NASA CR.
141455

# PROCEDURE
# FOR
# PREPARATION FOR SHIPMENT
# OF
# NATURAL GAS STORAGE VESSEL
# S/N MV 50487 B19

(NASA-CR-141455) PROCEDURE FOR PREPARATION FOR SHIPMENT OF NATURAL GAS STORAGE VESSEL (Kentron Hawaii Ltd., Houston, Tex.) 15 p HC $3.25 CSCL 13L

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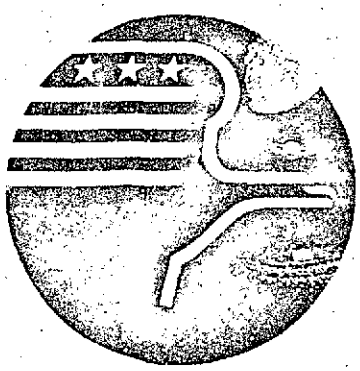

*National Aeronautics and Space Administration*

***LYNDON B. JOHNSON SPACE CENTER***

***Houston, Texas***

October 1974

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Manned Spacecraft Center
Houston, Texas

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# PROCEDURE FOR PREPARATION FOR SHIPMENT OF NATURAL GAS STORAGE VESSEL S/N MV50487 B19

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REVISIONS

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TABLE OF CONTENTS

## 1.0 PURPOSE

1.1 The purpose of this procedure is to provide a method for preparation for shipment of the Natural Gas Storage Vessel, Serial No. MV 50487 B19.

Vessel stored natural gas at 3000 pound per square inch. Extreme caution must be exercised at all times. Vessel is being shipped to Atomic Energy Commission.

## 2.0 REFERENCE

2.1 Applicable publication: Gas Engineers Handbook, Section 14 Purging, Chapter 1, 2 and 4, was used as reference materials for this procedure. Refer to these chapters for detailed explanation of recommended purging procedure and exit gas flow sampling method. See Appendix A.

## 3.0 SAFETY REQUIREMENTS

3.1 Caution all workmen that both the natural gas and purge gas are suffocating and toxic and should not be inhaled.

Take precautions against all sources of ignition (open flames, welding and burning, smoking, or electrical equipment) in the immediate vicinity of the vessel. Purging should not be started during an electrical storm.

## 4.0 MATERIAL

4.1 Material required to perform this procedure:

1) Valve, 3/4", 200 lb.,WOG Bronze gate
2) Pressure gauge, 2-1/2", 0 to 30 range, 1/2" N.P.T.

3) Valve, 1/2", 200 lb. WOG Bronze gate
4) Valve, bar stock, 1/2", 3000 lb. operating pressure
5) Regulation, two stage, 0 to 3000 psig range, P/N 2068 Rego or equal.
6) Hose, 6'L, rated 3000 lb.
7) Fittings, carbon steel per ASTMA 181
8) Nitrogen, "K" cylinder, 2200 psig, Quantity six at start, more may be needed
9) Metal tag
10) Black paint
11) Ladder or scaffolds
12) Pipefitters tools

5.0 PROCEDURE

Prior to starting this procedure, notification of date and time when procedure will be performed must be given to Johnson Space Center Safety Office and Fire Department.

Contact Kelsey-Seybold, X 3597, to request personnel to analyze natural gas concentration using Explosi Meter.

5.1 Close hand valve ⟨1⟩, valve nearest to the gas main. Close hand valves ⟨3⟩, ⟨4⟩, ⟨5⟩, and ⟨6⟩. See Figure 1.

5.2 All personnel not required by this procedure shall vacate the area. There shall be no sources of ignition within 50 feet of the storage vessel.

5.3 Open valve ⟨5⟩, venting gas to atmosphere through vent pipe. When pressure gauge ⟨7⟩ indicates 0 psig and there is no sound of escaping gas, vent gas in line leading from storage vessel to service island by

opening valve ⟨3⟩. When pressure gauge indicates 0 psig and there is no sound of escaping gas, vent gas in line from compressor by opening valves ⟨4⟩ and ⟨2⟩. Verify that pressure gauge ⟨7⟩ reads zero and there is no sound of escaping gas. If pressure gauge ⟨7⟩ does not read zero, proceed with caution. Vent line may be clogged. Wait until sound of escaping gas stops.

