000
RANGES:	One 0-50 microamps, converted to 500 ppm using calibration chart.
SENSITIVITY:	10 ppm
EXCITATION:	110v, 60 Hz
OUTPUT SIGNAL IMPEDANCE:	Reading on panel indicating instrument
REPEATABILITY:	10% full scale accuracy
SIZE:	15" x 16" x 9 3/4"
WEIGHT:	35 lbs.
PORTABILITY:	Portable unit
PRICE:	$715
DELIVERY TIME:	2 - 6 weeks
REMARKS:	Halide vapor comes in to contact with the hot tip of a copper electrode and reacts to form a copper halide, which vaporizes at the temperature of the electrode and is carried into an electric arc between two electrodes. The intensity of the blue lines of the copper spectrum produced in the electric arc is continuously measured with a photoelectric photometer using a blue sensitive phototube fitted with a blue glass color filter. The intensity of the blue spectrum is in proportion to concentration of halide vapor present. This is converted to reading on indicating instrument. Sample is pumped through a flow indicator, into an arc chamber where analysis is accomplished. It is then discharged through a vent at the top of the chamber.

MANUFACTURER: Dawe Instruments, Ltd.

OPERATING PRINCIPLE: Sonic - Ultrasonic Range

MODEL NO. & TRADENAME: 1873A Ultrasonic Leak Detector

RANGES: Indication only

SENSITIVITY: Leaks down to 0.002" dia. at 2 psi can be detected

EXCITATION: Battery 7.5v

OUTPUT SIGNAL IMPEDANCE: Meter indication and headphones

RESPONSE TIME: Limited by meter response to approximately 0.2 sec.

ENVIRONMENT EFFECTS: 0°F - 140°F

DOES IT FAIL SAFE: No

MAINTENANCE: Check batteries - internal meter and replace as necessary (150 hours use)

LIFE EXPECTANCY: 10 years

SIZE: 2" dia. - 13 1/2" long

WEIGHT: 2 lbs. (1 kg) approximately

PORTABILITY: Very portable unit is shaped like a large round flashlight

TIME ON MARKET: 1 1/2 years

PRICE: £ 120 (Approximately $265)

DELIVERY TIME: 3 weeks

REMARKS: Unit is supplied complete in carrying case with contact probe - for checking leaky valves, etc., - and extension lead.

The flat carrying case can be strapped to the chest and the microphone used on the extension lead. This is particularly convenient when large and complex systems are being checked.

MANUFACTURER:	The Decker Corporation
OPERATING PRINCIPLE:	Pressure change - gas
SPECIFICITY:	None
MODEL NO. & TRADENAME:	LT-101 and LT-102
RANGES:	Full range 0.1 inches of water differential, others available
SENSITIVITY:	Leaks down to 1 x 10^{-4} std. cc/sec. can be detected with 10 sec. test time.
EXCITATION:	115v, 60 Hz
OUTPUT SIGNAL IMPEDANCE:	Panel Meter. Relay and 5v dc high impedance
REPEATABILITY:	2% Full Scale
RESPONSE TIME:	1 sec. to 10 sec.
ENVIRONMENT EFFECTS:	At excitation of 105 to 125v and 60°F to 80°F, performs within stated repeatability.
DOES IT FAIL SAFE:	No
MAINTENANCE:	Check zero and span daily if required. No specific servicing interval.
LIFE EXPECTANCY:	10 years
SIZE:	25" x 22" wide x 19" deep
WEIGHT:	40 to 80 pounds depending on manifolding
PORTABILITY:	Can be set on wheeled cart
TIME ON MARKET:	2 years
PRICE:	\$3,600 to \$6,000
DELIVERY TIME:	6 to 12 weeks
REMARKS:	Variations available to conform to customer's requirements. LT-101 and 102 are fully automated production Leak Detectors, with electrically sequenced operation. Adjustable high and low limits give out-of tolerance relay signals and red light reject signal. Optional accessories: recorder, counter, alarm buzzer, calibration samples, etc.

MANUFACTURER:	Devco Engineering, Incorporated
OPERATING PRINCIPLE:	Thermal Conductivity
MODEL NO. & TRADENAME:	#MHA 40
RANGES:	Single or multiple available
SENSITIVITY:	Under proper design conditions and operating temperature, sensitivity of 1 ppm or lower can be achieved.
EXCITATION:	115v, 60 Hz
REPEATABILITY:	±2% of full scale for most applications
RESPONSE TIME:	Detection within approximately 10 seconds. Deflection of 90% of final reading within approximately 30 seconds.
ENVIRONMENT EFFECTS:	Presence of more than 2 gases can affect accuracy.
DOES IT FAIL SAFE:	No
PORTABILITY:	Is not portable - installed at site.
REMARKS:	Units are usually designed for required sensitivity to detect percentage concentration of bi-gaseous mixtures. Highest sensitivity is obtained when the 2 constituent gases vary greatly in thermal conductivity. Various dc readout instrumentation available. Units are basically monitoring units for either gases or vapors.

MANUFACTURER:	Devco Engineering, Inc.
OPERATING PRINCIPLE:	Thermal Conductivity
SPECIFICITY:	Selectivity to specific gases can be achieved with suitable filters.
MODEL NO. & TRADENAME:	MHA-90
RANGES:	Typical 20 PPM H_2S, others available.
EXCITATION:	115v ac, 60 Hz
OUTPUT SIGNAL	Meter, recorder
IMPEDANCE:	
REPEATABILITY:	0.5% full scale
RESPONSE TIME:	90% in 5 sec.
DOES IT FAIL SAFE:	Yes
MAINTENANCE:	Check span every 60 days
LIFE EXPECTANCY:	Contingent on maintenance.
WEIGHT:	Depends on design
PORTABILITY:	No
TIME ON MARKET:	15 years
PRICE:	$1200 to $5000
DELIVERY TIME:	60 days

MANUFACTURER:	Devco Engineering, Incorporated
OPERATING PRINCIPLE:	Tracer - Halogen
SPECIFICITY:	Halogen gas
MODEL NO. & TRADENAME:	#FB23-A
RANGES:	One
SENSITIVITY:	0.02 oz./yr. Arcton (dichlorodifluoromethane)
EXCITATION:	115 or 230v, 60 Hz
OUTPUT SIGNAL IMPEDANCE:	Flashing lamp
RESPONSE TIME:	Almost instantaneous
ENVIRONMENT EFFECTS:	Test area should be free of halogen contamination. Exposure to high concentrations of halogen gases tends to desensitize sensing element.
DOES IT FAIL SAFE:	No
MAINTENANCE:	Whenever necessary - no specific servicing interval
LIFE EXPECTANCY:	Determined by exposure of sensing element to desensitizing agents.
SIZE:	8" x 3 1/2" x 5"
WEIGHT:	6 3/4 lbs.
PORTABILITY:	Can be hand carried
PRICE:	$345
DELIVERY TIME:	From stock
REMARKS:	Unit must be regarded as "naked flame" and must not be used in presence of inflammable vapors.

MANUFACTURER:	Devco Engineering, Incorporated
OPERATING PRINCIPLE:	Tracer - Halogen
SPECIFICITY:	Halogen gas
MODEL NO. & TRADENAME:	#FB24
RANGES:	Two (X5 range switch)
SENSITIVITY:	0.02 oz./yr. Arcton (dichlorodifluoromethane)
EXCITATION:	110/120v, 60 Hz or 200/250v, 60 Hz
OUTPUT SIGNAL IMPEDANCE:	Output meter 0-10 flashing lamp and speaker
RESPONSE TIME:	Almost instantaneous
ENVIRONMENT EFFECTS:	Test area should be free of halogen contamination. Exposure to high concentrations of halogen gases tends to desensitize sensing element.
DOES IT FAIL SAFE:	No
MAINTENANCE:	Whenever necessary - no specific servicing interval
LIFE EXPECTANCY:	Determined by exposure of sensing element to desensitizing agents.
SIZE:	9 1/2" x 8 1/2" x 7 1/2"
WEIGHT:	20 lbs.
PORTABILITY:	Can be hand carried
PRICE:	$975
DELIVERY TIME:	4 - 6 weeks
REMARKS:	Unit must be regarded as "naked flame" and must not be used in presence of inflammable vapors. Sensing head is connected to the main instrument by cable, hence providing greater ease in probing for leaks.

MANUFACTURER:	Dragerwerk-Lubeck (West Germany) Scott Aviation, Lancaster (U.S. distributor)
OPERATING PRINCIPLE:	Chemical Indicator - Reagent
SPECIFICITY:	Reagent type detector tube chosen for specific gas of interest. Available for detecting about 100 different vapors and gases.
MODEL NO. & TRADENAME:	Scott/Draeger Model 21/31 multi-gas detector
RANGES:	Depends upon gas of interest. For most common gases several different tubes available, each with different range.
SENSITIVITY:	Depends upon gas of interest. Some tubes sensitive to as little as 0.1 ppm, others range to 250,000 ppm.
RESPONSE TIME:	Depends upon number of strokes of hand-pump required for specific tube being used.
ENVIRONMENT Effects:	Performance not effected by temperature or humidity changes.
MAINTENANCE:	Replacement of rubber parts in pump recommended annually.
LIFE EXPECTANCY:	Infinite, if rubber parts periodically replaced
SIZE:	Can be held in one hand
WEIGHT:	Pump alone - 1 lb. Pump with carrying case - 4 lb. 4 oz.
PORTABILITY:	Furnished with carrying case 6-3/4" long. 5" wide 5-3/4" deep.
TIME ON MARKET:	More than 10 years
PRICE:	Pump with carrying case $95.00. Tubes vary depending on type, average $6.50/pkg. of 10 tubes.
DELIVERY TIME:	Tubes most commonly used available immediately from stock. Types less frequently used, 1 to 2 weeks.
REMARKS:	Unit uses a 1-hand operated bellows type pump to draw gas through a reagent type detector tube, in which the reagent changes color if the gas of interest is present in the specimen. Tubes are marked with a direct reading scale, the quantitative reading being determined by the length of the stain.

MANUFACTURER:	Eastern Laboratories, Inc.
OPERATING PRINCIPLE:	Bubble (Liquid Applicant)
MODEL NO. & TRADENAME:	"Bubble-Coat"
EXCITATION:	None
OUTPUT SIGNAL IMPEDANCE:	Visual - Bubble (foam) formation at leak
DOES IT FAIL SAFE:	No
SIZE:	8 ounces; 1 gallon; 55 gallon
WEIGHT:	Up to 500 lbs.
PORTABILITY:	Yes
TIME ON MARKET:	8 years
PRICE:	8 oz. size - 70¢ to $1 depending on the formulation
DELIVERY TIME:	Immediate
REMARKS:	Some solutions useful to -65°F. Non-toxic, non-corrosive, odorless, non-irritating, non-flammable and meets MIL-L 25567A spec.

MANUFACTURER: Edwards High Vacuum, Inc.

OPERATING PRINCIPLE: Ion Gauge (with palladium window)

SPECIFICITY: Hydrogen

MODEL NO. & TRADENAME: Model LT4A with PL2 detector head

RANGES: Five

SENSITIVITY: 1 x 10^{-7} torr liter/sec.

EXCITATION: 100-125 v 50/60 Hz or 200-250v 50/60 Hz.

OUTPUT SIGNAL IMPEDANCE: Visual indication as indicating instrument and also audible leak indicator.

SIZE: Detector head- 9 5/16" long x 2 1/4" dia. Control unit 19" wide x 10 1/2" high x approximately 16" deep.

PORTABILITY: No

TIME ON MARKET: 5 years

PRICE: $1145 (for Model LT4A control unit with PL2 detector head)

DELIVERY TIME: 6-8 weeks.

REMARKS: Highly evacuated hot cathode ionization gauge detector, in detector head is isolated from the pumping system by means of a palladium metal barrier which also acts as the detector anode. During operating the palladium anode is heated to red heat by electron bomardment, at which temperature it becomes permeable exclusively to hydrogen. Hydrogen, applied to a leak, passes through the hot palladium anode into the detector head where it is ionized, changing the ion current. This change is amplified by the control unit (LT4A) and indicated on an indicating instrument. Indication is compared to indication caused by calibration of unit using calibrated reference leak. Control unit has overload relay which switches off detector head power if ion current becomes excessive.

Hand held leak indicating instrument available as an accessory.

MANUFACTURER: Edwards High Vacuum, Inc.

OPERATING PRINCIPLE: Thermal Conductivity

SPECIFICITY: Vane

MODEL NO. & TRADENAME: Model LT6B with remote hand

RANGES: Four

SENSITIVITY: 1 x 10^{-5} torr liter/sec.

EXCITATION: 100-130v or 200-260v 60 Hz

OUTPUT SIGNAL IMPEDANCE: Visual on panel indicating instrument and audible leak indicator.

SIZE: Main unit - 13 3/4" wide x 7 3/8" high x 8 1/2" deep. Remote hand unit-body length 9 1/2" x approximately 2" diam. with 4 3/4" tube type probe.

WEIGHT: Main unit - 16 1/2 lbs.
Remote hand unit 3 1/2 lbs.

PORTABILITY: Is portable

TIME ON MARKET: 5 years

PRICE: $650.00 (for main unit with remote hand unit)

DELIVERY TIME: 6-8 weeks.

REMARKS: Wide range of search gases can be used, but best results are obtained with gases whose thermal conductivities differ most from air, such as hydrogen or helium.

The leak test unit connected to the system under test, detects leaks covering all pressure states, from vacuum to positive pressures. System being tested is partially or totally enclosed by a bag filled with a search gas or the outside can be sprayed with the search gas.

Use of the remote hand unit, which is connected to the main unit, enables testing of pressurized vessels or pipelines. The hand unit has a built-in fan which draws leaking gas through its probe and into a chamber containing a heated filament. Cooling effect of leaking gas is compared as a change of resistance with the cooling effect of the surrounding atmosphere on another filament. Resistance difference indicates a leak by instrument indication and change in loudspeaker tone.

MANUFACTURER:	Edwards High Vacuum Inc.
OPERATING PRINCIPLE:	Mass Spectrometer - (180° Sector Field)
SPECIFICITY:	Gas selection switches makes it suitable for Helium$_3$, Helium$_4$, Hydrogen and Argon.
MODEL NO. & TRADENAME:	Model 8A
RANGES:	10 Ranges, 10^{-2} torr liter/second-maximum
SENSITIVITY:	10^{-12} torr liter/second, varies with ranges
EXCITATION:	115 or 220 v, 60 Hz
OUTPUT SIGNAL IMPEDANCE:	Both audible and visual (speaker and panel instrument)
ENVIRONMENT EFFECTS:	Designed for: 50°F to 95°F
DOES IT FAIL SAFE:	No
MAINTENANCE:	Check mechanical and diffusion pump oil electrical checks spelled out in working instructions.
SIZE:	29" wide, 22-3/4 deep, 38" high
WEIGHT:	320 lbs.
PORTABILITY:	Main unit mounted on 4 casters, readout indicator unit is hand carry type.
TIME ON MARKET:	2 years
PRICE:	$4,800.00
DELIVERY TIME:	stock
REMARKS:	Filament is protected both electrically and mechanically with large LN_2 trap. Fully demountable portable unit gives operator local control.

MANUFACTURER:	Electronic Associates, Inc.
OPERATING PRINCIPLE:	Mass Spectrometer - Quadrupole (RGA)
SPECIFICITY:	All gases 1 -150 amu
MODEL NO. & TRADENAME:	QUAD 150
RANGES:	1 - 150
SENSITIVITY:	1×10^{-15} torr for N_2
EXCITATION:	115 v, 60 Hz, 6 amp
OUTPUT SIGNAL IMPEDANCE:	1 μa to 100 ma/1 meg ohm
REPEATABILITY:	5%
RESPONSE TIME:	100 milliseconds
ENVIRONMENT EFFECTS:	Detector from 15°K to 250°C Console from 0°F to 125°F
DOES IT FAIL SAFE:	No
MAINTENANCE:	No specific program required
LIFE EXPECTANCY:	10 years
SIZE:	Head: 6 diam. by 10" long; Electronics: 19" x 8 3/4"
WEIGHT:	150 lbs.
PORTABILITY:	Yes
TIME ON MARKET:	18 months
PRICE:	$7,950
DELIVERY TIME:	4 weeks
REMARKS:	Special systems available to meet customer requirements, including integrated vacuum systems, process control, etc. Quadrupole assembly is bakeable at 400°C.

MANUFACTURER:	Electronic Associates, Inc.
OPERATING PRINCIPLE:	Mass Spectrometer - Quadrupole (RGA)
SPECIFICITY:	All gases 1-500 amu
MODEL NO. & TRADENAME:	QUAD 250
RANGES:	1- 50; 10 - 150; 50 - 500
SENSITIVITY:	1×10^{15} torr for N_2
EXCITATION:	115v, 60 Hz, 6 amp
OUTPUT SIGNAL IMPEDANCE:	1 μa to 100 ma/1 meg ohm
REPEATABILITY:	5%
RESPONSE TIME:	100 milliseconds
ENVIRONMENT EFFECTS:	Detector from 15°K to 250°C Console from 0°F to 125°F
DOES IT FAIL SAFE:	No
MAINTENANCE:	No specific program required
LIFE EXPECTANCY:	10 years
SIZE:	Head: 6" diam. x 10" long; Electronics: 22 1/2" x 25 1/2" x 60"
WEIGHT:	500 lbs.
PORTABILITY:	Yes
TIME ON MARKET:	3 years
PRICE:	$13,635
DELIVERY TIME:	4 weeks
REMARKS:	Special systems available to meet customer requirements, including integrated vacuum systems, process control, etc. Quadrupole tube is bakeable to 400°C.

MANUFACTURER:	Erdco Engineering Corporation
OPERATING PRINCIPLE:	Catalytic Combustion
SPECIFICITY:	Combustible Gases
MODEL NO. & TRADENAME:	05HCS - TOX-EX
RANGES:	0-100% LEL, 0-10% LEL
SENSITIVITY:	5% full scale
EXCITATION:	Battery operated, 2D Cells, 2 #228 cells for audible alarm.
OUTPUT SIGNAL IMPEDANCE:	Visual reading plus audible alarm
REPEATABILITY:	5%
RESPONSE TIME:	Less than 3 seconds with 25' hose.
ENVIRONMENT EFFECTS:	Temperature Compensated
DOES IT FAIL SAFE:	No
MAINTENANCE:	9 Months
LIFE EXPECTANCY:	5 years
SIZE:	9" x 2 3/4" x 3 1/2"
WEIGHT:	40 ounces
PORTABILITY:	Hand carried portable
TIME ON MARKET:	1 1/2 years
PRICE:	$183.50 complete with handle
DELIVERY TIME:	Stock item.
REMARKS:	Detects combustible gas leaks - electrically differentiates methane from petroleum vapors. Accessories include sampling hose, calibrator. Can be purchased with Ni-Cad rechargeable batteries. Gas sample can be admitted by diffusion or by aspirator bulb.

MANUFACTURER:	Erdco Engineering Corporation
OPERATING PRINCIPLE:	Catalytic Combustion
SPECIFICITY:	Combustible Gases
MODEL NO. & TRADENAME:	03HCS - TOX-EX
RANGES:	0-100% LEL
SENSITIVITY:	5% LEL
EXCITATION:	Battery operated - 2 D Cells
OUTPUT SIGNAL IMPEDANCE:	Visual reading on indicating instrument
REPEATABILITY:	5%
RESPONSE TIME:	Less than 3 seconds with 25' hose
DOES IT FAIL SAFE:	No
MAINTENANCE:	9 Months
LIFE EXPECTANCY:	5 years
SIZE:	8" x 1 3/4" x 3"
WEIGHT:	28 ounces
PORTABILITY:	Hand carried portable
TIME ON MARKET:	2 years
PRICE:	$75.00
DELIVERY TIME:	Stock item
REMARKS:	Detects combustible gas leaks - electrically differentiates methane from petroleum vapors. Accessories include sampling hose, dilution valve for reading concentrations above LEL. Can be purchased with Ni-Cad rechargeable batteries. Gas sample can be admitted by diffusion or by aspirator bulb.

MANUFACTURER:	Erdco Engineering Corporation
OPERATING PRINCIPLE:	Catalytic Combustion
SPECIFICITY:	Combustible Gases
MODEL NO. & TRADENAME:	06HCS - TOX-EX
RANGES:	0 - 100% LEL
SENSITIVITY:	5%
EXCITATION:	Battery operated - 8D Cells
OUTPUT SIGNAL IMPEDANCE:	Visual reading on indicating instrument
REPEATABILITY:	5%
RESPONSE TIME:	Less than 3 seconds with 25' hose.
DOES IT FAIL SAFE:	No
MAINTENANCE:	9 months
LIFE EXPECTANCY:	5 years
SIZE:	6 - 3/4 " x 5 - 7/8" x 3 - 1/4"
WEIGHT:	4 lbs.
PORTABILITY:	Neck strap portable
TIME ON MARKET:	3 months
PRICE:	$110.00
DELIVERY TIME:	Stock item
REMARKS:	Detects combustible gas leaks - electrically differentiates methane from petroleum vapors. Accessories include semi-rigid nylon tube probe and a calibrator. Model 06HCS is fully illuminated for unlighted areas. Gas sample can be admitted either by diffusion or by aspirator bulb.

MANUFACTURER:	Euphonics Industries, Inc. (The Elwood Corporation is the sole distributor)
OPERATING PRINCIPLE:	Sonic - Ultrasonic Range
MODEL NO. & TRADENAME:	EI-100 Leak Detector
SENSITIVITY:	A function of pressure, orifice, and detection distance.
EXCITATION:	9 volt battery (standard transistor radio type)
OUTPUT SIGNAL IMPEDANCE:	Audio, 2000 Ohms (earphones)
ENVIRONMENT EFFECTS:	Uneffected by the normal variations of humidity and temperature.
DOES IT FAIL SAFE:	No
MAINTENANCE:	None with the exception of battery change.
LIFE EXPECTANCY:	10 years
SIZE:	9" long and 1 1/2" diameter.
WEIGHT:	1 3/4 pounds in the carrying case, 9 ozs. without case.
PORTABILITY:	Hand held instrument
TIME ON MARKET:	One year
PRICE:	$115.00
DELIVERY TIME:	From stock
REMARKS:	Ultrasonic sound is converted to sonic range and detector by earphones. Leaks can be detected at a distance.

MANUFACTURER:	Excelsior Varnish, Inc.
OPERATING PRINCIPLE:	Bubble (Liquid Applicant)
MODEL NO. & TRADENAME:	Excelsior Leak Finding Compound
OUTPUT SIGNAL IMPEDANCE:	Bubble
SIZE:	Packaged in 55 gal. drums, 30 gal. 1/2 drums, 5 gal. pails
WEIGHT:	8 1/3 pounds per gallon concentrated
PORTABILITY:	Applicator can be hand carried
TIME ON MARKET:	26 years
PRICE:	Depends on quantity purchased
DELIVERY TIME:	Orders shipped in 24 hours
REMARKS:	Is diluted with equal amount of water. Covers 1,000 to 1,500 square feet to the gallon after reduction. Will not clog small holes. Will not freeze or deteriorate in the package. Will not harden or cake in hot weather. Apply over welded metal surface then use 3 to 5 pounds of air pressure to the opposite side for long lasting bubbles that show up leaks. Quickly rinses off with clear water.

MANUFACTURER:	Fisher Research Laboratory, Inc.
OPERATING PRINCIPLE:	Sonic - Sonic Range
MODEL NO. & TRADENAME:	WM, "Master Electronic Witch"
RANGES:	4 ranges
SENSITIVITY:	32db full scale to 100 db full scale.
EXCITATION:	Battery operated (9v dc)
OUTPUT SIGNAL IMPEDANCE:	Visual and audio (2000Ω earphones)
REPEATABILITY:	Good
ENVIRONMENT EFFECTS:	Input voltage should be within ±10%, temperature range - -20°C to + 60°C
DOES IT FAIL SAFE:	No
MAINTENANCE:	Mainly depends on battery life, approximately 2000 hrs. of operation.
LIFE EXPECTANCY:	10 years
SIZE:	15 1/2" x 9 1/2" x 11 1/2"
WEIGHT:	20 lbs.
PORTABILITY:	Can be hand carried
TIME ON MARKET:	4 years (transistorized model)
PRICE:	$395 F.O.B. Palo Alto
DELIVERY TIME:	Stock item
REMARKS:	Vibrations in frequency range of 40 to 10,000 cycles are detected and amplified. This unit is a leak detector and pipe finder combination. Chiefly used for locating pipe leaks principally in oil and water systems.

MANUFACTURER:	Fisher Research Laboratory
OPERATING PRINCIPLE:	Sonic - Sonic and Ultrasonic range
MODEL NO. & TRADENAME:	LT-10
RANGES:	30 Hz to 10 kHz. Tunable filter zero - in desired frequency
SENSITIVITY:	Low position 32 db, mid position 55db, hi position 85 db
EXCITATION:	9 volts dc internal battery
OUTPUT SIGNAL IMPEDANCE:	Audio signal, panel meter
RESPONSE TIME:	Speed of sound
ENVIRONMENT EFFECTS:	Temperature -20°C to +60°C. Input voltage ±15%.
DOES IT FAIL SAFE:	No
MAINTENANCE:	Battery replacement, approximately 300 hrs. of operation
LIFE EXPECTANCY:	Under normal instrument care 5 yrs
SIZE:	11" x 7.12" x 3.25"
WEIGHT:	Operating weight - complete 4.5 lbs.
PORTABILITY:	Sturdy leatherette carrying case with compartment for accessories.
TIME ON MARKET:	Transistorized model 6 yrs. Tube model over 30 yrs.
PRICE:	$199.50
DELIVERY TIME:	In stock
REMARKS:	High gain audio amplifier with sonic transducer as pick-up probe. Detecting vibration of escaping liquid through an irregular orifice. Designed primarily for locating fluid leaks in water and oil systems. Exclusive tunable filter circuit to pinpoint exact leak frequency, eliminating other noise sources. Also broad position for preliminary detection. Very good portability and compactness.

MANUFACTURER:	Fisher Research Laboratory
OPERATING PRINCIPLE:	Sonic - Sonic and Ultrasonic range
MODEL NO. & TRADENAME:	LT-15
RANGES:	30 Hz to 10 kHz-nine frequency filters
SENSITIVITY:	Four sensitivity ranges - X1-32db X2-52db X3-81db X4-110db.
EXCITATION:	9 volts dc internal battery
OUTPUT SIGNAL IMPEDANCE:	Audio signal. Panel meter.
RESPONSE TIME:	Speed of sound through the ambient
ENVIRONMENT EFFECTS:	Temperature 20°C to +60°C. Input voltage ±15%.
DOES IT FAIL SAFE:	No
MAINTENANCE:	Battery replacement after approximately 1000 hrs. of operation.
LIFE EXPECTANCY:	Under normal instrument care, 5 years
SIZE:	12" x 8" x 5"
WEIGHT:	Operating weight 7 lbs.
PORTABILITY:	Sturdy leatherette carrying case with compartment for accessories.
TIME ON MARKET:	Transistorized model 7 yrs. Tube models over 30 yrs.
PRICE:	$395 with carrying case and complete accessories
DELIVERY TIME:	In stock
REMARKS:	High gain audio amplifier with sonic transducer as pick-up probe. Standard accessories: stainless steel-variable length extension rods, ground sound plate, various type attachments for the crystal pick-up, transducer, headphones, extension cables. Designed primarily for locating leaks in fluids. Nine position narrow band filter, four sensitivity ranges and FINE tuning sensitivity control.

MANUFACTURER: Fisher Research Laboratory

OPERATING PRINCIPLE: Sonic - Ultrasonic range

MODEL NO. & TRADENAME: GT-4

RANGES: 36kHz to 44kHz

SENSITIVITY: Will detect a leak through hole of a .006" of 1 psi at distance of 5 ft.

EXCITATION: 9 v dc internal battery

OUTPUT SIGNAL IMPEDANCE: Audio signal, optional panel meter

RESPONSE TIME: Speed of sound

ENVIRONMENT EFFECTS: Normal operation temperature -20°C to +60°C. Input voltage ±15%.

DOES IT FAIL SAFE: No

MAINTENANCE: Battery replacement 150 - 200 hrs.

LIFE EXPECTANCY: Under normal operating conditions 5 yrs.

SIZE: 6" x 2.5" x 1.25"

WEIGHT: 12.5 oz.

PORTABILITY: Pocket size. Can be attached on a belt.

TIME ON MARKET: 4 years

PRICE: $149.50

DELIVERY TIME: In stock

REMARKS: Detects vibrations of gas pressure or vacuum leaks in ultrasonic frequencies and converts the same to audio range.

Sensing probe has conical directivity of 22°. Can be used to detect leaks in pressure or vacuum systems (especially checking pressurized telephone or power lines). Unit does not respond to ambient noise. Pressure leaks can be detected from a distance in excess of 50 ft. Contact probe optional.

MANUFACTURER:	Fisher Research Laboratory
OPERATING PRINCIPLE:	Sonic - Ultrasonic range
MODEL NO. & TRADENAME:	GT-5
RANGES:	36 kHz to 44 kHz
SENSITIVITY:	Will detect a leak through hole of .006" of 1 psi at distance of 5.5 ft.
EXCITATION:	9 volts internal battery dc.
OUTPUT SIGNAL IMPEDANCE:	Audio signal (speaker or headphones), panel meter
RESPONSE TIME:	Speed of sound
ENVIRONMENT EFFECTS:	Normal operation temperature -20° to + 60°C. Input voltage ±15%.
DOES IT FAIL SAFE:	No
MAINTENANCE:	Battery replacement after 750-800 hours of service.
LIFE EXPECTANCY:	Under normal operating conditions 5 years
SIZE:	9" x 5.5" x 4.75"
WEIGHT:	5 lbs. including probe and battery.
PORTABILITY:	Can be hand carried.
TIME ON MARKET:	4 years
PRICE:	$395
DELIVERY TIME:	In stock
REMARKS:	Detects gas pressure or vacuum leaks in ultrasonic frequencies and converts the same to the audio range. Sensing probe has conical directivity of 22°. Can be used to detect leaks in pressure and vacuum systems (especially checking pressurized telephone and power lines). Unit does not respond to ambient noise. Pressure leaks can be detected from a distance in excess of 50 ft. Contact probe optional.

MANUFACTURER:	Fisher Research Laboratory
OPERATING PRINCIPLE:	Sonic - Sonic range
MODEL NO. & TRADENAME:	AS "AUDIO-SCOPE"
RANGES:	Audio ranges of 30 Hz to 10 kHz
SENSITIVITY:	80 db, controlled by the sensitivity knob
EXCITATION:	9 v dc
OUTPUT SIGNAL IMPEDANCE:	Audio signal - headphones
RESPONSE TIME:	Speed of sound
ENVIRONMENT EFFECTS:	Normal operation temperature -20°C to +60°C. Input voltage ±15%.
DOES IT FAIL SAFE:	No
MAINTENANCE:	Battery replacement after approximately 700 hrs. of operation.
LIFE EXPECTANCY:	Under normal instrument care, 5 years
SIZE:	Length 5" diameter 3"
WEIGHT:	11 oz.
PORTABILITY:	Pocket size
TIME ON MARKET:	5 years
PRICE:	$67.50 including headphones and 6" contact rod
DELIVERY TIME:	In stock
REMARKS:	Transistorized amplifier, self-contained vibration and leak detector. Detects vibration of escaping fluids. Ground sound plate-optional. Carrying case-optional.

MANUFACTURER:	Flamort Chemical Company
OPERATING PRINCIPLE:	Bubble (Liquid Applicant)
MODEL NO. & TRADENAME:	Detect-A-Leak
OUTPUT SIGNAL IMPEDANCE:	Visual (bubbles)
SIZE:	8 oz. can with brush attached to cap.
WEIGHT:	Carton of 12 - 8 ozs. cans. 9 3/4 Lbs.
PORTABILITY:	Yes
TIME ON MARKET:	12 years
PRICE:	$12.60 per carton of 12 - 8 oz. cans; 1 gal. $4.80.
DELIVERY TIME:	From stock
REMARKS:	Can be used safely on rubber, plastic or any type of metal. It is non-corrosive and non-inflammable.

MANUFACTURER:	Flow Technology, Inc.
OPERATING PRINCIPLE:	Flow Sensor
SPECIFICITY:	Any gas or liquid
MODEL NO. & TRADENAME:	FTL series
RANGES:	Liquid: 0.001 to 0.1 gpm Gas: 4 to 4000 cc/min.
EXCITATION:	24 v dc (isolated)
OUTPUT SIGNAL IMPEDANCE:	Voltage pulses (50 mv) 1 to 500 Hz proportional to flow rate.
REPEATABILITY:	0.1% of full scale.
ENVIRONMENT EFFECT:	Normal: -20°F to +165°F Available: -430°F to +550°F
REMARKS:	Unit is a turbine type flowmeter.

MANUFACTURER:	Fluid Data Inc.
OPERATING PRINCIPLE:	Sonic-Ultrasonic range
MODEL NO. & TRADENAME:	Model UD-100 "Leakdata"
SENSITIVITY:	Depends on distance between location of leak and testing point.
EXCITATION:	4.5 v dc battery
OUTPUT SIGNAL IMPEDANCE:	10 mw in 600 ohm headphone
RESPONSE TIME:	Speed of sound
ENVIRONMENT EFFECTS:	Over normal temperature and humidity - slight range variation.
DOES IT FAIL SAFE:	No
LIFE EXPECTANCY:	Batteries have 500 hours life.
SIZE:	Electronics 4" X 8" X 2" - Probe (hand held) 1 1/2" diam. X 6" long.
WEIGHT:	3 Lbs.
PORTABILITY:	Yes
TIME ON MARKET:	Year
PRICE:	About $200.00
DELIVERY TIME:	2 - 3 weeks
REMARKS:	Solid state electronics.

MANUFACTURER:	The Fredericks Company
OPERATING PRINCIPLE:	Ion Gauge (hot filament)
MODEL No. & TRADENAME:	MODEL 3A-5 "Televac"
RANGES:	10^{-3} to 2 x 10^{-9} torr in 5 ranges
EXCITATION:	115v, 60 Hz
OUTPUT SIGNAL IMPEDANCE:	Indicating panel instrument and a "null balance" type recorder. Output from 0 to 1v (normally factory set at 10mv full scale)
ENVIRONMENT EFFECTS:	Power supply is regulated to compensate for line voltage variations from 95 to 130v.
WEIGHT:	Approximately 45 lbs.

MANUFACTURER:	Galaxie Products
OPERATING PRINCIPLE:	Bubble (Liquid Applicant)
SPECIFICITY:	None
MODEL NO. & TRADENAME:	I-SPY LEAK DETECTOR
RANGES:	Minus 10°F to +212°F
OUTPUT SIGNAL IMPEDANCE:	Visual - bubble formation at the leak
SIZE:	4 oz. and 8 oz. polyethylene squeeze bottles. 1 gallon plastic container
PORTABILITY:	Yes

MANUFACTURER:	Gas Analysis Systems, Inc.
OPERATING PRINCIPLE:	Thermal Conductivity
SPECIFICITY:	High signal response to all commonly used non-corrosive pressurizing or contaminating gases and vapors.
MODEL NO. & TRADENAME:	LC-5
RANGES:	Continuous attenuation (manual control of gain)
SENSITIVITY:	1×10^{-5} std. - cc/sec. helium in air
EXCITATION:	** 115v 60Hz or Type 'C' flashlight batteries
OUTPUT SIGNAL IMPEDANCE:	Visual 0-100 relative signal
REPEATABILITY:	Approximately ± 10%
RESPONSE TIME:	Approximately 1 second
ENVIRONMENT EFFECTS:	Ambient temperature, flow rate and background gas composition changes can be nulled out instantaneously.
DOES IT FAIL SAFE:	Yes
MAINTENANCE:	No specific servicing interval, (except battery replacement).
LIFE EXPECTANCY:	5 years
SIZE:	3 1/2" x 4" x 9" - with 4' sample pick-up hose and probe
WEIGHT:	4 lbs.
PORTABILITY:	Can be hand carried or suspended by neck strap
TIME ON MARKET:	2 years - (this instrument series introduced 6 years ago).
PRICE:	$165.00
DELIVERY TIME:	Shelf stocked
REMARKS:	This instrument was designed for quickly checking leaks in pressurized piping or tanks and possible contaminated areas for toxic or non-toxic concentrations. Vacuum systems can be checked by temporarily pressurizing at 1 psig. ** Interchangeable bases are available.

MANUFACTURER: Gas Purifying Materials Co., Inc. (Instrument & Equipment Division)

OPERATING PRINCIPLE: Catalytic Combustion
Thermal Conductivity
Dual Cell Instrument

SPECIFICITY: Combustible gases and vapors. Inert gases by Thermal Conductivity.

MODEL NO. & TRADENAME: #GPM "Vaporgraph"

RANGES:

Catalytic Combustion	0-0.1% Natural Gas 0-1.0% Natural Gas 0-5.0% Natural Gas	Thermal Conductivity	0-100% Natural Gas

EXCITATION: Nickel Cadmium batteries with built-in charger (110v ac)

OUTPUT SIGNAL IMPEDANCE: dc mv output proportional to concentration - recorder available.

