Control No. U-65-4461

Thiokol
CHEMICAL CORPORATION
HUNTSVILLE DIVISION
HUNTSVILLE, ALABAMA

STANDARD COMPARISON TEST PROCEDURES FOR INITIATOR OUTPUT

Contract NAS 8-11551

Prepared For
George C. Marshall Space Flight Center
National Aeronautics and Space Administration
Huntsville, Alabama

Prepared By:

R. M. Latta
B. B. Stokes
G. E. Webb

Approved By:

G. F. Mangum
Project Manager

Published
April, 1965

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STANDARD COMPARISON TEST PROCEDURES
FOR INITIATOR OUTPUT

INTRODUCTION

SCOPE

This manual establishes standard terminology for defining initiator output and specifies the test methods to be used to determine initiator output characteristics in terms of the standard definitions. The term initiator (or squib) refers to a device used as the first element of an igniter train to produce a hot flash or flame of relatively low brisance for initiation of a pyrotechnic material.

SUMMARY OF PROCEDURES

The test procedures described herein can be utilized in the following ways:

1. To compare the output characteristics of an initiator with those of other initiators.

2. To establish the output characteristics of an initiator.

3. To serve as a systematic method for testing during initiator development.

4. To provide a procedure for quality control testing during production.

Briefly, the output of an initiator is determined in this procedure by calorific output tests in a bomb calorimeter, by pressure output tests in a variable volume closed bomb, by heat flux output tests in a closed bomb and in an open tube, and by relative brisance tests using inert pellets and foamed glass block as targets for the initiators. In addition, procedures are given for calculating estimates of initiator calorific output, maximum pressure generated by initiators in a closed bomb, and increases in maximum igniter pressure caused by pellet breakup due to "brisant" initiators.

The user of these procedures is assumed to have a fundamental background in the operation of the equipment specified herein or of similar equipment. Appendix A contains a list of manufacturer's manuals which should be referred to for the finer details concerning calibrating, connecting, tuning, and operating the equipment.

DEFINITIONS

Initiator	The first element in an ignition train which supplies the initial heat and pressure required to actuate the remaining components of the train
Calorific Output	The total heat (cal.) evolved by an initiator
Pressure Output of an Initiator	The general term for pressure and associated pressure transient characteristics produced by an initiator in a

	nonvented chamber
Heat Flux Output of an Initiator	The heat flux (cal. /cm.^{2}-sec.) from an initiator as recorded through a thin-film gage (a relative value) (Units may also be referred to in b. t. u. /ft.^{2}-sec. or b. t. u. /in.^{2}-sec.)
Brisance	The shattering (shock) effect of initiator output produced by extremely rapid pressure rise (a relative term)
Heat of Explosion	The amount of heat generated (cal. /gm.) by the combustion of a material in a constant volume inert atmosphere at a given initial pressure
Heat of Reaction	The useful energy, measured as heat (cal. /gm.), which becomes available as a result of a chemical reaction taking place at a constant temperature and pressure (a calculated value)
Maximum Pressure (P_{max})	The highest value of pressure (psia) attained
Function Time (t_1)	The time interval (msec.) from input of firing current to the initiator to first indication of pressure rise
Rise Time (t_2) (or apparent burning time)	The time interval (msec.) from first indication of pressure rise to attainment of maximum pressure
Average Pressure Decay Rate ($\dot{P}_{dk}$)	The average slope of the pressure decay curve (psi/msec.) during the first 10 msec. after maximum pressure in a closed bomb
Calibration Heat Flux (q)	The heat flux (b. t. u. /ft.^{2}-sec.) value used to calibrate the heat rate analogue unit
Maximum Temperature (T_{max})	The maximum temperature (°F.) recorded with a thin-film gage
Time to T_{max} ($t_{T_{max}}$)	The time interval (msec.) from first indication of temperature rise to maximum temperature
Fine Fraction	The ratio of the weight of pellets passing through a U. S. Standard No. 12 sieve to the total weight of pellets loaded into the fixture
Degree of Damage	The ratio of the weight of pellets passing through a U. S. Standard No. 12 sieve to the weight of damaged pellets

SAFETY PRECAUTION

The safety procedures for the facility in which this manual is used should take precedence over any operation specified in the manual. Warnings and safety precautions are noted throughout the procedures (in capital letters) to assure protection of personnel and equipment.

The following safety conditions should be provided before testing is begun:

1. Adequate grounding of all electrical equipment.

2. Nonconductive floors (or local safety requirements).

3. Approved operator and transient safety clothes including eye protection, nonflammable coveralls or lab coat, and nonconductive shoes (or local safety requirements).

4. Shield, test chamber, or other device for protecting the operator during an initiator firing.

5. Adequate interlocks on the equipment to prevent premature firing of the initiator.

6. Control of transient personnel in operating area.

EQUIPMENT AND MATERIALS

The following equipment and materials are required for the initiator output test procedures. The specifying of particular makes of equipment is not intended to imply that only those makes are satisfactory for use. Other manufacturers' equipment with similar response characteristics may also be used. When substitute equipment is used, descriptions of the equipment should be reported along with the test results.

Appendix A contains a list of operating manuals for the equipment described below. These manuals should be referred to for the finer details concerning calibration, operation, and maintenance of the equipment.

Item Number	Description
1	TX409-1 Closed Bomb Test Fixture, Thiokol drawing R-42453, Figure 1
2	Oscilloscope, Tektronix, Inc., Beaverton, Oregon, Type 555 (d.c.-to-33 m.c., dual-beam)
3	Camera, Oscilloscope, Tektronix, Inc., Type C-19, Part No. 122-568 with Mounting Bezel Part No. 016-226, Viewing Hood Part No. 016-001, Lense (f/1.4-1:1) Part No. 122-608, and Film, Type 47 ASA 3000
4	Preamplifier, Tektronix, Inc., Type K
5	Amplifier, Dynagage, Photocon Research Products, Pasadena, Calif., Model DC-605 with Power Supply Model PS-605 and Cable Termination Network Model 2573
6	Pressure Transducer, Photocon Research Products, Model No. 401-1531 with Appropriate Pressure Rating

Item Number	Description
7	Dead Weight Tester, Ashcroft Gauge, Manning, Maxwell, and Moore, Inc., Stratford, Conn., Model 1305-BH100
8	Foil Gap Switch and Triggering Circuit, Figure 2
9	Amplifier, Dual Trace Plug-in Unit, Tektronix, Inc., Model 53/54C
10	Thin-Film Gage, Heat Technology Laboratory, Inc., Huntsville, Ala., Model PTF50-P24-4F
11	Heat Rate Analogue Unit, George C. Marshall Space Flight Center, National Aeronautics and Space Administration, Huntsville, Ala., Model 3 (NASA-MSFC drawings C-362.1 through C-362.7), with
	a. Chopper Power Supply
	b. Chopper
12	Power Supply, d.c., Hewlett-Packard Co., Palo Alto, Calif., Model 712-B
13	Wheatstone Bridge, Leeds and Northrup Co., Philadelphia, Pa., Model 5305
14	Potentiometer, Leeds and Northrup Co., Model 8667
15	Muffle Furnace, Temco, Inc., Nashville, Tenn., Model 1623
16	Pyrometer Controller, Thermo Electric Co., Saddle Brook, N.J., Model 293
17	Thermocouple, Copper-Constantan
18	Decade Box, 2% Tolerance;
	a. One with a resistance range of 0 to 100 ohms
	b. One with a resistance range of 0 to 200 ohms
19	Open-Tube Test Fixture, Figure 9
20	Bridge Circuit, Thin-Film Gage, Figure 10
21	Circuit Tester, Allegany Instrument Co., Cumberland, Md., Model 101-5AF
22	Inert-Pellet Test Fixtures, Figures 12 and 13
23	Pellets, Inert, ALCLO[1], Figure 14

1. A trademark name of the Aerojet-General Corporation, Azusa, California.

Item Number	Description
24	Pellets, Inert, B-KNO_3, Figure 14
25	Glass-Block Test Fixture, Figure 15
26	Glass Block, Figure 15
27	Bomb Calorimeter, Parr Instrument Co., Moline, Ill., Series 1200 Adiabatic Bomb Calorimeter with Associated Apparatus (Procedure 1.a.)
28	Miscellaneous Materials Check List:

a. Zinc chromate putty

b. Heat resisting tape

c. Insulating phenolic sleeve, 1/2-inch O. D. x 10 inches long

d. Potting compound--nonelectrical conducting

e. Coaxial cabling and connectors

f. Distilled water

g. Crushed ice made from distilled water

h. Dewar flask

i. O-Ring lubricant

Because the equipment required for Procedure 1.a., "Calorific Output of Initiators Using a Bomb Calorimeter," is not used for any other procedure, the accessory apparatus are not included in this equipment list but are described within the procedure.

PROCEDURE SELECTION GUIDE

General

The purpose of this guide is to recommend the appropriate procedures for comparing, characterizing, developing, and quality control testing initiators and to aid the user in selecting closed bomb volumes, numbers of tests, special environmental conditions, etc. Because the output variations of initiators differ widely, no attempt has been made to establish the number of tests to conduct under each procedure. Some initiators may require many tests to assure that they are sufficiently characterized, while others may require only two or three tests if their outputs are consistent.

If an initiator is to be used in a high altitude environment, some of the comparison and characterization testing should be conducted under vacuum conditions; especially the closed bomb pressure testing. Procedure 2.b. discusses the selection of the appropriate closed bomb volume. Generally, for initiators expected to develop low pressures, a closed bomb volume of from 15 cc. to 30 cc. should be used, whereas for high pressure output initiators, a volume of from 25 cc. to 40 cc. is recommended. This manual recommends the units in which the data should be reported and provides a list of conversion factors in Appendix B for converting from the British system to the metric system.

Comparing Initiator Output

Procedures 1, 2, 3, and 4, in that order, are recommended for comparing the outputs of two or more initiators. The "b" portions of Procedures 1 and 2 should be used initially if sufficient data are available and, if the results support continuing the comparison tests, Procedures 3.a. and 4.b. should be used to further compare the outputs of the initiators. Because the importance of a particular initiator output parameter varies with the intended application, no limits have been placed on the range of acceptable variation of the parameters. When using any of the procedures for comparing initiator output, extreme care should be taken to duplicate all test conditions from one test to another including instrumentation setups, surrounding environmental conditions, initial fixture conditions, and sensor response capabilities.

Characterizing Initiator Output

Although most of the procedures described in this manual, because of their qualitative nature, are intended for comparing initiator output, the procedures can also be used to characterize the output of a particular initiator. Procedures 1 and 2 for obtaining the total heat output and the closed bomb pressure of an initiator are the most practical and most quantitative procedures by which initiator output can be characterized.

Initiator Development Testing

All of the procedures can be usefully employed during development of an initiator. Procedure 3.b. for heat flux output measurements in an open-tube test fixture is especially useful for "microscopic" evaluations of initiator gas flow. A heat flux measuring device (thin-film gage--TFG) measures the temperature at the surface of a substrate material (this temperature is related to the temperature of the initiator gases), and heat flux to the gage surface from the initiator combustion products can be determined. The advantages of open-tube testing are (1) that the hot gas flow from an initiator can be restricted to one-dimensional flow patterns which are reproducible and conducive to an analysis similar to the heat transfer to the walls of a shock tube, (2) that the open tube makes testing much faster and easier than the closed bomb, and (3) that the TFG can be replaced (at the same location and geometry) by various pellets to study the go-no-go ignition of the pellets and compare this actual ignition to the heat transfer measured at the location with the TFG.

Initiator Quality Control Testing

Procedures 2.a. and 4.b. can be easily adapted to quality control testing of initiators. Most quality control procedures require closed bomb pressure tests and functioning time tests in addition to the usual electrical input safety tests. Procedure 4.b. can be used in conjunction with functioning time measurements and is one method of comparing the lot-to-lot variations of initiator brisance.

PROCEDURE 1. a.

CALORIFIC OUTPUT OF INITIATORS USING A BOMB CALORIMETER

PROCEDURE 1.a.

CALORIFIC OUTPUT OF INITIATORS USING A BOMB CALORIMETER

SCOPE

This procedure describes a method of determining the total heat output of initiators using a bomb calorimeter.

SUMMARY OF METHOD

The total heat output of an initiator is determined in this procedure by firing the initiator (or a cluster of initiators) in a bomb calorimeter under 25 atmospheres of helium (or argon). The calorific output of the initiator is calculated by multiplying the temperature rise in the calorimeter by the energy equivalent factor (effective heat capacity or water equivalent) of the system and dividing this product by the number of squibs fired into the bomb. The procedure is based on the use of a Parr Instrument Co., Moline, Ill., adiabatic bomb calorimeter Series 1200; however, other calorimeters may be used if the initial bomb conditions are not altered and the calorific output of initiators is reported as described in this procedure.

Alternately, if a sufficient amount of initiator pyrotechnic charge is available, the total heat output of the initiator may be obtained by burning a known quantity of the charge in the bomb calorimeter under 25 atmospheres of helium (or argon), thus determining the heat of explosion (calories/gram) of the charge, and multiplying the heat of explosion by the initiator charge weight. Normal bomb calorimeter procedures for acid corrections, sample weight selection, and safety precautions should be utilized.

GENERAL CONSIDERATIONS

Nomenclature

The bomb calorimeter referred to in this procedure consists of three essential parts, namely:

1. The bomb or vessel in which the combustible charge is burned (or the initiator is fired).

2. The bucket or container holding a measured quantity of water in which the bomb, thermometer, and stirring device are immersed.

3. The jacket which protects the bucket from the effects of variations in room temperature, drafts, etc.

Safety Precautions

The user of this procedure is assumed to have a basic knowledge of the use of bomb calorimeters (in particular, the Parr Instrument Co. adiabatic calorimeter, Series 1200) for heat of combustion measurements. Parr Manual No. 130 (Appendix A), which contains a discussion of calorimetry and combustion methods as well as a summary of the hazards of operating a bomb calorimeter, should be reviewed before proceeding with the test.

SPECIAL PRECAUTIONS MUST BE TAKEN TO ASSURE THAT THE INITIATOR TO BE TESTED DOES NOT PRODUCE EXCESSIVE INSTANTANEOUS PRESSURE WHEN FIRED IN THE BOMB AND THAT THE MAXIMUM PERMISSIBLE CALORIFIC OUTPUT IS NOT EXCEEDED. When there is doubt concerning the pressure output of an initiator, several tests should be conducted first in a closed bomb and the results used to predict the pressure effects of the initiator in the calorimeter bomb (Procecure 2.b.). The Parr No. 1101 bomb, around which this procedure was established, has a volume of 360 milliliters and can withstand a working pressure of 100 atmospheres and a total sample heat liberation of 10,000 calories. The Parr No. 1104 high pressure bomb may be used for an initiator which produces extremely high pressures or is highly brisant.

Initiator Samples

The choice of the number of initiators to test in the bomb at one time depends on the pressure and estimated calorific output of the initiator, the cost and availability of the initiator, and the type of initiation (low voltage or EBW) required. The following statements are presented as guides for determining the number of initiators to test at one time:

1. No more than two exploding bridgewire initiators should be tested at one time.

2. No more than five low voltage initiators should be tested at one time.

3. The effects of testing errors are lessened as the temperature rise in the calorimeter becomes greater. Therefore, the greatest number of initiators that can practicably be tested (up to a maximum of five low voltage initiators and two EBW initiators) should be fired, provided the pressure and calorific limits of the bomb are not exceeded. (A calorific output of 1350 calories will raise the temperature of the bomb approximately 1°F. A temperature rise of from 0.1°F. to 0.5°F. gives satisfactory results, although a larger rise is more desirable.)

Effects of Errors

Normal bomb calorimeter procedures for maintenance, control of surrounding conditions, and precision should be followed to assure that errors do not bias the results and that they are kept to a minimum. The following examples illustrate the magnitude of errors which may result from faulty operation. They are based upon an assumed calorimetric experiment burning a 1.0000-gram sample to produce a 5.000°F. temperature rise in a calorimeter having an energy equivalent of 1350 cal./°F. (Reference Parr Manual No. 130).

An error of 1 gram in measuring the 2 kilograms of water for the calorimeter will change the thermal value 3.4 calories.

An error of 0.01°F. in measuring the temperature rise will change the thermal value 13.5 calories.

APPARATUS

Bomb Calorimeter

This procedure is based on the use of a Parr Instrument Co. adiabatic bomb calorimeter Series 1200 (Item No. 27 of Equipment and Materials List, Page 5). Other calorimeters may be used, but the initial test conditions as described herein should be the same. The maximum pressure and calorific output limitations of a substitute calorimeter should be thoroughly investigated before use.

Both the double-valve and the single-valve Series 1200 self-sealing bombs are suitable for use with low voltage initiators. However, when exploding bridgewire initiators are tested, the bomb must be modified to provide high voltage attachments through the head. Figure 1.a.1 shows a suggested method of modifying a double-valve bomb head. Any modified bomb should be pressure tested under operator-protected conditions before use in the calorimeter. The bomb should also be checked for leaks by immersing the pressurized bomb in water and watching for bubbles.

Ignition Unit

The ignition unit should supply the proper electric current for firing standard calibration samples (Parr Series 2900 ignition units or equivalent).

Ignition Battery

Either a dry cell or a wet cell battery is required for firing low voltate initiators. A firing current of 5 amperes per initiator is satisfactory for most applications.

Exploding Bridgewire Firing Unit

The EBW firing unit should be capable of supplying the required firing pulses at voltages of 500 to 3000 volts from a 0.5 to 1.5 microfarad capacitor.

Hot Water Source

A Parr Series 1500 water heater may be used to supply both hot and cold water to the calorimeter. It is also advisable to have a source of chilled water (such as from a water cooler drinking fountain) to assist in controlling the calorimeter jacket temperature during a test.

Distilled or Demineralized Water

The distilled or demineralized water used in the calorimeter bucket should be 2.0 to 2.5°F. below room temperature.

Thermometers

Two narrow-range (approximately 66 to 95°F.) matched thermometers having 0.05°F. graduations which can be estimated to 0.005°F. (Parr No. 1601 thermometer furnished with a Parr certificate and correction chart or equivalent) are required. Reading lenses (Parr No. 3003 or equivalent) should be used.

Firing Wire

The standardization sample may be ignited by means of Parr No. 45C10 nickel-alloy fuse wire or equivalent.

Balance

A balance or other weighing device capable of weighing 2,000 grams of water with 0.5-gram accuracy is required. A balance for weighing a 0.9- to 1.1-gram sample of standard combustion material with 0.0001-gram accuracy is also required.

Timing Device

A stop watch or other timing device capable of keeping time up to about 30 minutes is needed.

REAGENTS

Helium Gas

Commercial helium containing not more than 0.01 percent oxygen is required. Commercial argon gas may be used instead of helium.

Standard Samples

Benzoic acid powder or pellets (from Parr or the National Bureau of Standards, Washington 25, D. C.) may be used for calibrating the bomb calorimeter. Other materials such as naphthalene or sucrose may also be used.

Titration Solution

A standard alkali solution is needed for acid titration of the bomb washings during calibration. A 0.0725N sodium carbonate solution, prepared by dissolving 3.84 grams Na_2CO_3 in water and diluting to 1 liter, is recommended.

Acid Indicator

Methyl orange or methyl red is used for acid-alkali titrations.

STANDARDIZATION

Determine the energy equivalent of the calorimeter as the average of not less than two tests using the procedure described in Parr Manual No. 130. Briefly, the calibration procedure consists of burning a known weight of benzoic acid in 25 ± 1 atmospheres of oxygen and determining the energy equivalent of the calorimeter as the product of the weight of the sample and its heat of combustion per gram divided by the corrected rise in temperature. Corrections are made for the heat of formation of nitric acid and for the heat of combustion of the ignition wire. The energy equivalent of the calorimeter must also be adjusted for the addition of initiator components during a total heat output test. This can be done either by using the weights of the components and their specific heats or, preferably, by placing the same type of fired initiator components in the bomb as those live initiator components used in the total heat output

PROCEDURE 1. b.

CALCULATED CALORIFIC OUTPUT OF INITIATORS

test. The fired initiator components must be stripped of all combustible materials such as leadwire insulation, plastic spacers, and thin metal components (closures) which would burn in the presence of excess oxygen. If a powdered combustion material is used to calibrate the system, extra care must be taken to assure that combustible initiator components are not placed in the bomb because they are more likely to come into direct contact with the combustion flame as the powder "splashes" out of the capsule during burning. Leadwire lengths and firing connector components should be the same for standardization and for initiator calorific output tests.

PROCEDURE

General

Accepted calorimetric techniques should be used throughout the testing procedure. Parr Instrument Co. Manual No. 130, titled "Oxygen Bomb Calorimetry and Oxygen Bomb Combustion Methods," describes the techniques of calorimetry applied to the heat of combustion measurement. Manual No. 130 supplements this procedure and should be used whenever specific steps for conducting the calorific output test for initiators are not described in detail. A minimum of two total heat output determinations should be conducted for each initiator.

Preparation of Samples

The initiators must be stripped of any combustible materials externally attached to the hardware. For example, insulation must be removed from the leadwires of plug-and-shell initiators. Several techniques can be used to cluster initiators together and to attach their leads to the electrodes or firing connector. Any connector pin, solder, or other item used to cluster the initiators must have been placed in the bomb during calibration or must be corrected for in the final calculations. Initiator bridgewire continuity should be checked before and after clustering.

Preparation of Bomb

Place in the bomb an empty metal combustion capsule similar to the one used during calibration (or, alternately, correct the test results using the weight of the capsule and its specific heat). Do not add water to the bomb for acid correction. Insert the head with initiators attached into the bomb making sure that the initiator circuit does not touch the sides of the bomb and that the circuit is not fouled. Close the bomb by turning the cap screw down firmly by hand. Check the firing circuit continuity before proceeding with filling the bomb.

Purging and Filling the Bomb

Loosely attach the filling connection of the helium (or argon) gas tank to the inlet valve of the bomb and slowly purge the gas line of air. Tighten the filling connection and slowly admit gas to approximately 10 atmospheres gage pressure at room temperature. Slowly vent the gas to the atmosphere through the outlet valve (or remove the filling connection and vent through the inlet valve if a single-valve or EBW modified double-valve head is being used). Repeat this filling and venting process three times to purge the bomb of entrapped air. After the third purging, fill the bomb to a pressure of 25 ± 1 atmospheres, remove the filling connection, and attach the valve nut to give added security to the check valve. The bomb is now ready for use.

Calorimeter Water

Fill the calorimeter bucket with 2000 ± 0.5 grams of distilled or demineralized water at 2.0 to 2.5°F. below room temperature. The amount can be determined either by measurement in a standard flask or by weighing, using the same amount as that used in the standardization of the apparatus. Space is provided on the suggested initiator calorific output data sheet shown on Figure 1. a. 2 for recording the combination of weights (or the volume at a particular temperature) used to obtain the 2000 grams of calorimeter water. A sample filled-in data sheet is shown on Figure 1. a. 3.

Assembling the Calorimeter

Place the bucket of water into the calorimeter, lower the bomb into the bucket, and attach the thrust terminal to the bomb. If the bomb has been modified to allow testing of EBW initiators, position the firing leads so that they extend from under the calorimeter cover, close the calorimeter, and start the stirrer.

Temperature Adjustment and Observations

With the calorimeter assembled, adjust the temperature of the water circulating in the jacket so that it is the same as that of the water in the bucket. Allow five minutes for attainment of equilibrium; then adjust the jacket temperature to match the calorimeter within ±0.01°F. and hold for three minutes. Read and record the calorimeter temperature to the nearest 0.005°F. and fire the initiator(s) with the appropriate ignition unit. (Use a data sheet similar to that shown on Figure 1. a. 2 for recording pertinent information.) Add hot water to the jacket during the temperature rise period to keep the calorimeter and jacket temperatures as nearly alike as possible (if the cold tap water is ineffective in keeping the jacket temperature from "overshooting" the calorimeter temperature, the addition of chilled drinking fountain water to the jacket will help to control its temperature). Adjust the temperatures to within ±0.01°F. after three minutes and record the calorimeter temperature at one minute intervals until the same temperature is observed in three successive readings.

Opening the Calorimeter

After recording the final maximum temperature, open the calorimeter, remove the bomb, and release the gas into a hood before opening the bomb. The bomb valves should be cleaned often to prevent them from becoming clogged with initiator exhaust products.

CALCULATIONS

Using the initial and final corrected temperatures and the energy equivalent of the system determined during calibration, calculate the total heat output of the initiator as the product of the temperature rise (°F.) and the energy equivalent (cal./°F.) divided by the number of initiators tested. Record the total heat output to the nearest calorie.

PROCEDURE 1.b.

CALCULATED CALORIFIC OUTPUT OF INITIATORS

SCOPE

This procedure discusses general methods and guidelines for calculating and reporting estimates of the calorific output of initiators.

SUMMARY OF METHOD

The procedure is based on utilizing known heat content data of the individual initiator ingredients or of similar materials to calculate the total calorific output of the initiator. If little is known about the quantity and type of initiator charge ingredients, the estimates obtained using some methods discussed herein may be useful only as "quick look" estimates of calorific output prior to employing Procedure 1.a. or prior to obtaining additional information.

PROCEDURE

Figure 1.b.1 shows heat of explosion of several metal-oxidant initiator materials as a function of percent by weight of metal. This figure may be useful in calculating the total heat output of an initiator whose charge types and compositions are known. The calorific output of an initiator is obtained simply by multiplying the weights (usually expressed in grams) of the several initiator charges by their corresponding values for heat of explosion (expressed in calories/gram) and adding the products. The validity of calorific output estimate is dependent, of course, on the accuracy of the charge type-and-weight information. Whenever possible, total heat output estimates should be based on heat of explosion, but, in all cases, the method used to determine the total heat output of an initiator should always be described along with the reported value.

Another method of determining the total heat output of an initiator is to conduct bomb calorimeter tests (following Procedure 1.a.) to obtain values for heat of explosion using either the entire initiator contents or the individual charge materials if the materials are available. The heat of explosion of nonheat-sensitive materials such as those sometimes used in exploding bridgewire charges can be determined in a bomb calorimeter by boosting the hot initiation wire with a heat-sensitive charge. The heat content may also be estimated from reaction equation calculations.[1]

1. The heats of reaction of metal-oxidant mixtures can be calculated by a method given in the following reference: "Metal-Oxidant Igniter Materials," Bulletin of the Second Symposium on Solid Propellant Ignition, Vol. I, October 2 - 4, 1956, CONFIDENTIAL.