5.4 Remove unions ⟨8⟩ and ⟨9⟩.

5.5 Remove union ⟨10⟩ and line ⟨11⟩. Install new union half and hand valve ⟨12⟩. Hand valve shall be 3/4", 200 lb. WOG Bronze gate valve. Fittings shall be screwed, carbon steel.

5.6 Replace pressure gauge ⟨7⟩ with calibrated gauge 2-1/2", 0 to 30 range.

5.7 Remove plug from valve ⟨6⟩. Install temporary line and components as shown on Figure 1. Valve ⟨13⟩ shall be 1/2", 200 lb. WOG Bronze gate valve. Valve ⟨14⟩ shall be bar stock 1/2" F.N.P.T., with 3000 lb. operating press. Regulator shall be two stage, 0 to 3000 press range, P/N 2068, Rego or equal. Hose between valve ⟨14⟩ and regulator ⟨15⟩ shall be rated at 3000 psig operating pressure. Line between valve ⟨6⟩, ⟨13⟩ and ⟨14⟩ shall be screwed carbon steel fittings. Before installing regulator ⟨15⟩ insure that adjusting knob is in zero delivery position. Nitrogen cylinder shall be Type "K" filled with certified oil free. (water-pumped) nitrogen. Caution: Connect only one cylinder at a time. DO NOT MANIFOLD CYLINDERS.

5.8 Close valves ⟨4⟩, ⟨5⟩ and ⟨13⟩. Open valves ⟨12⟩, ⟨6⟩ and ⟨14⟩. Caution: Never close valves ⟨6⟩ and ⟨13⟩ at the same time; one or the other must be open at all times.

5.9 Open nitrogen cylinder valve. Verify that cylinder is full. Pressure should be approximately 2200 psig. Set regulator ⟨15⟩ adjusting knob to

delivery pressure of 10 psig. This setting will permit a nitrogen flow rate of approximately 600 CFH. Verify gas venting out valve ⟨12⟩. Observe pressure gauge ⟨7⟩. Pressure gauge should read below 5 psig.

5.10 Observe cylinder pressure. When pressure falls to 25 psig, close valves ⟨12⟩, ⟨6⟩, ⟨14⟩ and open valve ⟨13⟩, replace cylinder with full cylinder. Close valve ⟨13⟩ and open valves ⟨12⟩, ⟨6⟩, ⟨14⟩. Continue purging vessel.

5.11 Repeat Step 10. While purging with third cylinder, began analyzing exit gas flow at valve ⟨12⟩ for natural gas concentration. Analysis shall be performed using an Explosi Meter. When Explosi Meter indicates a safe condition at valve ⟨12⟩, an acceptable natural gas concentration exists. Contact Kelsey-Seybold, X 3597, to perform gas analyzing with Explosi Meter. If a safe concentration cannot be reached with third cylinder, connect another and continue.

5.12 If safe concentration cannot be reached when fourth cylinder is exhausted, cease purging. Close valves ⟨12⟩, ⟨6⟩, and ⟨14⟩. Open valve ⟨13⟩. Contact Safety Office for additional instructions.

5.13 When safe condition exists in vessel close valve ⟨12⟩. Increase regulator ⟨15⟩ setting to 20 psig. Observe pressure gauge ⟨7⟩. When gauge reads 20 psig close valves ⟨6⟩ and ⟨14⟩. Open valve ⟨13⟩. Close cylinder valve and relief pressure on regulator ⟨15⟩. Replace cylinder whenever cylinder pressure falls to 25 psig.

5.14 Wait 24 hours. Check safe concentration of natural gas in vessel. Analyze gas flow at valve ⟨12⟩, using Explosi Meter.

5.15 If natural gas concentration is acceptable close valve ⟨12⟩. If natural gas concentration is unacceptable repeat steps 8 through 14.

5.16 If natural gas concentration was acceptable, bring vessel pressure up to 20 psig. Close valve ⟨6⟩ and cylinder valve. Open valve ⟨13⟩. When pressure between regulator ⟨15⟩ and valve ⟨6⟩ reaches atmospheric pressure, adjust regulator setting to full open, venting gas from cylinder valve. Remove temporary line, components and cylinder. Reinstall plug in valve ⟨6⟩. Install new plug in valve ⟨12⟩. Install union half with plug in unions ⟨8⟩, ⟨17⟩ and ⟨18⟩. Remove vent line.

5.17 Identify vessel per National Fire Prevention Association Guide on Hazardous Material, Fifth Edition, with stamped metal tag. Include a copy of this Quality Control verified completed procedure with gas analysis results in the data accompanying this vessel.