REPEATABILITY: ± 1%

RESPONSE TIME: 1 second

ENVIRONMENT EFFECTS: Compensated for temperature and humidity variations.

DOES IT FAIL SAFE: No

MAINTENANCE: Operation check using known standard when necessary.

LIFE EXPECTANCY: Indefinite

SIZE: 3" x 6" x 8"

WEIGHT: 7 pounds with battery

PORTABILITY: Portable unit

TIME ON MARKET: 2 years

PRICE: $360

DELIVERY TIME: 3 - 6 months

REMARKS: Automatic sampling by steady flow diaphragm pump.
Standard Ranges: 0 to 1.0%; 0 to 100% natural gas.
Additional Ranges Available: 0 to 0.1%; 0 to 5%* natural gas.
Special Ranges available to suit application.
Options include: Outlets for recorder and alarm and dc power supply.

* 5% natural gas is LEL.

MANUFACTURER:	Gas Purifying Materials Co., Inc.
OPERATING PRINCIPLE:	Thermal Conductivity and Catalytic Combustion
SPECIFICITY:	Gas and vapor detection is positive by separation by gas chromatography - Air carrier for atmospherics
MODEL NO. & TRADENAME:	ANALOGRAPH
RANGES:	For combustible vapors and gases can read from 1 ppm to 100%.
SENSITIVITY:	Four filament bridge permits 1 PPM and upper PPB detection.
EXCITATION:	100 - 115v, 60 Hz or battery
OUTPUT SIGNAL IMPEDANCE:	Millivolts or microamps - low impedance
REPEATABILITY:	±1% of output
RESPONSE TIME:	1/2 second to several minutes - totals immediate
ENVIRONMENT EFFECTS:	Temperature compensated by balanced bridge circuit.
DOES IT FAIL SAFE:	Can be installed if requested - hi-lo limits alarm
MAINTENANCE:	Indefinite - monthly check suggested
LIFE EXPECTANCY:	Indefinite
SIZE:	6" x 6" x 8"
WEIGHT:	10 pounds without batteries - 14 lbs. with batteries
PORTABILITY:	Portable unit
TIME ON MARKET:	One year
PRICE:	$1200
DELIVERY TIME:	4 months
REMARKS:	Each unit is constructed to suit the specific requirements of the purchaser for example modifications can be made to sense sulfur dioxide, hydrocarbons, gases, etc. Concentration sampling can be installed. Diaphragm pump draws in sample if necessary. Recorder outlet and power failure alarm optional.

MANUFACTURER:	Gas Purifying Materials Co., Inc. (Instrument & Equipment Division)
OPERATING PRINCIPLE:	Catalytic Combustion Thermal Conductivity Triple Cell Instrument Reagent (colorimetric)
SPECIFICITY:	Catalytic - combustible gases and vapors Thermal Conductivity - inert gases Reagent - reactive and low concentrations toxic components (Mercaptans Propylene, Co.)
MODEL NO. & TRADENAME:	#GPM "Odorgraph"

RANGES:	Catalytic Combustion	Thermal Conductivity	Colorimetric Reagent Tube
	0-0.1% Natural Gas	0 to 100% Natural Gas	0 - 100 ppm
	0-1.0% Natural Gas		
	0-5%* Natural Gas		

SENSITIVITY:	0.1% full range
EXCITATION:	Nickel Cadmium batteries with built-in charger (110v ac).
OUTPUT SIGNAL IMPEDANCE:	dc mv output for catalytic and thermal conductivity cells.
REPEATABILITY:	± 1%
RESPONSE TIME:	Electrical - 1 second Colorimetric - 1 minute
ENVIRONMENT EFFECTS:	Compensated for temperature and humidity variation.
DOES IT FAIL SAFE:	No
MAINTENANCE:	As needed.
SIZE:	3" x 6" x 8"
WEIGHT:	7 pounds with battery
PORTABILITY:	Portable unit
TIME ON MARKET:	6 years
PRICE:	$360
DELIVERY TIME:	3 - 6 months
REMARKS:	Automatic sampling by steady flow diaphragm pump. Standard Ranges: 0-1.0%; 0-100%; 0-100 ppm Natural Gas. Additional Ranges available: 0-0.1% and 0-5%* Natural Gas. Special Ranges available to suit application. Options include: dc power supply, recorder outlet and alarm outlet. * 5% natural gas is LEL.

MANUFACTURER:	George W. Gates & Company, Incorporated
OPERATING PRINCIPLE:	Chemical Indicator - Fluorescent Dye
MODEL NO. &	GPC Water Soluble Fluorescing Agent -5GA Oil Soluble TFS4-B90 Raymaster
EXCITATION:	Battery operated 2-45 volt B batteries for "black light" lamp
OUTPUT SIGNAL IMPEDANCE:	Bright glow of fluorescence under rays of exploring lamp.
RESPONSE TIME:	Glow can be seen at once.
ENVIRONMENT EFFECTS:	Darkened area for best results - no changes
MAINTENANCE:	Depends on care and usage.
LIFE EXPECTANCY:	Determined by usage
SIZE:	Battery unit 4 1/4" x 5 1/2" x 8" Lamp unit 3 1/4" x 6 1/2" x 1 3/4"
WEIGHT:	Battery unit 11 lbs. Lamp unit 1 lb.
PORTABILITY:	Can be hand carried
TIME ON MARKET:	15 years
PRICE:	$37.00 for "Raymaster" unit - $5.50/lb. water soluble fluorescing agent - $13.00/lb. oil soluble fluorescing agent.
DELIVERY TIME:	3 to 4 days
REMARKS:	Non-corrosive, non-toxic-different fluorescing agents available for customers requirements. Agent is a dry powder and is diluted in liquid in system to be leak tested. GPC agent is for water dilution. 5GA agent is for oil dilution. Detection equipment is for liquid leaks, not gas or vapor.

MANUFACTURER:	General Air Products Corporation
OPERATING PRINCIPLE:	Pressurized (CO_2) - frosting of atmospheric moisture
MODEL NO. & TRADENAME:	Test-King
OUTPUT SIGNAL IMPEDANCE:	Pressure gage, audible signal and visual observation of frosting of moisture in the area of a leak.
DOES IT FAIL SAFE:	Yes
MAINTENANCE:	Tank requires periodic recharge with CO_2
LIFE EXPECTANCY:	20 to 30 years
SIZE:	25" x 6 3/4"
WEIGHT:	40 lbs.
PORTABILITY:	Can be hand carried
TIME ON MARKET:	15 years
PRICE:	$90.00
DELIVERY TIME:	2 weeks
REMARKS:	Test system is connected to regulator of pressurized CO_2 tank. Tank may be removed for recharging or for use elsewhere while leaving system being tested under pressure. Detects leaks by frosting of atmospheric moisture. Provides an audible leak signal and a system pressure gage. Meets all Interstate Commerce Commission regulations.

MANUFACTURER:	General Electric Company, Instrument Department
OPERATING PRINCIPLE:	Tracer - Halogen
SPECIFICITY:	Halogen Gas
MODEL NO. & TRADENAME:	Type H-11 Serviceman's Leak Detector
RANGES:	One
SENSITIVITY:	0.5 oz./yr. R-12
EXCITATION:	1.25 v, 7 ampere-hour rechargeable battery
OUTPUT SIGNAL IMPEDANCE:	Change in flashing rate of neon probe lamp.
REPEATABILITY:	Good - built-in reference leak provides check on accuracy.
RESPONSE TIME:	Approximately 1 second
ENVIRONMENT EFFECTS:	(2) 32°F to 136°F (0°C to 58°C) operating range 32°F to 104°F (0°C + 40°C) charging range must avoid corrosive fumes and salt spray
DOES IT FAIL SAFE:	No
MAINTENANCE:	As required - normally only new sensing element need be replaced.
LIFE EXPECTANCY:	Determined by usage
SIZE:	Detector 8 1/2" x 4 5/8" x 3 1/2" Charger 4" x 4" x 2 3/4"
WEIGHT:	Detector - 3 lbs. - Charger - 2 lbs.
PORTABILITY:	Can be hand carried
TIME ON MARKET:	1 year
PRICE:	(1) - $130.00
DELIVERY TIME:	Available from stock - sold through air conditioning and refrigeration distributors (wholesalers).
REMARKS:	(1) Unit furnished as one package, including detector and charger. (2) Unit must not be used in presence of flammable vapors.

MANUFACTURER: General Electric Company, Instrument Department

OPERATING PRINCIPLE: Tracer - Halogen

SPECIFICITY: Halogen gas.

MODEL NO. & TRADENAME: Type H-10

RANGES: Two

SENSITIVITY: High sensitivity range - 0.5 oz./yr. R-12
Low sensitivity range - 1.0 oz./yr. R-12

EXCITATION: 110-127v, 60 Hz, 15w

OUTPUT SIGNAL IMPEDANCE: Change in flashing rate of neon probe lamp.

REPEATABILITY: Good

RESPONSE TIME: Approx. 1 second

ENVIRONMENT EFFECTS: 32°F to 113°F (0 to 45°C) operating temperature range.
Must avoid corrosive fumes and salt spray.

DOES IT FAIL SAFE: No

MAINTENANCE: As required - normally only new sensing element need be replaced.

LIFE EXPECTANCY: Determined by usage.

SIZE: 4 1/2" W x 2 5/8" H x 8 9/16" L

WEIGHT: 3 lbs.

PORTABILITY: Can be hand carried.

TIME ON MARKET: Approximately 1 1/2 years

PRICE: $90.00

REMARKS: Above information is for Type H-10 leak detector.

Units must not be used in presence of flammable vapors.

MANUFACTURER:	General Electric Company, Instrument Department
OPERATING PRINCIPLE:	Tracer - Halogen
SPECIFICITY:	Halogen gas
MODEL NO. & TRADENAME:	Type H-2
RANGES:	10 ranges covering span from 10 x 10^{-5} std. cc/sec. to 3 x 10^{-9} std. cc/sec full scale.
SENSITIVITY:	Maximum 1 x 10^{-9} std. cc/sec. (6 x 10^{-6} oz./yr.) R-12
EXCITATION:	120v or 240v, 60 Hz, 100w
OUTPUT SIGNAL IMPEDANCE:	Amplified signal read-on control unit indicating instrument and indicating instrument on detector unit. Also audible signal.
REPEATABILITY:	Good if environmental conditions are kept constant.
ENVIRONMENT EFFECTS:	Temperature range: 32°F to 131°F (0 to 55°C) - Air velocity not to exceed 10 mph. No signs of corrosion after 16 hours, 90% relative humidity at 40°C. Exposure to high concentrations of halogen gases tends to desensitiz sensing element.
DOES IT FAIL SAFE:	No
MAINTENANCE:	Whenever necessary - no specific servicing interval.
LIFE EXPECTANCE:	Determined by use and exposure to desensitizing agents
SIZE:	20" W x 14" H x 11" D (These are control unit dimensions used with various detectors.)
WEIGHT:	Control unit 15 lbs., detector units 1 to 2.5 lbs.
PORTABILITY:	Can be hand carried
TIME ON MARKET:	Latest model - approximately 3 years older models - approximately 15 years.
PRICE:	Control unit - $770. Detector unit - $345.
REMARKS:	Calibrated leaks, capsules and leak standards are available for quantitatively calibrating units. Must <u>not</u> be used in presence of flammable vapors.

MANUFACTURER:	General Electric Company, Instrument Department
OPERATING PRINCIPLE:	Tracer - Halogen
SPECIFICITY:	Halogen gas
MODEL NO. & TRADENAME:	Model H-5P
RANGES:	10 ranges covering span from 10×10^{-5} std. cc/sec. to 3×10^{-9} std. cc/sec. full scale.
SENSITIVITY:	Maximum 1×10^{-9} std. cc/sec.
EXCITATION:	120v or 240v, 60 Hz, 100w
OUTPUT SIGNAL IMPEDANCE:	Amplified signal read on control unit indicating instrument. Also audible signal.
REPEATABILITY:	Good
RESPONSE TIME:	1 second.
ENVIRONMENT EFFECTS:	Temperature range: 32°F to 131°F (0 to 55°C). Air velocity not to exceed 10 mph. No signs of corrosion after 16 hours, 90% relative humidity at 40°C. Exposure to high concentrations of halogen gases tends to desensitize sensing element.
DOES IT FAIL SAFE:	No
MAINTENANCE:	Whenever necessary - no specific servicing interval.
LIFE EXPECTANCY:	Determined by use and exposure to desensitizing agents.
SIZE:	20" W x 14" H x 11" D (These are control unit dimensions used with the various detectors.)
WEIGHT:	Control unit 15 lbs. Detector units 1 to 2.5 lbs.
PORTABILITY:	Can be hand carried.
TIME ON MARKET:	Latest model - approximately 3 years. Older models - approximately 15 years.
PRICE:	Control unit - $770. Detector unit - $345.
REMARKS:	Calibrated leaks, capsules and leak standards are available for quantitatively calibrating units. Must not be used in presence of flammable vapors.

MANUFACTURER:	General Electric Company, Materials Engineering Laboratory, Research and Development Center
OPERATING PRINCIPLE:	Particle Detector. Gases and vapors converted to particles type CNC (condensation nuclei counter).
SPECIFICITY:	Selectivity is possible with the use of specific chemical converters.
MODEL NO. & TRADENAME:	"Condensation Nuclei Counter" Cat. No. 112L428.
RANGES:	Eight
SENSITIVITY:	Varies with gas or vapor. Examples: Halocarbon refrigerants 12-21 = 2 PPM; Sulphur Dioxide = 0.001 PPM; Unsymmetrical dimethylhydrazine = 0.1 PPM.
EXCITATION:	115v, 60 Hz, 220 watts. (115v, 220v, 50 Hz units available)
OUTPUT SIGNAL IMPEDANCE:	Panel instrument: Provision for Recorder (1500 ohms) Outputs: 0-1 ma dc, 0-10 mv dc, positive above ground.
RESPONSE TIME:	2 seconds as particle detector, order of 2 to 5 seconds as gas detector.
MAINTENANCE:	Lubricate sleeve valve every 2000 hours, clean detector chamber and optics as needed. Clean prehumidifier - period determined by nature of gas to particulate conversion.
LIFE EXPECTANCY:	10 years
SIZE:	Cabinet 22" W x 10" H x 20" deep
WEIGHT:	127 lbs.
TIME ON MARKET:	6 years
PRICE:	$4800 less conversion units
DELIVERY TIME:	8 - 10 weeks
REMARKS:	1. Typical gases detected: nitrogen dioxide - ammonia - chlorine unsymmetrical dimethylhydrazine - phosgene 2. Automatic range changer available with or without recording devices. 3. Similar detectors have been engineered for shipboard and aircraft use. 4. Gas converters are not required for materials such as carbonyls - which produce airborn conversion particles directly.

MANUFACTURER:	General Electric Company - Vacuum Products Business Section
OPERATING PRINCIPLE:	Mass Spectrometer
SPECIFICITY:	Helium
MODEL NO. & TRADENAME	22LC010 & 22LC020 (Includes automatic roughing station)
RANGES:	4-position decade switch to provide ranges of x1, x10, x100, x1000.
SENSITIVITY:	$2x10^{-11}$ std cc/sec
EXCITATION:	(22LC010 - 120v, 7 amps, single phase 60 Hz (50 Hz units are (22LC020 - 120v, 15.4 amps, single " " available)
OUTPUT SIGNAL IMPEDANCE:	Panel meter
REPEATABILITY:	±5%
RESPONSE TIME:	Less than 1 second
ENVIRONMENT EFFECTS:	Units will operate within stated specifications over temperature range 40°F to 120°F, up to 100% RH and within range of 105 and 125 volts.
DOES IT FAIL SAFE:	Yes
MAINTENANCE:	Check sensitivity periodically--occasionally pump belt replacement, pump oil change, and cleaning--no specific service interval.
LIFE EXPECTANCY:	10 years
SIZE:	34" H x 25" W x 28" D with 4.8 sq. ft. work surface.
WEIGHT:	22LC010 is approx. 190 lbs. 22LC020 is approx. 345 lbs.
PORTABILITY:	Mounted on 4-fully swiveling casters.
TIME ON MARKET:	3 years
PRICE:	$3,850 to $5,225
DELIVERY TIME:	1 week
REMARKS:	Accessories such as standard calibrated leak inlet port adaptors, sniffing probe, helium jet audible alarm and base plate and bell jar attachment are available. Also models are available with mounted 10 cfm 7 15 cfm mechanical roughing pumps in place of the scfm pump normally supplied in the 22LC020.

MANUFACTURER:	General Electric Company - Vacuum Products Business Section
OPERATING PRINCIPLE:	Mass Spectrometer
SPECIFICITY:	Any gas or vapor having molecular weight in range 1-600.
MODEL NO. & TRADENAME:	22MS-100
RANGES:	8 ranges of Keithley picoammeter
SENSITIVITY:	Depends on application and probe gas.
EXCITATION:	115 v, 15 amps, 60 Hz (bakeout ovens 230 v, 115 amps, 60 Hz)
OUTPUT SIGNAL IMPEDANCE:	Meter display on electrometer, fast response recorder, oscilloscope optional.
REPEATABILITY:	±5%
RESPONSE TIME:	Depends on sensitivity range - as fast as 1 millisecond.
ENVIRONMENT EFFECTS:	Line voltage between 105 and 125 v.
DOES IT FAIL SAFE:	Can be with options.
MAINTENANCE:	Quarterly
LIFE EXPECTANCY:	10 years
SIZE:	Control console: 84 x 22 x 24 Analyzer console: 72 x 22 x 28
WEIGHT:	1450 lbs .
PORTABILITY:	Both units mounted on 4 fully swiveling casters.
TIME ON MARKET:	Since March, 1967
PRICE:	$24,500 + accessories
DELIVERY TIME:	Stock to 60 days

MANUFACTURER:	General Electric Company - Vacuum Products Business Section
OPERATING PRINCIPLE:	Mass Spectrometer
MODEL NO. & TRADENAME:	Monopole #600
RANGES:	1 to 600 AMU in a single mass range
SENSITIVITY:	Minimum detectable partial pressure: 1 x 10^{-14} torr (N_2) or lower.
EXCITATION:	105-125V, 50/60 Hz, 2 amps.
OUTPUT SIGNAL IMPEDANCE:	Panel meter calibration in mass number. Optional readout: Electrometer with recorder and/or oscilloscope.
RESPONSE TIME:	Slow scan time: 10 to 40 minutes for 1 to 600 AMU. Fast scan time: 50 milliseconds to 250 seconds for 1 to 600 AMU.
SIZE:	22" H x 19 3/4" W x 19" D
WEIGHT:	Console: 115 lbs. Monopole Tube 6 lbs.
PORTABILITY:	Yes
TIME ON MARKET:	March, 1967
PRICE:	Control Unit - $8000; Analyzer tube - $4000.
DELIVERY TIME:	Stock to 60 days.

MANUFACTURER:	General Electric Company - Vacuum Products Business Section
OPERATING PRINCIPLE:	Ion gauge, trigger gauge, ion pump. Accessory (audible leak detector). Connected to recorder output of ion pump or pressure gauge control.*
SPECIFICITY:	Variety of gases except air.
MODEL NO. & TRADENAME	Model No. 22LC100
RANGES:	Dependent upon system being tested.
SENSITIVITY:	4 millivolt input change produces 100 cycle freq. change.
EXCITATION:	Two batteries 5.4 volts each
OUTPUT SIGNAL IMPEDANCE:	Audible tone
REPEATABILITY:	Good
RESPONSE TIME:	Approximately one second
ENVIRONMENT EFFECTS:	Probe gas must be able to effect response of detector previously installed in system.
DOES IT FAIL SAFE:	No
MAINTENANCE:	Battery life 100 hrs.
LIFE EXPECTANCY:	5 years
SIZE:	4 1/2" x 3" x 2"
WEIGHT:	1 1/2 lbs.
PORTABILITY:	Hand carried
TIME ON MARKET:	2 years
PRICE:	$350
DELIVERY TIME:	1 week
REMARKS:	For use on vacuum systems only. To be used with vacuum system pressure gage detectors or ion pump controls.

*Probe gas penetrates into vacuum system through a leak and causes a variation in the detector tone.

MANUFACTURER:	General Monitors, Inc.
OPERATING PRINCIPLE:	Electrochemical Cell
SPECIFICITY:	N_2O_4, Hydrazines, and UDMH depending on model.
MODEL NO. & TRADENAME:	Model 150 Toxic Gas Unit
RANGES:	0 to 5 ppm, 0 to 200 ppm
SENSITIVITY:	Fuel - 1/4 ppm Oxidizer - 1/2 ppm
EXCITATION:	115v, 60 Hz
OUTPUT SIGNAL IMPEDANCE:	2v into 1K ohm load for analog signal. Panel meter provided.
REPEATABILITY:	5% full scale or the above sensitivity value whichever is larger.
RESPONSE TIME:	10 sec. to 90% reading
ENVIRONMENT EFFECTS:	35°F to 120°F
DOES IT FAIL SAFE:	Yes
MAINTENANCE:	20 days - recharge cells.
LIFE EXPECTANCY:	6 month warranty
SIZE:	Sensor - NEMA 12 housing Remote readout - rack mountable 7" panel height
WEIGHT:	30 lbs.
PORTABILITY:	Semi-portable
TIME ON MARKET:	1965
PRICE:	$3000 class
DELIVERY TIME:	60 days
REMARKS:	Miniaturization design in process. Other toxic gases can be handled. Electrolytic supply requires changing after approximately 3 weeks of service. Changing operation requires 5 minutes.

MANUFACTURER:	General Monitors, Inc.
OPERATING PRINCIPLE:	Catalytic Combustion
SPECIFICITY:	Most flammable gases
MODEL NO. & TRADENAME:	Model 175 Combustible Gas Detector
RANGES:	Adjustable for full scales of 20% to 125% LEL
SENSITIVITY:	1% of LEL
EXCITATION:	115v ± 20%, 50/60 Hz, 5w
OUTPUT SIGNAL IMPEDANCE:	1v into 1k ohm load - also panel type indicating meter.
REPEATABILITY:	1% of full scale
RESPONSE TIME:	1 sec. and up depending on density of gas.
ENVIRONMENT EFFECTS:	Remote probes - 200°F max., 100% humidity Control units 32°F to 120°F.
DOES IT FAIL SAFE:	No
MAINTENANCE:	60 to 90 days
LIFE EXPECTANCY:	One year warranty
SIZE:	3 1/2" x 9 1/2" x 10" panel, rack or wall mount.
WEIGHT:	3 lb./channel
PORTABILITY:	No
TIME ON MARKET:	1968
PRICE:	$425
DELIVERY TIME:	30 days
REMARKS:	Low temperature diffusion head probes. Single alarm system, buzzer alarm, contacts and lamp. Similar to Model #170.

MANUFACTURER:	General Monitors, Inc.
OPERATING PRINCIPLE:	Catalytic Combustion
SPECIFICITY:	Most flammable gases
MODEL NO. & TRADENAME:	Model 172 Explosion Proof Gas Detector
RANGES:	Adjustable for full scales of 20% to 125% LEL
SENSITIVITY:	1% of LEL
EXCITATION:	117v ± 20% 50/60 Hz, 12v dc, 5w
OUTPUT SIGNAL IMPEDANCE:	1v into 1k ohm load - also panel indicating meter.
REPEATABILITY:	1% of full scale
RESPONSE TIME:	1 sec. and up depending on density of gas.
ENVIRONMENT EFFECTS:	Remote probes - 200°F max., 100% humidity. Control units 32°F to 120°F.
DOES IT FAIL SAFE:	Yes
MAINTENANCE:	60 to 90 days
LIFE EXPECTANCY:	One year warranty
SIZE:	Approx. 9"x 9"x 8"wall mount or panel mount.
WEIGHT:	20 lbs.
PORTABILITY:	No
TIME ON MARKET:	1967
PRICE:	$850 to $900
DELIVERY TIME:	60 days
REMARKS:	Low temperature diffusion head probes. Dual alarm system. Similar to #170, but is in explosion-proof case.

MANUFACTURER:	General Monitors, Inc.
OPERATING PRINCIPLE:	Catalytic Combustion
SPECIFICITY:	Most flammable gases
MODEL NO. & TRADENAME:	Model 170 Combustible Gas Detector
RANGES:	Adjustable for full scales of 20% to 125% LEL
SENSITIVITY:	1% of LEL
EXCITATION:	117v ± 20% 50/60 Hz or 12v dc, 5w
OUTPUT SIGNAL IMPEDANCE:	1v into 1k ohm load for remote analog signal - also panel meter.
REPEATABILITY:	1% of full scale
RESPONSE TIME:	1 sec. and up depending on density of gas.
ENVIRONMENT EFFECTS:	Remote probes - 200°F max., 100% humidity. Control units 32°F to 120°F.
DOES IT FAIL SAFE:	Yes
MAINTENANCE:	60 to 90 days
LIFE EXPECTANCY:	One year warranty
SIZE:	4 3/8 x 2 1/8 x 8"/channel (rack mountable)
WEIGHT:	3 lbs.
PORTABILITY:	Semi-portable
TIME ON MARKET:	1966
PRICE:	$550
DELIVERY TIME:	30 days
REMARKS:	Low temperature diffusion head probes. Rugged, shock resistance control units and probes. Dual alarm system. Panel mounted readout meter, controls, alarm lamps, alarm buzzer and switches.

MANUFACTURER:	General Monitors, Inc.
OPERATING PRINCIPLE:	Catalytic Combustion
SPECIFICITY:	Most flammable gases
MODEL NO. & TRADENAME:	1100G-1100E-1100M
RANGES:	0 to 100% LEL
SENSITIVITY:	2% of full scale
EXCITATION:	2 rechargeable D cells - built-in charger.
OUTPUT SIGNAL IMPEDANCE:	Built-in compact panel meter audible alarm.
REPEATABILITY:	1% of full scale
RESPONSE TIME:	1 sec. and up depending on density of gas
ENVIRONMENT EFFECTS:	0°F to 120°F
DOES IT FAIL SAVE:	No -- audible alarm on low batteries
MAINTENANCE:	60 days. Recharge batteries after 8 hours operation.
LIFE EXPECTANCY:	1 year warranty except batteries
SIZE:	1100G - 7.25 x 7.9 x 2.25 1100E - 7.5 x 6.25 x 4
WEIGHT:	2 lbs.
PORTABILITY:	Yes
TIME ON MARKET:	1968
PRICE:	See remarks
DELIVERY TIME	30 days or stock
REMARKS:	Low temperature diffusion head probes. Remote probes, audible alarm (buzzer), visual alarms (lamps) are available. Available variations of the #1100 series are: #1100E - $287 - recharge on 115v, 60 Hz. #1100G - $375 - Same as #1100E, but has pistol grip design flashing alarm light and pulsating buzzer. #1100M - $600 - Same as #1100G, but is ruggedized.

MANUFACTURER:	General Monitors, Inc.
OPERATING PRINCIPLE:	Catalytic Combustion
SPECIFICITY:	Type I sensor, most flammable gases Type II sensor, hydrogen selective
MODEL NO. & TRADENAME:	H200 FS
RANGES:	Adjustable for full scales of 20% to 125% LEL
SENSITIVITY:	1% of LEL
EXCITATION:	117 ± 10%, 60 Hz ± 10%, 40 watts/channel
OUTPUT SIGNAL IMPEDANCE:	2v dc to 1 K ohm. Panel type indicating meter and alarms.
REPEATABILITY:	1% of full scale
RESPONSE TIME:	1 sec. and up depending on density of gas.
ENVIRONMENT EFFECTS:	Remote probes - 200°F max., 100% humidity. Control units - lab environment.
DOES IT FAIL SAFE:	Yes - several variations offered.
MAINTENANCE:	60 to 90 days.
LIFE EXPECTANCY:	One year warranty
SIZE:	Rack mounting, 5 channels. Modules 12 1/2" height.
WEIGHT:	5 channels - 60 lbs.
PORTABILITY:	No
TIME ON MARKET:	1961
PRICE:	$600/channel
DELIVERY TIME:	30 days
REMARKS:	Low temperature (200°F) diffusion head probes. Many options offered - relay panels, meter panels, special probes. Up to 50 channel systems are available.

MANUFACTURER:	Goldak Company, Incorporated
OPERATING PRINCIPLE:	Sonic - Sonic Range
MODEL NO. & TRADENAME:	#LC/4 "Dual-tronic"
SENSITIVITY:	Pipe - any size or type of metal. Water, air, and low viscosity leaks at 25 psi or more pressure.
EXCITATION:	Battery operated (4 "C" batteries in each transmitter and receiver).
OUTPUT SIGNAL IMPEDANCE:	Visual and audible
ENVIRONMENT EFFECTS:	Depth range - over 18 feet Tracing distance - 250 feet or more under average conditions.
MAINTENANCE:	Determined by battery life.
SIZE:	Transmitter and receiver are the same size 9" x 12" x 3"
WEIGHT:	Total operating weight = 9 1/2 lbs.
PRICE:	$329
REMARKS:	Chief use is for locating pipes and the liquid, air, or fuel leaks therein.

MANUFACTURER: The Goldak Company, Inc.

OPERATING PRINCIPLE: Sonic - Ultrasonic Range

SPECIFICITY: Water - low viscosity fuel, air under 25 psi or more.

MODEL NO. & TRADENAME: Model 727 "Hunter"

SENSITIVITY: Leaks to 1/32"

EXCITATION: 9 volt radio type battery at 500 micro amperes drain.

OUTPUT SIGNAL IMPEDANCE: Panel Meter - 2000 ohms - headphones

ENVIRONMENT EFFECTS: Complete stability +10°F to 115°F

DOES IT FAIL SAFE: No

MAINTENANCE: Battery change only - approximately once a year.

LIFE EXPECTANCY: No limit

SIZE: 6" high 3" wide

WEIGHT: 3 lbs.

PORTABILITY: Hand carried

TIME ON MARKET: Two years

PRICE: $129.50

DELIVERY TIME: Immediate upon arrival

REMARKS: A crystal microphone is used as the detecting element.

Leaks can be detected in pipelines buried under earth, hardtop, cement slabs, etc.

MANUFACTURER:	Gow-Mac Instrument Company
OPERATING PRINCIPLE:	Thermal Conductivity
SPECIFICITY:	No - all gases/vapors other than air
MODEL NO. & TRADENAME:	21-200 Gas Leak Detector Battery Operated
RANGES:	High, Medium Low
SENSITIVITY:	10^{-3} cc-atm/sec. Helium
EXCITATION:	Battery operated with rechargeable pump batteries
OUTPUT SIGNAL IMPEDANCE:	Panel Meter/available with audible signal as accessory 21-210
REPEATABILITY:	2% full scale
RESPONSE TIME:	2 seconds for 4 feet of sampling hose
ENVIRONMENT EFFECTS:	50-100°F
DOES IT FAIL SAFE:	No
MAINTENANCE:	Circuit batteries - approximately 300 hours Pump batteries - 2-3 hours continuous duty
LIFE EXPECTANCY:	Indefinite
SIZE:	5 1/2" x 10 1/2" x 3"
WEIGHT:	8 lbs.
PORTABILITY:	Yes, shoulder strap provided
TIME ON MARKET:	3 months
PRICE:	Model 21-200 \$430, 21-210 \$510 (with audible signal)
DELIVERY TIME:	Stock to 2 weeks
REMARKS:	Frequency of audible signal varies with gas concentration. Special units fabricated to customer specificiations.

MANUFACTURER:	Gow-Mac Instrument Company
OPERATING PRINCIPLE:	Thermal Conductivity
SPECIFICITY:	All gases/vapors other than air.
MODEL NO. & TRADENAME:	21-100 Gas Leak Detector (formerly Gas Hound)
RANGES:	High, Medium, Low
SENSITIVITY:	1×10^{-3} cc-atm/sec. Helium
EXCITATION:	110 volts, 60 Hz, less than 1 watt
OUTPUT SIGNAL IMPEDANCE:	Panel Meter/available with audible signal as accessory 21-110
REPEATABILITY:	2% full scale
RESPONSE TIME:	2 seconds for 4 feet of sampling tubing
ENVIRONMENT EFFECTS:	95-120 volts, 50° to 100°F
DOES IT FAIL SAFE:	No
MAINTENANCE:	Batteries used for readout require replacement after 3 hours operation.
LIFE EXPECTANCY:	Indefinite
SIZE:	5 1/2" x 10 1/2" x 3"
WEIGHT:	8 lbs.
PORTABILITY:	Yes, shoulder strap provided
TIME ON MARKET:	1 1/2 years
PRICE:	Model 21-100-$280, Model 21-110 -$360 (with audible signal)
DELIVERY TIME:	Stock to 2 weeks
REMARKS:	Audible signal frequency varies with gas concentration. Special units can be fabricated to customer specifications..

MANUFACTURER:	Granville-Phillips Company
OPERATING PRINCIPLE:	Mass Spectrometer
SPECIFICITY:	All gases 1 to 750 AMU
MODEL NO. & TRADENAME:	"Spectrascan" #750
RANGES:	1-50 AMU; 10-250 AMU; 100-750 AMU (Tri-range unit)
SENSITIVITY:	Minimum detectable total pressure --- 1 x 10^{-15} torr Minimum detectable partial pressure - 5 x 10^{-15} torr Resolution is 1000 at mass 500
EXCITATION:	115-230v, 50-60 Hz, 700w
OUTPUT SIGNAL IMPEDANCE:	Direct output from electron multiplier for use with oscilloscope or recorder with an input impedance of 10^5 ohms or higher.
REPEATABILITY:	Peak height reproducibility better than $\pm 1\%$ at N_2 for constant molecular concentration in ionizer volume at 1 x 10^{-7} torr.
RESPONSE TIME:	Continuously variable scanning rate from .025 sec. to 30 min. per mass range.
SIZE:	29 1/2" D x 20 3/4" W x 56 1/2" H
WEIGHT:	395 lbs.
PORTABILITY:	On casters
PRICE:	$13,635 - $15,135
DELIVERY TIME:	Stock

MANUFACTURER:	Granville-Phillips Company
OPERATING PRINCIPLE:	Pressure Change - Gas (non-conducting)
MODEL NO. & TRADENAME:	Series #212 (Capacitance Manometer)
RANGES:	Choice of 4 sensing heads: 0-1, 0-10, 0-100, 0-1000 torr, differential. Controller has full scale ranges of 1X, 0.3X, 0.1X, 0.03X, and 0.01X.
SENSITIVITY:	Minimum detectable pressure differential: 0-1 torr model: 5×10^{-4} torr 0-10 torr model: 5×10^{-3} torr 0-100 torr model: 5×10^{-2} torr 0-1000 torr model: 5×10^{-1} torr
EXCITATION:	110-120v, 50-60 Hz, or 220-240v, 50-60 Hz, 40w
OUTPUT SIGNAL IMPEDANCE:	Nulling method or direct readout on panel meter.
REPEATABILITY:	Accuracy: ±2% of full scale (after calibration)
ENVIRONMENT EFFECTS:	Designed to operate at normal room temperature. Balance unit controlled at 50°C. Sensor temperature sensitivity = 10^{-2} torr/°C on 10 torr unit.
SIZE:	Sensor and balance unit: 3 3/4" diameter x 3 1/2" long. Controller: cabinet style - 8 1/4" x 19 1/2" x 10" rack - 7" x 19" x 9"
WEIGHT:	Controller: cabinet 26 lbs., rack 17 lbs.
PORTABILITY:	Yes
PRICE:	Controller: $585 Sensing and balance units: $664 to $761.
DELIVERY TIME:	Stock item
REMARKS:	Sensing head can be baked at 450°C

MANUFACTURER:	Granville-Phillips Company
OPERATING PRINCIPLE:	Ion Gauge
MODEL NO. & TRADENAME:	Controller: Series 326, Model 102 Ionization Gauge, Series 274 (hot cathode-Bayard Alpert type)
RANGES:	10 to 10^{-11} torr in decade steps
SENSITIVITY:	Adjustable
EXCITATION:	105 to 125v, 50/60 Hz, 2 amps
OUTPUT SIGNAL IMPEDANCE:	Panel Meter - Pirani gage mode for pressures above 10^{-3} torr and in ion gage mode for lower pressures. Analog output connector: 10v (1 ma maximum)
REPEATABILITY:	± 1% F.S.
ENVIRONMENT EFFECTS:	Electrometer zero drift after 30 minute warmup, .03% F.S/hr. or 5×10^{-13} amps/hr. whichever is larger.
MAINTENANCE:	Repair facilities maintained at factory.
SIZE:	Controller: 19" x 7" x 9" - rack mounting Ionization gage tube 2 1/4" diameter, 6 3/4" long
WEIGHT:	Controller - Indicator: 20 lbs.
PORTABILITY:	Easily movable
PRICE:	Complete gage: manual range switching $850 Automatic range switching $940
DELIVERY TIME:	Available from stock
REMARKS:	Solid state circuit boards are quickly replaceable from the factory.