PROCEDURE 2. a.

PRESSURE OUTPUT OF INITIATORS IN A CLOSED BOMB

PROCEDURE 2.a.

PRESSURE OUTPUT OF INITIATORS IN A CLOSED BOMB

SCOPE

This procedure describes a method of determining the pressure output characteristics of initiators using the TX409-1 closed bomb test fixture (R-42453). The user of this procedure is assumed to have a fundamental background in the calibration and operation of pressure measuring instruments including high frequency pressure transducers, amplifiers, oscilloscopes, and oscilloscope cameras.

SUMMARY OF METHOD

The pressure output characteristics of an initiator are determined in this procedure by firing the initiator into a closed test chamber and measuring the transient pressure during burning of the initiator charge. The pressure output of the initiator is characterized by the rate at which the closed bomb chamber is pressurized and by the maximum pressure produced in selected chamber volumes of 20, 30, 40, or 50 cc. (or intermediate volumes).

APPARATUS

The apparatus for the closed bomb pressure test consists of the following items (see Equipment and Materials List, Page 3):

Item No.	Name	Item No.	Name
1	Closed Bomb (Fig. 1)	5	Amplifier, Dynagage
2	Oscilloscope	6	Pressure Transducer
3	Camera, Oscilloscope	7	Dead Weight Tester
4	Preamplifier, Type K	8	Foil Gap Switch & Triggering Circuit (Fig. 2)

PROCEDURE

Setup and Calibration of Instrumentation

1. Refer to the manufacturers' manuals (Appendix A) for the finer details concerning calibrating, connecting, tuning, and operating the equipment. Use coaxial cabling with UHF or BNC connectors. Cabling length should not exceed 25 feet between the transducer (Item No. 6) and the Dynagage (Item No. 5) and should be held to an absolute minimum between the Dynagage, preamplifier (Item No. 4), and oscilloscope (Item No. 2).

2. Select the appropriate dead weight tester (Item No. 7) adapter to fit the pressure transducer and install the transducer in the adapter applying the minimum torque to effect a good seal. Approximately 200 to 400 inch-pounds torque is satisfactory for the Photocon transducer with 18 - 1.5 mm. threads.

3. Zero the oscilloscope beam and set the "volts/cm." switch at 2 volts/cm. with the "variable volts/cm." control in the "calibrated" position.

4. Electrically connect the transducer to the Dynagage and the Dynagage to the oscilloscope.

5. Tune and balance the transducer and Dynagage using the manufacturers' manuals as guides. After tuning is complete, the output of the Dynagage should be adjusted

to zero output voltage as indicated by the oscilloscope deflection; i.e., the oscilloscope zero does not shift when the Dynagage is disconnected.

6. Calibrate the oscilloscope to read-out pressure using the dead weight tester manual as a guide. The maximum desired calibration pressure should deflect the oscilloscope beam 4 cm. The oscilloscope beam should show a 1-cm. deflection at 25% of the maximum pressure, a 2-cm. deflection at 50% pressure, and a 3-cm. deflection at 75% pressure. If the maximum pressure output of the initiator is not known, calibrate for a high maximum pressure for the initial tests and recalibrate as necessary for subsequent tests. If the maximum pressure is known for some other volume, estimate the pressure for the test volume by the method given in Procedure 2.b.

7. After calibrating the oscilloscope, remove the transducer from the dead weight tester and remove the outer flame shield from the transducer. Degrease the transducer and flame shield being careful not to allow the degreasing agent to contact the connector end of the transducer. Thoroughly dry the parts and reattach the flame shield to the transducer.

8. Mount the camera (Item No. 3) on the oscilloscope and load it with Type 47 ASA 3000 Polaroid film. Various types of initiators differ widely in time necessary to achieve maximum pressure in a closed bomb. If little is known about the functioning time of the initiator being tested, use both oscilloscope beams and select a fast recording speed (such as 1 millisecond/cm.) for one beam and a slow recording speed (such as 10 milliseconds/cm.) for the other beam to assure that the entire initiator functioning period is recorded. (The oscilloscope screen is 9 cm. wide.) A slow oscilloscope sweep speed requires the use of lower graticule lighting and allows less intensity to be used on the beam (trace). The film exposure time is determined by the duration of the sweep and the persistence of the cathode ray tube phosphor; therefore, the shutter speed is normally set to bulb (B) and the shutter is manually opened and closed to photograph the initiator firing. With the above in mind, use an aperture opening of f/2 to f/3 to achieve a balance between graticule and oscilloscope beam focus. Beam intensity and duration must be the reference points for camera settings, while graticule focus is the by-product.

   Adjust the astigmatism and intensity controls of the oscilloscope for a sharp beam.

9. Set the oscilloscope beam for a single sweep.

   Adjust the oscilloscope so that a small signal (on the order of 200 millivolts) impressed across the trigger input terminals will sweep the beam. Select a method of triggering the oscilloscope (Appendix C). In some cases, it may be advisable to use the trigger source provided by the manufacturer of the power supply used to fire the initiator--in other cases, for initiators with extremely slow functioning times (time from application of firing energy to initial pressure rise in the closed bomb), a foil gap switch (Item No. 8) inserted in the gas stream of the initiator may be the solution. The TX409-1 closed bomb with Body, R-42455, has provisions for using the gap switch. Figure 3 schematically illustrates the layout of the instrumentation for measuring pressure as well as for measuring heat flux described in Procedure 3.

<u>Assembly, Calibration, and Use of the Bomb</u>

1. The temperature of the room in which the test is conducted and of the bomb should be between 70° F. and 80° F.

2. IF AN APPROXIMATE MAXIMUM PRESSURE OUTPUT OF THE INITIATOR BEING TESTED IS NOT KNOWN BUT IS EXPECTED TO BE AS HIGH AS 3000 PSIG IN A SMALL VOLUME, MAKE THE INITIAL TEST AT A LARGE VOLUME (SUCH AS 50 cc.) TO ASSURE THAT THE BOMB WORKING PRESSURE OF 3000 PSIG IS NOT EXCEEDED.

   Alternately, the maximum pressure output of the initiator may be estimated for the test volume by the method given in Procedure 2. b., if the maximum pressure output of the initiator is known for some other volume.

3. The face of the calibrated pressure transducer must be coated with a 0.02- to 0.05-inch thick layer of zinc chromate putty during each test to protect it from damaging initiator exhaust. The putty should be removed and replaced as needed to assure that the face of the transducer is protected.

4. Using drawing R-42453 (Figure 1) and the following tabulation as guides, assemble the closed bomb test fixture (Item No. 1). Lubricate all O-rings with Celvacene.

Nominal Test Volume	Body	Parts
20 cc.	R-42455-51	Plug, R-42457, with O-ring, 2-28 Plug, MS 9015-04, with O-ring, 3-4, or, for vacuum tests, Union, AN815-4C, with O-ring, 3-4, and Vacuum Valve Screw, MS 9317-02 Washer, R-42456, as required Adapter, R-41913--appropriate threads, with O-ring, 2-28, and appropriate O-ring for Squib Pressure Transducer, PRP #401, with O-ring, 2-12
20 cc.	R-42455	Same parts as above plus: Plug, R-42459 Holder, R-42208-51, with O-ring, 2-12 Plug, MS 9015-03, with O-ring, 3-3, or Gap Switch, Figure 2, with O-ring, 3-3, or other Oscilloscope Triggering Device
30 cc.	R-42455-51	Add Spacer, R-42454, O-ring, 2-28, and Sleeve, R-41940, to 20 cc. Bomb with Body, R-42455-51
30 cc.	R-42455	Add Spacer, R-42454, O-ring, 2-28, and Sleeve, R-41940, to 20 cc. Bomb with Body, R-42455
40 cc.	R-42455-51	Add Spacer, R-42454-51, O-ring, 2-28, and Sleeve, R-41940-51, to 20 cc. Bomb with Body, R-42455-51
40 cc.	R-42455	Add Spacer, R-42454-51, O-ring, 2-28, and Sleeve, R-41940-51, to 20 cc. bomb with Body, R-42455
50 cc.	R-42455-51	Add Spacer, R-42454-52, O-ring, 2-28, and Sleeve, R-41940-52, to 20 cc. Bomb with Body, R-42455-51

Nominal Test Volume	Body	Parts
50 cc.	R-42455	Add Spacer, R-42454-52, O-ring, 2-28, and Sleeve, R-41940-52, to 20 cc. Bomb with Body, R-42455

Generally, the best test volume for low output initiators is from about 15 cc. to 30 cc., while higher output pressure initiators should be tested at volumes of about 25 cc. to 40 cc. Larger bomb volumes can be obtained by attaching various combinations of Spacers together.

<u>Check to see that the Sleeve (R-41940, R-41940-51, or R-41940-52) does not obstruct the pressure port and that it does not slide across the pressure port during subsequent handling.</u>

5. Position the assembled bomb (without initiator) with the initiator port in the Adapter up. Determine the volume by filling the bomb with water through the initiator port (1 ml. water per 1 cc. volume). To adjust the volume, remove the Adapter and add or subtract Washers, R-42456, as needed (one Washer changes the volume by approximately 0.5 cc.). The Screw, MS 9317-02, should be used during all tests to prevent the threads in the Plug, R-42457, from being damaged.

6. Record the combination of parts used to obtain the desired volume so that the bomb does not have to be calibrated for every test. The bomb should be recalibrated periodically to assure the correct volume.

7. For testing plug-and-shell squibs, strip the leadwires of insulation and solder them to the pins of pressure terminal #3344 making the leads as short as possible (Figure 4). Terminal #3344 is used with Adapter, R-41913 (basic), and O-ring 3-3. Other methods of mounting plug-and-shell squibs in the bomb may be used.

8. When using a gap switch to measure initiator functioning time or to trigger the oscilloscope (used with Body, R-42455 (basic), only), the pins of pressure terminal #3344 may need to be slightly bent away from the Adapter if a plug-and-shell squib is being tested. Connect the trigger switch leads to the oscilloscope trigger input terminals.

9. If the initiator has been temperature conditioned (the bomb assembly need not be conditioned), complete enough of the test setup before removing the initiator from the conditioning chamber so that the initiator can be fired within three minutes after removal from conditioning.

10. CHECK TO ASSURE THAT ALL BOMB PORTS ARE PLUGGED. PLACE THE BOMB IN A STEEL BOX, BEHIND A SHIELD, OR IN A SUITABLE OPERATOR-PROTECTING DEVICE.

11. For evacuated bomb tests, pump down to the desired vacuum and hold the vacuum for a minimum of one minute (temperature conditioned initiators must be fired within three minutes after removal from the conditioning chamber). The vacuum valve should be closed just a few seconds before firing the initiator.

12. Make final instrumentation adjustments, open the camera shutter, fire the initiator with the recommended firing energy, and close the shutter.

13. Slowly bleed the pressure by loosening the Adapter, R-41913. Completely disassemble and clean the bomb after each test. Cleaning may only involve brushing or wiping out the chamber when "clean" initiators are tested, or it may involve using detergents and water to remove material deposited by "dirty" initiators. Avoid scratching the surfaces of the chamber with stiff wire brushes. The chamber should be restored to as near its original condition as possible. The Sleeves (R-41940, R-41940-51, and R-41940-52) which are made from commercial stainless seamless tubing may be replaced periodically to maintain a clean bomb interior. New closed bomb parts should be degreased before using.

14. The bomb assembly should be hydrostatically pressure tested to 5000 psig periodically (depending on the amount of usage) to assure the integrity of the metal parts.

DATA REPORTING

A suggested data reporting sheet is presented in Figure 2.a.1 and a filled-in sample sheet is shown on Figure 2.a.2.

All of the following parameters may not be of interest for a particular application, but the important pressure related parameters are:

1. P_{max} (psia) = (Maximum oscilloscope beam deflection, cm., corrected for reference drift) (calibrated psi/cm.) + P_i, where P_i is the initial bomb pressure, (15 psia for one atm., etc.)

2. t_1 (msec.) = Function time defined as the time interval from input firing current to first indication of pressure rise on the oscilloscope trace.

   (NOTE: The most accurate measurement of function time can be obtained with an electronic counter by measuring the time interval from input current to the closing of the contacts on a foil gap switch mounted adjacent to the initiator closure.)

3. t_2 (msec.) = Rise time or apparent burning time, defined as the time interval from initial pressure rise on the oscilloscope trace to attainment of maximum pressure.

4. $\dot{P}_{dk}$ (psi/msec.) The average slope of the pressure decay curve during the first 10 msec. after maximum pressure. The magnitude of this decay rate gives an indication of the rate of heat transfer out of the bomb, particularly for initiators having a large percentage of condensable vapors.

   (NOTE: Beyond 15 to 20 msec., depending on the magnitude of the initiator heat flux, the Photocon pressure transducer (Item No. 6) Model 401, nonwater-cooled version, will be affected by thermal heating and will indicate a lower-than-actual pressure. Consequently, pressure decay rates beyond about 20 to 30 msec. from firing must be taken with reservations for "hot" initiators.)

In addition to including a copy of the Polaroid oscilloscope pressure versus time picture (or the actual photo) on the data sheet, the pressure-time trace may be replotted on an appropriate scale for comparison with traces from other initiator tests. Figure 2.a.3 shows a sample replot of an oscilloscope trace. Note that the units for pressure are psia.

PROCEDURE 2. b.

CALCULATED PRESSURE OUTPUT OF INITIATORS

PROCEDURE 2. b.

CALCULATED PRESSURE OUTPUT OF INITIATORS

SCOPE

This procedure describes a method of estimating maximum pressure produced by an initiator at various closed bomb volumes using a prediction equation derived from experimental data.

SUMMARY OF METHOD

The procedure consists of deriving a prediction equation for maximum pressure based on one experimentally determined pressure-volume data point and an assumed flame temperature of the burning initiator charge. The equation is used to estimate maximum pressures at various closed bomb volumes.

PROCEDURE

The most accurate prediction equations are derived from relatively large numbers (20 or more) of initiator tests at a fixed closed bomb volume between 15 cc. to 40 cc., depending on the maximum pressure produced by the initiator at the volume. For lower pressure initiators, the best test volume is usually from 15 cc. to 30 cc., while test data for higher pressure initiators should be obtained at volumes of from 25 cc. to 40 cc. The pressure versus volume prediction equation produces a hyperbolic curve with the ends of the curves asymptotic to pressure as the ordinate and volume as the abscissa (Figure 2. b. 1); therefore, at a small test volume, slight errors in volume calibration result in large variations in maximum pressure, whereas the use of large test volumes results in excessive heat losses (thus reduced maximum pressures) to the increased surface area of the bomb cavity walls. The most desirable choice of bomb volume in which to measure initiator pressure is in the region of maximum curvature of the pressure-volume curve.

Using the general prediction equation[1]

$$P_{p2} = (P_{m1} - P_{nf})(V_1/V_2) + P_{nf} \qquad (1)$$

where P_{p2} is the predicted maximum pressure that would be measured at volume V_2, P_{m1} is the actual measured maximum pressure at volume V_1, and P_{nf} is the partial pressure of nitrogen at the initiator flame temperature, derive the prediction equation for the initiator of interest as follows:

1. Determine the final partial nitrogen pressure produced by heating the nitrogen in the closed bomb to the flame temperature of the burning initiator charge using the equation

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1. For derivation of the equation, refer to "Monthly Technical Progress Report--Development of a Standard Comparison Test Procedure for Initiators," 22 December 1964 through 21 January 1965, Thiokol Chemical Corporation-Huntsville Division Control No. U-65-322A, 12 March 1965.

$$P_{nf} = P_{ni} \left(\frac{T_f}{T_i}\right) = 11.7 \left(\frac{T_f}{535}\right). \tag{2}$$

where P_{ni} is the initial partial nitrogen pressure assumed to be 11.7 psia at the initial temperature, T_i, of 535°R. and T_f is the final nitrogen temperature, in °R., assumed to be the same as the flame temperature of the burning initiator charge. The flame temperature of the major initiator charge ingredient may be used as a reasonable estimate of the actual flame temperature.[1] As an example, assuming that the flame temperature of an initiator is 6700°F., the partial nitrogen pressure is found from Equation 2 to be

$$P_{nf} = 11.7 \left(\frac{6,700}{535}\right) = 146 \text{ psia.}$$

2. Substitute the value for P_{nf} determined in the above step into the general prediction Equation 1 to obtain the prediction equation for the initiator of interest. To continue the above example, the prediction equation would be

$$P_{p2} = \left(P_{m1} - 146\right) \left(V_1/V_2\right) + 146.$$

3. Using the average maximum pressure, P_{m1} in psia, measured in several initiator tests (20 or more tests are desirable) at a fixed volume, V_1, reduce the prediction equation derived in Step 2 to two unknowns. For the above example with an average measured pressure of 715 psia at a volume of 30 cc., the prediction equation reduces to

$$P_{p2} = \left(715 - 146\right) \left(30/V_2\right) + 146$$

or

$$P_{p2} = \frac{17,070}{V_2} + 146.$$

4. Generate several data points for chosen volumes from the equation derived in Step 3, plot the points using a convenient scale, and connect the points with a smooth curve. The curve can be used to predict maximum initiator pressure at various closed bomb volumes and should be used as a guide for selecting closed bomb volumes for additional testing. The most desirable choice of bomb volume is in the region of maximum curvature of the pressure-volume curve. As the bomb volume increases significantly, the initial air (nitrogen) in the closed chamber and the interior surfaces of the bomb provide "heat sinks" and cause the actual measured pressures to be lower than the predicted pressure. Figure 2.b.2 is a sample plot illustrating the deviation of measured pressure (of a relatively small initiator) from the prediction curve at large closed bomb volumes. On the other hand, at too small a test volume, small errors in bomb volume calibration result in possible large deviations of measured pressure from the predicted value.

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1. The adiabatic flame temperatures of metal-oxidant mixtures can be calculated by a method given in the following reference: "Metal-Oxidant Igniter Materials," Bulletin of the Second Symposium on Solid Propellant Ignition, Vol. I, October 2 - 4, 1956, CONFIDENTIAL.

PROCEDURE 3.a.

HEAT FLUX OUTPUT OF INITIATORS IN A CLOSED BOMB

PROCEDURE 3. a.

HEAT FLUX OUTPUT OF INITIATORS IN A CLOSED BOMB

SCOPE

This procedure describes a method of determining the heat flux output characteristics of initiators using the TX409-1 closed bomb test fixture (R-42453) with Body, R-42455 (basic). The user of this procedure is assumed to have a fundamental background in the operation of amplifiers, oscilloscopes, and oscilloscope cameras. The calibration and operation of the relatively unique heat flux measuring equipment used in this procedure are described in detail. The thin-film gage (TFG) used as the sensor of temperature changes is not suited for use with highly brisant initiators nor with initiators whose exhaust products contain a large amount of slag or hot particles. Also, the TFG may fail if exposed to hot gas flow continuously for more than 25 milliseconds because of possible failure of its solder joints.[1]

SUMMARY OF METHOD

The heat flux output characteristics of an initiator are determined in this procedure by firing the initiator into a closed bomb test chamber, sensing the transient temperatures at the surface of a heat flux gage during burning of the initiator charge, and converting the temperature versus time signal to heat flux versus time (to the gage surface) by a direct electric analogue method. When only temperature is recorded, use the instrumentation setup described in Procedure 3. c. Initiator heat flux output characteristics can be measured at closed bomb volumes of 20, 30, 40, or 50 cc. (or between volumes).

APPARATUS

The apparatus for the closed bomb heat flux test consists of the following items (refer to Equipment and Materials List, Page 3, for details):

Item No.	Name	Item No.	Name
1	Closed Bomb (Fig. 1)	12	Power Supply, d.c.
2	Oscilloscope	13	Wheatstone Bridge
3	Camera, Oscilloscope	14	Potentiometer
4	Preamplifier, Type K	15	Muffle Furnace
8	Foil Gap Switch & Triggering Circuit (Fig. 2)	16	Pyrometer Controller
10	Thin-Film Gage	17	Thermocouple
11	Heat Rate Analogue Unit	18	Decade Box (2 Req'd)

1. Solder currently used on some thin-film gages melts at 390°F. TFG's with higher melting point solder should be used if available. Also, TFG's with low gage resistances (less than 50 ohms) may hold up better under repeated testing because of their thicker platinum films.

PROCEDURE

Setup and Calibration of Instrumentation

1. Refer to the manufacturers' manuals (Appendix A) for the finer details concerning calibrating, connecting, tuning, and operating the equipment. Use coaxial cabling with UHF or BNC connectors, where possible, for connecting all equipment.

2. Calibrate the thin-film gage (Item No. 10) using the following procedure. Figure 5 shows a suggested data sheet to aid in recording the pertinent gage information. (Figure 6 is a sample of a filled-in data sheet.)

   a. Turn on the muffle furnace (Item No. 15) and the pyrometer controller (Item No. 16) and set the controller at 100°F.

   b. Measure the resistance (within ±.1 ohm) of the thin-film gage at 75 ± 1°F. using the Wheatstone bridge (Item No. 13). It is important that this measurement be accurately made and recorded for later use. This resistance is designated R_g.

   c. Thread the leads of the TFG through a phenolic insulating sleeve approximately 0.5 inch in outside diameter and 10 inches in length and position the TFG so that only the face on the gage protrudes from the sleeve. Use heat resisting tape to hold the gage in place.

   d. Place a copper-constantan thermocouple (Item No. 17) on the phenolic sleeve and position the thermocouple junction so that it is even with the face of the TFG. Use heat resisting tape to hold the thermocouple in place.

   e. Connect the leads of the TFG to the Wheatstone bridge.

   f. Insert the phenolic sleeve, with TFG and thermocouple attached, into the 100°F. furnace (through the small circular opening in the furnace door) and place the TFG and thermocouple next to and in the same plane with the furnace temperature sensing element.

   g. Place the reference junction of the thermocouple in a Dewar flask containing crushed ice made from distilled water and add enough distilled water to cover the reference junction. Connect the open leads of the thermocouple to the potentiometer (Item No. 14). The thermocouple is used to give a more accurate reading of furnace temperature than the pyrometer controller. The furnace temperature should be adjusted so that the thermocouple, not the pyrometer, reads the desired temperature.

   h. Measure the resistance of the TFG at 100 ± 1°F. Make several measurements until the resistance of the TFG remains constant for two to five minutes. Record this value.

   i. Raise the temperature of the muffle furnace to 200, 250, 300, and 350°F. and at each setting allow enough time (two to five minutes) for the TFG resistance to settle out before recording. (Solder currently used on some TFG's melts at 390°F., while others may have higher temperature solder. In any case, calibrate the TFG up to a temperature safely below the melting point of the solder.)

j. Plot the five temperature settings and resistance readings to check the linearity of the TFG and determine the change in gage temperature per degree F. from the slope of the plot (this value, in ohms/°F., is called the gage constant, Φ).[1]

To calibrate the heat rate analogue unit (Item No. 11), a heat flux value, q, within the expected output range of the initiator must be selected. A value of 720 b. t. u. /ft.^{2}-sec. (same as 5 b. t. u. /in.^{2}-sec. or 195 cal. /cm.^{2}-sec.) is usually chosen as representative of the range to be measured. (The units are expressed in b. t. u. /ft.^{2}-sec. because the nomograph, described below and obtained from NASA-Marshall Space Flight Center, Huntsville, Alabama, is in these units.) A calibration resistor, R_c, which simulates the chosen heat flux value (or is its electrical equivalent across the heat rate analogue unit), must be determined using Figure 7. This figure is a nomograph for the following equation:

$$R_c = \frac{10,000}{\Phi\, q}\left[\left(\frac{2000 + R_g}{2100}\right)^2 + \frac{\Phi\, q\,\left(4100 + R_g\right)}{441 \times 10^4}\right] - 100$$

where R_c is in ohms, Φ is in ohms/°F., q is in b. t. u. /ft.^{2}-sec., and R_g, the resistance of the TFG at 75°F., is in ohms.

Following the example given on Page 1 of Figure 7, use the nomograph with the appropriate range for heat flux, q, to obtain the value of R_c equivalent to q. For most cases, locate the 720 b. t. u. /ft.^{2}-sec. point on the left-hand ordinate of the log-log plot given on Page 5 of Figure 7. Move across (towards the right) to the appropriate constant " Φ line, " then vertically (down) to the appropriate constant R_g curve. From the R_g curve, move across (towards the right) to the right-hand ordinate of the figure and read the calibration resistance R_c. (Note the " Φ scale" reading aid on Page 6 of Figure 7.) This value of R_c is the calibration resistance for the analogue circuit. When this value of R_c is used as described in the calibration Steps 3 through 10 (below), the vertical deflection on the oscilloscope for a given R_g and Φ will correspond to 720 b. t. u. /ft.^{2}-sec.

k. Mount the calibrated TFG in a Holder (R-42208) using Figure 8 as a guide.

3. Without turning on the chopper power supply (Item No. 11a), connect it to a 110-volt a. c. outlet and connect the power supply output to the chopper (Item No. 11b). Put the chopper output phone plug into the power supply jack labeled "CHOPPER OFF."

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1. Another (approximate) method of calculating Φ is using the equation $\Phi = \alpha R_g$, where α is the coefficient of thermal expansion (.00125 ohms/ohm-deg. F.) of Liquid Bright #05-X platinum paint, manufactured by Hanovia Chemical & Manufacturing Co., East Newark, N. J., and where R_g is the TFG resistance at 75°F.

4. Connect the heat rate analogue unit (Item 11) connector labeled "SCOPE" through the preamplifier (Item No. 4) to one beam of the oscilloscope (Item No. 2). (If temperature versus time is also to be recorded, connect the connector labeled "TO OR FROM PREAMP." to the other beam through the amplifier (Item No. 9) to the oscilloscope. Use of two different beams of the oscilloscope allows the display of heat flux at one sweep speed and temperature at another sweep speed.)

5. Connect the analogue unit connector labeled "DC VOLTAGE" to the d.c. power supply (Item No. 12) and the analogue unit connector labeled "GAGE" to a decade box (Item No. 18b) set to the same ohmic value as the 75°F. resistance of the TFG (R_g) recorded in Step 2.b., above.

6. Set the other decade box (Item No. 18a) to the exact value of the calibrating resistance (R_c) as determined in Step 2.j., above, and connect the decade box to the chopper.

