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MSC INTERNAL NOTE

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Propellant Saturation Test

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PROPELLANT SATURATION TEST

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PROPELLANT SATURATION TEST

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INTRODUCTION

In rocket engine propulsion systems utilizing hypergolic propellants, a proper oxidizer/fuel ratio is required for ideal starting and burning conditions. If this ratio is changed by unbalanced propellant flows, loss of thrust can be experienced. This ratio imbalance can exist if gaseous helium saturates the propellant to a high degree, and evolves from the solution to displace the propellant subsequent to a series of pressure drops.

The objective of this test program was to determine the behavior of gas-saturated water and nitrogen tetroxide under various flow and pressure drop conditions. A second part of the test program is to be conducted at a later time to determine the rate of gas diffusion into propellants and the maximum amount of gas soluble in the propellants.

The test program was conducted by the Fluid Systems Test Section of the Thermochemical Test Branch for the Auxiliary Propulsion and Pyrotechnics Branch, Propulsion and Power Division. Testing was accomplished at the Fluid Systems Test Facility during the period from February 2, 1966, to May 3, 1966.

TEST ARTICLE DESCRIPTION

The test system as shown schematically in figure 1 was designed to provide controlled pressure drops and temperatures at a constant flow rate, and to measure the amount of gas coming out of solution under flow conditions.

Various required pressure drops were provided by handvalves for the water phase and by flat plate orifices for the nitrogen tetroxide phase. Temperatures were controlled by a jacket installed on the run tank for either ethylene glycol or water circulation.

The gas evolving from the solution was measured in graduated sight glasses after being collected in stay chambers (see figure 2). After the pressure drop through the orifice the gas was allowed to move to the top of the stay chambers and ultimately rise into the sight glasses for measuring.

All instrumentation equipment utilized in the test program was calibrated with standards directly traceable to the National Bureau of Standards (see figure 3).

TEST PROCEDURE

Test preparation was begun by setting the proper flow and pressure drops in the system. This was accomplished after instrument calibration by flowing water from the run tank through the orificing hand valves (see figures 4 and 5) and then adjusting them to the proper number of turns for the desired pressure drops (150, 75, 50, 25, and 10 psi).

Saturation of the water for Phase I testing was accomplished by bubbling the saturation gas into the run tank at a set rate for 24 hours (see figures 1 and 6), and maintaining tank pressure and temperature equal to the test run conditions. This rate was set by regulating a flow of gas into water in the run tank and determining relative saturation at periods of 18, 24, and 48 hours. At the end of each trial period, the water was flowed through the orifice system setup for a 150 psi pressure drop, and the gas evolution rate was recorded. Since the saturation of the water was the same for 24 and 48 hour periods, and lower for the 18 hour period, 24 hours was chosen as the minimum saturation time for the full run tank.

After the 24 hour saturation period, the test system was transferred from the gas saturation system to the pressurization system, and instrumentation calibration was verified.

The orificing handvalves were then set at the proper position for the desired pressure drop, and the test system was bled out to remove any trapped gases.

After a final check of all systems, water was allowed to flow through the system at a rate of 1.29 gallons per minute and a pressure of 320 $\pm$ 10 psig. All gas coming out of solution was collected in the calibrated sight glasses, and then a final test ending calibration was made.

Phase II testing with nitrogen tetroxide was similar to the water phase. However, an orifice plate (see figure 7) was used in place of one of the orificing handvalves, and a modified bleed procedure was utilized for more positive removal of gas from the stay chambers. This provided more accurate sight glass readings on the gas that came out of solution with each pressure drop setting.

A receiver tank system was added to the Phase I water test system to contain nitrogen tetroxide (see figure 8). This tank facilitated propellant transfer between tanks after test runs. Phase II propellant testing also included a manifold system to remove propellant fumes from the test area and transfer them to the oxidizer scrubber system (see figure 9). Air under pressure was injected into the scrubber system line, and the resulting negative pressure in the system moved the propellant fumes from the test system into the manifold scrubber system for disposal.

TEST PROGRAM

The test program consisted of the following phases:

Phase I Water Runs at 1.29 GPM and 320 ± 10 psig

A. 35 ± 5°F temperature

1. Gaseous Nitrogen

a. 150 psi drop
b. 75 psi drop
c. 50 psi drop
d. 25 psi drop
e. 10 psi drop

2. Gaseous Helium

a. 150 psi drop
b. 110 psi drop
c. 75 psi drop
d. 50 psi drop
e. 25 psi drop

B. 75 ± 5°F temperature

1. Gaseous Nitrogen

a. 150 psi drop
b. 110 psi drop
c. 75 psi drop
d. 50 psi drop
e. 25 psi drop
f. 10 psi drop

2. Gaseous Helium

a. 150 psi drop
b. 110 psi drop
c. 75 psi drop
d. 50 psi drop
e. 25 psi drop

C. 110 ± 5°F temperature

1. Gaseous Nitrogen

a. 150 psi drop
b. 75 psi drop
c. 50 psi drop
d. 25 psi drop
e. 10 psi drop

2. Gaseous Helium

   a. 150 psi drop
   b. 110 psi drop
   c. 75 psi drop
   d. 50 psi drop
   e. 25 psi drop

Phase II Nitrogen Tetroxide Runs with Gaseous Helium at 1.29 GPM and 320 ± 10 psig

A. 35 ± 5°F temperature

   1. 150 psi drop
   2. 110 psi drop
   3. 75 psi drop
   4. 50 psi drop
   5. 25 psi drop

B. 75 ± 5°F temperature

   1. 150 psi drop
   2. 110 psi drop
   3. 75 psi drop
   4. 50 psi drop
   5. 25 psi drop

C. 110 ± 5°F temperature

   1. 150 psi drop
   2. 110 psi drop
   3. 75 psi drop
   4. 50 psi drop
   5. 25 psi drop

RESULTS AND DISCUSSION

The initial test runs, which were conducted with water and gaseous nitrogen, proved the feasibility of conducting the test program, with examination of saturated propellant behvaior as the ultimate objective. These runs were conducted primarily to evaluate the test system and to develop procedures for later runs.