MANUFACTURER:	Hastings-Raydist, Inc.
OPERATING PRINCIPLE:	Flow
MODEL NO. & TRADENAME:	Hastings Mass Flowmeter - LF series
RANGES:	15 ranges 0-0.5 to 0-20,000 std. cc/min.
SENSITIVITY:	Down to 0.01 std. cc/min. with the lowest range model (LF-D5)
EXCITATION:	115v, 50 to 400 Hz
OUTPUT SIGNAL IMPEDANCE:	LF-D5 must be used with a one millivolt high impedance mv potentiometer. Other models have an indicating meter and can be used with a 0-2 mv recorder.
REPEATABILITY:	Within 1%
RESPONSE TIME:	10 seconds
ENVIRONMENT EFFECTS:	No gas pressure correction is required from 0.1 psia to 250 psia or gas temperatures up to 200°F.
PORTABILITY:	Yes - by hand
PRICE:	$365 - $725 dependent on requirements
REMARKS:	Linear scale models and integral amplifiers for 0 - 5v dc output, are available. Add $200 for linear scale and $450 for amplifier. High sensitivity flow sensor can function as leak detector by measuring flow rate from an encapsulated component of a pressurized system.

MANUFACTURER:	The Hays Corporation
OPERATING PRINCIPLE:	Electrochemical Cell (membrane type galvanic cell)
SPECIFICITY:	Oxygen
MODEL NO. & TRADENAME:	Model 623.01 Electro-O_2-Chem Portable Membrane Oxygen Analyzer.
RANGES:	0 to 5%, 0 to 10%, 0-25% O_2
SENSITIVITY:	2 1/2" long scale on the panel instrument.
EXCITATION:	None required. Unit is a simple galvanic cell and generates its own power.
OUTPUT SIGNAL IMPEDANCE:	Panel instrument calibrated in percent oxygen. 25 mv dc; requires potentiometric receiver.
REPEATABILITY:	1% full scale deflection
RESPONSE TIME:	Dead time 1 second; time constant 6 seconds.
ENVIRONMENT EFFECTS:	Sample gas condition: Temperature +30°F to 120°F. Pressure -2 psig to +5 psig. Flow 0 to 10 CFH.
LIFE EXPECTANCY:	The operating life of the cell is approximately 5 months or 30,000% hours (whichever comes first).
SIZE:	7" L x 5" W x 4 1/4" D
PORTABILITY:	Yes
PRICE:	$345
REMARKS:	Not affected by non-corrosive redox inactive gases such as H_2, N_2, CO, A, He and H_2O. Not affected by CO_2 or most organic gases such as methane, ethane, propane, butane, ethylene, propylene, etc. Corrosive and redox active gases such as SO_2, Cl_2, and H_2S in large concentrations can interfere. After a cell completes its life cycle, it may be discarded for a new replacement cell or recharged in the field.

MANUFACTURER:	The Heckerman Corporation
OPERATING PRINCIPLE:	Bubble (Liquid Applicant)
SPECIFICITY:	Type I for detecting oxygen gas at room temperature (35°F to 160°F). Type II for detecting oxygen gas at -65° temperatures (-65°F to $+35^\circ$F). Type III for detecting all other gases at ambient temperatures.
MODEL NO. & TRADENAME:	Heck-Check Type I, II and III.
SENSITIVITY:	0.25 std. cc per hour
OUTPUT SIGNAL IMPEDANCE:	Visual
SIZE:	4 ounce bottles, gallon jugs and 55 gallon drums.
WEIGHT:	(See Size)
PORTABILITY:	4 ounce bottles for tool kit
TIME ON MARKET:	3 years
PRICE:	\$22.00 - \$35.00 per dozen (4 oz. bottles)
DELIVERY TIME:	Stock
REMARKS:	This is a bubble type liquid leak detector for use on gas pressurized systems. A mass of white foam forms at the leak source. Type I and Type II meet spec. MIL-L-25567B (ASG) Non Flammable; Non-Toxic; Harmless to skin & clothing.

MANUFACTURER:	Hewlett-Packard Company (Delcon Division)
OPERATING PRINCIPLE:	Sonic (Ultrasonic Range)
SPECIFICITY:	None. Senses all gases
MODEL NO. & TRADENAME:	Ultrasonic Translator Detector. Models 4917A, 4905A, 4916A, 4918A.
RANGES:	36 to 44 KHz
SENSITIVITY:	0.1 std. cc/sec. 1.0 psi-minimum pressure
EXCITATION:	Self-contained battery supply
OUTPUT SIGNAL IMPEDANCE:	Audio signal or audio signal and panel meter
RESPONSE TIME:	Speed of sound
ENVIRONMENT EFFECTS:	Operating temperature -20 to +55°C. Operation unaffected by wind up to 40 mph.
DOES IT FAIL SAFE:	Yes
MAINTENANCE:	Replace batteries 360 to 700 hours of service
LIFE EXPECTANCY:	5-10 years
SIZE:	Min. 4" x 7" x 1 3/4"
WEIGHT:	5 to 11 lbs.
PORTABILITY:	Yes
TIME ON MARKET:	5 years
PRICE:	$525.00 - $850.00
DELIVERY TIME:	Factory Stock
REMARKS:	Models 4917A and 4918A are listed by Underwriters' Laboratories, Inc., for use in hazardous locations Class I, Group D. Hand manipulated probe is 1 3/8 in diameter and 6 1/4 long. It does not respond to audible noise.

MANUFACTURER:	Highside Chemicals, Inc.
OPERATING PRINCIPLE:	Chemical Indicator - Dye - Pressurized
MODEL NO. & TRADENAME:	"Trace"
RANGES:	0-5000 psi -40°F to 350°F
SENSITIVITY:	Depends on time. (Small leaks take longer)
OUTPUT SIGNAL IMPEDANCE:	Red color
RESPONSE TIME:	Depends on size of leak.
LIFE EXPECTANCY:	Indefinite
SIZE:	2" x 2" x 5"
WEIGHT:	4 ounces
PORTABILITY:	Yes
TIME ON MARKET:	Twenty years
PRICE:	$1.15 - 4 ozs. plastic bottle to $18.40 for 1 gallon can.
DELIVERY TIME:	From stock Clifton, New Jersey
REMARKS:	An intensely colored refrigerant oil added to the system refrigerants is circulated through the system. Leaks are identified by bright red spots on outside of system at point of leak. "Trace" is usually visible through ice or frost. Coloring is harmless to refrigerating system. Can locate leaks that start and stop due to temperature or pressure changes.

MANUFACTURER:	Highside Chemicals, Inc.
OPERATING PRINCIPLE:	Bubble - (Liquid or foam applied)
MODEL NO. & TRADENAME:	Leak Finder Foam
OUTPUT SIGNAL IMPEDANCE:	Bubble
RESPONSE TIME:	Depends on size of leak
ENVIRONMENT EFFECTS:	Usable in the ranges -50°F to 212°F pressures 0 to 5000 psi. Humidity does not effect use.
LIFE EXPECTANCY:	Indefinite
SIZE:	2" x 2" x 9"
WEIGHT:	7 ounces
PORTABILITY:	Yes
TIME ON MARKET:	One and one-half years
PRICE:	$1.25 per 6 ounce plastic bottle
DELIVERY TIME:	From stock Clifton, New Jersey
REMARKS:	Foam from plastic bottle applied to suspected leak. Leak causes bubble to form. Adheres to surface more readily if surface is dry. Non-flammable - will not burn or support combustion. Non-corrosive, water soluble - may be wiped off with a damp rag. Not suitable for use on vacuum lines. Usable on all piping and machinery where refrigerants, gas or air leaks may occur.

MANUFACTURER:	Hilger & Watts, Ltd. (Hilger-I.R.D. Ltd., Division) Calibrated Instruments, Inc.
OPERATING PRINCIPLE:	Infrared (Infrared absorption - non-dispersive type)
SPECIFICITY:	As desired, detector tube used determines specificity of unit.
MODEL NO. & TRADENAME:	Type SC/LC
RANGES:	Up to 6 ranges if specified by customer (meter calibrated in volume concentration).
SENSITIVITY:	Will locate leaks to 10^{-2} lusec (1.28×10^{-5} std cc/sec).
EXCITATION:	95-115 v, 60Hz or 190-260 50Hz 100 va.
OUTPUT SIGNAL IMPEDANCE:	Panel meter and 50 to 550 microamps into external circuit not exceeding 200 ohms.
REPEATABILITY:	±1% of full scale reading.
RESPONSE TIME:	Approximately 15 seconds (depends on flow-rate and range).
ENVIRONMENT EFFECTS:	No effect under normal ambient temperature and humidity ranges.
DOES IT FAIL SAFE:	No
MAINTENANCE:	6 months interval
LIFE EXPECTANCY:	Approximately 10 years
SIZE:	20 1/4" high x 18" wide x 10 1/2" deep
WEIGHT:	Approximately 50 lbs.
PORTABILITY:	Transportable
TIME ON MARKET:	15 years
REMARKS:	Customer must supply information on ranges desired, analyzer tubes needed, and detector tubes needed. Modifications available to conform with customer's requirements. Most heteroatomic gases measured - except CO_2 and H_2O. Typical are carbon monoxide, nitrous oxide, sulphur hexafluoride, sulphur dioxide, etc.

MANUFACTURER:	Hoke, Incorporated
OPERATING PRINCIPLE:	Bubble (Liquid Applicant)
MODEL NO. & TRADENAME:	69001 "Chek-Seal"
OUTPUT SIGNAL IMPEDANCE:	Visual (bubbles or foam)
RESPONSE TIME:	Large leaks will form large bubbles instantly. Small leaks form white foam within 60 seconds.
ENVIRONMENT EFFECTS:	Temperature range: 15°F to 180°F
SIZE:	8 oz. bottles
PORTABILITY:	Yes
PRICE:	$1.75/8 oz. bottle; $9.45/6 - 8 oz. bottles
REMARKS:	Chek-Seal is a clear, non-flammable liquid which requires no mixing, and is safe and easy to use. It dries clean leaving no residue or toxic odors.

MANUFACTURER:	Honeywell, Inc. (Apparatus Controls Division)
OPERATING PRINCIPLE:	Ultraviolet Absorption
SPECIFICITY:	Any vapor which absorbs ultraviolet light from 1850 Å to 2250 A. Example: perchloroethylene, nitrogen dioxide, hydrocarbon refrigerant - 12, hydrazine.
MODEL NO. & TRADENAME:	Y457 A
EXCITATION:	115v, 60 Hz
OUTPUT SIGNAL IMPEDANCE:	Visual indication on panel instrument. Current output for recorder - ±50 microamperes.
RANGES:	Single - 0 to 100 ppm or 0 - 5000 ppm determined by vapor of interest.
SENSITIVITY:	±5 ppm depending on vapor.
REPEATABILITY:	±15% at control point during repeated standardizing cycles.
RESPONSE TIME:	Approximately 5 seconds
ENVIRONMENT EFFECTS:	120v (+10% -15%) Ambient temperature: 50 to 115°F at amplifier and detector. Allowable separation: 100 feet maximum between amplifier and detector.
DOES IT FAIL SAFE:	Yes
MAINTENANCE:	Normal servicing - yearly check of electronic tubes built-in standard cell used for automatic self-standardization of unit.
LIFE EXPECTANCY:	5 years
SIZE:	Amplifier - 8 1/2" x 11" x 5" Detector - 6" x 6" x 19"
WEIGHT:	Approximately 30 lbs.
PORTABILITY:	Can be hand carried
TIME ON MARKET:	2 years
PRICE:	$591.30
DELIVERY TIME:	4 weeks
REMARKS:	Vapor Detector consists of R7192A Amplifier and C7025 detector unit. Detector assembly has a fixed beam of ultraviolet radiation from an argon lamp to a self-quenching ultraviolet sensing tube. Fan draws in air sample to be measured. Stream absorbs UV energy in direct proportion to amount of vapor present, thus affecting the count or firing rate of the UV sensing tube. Detector output is a square wave of constant amplitude and duration for each count of the tube. Amplifier provides means of measuring vapor content against set control reference point. Panel indicating: instrument indicates variations from set control reference point.

MANUFACTURER:	Houston Atlas, Inc.
OPERATING PRINCIPLE:	Catalytic Combustion
SPECIFICITY:	Any flammable gas or vapor is detected in the range below the lower explosive limit (LEL)
MODEL NO. & TRADENAME:	Model 510 "Duotector"
RANGES:	0-4% Methane or 0 to 100% LEL of any flammable gas.
SENSITIVITY:	0.4% of gas in air
EXCITATION:	110v 50/60 Hz
OUTPUT SIGNAL IMPEDANCE:	100mv from 1000 ohms
REPEATABILITY:	1% full scale
RESPONSE TIME:	5 sec. to 90% of final value
ENVIRONMENT EFFECTS:	-20 to +40 degrees C - Coefficient is 0.1% per per degree C.
DOES IT FAIL SAFE:	Only as an option
MAINTENANCE:	Replace detecting element once each 4 months of continuous operation. Check zero once per week.
LIFE EXPECTANCY:	20 years
SIZE:	5 x 7 x 8 inches
WEIGHT:	14 lbs.
PORTABILITY:	Hand carry. Battery internal with charger for 8 hours use.
TIME ON MARKET:	5 years
PRICE:	$425.00 for single channel unit
DELIVERY TIME:	30 to 60 days
REMARKS:	Available in multichannel cabinets for simultaneous monitoring of several remote locations to 1,500 feet with sensing heads. Custom arrangements and systems available.

MANUFACTURER:	Japan Vacuum Engineering Co., Ltd.
OPERATING PRINCIPLE:	Mass Spectrometer
SPECIFICITY:	Helium gas tracing
MODEL NO. & TRADENAME:	Model DLMS
RANGES:	1 PPM He
SENSITIVITY:	Leak down to 1 x 10^{-11} torr liter/sec can be detected.
EXCITATION:	100v, 50/60 Hz, 1400w
OUTPUT SIGNAL IMPEDANCE:	Panel meter (300 ma/torr for He)
REPEATABILITY:	3% full scale
RESPONSE TIME:	50% change in one second with a standard leak only.
ENVIRONMENT EFFECTS:	0.25%/°C
DOES IT FAIL SAFE:	No
MAINTENANCE:	Check sensitivity, no specific servicing internal.
LIFE EXPECTANCY:	Pumping system 7 years, ULVATUBE shorter
SIZE:	750 mmW x 760 mmD x 1090 mmH
WEIGHT:	300 kg
PORTABILITY:	Mounted on wheels
TIME ON MARKET:	One year
PRICE:	$6,000 (FOB price)
DELIVERY TIME:	4 weeks

MANUFACTURER:	Japan Vacuum Engineering Co., Ltd.
OPERATING PRINCIPLE:	Mass Spectrometer
SPECIFICITY:	Helium gas tracing
MODEL NO. & TRADENAME:	Model DLMS-P
RANGES:	1 PPM He
SENSITIVITY:	Subject to the pumping system
EXCITATION:	100v, 50/60 Hz, 110w
OUTPUT SIGNAL IMPEDANCE:	Panel meter (300 ma/torr for He)
REPEATABILITY:	3% full scale
RESPONSE TIME:	50% change in one second with a standard leak only. The pumping speed at the test port 1 liter/sec.
ENVIRONMENT EFFECTS:	0.25%/°C
DOES IT FAIL SAFE:	No
MAINTENANCE:	Check sensitivity, no specific servicing internal
LIFE EXPECTANCY:	Pumping system 7 years, ULVATUBE shorter
SIZE:	490 mmW x 323 mmD x 250 mmH
WEIGHT:	15 kg
PORTABILITY:	By hand
TIME ON MARKET:	One year
PRICE:	$4,000 (FOB price)
DELIVERY TIME:	4 weeks
REMARKS:	Model DLMS-P is a portable type of which pumping system should be optionally provided.

MANUFACTURER:	Johnson-Williams Products - Bacharach Instrument Company, Division of American Bosch Arma Corporation
OPERATING PRINCIPLE:	Catalytic Combustion
SPECIFICITY:	Combustible gases or vapors
MODEL NO. & TRADENAME:	#G
RANGES:	0-1.0 LEL
SENSITIVITY:	1% of full scale
EXCITATION:	Battery operated. Internal "D" dry cells (8) 3v
OUTPUT SIGNAL IMPEDANCE:	Visual reading of millimeter
REPEATABILITY:	2% of full scale
RESPONSE TIME:	3 seconds
ENVIRONMENT EFFECTS:	Useful over normal ambient ranges 0-120°F.
DOES IT FAIL SAFE:	No
MAINTENANCE:	Depends on battery life (dry cells).
LIFE EXPECTANCY:	5 years
SIZE:	6" x 3" x 5"
WEIGHT:	4 lbs.
PORTABILITY:	Can be hand carried, fully portable.
TIME ON MARKET:	11 years
PRICE:	$100
DELIVERY TIME:	Stock
REMARKS:	Can be used for detection of leakage of fuel gases from piping and vessels under pressure, toxicity of working areas, and detection of hydrocarbons, etc. Various accessories available. Hand operated aspirator bulb for sample. Many additional accessories and modified Model G designs are available for specialized applications.

MANUFACTURER:	Johnson-Williams Products - Bacharach Instrument Company Division, American Bosch Arma Corporation
OPERATING PRINCIPLE:	Catalytic combustion
SPECIFICITY:	Usual combustible gases and vapors
MODEL NO. & TRADENAME:	Model G-P
RANGES:	Normally calibrated 0 to 1.0% of LEL
EXCITATION:	Rechargeable batteries
OUTPUT SIGNAL IMPEDANCE:	Panel indicating instrument
MAINTENANCE:	5 hours operation from fully charged battery.
PORTABILITY:	Yes
PRICE:	Approximately $200
REMARKS:	Integral sample pump

MANUFACTURER:	Johnson-Williams Products - Bacharach Instrument Company, Division of American Bosch Arma Corporation
OPERATING PRINCIPLE:	Catalytic Combustion
SPECIFICITY:	Combustible gases or vapors
MODEL NO. & TRADENAME:	#SS-P
RANGES:	0-1.0 LEL & 0-1000 ppm
SENSITIVITY:	1% of full scale
EXCITATION:	Battery operated. Ni-Cd rechargeable batteries (2) charger built into unit.
OUTPUT SIGNAL IMPEDANCE:	Visual reading of millimeter
REPEATABILITY:	2% of full scale
RESPONSE TIME:	3 seconds
ENVIRONMENT EFFECTS:	Useful over normal ambient ranges 0-120°F. Humidity compensator required. Is supplied with unit.
DOES IT FAIL SAFE:	No
MAINTENANCE:	Typically, every 100 hours.
LIFE EXPECTANCY:	5 years
SIZE:	8" x 3" x 6"
WEIGHT:	7 lbs.
PORTABILITY:	Can be hand carried, fully portable.
TIME ON MARKET:	3 years
PRICE:	$350
DELIVERY TIME:	Stock
REMARKS:	Can be used for detection of leakage of fuel gases from piping and vessels under pressure, toxicity of working areas, and detection of hydrocarbons, etc. Various accessories available. Has internal sample pump. Basic scale calibrated for benzene. Conversion factors given for other gases or vapors.

MANUFACTURER:	Johnson-Williams Products - Bacharach Instrument Company Division of American Bosch Arma Corporation
OPERATING PRINCIPLE:	Catalytic combustion
SPECIFICITY:	Principally used for the detection and measurement of natural gas concentrations.
MODEL NO. & TRADENAME:	Model H-P
RANGES:	Dual range (0 to 1.0% LEL - 0 to 100% natural gas)
EXCITATION:	Rechargeable batteries
OUTPUT SIGNAL IMPEDANCE:	Panel indicating instrument
MAINTENANCE:	5 hours operation from fully charged battery
PORTABILITY:	Yes
PRICE:	Approximately $250
REMARKS:	Integral pump. Actuates alarm lights and relays indicating lights for safe operation and filament burnout.

MANUFACTURER:	Justrite Manufacturing Company
OPERATING PRINCIPLE:	Halide Torch - Flame Color (Alcohol flame in contact with heated copper turns green in presence of refrigerant gas R-12).
SPECIFICITY:	(usually halide) non-combustible refrigerant gas or vapor.
MODEL NO. & TRADENAME:	#12360
MAINTENANCE:	Refill with anhydrous alcohol when necessary.
WEIGHT:	1 1/2 lbs.
PORTABILITY:	Can be hand carried.
PRICE:	$16.00
REMARKS:	Burns for 45 to 60 minutes on full charge.

MANUFACTURER:	Kelite Chemicals Corporation
OPERATING PRINCIPLE:	Bubble - (Liquid Applicant)
MODEL NO. & TRADENAME:	Bubble Fluid - 10
OUTPUT SIGNAL IMPEDANCE:	Bubble
RESPONSE TIME:	Immediately if container is pressurized.
ENVIRONMENT EFFECTS:	Suited for normal ambient temperatures.
LIFE EXPECTANCY:	Depends on use
SIZE:	Various
WEIGHT:	8.39 lbs./gal.
PORTABILITY:	Mixture can be hand carried.
PRICE:	$2.35/gallon in 55 gallon drums. $2.65/gallon in 15 gallon kegs.
REMARKS:	One part Bubble fluid mixed with 20 to 30 parts water. Mixture applied with brush. Fluid is non-toxic and non-flamable.

MANUFACTURER:	Kobbe-McCawley Corporation
OPERATING PRINCIPLE:	Chemical Indicator-Reagent Reaction: Burning S vs. NH_3. Nearness or contact white cloud forms.
SPECIFICITY:	Used for the detection of Ammonia Refrigerants as above.
MODEL NO. & TRADENAME:	Ammonia Leak Detector of Sulphur Taper
RANGES:	Detects by nearness of sulphur taper to leaking ammonia.
SENSITIVITY:	Extremely small NH_3 leaks are detected.
REPEATABILITY:	Eight inch taper may be reused.
RESPONSE TIME:	Immediate
ENVIRONMENT EFFECTS:	May be used near dry or damp contacts. Humidity not deterent.
MAINTENANCE:	None - expendable
LIFE EXPECTANCY:	Indefinite
SIZE:	8" L x 1/8" D (standard) may be cut to lesser lengths.
WEIGHT:	.01 gram
PORTABILITY:	Yes
TIME ON MARKET:	About 25 years
PRICE:	SEE BELOW
DELIVERY TIME:	Immediate
REMARKS:	Item made of high grade sulphur, melted and impregnated into cordage.

PRICES: Boxes 200 ea-extra long - slow burning:

1 box - $4.00
2-11 bxs - $3.75 ea.
12 bxs - $39.00/24 for $76.00

MANUFACTURER:	Lenk Manufacturing Company
OPERATING PRINCIPLE:	Halide Torch - Flame Color (Color of flame turns green in presence of a non-combustible refrigerant gas leak).
SPECIFICITY:	Non-combustible refrigerant gases.
MODEL NO. & TRADENAME:	#425
OUTPUT SIGNAL IMPEDANCE:	Visual color change in flame.
MAINTENANCE:	Replace compressed gas cylinder
LIFE EXPECTANCY:	Depends on length of time used
SIZE:	14 3/4" high - 3" diameter
WEIGHT:	1 3/4 lbs.
PORTABILITY:	Can be hand carried
PRICE:	$9.00

MANUFACTURER:	Lion Research Corporation
OPERATING PRINCIPLE:	Flow - (Pressure drop across a calibrated length of pipe measured with a sensitive transducer.)
SPECIFICITY:	Any non-corrosive gas or non-conducting liquid.
MODEL NO. & TRADENAME:	FM 400 Flowmeter
RANGES:	3, 1, .3, .1, .03, .01, .003, .001 cc/min. stp
SENSITIVITY:	Maximum for lowest range is .00003 liters per minute
EXCITATION:	Excitation volts: 110, 60 Hz, Power: 5w
OUTPUT SIGNAL IMPEDANCE:	10 ohms
REPEATABILITY:	.1%
RESPONSE TIME:	Typically 0.1 seconds
ENVIRONMENT EFFECTS:	Temperature range -45 to +165°F Humidity 0 to 100%
DOES IT FAIL SAFE:	Yes
LIFE EXPECTANCY:	2 years continuous
SIZE:	5 High 7 Deep 7 1/2 wide in inches (the driver) 4 1/2 High 3 1/2 Deep 6 wide in inches (the sensor)
WEIGHT:	4 1/2 lbs. (the exciter) 3 1/2 lbs. (the sensor)
PORTABILITY:	Portable except that it requires 110 volts
TIME ON MARKET:	On market for 3 months
PRICE:	$1295
DELIVERY TIME:	From stock - 2 weeks

MANUFACTURER: Loenco, Incorporated

OPERATING PRINCIPLE: Thermal Conductivity

SPECIFICITY: Highest sensitivity to helium or hydrogen

MODEL NO. & TRADENAME: Loenco

RANGES: Down to 100 ppm full scale

SENSITIVITY: Depends upon sensing and background gases

EXCITATION: Batteries or ac line supply

OUTPUT SIGNAL IMPEDANCE: Approximately 200 ohms

REPEATABILITY: 0.5% of scale

RESPONSE TIME: Approximately 5 sec. for 90% response

ENVIRONMENT EFFECTS: Depends upon required specifications. 90-130 volt line makes no detectable response.

DOES IT FAIL SAFE: Yes, goes off scale

MAINTENANCE: Zero adjust when used. Span check approximately once per month. No specific service interval.

LIFE EXPECTANCY: 10 years except for pump and detector elements.

SIZE: Depends upon application requirements. Size, exclusive of recorder, as small as 5" x 5" x 10".

WEIGHT: As low as 5 lbs.

PORTABILITY: Some units portable

TIME ON MARKET: Basic detection system since 1956

PRICE: Ranges from $500 to $2000, depending upon performance and service requirements.

DELIVERY TIME: 4 - 8 weeks, depending upon requirements

REMARKS: Loenco builds custom leak detection systems based on thermal conductivity using either thermistor or hot wire sensing elements. In some cases detection sensitivity (at 2 times short term noise) can be as low as one part in 10^8 in sampled gas. Flame ionization and electron capture detection systems are also manufactured.

MANUFACTURER:	Lumidor Products Corporation
OPERATING PRINCIPLE:	Sonic - Ultrasonic range
MODEL NO. & TRADENAME:	LP-600 Detec-tor
RANGES:	35-45 kc
SENSITIVITY:	.001" opening at 6 psi
EXCITATION:	9v transistor type radio battery
OUTPUT SIGNAL IMPEDANCE:	Audible and visual
MAINTENANCE:	Unconditionally guaranteed for one year. Thereafter unit will be repaired at the factory for a maximum cost of $22.50.
LIFE EXPECTANCY:	10 years
SIZE:	4" x 7" x 2"
WEIGHT:	6 lbs.
PORTABILITY:	Yes - furnished with carrying case and carrying sling.
TIME ON MARKET:	5 years
PRICE:	$200
DELIVERY TIME:	7 to 10 days

MANUFACTURER:	MKS Instruments, Incorporated
OPERATING PRINCIPLE:	Pressure Change - Gas (non-corrosive)
MODEL NO. & TRADENAME:	MKS Baratron Series 90
RANGES:	0 to ±1 to 0 to 30 torr, differential (each sensor has 8 ranges)
SENSITIVITY:	1×10^{-5} torr maximum
EXCITATION:	105 - 120v at 50 to 400 Hz
OUTPUT SIGNAL IMPEDANCE:	Analog output 0 to ±100 mv dc and 0 to 500 mv ac. Also panel meter and 5 place manual digital dials.
REPEATABILITY:	0.05% of reading
RESPONSE TIME:	10 milliseconds for a 63% response to a pressure step
ENVIRONMENT EFFECT:	Temperature manually compensated to 200°C with 10 turn potentiometer. Uncompensated temperature error is .02 to .05% of reading per °C.
DOES IT FAIL SAFE:	No
MAINTENANCE:	Calibrate at 6 month intervals
LIFE EXPECTANCY:	5 years minimum
SIZE:	Sensor: 2 1/2" diameter, 2 1/2" long Electronic Unit 2" x 4" x 3" Indicator Unit 6 3/4" x 19" x 5 1/4"
WEIGHT:	Total = 42 lbs.
PORTABILITY:	Easily movable
TIME ON MARKET:	Two years
PRICE:	Sensor system - $1470 to $1560 depending on range Indicator unit - $1280
DELIVERY TIME:	30 days
REMARKS:	Designed for high temperature service. Mechanical element of pressure sensor is separated from the intermediate electronic module. Pressure sensor can be baked at temperatures of 350 to 400°C.

MANUFACTURER:	MKS Instruments Incorporated
OPERATING PRINCIPLE:	Pressure Change - Gas (non-conducting)
MODEL NO. & TRADENAME:	MSK Baratron Series 77H
RANGES:	Full scale ranges: + or - differential pressure, 0 to 1 to 0 - 1000 torr with 8 sensitivity settings for each range
SENSITIVITY:	0.001% of full scale
EXCITATION:	105 - 120v at 60 to 400 Hz
OUTPUT SIGNAL IMPEDANCE:	Panel meter and 4 place digital dials. Also analog output 0 - ±100 mv dc and 0 to 500 mv ac
REPEATABILITY:	Meter readout - 1 to 3% of full scale, depending on range. On 4 place digital dials - 0.02% of full scale + 0.15% of reading.
RESPONSE TIME:	10 milliseconds for a 63% response to a step pressure change of 30 torr at 760 torr
ENVIRONMENT EFFECTS:	Temperature controlled at 120°F
DOES IT FAIL SAFE:	No
MAINTENANCE:	Calibrate at 6 month intervals
LIFE EXPECTANCY:	6 years minimum
SIZE:	Sensor 4" x 4" x 3 3/4" Indicator Unit 9" x 14" x 12"
WEIGHT:	Sensor plus cable: 7 lbs. - Indicator: 40 lbs.
PORTABILITY:	Easily movable
TIME ON MARKET:	6 years
PRICE:	$1195 to $1385 depending on ranges selected
DELIVERY TIME:	30 days
REMARKS:	High speed repetative production test leak detecting systems with line pressures up to 500 psi and various degrees of automation and digital readout are available. Special units are available for liquids.

MANUFACTURER: MKS Instruments, Incorporated

OPERATING PRINCIPLE: Pressure Change (Gas)

MODEL NO. & TRADENAME: Model 100 (Auto-Digital MKS Baratron)

RANGES: * 0 - 1000 torr differential pressure, with eight full scale sensitivity settings

SENSITIVITY: As low as 5 parts in 10^6 of nominal rating

EXCITATION: 115v, 60 to 400 Hz

OUTPUT SIGNAL IMPEDANCE: ±pressures are indicated automatically to 5 decimal places on a nixie display, a 6th place is provided for over-range. Condition of balance is indicated on a panel meter.
Parallel Binary**

REPEATABILITY: ±0.02% of reading + 1 digit. Interpolator permits higher repeatability over first 1% of range.

RESPONSE TIME: Approximately 250 milliseconds required to achieve balance.

ENVIRONMENT EFFECTS: Uses sensors of Model 77H and 90 units. See temperature effects listed for them.

MAINTENANCE: Calibrate at 6 month intervals

LIFE EXPECTANCY: 5 years minimum

SIZE: 12" x 18" x 12"

WEIGHT: 25 lbs.

PORTABILITY: No

TIME ON MARKET: 2 years

PRICE: $5,000 and up

DELIVERY TIME: Units are special building block types for systems approach.

REMARKS: A variation of this equipment having 18 bit binary coded output with no lighted front panel display is available as Model 105.

*Instrument is designed to operate with and requires an MSK Baratron variable capacitance pressure sensor. See information on Models 77H and 90.

**Coded Decimal electrical output is available on rear connector.

MANUFACTURER: Magnaflux Corporation

OPERATING PRINCIPLE: Chemical Indicators - Dye (Fluorescent)

MODEL NO. & TRADENAME: Zyglo

EXCITATION: 115v, 100w (for black light)

OUTPUT SIGNAL IMPEDANCE: Flourescent glow under black light

RESPONSE TIME: Penetrating time varies with materials being tested and type of defects.

ENVIRONMENT EFFECTS: Material must be cleaned before application of penetrant.

PORTABILITY: Portable kit

PRICE: $125.00 for test kit.

12 oz. spray can penetrant - $3.50
12 oz. spray can wet developer - $2.50
12 oz. spray can cleaner - $2.00
12 oz. can dry developer - $1.65

In cases of 12

REMARKS: Above information is for ZA-43 portable test kit. This kit includes: 2 pressure cans of penetrant, 2 pressure cans of developer, 1 pint can of dry developer, 4 pressure cans of cleaner, Black-Light unit, cleaning cloths, wire brush, and steel carrying case.

Penetrants, wet developers, and cleaners are available in pressurized cans or in bulk quantities. Can be applied by dipping, flushing, spraying, or brushing.

Dye penetrant is applied to surface. Developer reveals defect. Fluorescent under black light.

Three types of penetrants and two types of dry developer available. Zyglo is approved to Mil-Spec MIL-I-25135.

MANUFACTURER:	Marcol, S. A. (M. Paquet & Co., Inc., distributors)
OPERATING PRINCIPLE:	Sonic - Sonic Range (non-powered stethoscope)
MODEL NO. & TRADENAME:	Airsonic
RANGES:	0 - 17000 Hz.
EXCITATION:	Unit is non-powered
OUTPUT SIGNAL IMPEDANCE:	Audible - earpieces
REPEATABILITY:	Good
RESPONSE TIME:	Various depending on conditions
DOES IT FAIL SAFE:	No
LIFE EXPECTANCY:	For all practical purposes limitless
SIZE:	12" x 2 1/2" x 2 1/2"
WEIGHT:	4 lbs.
PORTABILITY:	Equipped with a carrying case
TIME ON MARKET:	In U.S. 10 years
PRICE:	$139 net delivered, destination
DELIVERY TIME:	7 days
REMARKS:	Tunable to acoustic frequency of interest using tuning knob with reference dial. Unit is equipped with six demountable attachments. Can detect gas leaks which are under pressure. Can locate liquid leaks under pressure. Can locate vacuum leaks.

MANUFACTURER:	Mast Development Company
OPERATING PRINCIPLE:	Electrochemical Cell
SPECIFICITY:	Strong oxidants, including ozone; chlorine, iodine, and nitrogen dioxide.
MODEL NO. & TRADENAME:	Detector Model 724-21; with recorder - Model 725-21.
RANGES:	0 to 100 PPHM by volume, 0-10 PPHM by volume for strong oxidants
SENSITIVITY:	1 PPHM by volume or less of ozone, chlorine and iodine.
EXCITATION:	120v, 60 Hz, battery operated model available.
OUTPUT SIGNAL IMPEDANCE:	0-20.0 microamperes represents 0 to 1000 PPB by volume
REPEATABILITY:	±2% for same instrument
RESPONSE TIME:	75% of full reading in 30 seconds
ENVIRONMENT EFFECTS:	Negligible
DOES IT FAIL SAFE:	No
MAINTENANCE:	Needs chemical solution every 3 days.
LIFE EXPECTANCY:	Several years - 1 year full guarantee
SIZE:	Detector unit 11.5" high x 7.5" x 6.5" Strip chart recorder 9" x 6.25" x 10"
WEIGHT:	Detector unit - 10.5 lbs. Strip chart recorder - 14.5 lbs.
PORTABILITY:	Can be hand carried
TIME ON MARKET:	3 years
PRICE:	Detector unit - $950 Strip chart recorder - $545
DELIVERY TIME:	30 days after receipt of order; rental program available.
REMARKS:	K1 solution is oxidized by oxidant which depolarizes cathode, allowing electric current to flow. Current flow can be measured on strip chart recorder. Pumps its own air sample. Continuous signal. Nitrogen oxide recorder and meter available. Accessories available.

MANUFACTURER:	The Matheson Company, Inc.
OPERATING PRINCIPLE:	Thermal Conductivity
SPECIFICITY:	None - responds to thermal conductivity of gas of interest.
MODEL NO. & TRADENAME:	Model 8013
RANGES:	Five
SENSITIVITY:	9×10^{-5} std. cc/sec. (R-12); 3.6×10^{-5} std. cc/sec. (Hydrogen); 5.4×10^{-5} std. cc/sec. (Helium)
EXCITATION:	Self-contained - 6 size D batteries
OUTPUT SIGNAL IMPEDANCE:	Audible and visual signals.
RESPONSE TIME:	Approximately 2 seconds
DOES IT FAIL SAFE:	No
MAINTENANCE:	Replace batteries every 40 hours of use, other - once a year.
LIFE EXPECTANCY:	Minimum of 5 years
SIZE:	3 1/8" x 7 3/4" x 9 3/4"
WEIGHT:	Approximately 4 pounds
PORTABILITY:	Can be hand carried
TIME ON MARKET:	4 years
PRICE:	$195
DELIVERY TIME:	Stock item. 3 - 5 days.
REMARKS:	Can be used to detect any type of leak in any constant background. Is more sensitive to gases with larger thermal conductivity difference than background. Wheatstone bridge with 4 filaments Detector responds to changes in gas composition. Stable composition returns output to zero.

