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NITROGEN AND HYDRAZINE LEAKAGE OF
MONOPROPELLANT ACS VALVES

Garreth J. Gunderson

Air Force Rocket Propulsion Laboratory
Edwards Air Force Base, California

April 1973

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G.J. GUNDERSON, SSGT, USAF

TECHNICAL REPORT AFRPL-TR-73-13

APRIL 1973

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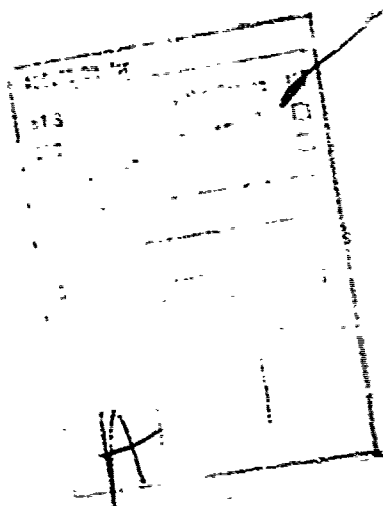
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FOREWORD

This report was prepared by the Engine Components Branch, Liquid Rocket Division, Air Force Rocket Propulsion Laboratory. The investigation was conducted under Project 30581ORH, "Valve Leakage Correlation Program," from July 1971 to March 1973, with SSgt G. J. Gunderson as Project/Test Engineer. This test program was requested by the Space and Missile Systems Organization (SAMSO) and the Aerospace Corporation. The work described herein completes the current program, the objectives which were threefold:

- (1) To demonstrate simple, reliable measurement techniques for valve seat leakage (liquid hydrazine and gaseous nitrogen)
- (2) To investigate pressure, temperature and cycling effects on valve seat leakage, and
- (3) To establish a correlation between liquid hydrazine leakage and gaseous nitrogen leakage.

This technical report has been reviewed and is approved.

PHIL S. MARTIN, Capt. USAF
Acting Chief, Engine Components Branch
Liquid Rocket Division

ABSTRACT

This report documents an in-house test program which was conducted by the Air Force Rocket Propulsion Laboratory (AFRPL) to expand understanding of the gas and liquid leakage flow phenomena associated with mono-propellant hydrazine attitude control system (ACS) valves. Over 800 gas (nitrogen) and liquid (hydrazine) leakage tests were conducted on two (each) PARKER-HANNIFIN hard seat, PARKER-HANNIFIN teflon seat, and HYDRAULIC RESEARCH AND MANUFACTURING hard seat valves. Analysis of the leakage test data for these particular valves indicates the following:

While nitrogen gas leakage is a strong function of valve inlet pressure, liquid hydrazine leakage is a very weak function of inlet pressure.

Liquid hydrazine leakage exhibits definite tendencies to decrease with valve exposure time to propellant.

Temperature studies to 250°F demonstrated an inverse relationship between valve temperature and nitrogen leak rate.

Cycling studies demonstrated a random leakage variation with each valve actuation, but a definite decrease in nitrogen leakage with extended cycling in the hydrazine propellant.

Attempts to establish a well-defined correlation between hydrazine and nitrogen leakage were hindered by the significant liquid leakage variation with time.

Additionally, the utility of a tiny, commercially available rotameter to instantaneously measure small amounts of hydrazine leakage is discussed.

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SECTION I

INTRODUCTION

At the request of the Air Force Space and Missile Systems Organization (SAMSO) this program was conducted to expand the understanding of the gas and liquid leakage flow phenomena associated with monopropellant hydrazine valves.

The prediction and measurement of valve seat leakage in liquid rocket attitude control systems (ACS) is a serious problem and an area of general uncertainty. The complexity of these leakage phenomena increases considerably when realistic valve hardware is being investigated with actual propellants. The difficulties involved in measuring minute amounts of liquid leakage, even at the component level, have resulted in a lack of experimental liquid leakage data on current ACS valve hardware. Without the necessary experimental data needed to effectively characterize gas and liquid leakage through actual valves with actual propellants, standard gas leakage measurement procedures (e.g., with nitrogen gas) are commonly used as the tools for establishing current leakage specifications for ACS valves at the component, subsystem, and system levels. These specifications, thus established, are now suspected to be overly conservative with respect to the actual liquid propellant leakages that they are thought to represent. High valve rejection rates (possibly due to an overly conservative gas spec) or the necessity for replacing or flushing valves already mated to thrusters can considerably increase mission costs.