The first test run was made at 35°F after saturating the water for a period of 24 hours. After the initial flow runs were conducted, a problem with gas entrapment in the original stay chambers was encountered. Due to the interior construction of the first type of chamber, gas was retained in the top of the chamber cavity and would not move up into the sight glass properly. A silicone coating was then applied to the interior of the chambers and of the sight glasses. This improved the gas movement to a point where reliable readings could be obtained in all 35°F, 75°F, and 110°F runs.

All water runs were subsequently conducted with the first type of stay chamber, but test data was not as consistent as it was with the second type. However, results were satisfactory and the test data obtained was acceptable.

The nitrogen tetroxide propellant runs were conducted with different sight glasses and redesigned stay chambers for freer movement of the gas into the sight glasses. In each run the gas did rise freely into the sight glasses and the data curves show the consistency of all three propellant runs.

In the Phase I water test runs, it was noted that a greater amount of gaseous nitrogen will come out of solution as the temperature is decreased, and that a greater amount of gaseous helium will come out of solution as the temperature is increased (see figures 10 and 11). This property of gaseous helium was also noted in the propellant runs; however, the amount of gas that came out of solution was much higher (see figure 12).

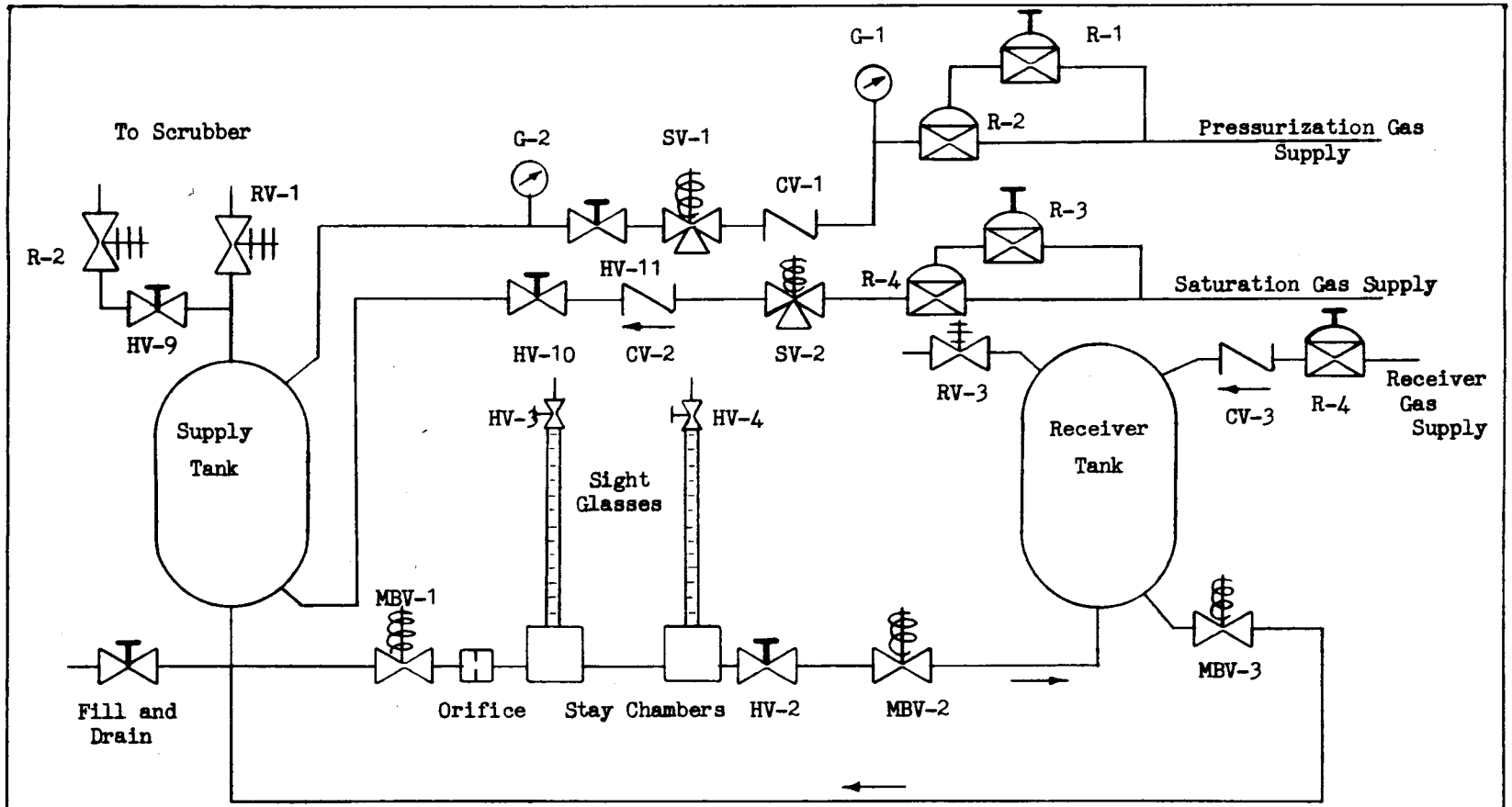
CONCLUSIONS AND RECOMMENDATIONS

1. Gases can be diffused into liquids such as water and nitrogen tetroxide under pressure, and then allowed to come out of solution in a measurable amount with controlled pressure drop and temperature conditions.

2. A greater amount of gaseous helium will come out of solution as the temperature is increased under pressure drop conditions.