MANUFACTURER:	The Matheson Company, Inc.
OPERATING PRINCIPLE:	Chemical Indicators - Reagent (color change in sensor detected by photoelectric system)
SPECIFICITY:	Carbon Monoxide
MODEL NO. & TRADENAME:	8010 and 8011
RANGES:	0-1000 ppm CO full scale
SENSITIVITY:	50 ppm CO (2% full scale)
EXCITATION:	Model 8010, 120v, 60 Hz, 3w Model 8011, Battery operated/ac
OUTPUT SIGNAL IMPEDANCE:	Visual on indicating instrument and audible alarm.
RESPONSE TIME:	Typical response time is 45 seconds for 1000 ppm (full scale).
ENVIRONMENT EFFECTS:	Voltage range: 105-125v ac Not sensitive to ambient changes of temperature and humidity.
DOES IT FAIL SAFE:	No
MAINTENANCE:	Replacement of indicating tab required after tripping alarm, otherwise maintenance is minimal.
LIFE EXPECTANCY:	5 years
SIZE:	8 5/16" x 4 1/4" x 3 3/16"
WEIGHT:	3 1/2 lbs.
PORTABILITY:	Both models 8010 and 8011 can be hand carried
TIME ON MARKET:	4 years
PRICE:	Model 8010 - $124.50. Model 8011 -$190.00
DELIVERY TIME:	Stock item. 3 to 5 days.
REMARKS:	Color change of tab in sensor is detected by photoelectric system. When CO concentration reaches a toxic level, a relay is tripped and a built-in alarm is sounded. In ventilating control, the alarm may be supplemented by setting into action a ventilating system. Model 8011 - when operated on ac, automatically converts to battery operation in event of line failure.

MANUFACTURER:	The Matheson Company
OPERATING PRINCIPLE:	Catalytic Combustion
SPECIFICITY:	Combustible gases (methane, ethane, propane, gasoline, etc.)
MODEL NO. & TRADENAME:	8420 and 8421
RANGES:	0-100% lower explosive limit
SENSITIVITY:	2% full scale (for methane)
EXCITATION:	4 standard "D" flashlight cells
OUTPUT SIGNAL IMPEDANCE:	Panel meter reading and alarm
REPEATABILITY:	2% full scale
RESPONSE TIME:	7 seconds with five feet of hose
ENVIRONMENT EFFECTS:	50 to 120°F
DOES IT FAIL SAFE:	No
MAINTENANCE:	8 hours of continuous service
LIFE EXPECTANCY:	5 years
SIZE:	6 3/4" x 5 1/2" x 2 1/2"
WEIGHT:	5 1/2 lbs. with batteries
PORTABILITY:	Carrying case with shoulder strap
TIME ON MARKET:	1 year
PRICE:	8420 - $180.00 8421 - $270.00
DELIVERY TIME:	Stock item 3 to 5 days
REMARKS:	Operation based on balanced Wheatstone Bridge principle. Combustibles in sample are burned on platinum filament, changing the resistance and unbalancing bridge.

MANUFACTURER:	Met-L-Chek Company, Inc.
OPERATING PRINCIPLE:	Chemical Indicator - Visible Dye or Fluorescent Dye (liquid penetrant)
MODEL NO. & TRADENAME:	"Met-L-Chek Flaw Findr"
SENSITIVITY:	Will detect cracks as small as a few ten thousandths of an inch.
OUTPUT SIGNAL IMPEDANCE:	Red dye on; white background, or bright fluorescent indications under black light.
RESPONSE TIME:	Penetrant dwell time - 5 minutes or longer. Approximately 5 minutes developer.
ENVIRONMENT EFFECTS:	Recommended use range, 60°F to 90°F or slightly more.
LIFE EXPECTANCY:	Indefinite shelf life.
SIZE:	12 ounce spray can, pints, quarts, gallons, 5-gal, 55-gal drum.
WEIGHT:	Kit - 5 lbs, complete, 55-gal drum 430 lbs. other sizes in proportion.
PORTABILITY:	Kit form 3 spray cans
TIME ON MARKET:	15 years
PRICE:	3 can kit - $14.00 - 12 oz. spray can $4.25. Prices lower on larger quantities and sizes.
DELIVERY TIME:	Stock - 1 week (policy to ship all orders same day received).
REMARKS:	Qualifies under pertinent portions of MIL-I-25135C and NAVSHIPS 250-1500-1.

MANUFACTURER:	Mine Safety Appliances Company
OPERATING PRINCIPLE:	Infrared Absorption
SPECIFICITY:	Gas selectivity is obtained by specific detector cells and infrared beam filtering.
MODEL NO. & TRADENAME:	"LIRA" Model 200
RANGES:	Customer to specify
SENSITIVITY:	0-10 ppm N_2O (Nitrous Oxide) as tracer gas.
EXCITATION:	110v, 60Hz, 200w, (50 Hz designs also available)
OUTPUT SIGNAL IMPEDANCE:	Visual reading on indicating meter. 0-100 mv dc output for potentiometer recorder.
REPEATABILITY:	±1% of full scale. Zero drift is less than 1% of full scale in 24 hours.
RESPONSE TIME:	90% of final reading in 5 seconds.
ENVIRONMENT EFFECTS:	Temperature range of 30 to 120°F. Constant voltage transformer supplied with equipment.
DOES IT FAIL SAFE:	No. Can be made fail safe at extra cost.
MAINTENANCE:	Zero and span check once a month.
LIFE EXPECTANCY:	10 years
SIZE:	19" x 12" x 12 3/4"
WEIGHT:	75 lbs.
PORTABILITY:	Is portable
TIME ON MARKET:	10 years
PRICE:	$2400 to $3230
DELIVERY TIME:	60 - 90 days
REMARKS:	Variations and modifications are available to conform with customer's requirements. Can detect most heteroatomic gases typically; nitrous oxide, sulphur hexafluoride, sulphur dioxide, etc. Unit can be sensitized to pressurized gas normally present within a system. Optional accessories: recorder, alarm circuit, calibration samples, complete console mounted system with probe, etc.

MANUFACTURER:	Mine Safety Appliances Company
OPERATING PRINCIPLE:	Catalytic Combustion
SPECIFICITY:	Combustible gases and vapors
MODEL No. & TRADENAME:	Model No. 20
RANGES:	0-100% LEL
SENSITIVITY:	5% of full scale
EXCITATION:	8 standard flashlite batteries
OUTPUT SIGNAL IMPEDANCE:	Panel meter
REPEATABILITY:	10% of full scale
RESPONSE TIME:	30 seconds
ENVIRONMENT EFFECTS:	No effect at livable ambients
DOES IT FAIL SAFE:	No
MAINTENANCE:	Periodic battery replacement
LIFE EXPECTANCY:	20 years
SIZE:	5" x 4" x 6"
WEIGHT:	6 lbs.
PORTABILITY:	Yes
TIME ON MARKET:	12 years
PRICE:	$152
DELIVERY TIME:	From stock - require one week for calibration for specific gas.
REMARKS:	Models available with calibration for use in sensing pentane, acetone, natural gas and petroleum vapors in air.

MANUFACTURER:	Mine Safety Appliances Company
OPERATING PRINCIPLE:	Ion Gauge Steady state ion current (generated by alpha emitter in ion-chamber) drops when particulate matter is introduced into the chamber. Incoming gas or vapor of interest is converted into particles by a reagent.
SPECIFICITY:	Can be made specific to a particular family of gases with the proper selection of reagent.
MODEL NO. & TRADENAME:	Portable "Billion-Aire"
RANGES:	Varies with gas of interest. Examples: Nitrogen Dioxide (or N_2O_4): 0-10 ppm to 0-250 ppm Hydrazine: 0-3 ppm to 0-50 ppm UDMH: 0-3 ppm to 0-50 ppm
SENSITIVITY:	Varies with compound to be detected, examples: Nitrogen Dioxide (or N_2O_4): 0.5 ppm Hydrazine: 0.15 ppm UDMH:
EXCITATION:	Either 110v ac or from self-contained nickel-cadmium rechargeable batteries. Charger is self-contained.
OUTPUT SIGNAL IMPEDANCE:	Meter reading, audible signal, flashing red light 0-10 mv or 0-100 mv dc for recorder
REPEATABILITY:	±2% of full scale. Zero drift: less than 1% in 8 hours
RESPONSE TIME:	90% of final reading within 10 seconds recovery time - the same.
DOES IT FAIL SAFE:	No
MAINTENANCE:	If used continuously for period of 16 hours, batteries should be recharged.
SIZE:	8" x 14" x 8"
WEIGHT:	18 lbs.
PORTABILITY:	Portable model - can be hand carried
TIME ON MARKET:	8 years
PRICE:	$1495
DELIVERY TIME:	60 days
REMARKS:	Customer should furnish specific information on his requirements, environmental conditions, etc. Field calibration kit available for many gases. Billion-Air Trace Gas Analyzer also available for continuous measurement of various compounds. This is not a portable unit.

MANUFACTURER:	Mine Safety Appliances Company
OPERATING PRINCIPLE:	Catalytic Combustion
SPECIFICITY:	Combustible gases and vapors
MODEL NO. & TRADENAME:	Model No. 2A "Explosimeter"
RANGES:	0-100% LEL
SENSITIVITY:	2% LEL
EXCITATION:	6 flashlight batteries
OUTPUT SIGNAL IMPEDANCE:	Panel meter
REPEATABILITY:	10% of full scale
RESPONSE TIME:	30 seconds
ENVIRONMENT EFFECTS:	No effect at livable ambients
DOES IT FAIL SAVE:	No
MAINTENANCE:	Replace batteries after 10 hours of continuous operation.
LIFE EXPECTANCY:	20 years
SIZE:	3 3/8" x 5 3/8" x 5 1/2"
WEIGHT:	4 lbs.
PORTABILITY:	Yes
TIME ON MARKET:	10 years
PRICE:	$100
DELIVERY TIME:	From stock
REMARKS:	Models available with calibration for use to measure oxygen, hydrogen, acetylene or gasoline vapors in air.

MANUFACTURER:	Mine Safety Appliances Company
OPERATING PRINCIPLE:	Dual System. One is Catalytic Combustion. Second is Thermal Conductivity.
SPECIFICITY:	System #1 - combustible gases and vapors System #2 - none
MODEL NO. & TRADENAME:	Model No. 53 - "Gascope"
RANGES:	System #1 - 0 to 100% L.E.L. natural gas System #2 - 0 to 100% by volume natural gas
SENSITIVITY:	5% of full scale
EXCITATION:	8 flashlight batteries
OUTPUT SIGNAL IMPEDANCE:	Panel meter
REPEATABILITY:	10% of full scale
RESPONSE TIME:	30 seconds
ENVIRONMENT EFFECTS:	No effect at livable ambients
DOES IT FAIL SAFE:	No
MAINTENANCE:	Periodic battery replacement
LIFE EXPECTANCY:	20 years
SIZE:	6" x 4" x 5 3/4"
WEIGHT:	6 lbs. 5 oz.
PORTABILITY:	Yes
TIME ON MARKET:	15 years
PRICE:	$157
DELIVERY TIME:	From stock
REMARKS:	Either system is available as a separate instrument.

MANUFACTURER:	Minear Scientific Instruments
OPERATING PRINCIPLE:	Sonic - Sonic Range
MODEL NO. & TRADENAME:	"Leakscope" 100
RANGES:	Complete audio spectrum
SENSITIVITY:	At a pressure of 80 torr - air detected escaping thru hole 0.0005" in diameter.
LIFE EXPECTANCY:	Depends on care taken with use.
SIZE:	About the size of stethoscope
WEIGHT:	8 oz.
PORTABILITY:	Can be hand carried
TIME ON MARKET:	Approximately 5 years
PRICE:	$22.95. Adapters: $6.95 each.
DELIVERY TIME:	2 weeks after receipt of order.
REMARKS:	Specially designed probe amplifies any air turbulence - does not contact surface. Adapters are available to contact flat or difficult to reach locations. Three different shape adapters, "T", "Y" and "J".

MANUFACTURER:	Minnesota Mining and Manufacturing Company - Chemical Division
OPERATING PRINCIPLE:	Immersion
MODEL NO. & TRADENAME:	Inert Perfluorinated Liquids Type Numbers: FC32, FC78, FC77, FC75, FC43
SENSITIVITY:	Leaks as small as 10^{-7} std. cc/sec.
OUTPUT SIGNAL IMPEDANCE:	Gas bubbles
REMARKS:	These fluids are available with boiling points from 88 to 345°F and Pour Points from -58 to -150°F. They are non-reactive, good dielectrics, non-toxic, colorless, tasteless, essentially odorless, non-flammable and drain clean. Surface tension is about one-fifth that of water. Example of application: Diodes are immersed in a fluorocarbon liquid maintained at 140°C. Air trapped within the component expands, forcing air bubbles through seal imperfections. By using a lighted magnifier, bubbles can be detected to the sensitivity stated above.

MANUFACTURER:	Moak Machine and Foundry Company
OPERATING PRINCIPLE:	Immersion
MODEL NO. & TRADENAME:	M34
EXCITATION:	Air (60 psi)
OUTPUT SIGNAL IMPEDANCE:	Air bubbles in water
RESPONSE TIME:	Depends upon size of part being tested
MAINTENANCE:	Normal maintenance as for any mechanical equipment
SIZE:	Depends upon size of part being tested
WEIGHT:	Varies again upon part being tested
PORTABILITY:	Usually not portable
PRICE:	Varies with each part being tested
DELIVERY TIME:	Depends upon how much design is needed
REMARKS:	Leak detection systems are designed and fabricated for specific components in production lines; for example, auto engine blocks.

The above equipment provides pneumatically or hydraulically driven cylinders which seal off openings in a part to be tested. Tests are conducted by applying 60 psi of air to the sealed inner cavity of the test piece and immersing it into a water tank. Leaks will be indicated by bubbles.

This leak testing equipment includes the necessary sealing pistons, controls, manifolds and indicators.

MANUFACTURER:	Moak Machine and Foundry Company
OPERATING PRINCIPLE:	Pressure Change - Gas
MODEL NO. & TRADENAME:	Model M24
EXCITATION:	Air (60 psi)
OUTPUT SIGNAL IMPEDANCE:	Gas pressure decrease
RESPONSE TIME:	Depends upon size of part being tested
MAINTENANCE:	Normal maintenance as for any mechanical equipment
SIZE:	Depends upon size of part being tested
WEIGHT:	Varies again upon part being tested
PORTABILITY:	Usually not portable
PRICE:	Varies with each part being tested
DELIVERY TIME:	Depends upon how much design is needed
REMARKS:	Leak detection systems are designed and fabricated for specific components in production lines; for example, auto engine blocks. Pneumatic pressure is applied to the sealed cavity and air pressure is monitored to determine the presence of leaks. This leak testing equipment includes the necessary sealing pistons, controls, manifolds and indicators. It is necessary to use some type of rust inhibitor in the water so that the part being tested will not rust. This inhibitor must be clear in color.

MANUFACTURER: Moak Machine and Foundry Company

OPERATING PRINCIPLE: Pressure - Water

MODEL NO. & TRADENAME: M8

EXCITATION: Hydraulic system (60 psi)

OUTPUT SIGNAL IMPEDANCE: Water leakage

RESPONSE TIME: Depends upon size of part being tested

MAINTENANCE: Normal maintenance as for any mechanical equipment

SIZE: Depends upon size of part being tested

WEIGHT: Varies again upon part being tested

PORTABILITY: Usually not portable

PRICE: Varies with each part being tested

DELIVERY TIME: Depends upon how much design is needed

REMARKS: Leak detection systems are designed and fabricated for specific components in production lines; for example, auto engine blocks.

The above equipment provides pneumatically or hydraulically driven cylinders which seal off openings in a part to be leak tested. Tests are conducted by applying high pressure water to the sealed inner cavity. Leaks are indicated by water penetration of part being tested.

This leak testing equipment includes the necessary sealing pistons, controls, manifolds and indicators.

It is necessary to use some type of rust inhibitor in the water so that the part being tested will not rust. This inhibitor must be clear in color.

MANUFACTURER:	Modern Engineering Company, Inc.
OPERATING PRINCIPLE:	Halide Torch - Flame Color
SPECIFICITY:	Halides
MODEL NO. & TRADENAME:	Stock 3081; "Jiffy"
OUTPUT SIGNAL IMPEDANCE:	Color change in flame
SIZE:	2 1/2" diameter x 6" long
WEIGHT:	10 oz.
PORTABILITY:	Yes
TIME ON MARKET:	10 years
PRICE:	$9.25
DELIVERY TIME:	Stock
REMARKS:	This is a conventional air-acetylene operated leak detector for use on halide and refrigerant gas leaks.

MANUFACTURER:	National Research Corporation (Equipment Division) subsidiary of Norton Company
OPERATING PRINCIPLE:	Mass Spectrometer
SPECIFICITY:	Helium; adjustable for hydrogen
MODEL NO. & TRADENAME:	NRC 925-20 Portable Direct-Coupled
RANGES:	11 ranges: 10×10^{-5} to 10×10^{-10} std. cc/sec. full scale
SENSITIVITY:	5×10^{-11} std. cc/sec. helium (slightly under 2×10^{-11} std. cc/sec air equivalent)
EXCITATION:	115v, 60 Hz Input power = 1000w
OUTPUT SIGNAL IMPEDANCE	0-20 microamperes/2500 ohms taut band panel meter
REPEATABILITY:	±2% full scale for given input signal
RESPONSE TIME:	63% of change in 1 second
ENVIRONMENT EFFECT:	90-130v (constant voltage transformer built in) 55 - 110°F
DOES IT FAIL SAFE:	Yes
MAINTENANCE:	Cleaning of (auxiliary, if used) cold trap every week cleaning of discharge gauge liner every 2 to 4 weeks
LIFE EXPECTANCY:	Indefinitely long, allowing for replacement of parts subject to wear or failure
SIZE:	Three pieces, less than 2 cubic feet total volume
WEIGHT:	50 lbs.
PORTABILITY:	Table or shelf mounted near vacuum system to be tested. Spectrometer tube mounts on system to be tested.
TIME ON MARKET:	3 years
PRICE:	$2,560
DELIVERY TIME:	2 - 3 weeks
REMARKS:	Audible alarm included but can be omitted. Ion source is single piece with two filaments built in. Ion source is low cost and disposable. Standard accessories include: portable vacuum system - isolated valve -- cold trap standard leak - helium jet probe Unique direct-coupled spectrometer tube attaches to high vacuum chambers like an ionization gauge, for fast response and recovery.

MANUFACTURER:	National Research Corporation (Equipment Division) subsidiary of Norton Company
OPERATING PRINCIPLE:	Mass Spectrometer
SPECIFICITY:	Helium; adjustable for hydrogen
MODEL NO. & TRADENAME:	NRC 925 "Manumatic" (R)
RANGES:	11 ranges: 10×10^{-5} to 10×10^{-10} std. cc/sec. full scale
SENSITIVITY:	1×10^{-11} std. cc/sec. helium (slightly under 4×10^{-12} std. cc/sec. air equivalent)
EXCITATION:	115v, 60 Hz Input power = 2200w
OUTPUT SIGNAL IMPEDANCE:	0-20 microamperes/2500 ohms taut band panel meter
REPEATABILITY:	±2% full scale for given input signal
RESPONSE TIME:	63% of change in 1 second
ENVIRONMENT EFFECTS:	90-130v (constant voltage transformer built in) 55 - 110°F
DOES IT FAIL SAFE:	Yes
MAINTENANCE:	Cleaning of cold trap recommended weekly, cleaning of discharge gauge liner every 2 to 4 weeks
LIFE EXPECTANCY:	Indefinitely long, allowing for replacement of parts subject to wear or failure
SIZE:	40" W x 25" D x 35 1/2" to work surface 48" overall height
WEIGHT:	600 lbs.
PORTABILITY:	Mounted on 4" rubber casters
TIME ON MARKET:	3 years
PRICE:	$6,190
DELIVERY TIME:	2 weeks
REMARKS:	Audible alarm included, but can be omitted. Ion source is single piece with two filaments built in. Ion source is low cost and disposable. Standard accessories include: bell jar port adapter kit base plate standard leak helium jet probe

MANUFACTURER:	National Research Corporation (Equipment Division) subsidiary of Norton Company
OPERATING PRINCIPLE:	Mass Spectrometer
SPECIFICITY:	Helium; adjustable for hydrogen
MODEL NO. & TRADENAME:	NRC 925 VFT (Very Fast Test) Production Leak Detector
RANGES:	11 ranges: 10×10^{-5} to 10×10^{-10} std. cc/sec. full scale
SENSITIVITY:	Basic 1×10^{-11} std. cc/sec helium (slightly under 4×10^{-12} std. cc/sec. air equivalent) Operating: 1×10^{-9} std. cc/sec. helium
EXCITATION:	115v, 60 Hz Input power = 2300w
OUTPUT SIGNAL IMPEDANCE:	Red "reject" lamp 0-20 microamperes/2500 ohms taut band panel meter
REPEATABILITY:	±2% full scale for given input signal
RESPONSE TIME:	63% of change in 1 second
ENVIRONMENT EFFECTS:	90-130v (constant voltage transformer built in) 55 - 110°F
DOES IT FAIL SAFE:	Yes
MAINTENANCE:	Cleaning of cold trap recommended weekly, cleaning of discharge gauge liner every 2 to 4 weeks
LIFE EXPECTANCY:	Indefinitely long, allowing for replacement of parts subject to wear or failure
SIZE:	52" W x 25" D x 35 1/2" to work surface - 48" overall height
WEIGHT:	650 lbs.
PORTABILITY:	Mounted on 4" rubber casters; floor mounted auxiliary pump
TIME ON MARKET:	2 years
PRICE:	$9,000 approximately - depends on work fixtures
DELIVERY TIME:	3 weeks
REMARKS:	Side mounted standard test port for conventional operation as desired. Ion source is single piece with two filaments built in. Ion source is low cost and disposable. Standard accessories for side test port: bell jar base plate helium jet probe port adapter kit standard leak Test enclosures: (flat packs, T05, etc.); test headers.

MANUFACTURER:	Newark Controls Company
OPERATING PRINCIPLE:	Gas Density (A gas density switch - density remains constant while pressure changes with temperature.)
SPECIFICITY:	Designed specifically for gases, vapors, and vapor-liquid atmospheres.
MODEL NO. & TRADENAME:	Gas Density Switches - Nos. RM76, SN88, SN98, SN129
RANGES:	Vary with type switch used
SENSITIVITY:	Varies with type switch used
OUTPUT SIGNAL IMPEDANCE:	Opens and closes switch
RESPONSE TIME:	Less than .001 second
ENVIRONMENT EFFECTS:	Switch and gas being sensed must be at same temperature. Temperature range varies with type of switch used (-85°F to +200°F being typical value). Units to +400F.
DOES IT FAIL SAFE:	Yes
MAINTENANCE:	Throw away and replace
LIFE EXPECTANCY:	3 to 5 years
SIZE:	Approximately 1" diameter x 2" long
WEIGHT:	2 oz. or less
PORTABILITY:	Can be hand carried
TIME ON MARKET:	6 years
PRICE:	$60 to $200
DELIVERY TIME:	4 to 8 weeks
REMARKS:	When the molecular density of a gas sealed in a chamber being monitored drops below a critical value this unit causes a switch to operate. It responds to gas density change in sealed containers over a specified temperature range. Temperature compensation is achieved by a trapped volume in a reference bellows.

MANUFACTURER: Nuclear Products Company (NUPRO Co.)

OPERATING PRINCIPLE: Bubble (Liquid Applicant)

MODEL NO. & TRADENAME: "Snoop" and "Real Cool Snoop"

OUTPUT SIGNAL IMPEDANCE: Bubble

ENVIRONMENT EFFECTS: Operating temperature range "SNOOP" + 27°F to 200°F
"REAL COOL SNOOP" - 65°F to 200°F
(-65°F to +35°F with oxygen)

LIFE EXPECTANCY: Depends on usage

PORTABILITY: Dispenser can be hand carried

REMARKS: Tradename "SNOOP". Non-toxic, no residue, dries clean, detects leaks on vertical surfaces. Meets MIL-L-25567A (ASG) Type 1.

Trade name "REAL COOL SNOOP", has wider operating temperature range. Low degree of toxicity. Dries clean. Is non-flammable in liquid state. Meets MIL-L-25667A (ASG) Type II specs.

Applicants detect leaks in pressurized systems.

MANUFACTURER:	Perkin-Elmer Corporation - Ultek Division
OPERATING PRINCIPLE:	Mass Spectrometer - Quadrupole
SPECIFICITY:	1 - 150 AMU
MODEL NO. & TRADENAME:	Quad #150
RANGES:	One
SENSITIVITY:	5 x 10^{-14} torr for N_2.
EXCITATION:	105 - 125v, 50 - 60 Hz.
OUTPUT SIGNAL IMPEDANCE:	Indicating instrument on front panel. Output at Electron Multiplier: 20 amps/torr.
RESPONSE TIME:	130 milliseconds scal mass range
SIZE:	Electronics: 8 3/4" x 19" rack mount (cabinet available)
WEIGHT:	Sensing elements in shipping container - 35 lbs. Electronics: shipping weight - 175 lbs.
PRICE:	$7950

MANUFACTURER:	Perkin-Elmer Corporation - Ultek Division
OPERATING PRINCIPLE:	Mass Spectrometer - Quadropole
SPECIFICITY:	1 - 500 AMU
MODEL NO. & TRADENAME:	Quad #250
RANGES:	Three ranges (1-50; 10-150; 50-500 AMU)
SENSITIVITY:	10^{-15} torr for N_2
EXCITATION:	117v, 60 Hz, 6 amps
OUTPUT SIGNAL IMPEDANCE:	Designed for use with oscilloscope, strip chart or x-y recorder. 100 amps/torr for N_2.
RESPONSE TIME:	500 microseconds
SIZE:	22 1/2" x 59 3/4" x 25 1/2"
WEIGHT:	Shipping weight: 470 lbs.
PRICE:	$13,700 (readout equipment extra).

MANUFACTURER:	Perkin-Elmer Corporation - Ultek Division
OPERATING PRINCIPLE:	Ion Gauge, Accessory - Is a current amplifier - tracer gas admitted through leak alters magnitude of ion gauge current. This current is amplified and monitored.
SPECIFICITY:	None. Any convenient bottled gas such as helium, argon, oxygen, CO^2, etc. can be used as probe gas.
MODEL NO. & TRADENAME:	#60-412
RANGES:	One
SENSITIVITY:	1% of the pumped gas pressure.
EXCITATION:	115v, 60 Hz, 10w.
OUTPUT SIGNAL IMPEDANCE:	Visual indication on panel meter 0-220 mv dc for full scale meter reading.
REPEATABILITY:	Good
RESPONSE TIME:	As fast as 1/2 second.
ENVIRONMENT EFFECTS:	105 to 125 volts, 50° to 100°F performs within stated specifications.
DOES IT FAIL SAFE:	Yes
MAINTENANCE:	In consistent everyday use, replace mercury battery each 3 months. Occasional vacuum tube replacement.
LIFE EXPECTANCY:	5 years
SIZE:	13 1/4" x 7 3/8" x 4"
WEIGHT:	8 1/2 lbs.
PORTABILITY:	Can be hand carried
TIME ON MARKET:	5 years
PRICE:	$380
DELIVERY TIME:	Stock item
REMARKS:	Requires equipment for measuring pressure such as ion gauge or ion pump systems. The leak detector amplifies the effects of small pressure or gauge sensitivity changes. Oxygen and argon found to give largest and most rapid response for ion pumped systems steady state pressure is cancelled so that any subsequent change in the reading is readily detectable.

MANUFACTURER: Phoenix Precision Instrument Co., Inc.

OPERATING PRINCIPLE: Particle Detector - (Detects airborne particulates by measurement of forward scattered light.)

SPECIFICITY: None. Response proportional to total concentration of airborne particulates.

MODEL NO. & TRADENAME: Model JM-2000 Sinclair-Phoenix Aerosol Photometer

RANGES: 100 to 0.001 micrograms/liter of 0.3 micron diameter particles.

SENSITIVITY: Dependent on sample concentration due to logarithmic response.

EXCITATION: 115v, 60 Hz, 2 amps - not including vacuum pump

OUTPUT SIGNAL IMPEDANCE: Panel instrument. Output for recorder (5mv dc). 50 ohms output impedance.

RESPONSE TIME: 1 second

ENVIRONMENT EFFECTS: Sensitivity adversely affected by excessively high humidity and temperature.

DOES IT FAIL SAFE: No

MAINTENANCE: 3 months

LIFE EXPECTANCY: Indefinite

SIZE: 21" x 11" x 15"

WEIGHT: 90 lbs.

PORTABILITY: Moveable from station to station on rolling lab cart.

TIME ON MARKET: 13 years

PRICE: $2213

DELIVERY TIME: 4 weeks

REMARKS: Described in tentative Test Method by ASTM Committee F-7, sub X; also Sandia Corp. Technical memorandum SC-TM-64-637. Aids in compliance with Fed.Std.#209.

Unit is useful in detecting leaks in clean-room filter seals.

Also available: Model JM-3000-AL Aerosol Photometer, having linear response with approximately 2 orders of magnitude greater sensitivity.

MANUFACTURER: Joseph G. Pollard Company, Inc.

OPERATING PRINCIPLE: Sonic - Sonic Range

SPECIFICITY: None

MODEL NO. & TRADENAME: P30 Sonoscope

EXCITATION: None required

OUTPUT SIGNAL IMPEDANCE: Audio - earpiece

WEIGHT: 5 ounces

PORTABILITY: Yes

PRICE: $6.50

DELIVERY TIME: 7 days ARO

REMARKS: Unit is an adaptation of a telephone earphone. It contains a tuning rod which protrudes on one end and vibrates on contact with a leaking pipe or system. The other end of the rod terminates at a metal diaphragm which generates sound from the rod vibration.

MANUFACTURER:	Joseph G. Pollard Company, Inc.
OPERATING PRINCIPLE:	Sonic - Sonic Range
SPECIFICITY:	None
MODEL NO. & TRADENAME:	LT-10
RANGES:	30 to 10,000 Hz.
EXCITATION:	9 volts - Internal Battery
OUTPUT SIGNAL IMPEDANCE:	Earphones
MAINTENANCE:	Replace battery after 300 hours of use
SIZE:	7" x 11" x 3 1/4"
WEIGHT:	4 1/2 lbs.
PORTABILITY:	Yes
TIME ON MARKET:	1 year
PRICE:	$199.50
REMARKS:	Sound generated by liquid leaking from pressurized system is detected, amplified and tuned to leak frequency.

MANUFACTURER:	Quantum Dynamics, Incorporated
OPERATING PRINCIPLE:	Flow
MODEL NO. & TRADENAME:	Models LST-4 and LBT-2
RANGES:	0.1 to 10,000 std. cc/min.
SENSITIVITY:	0.02 std. cc/min. maximum
EXCITATION:	115v, 60 Hz or 24v dc
OUTPUT SIGNAL IMPEDANCE:	Digital - can use counter
REPEATABILITY:	0.1% of full scale
ENVIRONMENT EFFECTS:	Designed for 50 to 120°F ambient
LIFE EXPECTANCY:	10 years
SIZE:	Single channel: 6" x 6" x 12" Multi-range unit: 24" x 24" x 84"
WEIGHT:	5 to 300 lbs.
PORTABILITY:	Small units are portable
TIME ON MARKET:	2 years
PRICE:	Single channel unit: $800 Large system, to $9500
DELIVERY TIME:	90 days
REMARKS:	Large systems can be used for long term tests (days-weeks), for very low leak rates. Various adaptations are available. Instruments and systems can be custom designed for specific applications.

MANUFACTURER:	Riken Keiki Fine Instrument Company, Ltd.
OPERATING PRINCIPLE:	Interferometer
MODEL NO. & TRADENAME:	Riken Gas Indicator - Type 18
SENSITIVITY:	Scale for Methane - 0-10; 0.5% per division Vernier scale for methane - 0-1: 0.02% per division
EXCITATION:	Single flashlight battery
OUTPUT SIGNAL IMPEDANCE:	Panel meter
ENVIRONMENT EFFECTS:	Designed for use in -30°C to +45°C ambient.
SIZE:	7 1/2" x 3 1/2" x 2 1/2"
WEIGHT:	3 1/2 lbs.
PORTABILITY:	Is hand carried
REMARKS:	Refractive index of the test gas is compared to that of air. Unit is useful for measuring the concentration of any gas in air. Unwanted gases must first be filtered out by absorbers.

MANUFACTURER:	Riken Keiki Fine Instrument Company, Ltd.
OPERATING PRINCIPLE:	Catalytic Combustion
SPECIFICITY:	All combustible gases can be detected
MODEL NO. & TRADENAME:	Riken Gas Auto-Alarm-Type GP120
RANGES:	All combustible gas: LEL 0 - 100% (0-1.8 vol % for C_4H_{10})
SENSITIVITY:	1% of LEL can be detected
EXCITATION:	100v 50/60 Hz
OUTPUT SIGNAL IMPEDANCE:	Panel meter and acoustic and lamp alarm (1ma into 60 ohms)
REPEATABILITY:	±5% full scale
RESPONSE TIME:	90% in 10 sec.
ENVIRONMENT EFFECTS:	Design for use at 80 to 120v, 0° to 40°C, and performs within stated repeatability.
DOES IT FAIL SAFE:	No
MAINTENANCE:	Check span every three months
LIFE EXPECTANCY:	Sensor one year, Instrument proper 5 years.
SIZE:	Power units: 4" x 8" x 8 1/4" Indicator (for one measuring point) 4" x 8" x 8 1/4" Detector heads (for one measuring point): 4 1/2" x 5 1/2" x 7"
WEIGHT:	11 lbs. (in the case of one measuring point)
PORTABILITY:	Stationary type
TIME ON MARKET:	5 years
PRICE:	FOB Japan (US $360) - (in case of 1 measuring point)
DELIVERY TIME:	Within one month

MANUFACTURER:	Riken Keiki Fine Instrument Company, Ltd.
OPERATING PRINCIPLE:	Catalytic Combustion
SPECIFICITY:	All combustible gases can be detected
MODEL NO. & TRADENAME:	Riken Combustible Gas Detector/Alarm-Type GP205
RANGES:	All combustible gas: LEL 0-100% (0 - 1.8 vol % for C_4H_{10})
SENSITIVITY:	1% of LEL can be detected
EXCITATION:	4 standard flashlight cells.
OUTPUT SIGNAL IMPEDANCE:	Panel meter and acoustic and lamp alarm (1ma into 60 ohms)
REPEATABILITY:	±5% full scale
RESPONSE TIME:	90% in 5 sec.
ENVIRONMENT EFFECTS:	At 2.2 to 3v, 0° to 40°C; performs within stated repeatability.
MAINTENANCE:	Check span every three months, battery replacement every 200 measurements.
LIFE EXPECTANCY:	Sensor one year, instrument proper 5 years.
SIZE:	5 1/2" x 6 3/4" x 3 1/2 "
WEIGHT:	5 1/2 lbs.
PORTABILITY:	Portable (supported by neck strap during use)
TIME ON MARKET:	3 years
PRICE:	F.O.B. Japan (US $75)
DELIVERY TIME:	Prompt
REMARKS:	There is also a model GP-204 which does not have an alarm and uses fewer batteries.

MANUFACTURER: Ruska Instrument Corporation

OPERATING PRINCIPLE: Gas Pressure Change - Gas (Fused Quartz Bourdon Tube)

MODEL NO. & TRADENAME: Series 38

RANGES: 0-2 psi through 0-1000 psi. Other ranges available on request.

SENSITIVITY: Resolution (10,000 counts) - 0.01% full scale

EXCITATION: 110v, 60 Hz (11va to 110va depending on model)

OUTPUT SIGNAL IMPEDANCE: Digital counter (built-in)

RESPONSE TIME: Slew rate: manual - 40 seconds full scale
motorized and servo - 20 seconds full scale

ENVIRONMENT EFFECTS: Operational temperature: 32° - 100°F
Storage temperature: 0° - 120°F

SIZE: Standard and motorized 14 1/2" x 8 1/2" x 10 1/2"

WEIGHT: Standard - 22 lbs.; motorized - 23 lbs.; servo - 30 lbs.

PORTABILITY: Yes

PRICE: Units with ranges of 200 psi or less:

Model 3823 - $1245
Model 3825 - $1690
Model 3833 - $1315

REMARKS:

Model 3820 - standard
Model 3823 - motorized
Model 3825 - servo-matic
Model 3830 - standard power pack) rechargeable battery
Model 3833 - motorized power pack)

MANUFACTURER:	Salen & Wicander, AB
OPERATING PRINCIPLE:	Catalytic Combustion (Combustion with photocell monitoring of filament)
SPECIFICITY:	Combustible gases and vapors.
MODEL NO. & TRADENAME:	KVC - 5/p/115
RANGES:	0-100% LEL of the gas concentration
SENSITIVITY:	10% LEL
EXCITATION:	Battery with built-in 115v, 60 Hz. Trickle charger.
OUTPUT SIGNAL IMPEDANCE:	Audible and visual
ENVIRONMENT EFFECTS:	Temperature: 0 to 125°F Pressure: atmospheric
MAINTENANCE:	Recharge batteries every 6 hours (4 hours if pump is worked continuously).
SIZE:	6" x 8" x 10"
WEIGHT:	17 pounds
PORTABILITY:	Can be hand carried
PRICE:	$580
DELIVERY TIME:	Stock item
REMARKS:	Audible and visual alarms adjustable from 10 to 100% LEL. Used to indicate % of LEL of flammable vapors in air.

