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Design and Operation of a Hybrid Rocket Test Apparatus

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UNITED STATES NAVAL POSTGRADUATE SCHOOL

DEPARTMENT OF AERONAUTICS

TECHNICAL NOTE

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HYBRID ROCKET TEST APPARATUS

by

JACK R. LOUSMA

UNITED STATES NAVAL POSTGRADUATE SCHOOL
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PREPARED BY: [signature] June 1965
for Jack R. Lousma, Capt., USMC

APPROVED BY: R. E. Reichenbach June 1965
Professor R. E. Reichenbach

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DESIGN AND OPERATION OF A
HYBRID ROCKET TEST APPARATUS

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SYMBOLS:

A_t	throat area (in^2)
c^*	characteristic velocity (ft/sec)
D_t	throat diameter (in)
g	acceleration of gravity
$\dot{m}$	mass flow rate (lbm/sec)
P_o	total pressure (psia)
P_{og}	total pressure (psig)
$\overline{R}$	universal gas constant (1545 ftlbf/lbm^{o}R)
T_o	total temperature (^{o}R)
W	molecular weight (lb/mole)
γ	ratio of specific heats

I INTRODUCTION

A hybrid rocket test apparatus was constructed at the United States Naval Postgraduate School located at Monterey, California in November of 1964. It is located at the rocket facility of the Astro/Aeronautical Laboratories. It was initially designed and constructed under the auspices of the Department of Aeronautics in order to accomplish a basic research project. The resulting thesis is available and is entitled "A Parametric Burning-Rate Study of the Polystyrene-Oxygen Hybrid System (Confidential)." The discussion which follows is for the purpose of describing the basic design and operation of the test apparatus.

II GENERAL DESCRIPTION

The hyrbrid rocket test apparatus is shown in Figures 1 and 2. Basically, it consists of supply and control systems and the burner assembly. The entire apparatus is semi-portable.

The supply system consists of the oxygen, nitrogen, and propane sources with their associated pressure regulators, fittings, and lines.

The control system allows electrical control of solenoid valves and ignition. It also provides manual control of the oxidizer flow rate.

The burner assembly consists of the oxidizer injector and fuel grain supports along with an assortment of hardware, depending upon test requirements. It is presently configured to burn cylindrical grains with an outside diameter of two inches. The fuel grains may be of varying length. An assortment of exhaust nozzles may be accommodated. The apparatus in its present configuration may be modified to provide for a variety of fuel grain sizes and experimental endeavors related to the hybrid rocket system.

III COMPONENTS

A. Supply System

1. Oxygen and nitrogen

Gaseous oxygen and nitrogen are contained in high pressure cylinders outside the test cell. Oxygen is used as the oxidizer, and nitrogen is used as a purge to extinguish residual burning at firing termination.

2. Pressure regulators

a. Oxygen

Pressure reduction and regulation is accomplished by means of a Victor GD 10-967 High Capacity Regulator. This device is designed for inlet pressures up to 3500 psig, delivery pressures up to 550 psig, and a flow capacity of 250 standard cubic feet per minute. A safety relief valve is set at 550 psig. Delivery pressure is impressed upon the regulator by opening the gas cylinder supply valve. Then the adjusting handle on the regulator may be turned clockwise to raise, and counterclockwise to decrease, delivery pressure. To decrease delivery pressure, the oxygen line must be bled so that the downstream pressure is less than that desired on the regulator. Due to flow losses between the regulator and the flow rate measuring apparatus, the delivery pressure must be set higher than that required for measuring the flow rate. This difference in pressure varies with the flow rate pressure, the "sonic choke" utilized, and the length and shape of the oxygen supply lines. Additional information regarding the oxygen pressure regulator is given in Appendix A.

b. Nitrogen

Nitrogen pressure is regulated by means of a standard low capacity Hoke-Phoenix regulator. It is capable of handling inlet pressures up to 2500 psig and delivery pressures up to 500 psig. However, a purge pressure of 200 - 300 psig is adequate. Operation of this regulator is identical to that of the oxygen regulator.

3. Propane

Propane, used for ignition, is contained in a small cylinder identical to that used in small scale soldering and heating applications. It is equipped with a shut-off valve. Pressure regulation is not required.

B. Control System

1. Electrical control

a. Control panel

Four toggle switches and an indicator light are mounted on the control panel. The switches are labeled as follows:

MASTER - a guarded switch which controls electrical power to the three remaining switches. The position of this switch is indicated by the light on the control panel;

OXYGEN - actuates the oxygen solenoid valve;

PURGE - actuates the nitrogen solenoid valve;

IGNITION - a spring-loaded switch which actuates the propane solenoid valve and the "spark generator" circuit simultaneously.

b. Spark generator

The "spark generator" consists of a six volt Model-T Ford ignition coil and a step-down transformer. This mechanism operates on standard AC current and provides a rapidly pulsating arc at the sparkplug for fuel grain ignition.

c. Solenoid valves

The three ASCO solenoid valves are designed for two-way, normally closed, 115v/60 cycle operation. Each has a safety factor of 5. Individual specifications are as follows:

Use	Stock No.	Maximum Operating Pressure Differential	Working Pressure
Oxygen	822323	750 psi	750 psi
Nitrogen	826223	300	750
Propane	8262A16	300	750

Additional information regarding the solenoid valves is contained in Appendix A.

2. Oxygen flow rate control

a. Throttle valve

The flow of oxygen to the test burner is controlled by means of a manually operated 3/8 inch Hydramatics ball valve. It may assume any position between fully closed and fully open. Thus, this valve controls the downstream pressure.

b. Reservoir

After passing through the throttle valve, the oxygen flows into a reservoir constructed of a two-inch seamless steel pipe which is capped at both ends. The wall thickness is 1/4 inch. The velocity of the oxygen flow in the reservoir is negligible compared to that through a small orifice ("sonic choke") further downstream. Thus, the pressure measured in this reservoir is essentially the stagnation pressure of the flow at this point.

c. Pressure gauge

The pressure in the above mentioned reservoir is measured by a Marsh Type 200-3S "Master Test" Test Gauge. This gauge is accurate to within 2-1/2 psig. The eight-inch dial has a range of 1000 psig in 5 psig increments. The internal mechanism includes a stainless steel Bourdon tube to withstand the corrosive effects of oxygen.

d. Sonic choke

A "sonic choke" is used as a metering device. It provides non-fluctuating flow regulation. It is placed in the oxygen line immediately downstream of the reservoir. Basically, it is simply a converging-diverging nozzle with known throat dimensions. As explained more completely later, mass flow versus total pressure characteristics can be plotted for oxygen at a given reservoir temperature for each "sonic choke." Then, assuming negligible total pressure loss and adiabatic flow between the reservoir and the "sonic choke," the flow rate may be selected by the throat size and the pressure setting.

Care must be taken to maintain $(P_o/P) > (P_o/P)_{crit}$ across the "sonic choke" in order to prevent "unchoking" of the nozzle. This is not difficult since the pressure downstream of the "sonic choke" is a known quantity. If the criteria for "choking" cannot be met at a given flow rate, a smaller choke should be selected.

The "sonic chokes" are made of aluminum, and those presently available have throat diameters of 0.081, 0.1068, 0.1368, and 0.191 inch. These chokes have been calibrated using master chokes of known pressure-mass flow rate characteristics. Calibration curves for oxygen at $T_o = 59^oF$ are given in Fig. 3. "Sonic choke" characteristics typically follow those theoretically predicted quite closely if due care is taken in design and fabrication. A detailed drawing of a "sonic choke" with dimensions is shown in Fig. 4.

C. Burner Assembly

The burner assembly is illustrated in Figs. 5, 6, and 7.

1. Injector

The injector is an integral part of the front support. It is constructed of stainless steel. No attempt has been made to induce a specific oxidizer spray pattern, although this may be accomplished quite readily by insertion of a nozzle. A sparkplug mounted in the injector and a propane port are used during ignition. A pressure tap is available for measuring combustion chamer pressure. The fuel grain is inserted into the 1/2 inch recess in the injector, and an "O-ring" around the periphery of this recess prevents gas leakage.

2. Aft support

The aft support is also made of stainless steel. It also has a 1/2 inch recess and an "O-ring" seal identical to that of the injector. In addition to supporting the fuel grain, it is designed to accommodate an assortment of exhaust nozzles which are held in place by a stainless steel threaded clamp. This nozzle retainer clamp may be screwed onto the aft support.

The fuel grain is clamped between the injector and the aft support by connector rods. The length of the connector rods may be varied to accommodate the fuel grain length. The present apparatus is designed to accommodate a fuel grain with a two-inch outside diameter. The diameter may be varied, however, by machining inserts to fit the front and aft supports, or by machining new injectors and aft supports. The maximum fuel grain size which may be tested on the present apparatus is dictated by the oxidizer mass flow rate desired and the pressure limitations of the system components, i.e., flow rate of 250 scfm and system pressure of 550 psig as required by the oxygen pressure regulator.