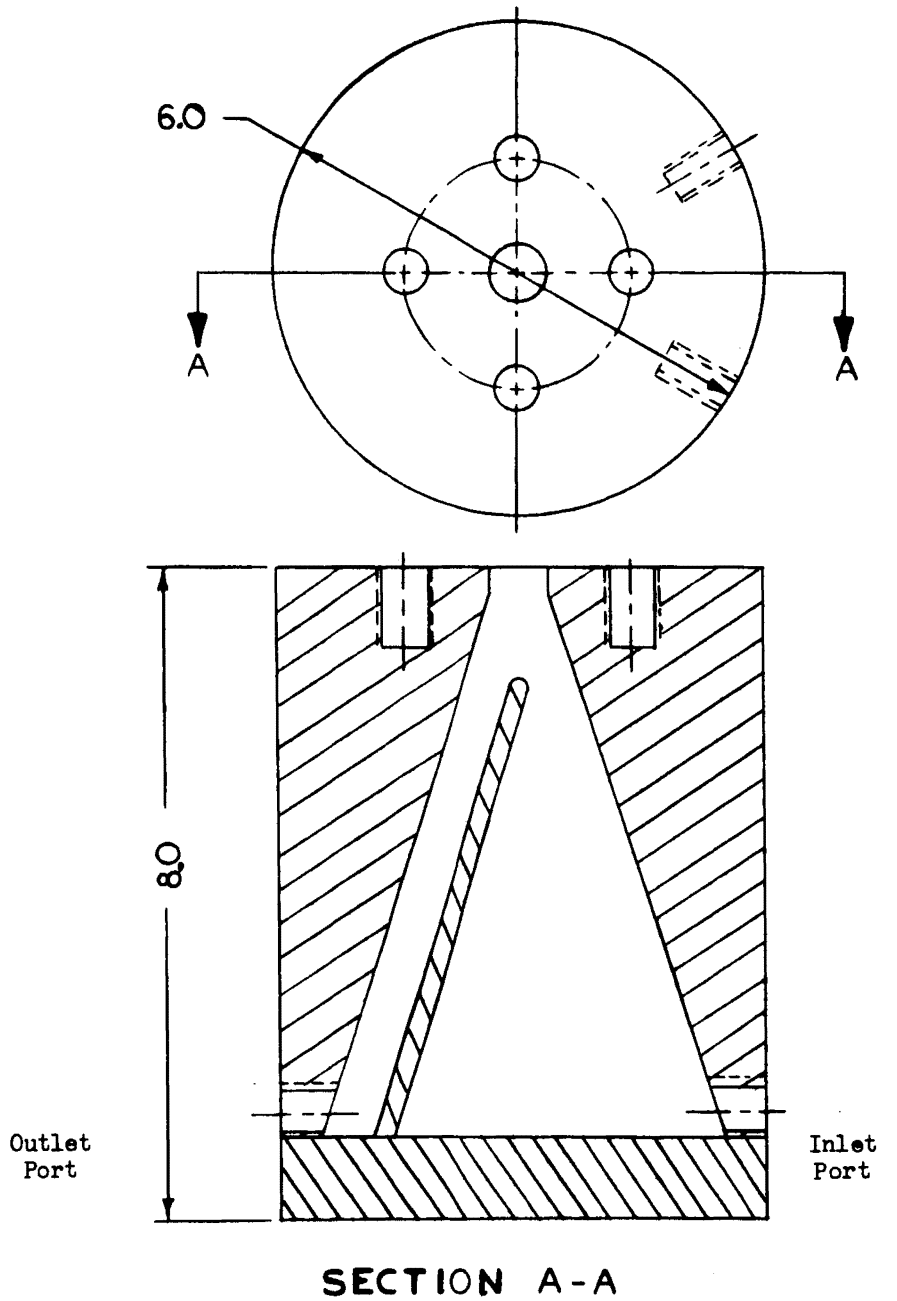
3. A greater amount of gaseous nitrogen will come out of solution as the temperature is decreased under pressure drop conditions.

4. Consideration should be given to test programs investigating engine performance with saturated and unsaturated propellants under controlled conditions.



SCHEMATIC DIAGRAM OF PROPELLANT
SATURATION FLOW TEST SYSTEM

FIGURE 1



SECTION VIEW OF FINAL STAY CHAMBER CONFIGURATION

FIGURE 2

TEST INSTRUMENTATION EQUIPMENT

Recording Equipment: Systems Engineering Laboratories

Digital Data Acquisition System, Model 600

Consolidated Electrodynamics Corporation

Recording Oscillograph, Model 5-114

Bristol Four Pen Recorder, Model Number 4P20H591-TE84B-09AX-TF160X-T188K-TF351X

Pressure Measurement: Taber Pressure Transducer, Model 206, 0-500 psig.

Statham Differential Pressure Transducer, Model 168, 0-1.0 psid

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FIGURE 3

TEST INSTRUMENTATION EQUIPMENT

Flow Measurement: Flow Technology Corporation

Flowmeter, Model FTM-75-LB, .75 - 7.5 GPM

Temperature Measurement: Research Incorporated Reference Junction Box

Model No. 4081, used in conunction with Chromel-Alumel Thermocouple Wire.

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FIGURE 3 (Cont.)