MANUFACTURER:	Salen & Wicander AB
OPERATING PRINCIPLE:	Catalytic combustion
SPECIFICITY:	Combustible gases and vapors, chlorine and freon
MODEL NO. & TRADENAME:	"Salwico" type KVC-5, KVC-50
RANGES:	0 - 100% LEL of the gas concentration
SENSITIVITY:	2% LEL
EXCITATION:	115 or 240v, 60 or 50 Hz 400w
OUTPUT SIGNAL IMPEDANCE:	Panel meter (1 ma into 700 ohms)
REPEATABILITY:	±5% full scale
RESPONSE TIME:	100% change in 2 sec.
ENVIRONMENT EFFECTS:	Designed for 100 to 130 or 215 to 260v at 0^{o} to 125^{o}F and atmospheric pressure
DOES IT FAIL SAFE:	No
MAINTENANCE:	Check zero and span monthly. No specific servicing interval.
LIFE EXPECTANCY:	10 years
PORTABILITY:	Both portable and fixed mounted models are available for multi channel systems.
TIME ON MARKET:	10 years
PRICE:	\$500 to \$10,000
DELIVERY TIME:	4 weeks
REMARKS:	Audible and visual alarm adjustable from 2% to 100% LEL.

MANUFACTURER:	Schneider Manufacturing Company
OPERATING PRINCIPLE:	Sonic - Sonic Range
SPECIFICITY:	No. It is an underground water and steam leak locator.
MODEL NO. & TRADENAME:	Globe Geophone
OUTPUT SIGNAL IMPEDANCE:	Stethoscope headpiece
ENVIRONMENT EFFECTS:	Normal atmospheric humidity and temperature has no effect on operation.
DOES IT FAIL SAFE:	No
MAINTENANCE:	Instruments now in for repair have been out for 10-16 years and after repair (about $28.00) will last for another 10-16 years.
LIFE EXPECTANCY:	(See above)
SIZE:	Carried in a wooden case 4" x 10" x 12"
WEIGHT:	12 lbs.
PORTABILITY:	Hand carried
TIME ON MARKET:	Since 1918 - 50 years
PRICE:	$105.00
DELIVERY TIME:	Same day order is received
REMARKS:	Geophone is non-electrical, rugged, sensitive and easily carried. Used to locate underground water and steam leaks.

MANUFACTURER: Shannon Luminous Materials Company, Tracer-Tech Division

OPERATING PRINCIPLE: Chemical Indicators - Dye (Fluorescent System, Fluorescent Tracer Concentrates). Dilutes in any solvent except water. (Water tracers available).

SPECIFICITY: Non-specific, detects any leakage-path through which a liquid can be transported.

MODEL NO. & TRADENAME: T-100/OS-31 (green) T-100/OS-80 (blue-white). Fluorescent Concentrates - "Tracer-Tech."

RANGES: Sensitivity adjustable, according to dilution.

SENSITIVITY: Flaws as small as 75 millimicrons can be detected. Sensitivity may be increased to about 10 millimicrons or less by a development technique.

EXCITATION: Black light lamps operate on 115v, 60 Hz, 4 to 100w. (50 Hz and high power up to 3 kw available).

OUTPUT SIGNAL IMPEDANCE: Visual inspection of fluorescent leak indications (photocell readout available).

REPEATABILITY: ± 5% in statistical count of defects.

RESPONSE TIME: Average penetration dwell time 10 minutes. (Depends on length of leakage path).

ENVIRONMENT EFFECTS: Recommended use temperature above 40°F., to maximum of 200°F.

LIFE EXPECTANCY: 10 years (plus).

SIZE: Supplied in pint bottles of concentrate - (Spray cans available - 12 oz. spray cans, 8 per kit).

WEIGHT: Approximately 1 lb./pint - Kit weights about 16 lbs.

PORTABILITY: Kits can be hand carried.

TIME ON MARKET: 10 years

PRICE: Spray can kit $30.50. Pint bottles $8.00. Ultraviolet lamps $14.50 to $95.00.

DELIVERY TIME: Stock - immediate shipment.

REMARKS: Qualifies under pertinent portions of MIL-I-25135C. Several different types of kits are available. Modifications are available to meet specific requirements of liquid systems, sensitivity, etc. Calibration instrumentation is available. Patented.

MANUFACTURER:	Shannon Luminous Materials Company, Tracer-Tech Division
OPERATING PRINCIPLE:	Chemical Indicator - Dye Indicator shows color change as result of shift in pH due to absorption of amine vapors.
SPECIFICITY:	Specific to amine gases, ammonia, diethylene triamine, ethylenediamine, and similar liquids and vapors.
MODEL NO. & TRADENAME:	T-621 Gas-Phase System "Tracer-Tech"
SENSITIVITY:	Estimate - leaks down to 1×10^{-7} std. cc/sec. can be detected.
OUTPUT SIGNAL IMPEDANCE:	Visual inspection of color change from pale blue to bright red in locality of leak.
REPEATABILITY:	Good. Presence of Ketone vapors and electrochemical effects of metals may interfere.
RESPONSE TIME:	Average time is a few seconds to reach equilibrium of indications.
ENVIRONMENT EFFECTS:	Recommended use temperature between $60^{\circ}F$ to $80^{\circ}F$. Elevated temperatures may accelerate electrochemical interference effects.
LIFE EXPECTANCY:	10 years
SIZE:	Supplied in pint bottles (complete kits include accessory materials, barrier film-former, protective film-former, cleaners, vapor source).
WEIGHT:	Kit weights approximately 16 lbs.
PORTABILITY:	Kits can be hand carried.
TIME ON MARKET:	5 years
PRICE:	T-621 Indicator - $20.00 per pint. Complete Kit - $60.00
DELIVERY TIME:	Stock - three days.
REMARKS:	Low volatility vapor sources are supplied which have less hazard than ammonia gas. The system has the capability of locating leakage points on the inside of a pressurized chamber, as in a honeycomb fuel tank. Patented.

MANUFACTURER:	Sherwin Incorporated
OPERATING PRINCIPLE:	Chemical Indicator - Fluorescent Dye
MODEL NO. & TRADENAME:	Tradename is "Dubl-Chek" - Fluorescent Dye Penetrant
RANGES:	Nonwater-washable and water-washable
SENSITIVITY:	Fraction micron
EXCITATION:	(Capillary Attraction)
REPEATABILITY:	Good
RESPONSE TIME:	Penetrant dwell-time 15 minutes; developing time 5 minutes
ENVIRONMENT EFFECTS:	Penetrants should be used above 60°F. Surfaces and flaws must be free of moisture and soil.
MAINTENANCE:	Bulk materials check for brightness periodically.
LIFE EXPECTANCY:	Indefinite
SIZE:	Spray cans (12 oz.) and bulk - 1/5/55 gallon containers.
WEIGHT:	30 lbs. Kit w/black light
PORTABILITY:	Portable but requires electric source for black light
TIME ON MARKET:	4 years
PRICE:	$150 with black light
DELIVERY TIME:	Two weeks
REMARKS:	Fluorescent Dye Penetrant (Liquid charged w/fluorescent dye, penetrates defects and exposes as glowing mark under black light) Qualified under MIL-I-25135C(ASG) and MIL-I-6866B.

MANUFACTURER:	Sherwin Incorporated
OPERATING PRINCIPLE:	Chemical Indicator - Dye
MODEL NO. & TRADENAME:	Tradename is "DUBL-CHEK" - Dye Penetrant
RANGES:	Nonwater-washable and Water-washable
SENSITIVITY:	Fraction micron
EXCITATION:	(Capillary Attraction)
REPEATABILITY:	Good
RESPONSE TIME:	Penetrant dwell-time 15 minutes; developing time 5 minutes
ENVIRONMENT EFFECTS:	Penetrants should be used above 60°F. Surfaces and flaws must be free of moisture and soil.
LIFE EXPECTANCY:	Indefinite
SIZE:	Spray cans (12 oz.) and bulk - 1/5/55 gallon containers
WEIGHT:	Kit (3 spray cans) weighs 5 lbs.
PORTABILITY:	Completely portable
TIME ON MARKET:	4 years
PRICE:	$13.95 for Kit of 3 spray cans
DELIVERY TIME:	Immediate
REMARKS:	Visible Dye Penetrant, a red liquid, penetrates defects and shows them as a red mark on white developer. Qualified under MIL-I-25135C(ASG); MIL-I-6866B; and NAVSHIPS 250-1500-1

MANUFACTURER:	J. & S. Sieger, Ltd. (Poole-Dorset-England) Agent: Smith-Jesse, Incorporated
OPERATING PRINCIPLE:	Catalytic Combustion
SPECIFICITY:	All explosive gases except acetylene, and vapors containing sulfur compounds which will poison detector element.
MODEL NO. & TRADENAME:	Sieger MK7 Series 1
RANGES:	20-25% to 100% LEL
EXCITATION:	110-250v, 50/60 Hz or 12v dc via power converter
OUTPUT SIGNAL IMPEDANCE:	Panel meter and 5 amp, 250v alarm relay
REPEATABILITY:	±2%
RESPONSE TIME:	1 to 10 seconds
ENVIRONMENT EFFECTS:	Humidity or pressure does not affect reading. Designed for use in 30°F to 130°F ambient
DOES IT FAIL SAFE:	Yes
MAINTENANCE:	Check monthly
LIFE EXPECTANCY:	Indefinite with normal servicing
WEIGHT:	6 lbs.
PORTABILITY:	Yes
TIME ON MARKET:	20 years
PRICE:	From $220 up
DELIVERY TIME:	3 - 4 weeks
REMARKS:	Also have Model P, Portable Battery Powered Unit. Features meter readout, any super-sensititive and standard 0-100% of LEL readout. From $170 up.

MANUFACTURER:	Sierra Engineering Company - Materials Research Division
OPERATING PRINCIPLE:	Tracer - Radioactive. Hermetically sealed components are placed into a chamber which is then pressurized with a Radio-tracer (Kr^{85} & Nitrogen) for a specific time and pressure. Components are then removed and tested for radioactive gas penetration.
SPECIFICITY:	Krypton-85 (Krypton-85 and Nitrogen mixture)
MODEL NO. & TRADENAME:	Radioflo Model 44-462
SENSITIVITY:	1×10^{-11} std. cc/sec.
EXCITATION:	115v, 25 amps, 60 Hz (50 Hz available)
OUTPUT SIGNAL IMPEDANCE:	Scintillation Crystal Counting Station
DOES IT FAIL SAFE:	Yes
SIZE:	56 1/4" x 54 7/8" x 44"
WEIGHT:	Complete system: 3640 lbs. (5 gallon Activation Tank)
PORTABILITY:	No
TIME ON MARKET:	12 years
PRICE:	Price on request

MANUFACTURER:	Sloan Instruments Corporation
OPERATING PRINCIPLE:	Mass Spectrometer (partial pressure)
SPECIFICITY:	Any between 2 to 50 Mass
MODEL NO. & TRADENAME:	Model R.G.A.
RANGES:	Masses 2 to 50
SENSITIVITY:	Partial pressures to 3×10^{-10} torr (100 ppm)
EXCITATION:	117v, 50-60 Hz
OUTPUT SIGNAL IMPEDANCE:	Recorder output 0 to 100mv
DOES IT FAIL SAFE:	Yes
MAINTENANCE:	Periodic tube element bake-out
LIFE EXPECTANCY:	Dependent on gas being used for leak detection
SIZE:	7" x 9 1/2" x 10 1/2"
WEIGHT:	12 lbs (without magnet)
PORTABILITY:	Yes - tube and magnet only can be installed in system R.G.A. moved anywhere
TIME ON MARKET:	Three years
PRICE:	R.G.A. $2400 Tube $265 Magnet $300
DELIVERY TIME:	30 days
REMARKS:	The Sloan R.G.A. is capable of measuring partial pressures to 3×10^{-10} torr over 2 mass range of 2 to 50. Can automatically sweep 10 mass numbers/minute or be set to scan for one gas only for leak detection or monitoring doping gases etc. Long term stability allows one peak observation for hours or even days. Signal can be generated when pressures exceed set limits.

MANUFACTURER:	Spectronics Corporation (Black Light Eastern Division)
OPERATING PRINCIPLE:	Chemical Indicators - Dye (Fluorescent)
SPECIFICITY:	Black light sources and additives to fluids in systems.
SENSITIVITY:	Depends on additive and ambient light.
EXCITATION:	90v dc to 110v ac for lamp
SIZE:	6" x 6" x 12"
WEIGHT:	10 lbs.
TIME ON MARKET:	11 years
PRICE:	$22.50 and up
DELIVERY TIME:	1 week
REMARKS:	Various models available. Dye is added to fluid. Used for detection of leaks in condensers, reactors, etc. Small traces of additives can be detected when leaks occur.

MANUFACTURER:	Sprague Devices, Incorporated
OPERATING PRINCIPLE:	Bubble (Liquid Applicant)
MODEL NO. & TRADENAME:	"Air Push" Leak Detector
OUTPUT SIGNAL IMPEDANCE:	Visual (bubbles)
RESPONSE TIME:	Within 5 seconds
LIFE EXPECTANCY:	2 years, minimum
SIZE:	4 oz. bottle - 1 pint - 1 gallon
WEIGHT:	7 oz.
PORTABILITY:	Yes
PRICE:	4 oz. - $1.00; 1 pint - $2.35; 1 gallon - $15.00

MANUFACTURER:	Starr-Kap Engineering Company
OPERATING PRINCIPLE:	Pressure Change - Liquid
SPECIFICITY:	Liquid appropriate to system
MODEL NO. & TRADENAME:	SKEC 1-200-TAR "Leak Check" Line Unit for Production Line
RANGES:	Standard Working Pressure 0 to 2000 psi 2000 to 15,000 psi - special application
SENSITIVITY:	0.015 cc/min at 2,000 psi system pressure
EXCITATION:	100 psi air pressure normal
OUTPUT SIGNAL IMPEDANCE:	*Visual readout to gauge
REPEATABILITY:	Absolute
RESPONSE TIME:	Immediate
ENVIRONMENT EFFECTS:	No effect
DOES IT FAIL SAFE:	Yes, unit is self testing
MAINTENANCE:	Minimum, depending on usage
LIFE EXPECTANCY:	Indefinite
SIZE:	20" x 15" x 13"
WEIGHT:	70 lbs. approximate
PORTABILITY:	For production line use
TIME ON MARKET:	10 years
PRICE:	$1,750 and up
DELIVERY TIME:	3 to 4 weeks
REMARKS:	*Automatic readout available; ticket printer also available. Readout is taken on a differential pressure gage. Measurement indicates pressure difference between a pressurized liquid system and the system being tested. Diaphragm seal is used between hydraulic and air system. Built-in intensifier increases shop line air pressure to desired value.

MANUFACTURER:	Starr-Kap Engineering Company
OPERATING PRINCIPLE:	Pressure Change - Liquid
SPECIFICITY:	Liquid appropriate to system
MODEL NO. & TRADENAME:	SKEC 2-200-TAR "Leak Check" Portable Model on wheels
RANGES:	Standard Working Pressure: 0 to 2000 psi 2000 to 15,000 psi - special application
SENSITIVITY:	0.015 cc/min at 2,000 psi system pressure
EXCITATION:	100 psi air pressure normal
OUTPUT SIGNAL IMPEDANCE:	*Visual readout to gauge
REPEATABILITY:	Absolute
RESPONSE TIME:	Immediate
DOES IT FAIL SAFE:	Yes, unit is self testing
MAINTENANCE:	Minimum, depending on usage
LIFE EXPECTANCY:	Indefinite
SIZE:	22" x 42" x 20"
WEIGHT:	200 lbs. approximate
PORTABILITY:	For repair or laboratory use
TIME ON MARKET:	10 years
PRICE:	$2,750 and up
DELIVERY TIME:	3 to 4 weeks
REMARKS:	*Automatic readout available; ticket printer also available. Similar to Model SKEC-1-200 TAR, except can be wheeled to test site, and has tank of hydraulic fluid to fill the system being tested.

MANUFACTURER:	Starr-Kap Engineering Company
OPERATING PRINCIPLE:	Pressure Change - Gas
SPECIFICITY:	Gas
MODEL NO. & TRADENAME:	LC 10234 "Air Check"
RANGES:	0 to 500 psi
SENSITIVITY:	Has capacity of detecting beyond one bubble in five seconds or less.
EXCITATION:	100 psi air pressure, depending on application
OUTPUT SIGNAL	*Visual readout on gauge
RESPONSE TIME:	Immediate. Time duration of test: 15 sec. to fill, 15 sec. to temperature stabilize, 10 sec. to test, 5 sec. to dump.
DOES IT FAIL SAFE:	Yes, unit is self testing
MAINTENANCE:	Minimum, depending on usage
LIFE EXPECTANCY:	Indefinite
SIZE:	18 1/2" x 30" x 10" (with air intensifier to 500 psi)
WEIGHT:	175 lbs. approximate (with air intensifier to 500 psi)
PORTABILITY:	For production or laboratory use
TIME ON MARKET:	5 years
PRICE:	$1,400 and up
DELIVERY TIME:	3 to 4 weeks
REMARKS:	*Automatic readout available also; ticket printer also available. Built-in air intensifier is used to raise test pressure above shop line pressure. Primarily for production testing of systems. Typical system volume is 250 in^3.

MANUFACTURER: Superior Signal Company, Incorporated

OPERATING PRINCIPLE: Tracer - Smoke. Smoke is generated by chemical reaction in a cartridge type bomb.

MODEL NO. & TRADENAME: Superior Smoke Candles and Superior Smoke Bombs

EXCITATION: None required. Flame manually applied to fuse.

OUTPUT SIGNAL IMPEDANCE: Visual observation and odor of escaping smoke through leak

RESPONSE TIME: Approximately 5 minutes

ENVIRONMENT EFFECTS: Should be stored below 65% humidity and 85°F

DOES IT FAIL SAFE: Yes

LIFE EXPECTANCY: 18 months

SIZE: Four sizes from 1/2" x 1 3/8" OD to 14" x 1 3/8" OD with burning time of 30 seconds, 60 seconds, three minutes or five minutes

WEIGHT: 1 1/2 oz. to 1 lb. each

PORTABILITY: Yes

TIME ON MARKET: 14 years

PRICE: $4.50 to $25.80 per dozen

DELIVERY TIME: 2 weeks

REMARKS: After the smoke device is started, a blower injects the non-toxic smoke into the system to be leak tested. Smoke will be observed escaping from leaks. This method can be used on large systems such as sewer lines. On smaller systems a blower may not be necessary and merely insertion of the smoke device is sufficient. Smoke volume normally should be sufficient to fill an area 5 or 6 times that of the test system. Various types of smoke devices available. Smoke will not stain clothing nor corrode metal.

MANUFACTURER:	Technicon, Inc.
OPERATING PRINCIPLE:	Chemical Indicator - Reagent
SPECIFICITY:	Specific for SO_2, NO, NO_2, formaldehyde, agone, ammonia, cyanide, acrolein, H_2S
MODEL NO. & TRADENAME:	Auto Analyzer
RANGES:	Variable from ppm upwards
SENSITIVITY:	1 ppm
OUTPUT SIGNAL IMPEDANCE:	0-10mv
REPEATABILITY:	± 1.0% relative
RESPONSE TIME:	3 - 5 minutes
DOES IT FAIL SAFE:	Yes
MAINTENANCE:	1 week
LIFE EXPECTANCY:	5 - 10 years
SIZE:	3 x 2 x 2 ft. cabinet
WEIGHT:	70 lbs.
PORTABILITY:	Yes
TIME ON MARKET:	New
PRICE:	$5,000
DELIVERY TIME:	90 days
REMARKS:	A gas sample is selectively scrubbed, as programmed, for one specific constituent at a time. The liquid concentrate for each analysis is delivered to a colorimeter for quantitative analysis. The colorimeter output is normally shown on a recorder chart.

MANUFACTURER:	Technology/Versatronics, Inc.
OPERATING PRINCIPLE:	Flow
SPECIFICITY:	Gases
MODEL NO. & TRADENAME:	"LINURMASS" Mass Flowmeter
RANGES:	0.16 std. cc/sec. air, through 50 lbs.min.
SENSITIVITY:	0.01 std. cc/sec. air
EXCITATION:	115v, 60 Hz or 28v dc
OUTPUT SIGNAL IMPEDANCE:	Panel Meter also 5v dc
REPEATABILITY:	±0.1% of reading
RESPONSE TIME:	70 ms for full step change at 10% of flow rate
ENVIRONMENT EFFECTS:	±2% full scale accuracy specified over ±25°F temperature span and pressure range of ±1 atm.
DOES IT FAIL SAFE:	No
MAINTENANCE:	Check zero and span every 6 months No specific servicing interval
LIFE EXPECTANCY:	10 yrs.
SIZE:	4.53" long 1.37" in diameter
WEIGHT:	8 oz.
PORTABILITY:	Due to light weight and small size easily portable.
TIME ON MARKET:	6 years
PRICE:	$1500 thru $2500
DELIVERY TIME:	4 weeks
REMARKS:	A self-heated thermistor placed in the gas flow path, senses mass flow rate. A second thermistor which is not in the flow path but held at the flow stream temperature, serves to compensate for temperature variations. Modifications are available to conform with customer's requirements.

MANUFACTURER: Technology/Versatronics, Inc.

OPERATING PRINCIPLE: Electrochemical Cell

SPECIFICITY: Oxygen

MODEL NO. & TRADENAME: p 0160

RANGES: 0 to 10%, 0 to 21%, 0 to 40%, or anywhere between 0 to 75 mmHg and 0 to 320 mmHg.

SENSITIVITY: 30 mv/mm on Model p 0160L; 6 mv/mm on Model p 0160B

EXCITATION: Line operated 115v, 50-60 Hz, 0.3 amps.
Battery operated 4 mallory RM12R current 1.3 ma.

OUTPUT SIGNAL IMPEDANCE: Panel Instrument with 10v dc on p 0160L (ac unit) and 1.5v dc on p 0160B (battery unit).

REPEATABILITY: ± 0.1% of reading

RESPONSE TIME: 5 seconds

ENVIRONMENT EFFECTS: ± 1% of full scale accuracy specified over temperature range of 32°F to 120°F and ± 10v ac variation.

DOES IT FAIL SAFE: No

MAINTENANCE: Recharge oxygen probe every 30 to 90 days.

LIFE EXPECTANCY: 5 years

SIZE: 5" x 9.5" x 6"

WEIGHT: 5 lbs.

PORTABILITY: Yes

TIME ON MARKET: 1 1/2 years

PRICE: $480 for p 0160L; $490 for p 0160B price includes electrode.

DELIVERY TIME: Off the shelf

MANUFACTURER:	Techsonics, Inc.
OPERATING PRINCIPLE:	Sonic - Ultrasonic Range
SPECIFICITY:	None; depends on sound of leak
MODEL NO. & TRADENAME:	110, 110M, 112 "Son-Tector"
SENSITIVITY:	Can detect 0.003" diameter hole at 25 psi at 25 feet (air)
EXCITATION:	9 volt transistor radio battery
OUTPUT SIGNAL IMPEDANCE:	Speaker, 8 ohm headset, meter movement
REPEATABILITY:	±5% of meter reading
ENVIRONMENT EFFECTS:	0 to 50°C
MAINTENANCE:	Periodic battery replacement (100-150 hours)
LIFE EXPECTANCY:	5 - 10 years
SIZE:	6 1/4" x 4 1/4" x 1 1/2"
WEIGHT:	15 oz. base unit, 5 pounds including case and all accessories.
PORTABILITY:	Normally hand carried or clipped to belt.
TIME ON MARKET:	4 1/2 years
PRICE:	$144.50 to $245.50 depending on accessories
DELIVERY TIME:	Stock
REMARKS:	Also available: Pole Mounting Amplifier for use in hazardous locations - complete high voltage isolation. Useful for locating leaks in gas and liquid pressure and in vacuum systems.

MANUFACTURER:	Techsonics, Inc.
OPERATING PRINCIPLE:	Sonic - Ultrasonic Range
SPECIFICITY:	None; depends on sound of leak
MODEL NO. & TRADENAME:	100, 101 "Son-Tector"
SENSITIVITY:	Can detect .003" diameter hole at 25 psi at 25 feet (air)
EXCITATION:	9 volt transistor radio battery
OUTPUT SIGNAL IMPEDANCE:	8 ohm headphone
ENVIRONMENT EFFECTS:	0 to 50^{o}C
MAINTENANCE:	Periodic battery replacement (150-200 hours)
LIFE EXPECTANCY:	5-10 years
SIZE:	Pistol shape - 6" x 8"
WEIGHT:	2 pounds
PORTABILITY:	Hand held
TIME ON MARKET:	4 1/2 years
PRICE:	$144.50 to $168.00 depending on accessories
DELIVERY TIME:	Stock
REMARKS:	Used to find leaks in both pressure and vacuum systems.

MANUFACTURER:	Tel Air Products Corp.
OPERATING PRINCIPLE:	Sonic-Ultrasonic Range (converted to audible signal)
MODEL NO. & TRADENAME:	Tel-A-Leak Model TA 700
SENSITIVITY:	Detects holes 0.0015" in diameter and larger.
EXCITATION:	9 v internal battery
OUTPUT SIGNAL IMPEDANCE:	Audible signal (headphones)
DOES IT FAIL SAFE:	No
MAINTENANCE:	(Servicing interval) 500 hours (low drain solid state circuitry)
SIZE:	Approximately 4" x 6" x 2"
PORTABILITY:	Yes
REMARKS:	This unit is designed to locate pressurized cable leaks at a distance.

MANUFACTURER:	Teledyne, Inc. (Analytical Instruments Division)
OPERATING PRINCIPLE:	Ultraviolet (Absorption of ultraviolet and/or visible radiation)
SPECIFICITY:	Selectivity can be achieved by selection of specific light sources and filter elements.
MODEL NO. & TRADENAME:	Series 600
RANGES:	Trace or Percent
SENSITIVITY:	± 1% of full scale
EXCITATION:	115v, 60 Hz, 160w.
OUTPUT SIGNAL IMPEDANCE:	0-5 mv dc
REPEATABILITY:	Within 1% of full scale in 24 hours.
RESPONSE TIME:	For most applications, 90% response obtained in 5 to 30 seconds.
ENVIRONMENT EFFECTS:	Ambient temperature: 40 to 110 degrees F.
DOES IT FAIL SAFE:	No
PORTABILITY:	Not portable
PRICE:	Depends upon application.
REMARKS:	Noise level: less than 0.25% for most applications; up to 2% on highly sensitive applications. Pump requirements: gas flow of 30 to 60 cubic inches per minute. Optional accessories available include: recorder, alarm contacts, multiple sampling systems, calibration samples, etc. Numerous standard modifications can be made to enable unit to handle a wide variety of applications.

MANUFACTURER:	Teledyne, Inc. (Analytical Instruments Division)
OPERATING PRINCIPLE:	Thermal Conductivity - preceeded by chromatographic columns for gas separation.
SPECIFICITY:	Can be made specific in many applications.
MODEL NO. & TRADENAME:	Model 850
RANGES:	Percent only
SENSITIVITY:	Depends on the thermal conductivity of carrier gas versus component measured. Typically is 1/2% full scale.
EXCITATION:	115v, 60 Hz, 200w
OUTPUT SIGNAL IMPEDANCE:	0-5 mv dc
REPEATABILITY:	± 1/2% of scale
ENVIRONMENT EFFECTS:	Ambient temperature 40-100°F
SIZE:	Analysis Unit: 15 x 15 x 19 Control Unit: 17 1/2 x 6 x 12
WEIGHT:	Approximately 110 lbs.
PORTABILITY:	No
PRICE:	$3200 plus options
DELIVERY TIME:	8 - 10 weeks
REMARKS:	A one to four component thermal conductivity analyzer that utilizes a separation system to give specific information relating to the components of interest in a complex gas composition. The analyzer is actually a system, composed of a minimum of three non-explosion proof sections (analysis and control sections, and recorder).

MANUFACTURER:	Teledyne, Inc. (Analytical Instruments Division)
OPERATING PRINCIPLE:	Flame Ionization
SPECIFICITY:	Hydrocarbons
MODEL NO. & TRADENAME:	Series 400
RANGES:	Triple Range Attenuator
SENSITIVITY:	As low as 0-2 ppm Methane equivalent
EXCITATION:	115v, 60 Hz
OUTPUT SIGNAL IMPEDANCE:	Linear signal. Meter readout and 0-5 mv dc. Other outputs available.
RESPONSE TIME:	Flame response is instantaneous.
ENVIRONMENT EFFECTS:	Model 403 for analysis of samples with dew points below 125°F and Model 404 with dew points up to 175°F.
DOES IT FAIL SAFE:	Yes
MAINTENANCE:	Replacement of support gases
SIZE:	Approximately 16" x 17" x 9" (slightly larger for other models).
PORTABILITY:	Portable and panel models offered.
TIME ON MARKET:	Approximately 3 years
PRICE:	Standard Model - $2450.00
DELIVERY TIME:	8 - 10 weeks
REMARKS:	The analyzers are continuous monitoring devices designed to measure trace quantities of total hydrocarbon contaminants in a gaseous atmosphere. The principle of operation is based on measuring the ion current generated when organic compounds are burned in a hydrogen flame. The signal is linear over a range of 0 to 10,000 ppm hydrocarbon.

MANUFACTURER:	Teledyne, Inc. - (Analytical Instruments Division)
OPERATING PRINCIPLE:	Thermal Conductivity
MODEL NO. & TRADENAME:	Series 200 Analyzers
RANGES:	Single or multiple, as requested, ppm or percent
SENSITIVITY:	Changes of 1/4 to 1/2% of scale detected reliably.
EXCITATION:	115v, 60 Hz, 115w.
OUTPUT SIGNAL IMPEDANCE:	0-5 mv dc standard
REPEATABILITY:	Zero drift is less than 1% full scale in 24 hours.
RESPONSE TIME:	90% response in approximately 50 seconds
DOES IT FAIL SAFE:	No
LIFE EXPECTANCY:	10 years
SIZE:	Approximately 15" x 17" x 10"
WEIGHT:	From 25 to 70 lbs., depending on unit.
PORTABILITY:	No
TIME ON MARKET:	Approximately 10 years
PRICE:	Dependent upon application requested.
DELIVERY TIME:	Usually 6 to 8 weeks
REMARKS:	Accuracy: ±1% full scale for most binary mixtures. Typical application: 0-1% hydrogen in air, nitrogen, or oxygen analyzer. Optional accessories available include readout indicators, automatic controls, alarms, etc. Sample requirement flow - 5 to 25 cubic inches per minute.

MANUFACTURER:	Teledyne, Inc. - (Analytical Instruments Division)
OPERATING PRINCIPLE:	Electrochemical Cell
SPECIFICITY:	Oxygen only
MODEL NO. & TRADENAME:	306W
RANGES:	2 ppm to 1%
SENSITIVITY:	1% full scale
EXCITATION:	115v, 60 Hz
OUTPUT SIGNAL IMPEDANCE:	0-5 mv dc
RESPONSE TIME:	90% in 5 sec.
ENVIRONMENT EFFECTS:	Temperature range 40-120°F. Cell is not sensitive to barometric pressure.
DOES IT FAIL SAFE:	No
MAINTENANCE:	Replacement and service of electrolytical cell.
LIFE EXPECTANCY:	Depends on cell
SIZE:	16" x 18" x 10"
WEIGHT:	67 lbs.
PORTABILITY:	Semi
PRICE:	Standard Model $2045.00
DELIVERY TIME:	2 to 4 weeks

MANUFACTURER:	Teledyne Inc. - (Analytical Instruments Division)
OPERATING PRINCIPLE:	Electrochemical Cell
SPECIFICITY:	Oxygen
MODEL NO. & TRADENAME:	Series 320
RANGES:	0 - 1% to 0 - 100%
SENSITIVITY:	1% full scale
EXCITATION:	None - detector cell furnishes all power for unit.
OUTPUT SIGNAL IMPEDANCE:	Visual reading on meter and 0-5 mv dc
RESPONSE TIME:	90% in 5 seconds
ENVIRONMENT EFFECTS:	Operating temperature range 30-125°F
DOES IT FAIL SAFE:	No
MAINTENANCE:	Cell replacement annually
SIZE:	Approximately 7 1/2" x 11" x 5 1/2"
WEIGHT:	4 lbs.
PORTABILITY:	Can be hand carried
TIME ON MARKET:	Approximately 4 years
PRICE:	$525.00 and up.
DELIVERY TIME:	2 to 4 weeks
REMARKS:	Accuracy: 1% of full scale at constant temperature. 5% of full scale throughout the temperature range. Model 330 is a pocket size unit (8 oz.) without probe or indicating instrument.

MANUFACTURER:	Teledyne, Inc. - (Analytical Instruments Division)
OPERATING PRINCIPLE:	Catalytic Combustion
SPECIFICITY:	Combustible gas and vapor
MODEL NO. & TRADENAME:	#100 Series
RANGES:	Single or multiple ranges are available. 0 to 1% concentration and greater range.
EXCITATION:	115v, 60 Hz (50 Hz on request)
OUTPUT SIGNAL IMPEDANCE:	0-5 mv dc, also, indicating intrument if requested
RESPONSE TIME:	95% of total change in 30 seconds
ENVIRONMENT EFFECTS:	Temperature range: 50°F to 100°F. Voltage: 115v ± 15%, 60 Hz.
SIZE:	15" x 17" x 10"
REMARKS:	Sample flow rate of 200 cc/sec. is required. This analyzer comprises complete sensing equipment. Optional accessories available include readout indicators, automatic controls, alarms, sampling systems, etc.

MANUFACTURER:	Teledyne, Inc. (Analytical Instruments Division)
OPERATING PRINCIPLE:	Infrared (Absorption of radiant energy)
SPECIFICITY:	Gas selectivity is obtained by separate detectors and selective infrared beam filtering.
MODEL NO. & TRADENAME:	#700 series
RANGES:	Single or multiple as required
SENSITIVITY:	Indicated by 0-10 ppm CO_2, 0-50 ppm CO full scale ranges.
EXCITATION:	115v, 60 HZ, 200w (other frequencies on special order).
REPEATABILITY:	Better than 1/2% of full scale
RESPONSE TIME:	90% of a change in 15 to 30 seconds. Faster response may be provided for special applications.
ENVIRONMENT EFFECTS:	Line voltage: 95 to 130v ac. Ambient temperature: 50°F to 100°F. Sample requirement: 30 to 200 cubic inches per minute.
REMARKS:	Components of detector are selected for optimum response to the sample component of interest and minimum interference of other sample components. Among selected detector components are: filling gases for detector and filter; sample, filter, and detector cell lengths; the cell window and rotating shutter materials. Above information is for series 700 Infrared Analyzer. This analyzer comprises the complete sensing equipment. Optional accessories available include recorder, alarm contact, multiple sampling systems, calibration samples, etc. Principle use as leak detector is with nitrous oxide tracer gas useful in detecting: cyanogen, hydrazine, hydrogen cyanide, nitric oxide, hydrocarbons, H_2S, CO, CO_2.

MANUFACTURER:	Tenvac, Incorporated
OPERATING PRINCIPLE:	Mass Spectrometer
SPECIFICITY:	Helium, Neon, Argon
MODEL NO. & TRADENAME:	TENVAC-850 Automatic Leak Tester
RANGES:	1, 5, 10, 50, 100, 500, 1000, 5000 & 10,000
SENSITIVITY:	10^{-10} cc/sec. H_e and larger leaks
EXCITATION:	115v, 60 Hz, 20 amps
OUTPUT SIGNAL IMPEDANCE:	Panel Meter & 2 amps at 110v.
REPEATABILITY:	0.5% full scale
RESPONSE TIME:	Less than 1 sec.
DOES IT FAIL SAFE:	Yes
MAINTENANCE:	Calibrate and zero daily - no other specific.
LIFE EXPECTANCY:	5 years
SIZE:	55" x 42" x 32"
WEIGHT:	500 lbs.
TIME ON MARKET:	1 year
PRICE:	$11,500.00
DELIVERY TIME:	8 weeks
REMARKS:	Detects leak rates of 5×10^{-9} atmosphere cc/sec. of helium in "prebombed" components. Automatically feeds, tests, and accepts or rejects up to 1500 parts per hour. Designed for production applications where high rates and automation are imperative.