5.18 Paint three sides of vessel 120° apart, in letters 3" high on "VESSEL HAS BEEN USED TO STORE NATURAL GAS UNDER 3000 PSIG". Prepare surfaces per manufacturer's instructions, paint with one coat of semi-gloss enamel per Federal Spec TT-E-5086, color Black #27040 per Federal Standard 595A. Letters shall be along vessel axis.

5.19 Procedure complete.

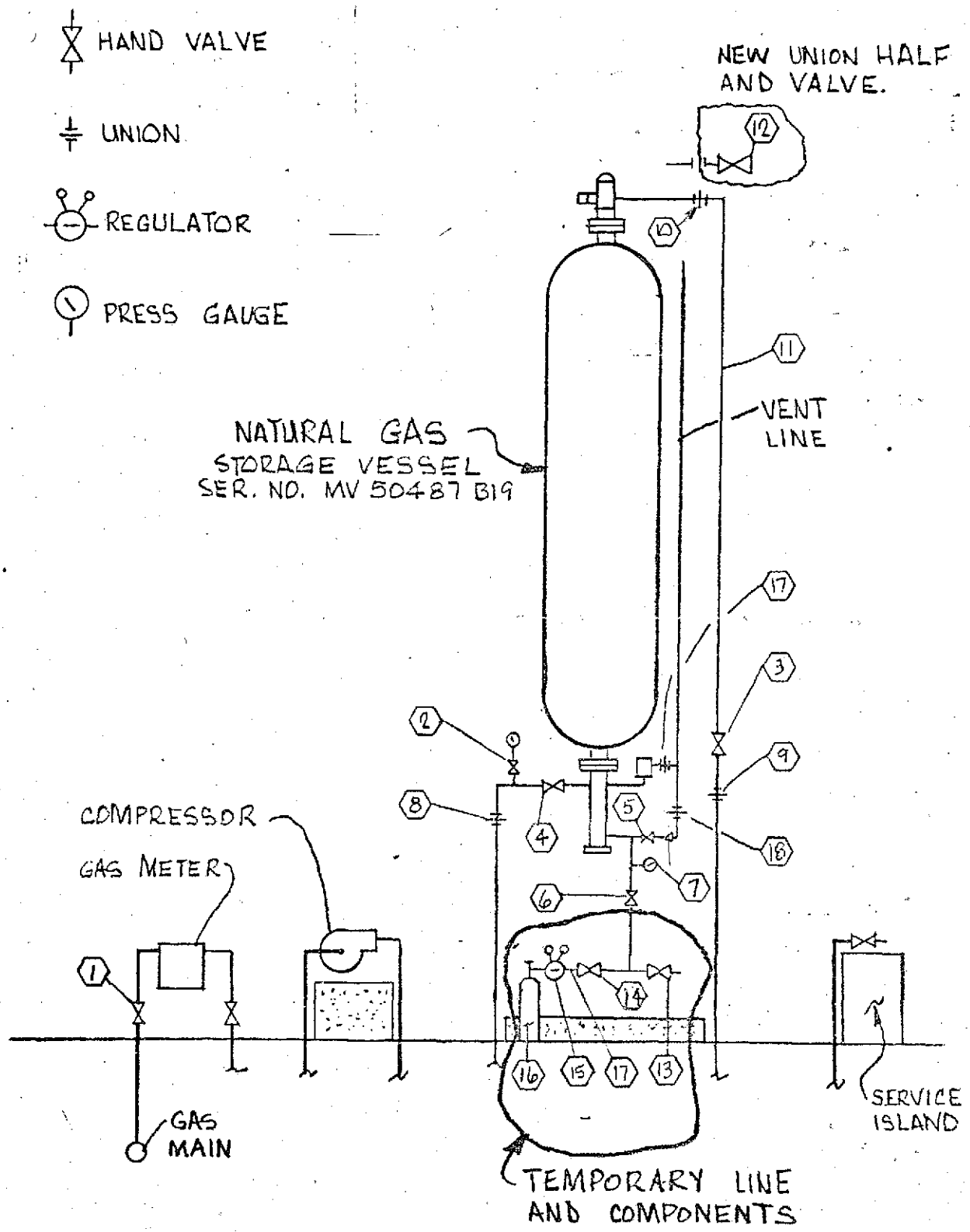

HAND VALVE
UNION
REGULATOR
PRESS GAUGE
NEW UNION HALF AND VALVE.
12
10
11
VENT LINE
NATURAL GAS STORAGE VESSEL SER. NO. MV 50487 B19
17
3
2
9
8
4
5
18
7
6
COMPRESSOR
GAS METER
1
14
16
15
17
13
GAS MAIN
SERVICE ISLAND
TEMPORARY LINE AND COMPONENTS

FIGURE 1.