IV OPERATING PROCEDURES

Toggle switches on the master control panel actuate the solenoid valves and "spark generator" which make oxygen, nitrogen, and ignition available to the system. The oxygen flow rate is manually controlled to the desired level by means of a throttle valve. The procedure and suggestions which follow should be adhered to for proper operation of the hybrid rocket test apparatus.

Initially, the operator should insure that all switches and valves are in the OFF or CLOSED position. The handles on the oxygen and nitrogen pressure regulators should be turned fully counterclockwise. Next, the valves on the oxygen and nitrogen bottles may be opened slowly to allow pressure to their respective regulators. The pressure in the bottles may be checked by the high pressure gauge on the regulators. The pressure regulators may now be adjusted to the desired level by turning the control handles clockwise while monitoring the low pressure gauges. The oxygen delivery pressure must be higher than the total pressure requirements determined to provide the desired oxygen mass flow rate. For the test apparatus in its present configuration, the delivery pressure versus total pressure conditions for a given "sonic choke" may be determined from Fig. 8. The delivery pressure determined from these curves is that which is required to give the total pressure desired when the throttle valve is fully open. Use of these curves allows pre-setting of the oxygen mass flow rate. After ignition, the throttle valve may be fully opened rapidly, and starting transients and delays in attaining the desired total pressure are minimized.

The nitrogen purge pressure may also be set on the nitrogen regulator. A purge pressure of 200 - 300 psig is more than adequate, and in no case should this pressure exceed the limitations imposed by the nitrogen solenoid valve, i.e., maximum operating pressure differential of 300 psig. The propane tank should also be turned ON. The pressures of all three gases are now being exerted up to their respective solenoid valves.

The master electrical control switch must be turned ON to provide power to the solenoid valves and "spark generator." When the oxygen solenoid is actuated, pressure is exerted up to the manual throttle valve. Each system may now be momentarily checked on an individual basis, if desired, to insure proper operation, by actuating the appropriate valve.

With the test grain securely installed in the burner assembly, the firing sequence may be accomplished as follows:

1. open the oxygen valve very slightly;
2. actuate the ignition system;
3. when the fuel grain is ignited, secure the ignition system, simultaneously opening the throttle valve to attain the predetermined reservoir pressure; and
4. upon completion of the test, close the oxygen throttle valve and actuate the purge system immediately to terminate residual burning.

The test grain should be removed from the burner assembly soon after completion of the test to prevent melting of the fuel grain. Carbon and melt from the fuel grain should be removed from the burner assembly. The "O-rings" should be checked for damage and replaced if necessary. The use of a non-oxidizing grease on the "O-rings" and ends of the fuel grains will help in sealing and will also reduce damage to the "O-rings." In addition, a high temperature anti-seize compound should be applied to the threads of the aft support to prevent seizing of the nozzle retainer clamp.

The supply lines should be bled at the completion of testing to relieve pressure. This is accomplished by first closing the oxygen, nitrogen, and propane cylinder valves. The lines are then bled by individually opening the appropriate valves until flow has stopped. The pressure regulator handles should then be turned fully counterclockwise in preparation for the next testing period. Finally, the throttle valve should be closed and all electrical switches turned OFF.

A Plexiglas safety shield is mounted between the burner assembly and the operator's panel. However, safety glasses should be worn at all times while operating the test apparatus. Heavy gloves, preferably of asbestos, are necessary for removal of the test grain and for cleaning and handling the aft support, nozzle retainer clamp, etc. Other safety precautions regarding the pressure limitations of the supply lines and other components should be observed.

Maintenance of this system is limited to occasional replacements of oxygen, nitrogen, propane, and "O-ring" seals.

Improvements to the hybrid test apparatus could include:

1. an automatic firing sequence control panel which would actuate recorders and control ignition, length of firing, termination, etc.;
2. a small thrust measuring device; and
3. an oxygen manifold to accommodate several gas cylinders.

V OXYGEN FLOW RATE DETERMINATION

The hybrid rocket test apparatus is configured with a pressure gauge and a "sonic choke" of known dimensions and flow characteristics, thus allowing determination of the oxygen flow rate. The discussion which follows describes the basis for this determination.

Ordinarily, the desired flow rate is known, and the problem becomes one of determining the pressure setting required to attain this flow rate. The following equation for "choked" flow may be derived from basic principles:

$$\dot{m} = P_o A_t g \left[\frac{\gamma W}{\bar{R} T_o g} \left(\frac{2}{\gamma + 1} \right)^{\frac{\gamma + 1}{\gamma - 1}} \right]^{1/2}$$

Let $$c^* \equiv \left[\frac{\gamma W}{R T_o g} \left(\frac{2}{\gamma + 1} \right)^{\frac{\gamma + 1}{\gamma - 1}} \right]^{-1/2}$$

Thus, $$\dot{m} = \frac{P_o A_t g}{c^*}$$

For oxygen at a standard temperature of $59^{o}F$:

$$c^* = \left[\frac{1.4(32)}{1545(519)(32.17)} \left(\frac{2}{1.4 + 1} \right)^{6} \right]^{-1/2} = 1310 \text{ ft/sec}$$

Thus, $$\dot{m} = 1.93 \times 10^{-3} P_o D_t^{2}$$

For a given "sonic choke," the oxygen mass flow rate versus total pressure may be plotted theoretically, assuming a constant total temperature. More precisely, each "sonic choke" may be calibrated against a similar one of known mass flow-pressure characteristics. This was done, and the calibration data was found to be within 2% of the theoretically predicted results. This deviation was within the experimental accuracy of the calibration apparatus, so the theoretically predicted mass flow rate-pressure behavior was considered applicable. Mass flow rate-pressure (gauge) characteristics for the four "sonic chokes" presently available are shown in Fig. 3.

To use Fig. 3, it is sufficient to merely select a "sonic choke" and a mass flow rate. The pressure gauge setting is determined from Fig. 3, or it may be calculated by using the equations shown for each throat size. Due regard should be given to conversions between absolute and gauge pressures. It is imperative, of course, to ensure that the pressure drop across the "choke" is large enough to cause "choking." Otherwise, another throat size may be selected.

No attempt is currently made to measure the total temperature directly. Instead, the gas is assumed to be at the same temperature as its container and the air around the container. The flow between the gas cylinder and the pressure reservoir is also assumed to be adiabatic. Temperature corrections to the curves of Fig. 3 may be desirable upon occasion, depending upon ambient conditions. This is easily done, although temperature variations of $\pm$ 5°F from the standard used are well within the experimental sensitivity of the equipment.