7. Zero the oscilloscope with the analogue circuit (power supplies) off.

8. Remove the chopper output phone plug from the chopper power supply jack labeled "CHOPPER OFF" and connect it to the analogue jack labeled "CALIBRATE."

9. Turn on the chopper power supply and turn on and set the d.c. power supply output to 50 volts. Adjust the sweep speed of the oscilloscope so that the square wave produced by the chopper will be displayed on the oscilloscope screen.

10. Calibrate the oscilloscope by adjusting the gain to give a 2-cm. peak-to-peak beam deflection for the chosen value of the calibration resistance R_c. The choice of a 2-cm. deflection corresponding to the value of R_c is arbitrary. However, a 2-cm. deflection for a heat flux calibration point of q = 720 b.t.u./ft.^{2}-sec. (5 b.t.u./in.^{2}-sec. or 195 cal./cm.^{2}-sec.) will allow the heat flux trace obtained from most initiators to be distributed across the four active vertical centimeters on the oscilloscope. The scale will be approximately linear over the operational range and will have the following conversion constants per centimeter: either 360 b.t.u./ft.^{2}-sec., 2.5 b.t.u./in.^{2}-sec., or 97.5 cal./cm.^{2}-sec. for each centimeter of vertical deflection on the oscilloscope. The analogue circuit is not linear throughout the total heat flux range, but it is probably within ±15% which is considered to be the reproducibility of the total measuring system.

11. Turn off the analogue circuit (power supplies), disconnect the chopper from the analogue unit jack labeled "CALIBRATE," and connect the chopper output phone plug to the chopper power supply jack labeled "CHOPPER OFF."

    Disconnect the decade box from the analogue unit connector labeled "GAGE."

12. Install the calibrated, mounted TFG in the assembled closed bomb (see Step 4 of Assembly, Calibration, and Use of the Bomb, below) and connect the TFG leads to the analogue unit connector labeled "GAGE."

13. Mount the camera (Item No. 3) on the oscilloscope and load it with Type 47 ASA 3000 Polaroid film. Various types of initiators differ widely in heat flux output characteristics and no one oscilloscope sweep speed setting is appropriate for all tests. A recommended sweep speed for initial tests is 1 millisecond/cm.

Slower recording speeds (such as 5 msec./cm.) or faster recording speeds (such as 0.5 msec./cm.) may be selected as required to assure that the entire initiator functioning period is recorded (the oscilloscope screen is 9 cm. wide). A slow oscilloscope sweep speed requires the use of lower graticule lighting and allows less intensity to be used on the beam (trace). The film exposure time is determined by the duration of the sweep and the persistence of the cathode ray tube phosphor; however, the shutter speed is normally set to bulb (B) and the shutter is manually opened and closed to photograph the initiator firing. With the above in mind, use an aperture opening of f/2 or f/3 to achieve a balance between graticule and oscilloscope beam focus. Beam intensity and duration must be the reference points for camera settings while graticule focus is the by-product.

Adjust the astigmatism and intensity controls of the oscilloscope for a sharp beam.

14. Set the oscilloscope beam for a single sweep.

    Adjust the oscilloscope so that a small signal (on the order of 200 millivolts) impressed across the trigger input terminals will sweep the beam. Select a method of triggering the oscilloscope (Appendix C). A foil gap switch (similar to one described as Item No. 8) or a breakwire (illustrated in Figure 2) should be used to trigger the beam rather than a trigger source provided by the power supply used to fire the initiator. The gap switch gives a more reproducible, faster (less than 2 microseconds delay) performance. Figure 3 schematically illustrates the layout of the instrumentation for measuring heat flux as well as for pressure described in Procedure 2.

Assembly, Calibration, and Use of the Bomb

1. The temperature of the room in which the test is conducted and of the bomb should be between 70°F. and 80°F.

2. IF AN APPROXIMATE MAXIMUM PRESSURE OUTPUT OF THE INITIATOR BEING TESTED IS NOT KNOWN BUT IS EXPECTED TO BE AS HIGH AS 3000 PSIG IN A SMALL VOLUME, MAKE THE INITIAL TEST AT A LARGE VOLUME (SUCH AS 50 cc.) TO ASSURE THAT THE BOMB WORKING PRESSURE OF 3000 PSIG IS NOT EXCEEDED.

   Alternately, the maximum pressure output of the initiator may be estimated for the test volume by the method given in Procedure 2.b., if the maximum pressure output of the initiator is known for some other volume.

3. If the pressure output of the initiator is to be measured concurrently with heat flux, follow Procedure 2.a. using a separate oscilloscope beam for pressure. If temperature is also to be measured along with heat flux, record pressure on the split temperature beam using the sweep speed selected for recording pressure. If pressure is not to be measured, an 18 - 1.5 mm. threaded plug, with O-ring 2-19, may be used to seal the pressure port, or the pressure transducer (Item No. 6) may be used. (The face of the transducer must be coated with zinc chromate putty to protect it from initiator exhaust products.)

4. Using drawing R-42453 (Figure 1) and the following tabulation as guides, assemble the closed bomb test fixture. Lubricate all O-rings with Celvacene.

Nominal Test Volume	Parts
20 cc.	Body, R-42455 Plug, R-42457, with O-ring, 2-28 Plug, MS9015-04, with O-ring, 3-4, or, for vacuum tests, Union, AN815-4C, with O-ring, 3-4, and Vacuum Valve Screw, MS 9317-02 Washer, R-42456, as required Adapter, R-41913--appropriate threads, with O-ring, 2-28, and appropriate O-ring for Initiator Plug, R-42459 Holder, R-42208, with O-ring, 2-12, and O-ring, 2-7 (Normally the TFG is positioned on the centerline of the bomb cavity. Stack two Holders together for centerline positioning. Use one Holder to position the TFG flush with the cavity wall. Use O-rings on all mating parts.) Thin-Film Gage, PTF50-P24-4F, mounted in Holder, R-42208, (Figure 8) Gap Switch, Item No. 8, with O-ring, 3-3, or Breakwire Triggering Device Pressure Transducer, PRP #401, with O-ring, 2-12, or, for no pressure measurement, 18 mm. Plug with O-ring, 2-12
30 cc.	Add Spacer, R-42454, O-ring, 2-28, and Sleeve, R-41940, to 20 cc. Bomb
40 cc.	Add Spacer, R-42454-51, O-ring, 2-28, and Sleeve, R-41940-51, to 20 cc. Bomb
50 cc.	Add Spacer, R-42454-52, O-ring, 2-28, and Sleeve, R-41940-52, to 20 cc. Bomb

Larger volumes can be obtained by attaching various combinations of Spacers together.

Check to see that the Sleeve (R-41940, R-41940-51, and R-41940-52) does not interfere with the thin-film gage and that it does not slide against the gage during subsequent handling.

The platinum strip of the thin-film gage should always be positioned perpendicular to the centerline of the bomb cavity, while the face of the gage should be parallel to the centerline.

5. Position the assembled bomb (without initiator) with the initiator port in the Adapter up. Determine the volume by filling the bomb with water through the initiator port (1 ml. water per 1 cc. volume). To adjust the volume, remove the Adapter and add or subtract Washers, R-42456, as needed (one Washer changes the volume by approximately 0.5 cc.). When testing in a 20 cc. (or less) volume, check to assure that the Washers do not interfere with the thin-film gage. The Screw, MS9317-02, should be used during all tests to prevent the threads in the

Plug, R-42457, from being damaged.

6. Record the combination of parts used to obtain the desired volume so that the bomb does not have to be calibrated for every test. The bomb should be recalibrated periodically to assure the correct volume.

7. For testing plug-and-shell squibs, strip the leadwires of insulation and solder them to the pins of pressure terminal #3344 making the leads as short as possible (Figure 4). Terminal #3344 is used with Adapter, R-41913 (basic), and O-ring, 3-3. Other methods of mounting plug-and-shell squibs in the bomb may be used.

8. When using a gap switch to trigger the oscilloscope, the pins of pressure terminal #3344 may need to be slightly bent away from the Adapter if a plug-and-shell squib is being tested. Connect the trigger switch leads to the oscilloscope trigger input terminals.

9. If the initiator has been temperature conditioned (the bomb assembly need not be conditioned), complete enough of the test setup before removing the initiator from the conditioning chamber so that the initiator can be fired within three minutes after removal from conditioning.

10. CHECK TO ASSURE THAT ALL BOMB PORTS ARE PLUGGED. PLACE THE BOMB IN A STEEL BOX, BEHIND A SHIELD, OR IN A SUITABLE OPERATOR-PROTECTING DEVICE.

11. For evacuated bomb tests, pump down to the desired vacuum and hold the vacuum for a minimum of one minute (temperature conditioned initiators must be fired within three minutes after removal from the conditioning chamber). The vacuum valve should be closed just a few seconds before firing the initiator.

12. Make final instrument adjustments, open the camera shutter, fire the initiator with the recommended firing energy, and close the shutter.

13. Slowly bleed the pressure by loosening the Adapter, R-41913. Completely disassemble and clean the bomb after each test. Cleaning may only involve brushing or wiping out the chamber when "clean" initiators are tested, or it may involve using detergents and water to remove material deposited by "dirty" initiators. Avoid scratching the surfaces of the chamber with stiff wire brushes. The chamber should be restored to as near its original condition as possible. The Sleeves (R-41940, R-41940-51, and R-41940-52) which are made from commercial stainless seamless tubing may be replaced periodically to maintain a clean bomb interior. New closed bomb parts should be degreased before using.

14. Measure the resistance of the TFG at $75 \pm 1°$F. using the Wheatstone bridge and compare this value with the pretest resistance (R_g) obtained in Step 2. b. of Setup and Calibration of Instrumentation, above. The resistance should always return to within 10% of its original value; otherwise, the test results should be voided and the test repeated. If the 75°F. postfiring resistance of a gage has not increased by more than about 60% of its prefiring resistance when "new" and if the platinum strip appears to be relatively unchanged when viewed under a microscope (after washing), the TFG may be reused after it has been recalibrated, as described in Step 2 of Setup and Calibration of Instrumentation, above. If the new gage constant

Φ is not relatively constant over the calibration temperature range, discard the TFG.

15. The bomb assembly should be hydrostatically pressure tested to 5000 psig periodically (depending on the amount of usage) to assure the integrity of the metal parts.

DATA REPORTING

A suggested data reporting sheet is presented in Figure 3.a.1, and a filled-in sample sheet is shown on Figure 3.a.2. In addition to including a copy of the Polaroid oscilloscope heat flux versus time plot (or the actual photo) on the data sheet, the q versus time trace may be replotted on an appropriate scale for comparison with traces from other initiator tests. Figure 3.a.3 shows a sample replot of an oscilloscope trace from the heat rate analogue unit. Note that the heat flux scales are given in both cal./cm.^{2}-sec. units and b.t.u./ft.^{2}-sec. units.

PROCEDURE 3. b.

HEAT FLUX OUTPUT OF INITIATORS IN AN OPEN TUBE

PROCEDURE 3. b.

HEAT FLUX OUTPUT OF INITIATORS IN AN OPEN TUBE

SCOPE

This procedure describes a method of determining the heat flux output characteristics of initiators using an open-tube test fixture.[1] The thin-film gage (TFG) used as the sensor of temperature changes is not suited for use with highly brisant initiators nor with initiators whose exhaust products contain a large amount of slag or hot particles. Also, the TFG may fail if exposed to hot gas flow continuously for more than 25 milliseconds because of possible failure of its solder joints.[2]

SUMMARY OF METHOD

This procedure is the same as described in Procedure 3. a., except for the deviations noted herein. The heat flux output characteristics of an initiator are determined by firing the initiator into an open-tube test fixture, sensing the transient temperature at the surface of a heat flux gage during burning of the initiator charge, and converting the temperature versus time signal to heat flux versus time by a direct electric analogue method. When temperature only is recorded, use the instrumentation setup described in Procedure 3. c.

APPARATUS

The apparatus for the open-tube heat flux test consists of the following items (refer to Equipment and Materials List, Page 3, for details):

Item No.	Name	Item No.	Name
2	Oscilloscope	13	Wheatstone Bridge
3	Camera, Oscilloscope	14	Potentiometer
4	Preamplifier, Type K	15	Muffle Furnace
8	Foil Gap Switch & Triggering Circuit (Fig. 2)	16	Pyrometer Controller
10	Thin-Film Gage	17	Thermocouple
11	Heat Rate Analogue Unit	18	Decade Box (2 Req'd)
12	Power Supply, d. c.	19	Open-Tube Fixture (Fig. 9)

1. This procedure should not be used as a standard method of comparing initiator heat flux output (in the manner that the closed bomb procedure can be used) because no attempt has been made to "standardize" an open-tube test fixture. The fixture (Item No. 19) illustrated in Figure 9 is one version of an open-tube test fixture; the user of this procedure should design a fixture particularly suited for his needs. The inside diameter of the tube should be as close to the exhaust diameter of the initiator as possible, and the thin-film gage should be located at a distance equal to at least five diameters from the initiator. The open-tube fixture is especially useful for studying the closure rupture and one-dimensional gas flow characteristics of an initiator during development.
2. Solder currently used on some thin-film gages melts at 390°F. TFG's with higher melting point solder should be used if available. Also, TFG's with low gage resistances (less than 50 ohms) may hold up better under repeated testing because of their thicker platinum films.

PROCEDURE

Setup and Calibration of Instrumentation

1. Refer to the manufacturers' manuals (Appendix A) for the finer details concerning calibrating, connecting, tuning, and operating the equipment. Use coaxial cabling with UHF or BNC connectors, where possible, for connecting all equipment.

2. Calibrate the thin-film gage (Item No. 10) using the following procedure. Figure 5 shows a suggested data sheet to aid in recording the pertinent gage information. (Figure 6 is a sample of a filled-in data sheet.)

   a. Turn on the muffle furnace (Item No. 15) and the pyrometer controller (Item No. 16) and set the controller at 100°F.

   b. Measure the resistance (within ±.1 ohm) of the thin-film gage at 75 ± 1°F. using the Wheatstone bridge (Item No. 13). It is important that this measurement be accurately made and recorded for later use.

   c. Thread the leads of the TFG through a phenolic insulating sleeve approximately 0.5 inch in outside diameter and 10 inches in length and position the TFG so that only the face of the gage protrudes from the sleeve. Use heat resisting tape to hold the gage in place.

   d. Place a copper-constantan thermocouple (Item No. 17) on the phenolic sleeve and position the thermocouple junction so that it is even with the face of the TFG. Use heat resisting tape to hold the thermocouple in place.

   e. Connect the leads of the TFG to the Wheatstone bridge.

   f. Insert the phenolic sleeve, with TFG and thermocouple attached, into the 100°F. furnace (through the small circular opening in the furnace door) and place the TFG and thermocouple next to and in the same plane with the furnace temperature sensing element.

   g. Place the reference junction of the thermocouple in a Dewar flask containing crushed ice made from distilled water and add enough distilled water to cover the reference junction. Connect the open leads of the thermocouple to the potentiometer (Item No. 14). The thermocouple is used to give a more accurate reading of furnace temperature than the pyrometer controller. The furnace temperature should be adjusted so that the thermocouple, not the pyrometer, reads the desired temperature.

   h. Measure the resistance of the TFG at 100 ± 1°F. Make several measurements until the resistance of the TFG remains constant for two to five minutes. Record this value.

   i. Raise the temperature of the muffle furnace to 200, 250, 300, and 350°F. and at each setting allow enough time (two to five minutes) for the TFG resistance to settle out before recording. (Solder currently used in some TFG's melts at 390°F., while others may have higher temperature solder. In any case, calibrate the TFG up to a temperature safely below the melting point of the solder.)

j. Plot the five temperature settings and resistance readings to check the linearity of the TFG and determine the change in gage temperature per degree F. from the slope of the plot (this value, in ohms/°F., is called the gage constant, Φ).[1]

To calibrate the heat rate analogue unit (Item No. 11), a heat flux value, q, within the expected output range of the initiator must be selected. A value of 720 b.t.u./ft.^{2}-sec. (same as 5 b.t.u./in.^{2}-sec. or 195 cal./cm.^{2}-sec.) is usually chosen as representative of the range to be measured. (The units are expressed in b.t.u./ft.^{2}-sec. because the nomograph, described below and obtained from NASA-Marshall Space Flight Center, Huntsville, Alabama, is in these units.) A calibration resistor, R_c, which simulates the chosen heat flux value (or is its electrical equivalent across the heat rate analogue unit), must be determined using Figure 7. This figure is a nomograph for the following equation:

$$R_c = \frac{10,000}{\Phi q} \left[\left(\frac{2000 + R_g}{2100} \right)^2 + \frac{\Phi q \left(4100 + R_g \right)}{441 \times 10^4} \right] - 100$$

where R_c is in ohms, Φ is in ohms/°F., q is in b.t.u./ft.^{2}-sec., and R_g, the resistance of the TFG at 75°F., is in ohms.

Following the example given on Page 1 of Figure 7, use the nomograph with the appropriate range for heat flux, q, to obtain the value of R_c equivalent to q. For most cases, locate the 720 b.t.u./ft.^{2}-sec. point on the left-hand ordinate of the log-log plot given on Page 5 of Figure 7. Move across (towards the right) to the appropriate constant "Φ line," then vertically (down) to the appropriate constant R_g curve. From the R_g curve, move across (towards the right) to the right-hand ordinate of the figure and read the calibration resistance R_c. (Note the "Φ scale" reading aid on Page 6 of Figure 7.) This value of R_c is the calibration resistance for the analogue circuit. When this value of R_c is used as described in the calibration Steps 3 through 10 (below), the vertical deflection on the oscilloscope for a given R_g and Φ will correspond to 720 b.t.u./ft.^{2}-sec.

k. Mount the calibrated TFG in the holder designated for use with the open-tube fixture.

3. Without turning on the chopper power supply (Item No. 11a), connect it to a 110-volt a.c. outlet and connect the power supply output to the chopper (Item No. 11b). Put the chopper output phone plug into the power supply jack labeled "CHOPPER OFF."

4. Connect the heat rate analogue unit (Item 11) connector labeled "SCOPE" through the preamplifier (Item No. 4) to one beam of the oscilloscope (Item No. 2). (If

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1. Another (approximate) method of calculating Φ is using the equation $\Phi = \alpha R_g$, where α is the coefficient of thermal expansion (.00125 ohms/ohm-deg. F.) of Liquid Bright #05-X platinum paint, manufactured by Hanovia Chemical & Manufacturing Co., East Newark, N.J., and where R_g is the TFG resistance at 75°F.

temperature versus time is also to be recorded, connect the connector labeled "TO OR FROM PREAMP." to the other beam through the amplifier (Item No. 9) to the oscilloscope. Use of two different beams of the oscilloscope allows the display of heat flux at one sweep speed and temperature at another sweep speed.)

5. Connect the analogue unit connector labeled "DC VOLTAGE" to the d. c. power supply (Item No. 12) and the analogue unit connector labeled "GAGE" to a decade box (Item No. 18b) set to the same ohmic value as the 75°F. resistance of the TFG (R_g) recorded in Step 2. b., above.

6. Set the other decade box (Item No. 18a) to the exact value of the calibrating resistance (R_c) as determined in Step 2. j., above, and connect the decade box to the chopper.

7. Zero the oscilloscope with the analogue circuit (power supplies) off.

8. Remove the chopper output phone plug from the chopper power supply jack labeled "CHOPPER OFF" and connect it to the analogue jack labeled "CALIBRATE."

9. Turn on the chopper power supply and turn on and set the d. c. power supply output to 50 volts. Adjust the sweep speed of the oscilloscope so that the square wave produced by the chopper will be displayed on the oscilloscope screen.

10. Calibrate the oscilloscope by adjusting the gain to give a 2-cm. peak-to-peak beam deflection for the chosen value of the calibration resistance R_c. The choice of a 2-cm. deflection corresponding to the value of R_c is arbitrary. However, a 2-cm. deflection for a heat flux calibration point of q = 720 b. t. u. /ft.^{2}-sec. (5 b. t. u. /in.^{2}-sec. or 195 cal. /cm.^{2}-sec.) will allow the heat flux trace obtained from most initiators to be distributed across the four active vertical centimeters on the oscilloscope. The scale will be approximately linear over the operational range and will have the following conversion constants per centimeter: either 360 b. t. u. /ft.^{2}-sec., 2.5 b. t. u. /in.^{2}-sec., or 97.5 cal. /cm.^{2}-sec. for each centimeter of vertical deflection on the oscilloscope. The analogue circuit is not linear throughout the total heat flux range, but it is probably within ±15% which is considered to be the reproducibility of the total measuring system.

11. Turn off the analogue circuit (power supplies), disconnect the chopper from the analogue unit jack labeled "CALIBRATE," and connect the chopper output phone plug to the chopper power supply jack labeled "CHOPPER OFF."

    Disconnect the decade box from the analogue unit connector labeled "GAGE."

12. Install the calibrated, mounted TFG in the open-tube test fixture (see Step 3 of Use of the Open-Tube Test Fixture, below) and connect the TFG leads to the analogue unit connector labeled "GAGE."

13. Mount the camera (Item No. 3) on the oscilloscope and load it with Type 47 ASA 3000 Polaroid film. Various types of initiators differ widely in heat flux output characteristics and no one oscilloscope sweep speed setting is appropriate for all tests. A recommended sweep speed for initial tests is 1 millisecond/cm. Slower recording speeds (such as 5 msec. /cm.) or faster recording speeds (such as 0.5 msec. /cm.) may be selected as required to assure that the entire initiator

functioning period is recorded (the oscilloscope screen is 9 cm. wide). A slow oscilloscope sweep speed requires the use of lower graticule lighting and allows less intensity to be used on the beam (trace). The film exposure time is determined by the duration of the sweep and the persistence of the cathode ray tube phosphor; however, the shutter speed is normally set to bulb (B) and the shutter is manually opened and closed to photograph the initiator firing. With the above in mind, use an aperture opening of f/2 or f/3 to achieve a balance between graticule and oscilloscope beam focus. Beam intensity and duration must be the reference points for camera settings, while graticule focus is the by-product.

Adjust the astigmatism and intensity controls of the oscilloscope for a sharp beam.

14. Set the oscilloscope beam for a single sweep.

    Adjust the oscilloscope so that a small signal (on the order of 200 millivolts) impressed across the trigger input terminals will sweep the beam. Select a method of triggering the oscilloscope (Appendix C). A foil gap switch (similar to one described as Item No. 8) or a breakwire (illustrated in Figure 2) should be used to trigger the beam rather than a trigger source provided by the power supply used to fire the initiator. The gap switch gives a more reproducible, faster (less than 2 microseconds delay) performance. Figure 3 schematically illustrates the layout of the instrumentation for measuring heat flux.

Use of the Open-Tube Test Fixture

1. The temperature of the room in which the test is conducted and of the test fixture should be between 70°F. and 80°F.

2. Assemble the gap switch (Item No. 8) or breakwire device (Figure 2) into the open-tube fixture and connect the leads to the oscilloscope trigger input terminals.

3. The TFG should be securely fastened in place. The TFG may be positioned along the centerline of the tube or flush with the tube wall. The platinum strip should always be positioned perpendicular to the centerline of the fixture.

4. If the initiator has been temperature conditioned (the fixture need not be conditioned), complete enough of the test setup before removing the initiator from the conditioning chamber so that the initiator can be fired within three minutes after removal from conditioning.

5. PLACE THE FIXTURE IN A STEEL BOX, BEHIND A SHIELD, OR IN A SUITABLE OPERATOR-PROTECTING DEVICE.

6. Make final instrument adjustments, open the camera shutter, fire the initiator with the recommended firing energy, and close the shutter.

7. Completely disassemble and clean the fixture after each test. Cleaning may only involve brushing or wiping out the tube when "clean" initiators are tested, or it may involve using detergents and water to remove material deposited by "dirty" initiators. The fixture should be restored to as near its original condition as possible.

8. Measure the resistance of the TFG at $75 \pm 1°F$. using the Wheatstone bridge and compare this value with the pretest resistance (R_g) obtained in Step 2.b of Setup and Calibration of Instrumentation, above. The resistance should always return to within 10% of its original value; otherwise, the test results should be voided and the test repeated. If the 75°F. postfiring resistance of a gage has not increased by more than about 60% of its prefiring resistance when "new" and if the platinum strip appears to be relatively unchanged when viewed under a microscope (after washing), the TFG may be reused after it has been recalibrated as described in Step 2 of Setup and Calibration of Instrumentation, above. If the new gage constant Φ is not relatively constant over the calibration temperature range, discard the TFG.

DATA REPORTING

The suggested data reporting sheet (Figure 3.a.1) given in Procedure 3.a. can also be used for reporting heat flux data from the open-tube test fixture. Because the test fixture for this procedure has not been "standardized," a detailed sketch of the fixture used should always be included with the reported data.

PROCEDURE 3. c.

MEASUREMENT OF TEMPERATURE-TIME HISTORY OF INITIATOR OUTPUT

PROCEDURE 3. c.

MEASUREMENT OF TEMPERATURE-TIME HISTORY OF INITIATOR OUTPUT

SCOPE

This procedure describes a method of measuring the temperature-time history of initiator output when heat flux measurements are not desired. Only the instrumentation setup is covered by this procedure. Procedure 3.a. or 3.b. should be referred to for details concerning the closed bomb or the open-tube test fixture, whichever is used. The thin-film gage (TFG) used as the sensor of temperature changes is not suited for use with highly brisant initiators nor with initiators whose exhaust products contain a large amount of slag or hot particles. Also, the TFG may fail if exposed to hot gas flow continuously for more than 25 milliseconds because of possible failure of its solder joints.[1]

SUMMARY OF METHOD

The temperature-time history of initiator output is determined in this procedure by firing the initiator into a closed bomb test chamber or an open-tube fixture, sensing the transient temperatures at the surface of a heat flux gage during burning of the initiator charge, and recording the signal on an oscilloscope. Because of the complications involved in converting temperature versus time to heat flux versus time, this procedure should be used only when a heat rate analogue unit is not available for direct conversion of temperature-time to heat flux-time.[2]

APPARATUS

The apparatus for the temperature-time measurement of initiator output consists of the following items (refer to Equipment and Materials List, Page 3, for details):

Item No.	Name	Item No.	Name
1 or 19	Closed Bomb (Fig. 1) Open-Tube Fixture (Fig. 9)	13	Wheatstone Bridge
		14	Potentiometer
2	Oscilloscope	15	Muffle Furnace
3	Camera, Oscilloscope	16	Pyrometer Controller
8	Foil Gap Switch & Triggering Circuit (Fig. 2)	17	Thermocouple
9	Amplifier, Dual Trace Plug-in Unit	18	Decade Box (2 Req'd)
10	Thin-Film Gage	20	Bridge Circuit (Fig. 10)

1. Solder currently used on some thin-film gages melts at 390°F. TFG's with higher melting point solder should be used if available. Also, TFG's with low gage resistances (less than 50 ohms) may hold up better under repeated testing because of their thicker platinum films.
2. Refer to "Final Report--Development of a Standard Comparison Test Procedure for Initiators," Thiokol Chemical Corporation, Huntsville Division, Report No. U-65-23A May, 1965, for methods of converting temperature-time data to heat flux-time data.