For this investigation, off-the-shelf valve hardware was to be procured and tested to note pressure, temperature, time, and cycling effects on seat leakage. The valves of interest were applicable to monopropellant catalytic hydrazine ACS thrusters of the five-pound thrust family. The generation of enough liquid and gas leakage correlation data to ultimately provide the basis for establishing more realistic gas leakage criteria for acceptance test purposes was the primary goal of the program.

Several other organizations have made attempts to correlate gas and liquid leak rates (References 1 through 4) and have generated data to that end. Unfortunately, for one reason or another "No generally satisfactory correlation has been found which is accepted by the propulsion community" (Reference 5).

An in-depth discussion of the gas and liquid flow phenomena, with a detailed explanation of the leakage data presented in this report is beyond the scope of this investigation. Consequently, the reader will note that sophisticated analyses of every leakage test in all test series have been carefully omitted. In those cases where explanatory remarks have been made, pertaining to leakage theory and the data observed, they reflect solely the judgment of the author. Since a limited number of tests were made on a small number of valves, application of the results to other hardware of the same or similar design should be done with caution.

In summary, it is hoped that this program has further illustrated the complexity of the valve leakage problem in liquid rocket systems. Some light has been shed on the various approaches which may be used to measure small amounts of valve leakage. For the valves studied, certain temperature, pressure, cycling and time effects have been noted. It is unfortunate that the correlation of liquid to gas leakage, which has been so earnestly sought after, still did not come forth.

SECTION II

APPROACH

The program was divided into five tasks. Task I entailed selection of the particular valves of most interest to SAMSO/AEROSPACE. The selection of the Parker and Hydraulic Research designs was made in light of their availability and the time/funding constraints imposed upon the program. The Task II effort consisted of the selection and qualification of the techniques to be used for measuring gas and liquid leakage. Particular attention was devoted to the study of earlier efforts in this area (References 2 and 3) and the techniques which had been used in those investigations. Having decided upon the methodology to be used for measuring the gas and liquid leaks, Task III of the program entailed incorporation of the selected techniques into a hydrazine flow system. Design, buildup, and checkout of the system with an adjustable micrometer needle valve to simulate tiny leaks was accomplished. In Task IV the actual gas and liquid leakage testing was done. Selected valves from those procured in Task I were installed individually in the test system and observed to note pressure, temperature, cycling and time effects on leakage. The data may be found in Tables I through VIII in Section VI of this report along with a discussion of those results. Program documentation was accomplished in Task V of the program.

SECTION III

TEST VALVE DESCRIPTIONS

PARKER HANNIFIN VALVES

Two varieties (hard seat and teflon seat) of Parker Hannifin solenoid valves were of particular interest to SAMSO due to their current application on an operational USAF system. These particular valves are used to control the flow of hydrazine to a Rocket Research Corporation catalytic engine in the five pound thrust range.

Depicted schematically in Figure 1 (shown with the teflon seat swaged in) the valve is normally closed until the coil is energized. Upon release of power, the stainless steel poppet (17-4 PH) is forced against the seat (either flat lapped 304-L or teflon) and held there by the coil spring and also the upstream pressure force. General operating characteristics of the Parker valve are listed in Table IX.

For this investigation, a total of six Parker valves, each of varying gas leakage characteristics, were procured. Three were of the hard seat variety and three were of the teflon seated variety. Within each group of three, one valve (for control purposes) was manufactured entirely to the Rocket Research production specification, while the remaining two differed only in their "built in" seat leakage. The valves were made to leak by physically abrading the poppet sealing faces to varying degrees of surface roughness. Baseline leakage characteristics of the valves can be found in the tabulated data in Section VI of this report.

HYDRAULIC RESEARCH VALVES

The Hydraulic Research and Manufacturing Company valve was also selected by SAMSO to be tested, considering its successful use on the Intelsat satellite series. Depicted schematically in Figure 2, these valves

use permanent magnet torque motors to drive their flat, lapped metal poppets. Each valve unit consists of two tungsten carbide seat/poppet sets in series to provide sealing redundancy in the normally closed off position. The general operating characteristics of the Hydraulic Research Valves are listed in Table X. They are used to control hydrazine flow to a Hamilton Standard catalytic engine, in the five pound thrust range, for satellite attitude control.

For this investigation, three Hydraulic Research valves of varying gas leakage characteristics were procured. As in the case of the Parker valves discussed earlier, one valve was built completely to the engine specification, while the remaining two differed only in internal seat leakage. Again, degradation of the poppet sealing surface finish was used to induce leakage. Baseline leakage characteristics of these valves may also be found in the tabulated data in Section VI of this report.