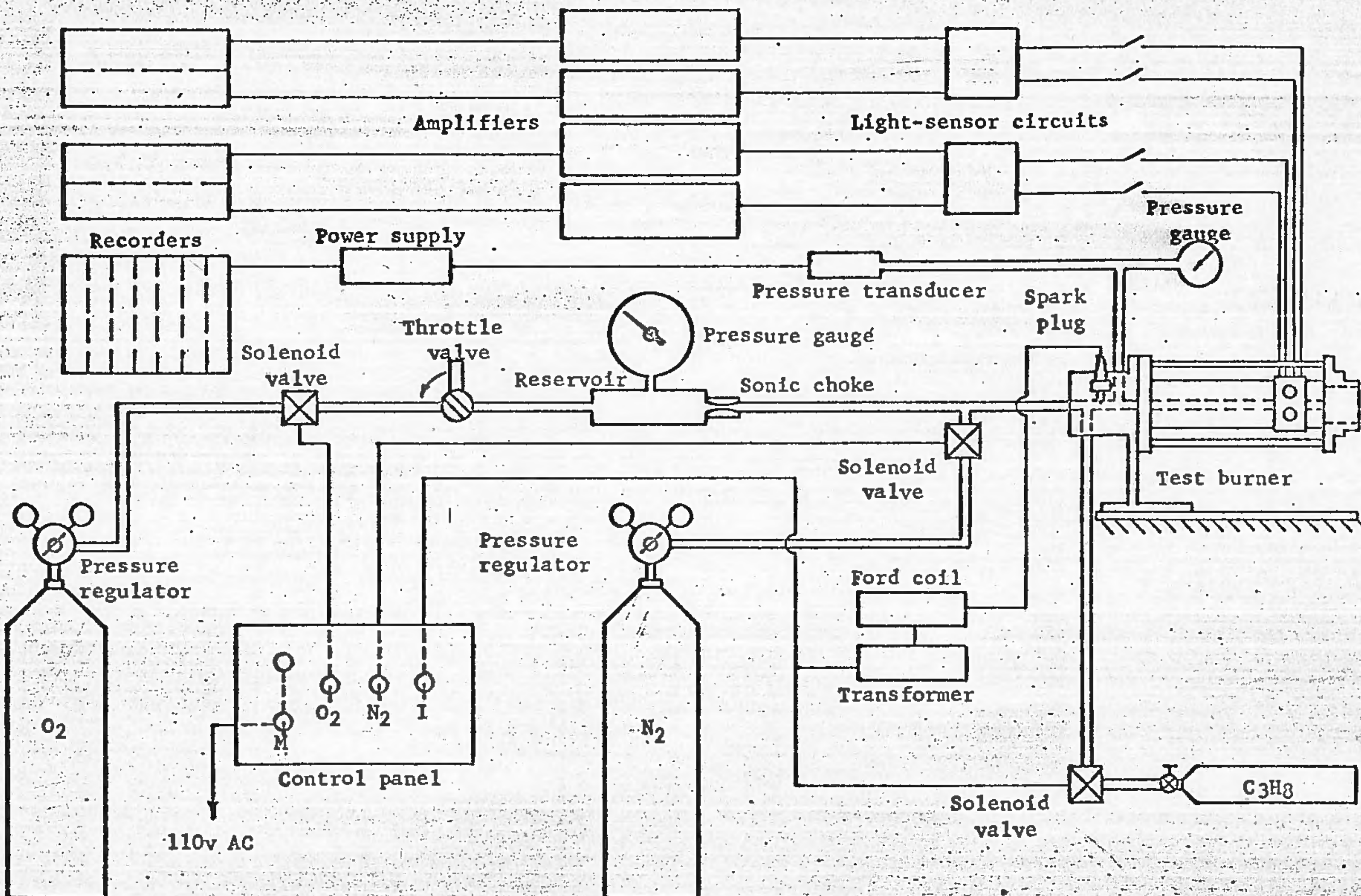


Figure 1. Hybrid Rocket Test Apparatus

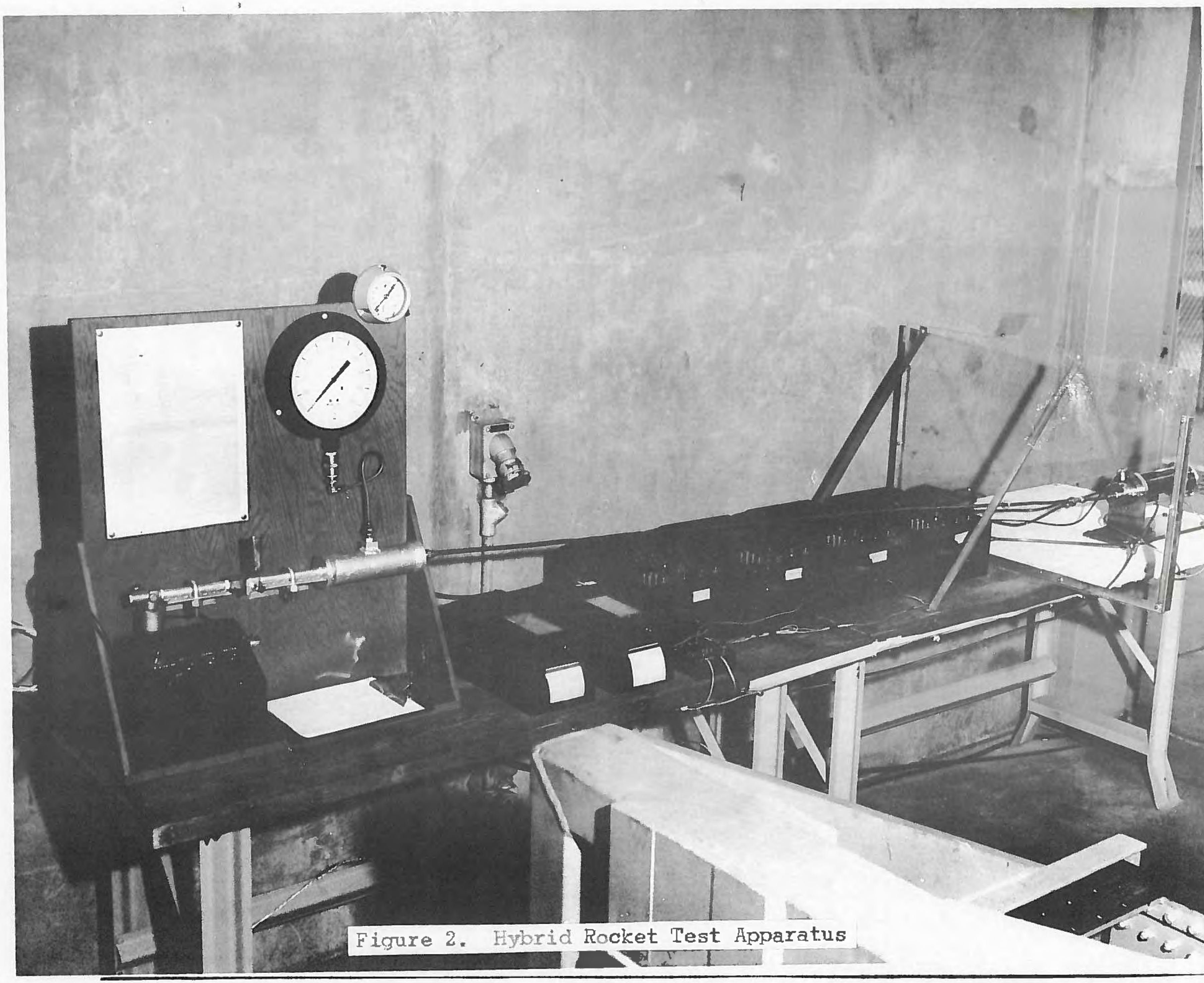