# APPENDIX

# APPENDIX A

# Gas Engineers Handbook

FUEL GAS ENGINEERING PRACTICES

1965

THE INDUSTRIAL PRESS

93 Worth Street, New York, N. Y.

# Chapter 2

# General Practices, Control Methods, and Instrumentation

## END POINT OF INERT GAS ADDITION

One method of establishing the end point of purging is to continue the operation until no combustible gas is present in the equipment being purged out of service or until no oxygen is present in that being purged into service.

Another method is to determine whether or not the gas mixture involved is: (1) flammable or (2) likely to become flammable during the course of operations. The relationships among constituents of the three-component system (flammable gas, atmospheric air, and inert gases) may be represented on triangular or rectangular coordinates. A rectangular plot for methane is given in Fig. 14-2.

The horizontal axis $XH$ of Fig. 14-2 represents natural gas concentration, the vertical axes $XV$ and $XV'$ show concentration of atmospheric air and oxygen, respectively, and the diagonal axis $VH$ illustrates concentration of the inert gases $CO_2$ and $N_2$. Point $V$ denotes 100 per cent air or 21 per cent $O_2$, zero per cent natural gas, and zero per cent inert gases. Point $O$ represents 100 per cent inert gases, zero per cent air (or $O_2$), and zero per cent natural gas. Point $H$ denotes 100 per cent natural gas, zero per cent air or oxygen, and zero per cent inert gases. Therefore, line $VH$ represents all possible concentrations of air and natural gas and zero inerts; all possible mixtures of natural gas, air, and inert gases are included within the area $XVH$. Points $A$ and $B$ on $VH$ represent the lower and upper flammable limits of natural gas in air, respectively.

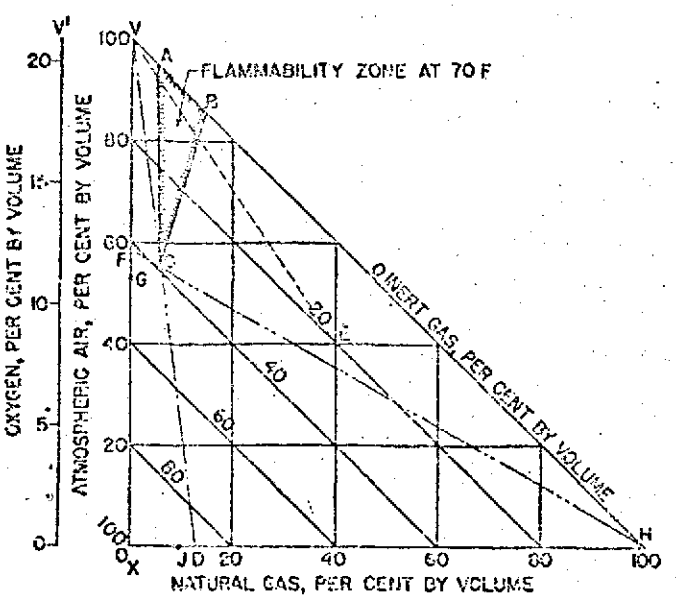



**Fig. 14-2** Flammability end point diagram for the purging of natural gas at 70 F. (At 1300 F, the flammability zone area is more than twice as large as that at 70 F. The A and B coordinates are 3.1 and 19.6 per cent natural gas, respectively, and the areas are approximately similar.) To see the effects of composition changes, move in a straight line from any point toward: (1) V, when adding air; (2) X, when adding inert gases; (3) H, when adding natural gas.

As inert gas is mixed with natural gas and air in the flammable range, other mixtures are formed which have different lower and upper flammable limits. These new limiting mixtures are represented by the lines $AC$ and $BC$. As more inert gas is added, $AC$ and $BC$ converge at $C$. No mixture of natural gas which contains less than the amount of air represented at point $C$ is flammable within itself, but all mixtures within $ABC$ are within the flammable limits and must be avoided for safe purging practice.