SECTION IV

TEST SYSTEM DESCRIPTIONS

GAS LEAKAGE SYSTEM

Measurement of nitrogen gas leakage through the valves was accomplished with a Nordquist Mark II Leak Meter manufactured by Madlab, Inc. This instrument utilizes interchangeable glass pipette flow tubes which range from one-tenth of a cubic centimeter to ten cubic centimeters full scale. The volumetric leak rate of the valve under test is measured by noting with a stop watch the time necessary for a slug of colored isopropyl alcohol to traverse a known increment of volume.

In addition to being sturdy and relatively inexpensive, the Mark II Leak Meter readily provides for horizontal positioning of the flow tubes and rapid removal of the tubes to accommodate range changes. Additionally, a vent immediately upstream of the flow tube provides a secondary escape path for the leaking fluid to prevent "blowing" the isopropyl alcohol slug out the end of the tube. Repositioning of the isopropyl alcohol slug to the zero location by physically tilting the entire apparatus allows gas leakage measurements to be repeated with a minimum amount of effort.

For consistency of test purposes, all nitrogen gas leakage measurements were made at five minute intervals after a thirty minute "stabilization" period when pressure and temperature conditions of the valve were changed. Figure 3 is a schematic representation of the system used to measure nitrogen gas leakage. Repeatability of stop watch readings was usually within ± 1 percent and a ± 5 percent overall leak rate error is probably a realistic figure.

LIQUID LEAKAGE SYSTEM

Demonstration of a technique(s) to easily measure liquid hydrazine leakage through the test valves was one of the primary objectives of this program. Any technique/device selected needed to be capable of measuring liquid hydrazine flow down to about 0.01 cc per hour, compatible with the hydrazine propellant, and, of course, reliable and leak free to at least 300 psig.

Earlier experimenters had used known-volume glass capillary sight tubes upstream of the leaking test valve (References 2 and 3). Positioning a hydrazine meniscus in that glass capillary tube and measuring its position change with time under known temperature and pressure conditions allowed direct calculation of the volumetric liquid flow rate over the time increment. Initial attempt to utilize this technique in this investigation resulted in the emergence of numerous difficulties. Securing a leak-free seal between the glass tubes themselves and the fittings used to incorporate those tubes into the rest of the flow system was the initial problem encountered. The fragile nature of the tubes themselves made breakage a continuous problem. Utilization of heat shrinkable polyethylene tubing around the glass tubes and a nylon sleeve around the polyethylene material to provide the seal material into which the swagelok ferrule "bites" was a successful approach to solve the external leakage problem.

Troublesome bubbles and what appeared to be vapor locks in the capillary tubes were also sources of concern. Additionally, thermal expansion and contraction effects on the columns of hydrazine visible within the tubes due to temperature changes sometimes overshadowed the meniscus position changes due to leakage. Repositioning the hydrazine meniscus was a slow process in itself, and, all factors considered, the technique was tedious and time consuming at best. Consequently, when the availability of an applicable microflowmeter (Gilmont Instruments, Inc) became known, the sight glass technique was cast aside.

The selected microflowmeter (Figure 4) is essentially a tiny rotameter calibrated for both air flow (1 to 900 scc per hour) and water flow (0.012 to 7.2 cc per hour) but for this investigation was used only to measure liquid hydrazine leakage. Viscosity and density corrections allow the user to calculate calibration curves for other fluids. Standard gas equations may be used to correct for non-standard pressure and temperature conditions. Construction being entirely of glass and teflon, with a synthetic ruby float, the flowmeter is compatible with a wide variety of corrosive fluids. The flowmeter (and the plastic safety shield) was easily adapted to the pressurized flow system with the fitting arrangement depicted in Figure 5 and was leak tight to 400 psig. A schematic of the total system used to measure liquid hydrazine leakage during this investigation depicted in Figure 6.

Besides being leak free, totally compatible with hydrazine, and individually calibrated, this type of rotameter has yet another significant advantage over the sight glass-meniscus technique. Leak rate data may be gathered at individual points in time, not as an average volumetric flow rate over some arbitrary time period. The ability to observe the dramatic variation (decrease) of liquid hydrazine leakage with time with this device made it ideal for this application. Vendor literature highlights the necessity to follow stringent cleanliness precautions when using the rotameter so as not to impede the movement of the float with residual debris. System filtration immediately upstream of the flowmeter eliminated that problem. A ± 10 percent error in liquid leakage measurement as suggested by the manufacturer for rotameters in this size range is probably a realistic figure.