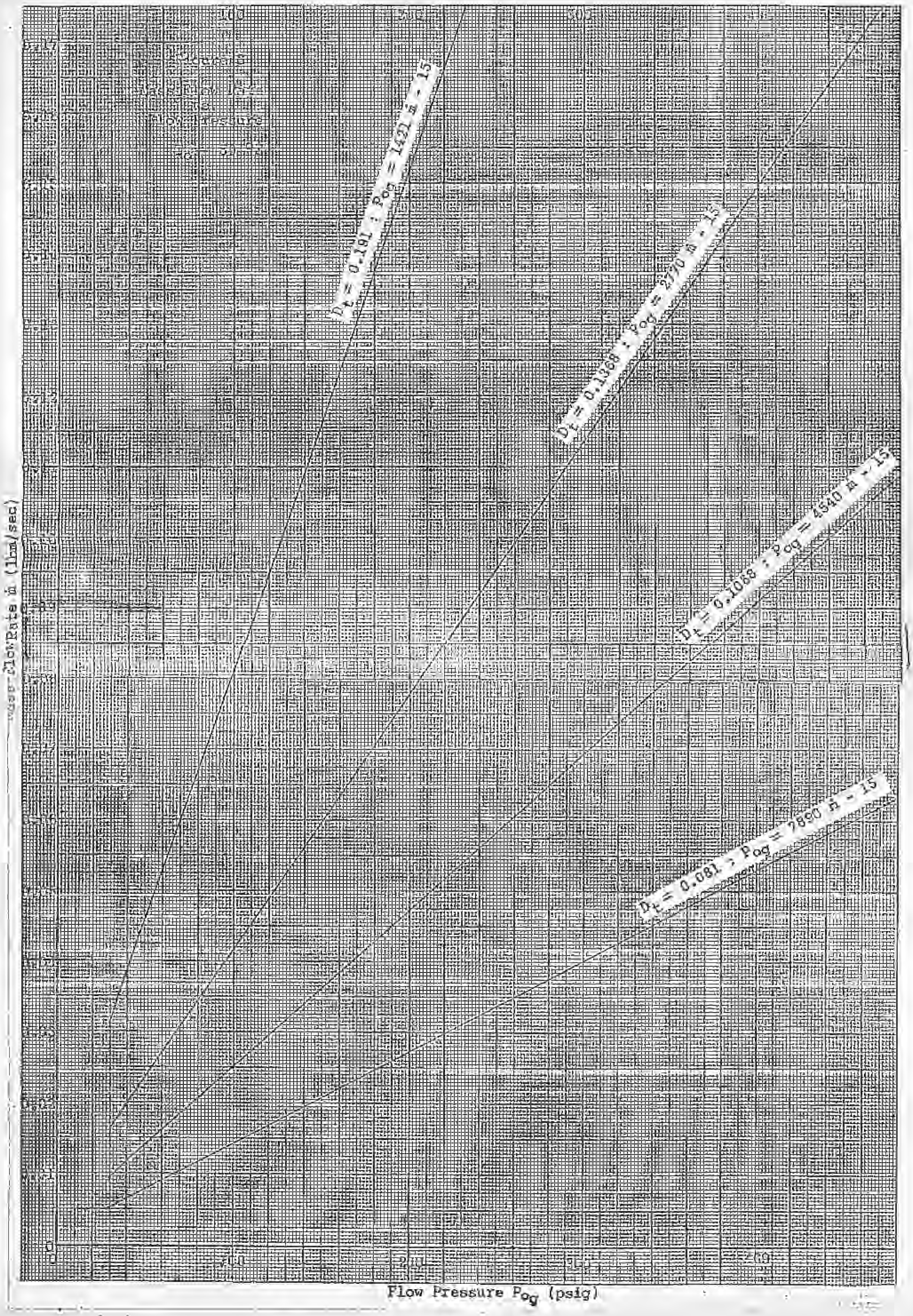
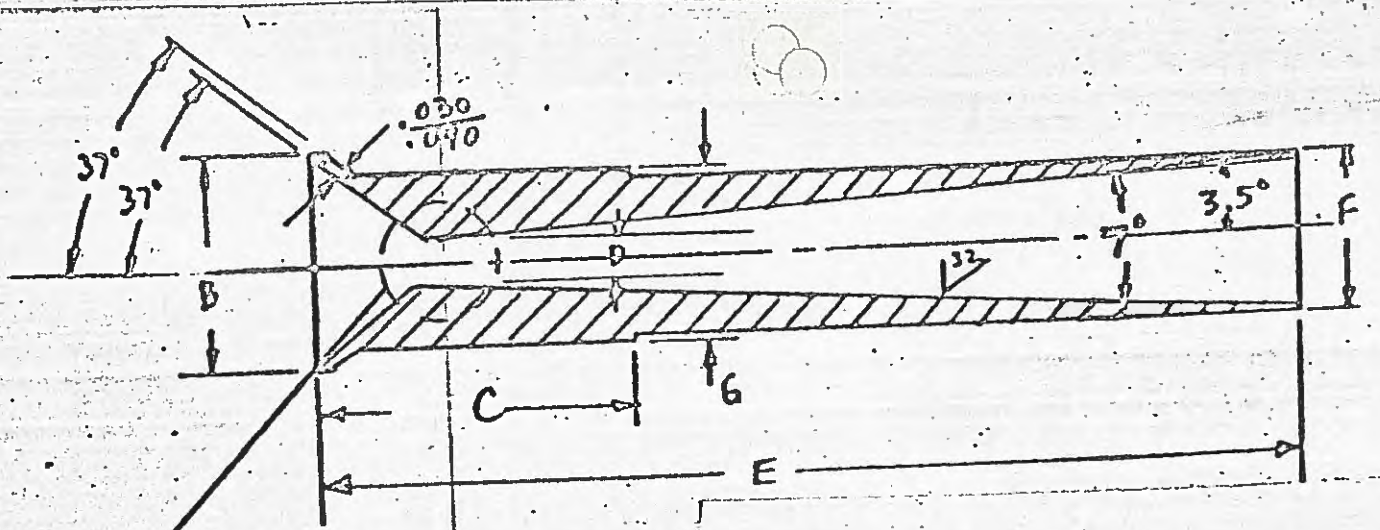
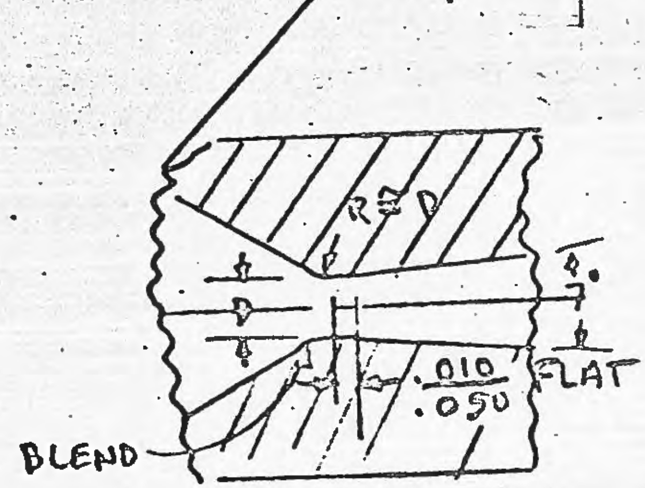