Mixtures within the area $DCBH$ are above the flammable limits, but will become flammable when air is added. Thus, on Fig. 14-2, a mixture containing 40 per cent air, 40 per cent natural gas, and 20 per cent inerts (point $E$) is not flammable. If air is added to this mixture, its composition will vary along the line $EV$, and as it enters the area $ABC$, the mixture becomes flammable.

Similarly, all mixtures within the area $VACF$ are below flammability limits but will become flammable if natural gas is added, since they will then enter the area $ABC$.

Mixtures indicated by points in the area $XDCF$ are not only nonflammable, but they *cannot* be made flammable by adding either natural gas or air.

## PURGING EQUIPMENT INTO SERVICE

The operation of safely purging air from a container subsequently to be filled with natural gas may be indicated on Fig. 14-2. As inert gas is added, the air concentration drops along ordinate $VX$ to any point $G$ below $F$. Subsequent addition of natural gas causes the mixture composition to change along line $GH$ (not shown), which crosses no part of the flammable zone $ABC$. In the example shown in Fig. 14-2, inert gas should be added until the purged atmosphere contains at least 42 per cent inerts, thereby reducing the air content in the purged atmosphere to 58 per cent, an oxygen concentration of about 12 per cent. (Table 14-2 makes more specific recommendations.)

To render a given combustible air mixture nonflammable it is desirable to know what percentages of inert gases are

14-2 Inert Gas End Points for Purging Into Service Using Carbon Dioxide or Nitrogen

| Combustible | Per cent required to render mixtures nonflammable[1] | | Purging end points with 20% safety factor | |
|---|---|---|---|---|
| | $CO_2$ | $N_2$* | $CO_2$ | $N_2$* |
| ydrogen | 57 | 71 | 66 | 77 |
| arbon monoxide | 41 | 58 | 53 | 66 |
| ethane | 23 | 36 | 38 | 49 |
| hane | 32 | 44 | 46 | 55 |
| ropane | 29 | 42 | 43 | 54 |
| Butane | 28 | 40 | 42 | 52 |
| -Butane | 26 | 40 | 41 | 52 |
| ntane | 28 | 42 | 42 | 54 |
| exane | 28 | 41 | 42 | 53 |
| soline | 29 | 43 | 43 | 55 |
| hylene | 40 | 49 | 52 | 59 |
| opylene | 29 | 42 | 43 | 54 |
| clopropane | 30 | 41 | 44 | 53 |
| utadiene | 35 | 48 | 48 | 49 |
| enzene | 31 | 44 | 44 | 55 |

* Nitrogen percentages do not include nitrogen of the air in e mixtures.

quired. Table 14-2 gives the values for a number of combus- bles investigated by the U. S. Bureau of Mines. To ensure fety, a purging should be continued to a point at least 20 r cent beyond the flammability limit, as shown by the ert gas end points tabulated at the right. Where combustion oducts are employed, the $CO_2$ percentage may be used as a easure of the inert gas present, but the percentage of the ni point for $N_2$ should be taken for safe purging control.

Sometimes it is more convenient to determine the oxygen ntent of the purged gases. In purging into service, inert gas added until the oxygen concentration of the container nients decreases to the point where no mixture with the mbustible gas would be flammable. Table 14-3 gives these ta. Suggested purging end point data with a 20 per cent fety factor are given at the right in terms of per cent of

Table 14-3 Oxygen End Points for Purging into Service Using Carbon Dioxide or Nitrogen

| Combustible | Per cent of oxygen below which no *mixture is* flammable[1] | | Purging end points with 20% safety factor | |
|---|---|---|---|---|
| | $CO_2$ | $N_2$ | $CO_2$ | $N_2$ |
| ydrogen | 5.9 | 5.0 | 4.7 | 4.0 |
| rbon monoxide | 5.9 | 5.6 | 4.7 | 4.5 |
| ethane | 12.6 | 12.1 | 11.7 | 9.7 |
| ane | 13.4 | 11.0 | 10.7 | 8.8 |
| opane | 14.3 | 11.4 | 11.4 | 9.1 |
| utane | 14.5 | 12.1 | 11.6 | 9.7 |
| -Butane | 14.8 | 12.0 | 11.8 | 9.6 |
| ntane | 14.4 | 12.1 | 11.5 | 9.7 |
| xane | 14.5 | 11.9 | 11.6 | 9.5 |
| soline | 14.4 | 11.6 | 11.5 | 9.3 |
| ylene | 11.7 | 10.6 | 9.4 | 8.0 |
| ylene | 14.1 | 11.5 | 11.3 | 9.2 |
| clopropane | 13.9 | 11.7 | 11.1 | 9.4 |
| adiene | 13.1 | 10.4 | 10.5 | 8.3 |
| nzene | 13.9 | 11.2 | 11.1 | 9.0 |

oxygen for the purging of containers in preparation to receive the various combustibles shown.