SECTION V

TEST RESULTS

PRESSURE EFFECTS ON LEAKAGE

When the leak rates of the respective valves were measured, whether with gas or liquid, that amount measured represented a summation of the fluid flow through each of the individual leaking "paths" present across the valve sealing area. The number and geometric configuration (length, shape, effective diameter, etc.) of these individual leak paths were unknown. Consequently, the particular mode of flow occurring within each path was also unknown. Gas flow may be either molecular, laminar, or turbulent, while liquid flow through each path could also be laminar or turbulent. It is highly probable that within a leaking valve under investigation, one would find numerous flow modes occurring in each of the neighboring leak paths and possibly even within a single leak path itself. Consequently, the measured leakage may be considered to be a "consolidation" of each of the distinct flow modes as well as their respective transition regimes. These facts alone make it a task of enormous complexity to predict the effect of valve inlet pressure on total valve seat leakage, when that fluid flow is a different function of ΔP in each flow mode.

From Reference 1, if P_1 and P_2 are downstream and upstream pressures respectively,

For Gases in the Molecular Regime, Flow is proportional
to $(P_2 - P_1)$

For Gases in the Laminar Regime, Flow is proportional
to $(P_2^2 - P_1^2)$

For Gases in the Turbulent Regime, Flow is proportional
to $(P_2^2 - P_1^2)^{1/2}$

For liquids in the Laminar Regime, Flow is proportional to $(P_2 - P_1)$

For Liquids in the Turbulent Regime, Flow is proportional to $(P_2 - P_1)^{1/2}$

In this investigation it is unlikely that molecular flow of gases or turbulent liquid leakage occurred through any of the valves, but there is no way of being certain of that fact.

Nitrogen and hydrazine leakage measurements were made at three distinct pressure levels characteristic of the "blow-down" pressure range prevalent in the mission situation. Inlet pressures of 250, 180, and 85 psig were arbitrarily selected. For gas measurement, the valves were leaking to atmosphere (NORDQUIST leak meter on downstream side) while liquid leakage was to a downstream pressure of approximately 2 mm Hg.

The data as presented in Tables I through VIII for nitrogen and hydrazine leakage suggest two things relative to pressure dependency. Gas leakage appears to be a relatively strong function of inlet pressure, while liquid leakage appears to be a relatively weak function of inlet pressure. In some cases, liquid leakage actually continued to decrease with time as the inlet pressure was increased. To illustrate the Pressure - Time - Leakage relationship, Figures 7, 8 and 9 were prepared for both nitrogen and hydrazine leakage of each of the three selected valve designs. In each case, the maximum and minimum leakage rates measured at the respective ΔP s have been plotted for visualization. All measurements were made without valve actuation. Of particular interest is the inability to make repeat liquid leakage measurements at the given pressure levels for verification purposes, due to a time dependency. The gas leakage - versus - inlet pressure relationships, on the other hand, were as expected.

It might be noted that the rate of increase in gas leakage for the Teflon seated valves from 180 to 250 psid was lower than that increase between 85 and 180 psid. This was not the case with the hard seated valves, where the slope of the line between 180 and 250 psid was greater than between the lower pressures. A possible explanation is the fact that at the higher pressure loadings with the Teflon seat, the effective leak path diameters were significantly decreased and some may have been eliminated entirely. The liquid hydrazine leakage being more dependent on time than on pressure drop made correlation studies difficult, and will be discussed in the liquid/gas correlation section of this report.

TEMPERATURE EFFECTS ON LEAKAGE

The overall effects of increased valve temperature (to simulate thermal soakback) on seat leakage are presented in Figures 10 and 11. The data indicates a significant decrease in nitrogen leakage at each inlet pressure level when the valves' temperature was raised to 150 and 250°F. This phenomenon occurred with both the hard and teflon seated valves which were studied. Tests 1 through 64 in Table I and Tests 1 through 73 in Table II illustrate this decrease dramatically. Attempts to cause a hard seat valve to leak hydrazine by raising its temperature were unsuccessful (Table VII, Tests 29 through 35). Also, in Tests 31 and 32 of Table VIII liquid hydrazine leakage of another hard seat valve was not significantly affected by raising its temperature to 250°F. It is probable that the temperature effect on liquid hydrazine leakage is over-shadowed by the time effect which was discussed earlier.

The overall temperature effect on valve seat leakage is undoubtedly made up of its individual effects on fluid properties and leak path geometry. The lack of experimental data relative to the liquid hydrazine leakage variation with temperature prohibits speculation at this time. The effects on gas leakage demonstrated in Figures 10 and 11 warrant further discussion.