Figure 2. Hybrid Rocket Test Apparatus


$D_t = 0.181$; $P_{og} = 1421\ \dot{m} - 15$
$D_t = 0.1368$; $P_{og} = 2770\ \dot{m} - 15$
$D_t = 0.1068$; $P_{og} = 4540\ \dot{m} - 15$
$D_t = 0.081$; $P_{og} = 7890\ \dot{m} - 15$
Mass Flow Rate $\dot{m}$ (lbm/sec)
Flow Pressure P_{og} (psig)





NOTE. SCRIBE "D" (inches) ON "F" SURFACE

MAT'L: 6061-T6 ALUM.

TOL:
.X ± .060
.XX ± .030
.XXX ± .010
FRACTION ± .060

Figure 4. Sonic Choke

TUBE SIZE	B	D		E	F	G
		INCHES	DRILL			
3/8	0.470	0.081	46	1 1/4	0.26	0.28
↓	↓	0.1065	36	↓	↓	↓
		0.136	29			
		0.1875	3/16			

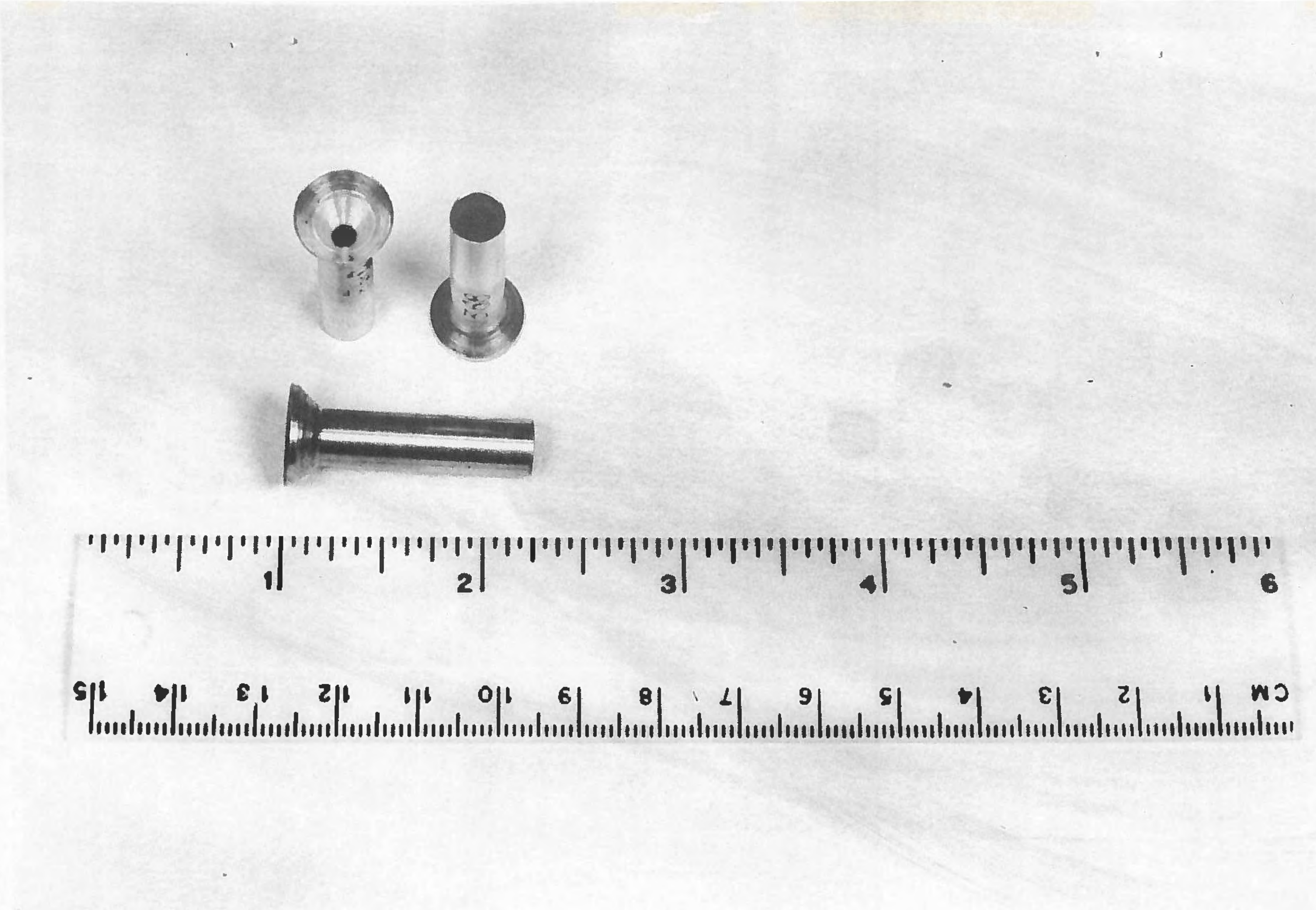


Figure 4a. Sonic Chokes

Figure 5. Hybrid Rocket Test Burner Assembly

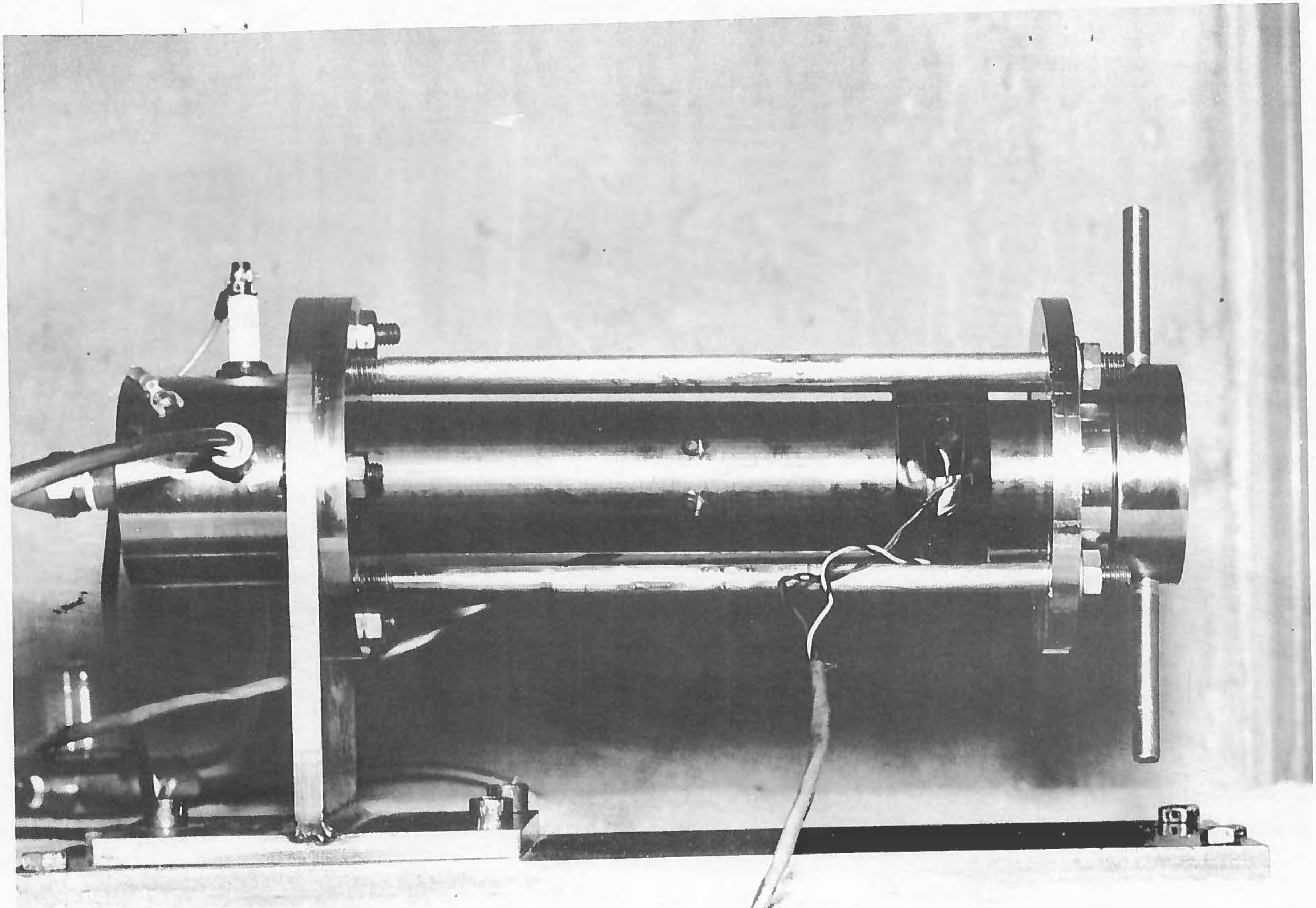


Figure 6. Hybrid Rocket Test Burner

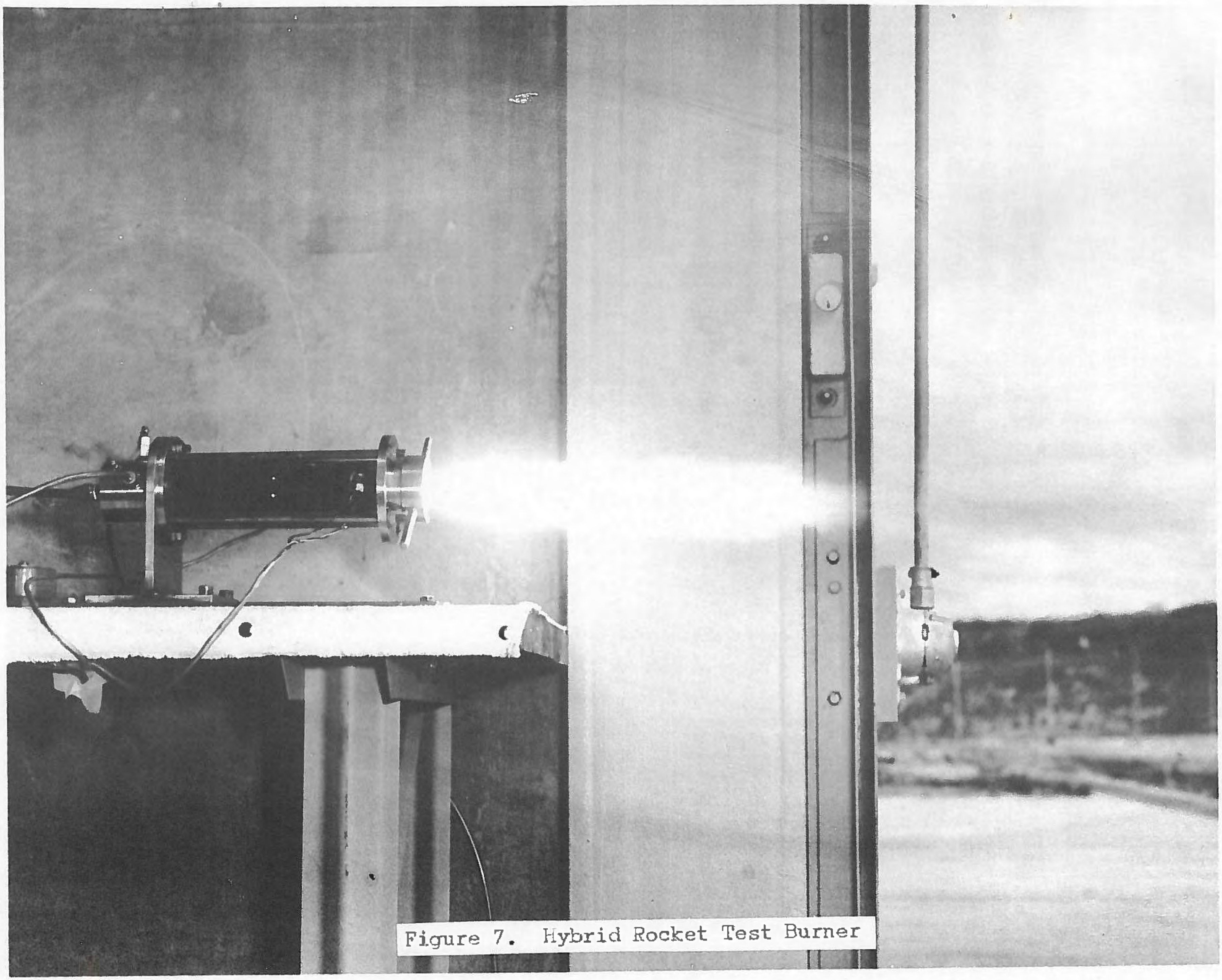


Figure 7. Hybrid Rocket Test Burner

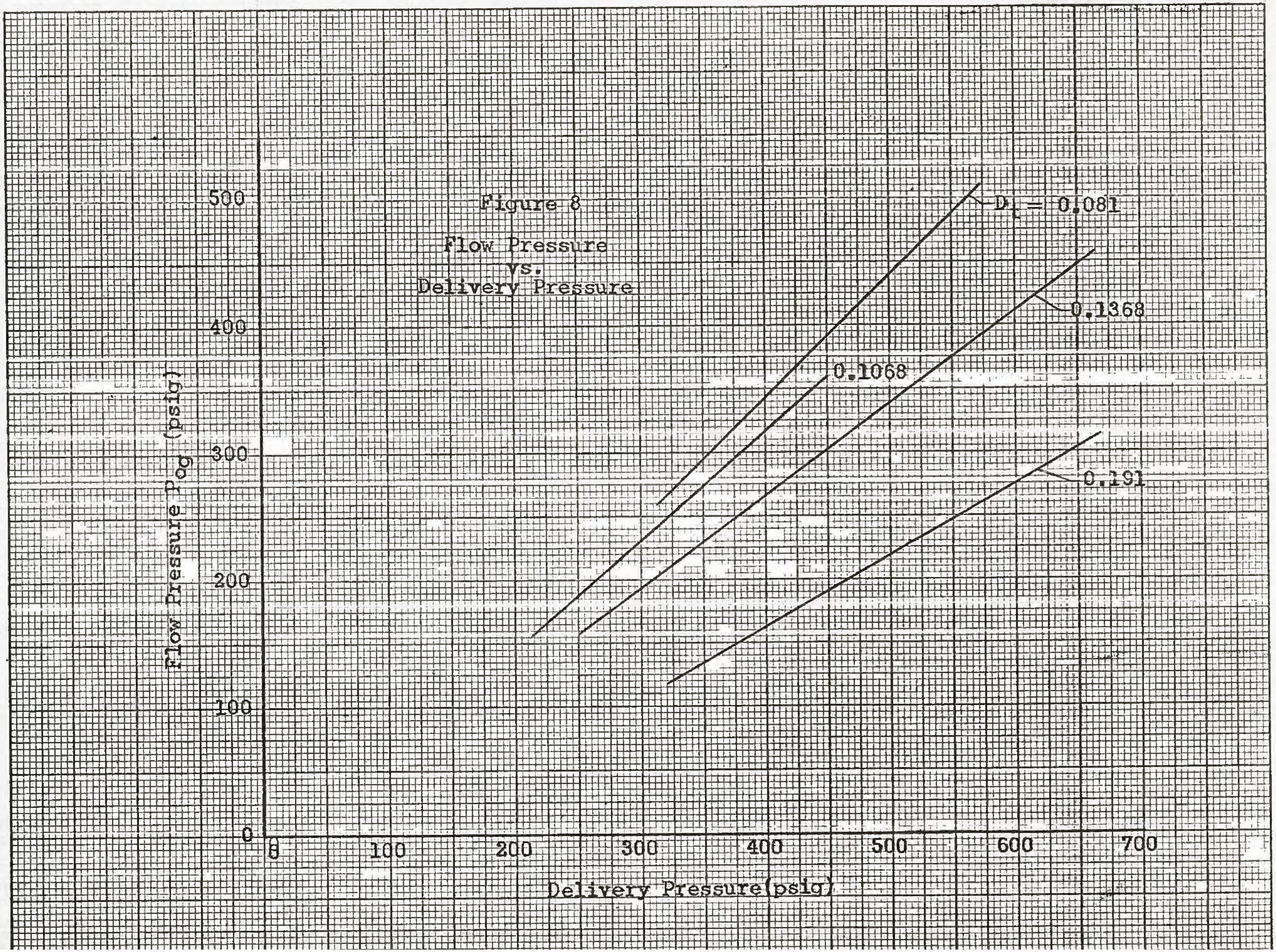


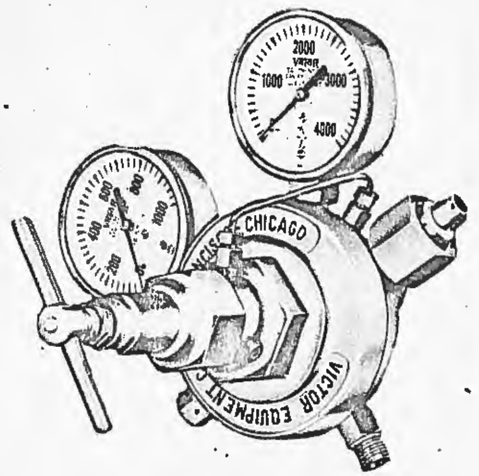
Figure 8

Flow Pressure vs. Delivery Pressure

VII APPENDIX A

MODEL GD10 SERIES REGULATOR

For Inlet Pressure Up To 3500 p.s.i.
Delivery Pressures Up To 500 p.s.i.
Flow Capacity To 250 s.c.f.m.



This regulator is controlled by a pilot regulator that both loads and relieves the dome of the master regulator. The single adjusting screw is turned clockwise to raise, and counter clockwise to decrease the delivery pressure. The regulator adjustment does not vent delivery pressure.

LOW AND HIGH TEMPERATURE OPERATION:

The GD10 Series Regulator is designed to operate in a range from −67°F. to +160°F.

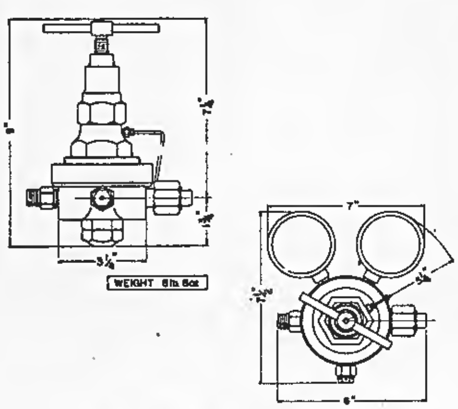
SAFETY RELIEF VALVES:

All GD10 Series Regulators are equipped with safety relief valves set at 550 p.s.i. unless otherwise specified. Regulators for hydrogen service have ventable safety relief valves so the explosive discharge gas can be piped to the outside.

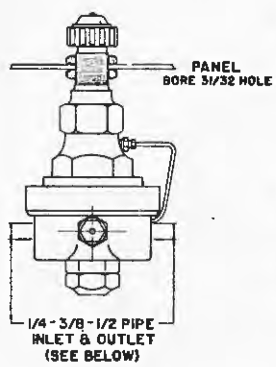
GAUGES—(except panel mounted regulators)

Inlet—4,000 p.s.i.—2½″—100 p.s.i. graduations