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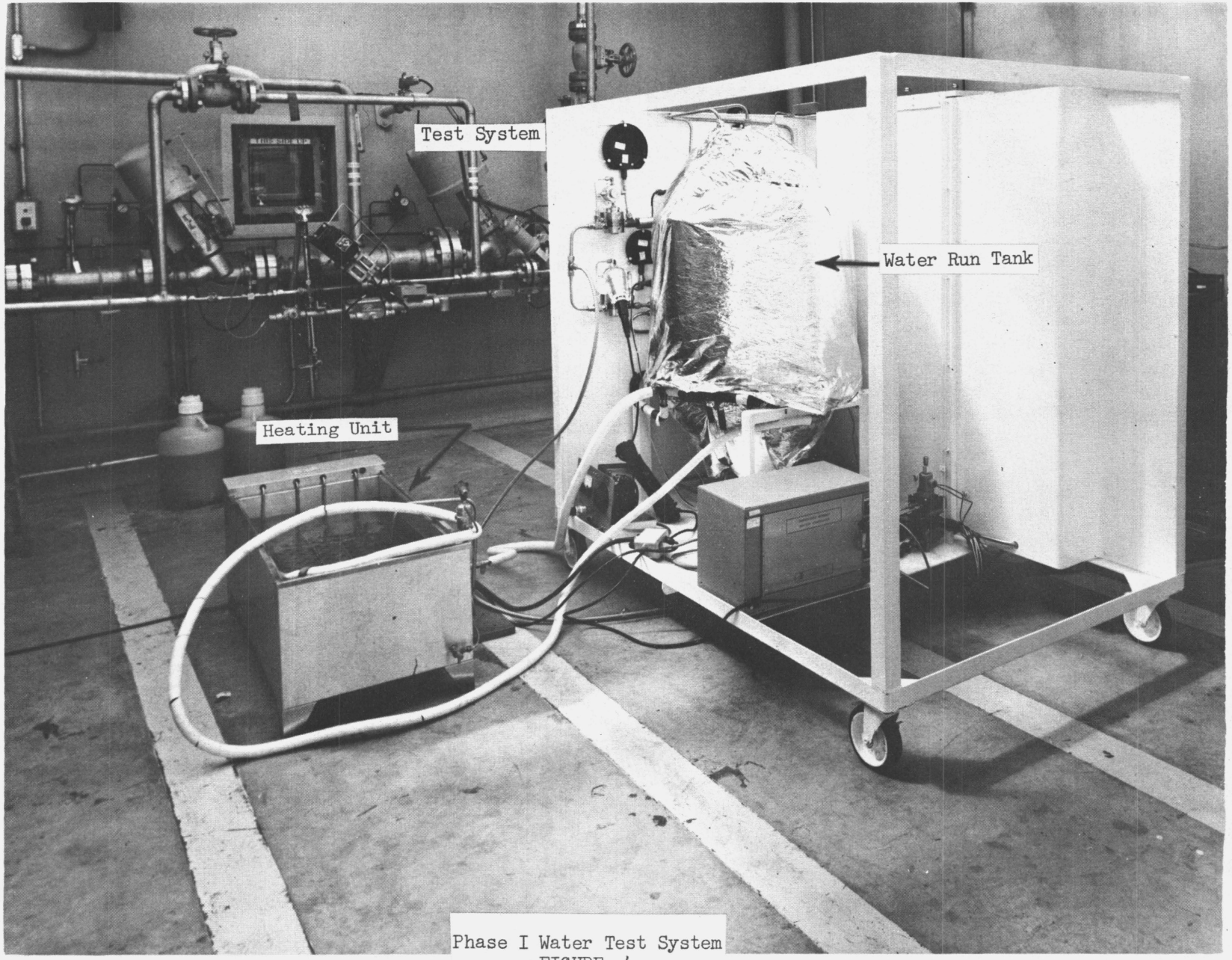

Phase I Water Test System
FIGURE 4