Gases are known to become more viscous at elevated temperatures, and according to Reference 5, nitrogen viscosity increases from 0.018 to 0.022 centipoise between 70°F and 250°F. Since fluid flow is inversely proportional to viscosity, this could account for part, but certainly not all of the leakage decrease at elevated temperature. It is likely that the thermal expansion effects of the elevated temperatures on the valve body and internal parts are of greater significance. Expansion and contraction of the end cap outlet (Figure 1) holding the seat, as well as the spring forcing the poppet against the seat could significantly affect valve sealing properties. On a smaller scale, especially in the metal-to-metal seat configurations, the leak path diameters could be affected by the elevated temperatures. As depicted in Figures 10 and 11, as the valve was cooled down, the leakage rates returned nearly completely to their initial values. A slight change in the leakage characteristics of the teflon seated valve was noted, but this should be expected, due to the swaged nature of that seat configuration that is unrestrained on one side.

CYCLING EFFECT ON LEAKAGE

The effect of valve actuation in a hydrazine environment on valve seat leakage is illustrated in Figures 12 and 13 for both the hard and teflon seat designs respectively. The Parker hard seat valve S/N 103 was actuated 10,000 times at a frequency of 1 Hz in hydrazine at a 10 psi pressure drop to conserve propellant. A definite decrease in nitrogen leakage characteristics tabulated in Table I, (Tests 89 through 108 and 159 through 178) was noted. Similarly, the Parker Teflon seat valve S/N 101 was actuated a total of 12,000 times with an even more significant decrease in nitrogen leakage noted (Table II, Tests 58 through 73 and 80 through 94).

Whereas opening and closing a valve usually resulted in random variation of leakage characteristics, extended cycling in a relatively particulate-free environment affects the poppet/seat interface roughness

to a much greater degree. Peaks and valleys causing leakage may be thought to be pounded down with the repeated impact condition. With the resultant "improvement" in surface roughness characteristics in sealing areas, the internal leakage might be expected to decrease. The leakage data generated in this program seems to substantiate that hypothesis.

CORRELATION OF LIQUID AND GAS LEAKAGE

The primary objective of this investigation was to establish a meaningful correlation between nitrogen gas and hydrazine liquid leakage at pressures ranging from 85 to 250 psid. A band of correlation data was expected, since gas and liquid flows increase at different rates with pressure. As explained by Marr (Reference 1) the most familiar flow equation for the laminar flow of gases through a straight tube of circular cross-section was developed by Poiseuille (Reference 5).

$$Q = \frac{\pi}{8} \left(\frac{d}{2} \right)^4 \frac{P_a}{\mu l} (P_2 - P_1)$$

where

Q = mass flow of gas in units of atm cc/time

d = diameter of flow path

P_a = average pressure across the flow path $\frac{P_2 + P_1}{2}$

μ = absolute viscosity of the gas

l = length of the flow path

P_2 = inlet pressure

P_1 = outlet pressure

Similarly, for the non-turbulent flow of a liquid through the same tube,

$$Q = \frac{\pi}{8} \left(\frac{d}{2} \right)^4 \frac{l}{\mu l} (P_2 - P_1)$$

Although we recognize that the flow phenomenon under consideration here is not through single, uniform diameter, uniform length, circular leak paths, the equations may still be used to predict the liquid/gas relationship as explained below.

The terms $\left(\frac{\pi}{8}\right)\left(\frac{d}{2}\right)^4\left(\frac{1}{l}\right)$ appear in both equations. Therefore, unless the valve is actuated, all leakage should be through the same paths when changing from gas to liquid so the common terms reduce to a common geometric constant and the overall relationships reduce to:

$$Q = K_{\text{geom}} P_a \frac{1}{\mu} (P_2 - P_1) \text{ for gases}$$

and

$$Q = K_{\text{geom}} \frac{1}{\mu} (P_2 - P_1) \text{ for liquids}$$

so, although we do not know the exact values of l , d , etc, we assume they will be the same for both gas and liquid flow since the valve is not actuated. By measurement of gas leakage, and knowing the pressure conditions, K_{geom} may be calculated and used in the second equation to predict the liquid flow. The theoretical correlation band between 85 and 250 psid shown on Figure 14 was constructed using this technique. Santler and Moller (Reference 4) have used these equations to construct a nomograph which is widely used for prediction purposes.