MANUFACTURER:	Tescom Corporation, Smith Welding Equipment Division
OPERATING PRINCIPLE:	Halide Torch - Flame Color
SPECIFICITY:	Non-combustible Halide. Refrigerant gases.
MODEL NO. & TRADENAME:	NE181-17 or NE182-17 with NE180, Handi-Heet Halide Detector
RANGES:	15 ppm to 1,000,000 ppm in air
SENSITIVITY:	15 ppm of halide gas in air
OUTPUT SIGNAL IMPEDANCE:	Visual observation of flame color change
REPEATABILITY:	Depends on visual detection of operator
RESPONSE TIME:	2 seconds
ENVIRONMENT EFFECTS:	Temperature -2° to 120°F
DOES IT FAIL SAFE:	No
MAINTENANCE:	Replace reactor element when consumed
LIFE EXPECTANCY:	40 years reactor element, 10 years detector
SIZE:	12" x 1"
WEIGHT:	16 oz.
PORTABILITY:	Can be carried to job by one person
TIME ON MARKET:	10 years
PRICE:	$16.00 range
DELIVERY TIME:	From stock

MANUFACTURER:	Testing Systems, Incorporated
OPERATING PRINCIPLE:	Chemical Indicator - Dye
SPECIFICITY:	Leakage of fluorescent penetrant detected by black light.
MODEL NO. & TRADENAME:	"Fluoro Finder" FL-50 System
SENSITIVITY:	Can detect any straight through leak regardless of size of opening
EXCITATION:	110v, 50-60 Hz black light (3660a.u.) Available also at 220v.
OUTPUT SIGNAL IMPEDANCE:	Fluorescent glow
RESPONSE TIME:	Immediate to 30 minutes
DOES IT FAIL SAFE:	No
LIFE EXPECTANCY:	Indefinite
SIZE:	KL-50 Kit 12 1/4" x 7 7/8" x 3 3/8"
WEIGHT:	KL-50 Kit - 9 lbs.
PORTABILITY:	Power Packs available to afford complete portability
TIME ON MARKET:	2 1/2 years
PRICE:	KL-50 Kit - $49.00; Penetrant - $45.00/gallon
DELIVERY TIME:	One week
REMARKS:	Variations and modifications are available to conform with customers requirements. Power Pack for portable application $198.00.

MANUFACTURER:	Texas Instruments, Incorporated
OPERATING PRINCIPLE:	Pressure change - Gas (Fused Quartz Bourdon Tube)
MODEL NO. & TRADENAME:	Fused Quartz Precision Pressure Gage Models 144 and 145
RANGES:	0-1.5 to 0-500 psi
SENSITIVITY:	0.001% full scale. Special units with 0.00033% full scale.
EXCITATION:	105 to 125v, 50 or 60 Hz, 80w.
OUTPUT SIGNAL IMPEDANCE:	Visual (digital readout) and recorder output
REPEATABILITY:	0.002% full scale
RESPONSE TIME:	Slew rate = 2 minutes full scale
ENVIRONMENT EFFECTS:	Operational temperature range: 0 to 38°C. Zero stability after warmup - 0.0005% full scale per degree C ambient temperature change.
SIZE:	Table model - 14 1/8" x 10 1/2" x 15 1/2" Rack mount model - 19" x 14" x 15"
WEIGHT:	32 1/2 lbs. table; 41 1/2 lbs. rack
PORTABILITY:	Yes
TIME ON MARKET:	7 years
PRICE:	Model 144 - $2085. Model 145 - $2680.
REMARKS:	Model 145 is a Servo-Nulling Readout Unit. Model 144 is a Motor Driven Readout Unit with manual control. Tubes with special sensitivity ranges or in evacuated capsules are available on special order. Gages consist basically of two parts - the interchangeable capsule containing the fused quartz pressure sensitive element and the readout unit. For use in absolute, differential or gage applications.

MANUFACTURER:	Thermal Industries of Florida, Inc.
OPERATING PRINCIPLE:	Tracer-Halogen (cold cathode plasma emission affected by minute traces of Halogen gas. When a leak is approached a loud, penetrating squeal is produced by the signal generator.)
SPECIFICITY:	Halogen Gas
MODEL NO. & TRADENAME:	TIF 550 Halogen Leak Detector
RANGES:	Single
SENSITIVITY:	Better than 1/2 ounce per year
EXCITATION:	2 standard type D flashlight batteries in parallel 1.5 volts.
OUTPUT SIGNAL IMPEDANCE:	Audible tone
REPEATABILITY:	Excellent
RESPONSE TIME:	Instantaneous
ENVIRONMENT EFFECTS:	0°F to 120°F - same environment as ordinary flashlight.
DOES IT FAIL SAFE:	No
MAINTENANCE:	Change batteries when needed - no specific servicing interval.
LIFE EXPECTANCY:	Indefinite - battery life 40 hours at 4 hours per day.
SIZE:	5.625" x 3.25" x 1.875"
WEIGHT:	25 ounces with batteries
PORTABILITY:	Designed for "in hand use"
TIME ON MARKET:	3 years
PRICE:	$97.50
DELIVERY TIME:	Stock - 1 week
REMARKS:	Supplied with practice leak; 1 ounce in 10 years. Complete solid state device - long flexible conductor with miniature probe. Pinpoints leaks, large or small, even in a room or fixture containing concentrations of Halogen gases.

MANUFACTURER:	Thermal Instrument Company
OPERATING PRINCIPLE:	Flow (thermal mass flow rate)
SPECIFICITY:	Any gas
MODEL NO. & TRADENAME:	Portable Model #59
RANGES:	0-0.12 to 0-3 x 10^5 std. cc/min.
SENSITIVITY:	0.01 std. cc/min.
EXCITATION:	115v, 60 Hz, 20w.
OUTPUT SIGNAL IMPEDANCE:	Panel meter and 0 to 10 mv to potentiometric instrument.
REPEATABILITY:	0.2%
RESPONSE TIME:	5 seconds
ENVIRONMENT EFFECTS:	Maximum effect of environmental temperature variations from 0 to 200°F is 1%. Excitation voltage variations (90-135v) have no effect.
DOES IT FAIL SAFE:	No
MAINTENANCE:	None required (solid state electronics)
LIFE EXPECTANCY:	10 years
SIZE:	Power and readout unit - 8" x 6" x 8" Sensor - 6" x 4" x 3"
WEIGHT:	Power Unit - 15 lbs. Sensor - 6 lbs.
PORTABILITY:	Yes
TIME ON MARKET:	9 years
PRICE:	$1180 - add $80 for panel type readout instrument - add $400 for built-in amplifier.
DELIVERY TIME:	6 to 8 weeks
REMARKS:	Standard sensor useable to 500°F. Special sensors available for 1100°F service. Standard flow wetted parts are made of 316S.S. Flow tubes made of other materials are available.

MANUFACTURER:	Thermal Instrument Company
OPERATING PRINCIPLE:	Flow (Thermal Mass Flow Rate)
SPECIFICITY:	For Liquids
MODEL NO. & TRADENAME:	Model 60
RANGES:	2.0 grams/min. to 0 to 200 lbs./min.
EXCITATION:	115v, 60 Hz, 20w.
OUTPUT SIGNAL IMPEDANCE:	0 to 10 mv dc. Optional indicating meter.
REPEATABILITY:	Better than 0.2% of reading.
RESPONSE TIME:	1 second
ENVIRONMENT EFFECTS:	Standard working pressure: 1200 psi; available to 20,000 psi Standard working temperature: to 500°F; specials available to 1100°F.
SIZE:	Standard - 7 1/2" x 13 1/4" x 9". Portable - 6" x 8" x 8".

MANUFACTURER:	Tinker & Rasor (Detectron Division)
OPERATING PRINCIPLE:	Sonic - Sonic Range
SPECIFICITY:	Primarily for fluid leaks
MODEL NO. & TRADENAME:	Detectron LD
RANGES:	Audio spectrum of interest
SENSITIVITY:	Amplifier frequency response shaped to emphasize leak sounds and reduce rumble and other outside interference.
EXCITATION:	Self contained 9v battery
OUTOUT SIGNAL IMPEDANCE:	Audio (2000 ohm earphones)
REPEATABILITY:	Good
RESPONSE TIME:	Instantaneous
ENVIRONMENT EFFECTS:	Temperature range $0^{o}F$ - $130^{o}F$
DOES IT FAIL SAFE:	Yes
SIZE:	Overall height 5", diameter 2 3/4"
WEIGHT:	1 lb.
PORTABILITY:	Can be hand carried
TIME ON MARKET:	4 years
PRICE:	$67.50
DELIVERY TIME:	Stock item
REMARKS:	Uses magnetic pick-up and converts mechanical vibrations into electrical impulses. These impulses are amplified and fed to a pair of earphones.

MANUFACTURER:	Tinker & Rasor - (Detectron Division)
OPERATING PRINCIPLE:	Sonic - Sonic Range
SPECIFICITY:	Fluid Leak Detector (gas or vapor not detected)
MODEL NO. & TRADENAME:	DETECTRON XL-2
RANGES:	Complete Audio Spectrum. One wide-band position - 10 filter selected frequencies.
SENSITIVITY:	3 course selections and fine tuning control to the acoustic frequency of interest.
EXCITATION:	Self-contained 9v battery
OUTPUT SIGNAL IMPEDANCE:	Visual & Audio (2000 ohm earphones)
REPEATABILITY:	Excellent
RESPONSE TIME:	Instantaneous
ENVIRONMENT EFFECTS:	Temperature Range 0°F to 130°F
DOES IT FAIL SAFE:	Yes
LIFE EXPECTANCY:	Battery life under normal conditions approximately 1 year.
SIZE:	5 1/8" x 7 1/8" x 2 1/2" (instrument only)
WEIGHT:	3 lbs.
PORTABILITY:	Hand carry
TIME ON MARKET:	1 year
PRICE:	$142.00 including carrying case
DELIVERY TIME:	Stock
REMARKS:	XL-2 consists of: Instrument with battery ready to operate, sensitive magnetic transducer, lightweight earphones, 7" probe, molded compartmented carrying case. Uses magnetic pick-up and converts mechanical vibrations into electrical impulses which are amplified and connected to a pair of earphones. Mute switch allows silencing of headphones without volume adjustment to allow control of repeatability.

MANUFACTURER:	Trans-Sonics, Incorporated
OPERATING PRINCIPLE:	Gas Pressure Change - Gas (Variable capacitance-diaphragm element)
MODEL NO. & TRADENAME:	Type No. 150 - System (consists of pressure cell and electronics unit)
RANGES:	10, 100, 1000 torr, absolute or differential
SENSITIVITY:	5×10^{-5} torr
EXCITATION:	115v, 60 Hz
OUTPUT SIGNAL IMPEDANCE:	5 and 10v dc at rated pressure
REPEATABILITY:	0.01% to 0.02% dependent on range
RESPONSE TIME:	0.1 second
ENVIRONMENT EFFECTS:	Requires correction for changes in environmental temperature.
SIZE:	Pressure cell and electronics unit each are 3 1/4" x 5 1/4" x 5 3/4"
WEIGHT:	Each unit - 4 lbs.
PORTABILITY:	Yes
TIME ON MARKET:	1 year
PRICE:	Pressure cell $485. Electronics unit $410.
DELIVERY TIME:	Stock item
REMARKS:	Additional instrumentation is required for reading output voltage. This equipment has been found useful for measuring gas leaks of flanges by measuring differential pressure across a capillary tube through which the leaking gas is allowed to pass.

MANUFACTURER:	Turco Products, Inc., Division of Purex Corp., Ltd.
OPERATING PRINCIPLE:	Chemical Indicator-Dye
MODEL NO. & TRADENAME:	"Dy-Chek"
REPEATABILITY:	Good
RESPONSE TIME:	Penetrant should remain on test area for 10 minutes.
ENVIRONMENT EFFECTS:	Test Area must be clean and dry. Best penetration obtained between 70°F and 120°F.
LIFE EXPECTANCY:	Shelf life one year minimum.
SIZE:	12 oz. spray cans to 55 gallon drums.
PORTABILITY:	Kits available for hand carry
TIME ON MARKET:	16 years
PRICE:	Complete kits $25.00 - penetrant $10 to $12 per gallon.
DELIVERY TIME:	One week
REMARKS:	Qualifies under pertinent portions of MIL-I-25135C - a visible dye penetrant.

MANUFACTURER: Turco Products, Inc., Division of Purex Corp., Ltd.

OPERATING PRINCIPLE: Chemical Indicator - Fluorescent Dye

MODEL NO. & TRADENAME: "Fluor Chek"

REPEATABILITY: Good

RESPONSE TIME: Penetrant should remain on test area for 10 minutes.

ENVIRONMENT EFFECTS: Test area must be clean and dry. Best penetration obtained between 70°F and 120°F.

LIFE EXPECTANCY: Shelf life one year minimum

SIZE: 12 oz. spray cans to 55 gallon drums

PORTABILITY: Kits available for hand carry

TIME ON MARKET: 10 years

PRICE: Penetrant: \$5 per gallon (\$31.28 per 12 - 12 oz. spray cans)
Emulsifier: \$3.50 per gallon - Developer: \$9.00 per gallon.

DELIVERY TIME: One week

REMARKS: Qualifies under pertinent portions of MIL-I-25135C - a fluorescent inspection penetrant.
Material is intended for detection of surface defects.
Process requires application of penetrant, then emulsifier and then a developer solution. Surface is inspected for flaws under ultraviolet light.
Several formulations available.

MANUFACTURER:	20th Century Electronics Ltd.
OPERATING PRINCIPLE:	Mass Spectrometer
SPECIFICITY:	Model A Helium/Hydrogen Model B Helium/Argon Model C Masses 2, 3, & 4
MODEL NO. & TRADENAME:	"CENTRONIC" LD401
RANGES:	Six positions (x1, x3, x10, x30, x100, Test)
SENSITIVITY:	10^{-11} std. cc/sec. 10^{-12} torr partial pressure Helium by accumulation
EXCITATION:	200-250 v 50 Hz 3.5 amp
RESPONSE TIME:	Less than one second is required to produce 50% full scale deflection on x1 scale of leak rate meter.
ENVIRONMENT EFFECTS:	30° C maximum due to use of air cooled diffusion pump.
DOES IT FAIL SAFE:	Yes
LIFE EXPECTANCY:	4 to 5 years with servicing at 6 month intervals.
WEIGHT:	165 Kg. (360 lb.)
PORTABILITY:	On four wheels
TIME ON MARKET:	3 years
PRICE:	£1200. 0. 0.
DELIVERY TIME:	4 weeks

MANUFACTURER:	Union Carbide Corporation - Linde Division
OPERATING PRINCIPLE:	Halide Torch - Flame Color
SPECIFICITY:	Non-Combustible halide refrigerant gases
MODEL NO. & TRADENAME:	Prest-O-Lite Model No. 2 (Part #11X16)
RANGES:	100 to 500,000 PPM
SENSITIVITY:	100 PPM in air
EXCITATION:	Flame heated copper or copper alloy
OUTPUT SIGNAL IMPEDANCE:	Change in color of flame within unit
REPEATABILITY:	100 PPM
RESPONSE TIME:	2 to 3 seconds
ENVIRONMENT EFFECTS:	Performs within stated repeatability at ambient temperatures of -65°F to 150°F.
DOES IT FAIL SAFE:	Yes
MAINTENACE:	Replacement of copper or copper alloy re-action plate --10 to 100 hours life expectancy
LIFE EXPECTANCY:	5 years normal usage
SIZE:	1 1/4" diameter x 6" long
WEIGHT:	4 ounces
PORTABILITY:	Yes
TIME ON MARKET:	23 years
PRICE:	$8.10 list
DELIVERY TIME:	One week after receipt of order
REMARKS:	Unit is a leak detecting attachment to an acetylene gas torch.

MANUFACTURER:	Union Carbide Corporation, Linde Division
OPERATING PRINCIPLE:	Halide Torch - Flame Color
SPECIFICITY:	Non-Combustible Halide Refrigerant Gases
MODEL NO. & TRADENAME:	Prest-O-Lite Model No. 1 (Part #10X32)
RANGES:	20 to 500,000 PPM
SENSITIVITY:	20 PPM in air
EXCITATION:	Flame heated copper or copper alloy
OUTPUT SIGNAL IMPEDANCE:	Change in color of flame within unit
REPEATABILITY:	20 PPM
RESPONSE TIME:	2 to 3 seconds
ENVIRONMENT EFFECTS:	Performs within stated repeatability at ambient temperatures of -65°F to 150°F.
DOES IT FAIL SAFE:	Yes
MAINTENANCE:	Replacement of copper or copper alloy re-action plate --10 to 100 hours life expectancy
LIFE EXPECTANCY:	5 years normal usage
SIZE:	1 1/4" diameter x 6" long
WEIGHT:	4 ounces
PORTABILITY:	Yes
TIME ON MARKET:	23 years
PRICE:	$8.10 list
DELIVERY TIME:	One week after receipt of order
REMARKS:	Unit is a leak detector attachment for an acetylene gas torch.

MANUFACTURING:	Union Industrial Equipment Corporation
OPERATING PRINCIPLE:	Chemical Indicators - Reagent
SPECIFICITY:	Reagent type detector tube chosen for specific gases of interest available for detecting nitrogen dioxide, oxygen, carbon dioxide, and many other gases and vapors.
MODEL NO. & TRADENAME:	Unico Model 400 - Kitagawa Detector
RANGES:	Reagent type detector tubes available for over 50 different gases and vapors with full scale ranges varying from 20 ppm to 30%.
SENSITIVITY:	As low as 1 ppm on some tubes
OUTPUT SIGNAL IMPEDANCE:	Length of reagent discoloration in tube
RESPONSE TIME:	Less than three minutes for complete test
ENVIRONMENT EFFORTS:	Temperature correction information is supplied. Contamination of test area by gases and vapors can affect accuracy of measurement of specific gas to be detected.
LIFE EXPECTANCY:	Reagent tubes are single test items
SIZE:	Complete kit - 10" x 8" x 2"
WEIGHT:	Complete kit - 3 lbs.
PORTABILITY:	Can be hand carried
TIME ON MARKET:	10 years
PRICE:	Cost of gas detector kit is $80.00. Cost of reagent tubes is $.50 to $1.00 each and are packaged in lots of 5-10-20.
DELIVERY TIME:	Immediate
REMARKS:	Gas detector kit includes all equipment and information required for making detection tests. Reagent tubes are purchased separately. Unit consists of a hand operated precision pump which draws a gas sample into a detector tube filled with a chemical reagent which changes color upon exposure to the gas of interest. The length of color change varies with gas concentration.

MANUFACTURER:	Union Industrial Equipment Corporation
OPERATING PRINCIPLE:	Chemical Indicator - Reagent
SPECIFICITY:	Oxygen in air
MODEL NO. & TRADENAME:	No. 707
RANGES:	2 to 30% by volume
SENSITIVITY:	±1% full scale
REPEATABILITY:	±5% full scale
RESPONSE TIME:	1 1/2 minutes for test
ENVIRONMENT EFFECTS:	Temperature correction table provided
LIFE EXPECTANCY:	Indefinite
SIZE:	Complete kit 8" x 4" x 2 1/2"
WEIGHT:	Complete kit 1 lbs.
PORTABILITY:	Complete portable
TIME ON MARKET:	3 years
PRICE:	$22.75
DELIVERY TIME:	From stock
REMARKS:	Can be used in explosive atmospheres. Manually operated piston type plunger draws gas sample into reaction tube. Length of discoloration in reaction tube is proportional to oxygen concentration.

MANUFACTURER:	Union Industrial Equipment Corporation
OPERATING PRINCIPLE:	Chemical Indicators-Reagent (Color change in sensor is detected by photoelectric reagent cell)
SPECIFICITY:	Carbon monoxide
MODEL NO. & TRADENAME:	Model No. 777
RANGES:	Is a function of both exposure time and gas concentration
SENSITIVITY:	50 ppm
EXCITATION:	120v, 60 Hz, 3w
OUTPUT SIGNAL IMPEDANCE:	Visual indicating instrument and audible alarm.
RESPONSE TIME:	Responds to full scale and sounds alarm in 2 to 3 minutes in a 1000 ppm concentration and in 4 to 5 hours for 50 ppm.
ENVIRONMENT EFFECTS:	Not sensitive to ambient changes in temperature and humidity.
DOES IT FAIL SAFE:	No
MAINTENANCE:	Replace sensing tab after tripping alarm or every 60 days of use.
LIFE EXPECTANCY:	10 years
SIZE:	8 5/16" x 4 1/4" x 3 3/16"
WEIGHT:	3 lbs.
PORTABILITY:	Yes - battery pack available for power source.
TIME ON MARKET:	4 years
PRICE:	$124.50
DELIVERY TIME:	From stock
REMARKS:	The detecting sensor responds to the presence of CO by changing color. The color change is detected by a photoelectric system. When the concentration reaches the toxic level, a relay is tripped and an alarm sounded.

MANUFACTURER:	Union Industrial Equipment Corporation
OPERATING PRINCIPLE:	Chemical Indicators - Reagent (Color change in sensor is detected by photoelectric cell)
SPECIFICITY:	Carbon monoxide
MODEL NO. & TRADENAME:	Model 888
RANGES:	Is a function of both the exposure time and gas concentration.
SENSITIVITY:	50 ppm
EXCITATION:	120v ac-dc plus internal nickel-cadmium battery and built-in charger
OUTPUT SIGNAL IMPEDANCE:	Visual indicating instrument and audible alarm
RESPONSE TIME:	Responds to full scale and sounds alarm in 2 to 3 min. ma 1000 ppm concentration and in 4 to 5 hours for 50 ppm.
ENVIRONMENT EFFECTS:	Not sensitive to ambient changes in temperature and humidity.
DOES IT FAIL SAFE:	Yes
MAINTENANCE:	Recharge batteries after 10 hours of service. Replace sensing tab after tripping alarm or every 60 days of use.
LIFE EXPECTANCY:	10 years
SIZE:	8 5/16" x 4 1/4" x 3 3/16"
WEIGHT:	3 1/2 lbs.
PORTABILITY:	Yes
TIME ON MARKET:	4 years
PRICE:	$190
DELIVERY TIME:	From stock
REMARKS:	Automarically converts to battery operation in event of power line failure. The sensor responds to the presence of carbon monoxide by changing color. The color change is detected by a photoelectric system. When the gas concentration reaches th toxic level, a relay is tripped and an alarm is sounded.

MANUFACTURER:	Union Industrial Equipment Corporation
OPERATING PRINCIPLE:	Interferometer
SPECIFICITY:	Gases
MODEL NO. & TRADENAME:	Model #760
RANGES:	As low as 0 to 2% by volume - varies with gas being measured.
SENSITIVITY:	0.1% for hydrogen, carbon dioxide or propane.
EXCITATION:	115v, 50/60 Hz.
OUTPUT SIGNAL IMPEDANCE:	Panel indicating instrument and audible and visual alarm.
REPEATABILITY:	±5% of full scale
RESPONSE TIME:	3 seconds
DOES IT FAIL SAFE:	No
MAINTENANCE:	Nominal
LIFE EXPECTANCY:	10 years
SIZE:	11 7/8" x 7 1/8" x 8 5/8"
WEIGHT:	15.5 lbs.
PORTABILITY:	Good portability
TIME ON MARKET:	3 years
PRICE:	$1500
DELIVERY TIME:	3 - 4 weeks
REMARKS:	The displacement of interference light fringes produced by the optical path difference between the sample gas and air standard is measured by a photoelectric circuit. A built-in vacuum pump draws the sample into the analyzing chamber. No special training is required for operation.

MANUFACTURER:	Union Industrial Equipment Corporation
OPERATING PRINCIPLE:	Catalytic Combusion
SPECIFICITY:	Combustible gases and vapors
MODEL NO. & TRADENAME:	Model #202
RANGES:	0 to 100% LEL
EXCITATION:	4 standard flashlight cells (6v)
OUTPUT SIGNAL IMPEDANCE:	Indicating instrument and audible alarm at 1/3 of LEL
DOES IT FAIL SAFE:	No
MAINTENANCE:	Replace batteries when necessary
SIZE:	6 1/2" x 5" x 3 1/4"
WEIGHT:	5 1/2 lbs.
PORTABILITY:	Yes
PRICE:	$180, With built-in battery charger $270
DELIVERY TIME:	From stock
REMARKS:	Alarm point at 1/3 of LEL

MANUFACTURER:	United States Gulf Corporation
OPERATING PRINCIPLE:	Bubble
MODEL NO. & TRADENAME:	"Detek"
SENSITIVITY:	1×10^{-4} cc/sec.
RESPONSE TIME:	Almost instant
ENVIRONMENT EFFECTS:	Formulas available to $-65^{\circ}F$ and to $+210^{\circ}F$
SIZE:	6 ounce plastic bottles - also available by the gallon
PORTABILITY:	Can be hand carried
PRICE:	From $19.10 to $24.00 per carton (8 bottles, 6 ounces each) depending on formulation.
REMARKS:	Detek dries clean and does not require removing after testing. Detek penetrates dirt, oil films, scale and grease. It is non-corrosive, non-flammable, non-explosive and is not harmful to users or apparatus. Various formulas are available for compatibility with gases such as oxygen, nitrogen, hydrogen, refrigerant gases, natural gas and air.

MANUFACTURER:	United States Safety Service Company
OPERATING PRINCIPLE:	Chemical Indicator - Reagent
SPECIFICITY:	Carbon monoxide
MODEL No. & TRADENAME:	#300 Saf-Co-Meter (Detector kit)
RANGES:	0 to 0.04% CO
SENSITIVITY:	0.005% CO
EXCITATION:	Gas is drawn through the indicating tube by aspirator bulb.
OUTPUT SIGNAL IMPEDANCE:	Color change of indicating gel in tube is compared to color chart.
RESPONSE TIME:	36 seconds exposure per tube
ENVIRONMENT EFFECTS:	Operating temperature range is 65 to 85°F. Can be used at altitudes up to 40,000 ft.
LIFE EXPECTANCY:	(Detector kit - indefinite) (Tubes - one year)
SIZE:	Kit: approximately 3 1/2" x 3" x 6"
WEIGHT:	1 lbs.
PORTABILITY:	Yes
TIME ON MARKET:	20 years
PRICE:	$30.00 complete with carrying case and 12 tubes
DELIVERY TIME:	Stock item
REMARKS:	Glass sealed indicating tubes developed by National Bureau of Standards and also conform to Military Spec MIL-T-3948A. Kits also may be obtained to Military Specification MIL-D-3945A upon request for quotation. Presence of nitrogen dioxide interferes with the normal development of color in the tube. Filter tubes of activated carbon placed ahead of the sensing tube will remove this gas from the sample.

MANUFACTURER:	Universal Controls Corporation
OPERATING PRINCIPLE	Flow
SPECIFICITY:	Gases
MODEL NO. & TRADENAME:	Dragnet
RANGES:	0-30 and 0-200 PSIG
SENSITIVITY:	1/4" water column pressure loss.
EXCITATION:	Hand Pump
OUTPUT SIGNAL IMPEDANCE:	Visual - Flow through bubbler bottle
RESPONSE TIME:	1 minute
ENVIRONMENT EFFECTS:	Volume displacement subject to temperature changes.
MAINTENANCE:	Yearly
LIFE EXPECTANCY:	5-10 years
SIZE:	10" diameter x 30"
WEIGHT:	26 lbs.
PORTABILITY:	Yes
TIME ON MARKET:	15 years
PRICE:	$100
DELIVERY TIME:	Stock - 3 weeks
REMARKS:	Pressure reference tank volume is approximately 110 cubic inches. Test systems should not be significantly different in volume. System and connected storage tank are pressurized by hand pump. A system leak is measured by flow through a bubbler bottle located between the reference tank and the system. Gas is admitted into test system to make up pressure loss due to gas leak. Gas volume admitted is measured by a bubbler bottle.

MANUFACTURER:	Uson Corporation
OPERATING PRINCIPLE:	Thermal Conductivity
SPECIFICITY:	None (on standard unit). Custom units available with partial selectivity to helium and argon.
MODEL NO. & TRADENAME:	Model 500 Series Leak Detectors
RANGES:	Automatic range change
SENSITIVITY:	1 x 10^{-3} std. cc/sec. full scale on Helium (Std.) Custom Unit available for 1 x 10^{-4} cc/sec.
EXCITATION:	Rechargeable batteries (6 volt) and/or directly from 105-125v, 50-63 Hz.
OUTPUT SIGNAL IMPEDANCE:	Meter-100 microampere, light and audible signal.
REPEATABILITY:	±5%
RESPONSE TIME:	Less than 1 second full scale, any range
ENVIRONMENT EFFECTS:	Voltage - 105-125v, 50-63 Hz Temperature - 10° to 130°F Humidity - 0 to 100% R.H.
DOES IT FAIL SAFE:	No
MAINTENANCE:	No periodic servicing (one year unconditional warranty).
LIFE EXPECTANCY:	20 years
SIZE:	Two units, each smaller than a telephone
WEIGHT:	Two, four pound packages
PORTABILITY:	Easily hand carried
TIME ON MARKET:	Four years
PRICE	$2600 - 3800
DELIVERY TIME:	Three weeks
REMARKS:	Detects helium, hydrogen, argon, all refrigerants, fluorine, and others. Unaffected by background gases. Available in totally explosion-proof version for Class 1, Division 1, Groups B & D (model 540). Explosion-proof Model 540 has FSN 4940-928-4698.

MANUFACTURER:	Vacuum Instrument Corporation
OPERATING PRINCIPLE:	Mass Spectrometer
SPECIFICITY:	Helium or Argon
MODEL NO. & TRADENAME:	MD 100, 100A, 120, 120A, 140
RANGES:	Seven (X1 to X1000) 1×10^{-4} std. cc/sec. to 5×10^{-14} std. cc/sec.
SENSITIVITY:	5×10^{-14} std. cc/sec.
EXCITATION:	115v ac, 10 amps.
OUTPUT SIGNAL IMPEDANCE:	Panel Meter
RESPONSE TIME:	Instantaneous at test port inlet.
ENVIRONMENT EFFECTS:	Normal factory environment is recommended. Can be used outdoors in good weather.
DOES IT FAIL SAFE:	Yes
LIFE EXPECTANCY:	10 years
SIZE:	34" x 24" x 30"
WEIGHT:	Approximately 400 lbs.
PORTABILITY:	Mounted on rubber casters
TIME ON MARKET:	5 years
PRICE:	$4675 to $6885
DELIVERY TIME:	2 - 4 weeks
REMARKS:	Accessories available include: Calibrated helium leak, tracer gas sprayer kit, sampling sniffer probe. Audible leak indicator, and test port adapters. Units do not require liquid nitrogen traps. Getter system removes all but inert gases.

MANUFACTURER:	Vacuum Instrument Corporation
OPERATING PRINCIPLE:	Mass Spectrometer
SPECIFICITY:	Helium
MODEL NO. & TRADENAME:	MD 190
RANGES:	Seven (X1 to X1000) 10^{-5} to 2×10^{-10} std. cc/sec.
SENSITIVITY:	2×10^{-10} std. cc/sec.
EXCITATION:	115v ac, 10 amps
OUTPUT SIGNAL IMPEDANCE:	Panel Meter
RESPONSE TIME:	Instantaneous at test port inlet.
ENVIRONMENT EFFECTS:	Normal factory environment is recommended. Can be used outdoors in good weather.
DOES IT FAIL SAFE:	Yes
PORTABILITY:	Moveable table model
TIME ON MARKET:	1 year
PRICE:	$1975
DELIVERY TIME:	2 - 4 weeks
REMARKS:	Accessories available include: Calibrated helium leak, tracer gas sprayer kit, sampling sniffer probe. Portable leak detector, and test port adapters. Units do not require liquid nitrogen traps. Getter system removes all but inert gases.

MANUFACTURER:	Varian Associates (Vacuum Division)
OPERATING PRINCIPLE:	Mass Spectrometer
SPECIFICITY:	Helium
MODEL NO. & TRADENAME:	#LD-100
RANGES:	7 sensitivity ranges - X1 to X1000
SENSITIVITY:	1×10^{-10} std. cc/sec.
EXCITATION:	Approximately 15 amps at 115v, 60 Hz with auxiliary roughing pump system.
OUTPUT SIGNAL IMPEDANCE:	Meter
DOES IT FAIL SAFE:	No
MAINTENANCE:	As needed
SIZE:	16" wide x 27" high
WEIGHT:	350 lbs.
PORTABILITY:	Is mounted on rubber wheels
TIME ON MARKET:	2 years
PRICE:	$5195
DELIVERY TIME:	30 days after recipt of order
REMARKS:	This equipment includes auxiliary mechanical pump and automatic rough, test and vent valving assemblies. Accessories available.

MANUFACTURING: Varian Mess Analysen Technik GmbH (Heraeus-Engelhard Vacuum, Inc. distributor)

OPERATING PRINCIPLE: Mass Spectrometer

SPECIFICITY: Helium (other gases mass 2-92)

MODEL NO. & TRADENAME: Atlas Gas Detector Model C

RANGES: Nine ranges: X1, X3, X10, X30, X100, X300, X1000, X3000, X10,000)

SENSITIVITY: Helium 1 x 10^{-12} std. cc/sec., Argon 1 x 10^{-12} std. cc/sec. Freon 5 x 10^{-10} std. cc/sec.

EXCITATION: 115v, 60 Hz, 600 volt amps

OUTPUT SIGNAL IMPEDANCE: 10 millivolt or 100 millivolt full scale

REPEATABILITY: ±2% of reading

RESPONSE TIME: Less than 0.5 seconds for 50% of leak when volume ot test sample is less than 5 liters.

DOES IT FAIL SAFE: Yes

MAINTENANCE: As required

SIZE: 20" x 22" x 18 1/2"

WEIGHT: Approximately 210 lbs.

PORTABILITY: Cart available as standard option

TIME ON MARKET: About 5 years

PRICE: Basic unit $6,080

DELIVERY TIME: Stock

REMARKS: Many accessories available for use in conjuction with mass spectrometer.

MANUFACTURER:	Veeco Instruments, Inc.
OPERATING PRINCIPLE:	Mass Spectrometer
SPECIFICITY:	Helium
MODEL NO. & TRADENAME:	Model MS-9ABC
RANGES:	7 sensitivity ranges (1-3-10-30-100-300-1000)
SENSITIVITY:	1 x 10^{-10} std. cc/sec or 1 part helium in 10 million parts air.
EXCITATION:	24 amps at 115 v 60 Hz.
RESPONSE TIME:	Almost instantaneous
ENVIRONMENT EFFECTS:	Can be used in normal factory environment.
DOES IT FAIL SAFE:	Yes - only in automatic operation.
MAINTENANCE:	Requires frequent daily tuning of electronics circuitry. Piping and vacuum lines cleaned approximately every 2 months to remove out gassing contaminants.
LIFE EXPECTANCY:	No experience in this area
SIZE:	41" x 27 3/4" x 36 1/2"
WEIGHT:	Approximately 600 lbs.
PORTABILITY:	Unit mounted on rubber casters.
PRICE:	Exact price not known, unit purchased thru a rental plan.
REMARKS:	Accessories available - calibrated leak helium probe assembly sniffer kit reducers audible alarm extension cable

MANUFACTURER:	Volumetrics
OPERATING PRINCIPLE:	Volumetric Displacement
MODEL NO. & TRADENAME:	VM
SENSITIVITY:	1 x 10^{-5} std. cc/sec helium
OUTPUT SIGNAL IMPEDANCE:	Digital indicator
ENVIRONMENT EFFECTS:	Requires constant gas temperature for maximum accuracy. Temperature range -65°F to + 180°F.
DOES IT FAIL SAFE:	No
MAINTENANCE:	None normally required.
LIFE EXPECTANCY:	250,000 cycles
SIZE:	Approximately 6" wide x 10" deep x approximately 3" high.
WEIGHT:	4.8 lbs.
PORTABILITY:	Portable when not attached to system.
TIME ON MARKET:	2 years.
PRICE:	$395.00
DELIVERY TIME:	From stock
REMARKS:	Accuracy of measurement depends on accuracy and repeatibility of the pressure sensor used, (auxiliary). System is pressurized, known period of time elapses, piston is adjusted to restore original system pressure, displacement is read on counter. Pressure range: 0-1000 psia. Adjustment sensitivity is 0.0005 psi. Model VM-II (cost $1475) is a volumetric micrometer with resolution of 1 x 10^{-6} cu in. provides adjustment range of 0.000001 to 0.880000 cu. in. Accuracy of 0.1% of reading throughout range of vacuum to 1000 psia, when using pressure sensor of such accuracy. With a fused-quartz pressure sensor, an accuracy of 0.015% of reading is available. Volume readout is digital.

MANUFACTURER:	Wallace & Tiernan, Inc.
OPERATING PRINCIPLE:	Pressure Change - Gas
MODEL NO. & TRADENAME:	Series 660A
RANGES:	Various ranges from 0-120 inches of water to 0-100 psi absolute, gage or differential.
SENSITIVITY:	0.005% of full scale
EXCITATION:	115v or 220v, 50 or 60 Hz; 100 watts
OUTPUT SIGNAL IMPEDANCE:	Digital readout (direct reading).
REPEATABILITY:	0.02% of full scale
RESPONSE TIME:	5 to 40 seconds, depending on range (5 seconds per thousand register counts)
ENVIRONMENT EFFECTS:	Temperature sensitivity is .05% for 10°F Operating temperature limits are 0°F to 120°F
SIZE:	11" x 10" x 8"
WEIGHT:	21 lbs.
PORTABILITY:	Can be carried by hand.
PRICE:	$1000 to $1200

MANUFACTURER:	Watsco, Incorporated
OPERATING PRINCIPLE:	Bubble (liquid Applicant)
SPECIFICITY:	None
MODEL NO. & TRADENAME:	DL-1 "Search"
OUTPUT SIGNAL IMPEDANCE:	Visual - Bubbles form in leak area
MAINTENANCE:	None
LIFE EXPECTANCY:	Indefinite
SIZE:	6" x 2 1/2" x 1 1/8"
WEIGHT:	4 fluid ounces squeeze bottle - 1 gal. (8 1/2 lbs.)
PORTABILITY:	Pocket size
TIME ON MARKET:	8 years
PRICE	$1
DELIVERY TIME:	Stock
REMARKS:	Contains no glycerin. Is safe to use with oxygen.