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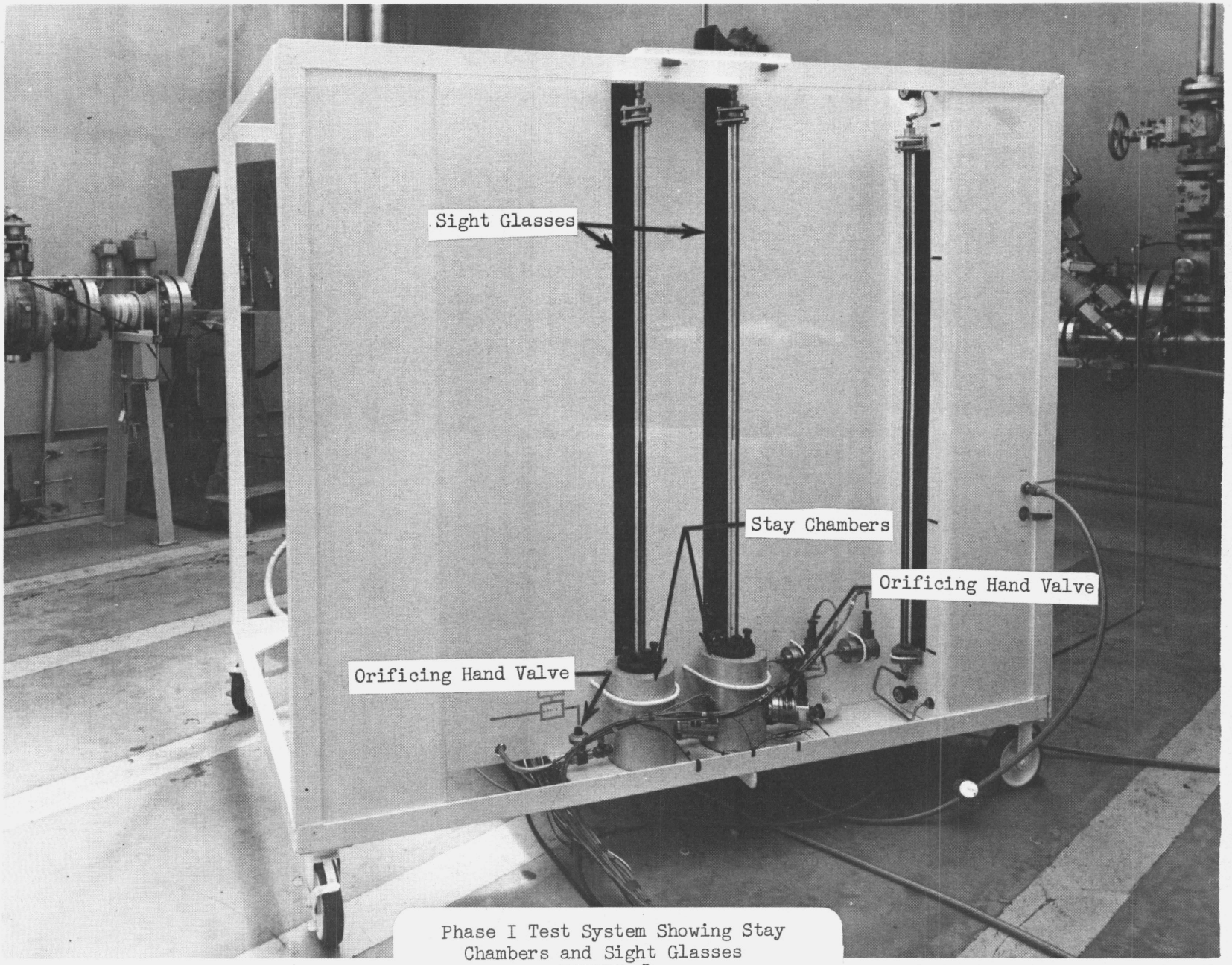
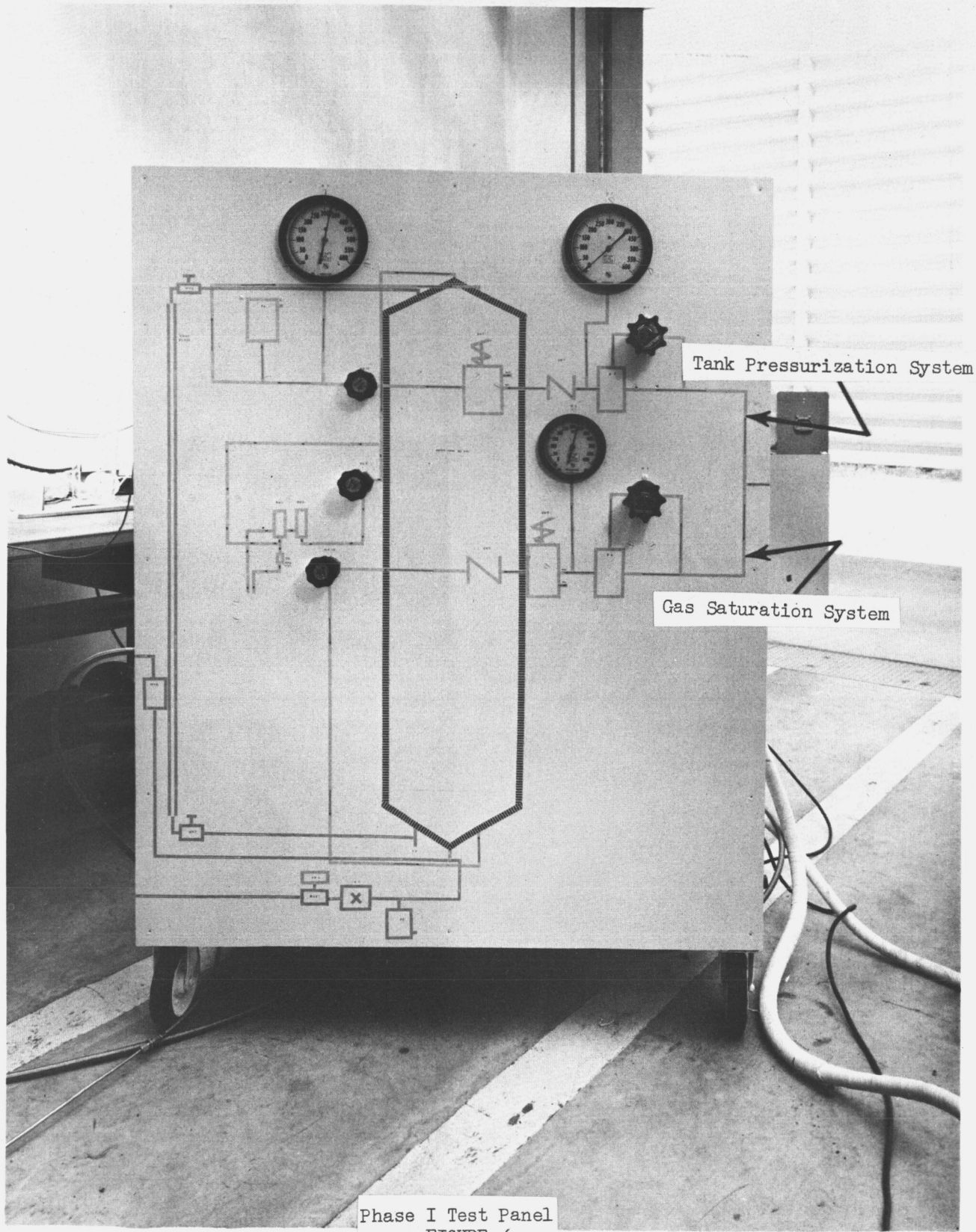