## PURGING EQUIPMENT OUT OF SERVICE

The operation of purging natural gas from a container to be filled subsequently with air may also be indicated on Fig. 14-2. As inert gas is added, the natural gas concentration decreases from point $H$ (at the left) along abscissa $HX$ to a point $J$ beyond $D$ (per safety factors in Table 14-3). Subsequent addition of air results in a change in the mixture composition along line $JV$ (not shown), which crosses no part of flammable zone $ABC$. In the example shown in Fig. 14-2, at least 88 per cent of the natural gas should be replaced by inert gas when the container is purged out of service. (Tables 14-4 and 14-5 make more precise recommendations.)

Table 14-4 Inert Gas End Points for Purging out of Service Using Carbon Dioxide or Nitrogen

| Combustible | Per cent required to render mixtures nonflammable when air is added in any amount | | Purging end points with 20% safety factor | |
|---|---|---|---|---|
| | $CO_2$ | $N_2$ | $CO_2$ | $N_2$ |
| Hydrogen | 91 | 95 | 93 | 96 |
| Carbon monoxide | 68 | 81 | 74 | 85 |
| Methane | 77 | 86 | 82 | 89 |
| Ethane | 88 | 93 | 91 | 95 |
| Propane | 89 | 94 | 91 | 95 |
| *n*-Butane | 91 | 95 | 93 | 96 |
| *iso*-Butane | 91 | 95 | 93 | 96 |
| Pentane | 96 | 97 | 97 | 98 |
| Hexane | 96 | 97 | 97 | 98 |
| Gasoline | 93 | 96 | 95 | 97 |
| Ethylene | 90 | 94 | 92 | 95 |
| Propylene | 94 | 96 | 95 | 97 |
| Benzene | 93 | 96 | 95 | 97 |

Table 14-5 Combustible Gas End Points for Purging out of Service Using Carbon Dioxide or Nitrogen

| Combustible | Per cent of combustible below which no mixture is flammable when air is added in any amount | | Purging end points with 20% safety factor | |
|---|---|---|---|---|
| | $CO_2$ | $N_2$ | $CO_2$ | $N_2$ |
| Hydrogen | 9 | 5 | 7 | 4 |
| Carbon monoxide | 32 | 19 | 26 | 15 |
| Methane | 23 | 14 | 18 | 11 |
| Ethane | 12 | 7 | 9 | 5 |
| Propane | 11 | 6 | 9 | 5 |
| *n*-Butane | 9 | 5 | 9 | 4 |
| *iso*-Butane | 9 | 5 | 7 | 4 |
| Pentane | 4 | 3 | 3 | 2 |
| Hexane | 4 | 3 | 3 | 2 |
| Gasoline | 7 | 4 | 5 | 3 |
| Ethylene | 10 | 6 | 8 | 5 |
| Propylene | 6 | 4 | 5 | 3 |
| Benzene | 7 | 4 | 5 | 3 |

To render a given combustible nonflammable if air is added to it, the required percentages of inert gases should be added. Table 14-4 gives the data for a number of combustibles investigated by the U. S. Bureau of Mines. Inert gas end points at least 20 per cent beyond the flammable limit are given at the right. Where combustion products are employed, the $CO_2$ percentage may be used as a measure of the inert gas present, but that of the end point for $N_2$ should be taken for safe purging control.

Sometimes a more convenient control method is to determine the combustible content of the purged gases. In purging out of service, inert gas is added until the combustible gas concentration of the container contents is decreased to the point where no mixture with any amount of air would be flammable. Table 14-5 gives such data. Suggested purging end point data with a 20 per cent safety factor are given at the right in terms of the percentage of combustible in a mixture which will remain nonflammable regardless of the amount of air which may be added to it.

## HOLDING PURGE

A holding purge is similar to the purging of equipment out of service except that an inert atmosphere is maintained and is not replaced at once by air. Alterations or repairs can sometimes be made safely on closed systems under such conditions, after which combustible gas is readmitted and the equipment is returned to service.