A major problem was encountered when approaching the gas leak and liquid leak data presented in Tables I through VIII from the correlation standpoint. As Figures 7, 8, and 9 illustrate, a wide range of liquid leak rates are found to correspond to the gas leakage measured at a particular pressure level. As discussed previously, the liquid leak rate usually decreased with time (Table I, tests 136 through 141). For consistency, and to maintain the highest degree of conservatism possible, the largest hydrazine leakage rates were paired with their corresponding minimum nitrogen leakage in the correlation data summary in Table XI. These data are plotted on Figure 14 along with the theoretical correlation band.

To note the effect of particulate contamination on the liquid/gas correlation (essentially inducing a change in the leak path geometry) selected valves were contaminated with 3-20 micron tungsten and aluminum powder (see Tables I and III). Those data are also summarized in Table XI and identified on Figure 14. It should be noted that the tendencies for liquid leakage to decrease with time were more pronounced in those cases where the valves had been artificially contaminated with the tiny particles. It is conceivable that although the trapped particles allowed much more nitrogen to leak (many relatively small leak paths) the smaller path sizes did not allow the liquid to leak through. Particle movement into and through the leak paths may have caused decreases in effective diameter and perhaps clogging of some of the paths entirely.

Thorough explanations of any or all of the data presented here is only speculative at best, and cannot be fully substantiated in this investigation. The limited number of valves used and the statistically small amount of data collected should temper any conclusions drawn by the reader.

SECTION VI

CONCLUSIONS

A number of overall conclusions can be drawn from analysis of the leakage test data generated during this program. These conclusions are:

1. While nitrogen gas leakage is a strong function of valve inlet pressure, liquid hydrazine leakage is a very weak function of inlet pressure.
2. Liquid hydrazine leakage exhibits definite tendencies to decrease with valve exposure time to propellant.
3. Temperature studies to 250°F demonstrated an inverse relationship between valve temperature and nitrogen leak rate.
4. Cycling studies demonstrated a random leakage variation with each valve actuation, but a definite decrease in nitrogen leakage with extended cycling in the hydrazine propellant.
5. Attempts to establish a well-defined correlation between hydrazine and nitrogen leakage were hindered by the significant liquid leakage variation with time.

In addition, the demonstrated ease of use of a small, commercially available rotameter indicates its excellent applicability to the measurement of small hydrazine leakage rates.