Outlet—1,000 p.s.i.—2½″—25 p.s.i. graduations

STANDARD REGULATOR DIMENSIONS



PANEL MOUNTING DIMENSIONS



FOR MANIFOLD SERVICE:

These regulators are also made to be used with Victor manifolds. See listing below.

PANEL MOUNTING REGULATORS

Panel Mounted Regulators are furnished without gauges. The regulator is threaded with ¼″ pipe (F) inlet and outlet gauge ports which are protected with pipe plugs.

INLET AND OUTLET CONNECTIONS:

The inlet and outlet connections as shown below are standard. Special connections such as AND-10050, AND10056, AMINCO, etc., may be furnished at extra cost. **Give complete information when ordering.**

ORDERING EXAMPLE: GD10-AND10050-6.

STANDARD REGULATORS

MODEL	CGA INLET NO.	GAS
GD10-250	¼ Pipe (F)	All non-corrosive
GD10-375	⅜ Pipe (F)	All non-corrosive
GD10-500	½ Pipe (F)	All non-corrosive
GD10-967	CGA-540	Oxygen, Nitrogen, Argon, Air
GD10-973	CGA-580	Water Pumped Argon, Helium, Nitrogen, Air
GD10-974	CGA-590	Oil Pumped Argon, Helium, Nitrogen, Air
GD10-982	None	Nitrogen (Oil Pumped)
GD10-983	CGA-350	Nitrogen, Helium
GD10-982 HYD	None	Hydrogen (with ventable safety relief valve)
GD10-983 HYD	CGA-350	Hydrogen (with ventable safety relief valve)

PANEL MOUNTING REGULATORS—(NO GAUGES)

MODEL	INLET AND OUTLET CONNECTIONS	GAS
GD10-PM-250	¼ Pipe (F)	All non-corrosive
GD10-PM-375	⅜ Pipe (F)	All non-corrosive
GD10-PM-500	½ Pipe (F)	All non-corrosive
GD10-PM-250 HYD	¼ Pipe (F)	Hydrogen (with ventable safety relief valve)
GD10-PM-375 HYD	⅜ Pipe (F)	Hydrogen (with ventable safety relief valve)
GD10-PM-500 HYD	½ Pipe (F)	Hydrogen (with ventable safety relief valve)

MANIFOLD REGULATORS

MODEL	INLET AND OUTLET CONNECTIONS**	GAS
GD10-996	Manifold (R.H.)	Oxygen, Nitrogen, Helium, Argon, Air
GD10-997 HYD	Manifold (L.H.)	Hydrogen (with ventable safety relief valve)

*All outlet connections 9/16-18 "B" R.H. Hydrogen L.H. ¼″ tube connection furnished on request. **See Victor regulator connection chart for details.