Phase I Test System Showing Stay Chambers and Sight Glasses
FIGURE 5



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Phase I Test Panel
FIGURE 6

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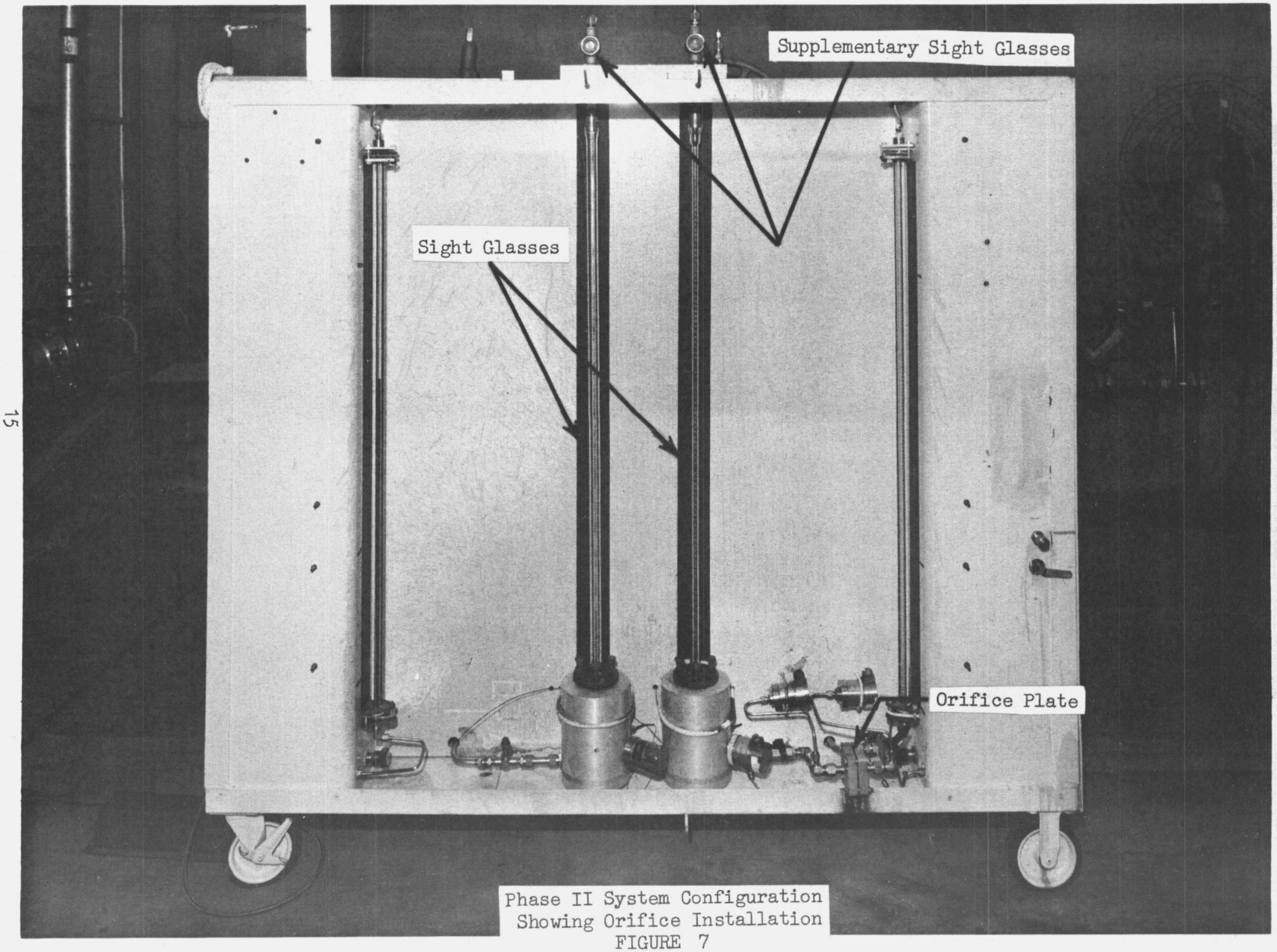
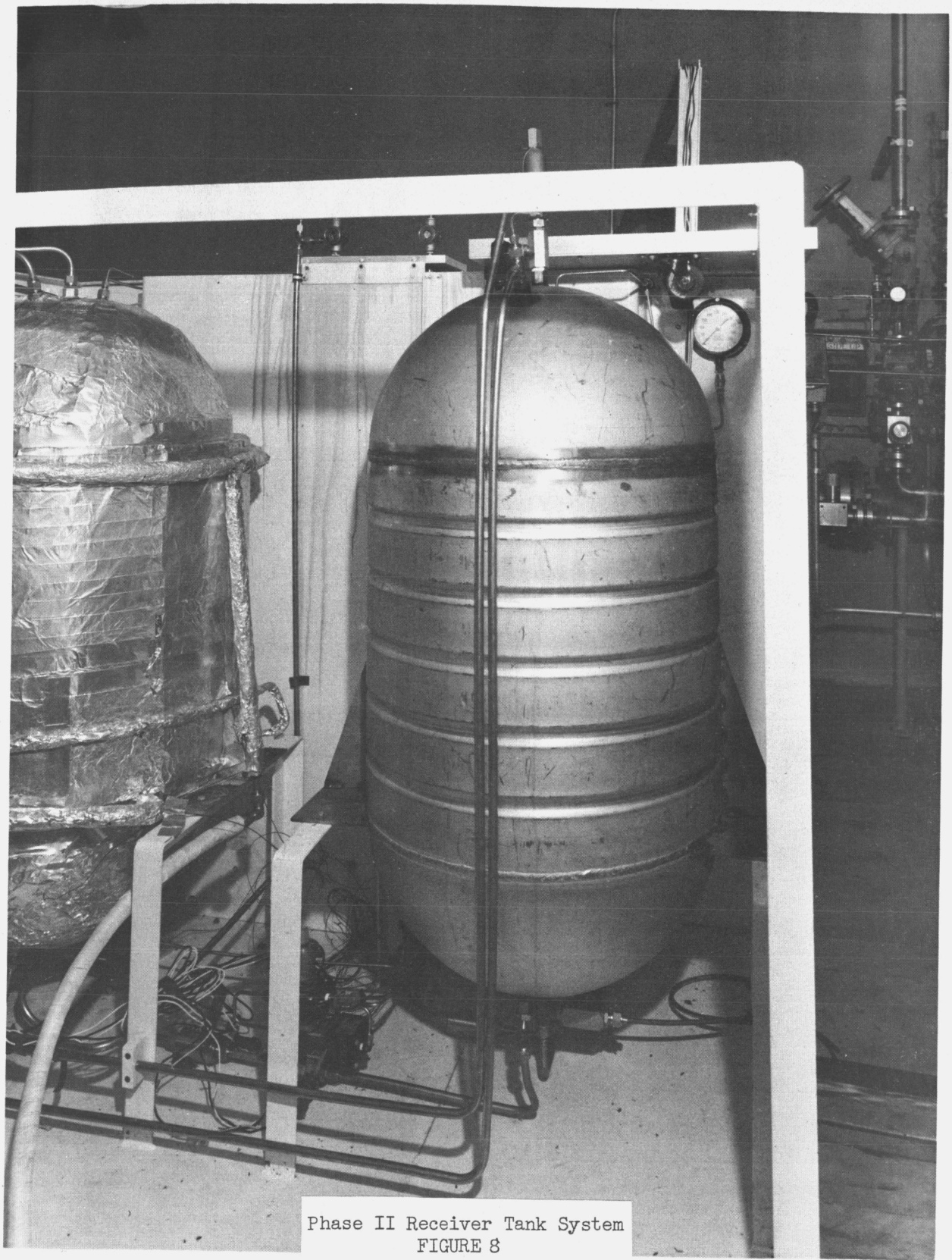


Phase II System Configuration
Showing Orifice Installation
FIGURE 7



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Phase II Receiver Tank System
FIGURE 8