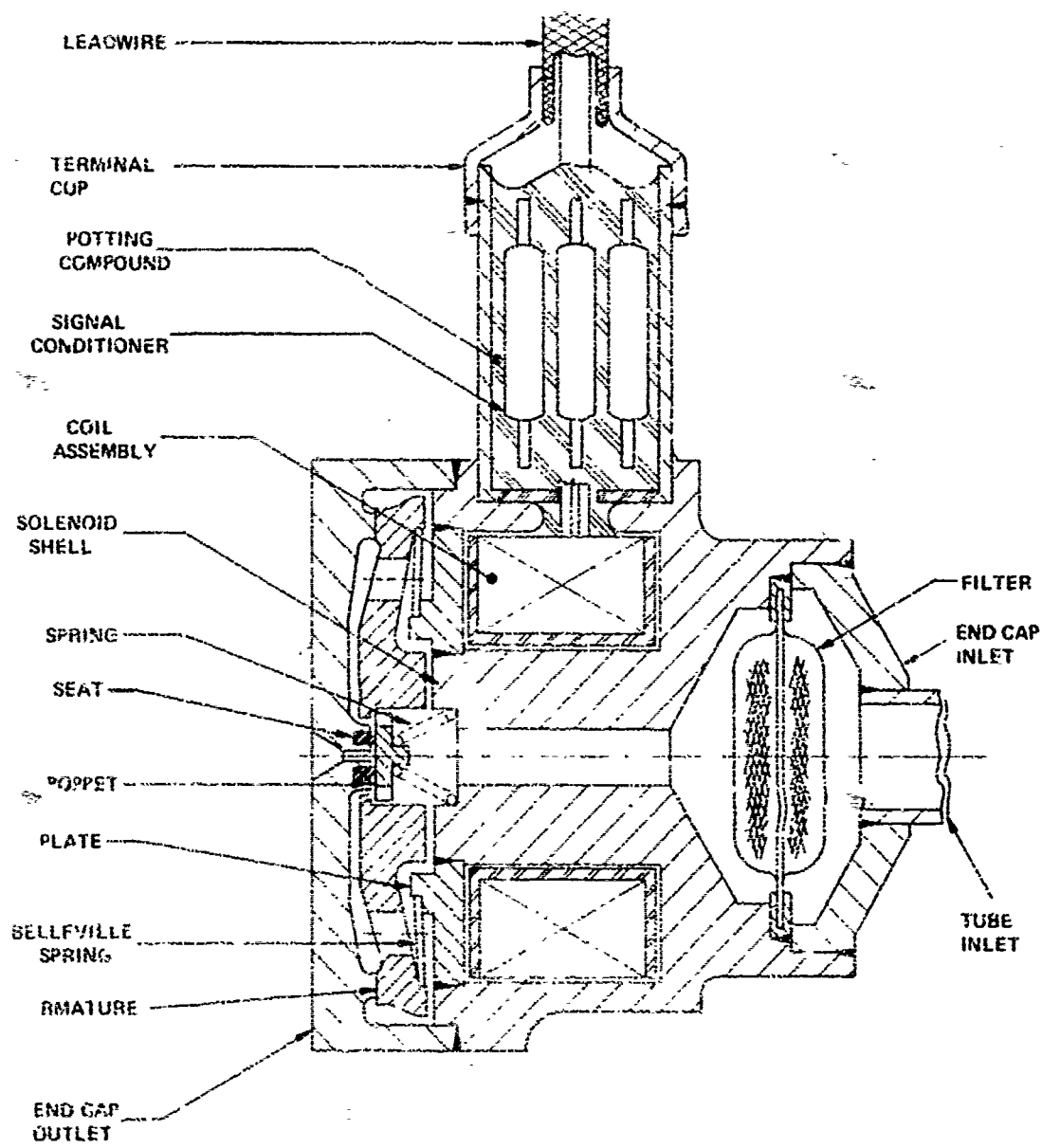


Figure 1. Parker Hannifin Valve (Teflon Seat)