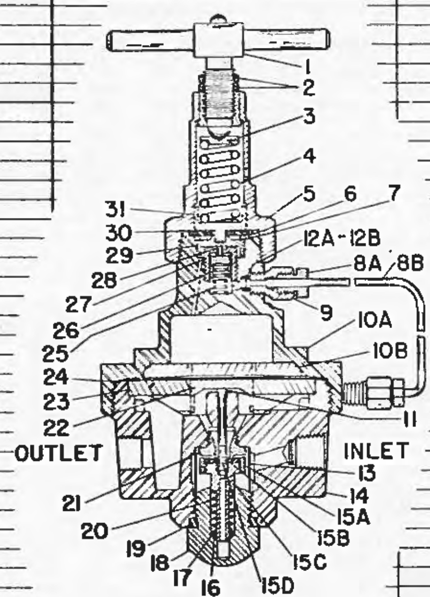
VICTOR EQUIPMENT COMPANY

FORM R14 | 844 Folsom Street, San Francisco 7 | 3821 Santa Fe Ave., Los Angeles 58 | 1145 E. 76th Street, Chicago 19

PARTS LIST MODEL GD10 REGULATORS

REF. NO.	DESCRIPTION	BASIC PARTS Standard GD10	Panel Mtg. GD10-PM
1	Adjusting Screw	0750-17	0750-30
2	Locknut (2)	GD41-07	1403-30
3	Spring Button	0706-07	
4	Adjusting Spring	0761-13	
5	Bonnet (Loading Regulator)	0720-17	0720-26
6	Diaphragm (Load-Regulator)	0731-16	
7	Stop Ring	0736-02	
8	Connector Tube Assembly	0729-27	
8a	Nut (2)	GD20-14	
8b	Tube 1/8 OD Tube 6" Lg	0729-2702	
9	Connector (2)	GD41-11	
10	Bonnet Assembly	0720-1602	
10a	Bonnet	0720-16	
10b	Upper Diaphragm Plate	0735-19	
11	Stem Extension	0744-05	
12	Screen Assembly		
12a	Screen (2)	0771-09	
12b	'O' Ring (2)	1407-01	
13	Filter Screen	0771-05	
14	Body	See Block	
15	Seat Holder Assembly	0740-36	
15ab	Seat Unit Assembly	0742-16	
15a	Seat Retaining Nut	0743-12	
15b	Seat	0741-16	
15c	Seat Holder	0746-01	
15d	Stem	0744-19	
16	Friction Bushing	1408-44	
17	'O' Ring Gland	0708-01	
18	Back Plug	0704-03	
19	Back Plug 'O' Ring	1407-21	
20	Valve Spring	0762-01	
21	Nozzle	0702-17	
22	Lower Diaph. Plate Button	0735-22	
23	Lower Diaphragm Plate	GD40-05	
24	Diaphragm	GD20-07	
25	Spring Valve	0762-07	
26	Seat	0741-25	
27	Nozzle	0702-18	
28	Stem	0744-20	
29	Lower Diaphragm Plate	0735-20	
30	Slip Ring	0705-05	
31	Upper Diaphragm Plate	0735-21	
32	Screen and Ring	930	
33	Inlet Connection Assembly	See Block	
34	Gauge 2-1/2 Br.	4000#	None
35	Gauge 2-1/2 Br.	1000#	None
36	Outlet Connection	See Block	
37	Safety Valve	See Block	
38	Plug 1/8 Pipe (2)	1105-05	
39	Plug 1/4 Pipe (2)	None	1105-04
	Max. Inlet Pressure	2500 psi	
	Max. Outlet Pressure	500 psi	

GD10 SERIES GAS-O-DOME REGULATOR



INLET CONNECTIONS		REF. #14 BODY	REF. #33 INLET CONN. ASSEMBLY	REF. #36 OUTLET CONN ASSEMBLY	REF. #37 SAFETY VALVE
967	CGA-540	0701-0113	0967-2102	50-20	0600-600
973	CGA-580	0701-0113	0973-0102	50-20	0600-600
974	CGA-590	0701-0113	0974-0102	50-20	0600-600
982	CGA-None	0701-0113	0982-2102	50-20	0600-600
983	CGA-350	0701-0113	0983-0102	50-20	0600-600
982 (Hyd.)	CGA-None	0701-0113	0982-2102	60-20	*0610-1500
983 (Hyd.)	CGA-350	0701-0113	0983-0102	60-20	*0610-1500
984	CGA-550	0701-0113	0984-0102	50-20	0600-600
996	Manifold	0701-0117	0996-0501	0996-08	0600-600
997 (Hyd.)	Manifold	0701-0117	0997-0601	0996-08	*0610-1500
250 (F)	1/4 Pipe	0701-0113	None	None	0600-600
375 (F)	3/8 Pipe	0701-0120	None	None	0600-600
500 (F)	1/2 Pipe	0701-0117	None	None	0600-600
AND10050-4	1/4 Tube	0701-0120	0917-6101	0917-61	0600-600
AND10050-5	5/16 Tube	0701-0120	0917-6201	0917-62	0600-600
AND10050-6	3/8 Tube	0701-0120	0917-6301	0917-63	0600-600
AND10050-8	1/2 Tube	0701-0120	0917-6401	0917-64	0600-600
AND10050-10	5/8 Tube	0701-0120	0917-6501	0917-65	0600-600
AND10050-12	3/4 Tube	0701-0120	0917-6601	0917-66	0600-600
AND10056-4	1/4 Tube	0701-0120	0917-67	0917-67	0600-600
AND10056-5	5/16 Tube	0701-0120	0917-68	0917-68	0600-600
AND10056-6	3/8 Tube	0701-0120	0917-6901	0917-69	0600-600
AND10056-8	1/2 Tube	0701-0120	0917-7001	0917-70	0600-600
AND10056-10	5/8 Tube	0701-0120	0917-7101	0917-71	0600-600
AND10056-12	3/4 Tube	0701-0120	0917-7201	0917-72	0600-600
AMINCO-1	1/4 Tube	0701-0120	0917-73	0917-73	0600-600
AMINCO-3	3/8 Tube	0701-0120	0917-74	0917-74	0600-600
AMINCO-9	9/16 Tube	0701-0120	0917-7501	0917-75	0600-600

* VENTED SAFETY VALVE - SET AT 600 P.S.I.

HOW TO ORDER REGULATOR

Write Inlet Connection after Regulator Model Number - example:

GD10-250
GD10-AND10050-6
GD10-PM-375
GD10-996

All regulators available for Hydrogen use - Place HYD. after Model Number - Example: GD10-AND10056-4 HYD.

TEMP. OPERATIONAL RANGE	WEIGHT
-67° F to +200° F	8 lb. 8 oz.

INSTALLATION AND MAINTENANCE INSTRUCTIONS
TWO-WAY PILOT CONTROLLED PISTON OPERATED SOLENOID VALVES

8223

ASCO

DESCRIPTION

Bulletin 8223 valves are of the internal pilot operated piston type. They are normally closed (closed when de-energized). A minimum operating pressure is required to open the valve and to maintain full flow. Check nameplate for minimum and maximum pressure, also for voltage.

Standard valves have a general purpose pressed steel Nema Type 1 solenoid enclosure as shown in Figures 1 and 2. Catalog numbers with prefix WP have a watertight Nema Type 4 solenoid enclosure as shown on separate Installation and Maintenance Form No. V-5101. Valves with "explosion proof" on nameplate have an explosion proof, Nema Type 7C, 7D, 9E, 9F, and 9G solenoid enclosure as shown on separate Installation and Maintenance Form No. V-5100.

INSTALLATION INSTRUCTIONS

Before installing valves, check nameplate for correct pressure, voltage and service.

POSITIONING

These valves may be mounted in any position. The flow through the valve must be according to the directional markings on the valve body.

PIPING

Apply pipe compound sparingly to the male fittings only. If applied to the valve threads, it may enter the valve and cause operational difficulty. Pipe strain on the valve body should be avoided by proper support and alignment of piping. When tightening the pipe, do not use the valve as a lever.

WIRING

Wiring must comply with Local and National Electrical Codes. Solenoid enclosures are provided with holes to accommodate standard 1/2 inch conduit connections. The solenoid enclosure may be rotated 360° to facilitate wiring. To rotate the solenoid enclosure, loosen cap nut.

NOTE: Alternating Current (AC) and Direct Current (DC) solenoids are of different construction. To change the service from AC to DC or the reverse, it is necessary to change the complete solenoid.