PROCEDURE

Setup and Calibration of Instrumentation

1. Refer to the manufacturers' manuals (Appendix A) for the finer details concerning calibrating, connecting, tuning, and operating the equipment. Use coaxial cabling with UHF or BNC connectors, where possible, for connecting all equipment.

2. Calibrate the thin-film gage (Item No. 10) by the method described in Step 2 of Setup and Calibration of Instrumentation in Procedure 3.a. Mount the calibrated TFG in the appropriate holder or fixture.

3. Calibrate the bridge circuit (Item No. 20) — oscilloscope (Item No. 2) system using the following procedure:

   a. Connect the bridge circuit terminals labeled "SCOPE" to one beam of the oscilloscope (through the amplifier (Item No. 9)) using coaxial cable. (If the closed bomb is used and pressure is to be measured, use separate oscilloscope beams for pressure and temperature.)

   b. Connect a decade box (Item No. 18b) to the bridge circuit terminals labeled "TFG."

   c. Estimate the total resistance change expected when the initiator is fired. Estimation of the resistance change is very difficult, but a few general statements will help. Usually, a "hot" output initiator will change the resistance of the TFG by about 100% during the test; a "medium" output initiator will change the resistance about 60% during the test; and a "soft" output initiator will change the resistance about 40% during the test. With this in mind, the system should be calibrated for 4 centimeters total deflection using 15 to 20 ohms/cm. deflection for "hot" initiators, 10 to 15 ohms/cm. deflection for "medium" initiators, and 5 to 10 ohms/cm. for "soft" initiators. Generally, it is better to calibrate for a much higher resistance change than expected for the first test.

   d. Set the decade box to the resistance of the TFG measured in Step 2 plus 25% of the total resistance change estimated in the above step. Calibrate the oscilloscope for 1 centimeter deflection.

   e. Repeat Step 3.d. setting the decade box to the resistance of the TFG plus 50% of the total expected resistance change, TFG resistance plus 75% of the resistance change, and TFG resistance plus 100% of the resistance change and calibrating the oscilloscope for 2, 3, and 4 centimeters deflection, respectively.

4. Remove the decade box from the circuit, install the TFG in the test fixture (see Step 2 of Assembly, Calibration, and Use of the Test Fixture, below), and connect the TFG leads to the bridge circuit terminals labeled "GAGE."

5. Set up and adjust the camera (Item No. 3), oscilloscope, and triggering system following the procedure given in Steps 13 and 14 of Setup and Calibration of Instrumentation in Procedure 3.a. Either select the same oscilloscope beam

sweep speed used for pressure or select a slower or faster sweep as desired. Figure 11 schematically illustrates the layout of the instrumentation for measuring temperature.

Assembly, Calibration, and Use of the Test Fixture

1. The temperature of the room in which the test is conducted and of the fixture should be between 70°F. and 80°F.

2. Use the appropriate procedures (Procedure 3.a. or Procedure 3.b.) to assemble and calibrate the closed bomb or open-tube test fixture, whichever is used. OBSERVE THE SAFETY PRECAUTIONS NOTED IN THESE PROCEDURES.

3. If the closed bomb is used and pressure is to be measured, use separate oscilloscope beams for pressure and temperature.

4. IF THE CLOSED BOMB IS USED, CHECK TO ASSURE THAT ALL PORTS ARE PLUGGED. PLACE THE TEST FIXTURE IN A STEEL BOX, BEHIND A SHIELD, OR IN A SUITABLE OPERATOR-PROTECTING DEVICE.

5. Make final instrument adjustments, open the camera shutter, fire the initiator with the recommended firing energy, and close the shutter.

6. Measure the resistance of the TFG at 75 ± 1°F. using the Wheatstone bridge and compare this value with the pretest resistance. The resistance should always return to within 10% of its original value; otherwise, the test results should be voided and the test repeated. If the 75°F. postfiring resistance of the gage has not increased by more than 60% of its prefiring resistance when "new" and if the platinum strip appears to be relatively unchanged when viewed under a microscope (after washing), the TFG may be reused after it has been recalibrated as described in Step 2 of Setup and Calibration of Instrumentation in Procedure 3.a. If the new gage constant Φ is not relatively constant over the calibration temperature range, discard the TFG.

DATA REPORTING

A suggested data reporting sheet is presented in Figure 3.c.1 and a filled-in sample sheet is shown in Figure 3.c.2. The following parameters should be recorded:

1. T_{max} (°F.) = (Maximum oscilloscope beam deflection, cm., corrected for reference drift) (calibrated °F./cm.) where the value for the calibrated °F./cm. is obtained by multiplying the calibrated ohms/cm. (Steps 3.c. through 3.e. of Setup and Calibration of Instrumentation, above) by the inverse of the gage constant, $1/\Phi$, in °F./ohm.

2. $t_{T_{max}}$ (msec.) = Time to maximum temperature defined as the time interval from first indication of temperature rise to T_{max}.

In addition to including a copy of the Polaroid oscilloscope temperature versus time picture (or the actual photo) on the data sheet, the temperature-time trace may be replotted on an appropriate scale for comparison with traces from other initiator tests. Figure 3.c.3 shows a sample replot of an oscilloscope trace.

PROCEDURE 4. a.

INERT-PELLET BREAKUP TEST

PROCEDURE 4. a.

INERT-PELLET BREAKUP TEST

SCOPE

This procedure describes a qualitative method of comparing the relative brisance of two or more initiators based on the amount of damage sustained by inert igniter pellets used as targets for the initiators. The test is not recommended as a routine standard procedure, but is suited for "first look" comparisons of initiator brisance.

SUMMARY OF METHOD

The relative brisance of two or more initiators is compared in this procedure by firing the initiators into charges of inert igniter pellets and determining the amount of damage sustained by the pellets. If a particular application for the initiators is of interest, the initiators can be compared utilizing actual igniter hardware and inert pellets with the same physical properties, shapes, and sizes as the active pellets.[1] Additional information can be obtained concurrently by instrumenting the inert-pellet test chamber for pressure measurements.

MATERIALS

Items Nos. 22, 23, and 24 of the Equipment and Materials List, Page 3, describe suggested inert-pellet test fixtures and inert versions of two types of igniter pellets; Al-$KClO_4$ (ALCLO) pellets and B-KNO_3 (2A and 2D) pellets. Inert versions of other pellets may also be used.

PROCEDURE

1. For use in later correlations, determine the crush strength (longitudinal and axial) and density of the inert pellets. These properties and the shape and size of the inert pellet should be as near the same as possible to those of the active pellet.

2. Assemble the inert-pellet test fixture. For comparison tests (when no particular igniter application is being evaluated), test setups similar to those illustrated in Figures 12 and 13 may be used. If the initiators are to be compared in the actual igniter hardware, at least the pellet charge portion of the igniter hardware, with inert pellets, should be assembled in the same manner as the active igniter. The choice of quantity and type of inert pellets depends on the availability of materials and on the expected "brisance" of the initiators being tested. Generally, for more brisant output initiators, better results are obtained with larger quantities of inert pellets. Record the total weight, in grams, of inert pellets.

3. PLACE THE ASSEMBLED INERT-PELLET TEST FIXTURE IN A STEEL BOX, BEHIND A SHIELD, OR IN A SUITABLE OPERATOR-PROTECTING DEVICE.

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1. The physical properties of active pellets may be extremely difficult, if not impossible, to duplicate with inert pellets; therefore, direct application of inert-pellet breakup test data to actual pellets may not be possible.

4. Some arrangement should be made to "catch" broken pieces of igniter pellets blown out of the test fixture (or igniter).

5. If igniter chamber pressure is measured concurrently, make final instrument adjustments and fire the initiator(s) with the recommended firing energy.

6. Disassemble the test fixture and sift the inert pellets remaining in the fixture and those blown out of the fixture through a U. S. Standard No. 12 (0.0661-inch grid) sieve. Record the weight, in grams, of pellets.

7. Calculate the ratio of the weight of pellets passing through the sieve to the total weight of pellets loaded into the fixture. This ratio is called the "fine fraction" and may be expressed as a percentage.

8. Visually inspect the inert-pellet charge and separate any pellet which is cracked, chipped, or otherwise reduced in size.

9. Calculate the ratio of the weight of pellets passing through the sieve (see Step 6) to the weight of damaged pellets (total loaded weight minus weight of undamaged pellets). This ratio is called the "degree of damage" and may be expressed as a percentage.

10. Repeat the test for the other initiator(s). The number of tests to conduct is left to the discretion of the user; however, at the very minimum, no less than two tests should be made with each initiator. Do not reuse the inert pellets.

ANALYSIS OF DATA

Compare the "fine fraction" and "degree of damage" ratios obtained for the initiators. As with any qualitative test, much of the data analysis is left to the judgment and experience of the procedure user. In addition to using the results of inert-pellet breakup test data to compare the brisance of initiators, the results may also be used to estimate increases in igniter chamber pressure due to initiator-damaged pellets. An estimate of the increase in pellet surface area can be obtained based on the sizes of the broken pellets as determined by using a certain size sieve to measure the weight of shattered pellets. Corresponding increases in "steady state" pressure can be estimated using the K_N (Pellet Surface Area/Igniter Vent Area) relationship for the pellet. Although such estimates are rough and usually result in conservative estimates, any information which can be used to determine the relationship between pellet burning-surface area increases due to initiator "shock" output and corresponding igniter overpressure is valuable. Use of the inert-pellet breakup test data to estimate igniter overpressures is illustrated by way of the following example:

Given A pellet tube igniter containing a 60-gram 2A (boron-potassium nitrate) pellet charge (See Figure 14) utilizes a mild squib X, with almost no shock output, for initiation. It is desired to substitute squib Y for squib X. Squib Y is known to have a relatively high "shock" output, but produces a maximum pressure in a closed bomb equal to that of squib X. The igniter tube has 165 vent holes, each having a diameter of 0.13 inch (0.0137 in.^{2} area) with a total orifice area of 2.1890 in.^{2}. The surface area of a 2A pellet is 0.0736 in.^{2} and one gram of charge contains 15.3 pellets.

Problem To estimate the increase in igniter pressure resulting from the use of the more brisant squib Y.

Solution By knowing the value of

$$K_N = \frac{\text{Total Surface Area of Pellets}}{\text{Total Orifice Area}}$$

an estimate of peak igniter pressure can be obtained from the plot of K_N versus chamber pressure for B-KNO_3 pellets[1] shown in Figure 4.a.1. For this example:

$$\text{initial } K_N = \frac{(60 \text{ gm.})(15.3 \text{ pellets/gm.})(0.0736 \text{ in.}^2\text{/pellet})}{2.1890 \text{ in.}^2}$$

$$\text{initial } K_N = \frac{(918)(0.0736) \text{ in.}^2}{2.1890 \text{ in.}^2} = \frac{67.5933}{2.1890}$$

$$\text{initial } K_N = 30.88$$

and an igniter chamber pressure of 430 psia is obtained from Figure 4.a.1.

Squib Y is fired into 60 grams of inert 2A pellets (assumed to have physical properties equal to those of active 2A pellets) loaded into a 165-vent-hole igniter tube and 6 grams of pellets are shattered enough to pass through a No. 12 (0.0661-inch grid) sieve. A conservative estimate of the increase in maximum pressure of the igniter can be determined from (1) the weight of material passing through the sieve and (2) certain assumptions about the least increase in surface area of the material that passes through the sieve. Because the radius of a 2A pellet is approximately equal to the grid size of the sieve, assume that the largest chunk of 2A pellet that can pass through the 0.0661-inch grid is a longitudinal quarter section of the pellet. To quarter a 2A pellet requires two orthogonal slices generating an increase in surface area of:

$$A_{incr} = 8 \, r \, L$$

where 8 is the number of new faces created of width r (radius of pellet) and length L (length of pellet). For

$$r = d/2 = 0.0625 \text{ in. and } L = 0.1875 \text{ in.,}$$

$$A_{incr} = (8)(0.0625)(0.1875) = 0.0938 \text{ in.}^2.$$

1. Stokes, B. B. and Webb, G. E., "Literature Survey Report--Standard Initiator Test Procedure," Thiokol Chemical Corporation, Huntsville Division, Report No. 4486-64, May, 1964, p. B44. CONFIDENTIAL

Therefore, the percentage increase in area (% A_{incr}) for the 6 grams of shattered pellets compared to the original 60 grams of pellets is:

$$\% A_{incr} = \frac{(6 \text{ gm.})(15.3 \text{ pellets/gm.})(0.0938 \text{ in.}^2\text{/pellet})}{(60 \text{ gm.})(15.3 \text{ pellets/gm.})(0.0736 \text{ in.}^2\text{/pellet})}$$

$$\% A_{incr} = 12.7\% \text{ or } A_{new} = 1.127 A_{original}.$$

Consequently, the new value of K_N will be:

$$K_{N_{new}} = 1.127 K_{initial} = 1.127 (30.88) = 34.8.$$

From Figure 4.a.1, the peak igniter chamber pressure corresponding to K_N = 34.8 is 510 psia or an increase of about 20% in pressure because of the increase in pellet burning surface area. To find the absolute percentage increase, the pressure of the initiator would have to be taken into account. Although this analysis can obviously not give an exact answer to the question "What is the increase in igniter pressure resulting from pellet breakup?", it is an estimate of increase in pressure assuming a minimum possible increase in the surface area of the material that passed through the No. 12 sieve. A visual inspection of the actual crushed pellets that passed through the sieve shows that the average particle size is much smaller than a quarter section of the original 2A pellet. Consequently, the burning-surface area increase is somewhat greater than the above minimum estimate and the subsequent increase in pressure is greater than 20%. Another estimate of pressure (also on the low side) can be obtained by assuming that the 2A pellet is quartered down the centerline and cut into three equal pieces longitudinally. The subsequent area increase gives approximately 28% increase in pressure.

PROCEDURE 4. b.

GLASS-BLOCK TEST

PROCEDURE 4. b.

GLASS-BLOCK TEST

SCOPE

This procedure describes a qualitative method of comparing the relative brisance of two or more initiators based on the sizes of cavities formed in blocks of foamed glass used as targets for the initiators. The test is not recommended as a routine standard procedure, but is suited for "first look" comparisons of initiator brisance.

SUMMARY OF METHOD

The relative brisance of two or more initiators is compared in this procedure by firing the initiators into blocks of foamed glass and using the depths and volumes of the resulting cavities as estimates of the relative "shock" output of the initiators.

MATERIALS

Items Nos. 25 and 26 of the Equipment and Materials List, Page 3, describe a suggested glass-block test fixture (Figure 15) and the glass block which are used in this procedure.

PROCEDURE

1. Assemble the glass-block test fixture. The fixture should confine the glass block on all sides to minimize the errors caused by shifting of the block during testing. The initiators must be held firmly against the block. Highly "brisant" initiators may require a block of foamed glass larger than the suggested four-inch cube. The test setup should be identical for each comparison test.

2. PLACE THE ASSEMBLED GLASS-BLOCK TEST FIXTURE IN A STEEL BOX, BEHIND A SHIELD, OR IN A SUITABLE OPERATOR-PROTECTING DEVICE.

3. Fire the initiator with the recommended firing energy.

4. Disassemble the test fixture and visually inspect the glass block to ascertain its condition. If the block is badly cracked, the test may be repeated with lead foil or some other material between the initiator and the block to attenuate the initiator output.

5. Determine the depth and the volume of the cavity. The volume may be measured by a sand or water displacement method.

6. Repeat the test for the other initiator(s) using the same test setup. The number of tests to conduct is left to the discretion of the user; however, at the very minimum, two tests should be made with each initiator.

ANALYSIS OF DATA

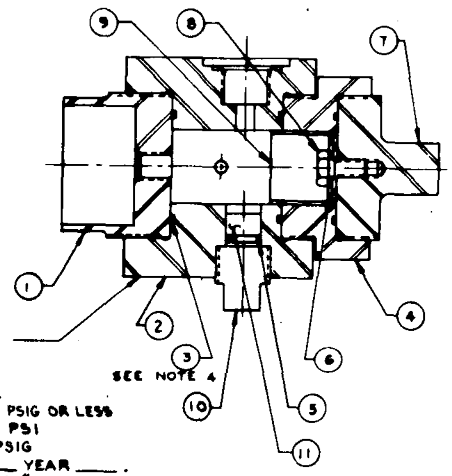
Compare the depths and volumes of the cavities created in the glass block by the initiators. As with any qualitative test, much of the data analysis is left to the judgment and experience of the procedure user. The results of the glass-block test may be expected to exhibit the following characteristics:

1. If the glass block is completely shattered by the initiator and it is impossible to measure a cavity depth or volume, the fact that the block was shattered still gives a comparative indication of initiator brisance.

2. Initiators which emit a large amount of hot particles may cause excessive cavities--not because of brisant outputs, but because the hot particles melt some of the glass block.

3. Measuring errors may be expected to be large for small cavity displacements; therefore, the outputs of the initiators may best be compared by visually inspecting the glass blocks.

R42453



APPLY THE FOLLOWING
NOTE PER TCC SP-113
TYPE I, CLASS 1
"ASSY R42455-SN ____
WORKING PRESSURE 3000 PSIG OR LESS
YIELD PRESSURE 6000 PSI
HYDROTESTED TO ____ PSIG
ON MONTH ____ DAY ____ YEAR ____.
THIOKOL CHEMICAL CORP."

DATE APPROVED 1-17-62
CLEARED
HUNTSVILLE PLANT
OTC APPROVAL NO. 5191

SYM	DESCRIPTION	ZONE	DRWN	DATE	CHD	USER	RE	PM	EDR
	SEE EO								
A	SEE EO								

QTY REQD	PART OR IDENTIFYING NO.	CODE IDENT	NOMENCLATURE OR DESCRIPTION	SPECIFICATION	MATERIAL OR NOTE	UNIT WT	ZONE	ITEM NO.
	3344		PRESSURE TERMINAL	HOLEX INC. HOLLISTER CALIF.	SEE NOTE 2,3			REF
	2-7-N219-7		O-RING	PARKER SEAL CO. CLEVELAND OHIO	SEE NOTE 2,3,12			REF
	3-8-N219-7		O-RING	PARKER SEAL CO. CLEVELAND OHIO	SEE NOTE 2,3,11			REF
	3-7-N219-7		O-RING	PARKER SEAL CO. CLEVELAND OHIO	SEE NOTE 2,3,10			REF
	3-6-N219-7		O-RING	PARKER SEAL CO. CLEVELAND OHIO	SEE NOTE 2,3,9			REF
	3-5-N219-7		O-RING	PARKER SEAL CO. CLEVELAND OHIO	SEE NOTE 2,3,8			REF
	3-4-N219-7		O-RING	PARKER SEAL CO. CLEVELAND OHIO	SEE NOTE 2,3,7			REF
	3-3-N219-7		O-RING	PARKER SEAL CO. CLEVELAND OHIO	SEE NOTE 2,3,6			REF
	2-19-N219-7		O-RING	PARKER SEAL CO. CLEVELAND OHIO	SEE NOTE 2,3,5			REF
	AN815-4C		UNION-FLARED TUBE		SEE NOTES 2,3			REF
	MS9015-031-04		PLUG MACHINE		SEE NOTES 2,3			REF
			BALL VALVE, VACUUM		SEE NOTES 1,2			REF
	401		PRESSURE TRANSDUCER	PHOTOCON RESEARCH PROD. PASADENA CALIF.	SEE NOTES 2			REF
1	R42208-51		HOLDER		SEE NOTE 2			11
1	R42208		HOLDER					11
1	R42459		PLUG					10
1	R41940-52		SLEEVE					9
1	R41940-51		SLEEVE					9
1	R41940		SLEEVE					9
1	MS9517-02		SCREW, SLOTTED HEX HEAD					8
1	R42457		PLUG					7
AR	R42456		WASHER					6
1	2-12-N219-7		O-RING	PARKER SEAL CO. CLEVELAND OHIO				5
					R42453			
1	R42454-52		SPACER					4
1	R42454-51		SPACER					4
1	R42454		SPACER					4
AR	2-28-N219-7		O-RING	PARKER SEAL CO. CLEVELAND OHIO				3
1	R42455-51		BODY					2
1	R42455		BODY					2
1	R41913-56		ADAPTER					1
1	R41913-55		ADAPTER					1
1	R41913-54		ADAPTER					1
1	R41913-53		ADAPTER					1
1	R41913-52		ADAPTER					1
1	R41913-51		ADAPTER					1
1	R41913		ADAPTER		SEE NOTE 2			1

LIST OF MATERIAL OR PARTS LIST

12. USE WITH R42208.
11. USE WITH R41913-54 & R41913-55.
10. USE WITH R41913-56
9. USE WITH R41913-53.
8. USE WITH R41913-52.
7. USE WITH MS9015-04, AN815-4C AND R41913-51.
6. USE WITH MS9015-03 AND R41913.
5. USE WITH TRANSDUCER.
4. LUBRICATE ALL O-RINGS WITH CELVACENE LUBRICANT (MED.) CONSOLIDATED VACUUM CO. ROCHESTER, NEW YORK.
3. THESE PARTS ARE SUPPLIED WITH THIS ASSEMBLY.
2. THE COMBINATION AND QUANTITY OF PARTS FORMING AN ASSEMBLY SHALL BE DETERMINED AND RECORDED BY USER.
1. JAMESBURY CORP. WORCESTER, MASS. 1/4 HT(HV) 36M (REINFORCED TEFLON) TYPE 316 STAINLESS STL. OR EQUAL.

NOTES:

UNLESS OTHERWISE SPECIFIED ALL DIMENSIONS ARE IN INCHES

MATERIAL

OTC APPROVAL REQD

Thiokol CHEMICAL CORPORATION
HUNTSVILLE DIVISION—HUNTSVILLE PLANT HUNTSVILLE, ALABAMA

CLOSED BOMB ASSY

CODE IDENT NO. 02266 | SIZE C | R42453
SCALE 1/1 | WEIGHT | SHEET 1 OF 1

Figure 1. TX409-1 Closed Bomb Test Fixture

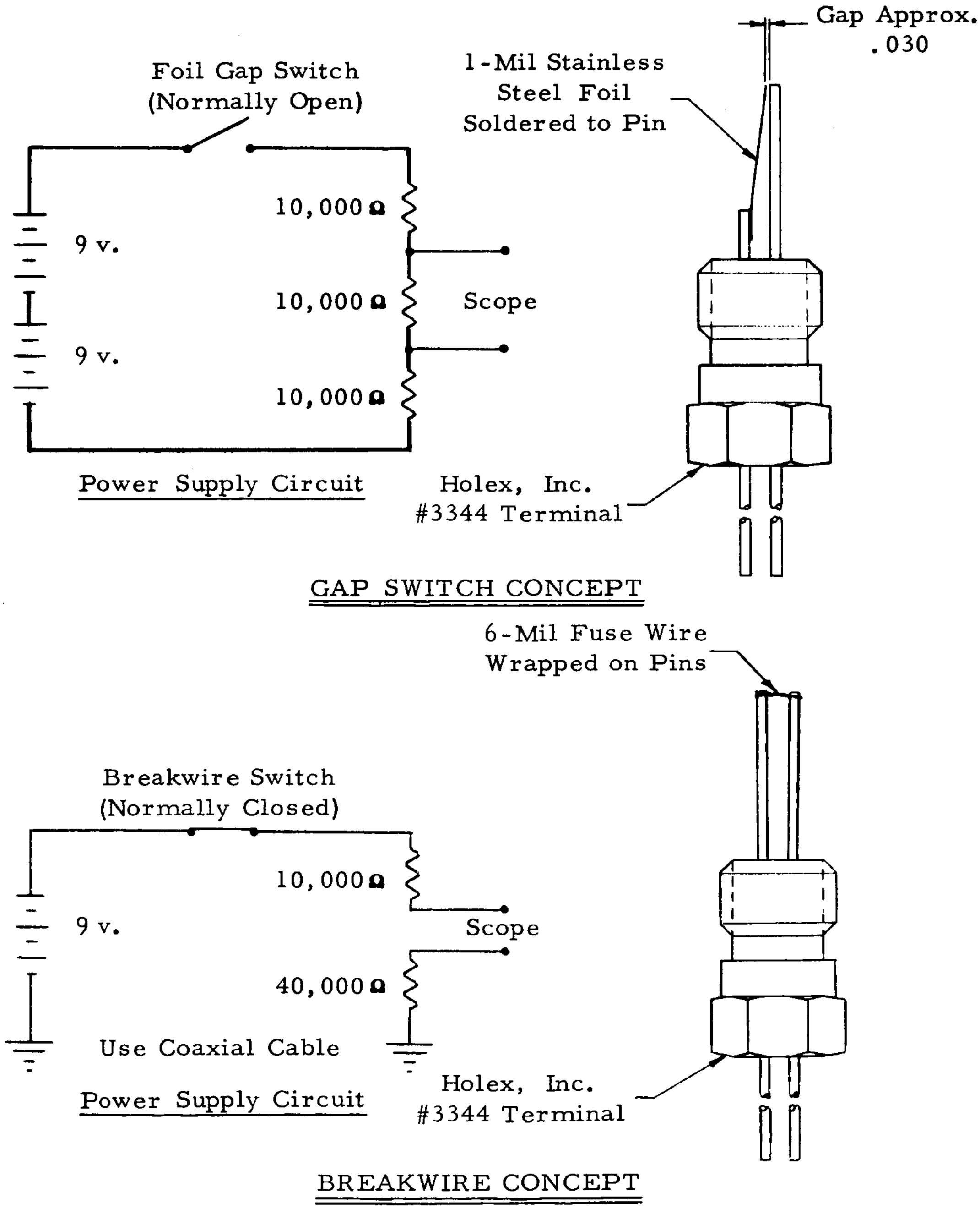
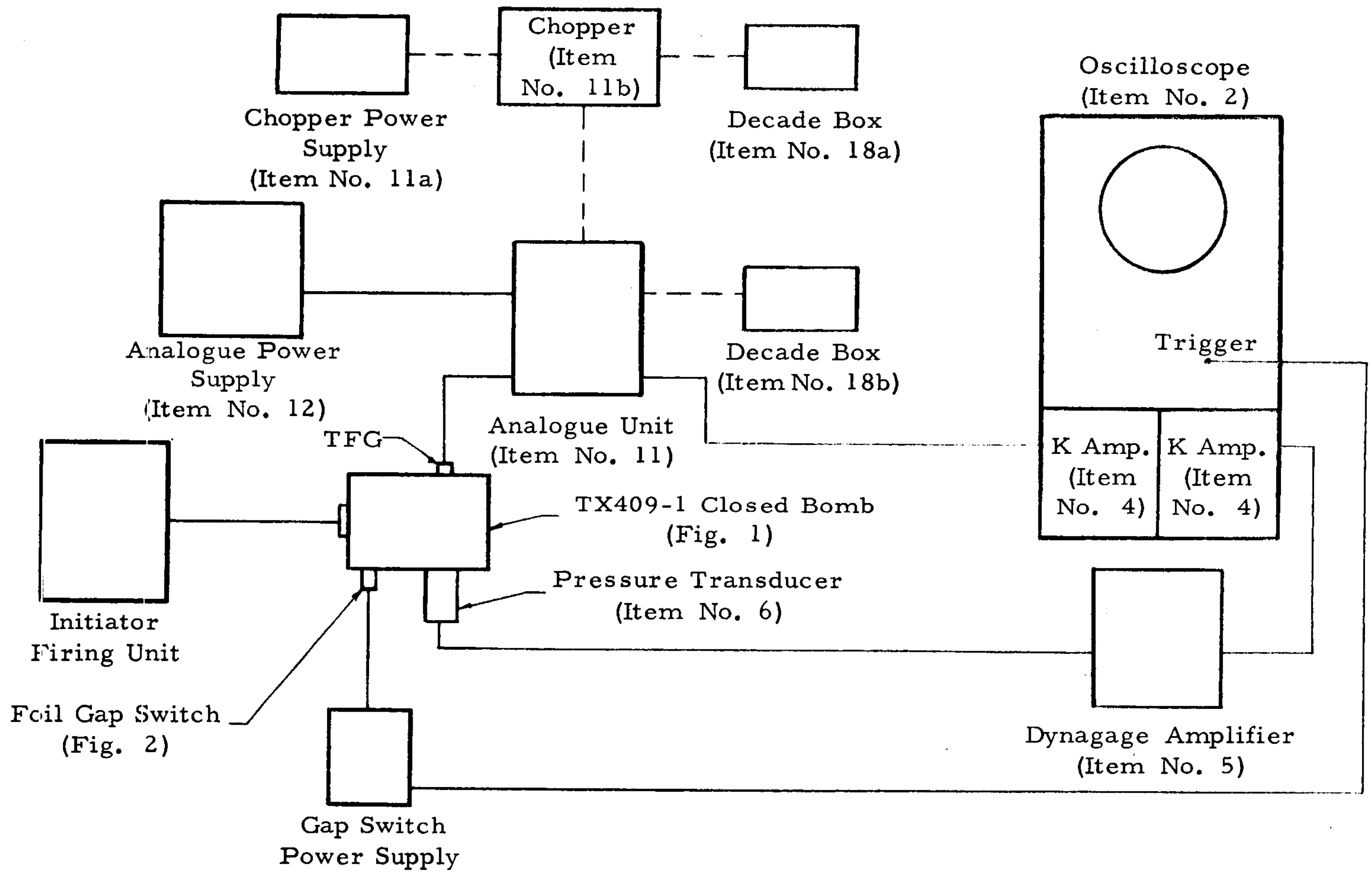


Figure 2. Foil Gap Switch and Triggering Circuit
(Alternate Breakwire Concept)



NOTE: Equipment connected to analogue unit with dotted line is used for calibration only.

Figure 3. Schematic Layout of Pressure and Heat Flux Measuring Apparatus

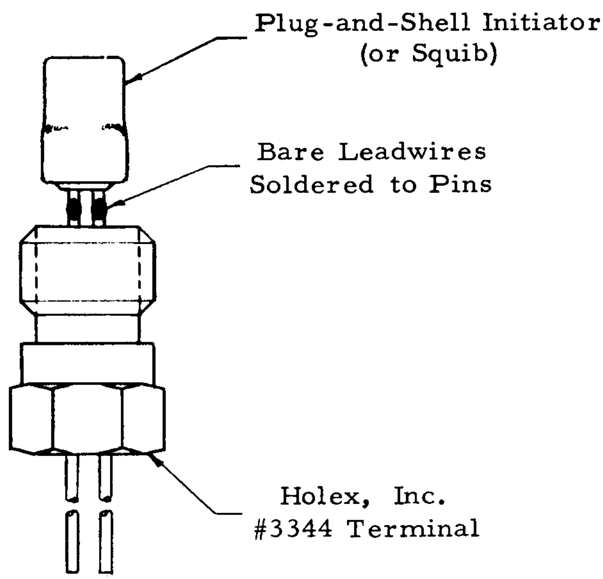


Figure 4. Method of Mounting a Plug-and-Shell Initiator for Closed Bomb Testing

DATA SHEET FOR
DETERMINATION OF THIN-FILM GAGE CONSTANT ♦

(Plot a curve of temperature versus resistance for each set of data to obtain ♦)

Date____________________

Operator____________________

	Gage No.	a n								b ♦
Gage Temperature			R_g 75°F.	100°F.	150°F.	200°F.	250°F.	300°F.	350°F.	Ω/°F.
Gage Resistance										
Gage Temperature										
Gage Resistance										

a. Number of times the gage has been calibrated to determine a ♦ value. (Gage may be recalibrated until the value of ♦ ceases to be a constant between 75°F. and 400°F. Do not use the TFG after the 75°F., postfiring resistance has been increased 60% unless the temperature versus change in resistance curve is a straight line.)

b. ♦ is obtained by plotting the above temperature versus time data and determining the average slope of the line so the units will be ohms/°F.

Figure 5. Suggested Data Sheet for Determining Thin-Film Gage Constant ♦

DATA SHEET FOR
DETERMINATION OF THIN-FILM GAGE CONSTANT Φ

(Plot a curve of temperature versus resistance for each set of data to obtain Φ)

Date 17 Nov 64

Operator R.M. LATTA

	Gage No.	n [a]								Φ [b]
Gage Temperature	12	1	R_g 75°F.	100°F.	150°F.	200°F.	250°F.	300°F.	350°F.	Ω/°F.
Gage Resistance			38 Ω	40 Ω	42.6 Ω	44.9 Ω	47.1 Ω	49.2 Ω	51.5 Ω	.046
Gage Temperature										
Gage Resistance										

a. Number of times the gage has been calibrated to determine a Φ value. (Gage may be recalibrated until the value of Φ ceases to be a constant between 75°F. and 400°F. Do not use the TFG after the 75°F., postfiring resistance has been increased 60% unless the temperature versus change in resistance curve is a straight line.)

b. Φ is obtained by plotting the above temperature versus time data and determining the average slope of the line so the units will be ohms/°F.

Figure 6. Sample Filled-In Copy of Figure 5

"q" Minimum to 0.5 b.t.u./ft.^{2}-sec.

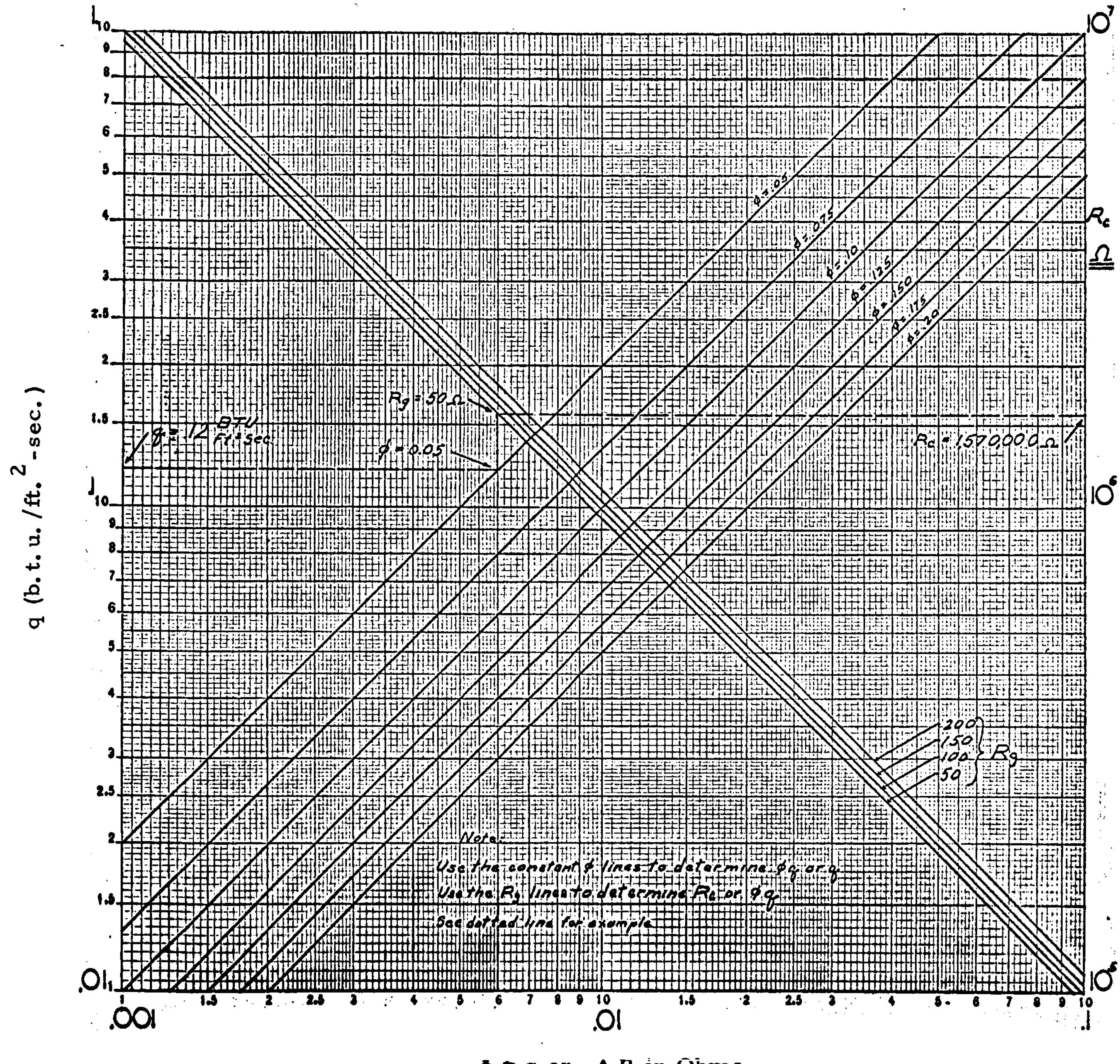


Figure 7. Nomograph for Determining Heat Flux Calibration Resistance, R_c

"q" 0.2 to 5 b.t.u./ft.^{2}-sec.

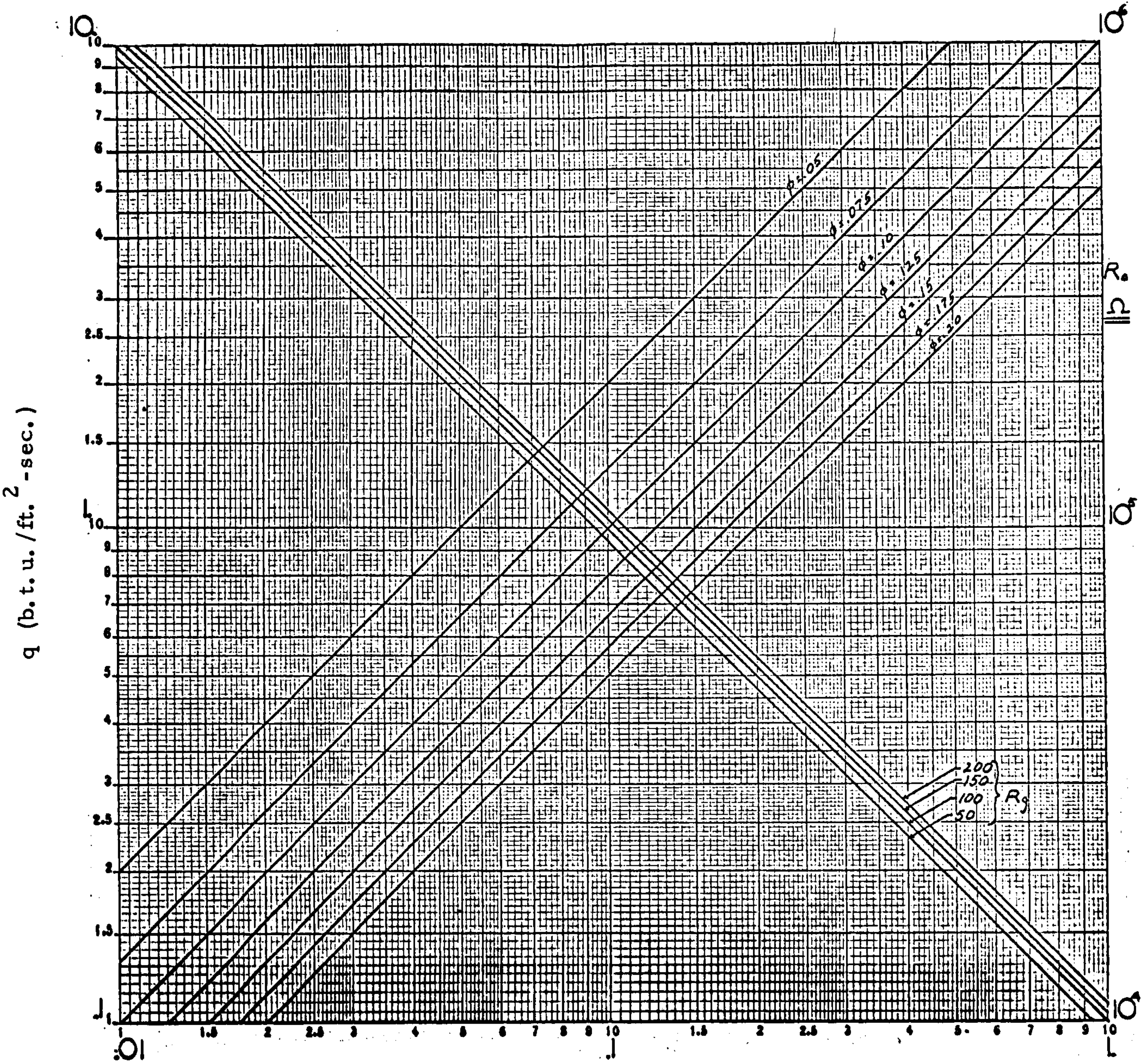


Figure 7. (Continued)

"q" 2 to 50 b.t.u./ft.^{2}-sec.

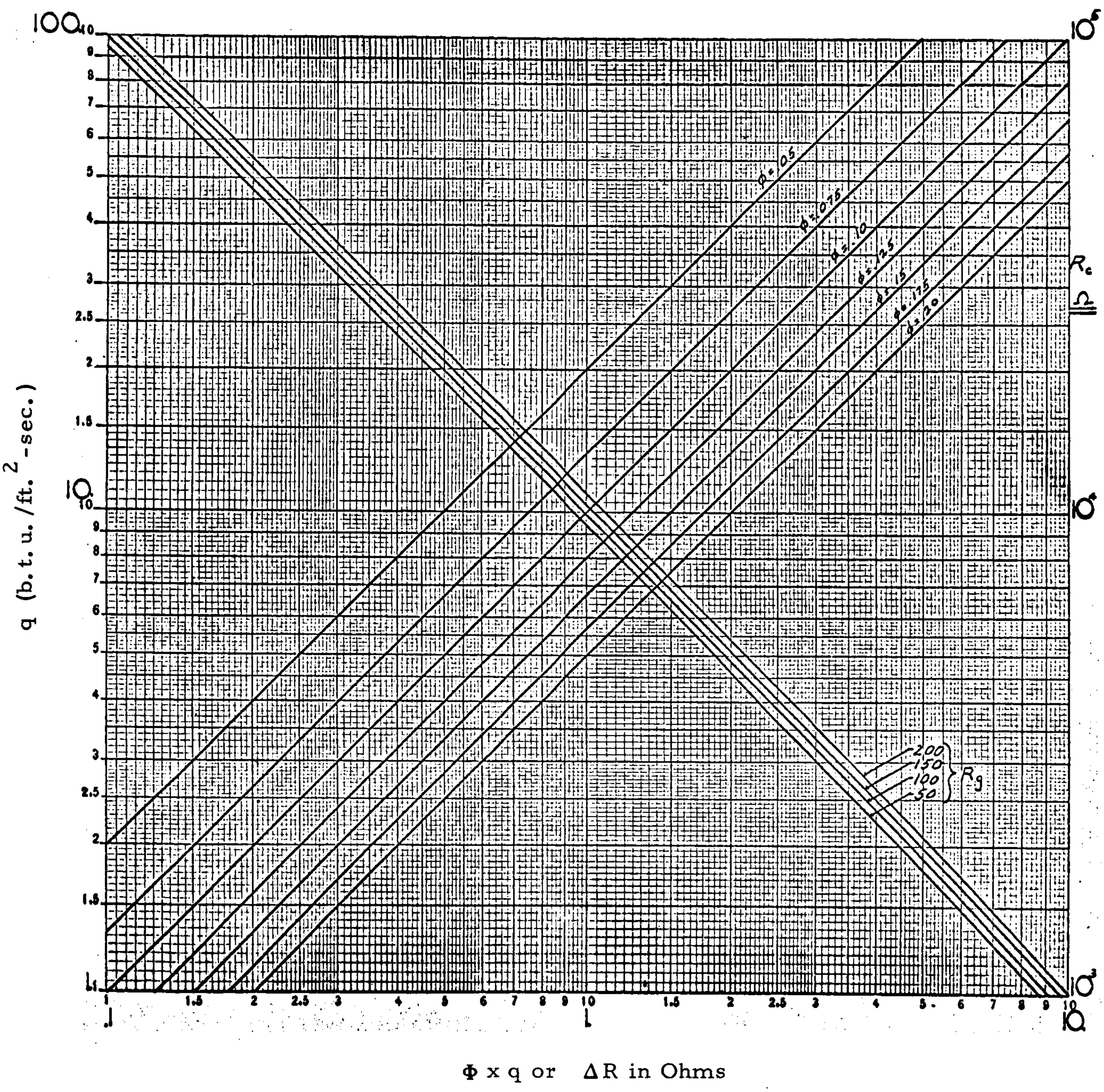


Figure 7. (Continued)

"q" 20 to 250 b.t.u./ft.^{2}-sec.

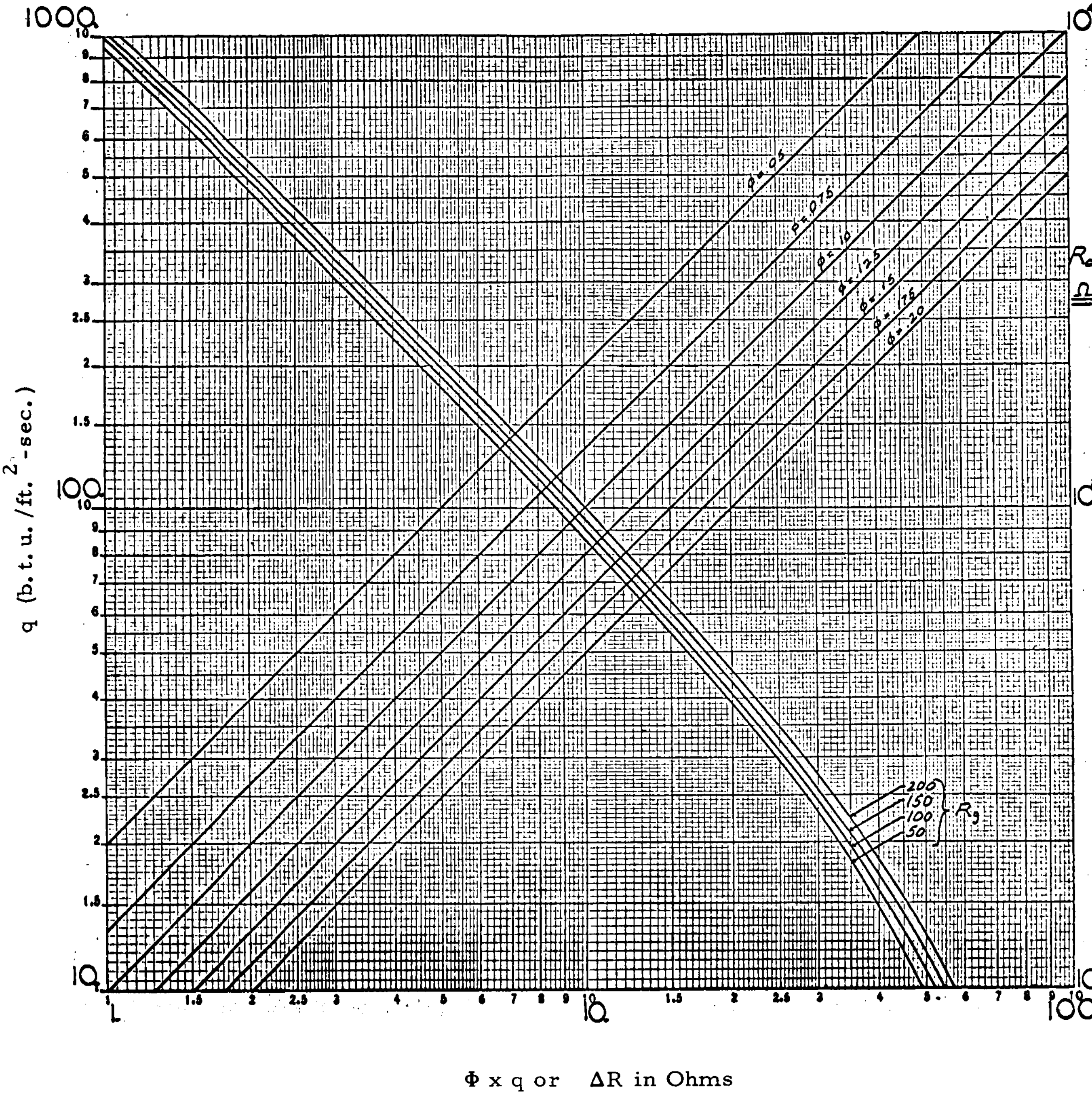


Figure 7. (Continued)

"q" 200 to Maximum

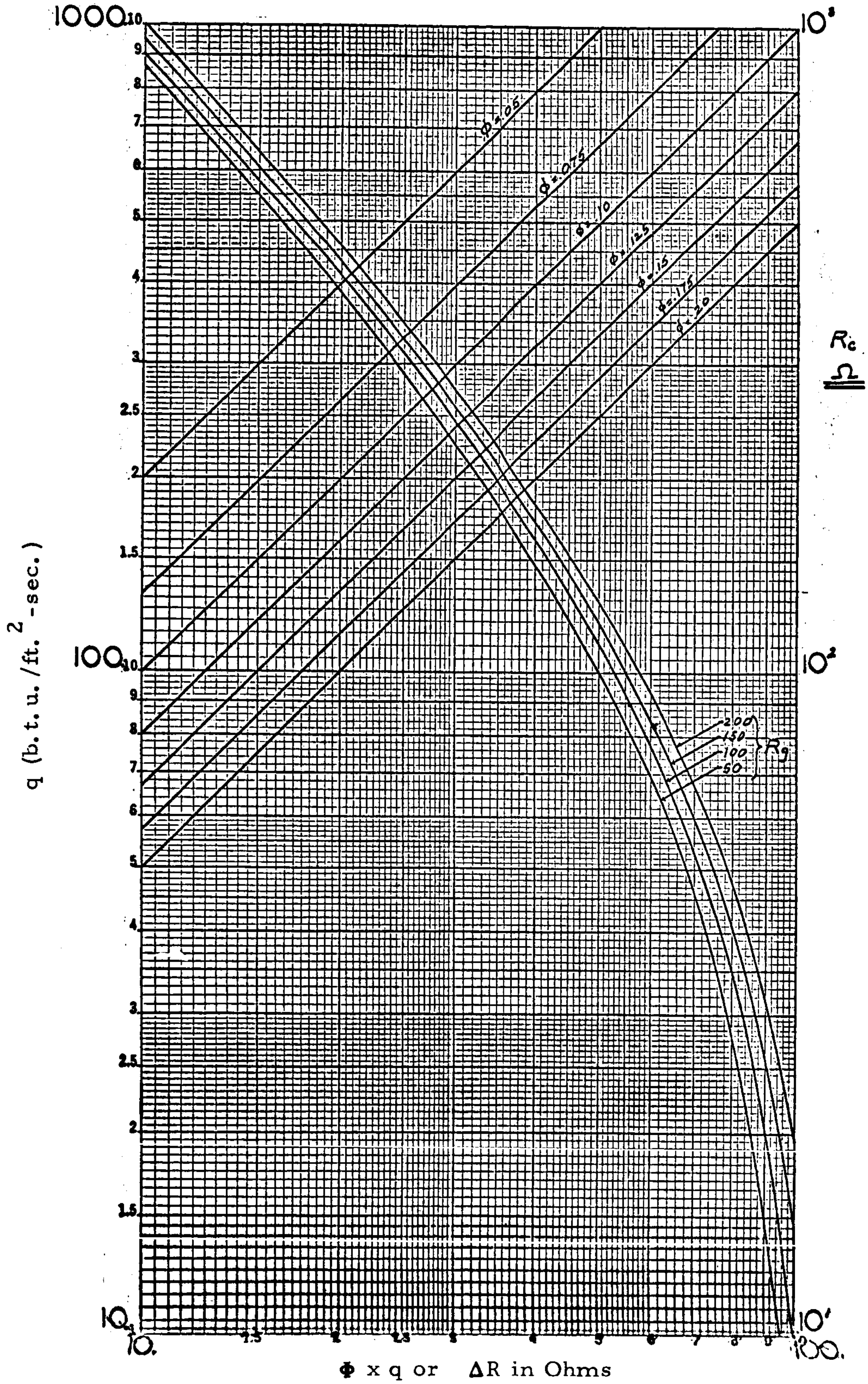


Figure 7. (Continued)