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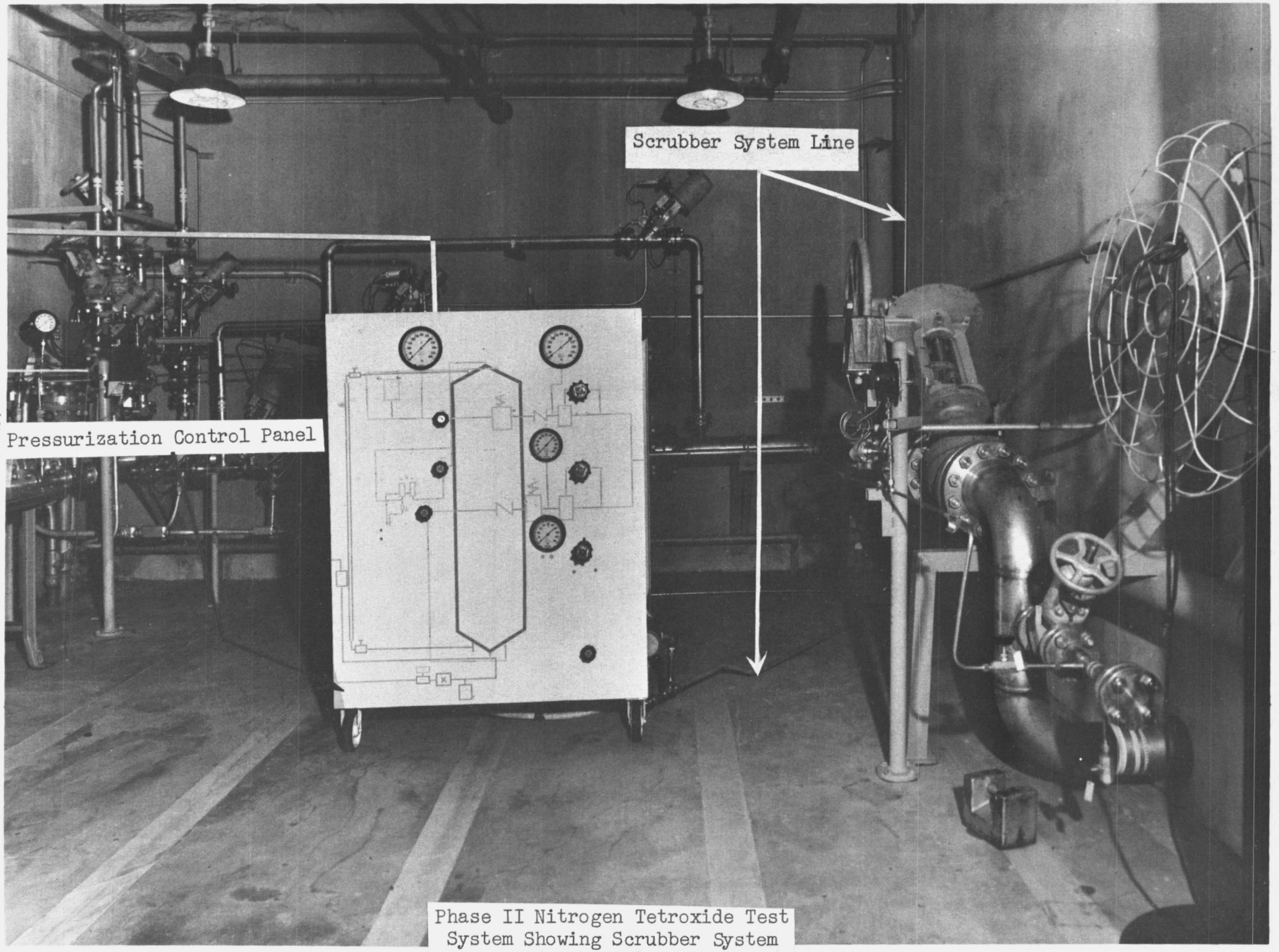

Phase II Nitrogen Tetroxide Test
System Showing Scrubber System
FIGURE 9

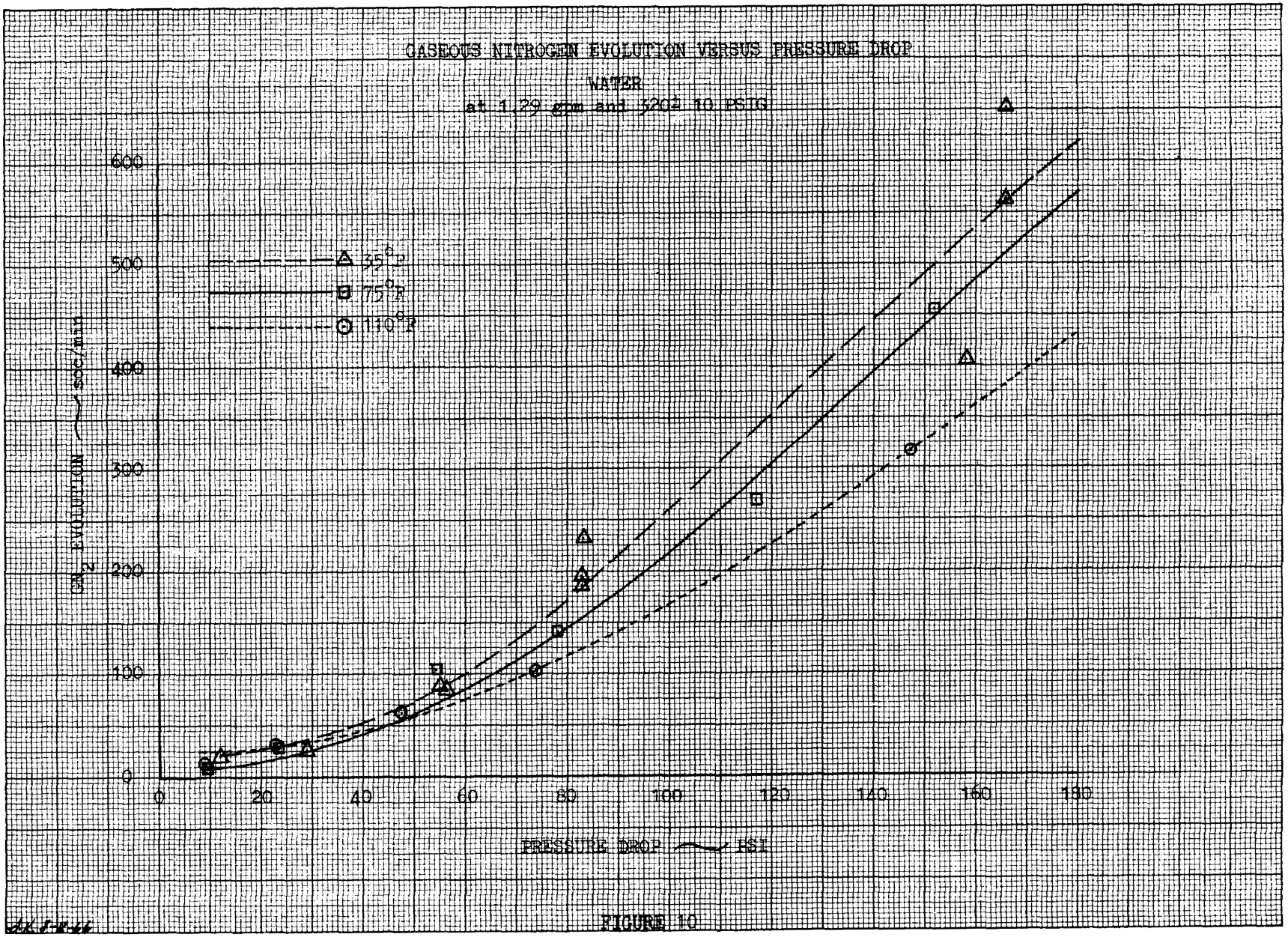
GASEOUS NITROGEN EVOLUTION VERSUS PRESSURE DROP
WATER
at 1.29 gpm and 320± 10 PSIG
35°F
75°F
110°F
600
500
400
300
200
100
0
0
20
40
60
80
100
120
140
160
180
PRESSURE DROP — PSI