SOLENOID TEMPERATURE

Standard catalog valves are supplied with coils designed for continuous duty service. When the solenoid is energized for a long period, the solenoid enclosure becomes hot and can be touched by hand only for an instant. This is a safe operating temperature. Any excessive heating will be indicated by the smoke and the odor of burning coil insulation.

Catalog numbers 822351, 822352, 822361, and 822362 are for high pressure DC applications and valves may be energized only intermittently not longer than 15 seconds during a 60 second period.

MAINTENANCE INSTRUCTIONS

Before making repairs turn off electrical power and depressurize valve. It is not necessary to remove valve from pipe for repairs.

CLEANING

A periodic cleaning of all solenoid valves is desirable. The time between cleanings will vary, depending on the media handled and service conditions. In general, if the voltage to the coil is correct, sluggish valve operation or excessive leakage will indicate that cleaning is required.

IMPROPER OPERATION

1. Faulty Control Circuit: Check electrical system by energizing the solenoid. A metallic click will be heard if the solenoid is operating properly. Absence of the click indicates loss of power supply. Check for loose or blown-out fuses, open-circuited or grounded coil, broken lead wires or splice connections.
2. Burned Out Coil: Check for open-circuited coil with a test-lamp. Replace coil, if necessary.
3. High or Low Voltage: Check voltage across the coil leads with a voltmeter. Voltage must be between 85% and 110% of nameplate rating.
4. Incorrect Pressure: Check valve pressure. Pressure must be within the range specified on nameplate.
5. Excessive Leakage: Disassemble valve and clean all parts. Replace any parts that are worn or damaged.
6. Improper Opening or Closing: Disassemble valve and clean bleed passages in valve body. Clean all parts and replace worn or damaged ones.

COIL REPLACEMENT

Turn off electrical power, disconnect lead wires and disassemble solenoid in order shown in exploded view, Figs. 1 & 2.

VALVE DISASSEMBLY AND ASSEMBLY

De-pressurize valve and remove solenoid base assembly (with solenoid) from valve body. Then disassembly further according to exploded views Figures 1 & 2.

Assemble valve in reverse order of disassembly.

FORM NO. V-5051-R1 Printed in U.S.A. 1963

ASCO Valves

Automatic Switch Co. FLORHAM PARK, NEW JERSEY

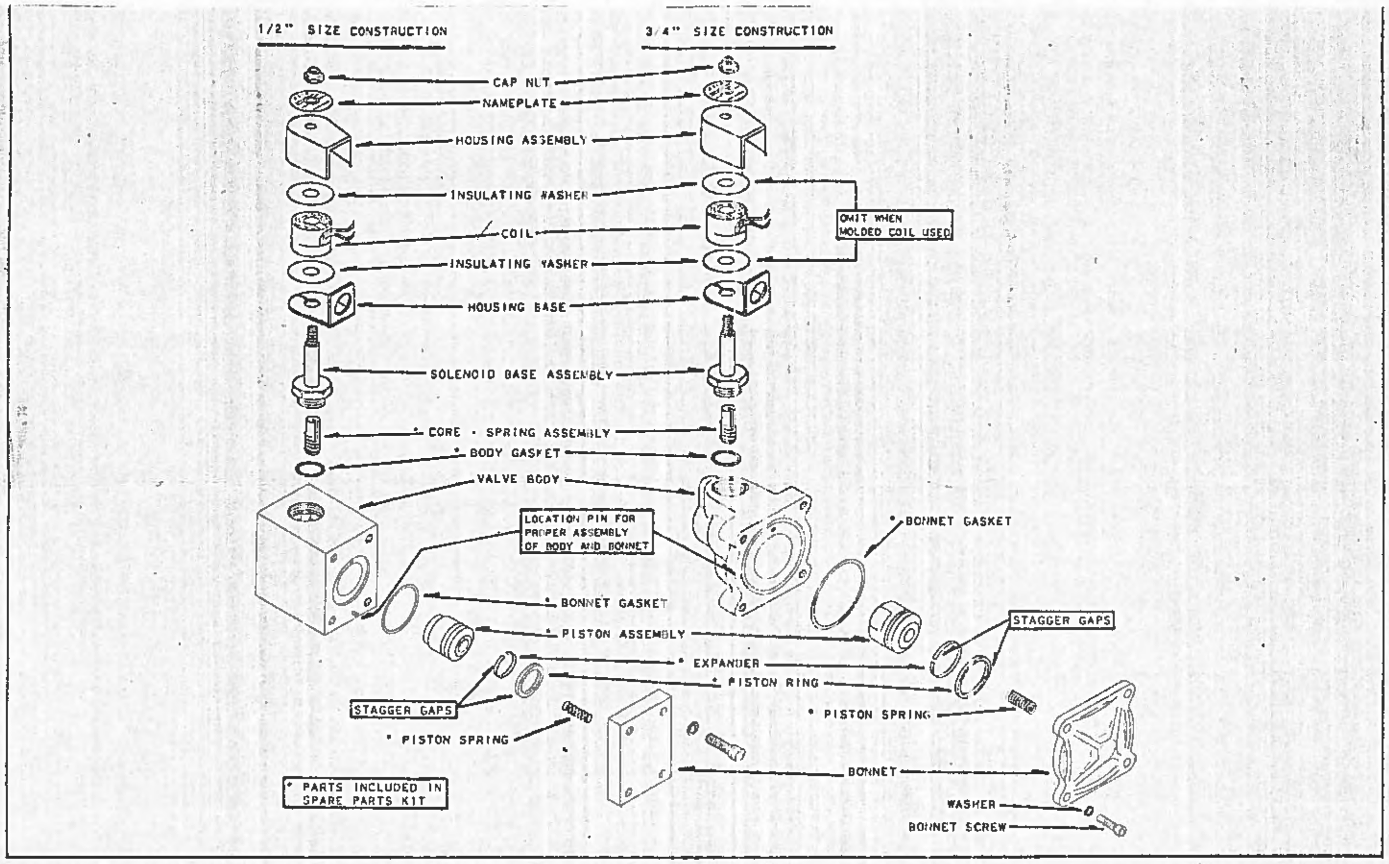


Fig. 1. Bulletin 8223 - 1/2 & 3/4 NPT Construction

SPARE PARTS KIT

CATALOG NUMBER		KIT NUMBER	
NEMA 1 & 4	NEMA 7	DC	AC
3	4	70-939	70-938
5, 52	6	71-054	71-055
10	11	70-941	70-940
12, 62	13	68-159	68-158
21, 23	22,24	78-965	78-964
25, 27	26, 28	78-963	78-962

KIT CONTENTS

Core-spring assembly, Piston assembly with ring, 'O'-ring, gasket, piston spring.

WHEN ORDERING SPARE PARTS KITS OR COILS, SPECIFY VALVE CATALOG NUMBER, SERIAL NUMBER AND VOLTAGE.

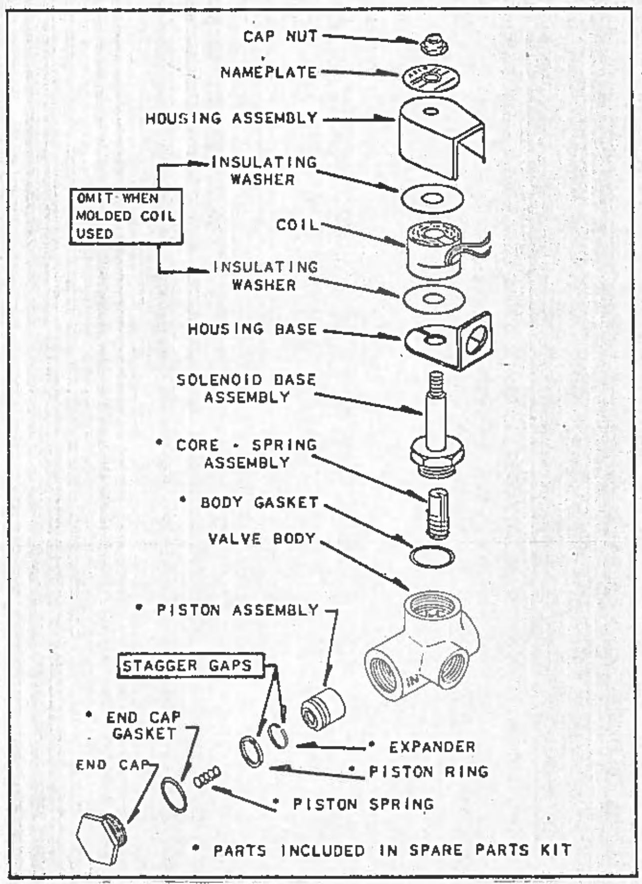


Fig. 2. Bulletin 8223
1/4 & 3/8 NPT Construction