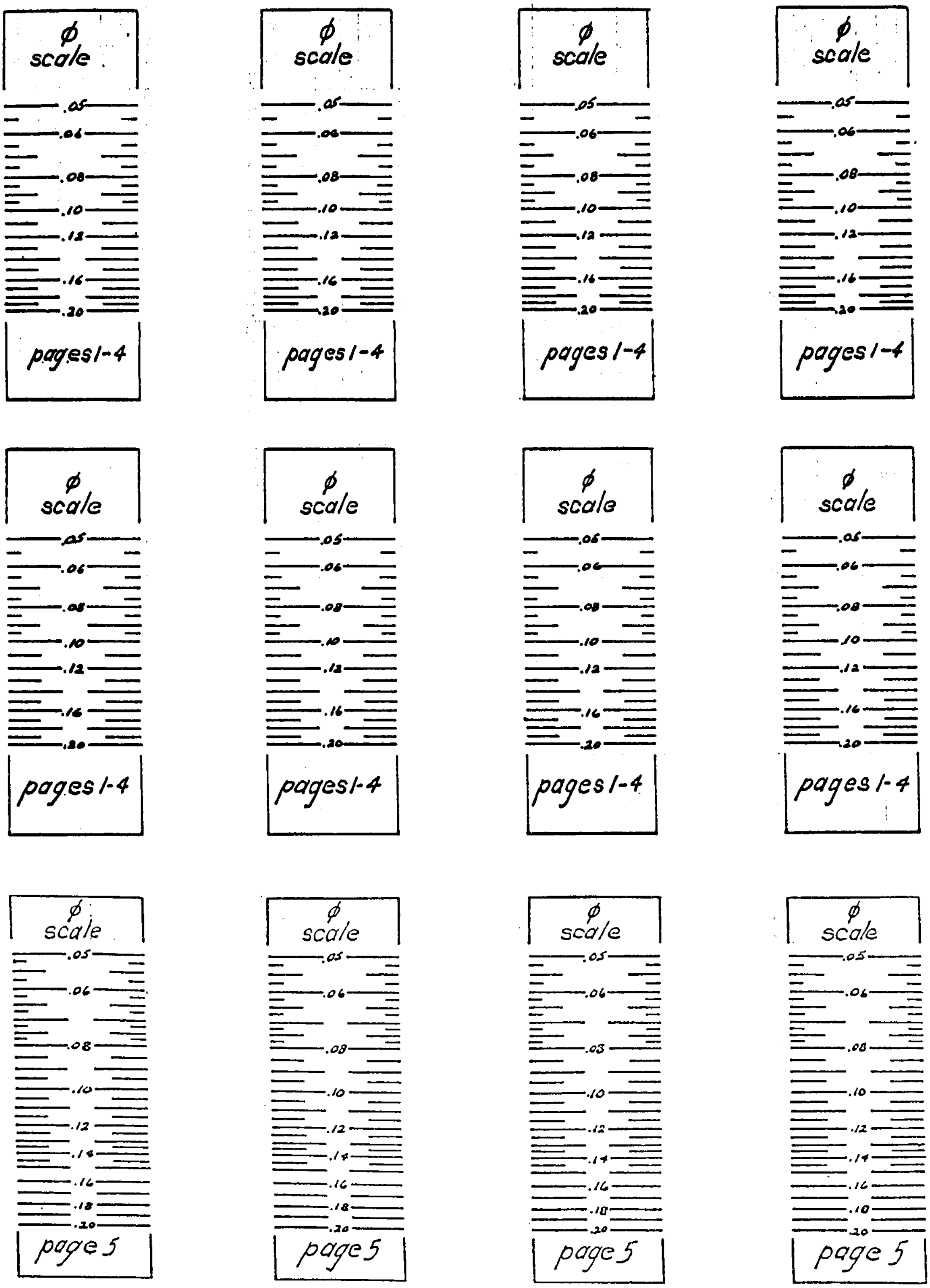


Figure 7. (Continued)

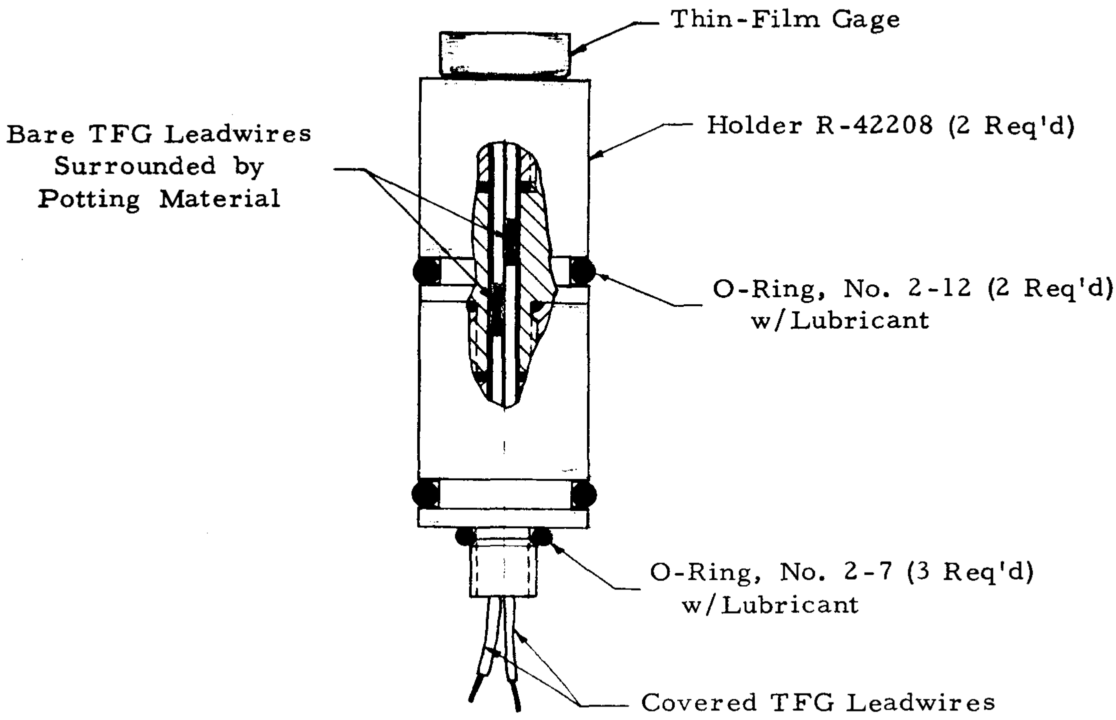


Figure 8. Thin-Film Gage Mounted in Holder R-42208

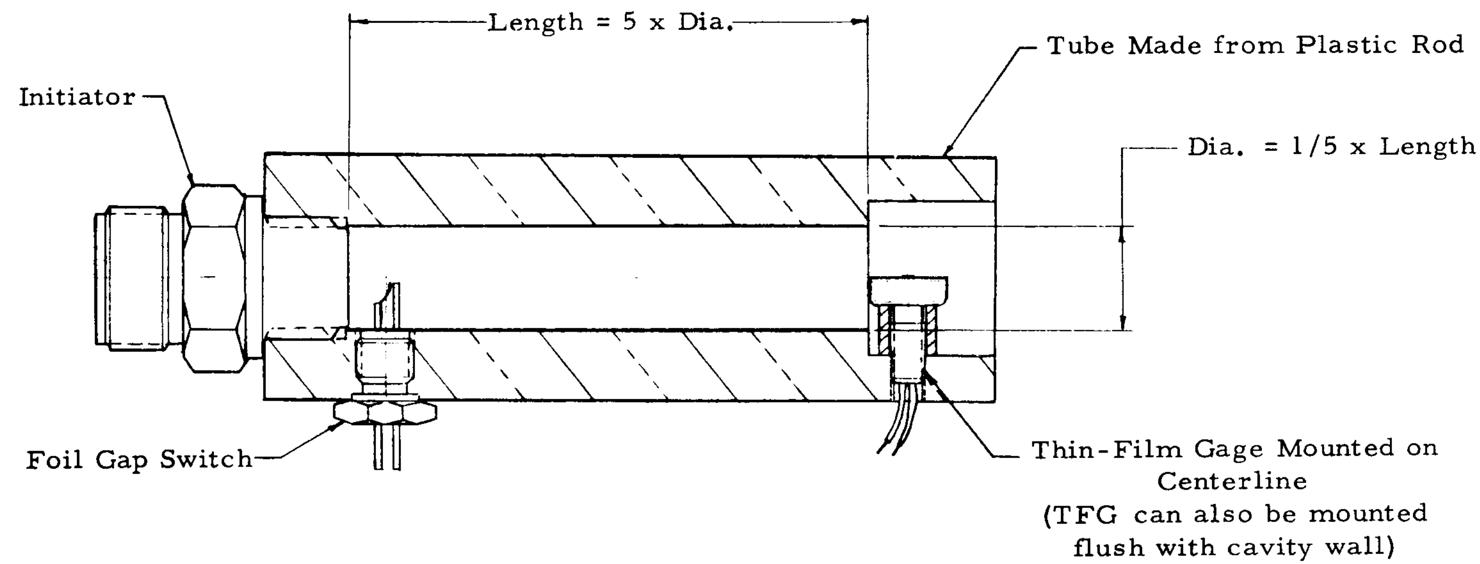


Figure 9. Example of an Open-Tube Test Fixture

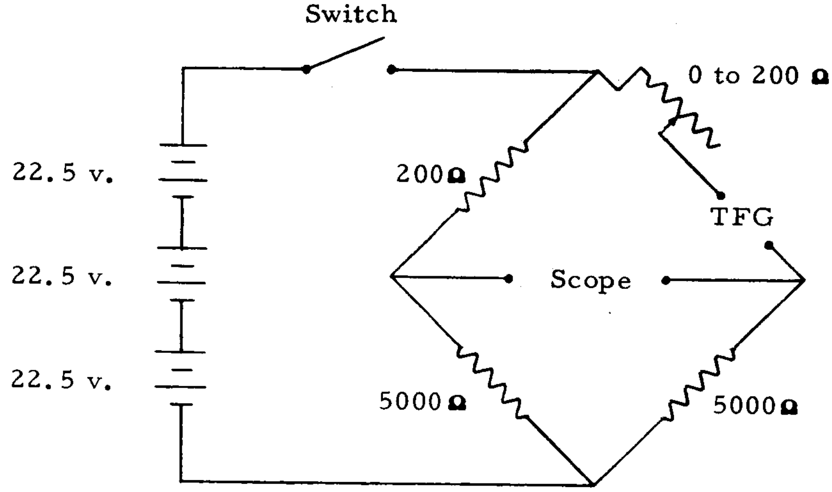
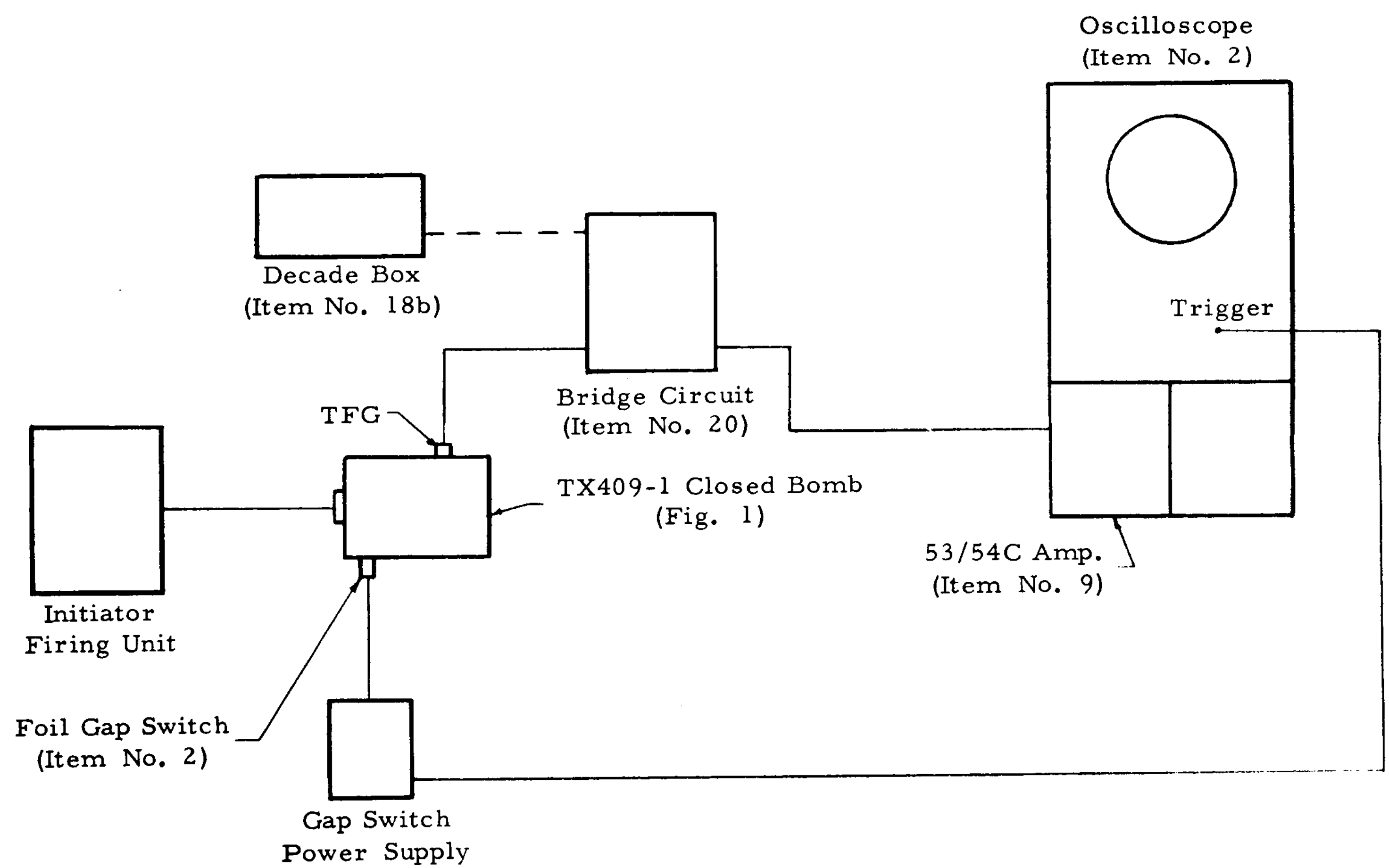


Figure 10. Bridge Circuit for Thin-Film Gage Temperature Measurements



NOTE: Decade box is connected to bridge circuit only during calibration

Figure 11. Schematic Layout of Temperature Measuring Apparatus

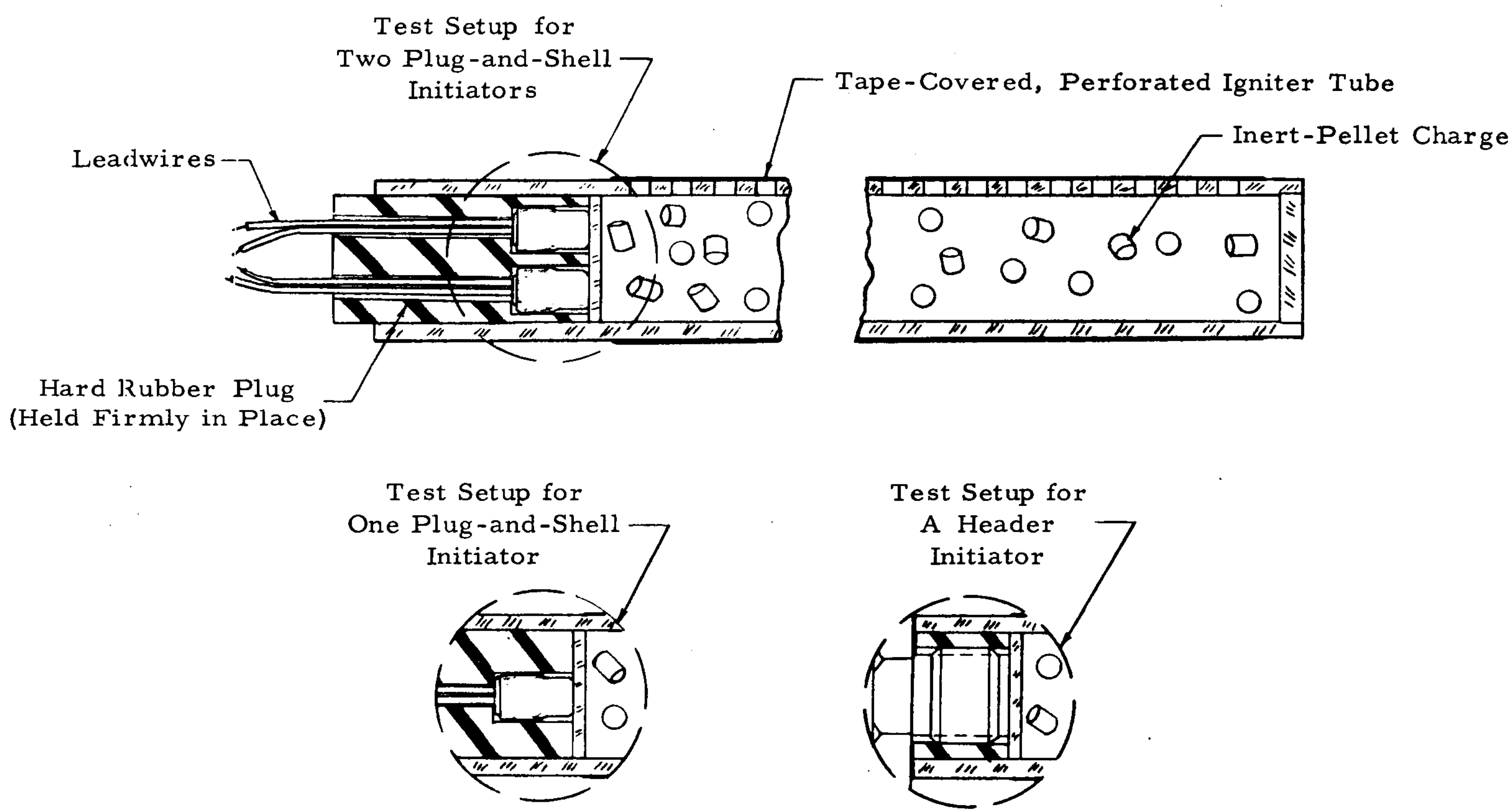


Figure 12. Inert-Pellet Test Setup--Pellet Tube Igniter

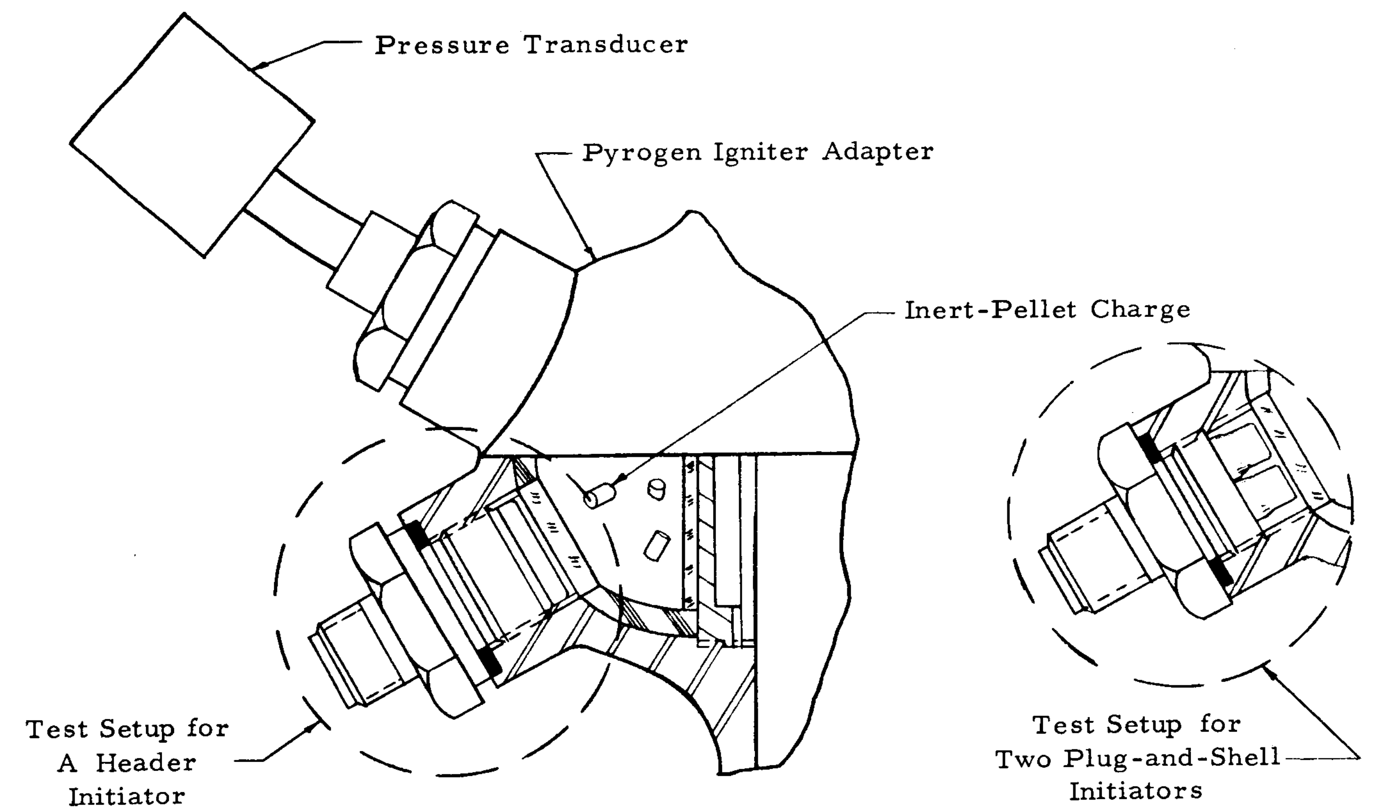
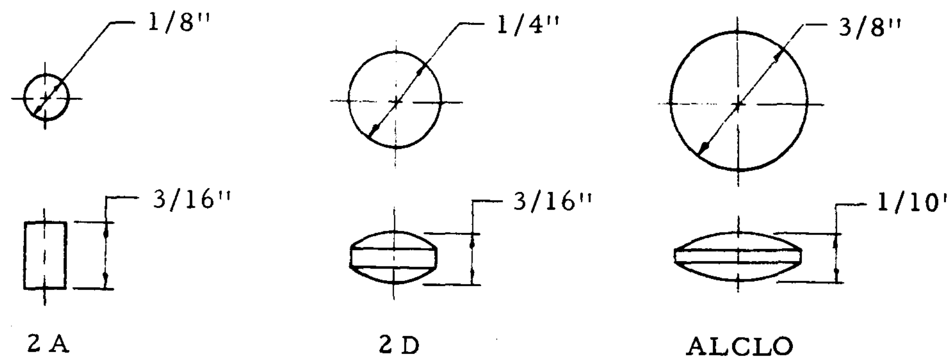


Figure 13. Inert-Pellet Test Setup--Pyrogen Igniter



Designation	Composition of Active Pellet	Manufacturer	Manufacturers' Designation
2 A	B-KNO_3	Flare Northern Division Atlantic Research Corp. Saugus, California	Inert 2A Pellets with same physical properties as Thiokol spec. SP-168
2 D	B-KNO_3	Flare Northern Division Atlantic Research Corp. Saugus, California	Inert 2D Pellets with same physical properties as Thiokol
ALCLO	Al-$KClO_4$	Aerojet-General Corp. Azusa, California	Inert ALCLO Pellets AS 8011Z3* - 100*

*Appropriate radius and thickness can be selected.