FIGURE 10

GASEOUS HELIUM EVOLUTION VERSUS PRESSURE DROP
WATER
at 1.29 gpm and 520 ± 10 PSIG
35 °F
45 °F
100 °F
CHe EVOLUTION ~ scc/min
PRESSURE DROP ~ PSI
500
400
300
200
100
0
0
20
40
60
80
100
120
140
160
180

FIGURE 11

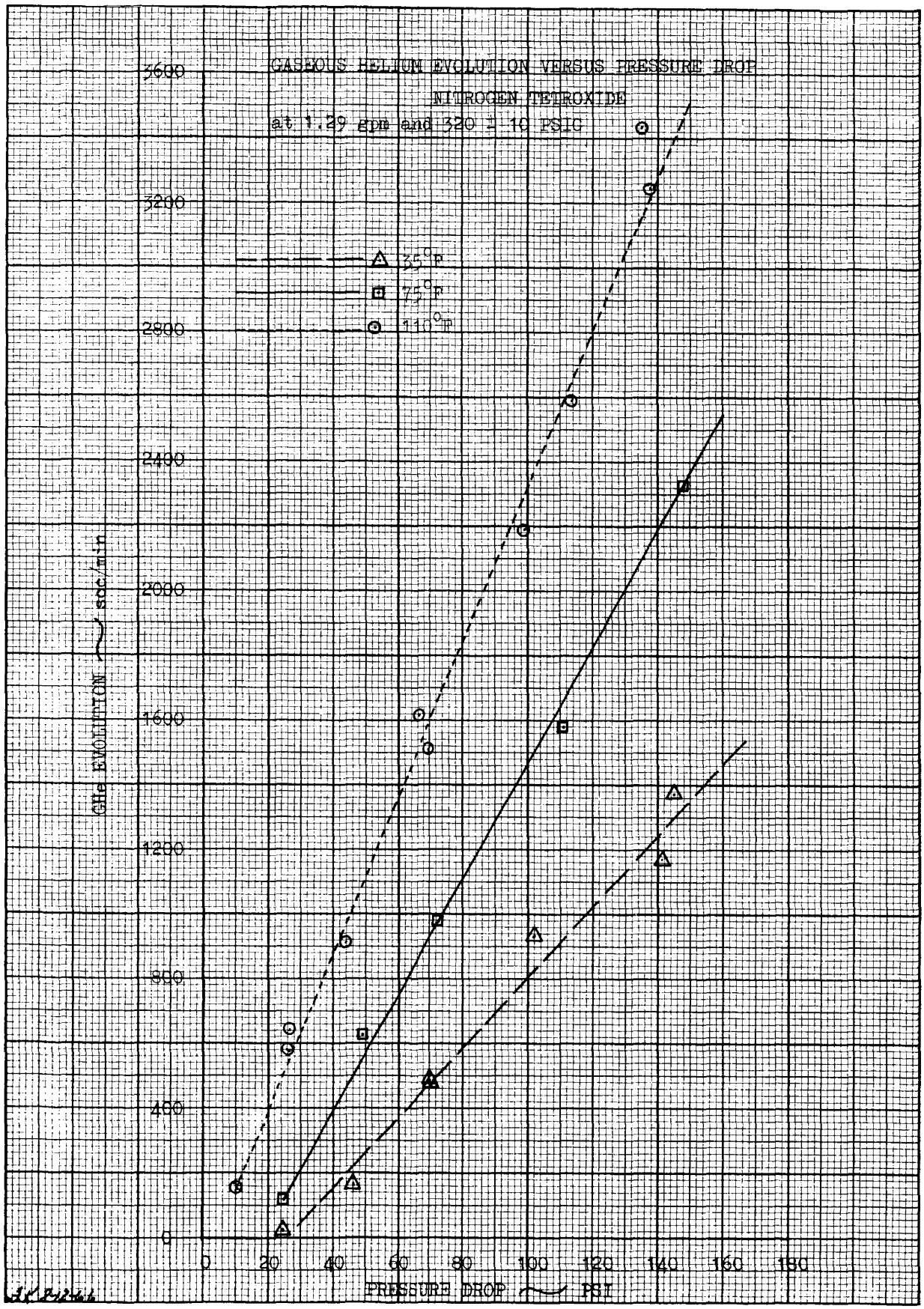
GASEOUS HELIUM EVOLUTION VERSUS PRESSURE DROP
NITROGEN TETROXIDE
at 1.29 gpm and 320 ± 10 PSIG
35°F
75°F
110°F
GHe EVOLUTION ~ scc/min
3600
3200
2800
2400
2000
1600
1200
800
400
0
0
20
40
60
80
100
120
140
160
180
PRESSURE DROP ~ PSI

FIGURE 12