Figure 14-2 may also be applied to a holding purge for natural gas. Natural gas concentration decreases during purging from point *H* (at the left) along abscissa *HX* to a point *J* beyond *D* (per safety factors in Tables 14-4 and 14-5). Combustible gas may then be readmitted at any time, the composition of the mixture changing from *J* along *XH* until *H* is reached and the equipment is returned to service.

## GENERAL PRECAUTIONS

In any purging operation, it is a good rule to purge too much rather than too little. When there is any doubt, the purging should be conducted as though the container were to be purged of hydrogen or to be prepared for its admission. Hydrogen, which is present in most manufactured gases, has the widest known explosive limit range of the common fuel gas constituents. Natural gas, however, does not contain any free hydrogen.

After a purging operation has been conducted according to a safe procedure and brought to a satisfactory end point, the purged atmospheres must be closely rechecked, so that condensates, residues, leaks, or some other condition will not create a dangerous condition within the container later. Due consideration should be given to the possible presence of substances which, because of chemical reactions, may produce combustible elements or cause spontaneous combustion.

## SAMPLING

Control of purging operations is based on periodic sampling and testing of the gas mixture discharged from equipment during its purging. Three general types of gases are involved: (1) inert gas; (2) air or, more specifically, oxygen; and (3) flammable gas.

Representative samples of gas mixtures of adequate but convenient size are required for subsequent analysis, to show the extent of variations in such mixtures in different parts of the system and their relation to performance, health, and safety. Samples must be representative to be fully satisfactory. Precautions should be observed to assure that they are not contaminated or altered by any agent which might affect the representativeness or quality of the sample.

For satisfactory results, sampling points should be chosen with care and located close to the desired reaction or process. A sufficient number of sampling points should be established to furnish all necessary information for purging control. Information secured at one or more of the original points may not be pertinent, and additional or substitute sampling points may be found necessary during purging. There should be no hesitation in justifiable changing of sampling locations.

Sample tube connections should be of the correct size and as short as possible. They may be of rubber (except for LP-gas), glass, copper, iron, plastic, or any other convenient material which will not allow any adulteration, contamination or loss of the sample.

An adequate sample may be obtained thru simple connections in places where the gas is well mixed, as in purge vents or small mains. Sampling connections which extend only thru the wall or shell of large containers or mains are generally not satisfactory. They should extend far enough inside to prevent possible surface condensates from entering the sample tube. In large mains the sampling tube should extend inside from one-third to one-half the main diameter.

## GAS ANALYSIS AND DETECTION

The Orsat gas analysis apparatus is widely used for chemical analysis of samples from purging operations. Concentrations of carbon dioxide, oxygen, and carbon monoxide are determined by their successive selective absorption in chemical solutions. If a more complete analysis is required, other absorption pipettes and combustion tubes may be included to remove additional constituents. Chromatographic and infra-red analyzers may also be used.

### Combustible Gas Indicators

These instruments indicate the presence of combustible gases without identifying them. They are used chiefly in purging equipment out of service. They are most useful up to the lower explosive limit. An advantage in using them is that results are available at once on passage of the sample, so that numerous tests can be made quickly.

These indicators should be calibrated for the gases to be tested. They are not sensitive enough to detect concentrations below about 0.2 per cent of combustible. They carry flame arresters as standard equipment. However, when large concentrations of hydrogen or acetylene are tested, a small sample should be withdrawn into a container. This sample should then be tested with the combustible gas indicator at a distance from the purge site. Activated charcoal filters should not be used during purging operations.

### Pauling Oxygen Analyzer

Oxygen is one of the three general constituents most significant in purging control. The Pauling oxygen analyzer

is based upon the magnetic susceptibility of gases. It is practically specific for oxygen in any gas mixture ordinarily encountered in the gas industry. It may be used for determining the oxygen content of the container mixture when purging equipment either into or out of service.

### Specific Gravity Indicators

The change in specific gravity of the gas mixture during a purging operation can be used to indicate purging progress. Gas is drawn thru the instrument at a high rate of flow. The indication is instantaneous. Self-contained indicators are available. These units operate on either 120 v a-c or 6 v d-c, and can run continuously for at least 5 hr on one charging.

## TESTS FOR GASES HAZARDOUS TO HEALTH

Purging containers either into or out of service may involve handling gases which are injurious to health. Since one of the principal objectives of purging is to remove equipment from service for repairs, tests should be made of the contents of such purged containers to make sure that their atmospheres are safe and will remain so for repairmen.