MANUFACTURER:	The Welch Scientific Company
OPERATING PRINCIPLE:	Spark Coil (Tesla Type)
SPECIFICITY:	For finding leaks in glass vacuum systems.
MODEL NO. & TRADENAME:	Leak Detector - Catalog No. 2619
EXCITATION:	115 volts ac or dc
OUTPUT SIGNAL IMPEDANCE:	Glow is produced in a vacuum system when a leak is approached with the spark
SIZE:	2" dia. x 12" long
PORTABILITY:	Hold in hand
PRICE:	$16.75
REMARKS:	Not recommended for very thin wall systems.

MANUFACTURER: Whittaker Corporation - Pace Wiancko Division

OPERATING PRINCIPLE: Pressure Change - Gas

MODEL NO. & TRADENAME: Model Q3403 - Secondary Pressure Standard

RANGES: 18 ranges from 0-1 to 0-10,000 psi gage, absolute or differential.

SENSITIVITY: *Less than 0.05% full scale

EXCITATION: 105-125v ac, 60 Hz, 65w

OUTPUT SIGNAL IMPEDANCE: 10v rms (nominal) at 10,000 Hz at 0 input and 12,500 Hz at full scale.
Output impedance is approximately 1,000 ohms.

ENVIRONMENT EFFECTS: Operating temperature: 40°F to 110°F.

WEIGHT: Less than 25 lbs. (including plug-in pressure head)

PORTABILITY: Has a carrying handle

PRICE: $2700 including one pressure head

REMARKS: Two types of pressure heads are offered. One mounts in the front panel of the Secondary Pressure Standard and the other is for remote operation at distances up to 500 feet. Each head incorporates an integral heater and thermostat to stabilize the temperature of the transducer for optimum performance.

*With the optional Frequency Multiplier, the basic 2500 Hz full scale frequency can be multiplied by 2 or 4 increasing the pressure reading resolution.

MANUFACTURER:	Whittaker Corporation - Pace Wiancko Division
OPERATING PRINCIPLE:	Pressure Change - Gas
SPECIFICITY:	None (Can handle corrosive liquids and gases on both sides of pressure sensor)
MODEL NO. & TRADENAME:	Model DM1 - Digital Manometer (4 digit presentation)
RANGES:	Interchangeable dual range pressure heads of 0-1 and 0-10; 0-100; 0-100 and 0-1000 mm Hg. (Differential, gage or absolute)
SENSITIVITY:	Resolution: Better than 0.001% of range
EXCITATION:	110-120v, 60 Hz
OUTPUT SIGNAL IMPEDANCE:	Visual (Digital Indicator) and Analog output voltage 0-10 volts dc full scale
REPEATABILITY:	Accuracy: ±1/4% range, including linearity and repeatability.
RESPONSE TIME:	No error to 1000 Hz.
ENVIRONMENT EFFECTS:	Ambient temperature range: 32° to 150°F
SIZE:	6" x 10 3/4" x 7.5"
WEIGHT:	9 lbs.
PORTABILITY:	Yes
PRICE:	0 to 1 mm Hg range system - $1245 All other ranges - $995 Additional pressure heads - $350 each
DELIVERY:	Six weeks
REMARKS:	The pressure head may be detached and installed at a remote point using an extension cable (10 ft.) supplied for the purpose.

MANUFACTURER:	Winton Products Co., Inc.
OPERATING PRINCIPLE:	Bubble
MODEL NO. & TRADENAME:	"Sherlock"
RANGES:	-65° to plus 160°F
SENSITIVITY:	0.16 ounce per year (2.88×10^{-5} std. cc/sec.)
OUTPUT SIGNAL IMPEDANCE:	Clusters of foam or bubbles
RESPONSE TIME:	5 seconds to 1 minute depending on size of leaks
LIFE EXPECTANCY:	Shelf life 1 year
SIZE:	4 oz. dispensers to 55-gal. drums
WEIGHT:	Depends on container size
PORTABILITY:	4 and 8 oz. dispensers can be hand carried
TIME ON MARKET:	16 years
PRICE:	Depends on type of fluid ordered and container size Type I: 4 oz. \$0.70 - \$3.70 gal. Type II: 4 oz. \$0.85 - \$5.20 gal.
DELIVERY TIME:	24 hours receipt of order
REMARKS:	Various types Regular - for use above freezing Low Temp. - for use below and above freezing Extra Low - extreme temperatures (-50°F) Type CG - for pure oxygen and compressed gases Type F - for refrigeration and air conditioning applications Type I - for oxygen ($+35^{\circ}$F to 160°F) - meets AF Spec MIL-L-25567A (ASG) Type II - for oxygen (-65°F to $+35^{\circ}$F) - meets AF Spec MIL-L-25567A (ASG) Various type applicators and spraying equipment available. Dries clean.

MANUFACTURER:	Yellow Springs Instrument Company, Inc.
OPERATING PRINCIPLE:	Electrochemical Cell
SPECIFICITY:	Sensor is selective for oxygen except for Halogens and easily reduced gases rarely encountered.
MODEL NO. & TRADENAME:	#52
RANGES:	0-50% oxygen
SENSITIVITY:	0.2%
EXCITATION:	Two 7.0v Hg. batteries; one 1.3v Hg. battery
OUTPUT SIGNAL IMPEDANCE:	Panel Instrument
RESPONSE TIME:	90% complete within 30 seconds; stable within 45 seconds
ENVIRONMENT EFFECTS:	Sample should be close to ambient when collected. Analyzing cell is temperature compensated.
MAINTENANCE:	Recharge the cell and change Teflon membrane every few months.
LIFE EXPECTANCY:	Battery life is six months in normal operation or 500 hours of continuous use.
SIZE:	9 1/2" x 7 1/2" x 7 1/2"
WEIGHT:	5 lbs.
PORTABILITY:	Yes
PRICE:	$245
DELIVERY TIME:	Stock

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None

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Appendix A

PROPERTIES OF TRACER GASES

PRECAUTIONARY MEASURES FOR USING VARIOUS TRACER GASES

PROPERTIES OF TRACER GASES

Name	Chemical Formula	Molecular Weight	Thermal Conductivity BTU/hr ft^2 F/ft at 20°C	Viscosity poise x 10^6 at 0°C	Diffusion Coefficient ft^2/hr at 1 atm and 0°C	Heat Capacity Ratio Cp/Cv	Molecular Diameter cm x 10^8
Acetylene	C_2H_2	26	0.01128	93.5	0.55	1.26, 15C	
Air	mixture	29.9	0.01478	170.8		1.403, 0C	
Ammonia	NH_3	17	0.01333	91.8	0.66	1.31, 25C	2.97
Argon	A	39.9	0.01016	209.6	0.61	1.67, 25C	3.67
Benzene	C_6H_6	78	0.00538	70.9	0.30	1.10, 90C	7.65
Butane	C_4H_{10}	58	0.00822	84.04,14.7C	0.33	1.11, 15C	7.06
Carbon dioxide	CO_2	44	0.00873	139.0	0.52	1.29, 25C	4.65
Carbon disulfide	CS_2	76	0.00410	91.1	0.36	1.63,99.7C	
Carbon monoxide	CO	28	0.01360	166	0.67	1.404, 15C	3.19
Ethane	C_2H_6	30	0.01102	84.8	0.49	1.19	5.37
Ethylene	C_2H_4	28	0.01025	90.66,0.05C	0.52	1.255, 15C	
Halogenated hydrocarbon F-11	CCl_3F	137.4	0.00470	96.0	0.30	1.124,160F	
Halogenated hydrocarbon F-12	CCl_2F_2	120.9	0.00542	328, 5F	0.32		
Halogenated hydrocarbon F-21	$CHCl_2F$	102.9	0.00554	101.0	0.33	1.157,160F	
Halogenated hydrocarbon F-22	$CHClF_2$	86.5	0.00660	286, 5F	0.37		
Halogenated hydrocarbon F-113	$CCl_2F\text{-}CCl_2F$	187.4	0.00438	93.0	0.25	1.077,160F	
Halogenated hydrocarbon F-114	$CClF_2\text{-}CClF_2$	170.9	0.00629	102.0	0.28	1.080,160F	
Helium	He	4	0.08740	186	2.7	1.67, 25C	2.18
Hydrogen	H_2	2	0.10770	83.5	2.6	1.41	2.75
Hydrogen sulfide	H_2S	34	0.00770	116.6	0.53	1.32, 15C	
Krypton	Kr	83.8	0.00540	232.7	0.51	1.68, 19C	4.15
Methane	CH_4	16	0.01872	102.6	0.72	1.31, 15C	4.19
Neon	Ne	20.2	0.02660	297.3	1.1	1.64, 19C	2.60
Nitric oxide	NO	30	0.01180	178	0.70	1.4, 15C	
Nitrogen	N_2	28	0.01462	166	0.68	1.40	3.15
Nitrous oxide	N_2O	44	0.00925	136.2	0.52	1.303, 15C	
Oxygen	O_2	32	0.01490	189	0.68	1.40	2.92
Propane	C_3H_8	44	0.00925	79.5,17.9C	0.39	1.13	6.32
Sulfur dioxide	SO_2	64	0.00514	117	0.42	1.29, 15C	
Water vapor	H_2O	18	0.01087	90.4	0.85	1.324,100C	
Xenon	Xe	131.3	0.03000	210.1	0.42	1.66, 19C	4.91

PRECAUTIONARY MEASURES FOR USING VARIOUS TRACER GASES*

AMMONIA

At room temperature and atmospheric pressure, ammonia is a colorless, alkaline gas having a pungent odor. Ammonia dissolves readily in water. It is shipped as a liquefied gas under its own vapor pressure of 114 psig at 70°F.

The pungent odor of ammonia provides ample warning of its presence. The American Conference of Governmental Industrial Hygienists has recommended 100 parts per million as the maximum allowable concentration for an eight-hour daily exposure. However, concentrations in the range of 50 to 100 ppm, although not harmful, will be of considerable nuisance. It is therefore unlikely that an individual would unknowingly become overexposed.

The physiological effects of various concentrations of ammonia are:

Atmospheric Concentration	Physiological Effects
20 ppm	First perceptible odor
40 ppm	A few individuals may suffer slight eye irritation
100 ppm	Noticeable irritation of eyes and nasal passages after few minutes exposure
400 ppm	Severe irritation of the throat, nasal passages, and upper respiratory tract
700 ppm	Severe eye irritation. No permanent effect if the exposure is limited to less than one-half hour
1700 ppm	Serious coughing, bronchial spasms, less than a half hour of exposure may be fatal
5000 ppm	Serious edema, strangulation, asphyxia; fatal almost immediately

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*Courtesy of Mr. R.J. Roehrs, Nooter Corporation, St. Louis, Missouri

The corrosive action of high concentration of ammonia (above 700 ppm) can cause extensive injuries to the eyes, causing severe irritation, hemorrhages, and swollen lids. If it is not treated immediately, partial or total loss of sight may result. The mucous lining of the mouth, throat, nose and lungs is particularly sensitive to ammonia attack.

One percent ammonia in the atmosphere is mildly irritant to moist skin; two percent has a more pronounced effect; three percent produces a stinging sensation and may produce chemical burns with blisters after a few minutes. Liquid ammonia in contact with the skin will produce severe burns, and the freezing effect due to rapid evaporation from the skin surface can cause frostbite.

Anyone working with ammonia should wear rubber gloves, chemical goggles, and a rubber or plastic apron. Cylinders should never be dropped or be permitted to strike each other violently. No part of a cylinder should be subjected to a temperature higher than 125°F. Ammonia cylinders should never be directly heated by steam or flames. Uncontrolled heating of a cylinder can cause the liquid to expand to a point where dangerous hydrostatic pressure will be developed. Any heating should be done in a thermostatted water or oil bath. The temperature should not be allowed to exceed 125°F. Cylinders containing less than 165 pounds of ammonia are not equipped with safety devices.

Although ammonia does not represent a serious flammability hazard, mixtures of air and ammonia containing from fifteen percent to twenty-eight percent ammonia by volume will ignite when sparked or exposed to temperatures exceeding 1200°F. Therefore, flames and sparks should not be allowed in the area where ammonia is being used.

Iron and steel are recommended for all equipment coming in contact with ammonia. Copper, tin, zinc, and their alloys are attacked by moist ammonia and should not be used. Piping should be rigid steel except where short connections are needed, such as between cylinders and manifold or pipe lines. For these applications reinforced, flexible neoprene line is recommended.

Ammonia can combine with mercury to form explosive compounds; therefore, instruments containing mercury that will be exposed to ammonia should not be used.

ARGON

Argon is a colorless, odorless, and tasteless gas, somewhat soluble in water (4 volumes in 100). It is normally supplied as a nonliquefied gas compressed into cylinders at a pressure of approximately 2200 psig at 70°F.

Argon is nontoxic, but can act as a simple asphyxiant by displacing the amount of air necessary to support life.

Argon is a chemically inactive gas. It will not react with other elements or compounds. While a few compounds of argon and other rare gases are reported to have been prepared, the results obtained may be considered of scientific interest only.

CARBON DIOXIDE

Carbon dioxide is a nonflammable, colorless, odorless, slightly acid gas. It is approximately one and one-half times as heavy as air. One volume of carbon dioxide will dissolve in approximately one volume of water at atmospheric pressure and 15°C. In high concentrations it has an acidic taste. Carbon dioxide is shipped in Interstate Commerce Commission approved, high-pressure steel cylinders as a liquid under its own vapor pressure of approximately 830 psig at 70°F.

In high concentrations carbon dioxide can paralyze the respiratory center. It is, therefore, an industrial hazard. It is heavier than air and does not diffuse readily; consequently, it may collect in confined, unventilated areas. Where persons are working in confined spaces, the amount of carbon dioxide formed by breathing may assume dangerous proportions. Carbon dioxide is the regulator of the breathing function; an increase in the carbon dioxide inhaled will cause an increased rate of breathing:

Carbon Dioxide in Air (volume percent)	Increased Lung Ventilation
0.1-1	Slight and unnoticeable increase
2	50% increase
3	100% increase
5	300% increase, breathing becomes laborious

Ten percent carbon dioxide in air can be endured for only a few minutes. Twelve to fifteen percent soon causes unconsciousness. Twenty-five percent may cause death in exposures for several hours. A generally recommended maximum allowable concentration for an eight-hour day is 5000 ppm. The normal concentration of carbon dioxide in the air is 0.03 percent, or 300 ppm.

Carbon dioxide is not a chemically active compound. High temperatures are generally required to promote its reactions. Carbon dioxide is stable under normal conditions, but at temperatures above 1500°C carbon dioxide almost completely dissociates into oxygen and carbon monoxide according to the following formula:

$$2\ CO_2 \rightarrow 2\ CO + O_2$$

DICHLORODIFLUOROMETHANE (F-12)

Dichlorodifluoromethane (Freon 12, Genetron 12, Isotron 12, Ucon 12) is a colorless, nonflammable gas at normal temperatures and pressure. In concentrations of less than 20 percent dichlorodifluoromethane is odorless; in higher concentrations its odor is mild and somewhat ethereal, and similar to that of carbon tetrachloride. It is readily liquefied and is shipped in steel cylinders as a liquefied gas under its own vapor pressure of about 70 psig at 70°F.

Dichlorodifluoromethane is practically nontoxic. It shows no toxic effects in guinea pigs in concentrations up to at least 20 percent (by volume) for two hour exposures. In higher concentrations, it may produce some physiological action, caused primarily by oxygen deficiency. The generally accepted maximum allowable concentration for an eight-hour daily exposure is 1000 parts per million.

No part of a cylinder should be subjected to a temperature higher than 125°F. Temperatures in excess of 125°F may cause excessive hydrostatic pressure buildup. Never permit a flame to come in contact with any part of a compressed-gas cylinder.

In general, gasket materials should not contain natural rubber. Neoprene or isoprene rubber, pressed fibers, including asbestos, with a number of insoluble binders and metallic gaskets may be used.

Dichlorodifluoromethane is thermally stable. It is nonflammable in any mixture with air and will not explode or propagate a flame. It is hydrolytically stable. It is noncorrosive under normal conditions to all common metals of construction, but it is corrosive at elevated temperatures.

HELIUM

Helium is the lightest member of the rare gas family. It is an inert, colorless, odorless, and tasteless gas, and is only slightly soluble in water (0.87 part in 100 parts). Helium is compressed into cylinders at a pressure of approximately 2200 psig at 70°F.

Helium is nontoxic but can act as an asphyxiant by displacing the necesssary amount of air to support life.

Helium is a chemically inactive gas. It will not react with other elements or compounds under ordinary conditions.

HYDROGEN CHLORIDE

Anhydrous hydrogen chloride is a colorless, pungent, corrosive gas having a suffocating odor. Hydrogen chloride is heavier than air; it fumes strongly in moist air. It is very soluble in water and alcohol, and in ether. While in the cylinder under pressure, hydrogen chloride is in the form of a gas over liquid, the cylinder pressure being about 613 psig at 70°F. As long as liquid is present in the cylinder, the pressure will remain fairly constant.

Hydrogen chloride is a highly toxic gas; it is severely irritating to the upper respiratory tract and corrosive to the eyes, skin, and mucous membranes. The acid formed neutralizes the alkali of the tissues and causes death as a result of edema or spasm of the larynx and inflammation of the upper respiratory system.

According to Walsh-Healey legislation the threshhold limit value for hydrogen chloride gas is 5 ppm by volume in air. This is a ceiling limit and cannot be time-weighed. The short exposure tolerance is 50 ppm and the atmospheric concentration immediately hazardous to life is 1000 to 2000 ppm. Hydrogen chloride provides adequate warning for prompt voluntary withdrawal from contaminated atmospheres.

Workers who handle hydrogen chloride should wear protective clothing such as rubber or plastic aprons, rubber gloves, and suitable gas-tight chemical safety goggles. Outside clothing of wool or other acid-resistant fabrics is also recommended.

Hydrogen chloride is essentially inert to metals and does not attack the commonly used structural metals under normal conditions of use (room temperature and atmospheric pressure). In the presence of moisture, however, hydrogen chloride will corrode most metals other than silver, platinum, and tantalum. When used at higher pressures, it is necessary to use extra-heavy black-iron pipe throughout. No galvanized pipe or brass or bronze fittings should be used, since these will corrode. High-pressure monel or aluminum-iron-bronze valves should be used throughout. Hydrogen chloride lines should always be shut off from the use end, backward to the cylinders.

Hydrogen chloride is thermally stable. It is stable to oxidation except at elevated temperatures. Hydrogen chloride is extremely soluble in water; its aqueous solution is a strong acid.

HYDROGEN

Hydrogen is colorless and odorless, and is the lightest gas known. Hydrogen is only very slightly soluble in water (1.93 volumes in 100 volumes of water). Hydrogen is usually shipped in high-pressure steel cylinders, 2000 psig at 70°F.

Hydrogen is nontoxic, but can act as an asphyxiant by displacing the amount of air required to support life.

Cylinders of hydrogen should never be used in areas where flames, excessive heat, or sparks may occur. Only explosion-proof equipment and spark-proof tools should be used in areas where hydrogen is handled. All equipment and lines used with hydrogen should be grounded. A flame should never be used to detect hydrogen gas leaks. Reserve stocks of hydrogen should never be stored with cylinders containing oxygen or other highly oxidizing materials.

Hydrogen, although relatively inactive at ambient temperatures, reacts with almost all the other elements at high temperatures. The reaction between hydrogen and oxygen at high temperatures is usually violent. Hydrogen will reduce metallic oxides at elevated temperatures.

KRYPTON

Krypton is an inert gas, and one of the rarest gases known. Krypton exists in minute traces in the atmosphere (1 ppm by volume of air). Krypton is a colorless and odorless gas, and only slightly soluble in water. Krypton is available in small cylinders at various pressures up to 800 psig, and in Pyrex liter flasks.

Krypton is chemically inert under all normal conditions, and does not combine chemically with other elements or compounds.

METHANE

Methane is a flammable, colorless, odorless, and tasteless gas. It is the major constituent of natural gas. The material is normally shipped as a nonliquefied gas in high-pressure cylinders, approximately 2265 psig at 70°F.

Methane is not considered a toxic gas. Physiologically, it is a simple asphyxiant; in high concentrations it can displace the oxygen required to sustain life. Miners frequently breathe air containing nine percent of methane and do not appear to suffer. When the percentage rises above this point, pressure on the forehead and eyes is noticed. However, this pressure disappears when fresh air is again breathed.

The hazards due to the handling of methane stem mainly from its extreme flammability. Although methane is generally inert at room temperature and atomospheric pressure, it can undergo reaction under certain conditions. Cylinders of methane should be stored in a well-ventilated area away from heat and all ignition sources. Flames should never be used to detect flammable gas leaks. Methane should not be used around sparking motors or other non-explosion-proof equipment. Reserve stocks of methane cylinders should never be stored with cylinders containing oxygen, chlorine, or other highly oxidizing or flammable materials.

NEON

Neon is a rare inert gas that exists in the atmosphere. Neon constitutes 0.00182 percent, by volume, of air. Neon is a colorless and odorless gas; it is normally available in compressed cylinders at varying pressures up to 1800 psig, and also in Pyrex flasks at atmospheric pressure.

Neon is nontoxic but can act as an asphyxiant by displacing the amount of air necessary to support life.

Neon is chemically inert under all normal conditions.

NITROGEN

Nitrogen comprises approximately 79 percent, by volume, of the air. It will not burn and will not support combustion. Nitrogen is normally available in cylinders compressed to 2200 psig at 70°F.

Nitrogen is nontoxic but can act as an asphyxiant by displacing the amount of air necessary to sustain life.

Nitrogen is extremely inert, except when heated to very high temperatures, where it combines with metals to form nitrides.

NITROUS OXIDE

Nitrous oxide is a colorless, nonflammable, nontoxic gas with a slightly sweetish taste and odor. It is shipped as a liquefied compressed gas under its own vapor pressure of about 745 psig at 70°F. It is somewhat soluble in water and more soluble in alcohol.

Nitrous oxide is nonirritating and is extensively used as an anesthetic in medicine and dentistry. It is a rather weak anesthetic, and must be inhaled in high concentrations mixed with air or oxygen. When inhaled without oxygen, it is a simple asphyxiant. Inhalation of small amounts often produces a type of hysteria; hence its trivial name, laughing gas.

Nitrous oxide is stable and comparatively unreactive at ordinary temperatures. At elevated temperatures nitrous oxide decomposes into nitrogen and oxygen, the rate of decomposition being appreciably above 565°C. At elevated temperatures, nitrous oxide supports combustion and oxidizes certain organic compounds, the alkali metals, etc.

OXYGEN

Oxygen is a colorless, odorless, and tasteless gas. Its outstanding properties are its ability to sustain animal life and to support combustion. It is somewhat soluble in water. It is usually shipped as a nonliquefied gas at 2200 psig at 70°F.

The inhalation of 100 percent oxygen at atmospheric pressure for periods up to 16 hours per day, for many days, has caused no observed injury to man. Long periods of exposure to higher pressures can adversely affect neuromuscular coordination and power of attention.

Oil, grease, or other readily combustible substances should never contact oxygen cylinders, valves, regulators, gages, and fittings. Oxygen valves, regulators, gages, or fittings should never be lubricated with oil or any other combustible substance. In welding shops and industrial plants using both oxyacetylene and electric welding apparatus, care should be taken to avoid the handling of these equipments in any manner which may permit the compressed-gas cylinders to come in contact with electrical circuits. Manifolds should never be used for oxygen cylinders unless constructed by a qualified engineer under the standards of a recognized safety authority. Oxygen should not be allowed to enter the cylinder or valve. Cylinders of oxygen should not be stored near cylinders of acetylene or other combustible gases. Unless they are well separated, there should be a fire-resistant partition between oxygen and acetylene or other cylinders of combustible gases.

SULFUR DIOXIDE

Sulfur dioxide is a highly irritating, nonflammable, colorless gas at room temperature and atmospheric pressure. It is soluble in water, forming a weak solution of sulfurous acid. It is readily liquefied and is shipped in steel cylinders as a liquefied gas under its own vapor pressure of about 35 psig at 70°F.

Sulfur dioxide is a highly irritating gas in the vapor form; it is readily detectable in concentrations of three to five parts per million, providing ample warning of its presence. In higher concentrations, the severely irritating effect of the gas makes it unlikely that any person would be able to remain in such a contaminated atmosphere unless he were unconscious or trapped.

Liquid sulfur dioxide may cause skin and eye burns upon contact with those tissues. This results from the freezing effect of the liquid on the skin or eyes.

Acute exposure to sulfur dioxide has the following effects:

Atmospheric Concentration	Physiological Effects
8-12 ppm	Causes throat irritation, coughing, constriction of the chest, tearing, and smarting of the eyes
150 ppm	Causes extreme irritation; can be tolerated only for a few minutes
500 ppm	So acutely irritating that it causes a sense of suffocation

There are no known systemic effects of acute exposure to sulfur dioxide. The generally accepted maximum allowable concentration of sulfur dioxide for an eight-hour daily exposure is ten parts per million.

Sulfur dioxide should be handled only in a well-ventilated area, preferably a hood with forced ventilation. Personnel handling sulfur dioxide should wear chemical safety goggles and/or plastic face shields, approved safety shoes, and rubber gloves. In an emergency, gas masks approved by the U.S. Bureau of Mines for sulfur dioxide should be worn as required. Additional gas masks, air-line gas masks, and self-contained breathing apparatus should be conveniently located for use in emergencies. Instant-acting safety showers should be available in convenient locations.

Sulfur dioxide forms both sulfite and bisulfite salts.

Appendix B

LEAK TESTING SPECIFICATIONS

American Vacuum Society -- AVS 2.1-1963

American Nuclear Society -- ANS 7.60

Helium Mass-spectrometer Leak-Detector Calibration

1. INTRODUCTION

1.1 Scope. This standard prescribes procedures to be used for calibrating leak detectors of the mass-spectrometer type, that is, for determining a sensitivity figure for such leak detectors. The procedures require the use of a calibrated leak and a standard mixture; the preparation and standardization of these is outside the scope of this standard. Refer to the appropriate AVS standards.

While various leak-tracing gases have been used in conjunction with mass-spectrometer leak detectors, the present standard has reference only to the use of helium-4.

The application of this standard is restricted to leak detectors with rated sensitivity corresponding to leak rates larger than 10^{-11} atm cc/sec. Factors that are unimportant for larger leaks may become significant for gas flows that are substantially less than 10^{-11} atm cc/sec; consequently, a separate standard will cover the calibration of detectors designed for leaks smaller than this figure.

1.2 Mode of Presentation. Sections 2–4 deal with preliminary matters such as definitions.

The determination of sensitivity (Secs. 6 and 7) involves a figure referred to as the minimum detectable signal. The procedure for determining this figure is covered in Sec. 5 for the determination in Sec. 6, and in Sec. 7.2 for the determination in Sec. 7.

Section 6 covers two procedures for determining minimum detectable leak, the second procedure being followed if rubber or other polymeric substances are present in the connections to the standardizing leak. Section 7 presents the procedure for determining minimum detectable concentration ratio.

2. DESCRIPTION OF LEAK DETECTOR

The helium-leak detector is essentially a gas analyzer, employing the mass-spectrometer principle. In the mass-spectrometer tube, a mixture of gases to be analyzed is first ionized, then separated into a series of ion beams or groups, each group ideally representing a single species of gas. (Strictly speaking, the ions in each beam have the same mass-to-charge ratio.) In the helium-leak detector, means are provided for "tuning" the instrument so that only the beam due to helium hits an ion collector. (The detector can generally be tuned to respond to other gases.) The current produced by the beam is amplified, and its magnitude is a measure of the partial pressure of the helium gas in the incoming sample. It will be assumed that the gas ionization is produced by the electrons from a hot filament.

Mass-spectrometer leak detectors consist of a mass-spectrometer tube, a high-vacuum system for maintaining the tube under suitable vacuum with a flow of gas sample through or into the tube, suitable voltage supplies, and an ion-current amplifier. The output of the amplifier is displayed on an output meter, and means are provided for reducing the output so that a large range of leak sizes can be detected and measured. In other words, the leak detector may be set at one of a number of different detection levels, hereafter referred to as *sensitivity settings*.

Since the spectrometer tube must be able to receive a gas sample from the system under test and must also be kept under vacuum, a line is provided for leading gas from the outside into the spectrometer tube, and this line must have an isolation valve in it. In this standard, the line is referred to as the *sample inlet line*.

3. DEFINITIONS

3.1 General. Many of the technical expressions used in this standard are defined in *Glossary of Terms Used in Vacuum Technology*, issued by the American Vacuum Society (Pergamon Press Inc., New York, 1958). Starred definitions are not from the AVS Glossary.

3.2 Channel Leak. A hole, or pores, in the wall of an enclosure, capable of passing gas from one side of the

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Approved by American Vaccum Society, Inc., October 1963

Additional copies of this Standard are available at $1 each from the secretary of AVS, P. O. Box 1282, Boston, Mass. 02014.

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wall to the other under action of a pressure or concentration differential existing across the wall.

***3.3 Calibrated Leak.** A device that permits leakage through it at a specified rate, of a specified gas, under specified conditions, the downstream side of the device being exposed to a pressure sufficiently low to have negligible effect on the leak rate.

***3.4 Standard Leak Rate.** The rate of flow of atmospheric air of dewpoint less than −25°C through a leak under standard conditions specified as follows: the inlet pressure shall be 1 standard atmosphere ±5%, the outlet pressure shall be less than 0.01 of 1 atmosphere pressure, and the temperature shall be 23°C ± 3.

***3.5 Viscous Leak.** A leak, the flow through which is controlled by viscosity.

***3.6 Membrane Leak.** A leak that produces a gas flow by permeation of the gas through a nonporous wall. For helium, this wall may be of glass, quartz, or other suitable material.

3.7 Concentration Ratio. In this standard, the ratio of partial pressure to total pressure.

3.8 Sensitivity.

3.8.1 In the case of a leak detector, the smallest leak that can be detected. The leak is specified in terms of its standard leak rate (see 3.4). A synonym used in this standard is *minimum detectable leak.*

3.8.2 In the case of a leak detector, the minimum concentration ratio of helium gas in a helium–air mixture that can be detected by the device.

4. TEST CONDITIONS AND APPARATUS

4.1 Ambient Temperature. Ambient temperature shall be 23°C ± 3.

4.2 Ambient Pressure. Ambient pressure shall be 760 Torr ± 5%.

4.3 Calibrated Leaks. Two calibrated leaks may be required: one with a relatively small leak rate and the other with a relatively large leak rate. The small leak is used for determining minimum detectable leak, the large leak for minimum detectable concentration ratio. The small leak may be of the channel type or of the membrane type. The leaks are specified as follows:

4.3.1 Small Channel Leak. This shall have a leak rate such that when helium, at 1 standard atmosphere pressure, is fed to the leak and thence into the leak detector under test, a deflection is produced on the output meter of not less than 100 times the minimum detectable signal (see Sec. 5.3 below). The leak detector shall have been adjusted as in Sec. 4.8 below

4.3.2 Small Membrane Leak. This shall leak helium at a rate to produce a deflection as specified under Sec. 4.3.1. above. Its leak rate shall be specified in terms of *equivalent air leakage rate.* The equivalent air leakage rate shall be taken as 0.37 times the helium leakage rate through the membrane under specified conditions. A temperature correction shall be specified for the leak, and the correction applied for the difference between the temperature of the leak at the time of use and the temperature specified in the calibration.

4.3.3 Large Calibrated Leak. This shall be a viscous leak of such leakage rate that, when connected to the leak detector with ambient air at the inlet side of the leak, the pressure in the leak detector rises to the optimum (high) operating pressure specified by the manufacturer.

4.4 Helium. This shall be at least 99.9% helium (available from commercial dealers in cylinder gases).

4.5 Helium Mixture. This shall be a helium and air mixture of a known concentration such that it produces a deflection of at least 10 times the minimum detectable signal (see Sec. 7.2) when fed at a pressure of 760 Torr ±5% and at ambient temperature to the large calibrated leak (Sec. 4.3 above) and thence into the leak detector under test. Where applicable, atmospheric air may be used as the helium mixture; in any case, the mixture air shall be obtained from a point at least 5 ft outside the walls of the building housing the test equipment. Helium concentration ratio shall be expressed as a fraction with numerator reduced to unity, and this ratio will be represented by the symbol C. Alternatively, the concentration ratio may be expresed in parts of helium per million parts of mixture (parts per million by volume). The concentration ratio of helium in air shall be taken arbitrarily as 1/200 000 or 5 parts per million, and this figure shall be taken into account when preparing mixtures containing more helium. [*Note:* The latest data indicate 5.24 parts per million of helium in air by volume.[1]]

4.6 Leak Detector.

4.6.1 The leak detector shall have been connected to a power source conforming in voltage, frequency, and regulation to the manufacturer's specifications.

4.6.2 The leak detector shall have been "warmed up" as specified by the manufacturer, prior to all test procedures.

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[1] E. Glueckauf, "Compendium of Meteorology," T. F. Malone, ed., (American Meteorological Society, Boston, 1951), pp. 3–10.

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4.6.3 The leak detector under test shall have been adjusted for detecting helium in the manner specified by the manufacturer.

4.7 Chart Recorder. This shall be an instrument of at least 1-h recording time suitable for recording the output of the leak detector under test and adjustable so that full scale on the recorder equals full scale of the leak-detector output meter when the leak detector is set at its most sensitive detection setting. The time constant of the recorder shall not be greater than that of the leak-detector output meter. In the absence of a suitable recorder, visual observations of the output meter may be used.

4.8 Test Setups. These are illustrated diagrammatically in Figs. 1.0 and 1.1.

5. TEST PROCEDURE—MINIMUM DETECTABLE SIGNAL[2]

5.1 Drift Determination

5.1.1 The output of the leak detector is connected to the recorder, the leak detector being at its maximum sensitivity setting and the inlet valve being closed.

5.1.2 The leak detector is adjusted so that the recorder reads less than 10% of full scale, the electron-producing filament being on.

5.1.3 The output is recorded for 60 min or until the output indication has reached full scale.

5.1.4 Generally, the recorded-output curve will show spikes. If spikes do appear, the curve is to be faired in standard engineering fashion.

5.1.5 From the faired curve, the output is determined initially and at the end of each minute, in scale divisions.

5.1.6 The change in output is calculated for each 1-min period and the largest of these changes is determined. This largest change shall be called the *drift* (scale divisions). If the change of output per minute is always less than $\frac{1}{2}$ of 1% of full scale, the total change in the 60-min observation period is determined. The total change divided by 60 shall be called the *drift*.

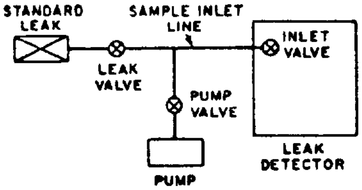

FIGURE 1.0.

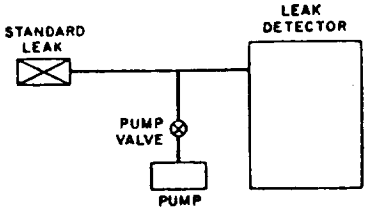

FIGURE 1.1.

5.2 Noise Determination. The recorded output curve is examined to determine the two spikes, one on each side of the faired curve, that extend furthest from the curve. The departures are measured (in scale divisions) and the two figures are added. The sum shall be called the *noise*. If the output is such that spikes appear only on one side, the noise shall be taken as *twice* the largest departure from the curve (scale divisions).

5.3 Minimum Detectable Signal. The minimum detectable signal shall be taken to be equal to the sum of the drift and the noise (scale divisions). If the sum is less than the scale divisions corresponding to 2% of full scale, then the scale divisions corresponding to 2% of full scale shall be called the minimum detectable signal.

6. TEST PROCEDURE—MINIMUM DETECTABLE LEAK

6.1 General. In the procedures below, a calibrated leak is connected to the leak detector under test. Preferably, the connections should contain no rubber or other polymeric surfaces between the leak and the leak valve (see Fig. 1.0); if such is the case, the procedure under Sec. 6.2 is followed. If rubber or polymeric surfaces are present, the procedure under Sec. 6.3 is followed.

6.2 Sensitivity Determination I. The leak detector is prepared as in Sec. 4.8 and connected to the recorder.

6.2.1 The small calibrated leak (see Sec. 4.3) is connected to the leak detector in a manner specified by the manufacturer. Refer to Fig. 1.0.