Figure 14. Descriptions of Three Inert Pellets

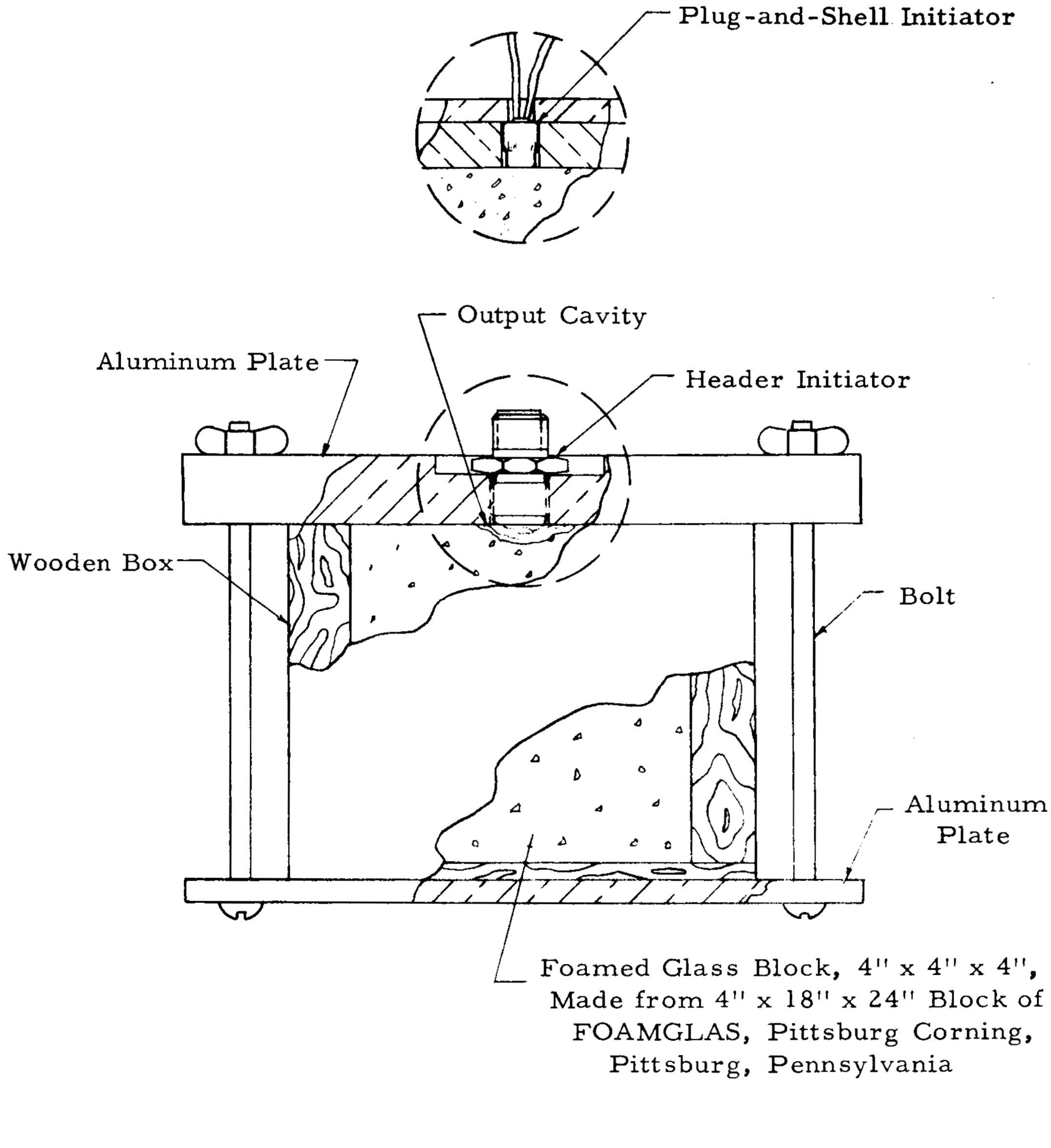


Figure 15. Glass-Block Test Setup

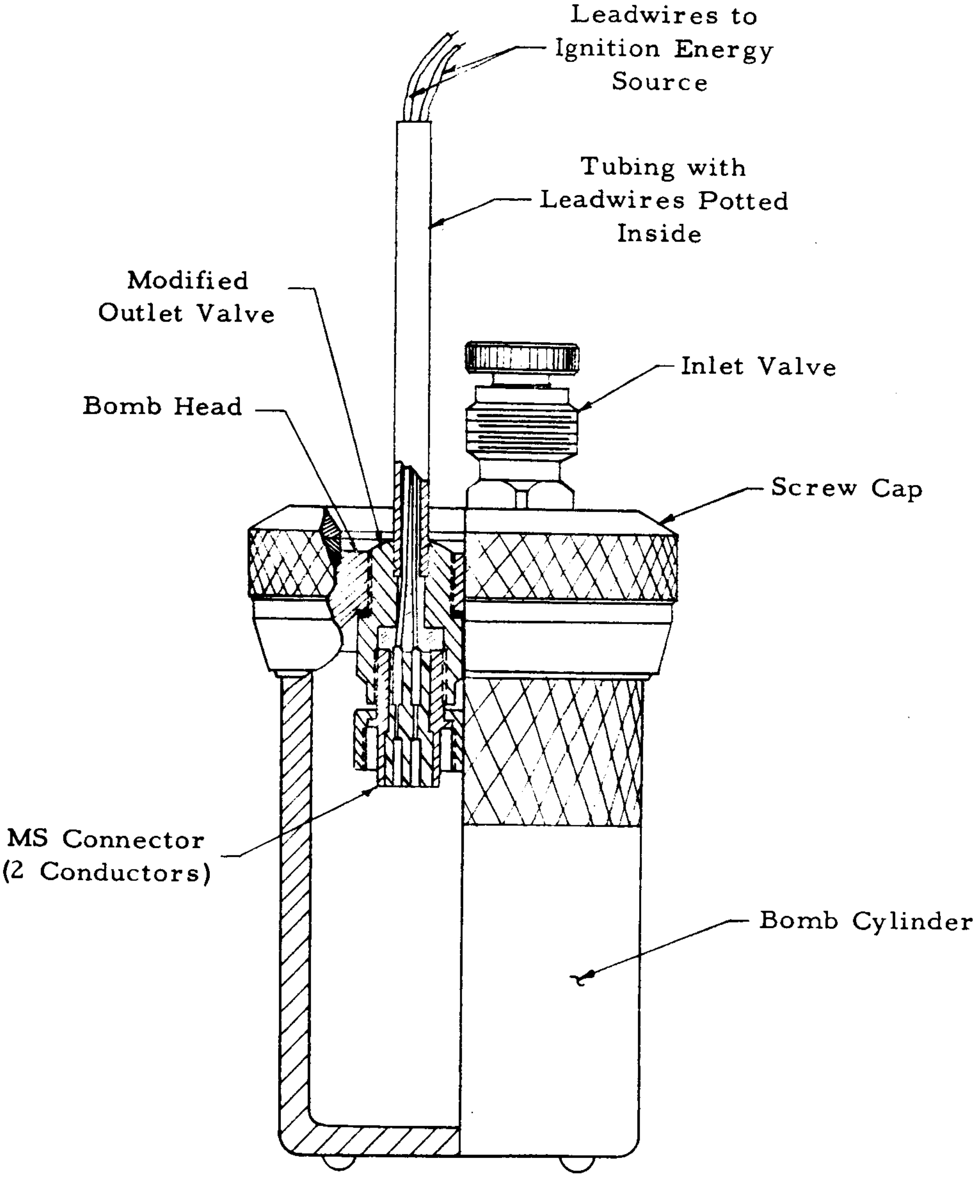


Figure 1.a.1. Parr Bomb Calorimeter Modified for Testing Initiators

INITIATOR CALORIFIC OUTPUT TEST

Initiator Designation ____________________ S/N ____________

Test Facility ____________________ Operator ____________

Bomb Conditions ____________________ Date ____________

Time (Min.)	Temperature (°F)
0	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	

Wt. of Water & Bucket ____________ gm.

Wt. of Bucket ____________

Wt. of Water (or Vol. @ ______ °F) ____________ gm. (ml.)

Initial Temperature ________ $\pm$ ________ = ________ °F

Final Temperature ________ $\pm$ ________ = ________ °F

Temperature Rise, ΔT = ________ °F

Energy Equivalent (Calibr. # ________), W = ________ cal./°F

No. of Initiators Clustered, N = ____________

Calorific Output per Initiator $= \dfrac{W \times \Delta T}{N}$

$= \dfrac{\qquad \times \qquad}{\qquad}$

= ____________ cal.

Corrections/Notes:

Corrected Calorific Output ____________ cal. ←

Figure 1.a.2. Suggested Initiator Calorific Output Data Sheet

INITIATOR CALORIFIC OUTPUT TEST

Initiator Designation MS 2451 (McSA) S/N 3286

Test Facility THIOKOL CHEM. CORP., HUNTSVILLE DIV. Operator HEwill

Bomb Conditions 25 ATM. HELIUM Date 27 OCT 64

Time (Min.)	Temperature (°F)
0	73.420
3	74.050
4	74.090
5	74.110
6	74.130
7	74.140
8	74.150
9	74.155
10	74.155
11	74.155
12	
13	
14	
15	

Wt. of Water & Bucket 2,996.50 gm.

Wt. of Bucket 996.45

Wt. of Water (or Vol. @ 71.4 °F) 2,000.05 gm. (ml.)

Initial Temperature 73420 $\pm$ 0.028 = 73.392 °F

Final Temperature 74.155 $\pm$ 0.029 74.126 °F

Temperature Rise, ΔT = 0.734 °F

Energy Equivalent (Calibr. # 2) W = 1358.818 cal./°F

No. of Initiators Clustered, N = 2

Calorific Output per Initiator $= \frac{W \times \Delta T}{N}$

$= \frac{1358.818 \times 0.734}{2}$

= 498.69 cal.

Corrections/Notes:

NONE

Corrected Calorific Output 499 cal.

Figure 1.a.3. Sample Filled-In Copy of Figure 1.a.2

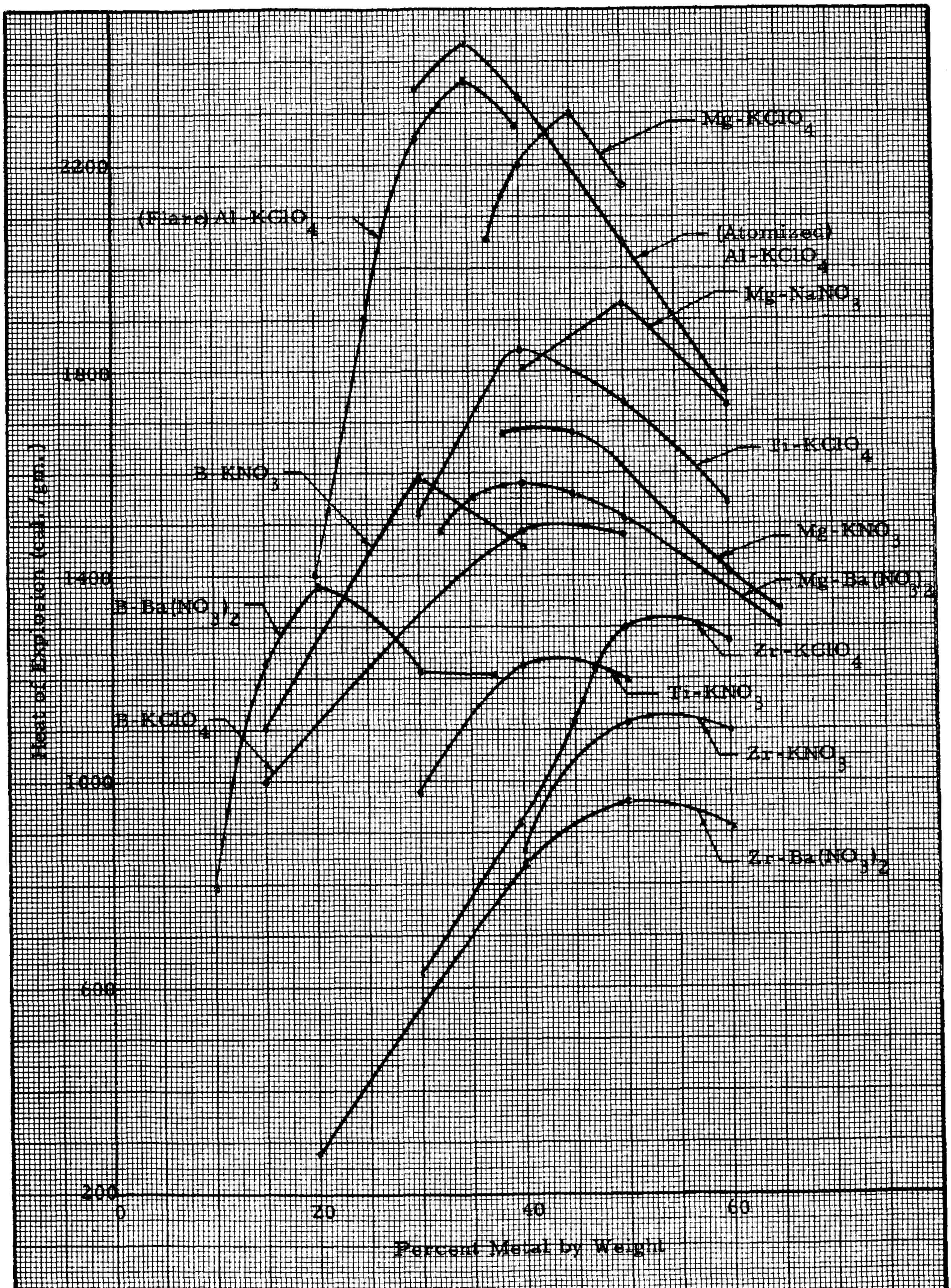


Figure 1. b. 1. Plot of Heat of Explosion Versus Percent Metal for Several Metal-Oxidant Initiator Materials

INITIATOR PRESSURE OUTPUT TEST

Initiator Designation ______________________ S/N ____________

Test Facility ______________________ Operator ____________

Purpose of Test ______________________ Date ____________

______________________ Run No. ____________

PLACE OSCILLOSCOPE PHOTO HERE	**Oscilloscope Calibration**
	Pressure Trace 1 — Pressure ________ psi/cm.; Sweep Speed ________ msec. /cm.
	Pressure Trace 2 — Pressure ________ psi/cm.; Sweep Speed ________ msec. /cm.

Instrumentation	**Initial Test Conditions**
Pressure Transducer ________	Bomb Pressure ________
Range of Transducer ________	Bomb Temp., °F. ________
Amplifier ________	Initiator Temp., °F. ________
Oscilloscope ________	**Bomb Data**
Camera ________	Dwg. ________
	Vol., cc. ________
Remarks	Triggering Device ________
	Data Obtained
	P_{max}, psia ________
	t_1, msec. ________
	t_2, msec. ________
	$\dot{P}_{dk}$, psi/msec. ________

Figure 2.a.1. Suggested Data Sheet for Closed Bomb Pressure Measurements

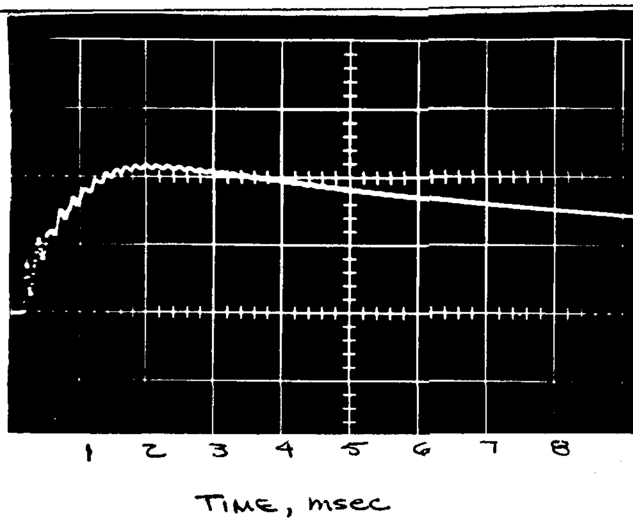
INITIATOR PRESSURE OUTPUT TEST

Initiator Designation TX 346 (TCC) S/N 1012 (Lot No. 2)

Test Facility Thiokol Chem. Corp., Hunts. Div. Operator R.M. LATTA

Purpose of Test To obtain Post and observe cool down curve Date 10 JAN 65

Run No. 10



Oscilloscope Calibration

Pressure Trace 1
- Pressure: 125 psi/cm.
- Sweep Speed: 1 msec./cm.

Pressure Trace 2
- Pressure: N/A psi/cm.
- Sweep Speed: ______ msec./cm.

Instrumentation

Pressure Transducer PHOTOCON MODEL 401

Range of Transducer 0 to 1000 psi

Amplifier TEKTRONIX TYPE K

Oscilloscope TEKTRONIX TYPE 555

Camera C-19 WITH TYPE 47 ASA 3000 FILM

Initial Test Conditions

Bomb Pressure 1 ATM.

Bomb Temp., °F. 75

Initiator Temp., °F. 75

Bomb Data

Dwg. R-42453 (BODY R-42455-51)

Vol., cc. 30

Triggering Device INITIATOR FIRING UNIT

Remarks

FIRING ENERGY 2300 VOLTS 0.75 μf

2 WASHERS, R-42456, USED TO ADJUST VOL.

Data Obtained

P_{max}, psia 270

t_1, msec. 0.20

t_2, msec. 1.80

$\dot{P}_{dk}$, psi/msec. 13.3 (to 6 msec)

Figure 2.a.2. Sample Filled-In Copy of Figure 2.a.1

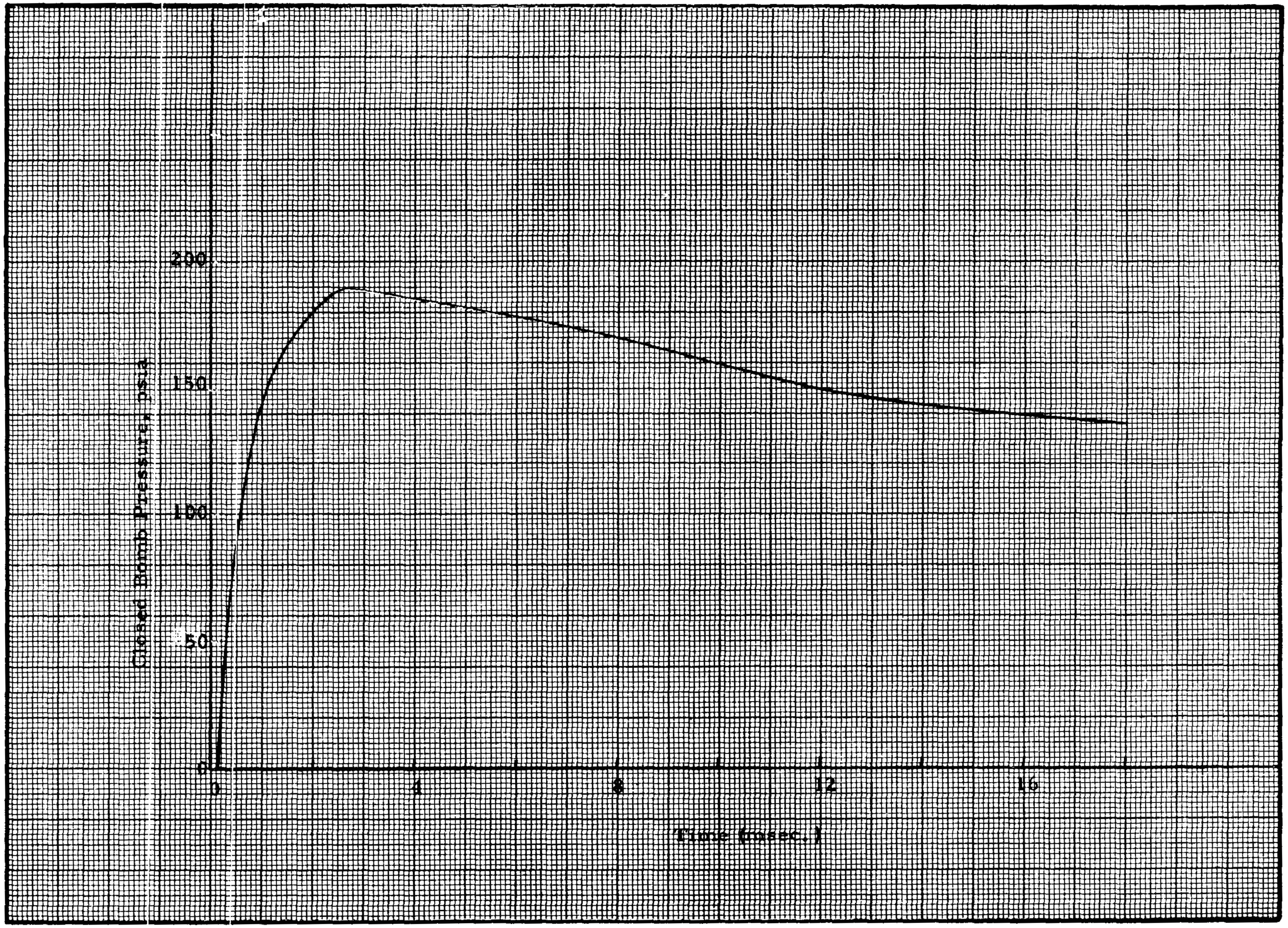


Figure 2.a.3. Sample Plot of Oscilloscope Trace from Pressure Measurement

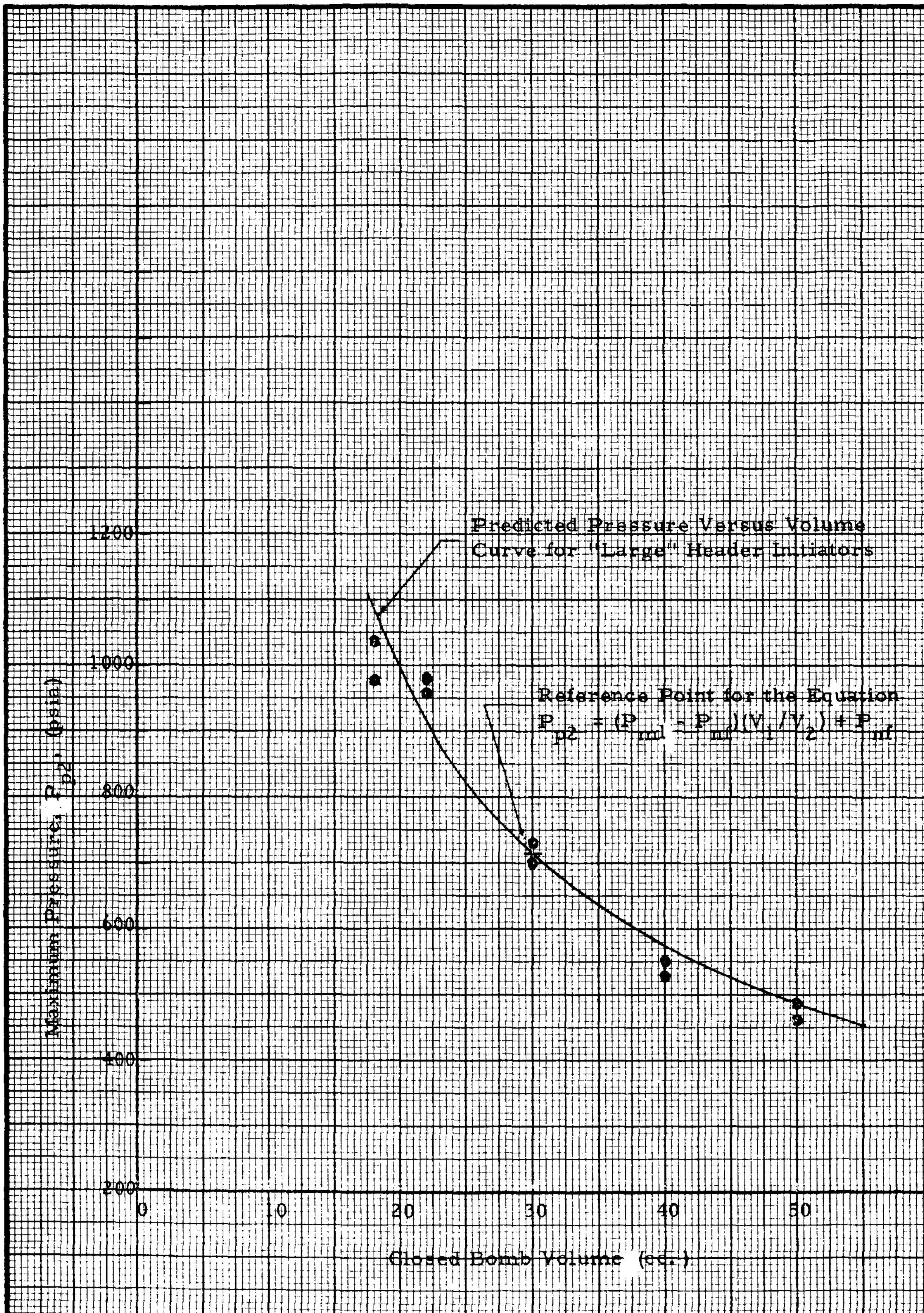


Figure 2.b.1. Plot of Predicted Initiator Pressure Versus Closed Bomb Volume

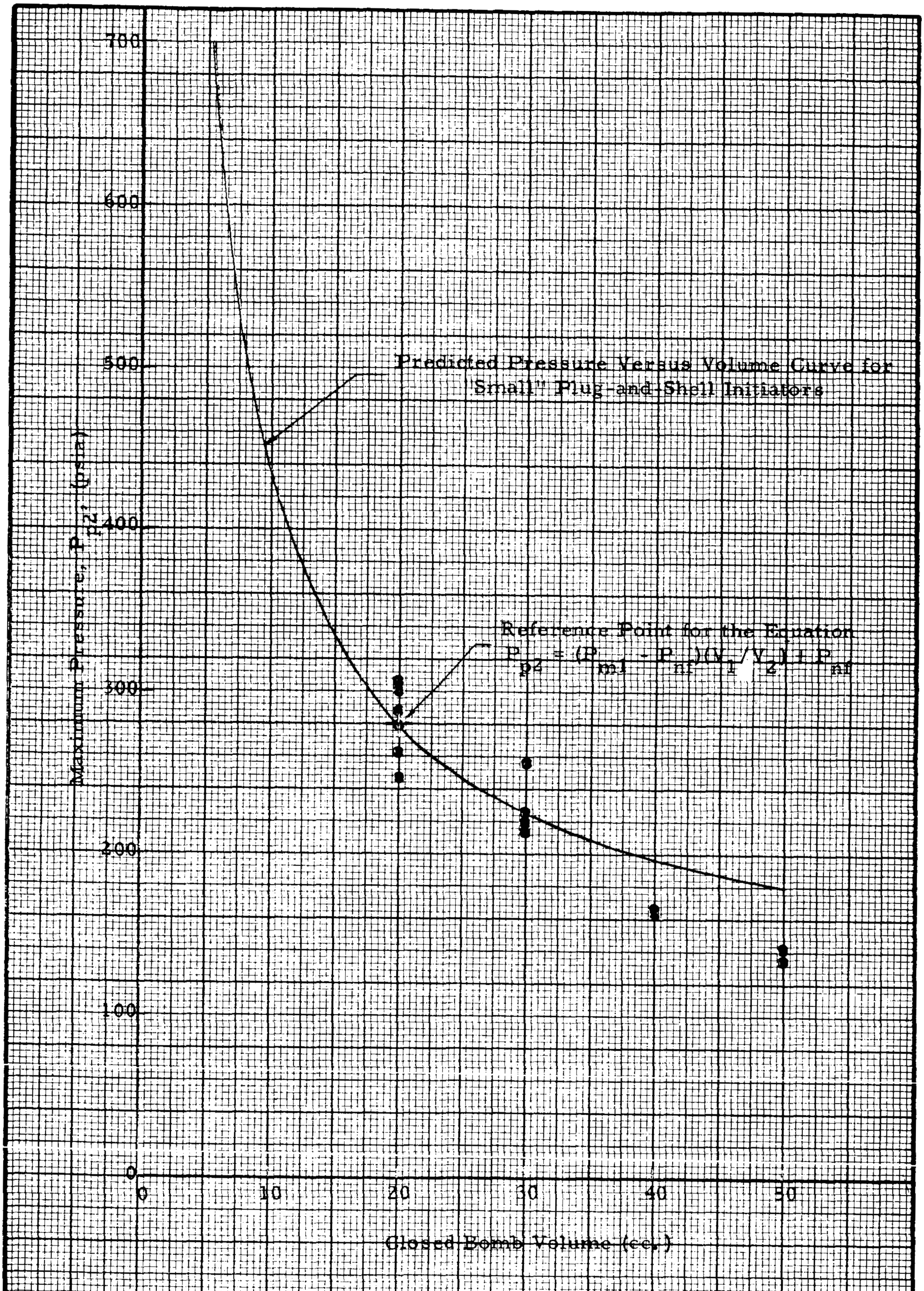


Figure 2.b.2. Plot Showing Deviation of Measured Pressure from Prediction Curve at Large Bomb Volumes

INITIATOR HEAT FLUX OUTPUT TEST

Initiator Designation ______________________ S/N __________

Test Facility ______________________ Operator __________

Purpose of Test ______________________ Date __________

______________________ Run No. __________

PLACE OSCILLOSCOPE PHOTO HERE	**Oscilloscope Calibration** Heat Flux ________ b.t.u./ft.^{2}-sec. per cm. ________ cal./cm.^{2}-sec. per cm. ________ cm. total deflection Sweep Speed ________ msec./cm.
Instrumentation Heat Rate Anal. Unit ________ Prescribed Oper. Time, msec. ________ Calibration Resis. (R_c), ohms ________ Oscilloscope ________ Amplifier ________ Camera ________	**Initiator Test Conditions** Pressure ________ Fixture Temp., °F. ________ Initiator Temp., °F. ________ **Test Fixture** Open Tube: Dwg. ________ Closed Bomb: Dwg. ________ Vol., cc. ________
Thin-Film Gage Data TFG No. ________ S/N ________ R_g at 75°F. (pretest), ohms ________ R_g at 75°F. (posttest), ohms ________ Gage Constant (Φ), ohms/°F. ________ Condition of Gage After Test ________ ________	**Remarks**

Figure 3.a.1. Suggested Data Sheet for Heat Flux Measured with Electric Analogue Unit

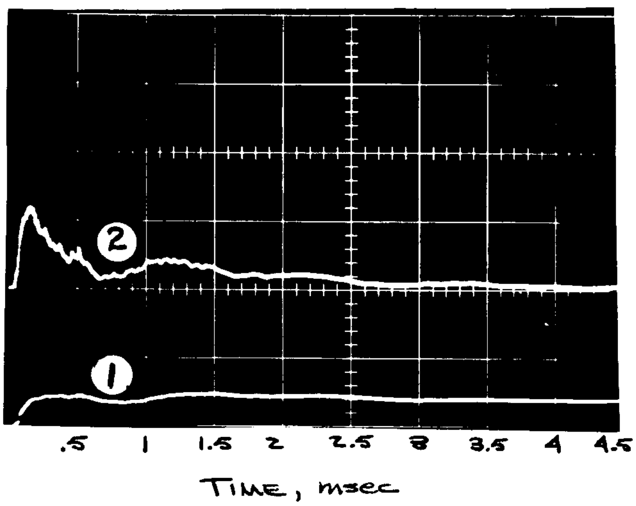
INITIATOR HEAT FLUX OUTPUT TEST

Initiator Designation S90 (DU PONT) S/N LOT 20

Test Facility THIOKOL CHEM. CORP., HUNTS. DIV Operator R.M. LATTA

Purpose of Test TO CHARACTERIZE HEAT FLUX OUTPUT OF S90 SQUIB Date 16 DEC 64

Run No. 5



Oscilloscope Calibration

Heat Flux

240 b. t. u. /ft.^{2}-sec. per cm.