### Inert Gases

Adequate vents to carry excess inerts ($CO_2$ and $N_2$) outside the containers should be provided. Absence of such vents may allow the oxygen content to fall low enough to cause oxygen starvation or smothering.

When the oxygen of the air is decreased (to about 16 per cent), the breathing rate increases, the pulse rate accelerates, and the ability to think clearly diminishes. Constant indications of oxygen content are advisable to warn of oxygen deficiencies (Table 14-6).

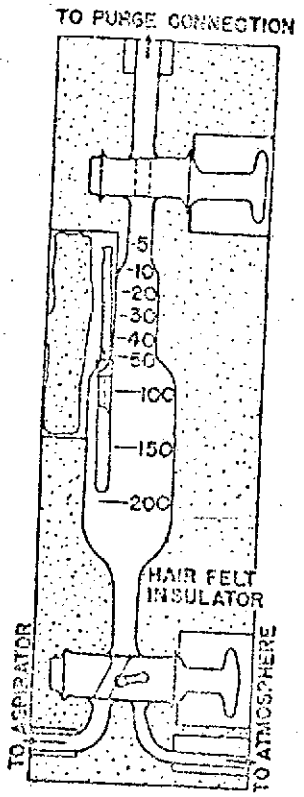
Carbon dioxide is odorless and nontoxic in small quantities, but it acts as a respiratory stimulant. Above six per cent concentration, physical impairments are experienced, such as headache, drowsiness, and general nervousness.

### Flue or Exhaust Gases and Purging Machine Gas

When used as inerts, these gases contain small percentages of carbon monoxide. Instruments capable of determining CO in concentrations as low as 0.002 per cent should be used to analyze the contents of a space where men may work. Physiological effects of carbon monoxide (Table 6-4 and Fig. 6-24) and instruments for its determination are available; see Fig. 6-27. Table 1-30 gives the threshold limits for a number of gases and vapors which may be encountered.

**Table 14-6 Physiological Effects of Oxygen Deficiency**

| $O_2$, vol % | Effect |
|---|---|
| 20.99 | Normal air supply. |
| 17.5 | Flame lamp extinguished. Atmosphere can be breathed and work done without ill effect for several hours. |
| 13.0 | Acetylene flame extinguished. Work difficult; considerably increased rate of breathing; lips blue; nausea and headache. |
| 8 to 11 | Loss of consciousness on exertion. |
| below 6 | Unconsciousness and death if adequate supply not quickly restored. |



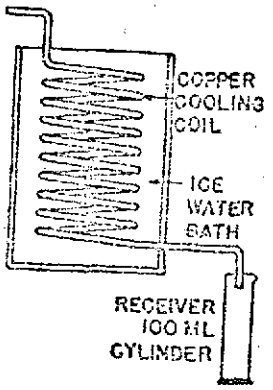




**Fig. 14-3** (left) Steam purge indicator.
**Fig. 14-4** (right) Condensing-coil for steam purge testing with volatile combustibles present.

**Steam Purging Indicators.** Steam, as a purging medium, has the advantage of usually being available in quantity. It is well suited to operations where volatile combustibles are present. The pressure at which it is supplied should not exceed the design pressure of the equipment to be purged. The operation must be continuous, to avoid drawing in air by steam condensation.

The steam purge indicator (Fig. 14-3) consists of an insulated Pyrex glass bulb of 400-ml capacity with a graduated small diameter neck at its upper end and suitable cocks at each end. One leg of the three-way bottom cock is connected to a water-filled leveling bottle.

The bulb is filled with water to displace all air and then connected to the sampling line at the purging vent. Purge gas is drawn in by allowing the water to drain into a bottle. Then the cocks are manipulated so that purge gas is allowed to flow thru the indicator until temperature equilibrium is reached. By closing the top cock and reversing the bottom, water from the bottle will be drawn in by the condensing steam. The per cent of gas or air remaining will be indicated by reading the water level in the graduated neck.

When volatile combustibles are present, a second operation is necessary. The purge gas is passed thru an adequately cooled condensing coil (Fig. 14-4), and the condensate is collected in a 100-ml cylinder. The oil layer may then be measured. Condensate temperature should not exceed 70 F.

## REFERENCE

1. Jones, G. W., and Scott, G. S. *Extinction of Isobutane Flames by Carbon Dioxide and Nitrogen.* (U. S. Bur. Mines Rept. Invest. 1995) Washington, D. C., 1947.