Specified connections shall include a valve (preferably all-metal) that does not act as a source of helium, located between the leak and the leak detector. This valve will be referred to as the *leak valve*.

Specified connections shall include a pumping line to permit evacuation of said connections. The pumping line shall include a valve hereafter referred to as the *pump valve*, which shall be located adjacent to the pump.

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[2] As used here, *minimum detectable signal* refers to the performance of a particular leak detector; it is determined by spurious outputs of the device that set a lower limit to the helium flow rate which rate will produce an unambiguous output signal.

Specified connections shall contain a minimum of rubber or other polymeric surface(s). Preferably, such surface(s) shall consist only of the exposed partial surface(s) of O ring(s).

6.2.2 The output is zeroed, with the filament on.

6.2.3 The leak valve is opened.

6.2.4 The pump valve is opened.

6.2.5 Helium at 760 Torr pressure is applied to the leak. If the leak has its own supply of helium, this step is omitted.

6.2.6 The atmospheric air present in the connections between the leak and the leak detector is evacuated to protect the leak detector.

6.2.7 The pump valve is closed.

6.2.8 The inlet valve in the leak detector sample line is opened promptly after Sec. 6.2.7. [*Note:* The filament of the mass spectrometer tube may be turned off before Sec. 6.2.7 above.] The pressure in the leak detector is allowed to reach a steady value, showing no observable change in 1 min.

6.2.9 Turn on filament of mass-spectrometer tube if it is not on.

6.2.10 At this point, it may be necessary to change the sensitivity setting. When the output signal has reached a steady value, showing no observable change in 1 min, the reading is noted (scale divisions).

6.2.11 The stop watch is started and simultaneously the leak valve is closed *as rapidly as feasible*.

6.2.12 The output is observed continuously, and the stop watch is stopped when the reading has decreased to 37% of the reading obtained in Sec. 6.2.10 above. The reading of the stop watch is noted (T sec).
T is a measure of the time required to remove the output signal initially caused by the helium input; this time figure is referred to as the *cleanup time*. It is assumed, for the purpose of this standard, that the leak detector is so constituted that the cleanup time and response time are equal, the *response time* being a measure of the speed of response of the leak detector to an incoming helium sample. Hereafter, T will be called the response time.

6.2.13 When the output signal has reached a steady reading, showing no observable change in 1 min, the reading is noted.

6.2.14 The signal due to the calibrated leak shall be taken as the difference between the reading noted in Sec. 6.2.10 above and that noted in Sec. 6.2.13 above. If the leak detector has been set at reduced sensitivity, the difference shall be converted into equivalent scale divisions at full-sensitivity setting. minimum detectable leak shall be calculated by the formula below and shall *always* be stated together with the response time, T.

$$\text{MINIMUM DETECTABLE LEAK, WITH RESPONSE TIME } T = \text{CALIBRATED LEAK RATING} \times \frac{\text{MINIMUM DETECTABLE SIGNAL}}{\text{SIGNAL DUE TO CALIBRATED LEAK}}$$

6.3 Sensitivity Determination II.

6.3.1 The leak detector is prepared as in Sec. 4.8 and connected to the recorder.

(a) A stainless-steel plug is connected to the leak detector, in place of the calibrated leak shown in Fig. 1.0. Refer to Sec. 6.2.1.
(b) The output is zeroed, with the filament on.
(c) The leak valve is opened.
(d) The pump valve is opened.
(e) The atmospheric air present in the connections between the plug and the leak detector is evacuated to protect the leak detector.
(f) The pump valve is closed.
(g) The inlet valve is opened promptly after Sec. 6.3.1f above. [*Note:* The filament of the mass-spectrometer tube may be turned off before Sec. 6.3.1f]. The pressure in the leak detector is allowed to reach a steady value, showing no observable change in 1 min.
(h) Turn on filament of mass spectrometer tube if it is not on.
(i) When the output has reached a steady value, but in any case not longer than 3 min after Sec. 6.3.1g above, the output reading is noted. If the leak detector has been set at reduced sensitivity, the reading shall be converted to the equivalent scale divisions for full-sensitivity setting.
(j) Close the leak valve.
(k) When the output has reached a steady value, showing no observable change in 1 min, the output reading is noted. As in Sec. 6.3.1i, convert the reading if necessary.
(l) The difference between the readings in Secs. 6.3.1i and 6.3.1k, above, is calculated and will be considered a correction figure in Sec. 6.3.2m below.
(m) Close the inlet valve.

6.3.2 The plug *only* is removed from the inlet line. All connections are to remain in place.

(a) The small calibrated leak is put in place of the plug removed in Sec. 6.3.2 above, the leak being inserted the same distance into the connections as the plug had been.
(b) The output is zeroed, with the filament on.
(c) The leak valve is opened.

(d) The pump valve is opened.

(e) The atmospheric air present in the connections between the plug and the leak detector is evacuated to protect the leak detector.

(f) The pump valve is closed.

(g) The inlet valve is opened promptly after Sec. 6.3.2f [*Note:* The filament of the mass-spectrometer tube may be turned off before Sec. 6.3.2f above.] The pressure in the leak detector is allowed to reach a steady value, showing no observable change in 1 min.

(h) Turn on filament of mass-spectrometer tube if it is not on.

(i) When the output has reached a steady value, but in any case not longer than 1 min after step 6.3.2g above, the output reading is noted. If the leak detector has been set at reduced sensitivity, the reading shall be converted to the equivalent scale divisions for full-sensitivity setting.

(j) Close the leak valve.

(k) When the output has reached a steady value, showing no observable change in 1 min, the output reading is noted. As in Sec. 6.3.2i, convert the reading if necessary.

(l) The *uncorrected* signal due to calibrated leak shall be taken as the difference between the reading noted in Sec. 6.3.2i above and that noted in Sec. 6.3.2k above. If the leak detector has been set at reduced sensitivity, the difference shall be converted into equivalent scale divisions at full-sensitivity setting.

(m) The signal due to the calibrated leak shall be taken as the difference between the uncorrected signal, Sec. 6.3.2l above, and the correction in Sec. 6.3.1l above. The minimum detectable leak shall be calculated by the formula below and shall always be stated together with the response time, *T*.

$$\text{MINIMUM DETECTABLE LEAK, WITH RESPONSE TIME } T =$$

$$\text{CALIBRATED LEAK RATING} \times \frac{\text{SIGNAL DUE TO CALIBRATED LEAK}}{\text{MINIMUM DETECTABLE SIGNAL}}$$

7. TEST PROCEDURE—MINIMUM DETECTABLE CONCENTRATION RATIO

7.1 General. A significant determination of minimum-detectable concentration ratio requires means within the leak detector under test for scanning the helium peak. This refers to the ability to tune or adjust the detector for detecting helium (see Sec. 2.) and thereby to attain a maximum or peak output for a given helium input, and the ability to detune either side of the peak adjustment until a minimum signal is produced. The process of adjusting a leak detector from one side of the correct adjustment for helium, to the correct adjustment, and then past the correct adjustment, is referred to as *scanning the (helium) peak.* The leak-detector adjustment referred to above is almost always an adjustment of the accelerating voltage, and it will be assumed that this is the case. When leak-detector output (scale divisions) is plotted against accelerating voltage, a curve is obtained whose general features are illustrated by the solid line in Fig. 2.0. (Note that voltage may be plotted in the reverse direction and this will give a reverse slope to the curve.) The rise in the curve to a peak at B is due to the presence of helium. The faired curve indicated by a broken line is due to a varying *background* signal contributed by other ions than helium. With helium present, and in the absence of background, the curve obtained would be symmetrical, tailing to zero on either side of the peak voltage. The curve shown in Fig. 2.0 is very nearly a direct superposition of the background curve and the symmetrical pure-helium curve.

It will be noted that, as one varies the voltage from the left side of the graph to the right, the output first decreases, then increases, and finally decreases again. This reversal in direction, indicating the presence of helium, is very easily detected when the scan is being observed visually on a meter. As the helium input signal becomes smaller, the reversal becomes smaller. At some point, a curve such as is shown by the solid line in Fig. 2.1 is obtained. At this point, the output never reverses; it "stands still" for a very short interval. Such a condition will just barely be detected by the usual visual observations. Accordingly, in the absence of noise and drift, the concentration ratio of helium which produces this condition determines the minimum-detectable concentration ratio.

Under practical conditions, it is not possible to make a rigidly correct determination of the minimum detectable concentration ratio as defined above. In the following, somewhat arbitrary determinations are used for calculating a sensitivity figure. The sensitivity so obtained is one that is reasonable in light of practical experience.

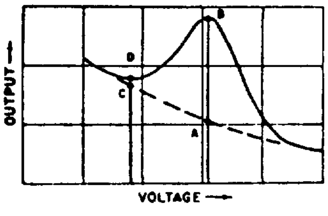

FIGURE 2.0.

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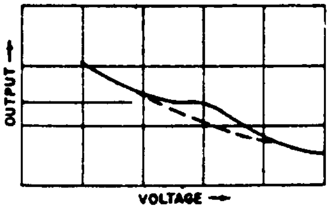

FIGURE 2.1.

7.2 Test Procedure—Minimum Detectable Signal[3]

7.2.1 Drift Determination.

(a) The output of the leak detector is connected to the recorder, the leak detector being at its maximum sensitivity setting and the inlet valve closed. Refer to Sec. 4.6.

(b) The large calibrated leak (see Sec. 4.3.3) is connected to the leak detector in a manner specified by the manufacturer. Refer to Fig. 1.1.

Specified connections shall include a pumping line to permit evacuation of said connections. The pumping line shall include a valve hereafter referred to as the *pump valve*, which shall be located adjacent to the pump.

Specified connections shall contain a minimum of rubber or other polymeric surfaces. Preferably, such surfaces shall consist only of the exposed partial surfaces of O rings.

(c) Atmospheric air (see Sec. 4.5) is fed at 760 Torr ±5% to the leak. The feed line shall not of itself act as a source of helium, and should preferably be of all-metal construction.

(d) The pump valve is opened.

(e) The atmospheric air present in the connections between the leak and the leak detector is evacuated.

(f) The pump valve is closed.

(g) The valve in the leak detector sample inlet line is opened. [*Note:* The filament of the mass spectrometer may be turned off before Sec. 7.2.1f above.] The pressure in the leak detector is allowed to reach a steady value.

(h) Turn on the filament of the mass spectrometer if it is not on.

(i) Observe the leak-detector output. If the recorder is no scale, detune until the recorder reads half-scale. If the recorder is off scale, *slowly* tune the leak detector *off* the helium peak setting until the recorder comes just on scale. Then detune further until the recorder reads half-scale.

(j) The output is recorded for 30 min or until the recorder has reached the end of its scale.

(k) Generally, the recorded output curve will sh spikes. If spikes do appear, the curve is to be faired in standard engineering fashion.

(l) From the faired curve, the output is determined initially and at the end of each minute, in scale divisions.

(m) The change in output is calculated for each 1-min period and the largest of these changes is determined. This largest change shall be called the drift (scale divisions). If the change of output per minute is always less than ½ of 1% of full scale, the total change in the 30-min observation period is determined. The total change divided by 30 shall be called the drift.

7.2.2 Noise Determination. The recorded output curve is examined to determine the two spikes, one on each side of the faired curve, which extend furthest from the curve. The departures are measured (in scale divisions) and the two figures are added. The sum shall be called the *noise*. If the output is such that down-scale spikes cannot be observed, the noise shall be taken as *twice* the largest departure from the curve (scale divisions).

7.2.3 Minimum Detectable Signal. The minimum detectable signal shall be taken to be equal to the sum of the drift and the noise (scale divisions). If the sum is less than the scale divisions corresponding to 2% of full scale, then the scale divisions corresponding to 2% of full scale shall be called the minimum detectable signal.

7.3 Helium Background

7.3.1 With the inlet valve closed, turn on the filament of the mass-spectrometer tube if it is not already on.

7.3.2 Set the leak detector for the greatest sensitivity that gives on-scale readings.

7.3.3 When the output signal has reached a steady reading, showing no observable change in 1 min, the helium peak is scanned as specified for the instrument. Provision is to be made for measuring the accelerating voltage as the scan is performed, and the corresponding outputs are to be observed and recorded.

7.3.4 Plot the output against the voltage and draw a smooth curve through the plotted points. The curve is also faired as shown by the dotted line in Fig. 2.0. The ordinate AB is taken as a measure of the helium background, B being located at the maximum of the curve.

7.3.5 If AB is different than zero, the scanning is to

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[3] As used here, minimum detectable signal refers to the performance of a particular leak detector; it is determined by spurious outputs of the device that set a lower limit to the helium-concentration ratio, which ratio will produce an unambiguous output signal.

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be repeated at 15-min intervals until AB has become zero or has not changed over a 2-h period.

7.3.6 If AB is ultimately different than zero, its magnitude is determined and is referred to as the ***helium background*** (scale divisions). If the leak detector is at reduced sensitivity setting, the background shall be converted to equivalent scale divisions at full-sensitivity setting. Helium background will be abbreviated *HB*.

7.4 Sensitivity Determination

7.4.1 Directly after Sec. 7.3, the large calibrated leak (see Sec. 4.3.3) is connected to the leak detector in a manner specified by the manufacturer. Refer to Fig. 1.1.

Specified connections shall include a pumping line to permit evacuation of said connections. The pumping line shall include a valve hereafter referred to as the ***pump valve***, which shall be located adjacent to the pump.

Specified connections shall contain a minimum of rubber or other polymeric surfaces. Preferably, such surfaces shall consist only of the exposed partial surfaces of O rings.

7.4.2 The helium mixture (see 4.5) is fed at 760 torr ±5% to the Leak. The feed line shall not of itself act as a source of helium, and should preferably be of all-metal construction.

7.4.3 The pump valve is opened.

7.4.4 The atmospheric air present in the connections between the leak and the leak detector is evacuated.

7.4.5 The pump valve is closed.

7.4.6 The valve in the leak detector sample inlet line is opened. [*Note:* The filament of the mass spectrometer may be turned off before Sec. 7.4.5 above.] The pressure in the leak detector is allowed to reach a steady value.

7.4.7 Turn on the filament of the mass spectrometer if it is not on.

7.4.8 When the output signal has reached a steady reading, showing no observable change in 1 min, the helium peak is scanned as specified for the instrument. Record the scanning voltage and the corresponding output (scale divisions). If the leak detector is at reduced sensitivity setting, the output shall be converted to equivalent scale divisions at full-sensitivity setting.

7.4.9 Plot the output against the voltage and draw a smooth curve through the plotted points. The curve is also faired as shown by the dotted line in Fig. 2.0.

7.4.10 Mark on the curves the point B (scan maximum), point A, point D (scan minimum), and point C directly below D. Measure the distances of these points from the voltage axis (scale divisions), and denote these ordinates, respectively, by b, a, d, and c.

7.4.11 The minimum-detectable concentration ratio shall be calculated by the following formula:

$$\mathrm{MDCR} = C_m \times (c - a)/(b - a - HB),$$

where *MDCR* is the minimum-detectable concentration ratio C_m is the concentration ratio of helium mixture (see Sec. 4.5) *HB* is the helium background (see Sec. 7.3.6) Or, if $c - a$ is less than the MDS (minimum-detectable signal, see Sec. 7.2.3), use the formula

$$\mathrm{MDCR} = C_m \times (\mathrm{MDS})/(b - a - \mathrm{HB}).$$

ANS 7.60

Proposed Standard

for

Leakage Rate Testing of Containment Structures for Nuclear Reactors

Approved for Publication for Comments

June 15, 1964

ANS Standards Committee

B-8

Foreword

(This foreword is not a part of the proposed standard.)

This proposed standard was prepared by Evan F. Wilson of the Allis-Chalmers Manufacturing Company in his capacity as a member and, presently, Chairman of Subcommittee ANS-7, Reactor Components, of the American Nuclear Society Standards Committee. The work was initiated early in 1959, and the standard has undergone some ten or more reviews and revisions. Corrections and additions were incorporated into four formal revisions of which this is the latest. Representatives of 16 companies involved in nuclear research and development and other companies involved in the fabrication and construction of containment vessels participated in the reviews of this standard. The following are presently members of Subcommittee ANS-7:

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S. F. Bacharach, Aerojet-General, Azusa
E. S. Brown, Phillips Petroleum Company, NRTS
S. Davis, United Nuclear Corporation
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Following review and discussion in the June 15, 1964 meeting of the ANS Standards Committee, a vote was taken that was in favor of publication of this draft for comment by ANS members. The vote was not unanimous; the dissenting members were of the opinion that Section 8 should be a separate standard.

This proposed standard is issued for review and comment by ANS members and other interested persons. Comments will be accepted until February 1st and should be addressed to:

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American Nuclear Society

It is the policy and practice of the Standards Committee of the American Nuclear Society through its subcommittees to formulate and promulgate proposed standards for the nuclear industry. This standard was prepared on the consensus principle and is based on the experience and knowledge available at the time. This standard is intended as a guide to aid the manufacturer, the consumer, and the general public. The existence of a standard does not in any respect preclude any party from manufacturing, selling, or using products, processes, or procedures not conforming to the standard. This standard is subject to periodic review and reaffirmation or revision. The existence of this standard does not relieve its user from the requirement that he exercise good judgment in its application, and that he provide himself with technical competence commensurate to his activities, nor does compliance with ANS Standards assure acceptability to federal, state, or local authorities.

Contents

Proposed Standard
for
Leakage Rate Testing of Containment Structures for Nuclear Reactors

1. Purpose and Scope

1.1 Purpose. The purpose of this standard is to specify uniform methods for determining the ability of a reactor container to retain, within the limits of permissible leakage rates, any gases, vapors, liquid, or other fluid materials which would be of a hazardous nature if not contained and which might be present in the containment structure as a result of an energy release, rupture, or leak in the nuclear reactor components or accessories. The need for restriction of leakage from the containment structure is based on the maintenance of public health and safety, the protection of operating and maintenance personnel, and the preservation of property.

1.2 Scope. The provisions of this standard specify the preferred practices and test requirements for the quantitative determination of gas leakage rates of containment structures for the housing of operating nuclear reactors. The provisions apply to containment structures for nuclear power, test, research, and training reactors, wherever a gas-tight containment structure is specified as a condition for operation.

2. Conjunctive Standards

2.1 Conditions of Applicability. This standard shall be applied in conjunction with other standards and codes as they may apply and are also specified. Acceptance of a containment structure with respect to the requirements of this standard shall be contingent upon compliance with the specified codes for design, fabrication, construction, inspection, proof testing, and maintenance, as subsequently listed in 2.2.

2.2 Conjunctive Standards. Standards or codes which are conjunctive to the present standard are the following:

2.2.1 *ASME Boiler and Pressure Vessel Code*, Section 3, Nuclear Vessels.

2.2.2 *ASME Boiler and Pressure Vessel Code*, Section 2, Material Specifications.

2.2.3 *ASME Boiler and Pressure Vessel Code*, Case Interpretations, 1962 and later revisions.

2.2.4 ASA N 6.2: Proposed *Safety Standard for Design Fabrication and Maintenance of Steel Containment Structures for Stationary Atomic Power Reactors.*

2.2.5 ASA Standard A57.1: American Institute of Steel Construction, *Specifications for the Design, Fabrication and Erection of Structural Steel for Buildings.*

2.2.6 ASA Standard A58.1: *Building Code Requirements for Minimum Design Loads in Buildings and Other Structures.*

2.2.7 ASA Standard A89.1: *Building Code Requirements for Reinforced Concrete.* (ACI-318)

2.2.8 *National Fire Codes*, National Fire Protection Association.

2.2.9 American Petroleum Institute, *Recommended Rules for the Design and Construction of Large, Welded, Low-Pressure Storage Tanks.*

3. Definitions and Descriptions of Terms

To assure common understanding of the terms employed in this specification, the following definitions shall apply.

3.1 Containment Structure. A containment structure, within the meaning of this standard, shall be an erected vessel, building, or underground location that provides an outer housing for the reactor system, including the primary vessels, components, and accessories. The function of the containment structure shall be the emergency and secondary retention of fluids and objects in the event of their accidental release from the reactor vessels or system.

3.2 Leak. A leak, in the context of this standard, shall constitute an opening, however minute, which allows the passage of a fluid and which is detectable by the means and methods specified herein for leak detection or leakage measurement.

3.3 Leakage. Leakage shall be interpreted as the measureable quantity of fluid escaping from a leak. For the purposes of this standard, air shall be used as the reference fluid.

3.4 Leakage Rate. Leakage rate is that leakage experienced during a specified period of time. For the purposes of this standard, leakage rate shall be reported as the percentage by weight of the original content of air by weight pressurized to the leakage rate test pressure which could escape during a 24-hour period. The leakage rate shall be that experienced at the outside atmosphere and containment structure air conditions prevailing during the period of leakage rate testing.

3.5 Maximum Allowable Leakage Rate. The maximum allowable leakage rate governing the acceptability of the containment structure by those responsible for its reliability shall be that stipulated in the specification for the individual containment structure.

4. Preliminaries to Leakage Rate Testing.

4.1 Sequence of Tests. Leakage rate testing should be conducted after the inspection and testing of welded joints, penetrations, and mechanical closures; completion of repair measures for the minimizing of leakage; and completion of containment structure pressure tests for strength. Where the containment structure is to be subsequently covered with concrete or will otherwise be inaccessible to direct examination, particular care should be given to inspection of these areas prior to such coverage. Integral or local leak detection should preferably precede leakage rate tests.

4.2 Pressure Tests for Strength. Hydrostatic or pneumatic pressure tests to determine whether the containment structure complies with specified strength and design requirements shall precede leakage rate testing. Also, the results of pressure tests shall meet the stipulated requirements before leakage rate tests are initiated.

4.3 Integral Pneumatic Leak Detection Tests. The detection of individual leak locations, preliminary to leakage rate testing, may be effected by local or integral pressurizing of the containment structure or both. and the use [illegible] oa solution to provide air-bubble indications on exterior surfaces. In the initial integral testing for location of leaks, the air pressure should be between 85% and 100% of the design pressure for the containment structure. Repairs or adjustments should be made as the leak detection results indicate. The use of integral pneumatic leak detection methods is particularly adapted to the examination of welded joints, gaskets, threaded connections, and mechanical closures, such as air locks, valves vacuum breakers, and ducts, where local leak detection methods are not conveniently applicable.

4.4 Local Leak Detection Tests. Localized pressure tests may be advantageously employed in some circumstances where the part or area is especially susceptible to leakage or it is wished to employ higher pressures than in the integral-pressurizing detection test. Local leak detection methods may include the pneumatic soap-bubble test, vacuum testing, air-ammonia and halogen sniffer tests, or other tests developed for special examinations. Local tests are particularly suitable for inspection of equipment prior to installation in the container and for inspection of mo[illegible]ately small but complex assemblies where leaks are difficult to locate and where the leakage rate is especially slow. Descriptions of local leak detection methods are given in Appendix A. If the local leak detection test is carried out with internal pressurizing, a pressure of at least 5 psig shall be used if the design pressure of the containment structure is above 10 psig; and at least one half of the design pressure, if this pressure is 10 psig or less.

4.5 General Preparations for Test Pressurizing. Preparatory to test pressurizing for leakage rate determination, contents of the containment structure that are sensitive to damage by a pressure differential, such as some instruments, should be removed or otherwise protected. This also applies to fan and blower motors employed for air circulation where the load is a function of air density. The protection of the structure from damage, such as by underpressure, should be assured by checking the operative reliability of vacuum breakers. The vacuum release devices should operate within 10% of their design pressures for internal or external loading.

4.6 Time Scheduling of the Leakage h [illegible] Test. To assure favorable test conditions for leakage rate tests without large or abrupt changes in atmospheric temperatures or barometric pressures, the scheduling of the test should be planned insofar as feasible in accordance with advance weather predictions. Final weather checks to assure safety of the containment structure should be made just prior to and during the test. To minimize temperature fluctuations caused by solar radiation, wind effects, or appreciable changes in temperature, a relatively windless day during a period of relatively stable weather conditions is to be preferred. The anticipated weather conditions during the test should indicate little or moderate barometric pressure variations in order to improve the reproducibility of leakage rate results.

5. Leakage Rate Test Methods

5.1 Applicable Test Methods. Leakage rate test procedures applicable to this standard may be either the absolute method or the reference vessel method. The choice of either method shall be a matter of agreement between parties who are charged with responsible acceptance of the vessel and those in charge of the leakage rate test procedures.

5.2 Description of Methods. The absolute method of leakage rate testing shall constitute the determination and calculation of air losses by containment structure leakage over a stated period of time by the means of direct pressure and temperature observations during the period of test with temperature detectors properly located to provide an average air temperature. The reference vessel method shall constitute the determination and calculation of air losses by observations of the pressure differentials between the containment structure and a gas-tight reference system, with the reference vessels located so as to represent, with reasonable accuracy, the average temperature of the aggregate containment air.

5.3 Leakage Rate Pressures. Leakage rate determinations shall be conducted at the pressure at which the leakage rate was specified and after all other pressure testing required in the specification.

6. Test Equipment and Facilities

6.1 Pressurizing Facilities. Pressurizing facilities for containment structure leakage rate tests should be of sufficient capacity to bring the structure pressure to the test level within a sufficient period of time for scheduling with reference to favorable weather conditions. Valves and repressurizing facilities should be available for adjusting to subsequent atmospheric changes, as appropriate to specific test requirements.

6.2 Temperature Measurements. All thermometric equipment shall be compared over a normal range of atmospheric variations with a reference thermometer of established calibration. Corrections based on the reference thermometer shall be available before the leakage rate test is started. Thermometers, thermocouples, and thermographs employed in the leakage rate tests shall be reproducibly readable to 0.2°F, or equivalent, or to the extent specified as the tolerable error for the maximum allowable leakage rate of the structure subject to test.

6.3 Pressure Measurements. Mercurial or aneroid barometers for the observation of containment structure and outside atmospheres shall be reproducibly readable to 0.1 mm or less (0.004 in.) or to the extent specified as the tolerable error for the maximum allowable leakage rate. Barographs for the recording of the outside atmospheric changes need be only of such accuracy as will indicate gross barometric changes pertinent to the scheduling of tests. All barometric equipment shall be compared with a single precision mercurial barometer equipped with vernier and shall be correctable for temperature and readable to 0.1 mm. Manometers for the reading of pressure differentials shall be of precision bore and plainly readable to 1 mm (0.04 in.) or less of water by marked graduations.

6.4 Atmospheric Humidity. Hygrometers or psychrometers shall be available to determine relative humidities during the period of test within and outside the containment structure when required.

7. Test Procedures

7.1 The Absolute Method. The absolute method of leakage rate determination depends on the measurement of the temperature and pressure of a constant volume of containment structure air with suitable correction for changes in temperature and humidity control under a nearly constant pressure difference with respect to the atmosphere outside the structure. It is assumed that the temperature variations during the test will be insufficient to effect significant changes in the internal volume of the structure or the partial pressure of water vapor in the contained air.

7.2 The Reference Vessel Method. The reference vessel method of leakage rate determination depends on the changes in pressure of a constant volume of contained air compared with that of a hermetically closed reference vessel which may be at the same pressure as the contained air at the start of the test or may have a small differential. The reference vessels shall be so placed and of such a geometry that they will assume the temperatures of the contained air within a reasonable time lag. The reference vessels shall be subject to leakage rate determination in accordance with the absolute method prior to their use for containment structure testing according to the applicable procedures of this standard or may be checked by the halogen sniffer test or by retention of vacuum.

7.3 Leak Minimization. Before pressurizing for leakage rate testing, all discernible leaks in the container shall be revealed by local and integral leak detection tests and shall be repaired or corrected. All openable closures and vacuum breakers shall be checked for leak tightness.

7.4 Pressurizing. Pressurizing for the leakage rate test shall be carried out under atmospheric conditions which provide relatively low air humidity in order to avoid moisture condensation within the containment structure. Any moisture that condenses out of the pressurized air and collects at the bottom of the structure shall be drained off prior to the start of the test to prevent re-evaporation. Reference vessels should be similarly drained. To provide low humidity and to improve pumping efficiency, cool night air is usually preferred for pressurization. The structure shall be pressurized to as near the design pressure as is possible under prevailing conditions or to pressures stipulated as a condition for test acceptance.

7.5 Temperature Measurements. Area surveys within the structure shall be made in advance of leakage rate testing to establish any tendencies to regional variations in temperature. Additionally, thermometers and thermocouples shall be located at different parts of the structure wherever local variations may be expected in the course of the test. Fans or other means for air circulation may be used to equalize temperatures in any region where representative temperature measurements are taken and appreciable temperature variations exist.

The temperature pattern revealed by the survey shall be employed in connection with the [illegible]n representative temperature determination for the absolute method of leakage rate testing. Location of reference vessels shall be made with consideration of the temperature pattern in order to reflect representative temperatures. Where testing experience with vessels of various configurations has established appropriate locations for reference vessels, temperature surveys may be eliminated for those vessels having similar proportions.

7.6 Personnel Access to Pressurized Containment Structures. Exposure of personnel to pressurized air and return to normal atmospheric pressures during the course of containment structure leakage rate testing shall be governed by approved decompression procedures involving a controlled depressurizing rate and waiting periods at intermediate pressures. For exposures of no longer than 200 min at pressures not greater than 14.3 psig, no intermediate holding periods or decompression stops are required provided that the time rate of pressure reduction in the air lock to atmospheric level is not less than 30 sec. For exposures to pressurization in excess of 14.3 psig and for exposure periods including repetitive exposure within 12 hr, the practices should conform to those stipulated in Section 1.5, Diving Tables of the U. S. Navy Diving Manual, NAVSHIP 250-538, January 1959.

7.7 Period of Test. The leakage rate test period shall extend to not less than 24 hr of retained internal pressure. Completion of the test should be scheduled to coincide with atmospheric temperatures and pressures close to those at the start of the test, as far as is possible. Check tests or repetition of tests shall be a matter of agreement between those responsible for the acceptance of the containment structure and those in charge of the leakage rate testing.

7.8 Humidity. The relative humidity of the containment structure shall be monitored during the course of the leakage rate test to assure that the dew point is not reached and that there is no condensation of moisture in any part of the structure. Concrete structures within the containment structure should be properly cured prior to testing to minimize high humidity from moisture release; however, where appreciable evaporation may occur from exposed surfaces of incompletely cured concrete, such surfaces should be covered with plastic sheeting, or other suitable precautions should be taken. Open pools of water may be similarly covered. To minimize the effect of variation in the partial pressure of water vapor, it is desirable to maintain the containment structure air at a reasonably constant temperature level, particularly near the completion of the test. Air conditioning, prior to testing, may be employed to approach this condition. Any moisture condensation occurring during the course of the test will result in an apparent leakage rate in excess of actual.

7.9 Recording of Data. Pressure, temperature, and humidity observations shall be made within the containment structure and recorded during the course of the leakage rate test at hourly or more frequent intervals. Pressure and temperature measurements of the outside atmosphere shall also be made and recorded at corresponding intervals and times. The times of observations shall be denoted in hours and minutes. A dated log of events and pertinent observations shall also be maintained during the test, and the correctness of data shall be attested to by those responsible for the test and, where specified, by a competent witness. Records of the leakage rate tests shall be maintained in accordance with the terms of agreements with those responsible for the acceptance of the containment structure.

7.10 Computation of Leakage Rate, The Absolute Method. For the absolute method of leakage rate testing, the calculation of the per cent leakage of air from the containment structure in terms of the original amount contained and that which escaped during a 24-hr period shall be made in accordance with the following formula:

$$\text{Per cent leakage in 24 hr} = \frac{24}{H}\left(1 - \frac{T_1 P_2}{T_2 P_1}\right) 100,$$

where

T_1 = mean absolute temperature of the containment structure air at the start of the test,

T_2 = mean absolute temperature of the containment structure air at the completion of the test,

P_1 = absolute pressure of the containment structure air at the start of the test,

P_2 = absolute pressure of the containment structure air at the completion of the test,

H = time period of the leakage rate test, in hours.

The derivation of this formula is given in Appendix B.

7.11 Computation of Leakage Rate, The Reference Vessel Method. For the reference vessel method of leakage rate testing, the calculation of the per cent leakage of air from the containment structure in terms of the original amount contained and that which escapes during a 24-hr period, shall be made in accordance with the following formula:

Per cent leakage in 24 hr =

$$= \frac{24}{H}\left[\frac{T_1 (P_2' - P_2)}{T_2 P_1} - \frac{(P_1' - P_1)}{P_1}\right] 100,$$

where P_1' and P_2' are, respectively, the absolute pressures of the reference vessel at the start and completion of the test.

8. Reinspection and Recheck of the Containment Structure

8.1 Reinspection. Annual reinspection is recommended to determine whether visual evidence of deterioration of the structure has occurred and whether this might affect its tightness with respect to the leakage rate. Such inspection should include evidence of unequal settlement of the foundations, significant corrosion, significant weathering of sealing compounds or other nonmetallic materials, cracking at weld areas or other regions of stress concentration, and damage resulting from operations or accidents. Penetrations and closures should be examined and their functional reliability determined.

8.2 Local Leak Detection Retests. Localized pressure tests, such as those described in 4.4, should be made whenever annual inspection tests or other circumstances show deterioration or otherwise indicate the desirability of such retests. Localized pressure tests shall be made whenever repairs or new construction are involved. A record of local leak tests results should be maintained for reference.

Appendix A.

Local Leak Testing Procedures.

(This material is informative only and is not a part of the Standard for Leakage Rate Testing of Containment Structures for Nuclear Reactors.)

A1. Applicability of Local Leak Tests. Local leak tests may be selected for the qualitative inspection of specific materials or components where methods other than air pressurizing are not objectionable and provide a more searching and convenient method. Such tests are particularly applicable to parts of or accessories to the containment structure.

A2. Water Submersion Test. The water submersion test consists of covering an area which may contain a leak with clean water on the low pressure side of a differential pressure. The water should be such as to provide full submergence with convenient observation of bubble formation. Repeated bubble formation occurring within 5 min after a previous bubble has been wiped away will indicate a leak.

A3. Vacuum Test. The vacuum test employs a vacuum box which can be placed over an area to be tested and evacuated to at least a 5-psi pressure differential with the atmospheric pressure where the edge seals provide a tight seating closure. Air leakage through the area tested may be revealed by changes in a manometer level after the absence of seating leakage is determined by soap-suds indicators. If a soap solution is applied to the test area before covering with the vacuum box, leaks may be revealed by bubble formation visible through a glass-covered opening in the box within a 5-min examination period.

A suitable soap solution for air leak indication is one consisting of equal parts of corn syrup, liquid detergent, and glycerin. The solution should not be prepared more than 24 hr preceding the test and bubble formation properties should be checked with a sample leak every half hour during the test.

A4. Air-Ammonia Test. The air-ammonia test is an air-pressurizing method employing anhydrous ammonia as an indicator. Where leaks are present, the leakage permeation of ammonia is revealed by a white chemical fog on probing the atmosphere with a swab wetted with 0.1 N hydrochloric acid. Sulphur dioxide, such as from a sulphur candle, can also be used as the revealing reactant. Other methods employing ammonia use 1.0% phenolphthalein in a solution of equal amounts of water and ethyl alcohol. A cloth dampened with the phenolphthalein solution and placed over the test area shows the location of leaks by a pink discoloration. The ammonia indicator can be introduced as an anhydrous gas or by placing a cloth saturated with ammonia solution within the pressurized space.

A5. Halogen Sniffer Test. The halogen sniffer test employs a halogen compound leak indicator, such as freon gas, in the pressurized air. About 0.3 ounces per cubic foot of air is commonly used. Leakage is revealed by traversing the test area with a detector that senses the effects of the halogen compound on ion emission from a heated metal surface. Locating the leak is best accomplished by holding the sniffer at about 1/2 in. from the surface to be examined and traversing this at a rate of 1/2 in./sec. A leak is indicated by a milliammeter pointer movement or audible signal. Detection is also made by flame coloration from halogen indicator additions to the contained air. It should be realized that halogen detectors are sensitive to cigarette smoke or vapor from dry cleaning fluids in recently cleaned clothing. Also, if halogen compounds are used with stress-corrosion sensitive materials, chloride attack is possible unless thorough-cleaning follows this test.

Appendix B. Derivation of Formulas for Containment Structure Leakage Rates.

(This material is informative only and is not a part of the Standard for Leakage Rate Testing of Containment Structures for Nuclear Reactors.)

B1. Definition of Symbols.

P_1 = absolute pressure of containment structure air at the start of the leakage rate test,

P_2 = absolute pressure of containment structure air at the end of the leakage rate test,

T_1 = mean absolute temperature at the start of the leakage rate test, °F + 459.7° or °C + 273°,

T_2 = mean absolute temperature at completion of test,

w_1 = original weight of contained air at the start of the test,

w_2 = final weight of contained air at the end of the test,

V = internal volume of containment structure, assumed to remain constant,

R = gas constant for a perfect gas, applicable to air for the test conditions employed,

H = time length of test, in hours,

T', P', V' = reference vessel conditions.