65.08 cal. /cm.^{2}-sec. per cm.

2 cm. total deflection

Sweep Speed

0.5 msec. /cm.

Initiator Test Conditions

Pressure 1 ATM.

Fixture Temp., °F. 72

Initiator Temp., °F. 72

Test Fixture

Open Tube	Closed Bomb
Dwg. JIG 5A	Dwg. N/A
	Vol., cc.

Instrumentation

Heat Rate Anal. Unit NASA-MSFC MODEL 3

Prescribed Oper. Time, msec. 25

Calibration Resis. (R_c), ohms 46

Oscilloscope TEKTRONIX TYPE 555

Amplifier TEKTRONIX TYPE K

Camera C-19 WITH TYPE 47 ASA 3000 FILM

Thin-Film Gage Data

TFG No. PTF100-P24-4F S/N 98

R_g at 75°F. (pretest), ohms 124.0

R_g at 75°F. (posttest), ohms 120.0

Gage Constant (Φ), ohms/°F. 0.16

Condition of Gage After Test NO VISIBLE CHANGE

Remarks

GAGE LOCATED ON CENTERLINE OF TUBE

TRACE 2 IS HEAT FLUX

TRIGGERED SCOPE WITH GAP SWITCH

Figure 3. a. 2. Sample Filled-In Copy of Figure 3. a. 1

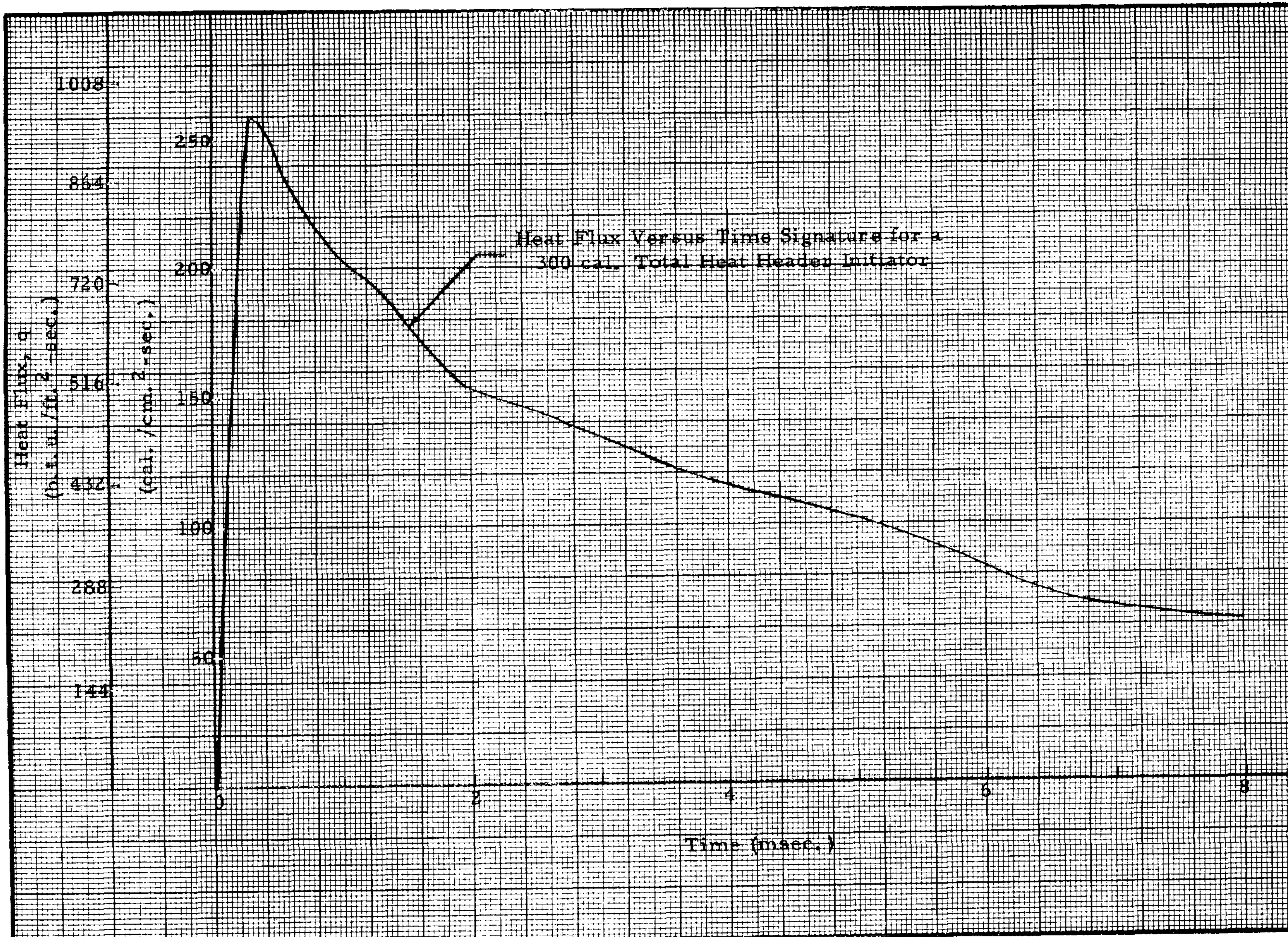


Figure 3.a.3. Sample Plot of Oscilloscope Trace from Heat Flux Analogue Unit

INITIATOR TEMPERATURE-TIME OUTPUT TEST

Initiator Designation ______________________ S/N __________

Test Facility ______________________ Operator __________

Purpose of Test ______________________ Date __________

______________________ Run No. __________

PLACE OSCILLOSCOPE PHOTO HERE	**Oscilloscope Calibration** Temperature __________ ohms/cm. or (ohms/cm.)(1/Φ) = _____ °F./cm. Sweep Speed __________ msec./cm.
Instrumentation Heat Rate Anal. Unit __________ Prescribed Oper. Temp., msec. __________ Oscilloscope __________ Amplifier __________ Camera __________	**Initial Test Conditions** Pressure __________ Fixture Temp., °F. __________ Initiator Temp., °F. __________ **Test Fixture** Open Tube: Dwg. __________ Closed Bomb: Dwg. __________ Vol., cc. __________
Thin-Film Gage Data TFG No. __________ S/N __________ R_g at 75°F. (pretest), ohms __________ R_g at 75°F. (posttest), ohms __________ Gage Constant (Φ), ohms/°F. __________ Condition of Gage After Test __________ __________	**Data Obtained** T_{max}, °F. __________ $t_{T_{max}}$, msec. __________ **Remarks**

Figure 3.c.1. Suggested Data Sheet for Temperature-Time Measurements

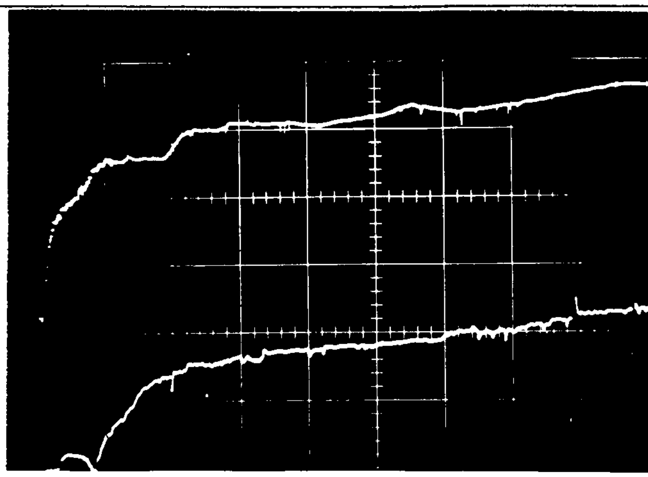
INITIATOR TEMPERATURE-TIME OUTPUT TEST

Initiator Designation XM 4 (TCC MOD. XM3) S/N LOT 51

Test Facility THIOKOL CHEMICAL CORP., HUNTS. DV. Operator R.M. LATTA

Purpose of Test TO OBTAIN T vs t AT TWO SWEEP SPEEDS Date 1 FEB 65

Run No. 1



TIME, msec

Oscilloscope Calibration

Temperature

16 ohms/cm. (BOTH TRACES)

or

(ohms/cm.)(1/ϕ) = 100 °F./cm.

Sweep Speed

TOP 0.20, BOTTOM 0.02 msec./cm.

Initial Test Conditions

Pressure 1 ATM.

Fixture Temp., °F. 78

Initiator Temp., °F. 78

Test Fixture

Open Tube	Closed Bomb
Dwg. J165A	Dwg.
	Vol., cc.

Instrumentation

Heat Rate Anal. Unit NASA-MSFC MODEL 3

Prescribed Oper. Temp., msec. 25

Oscilloscope TEKTRONIX TYPE 555

Amplifier TEKTRONIX MODEL 53/54C

Camera C-19 WITH TYPE 47 ASA 3000 FILM

Thin-Film Gage Data

TFG No. PTF50-PZA-4F S/N 120

R_g at 75°F. (pretest), ohms 40

R_g at 75°F. (posttest), ohms 42

Gage Constant (Φ), ohms/°F. .05

Condition of Gage After Test NO VISIBLE CHANGE

Data Obtained

T_{max}, °F. 3.6cm x 100°F/cm = 360

$t_{T_{max}}$, msec. 1.8

Remarks

TRIGGERED SCOPE WITH GAP SWITCH

Figure 3.c.2. Sample Filled-In Copy of Figure 3.c.1

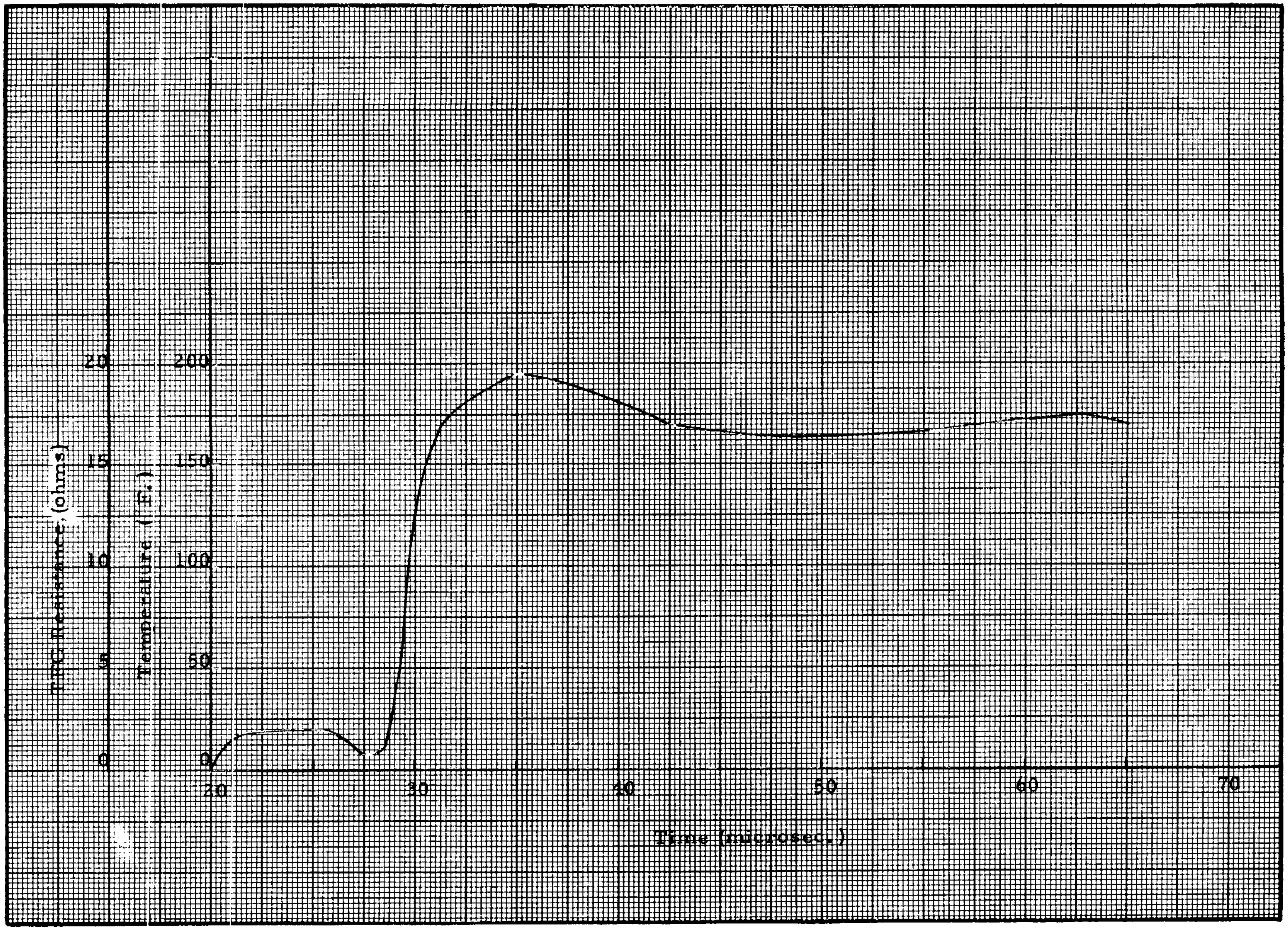


Figure 3. c. 3. Sample Plot of Oscilloscope Trace from Temperature Measurement

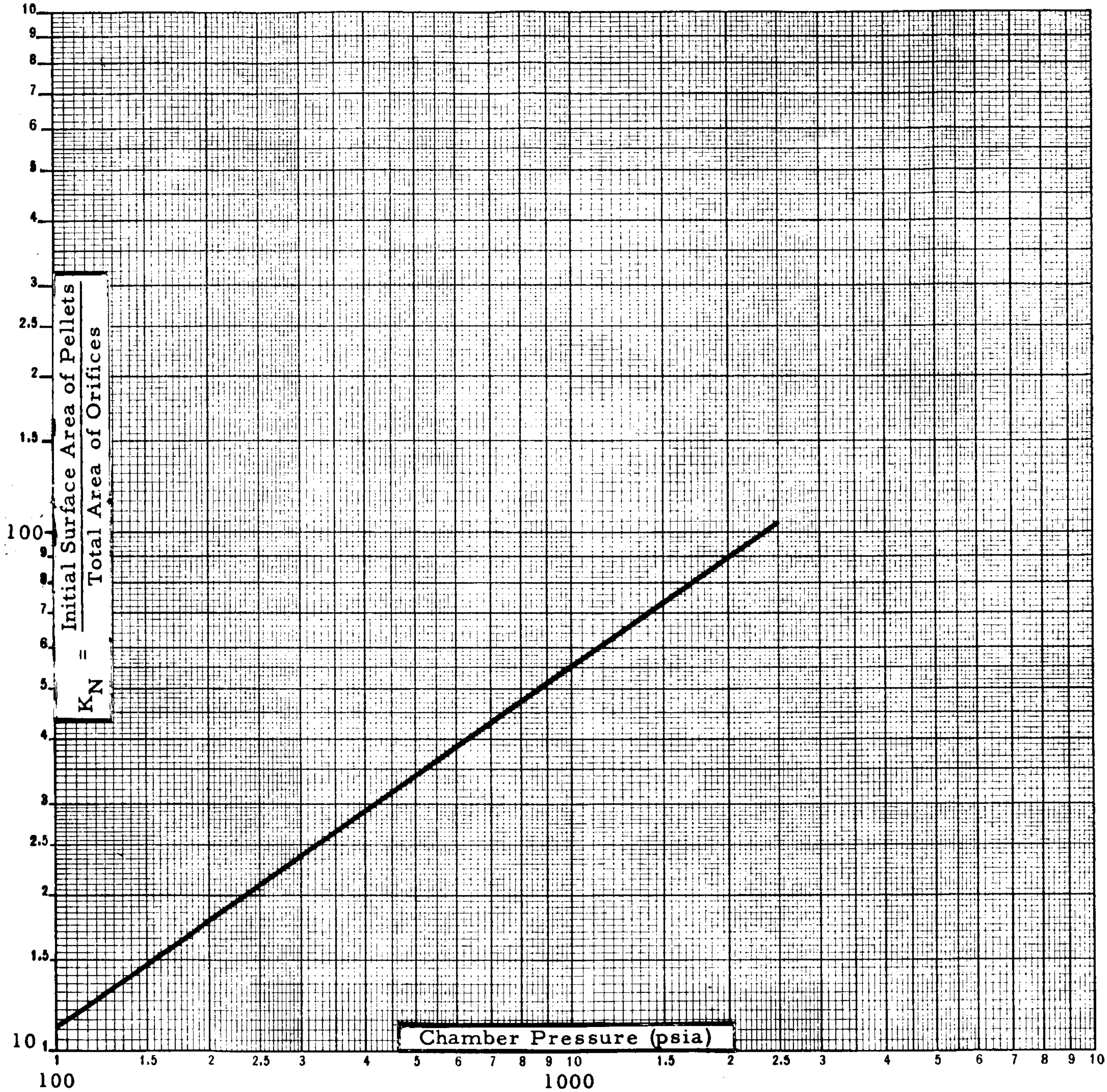


Figure 4.a.1. Peak Igniter Chamber Pressure for B-KNO_3 Pellets (K_N Versus Chamber Pressure)

APPENDIX A.

LIST OF OPERATING MANUALS

APPENDIX A.

LIST OF OPERATING MANUALS

Manual For	Description of Manual
Item No. 2	Instruction Manual for Type 555/21A/22A Oscilloscope, Tektronix, Inc., Beaverton, Oregon
Item No. 3	Instruction Manual for Type C-19 Oscilloscope Camera, Tektronix, Inc.
Item No. 4	Instruction Manual for Type K Amplifier, Tektronix, Inc.
Items Nos. 5 & 6	Instruction Manual for Pressure Transducers and Dynagage, Photocon Research Products, Pasadena, California
Item No. 7	Installation and Maintenance Manual for Dead Weight Tester, Manning, Maxwell, and Moore, Inc., Stratford, Connecticut, Manual No. 250-1526
Item No. 9	Instruction Manual for Type 53/54C Dual Trace Plug-in Amplifier, Tektronix, Inc.
Item No. 12	Instruction Manual for Model 712-B d.c. Power Supply, Hewlett-Packard Co., Palo Alto, California
Item No. 13	Operating Directions for Model 5305 Wheatstone Bridge, Leeds and Northrup Co., Philadelphia, Pennsylvania
Item No. 14	Operating Directions for Model 8667 Potentiometer, Leeds and Northrup Co., Booklet 1516
Item No. 16	General Instructions for Model 293 Pyrometer Controller, Thermo Electric Co., Saddle Brook, New Jersey, Instruction Sheets 100A - 101A, 1959
Item No. 21	Operating Instructions for Alinco Circuit Tester Model 101-5AF, Allegany Instrument Co., Cumberland, Maryland
Item No. 27	Oxygen Bomb Calorimetry and Combustion Methods, Parr Instrument Co., Moline, Illinois, Manual No. 130

APPENDIX B.

CONVERSION FACTORS

APPENDIX B.

CONVERSION FACTORS[1]

cm. X	.3937	=	in.
cm. .... =	2.54	X	in.
$cm.^2$ X	.15500	=	$in.^2$
$cm.^2$ .... =	6.4515	X	$in.^2$
$cm.^3$ X	.061025	=	$in.^3$
$cm.^3$ .... =	16.3872	X	$in.^3$
gm. X	.0022046	=	lb.
gm. .... =	453.6	X	lb.
cal. X	.0039683	=	b.t.u.
cal. .... =	251.996	X	b.t.u.
cal./gm. X	1.8	=	b.t.u./lb.
cal./gm. .... =	.5555	X	b.t.u./lb.
gm./$cm.^3$ X	.036127	=	lb./$in.^3$
gm./$cm.^3$ .... =	27.6814	X	lb./$in.^3$
cm./sec. X	.3937	=	in./sec.
cm./sec. .... =	2.54	X	in./sec.
cal./$cm.^2$-sec. X	3.6867	=	b.t.u./$ft.^2$-sec.
cal./$cm.^2$-sec. .... =	.2712	X	b.t.u./$ft.^2$-sec.
b.t.u./$in.^2$-sec. X	144	=	b.t.u./$ft.^2$-sec.
b.t.u./$in.^2$-sec. .... =	.006944	X	b.t.u./$ft.^2$-sec.
cal./$cm.^2$ X	3.6867	=	b.t.u./$ft.^2$
cal./$cm.^2$ .... =	.2712	X	b.t.u./$ft.^2$
cal./gm. °C. X	1	=	b.t.u./lb. °F.
cal./gm. °C. .... =	1	X	b.t.u./lb. °F.
°F. .... =	9/5°C. + 32		
°C. .... =	(°F. - 32) 5/9		
°R. .... =	°F. + 460		
°K. .... =	°C. + 273		

1. The conversion factors given for gm. and lb. are "force equivalents."

APPENDIX C.

METHODS OF TRIGGERING THE OSCILLOSCOPE

APPENDIX C.

METHODS OF TRIGGERING THE OSCILLOSCOPE

GENERAL

At least three methods of triggering the oscilloscope can be employed and the selection of the triggering mechanism to use depends on the purpose of the test. The three methods are (1) from input firing pulse to the initiator, (2) from the severing of a breakwire adjacent to the initiator closure, and (3) from the closing of a foil gap switch placed adjacent to the initiator closure. A brief discussion of each is presented below.

TRIGGERING BY INPUT FIRING PULSE TO THE INITIATOR

This is the simplest method of triggering the oscilloscope and has the advantage of portraying the function time of the initiator (time from input firing signal to initial pressure rise in a closed bomb). However, for initiators having function times on the order of 5 milliseconds, this method of triggering is undesirable when fast sweep speeds (0.5 msec. or faster) are used on the oscilloscope. The oscilloscope beam will have passed off the screen before the "event" occurs if triggering by input firing signal is used with "slow" initiators or if fast sweep speeds are used.

TRIGGERING BY BREAKWIRE

This method of triggering is often used to determine the function time of an initiator. However, the time delay associated with the severing of a breakwire depends on the output intensity of the initiator being tested. This delay time may be as long as 50 microseconds. Using a breakwire inside a closed bomb to trigger the oscilloscope is impractical because it is difficult to stretch a small wire across the initiator closure and connect it to insulated leads within the bomb. The major advantage in using the breakwire for any application is its simplicity of construction.

TRIGGERING BY FOIL GAP SWTICH

Although the foil gap switch does obstruct the flow to some extent and is more difficult to fabricate than the breakwire device, it is well adapted for use in a closed bomb or an open tube. The initial shock front from the initiator closes the contacts of the foil gap switch in a reproducible manner and the sensitivity of the foil flapper can be adjusted to actuate in less than 2 microseconds for most initiators. When rapid sweep speeds (such as 20 microseconds per cm.) are desired on the oscilloscope for observing the initial combustion wave front of an initiator, the foil gap switch is mandatory. It is recommended as the best all-purpose method of triggering the oscilloscope.