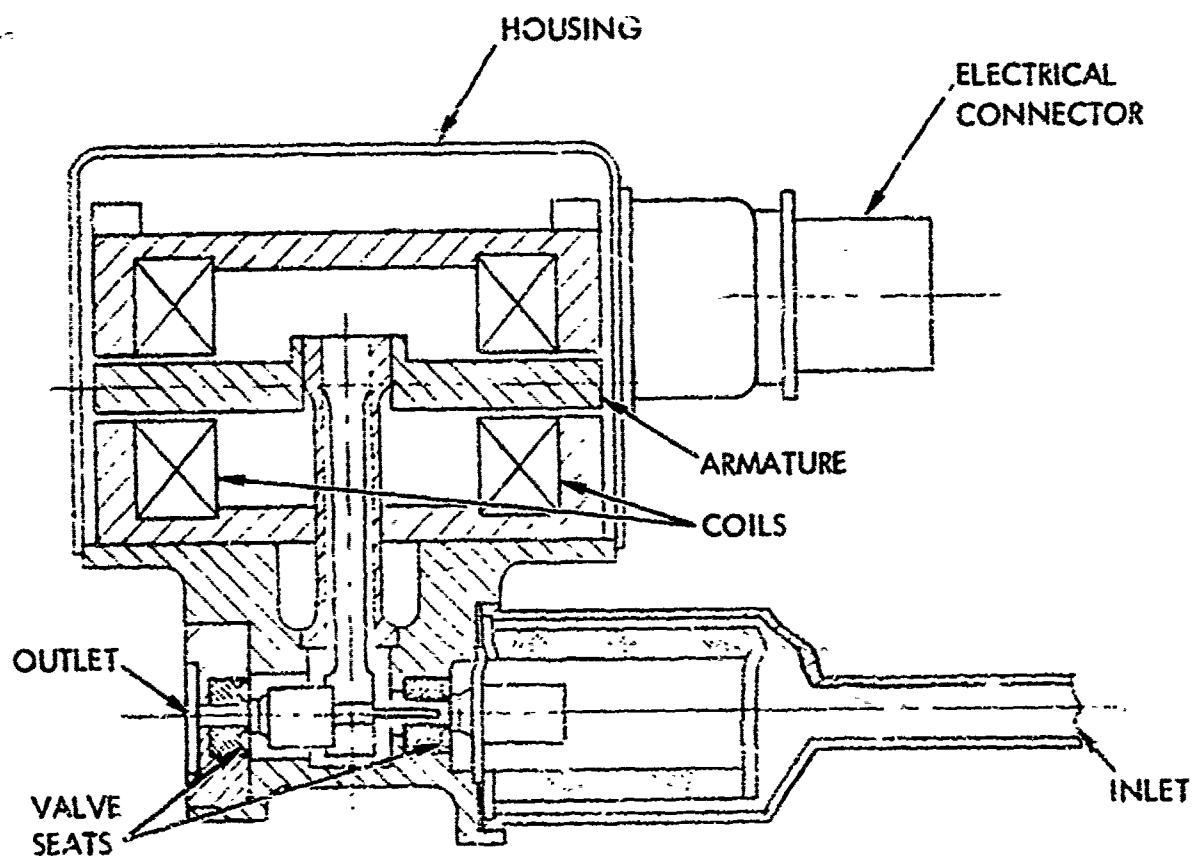


Figure 2. Hydraulic Research and Manufacturing Company Valve

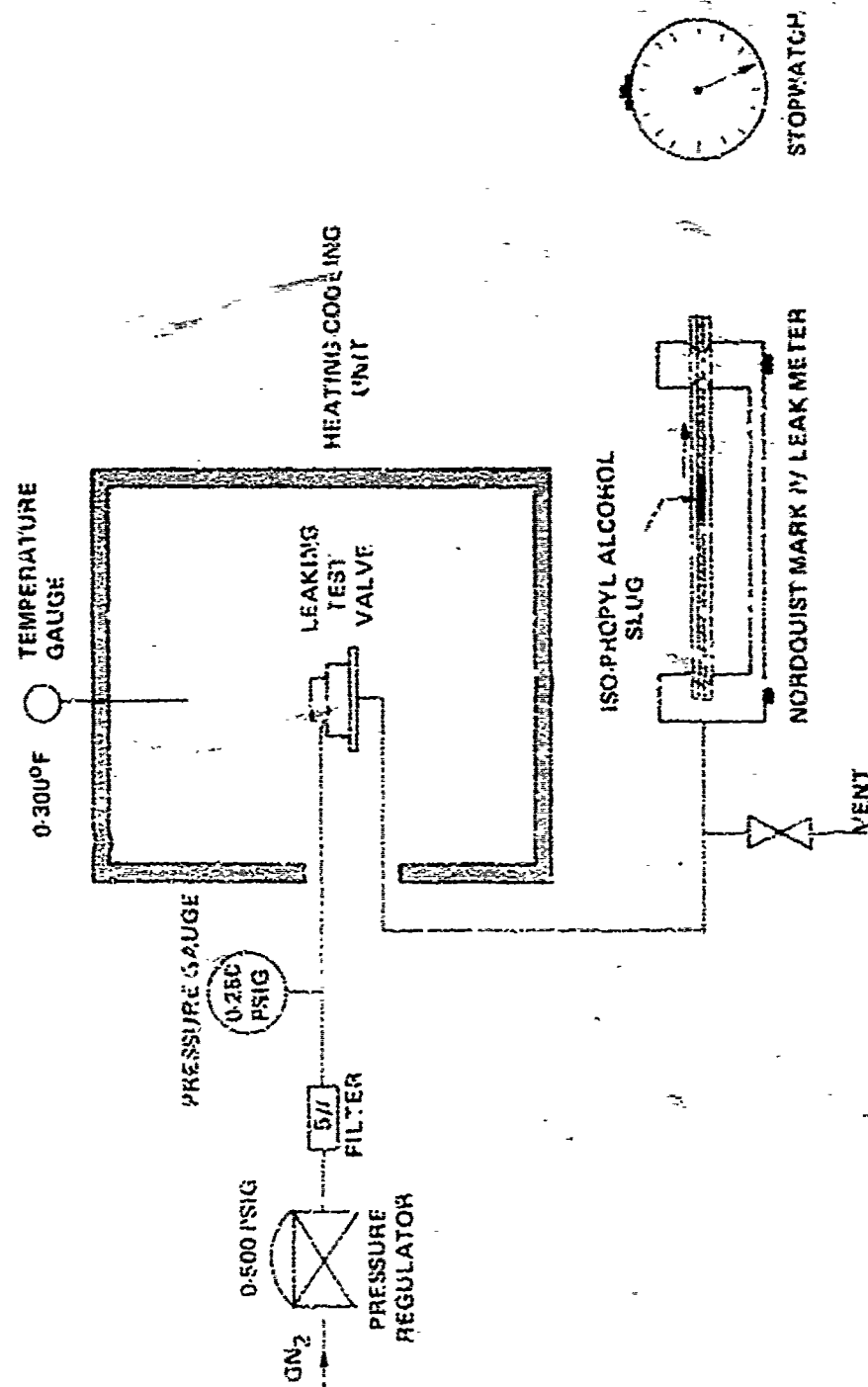


Figure 3. Nitrogen Leak Measurement System

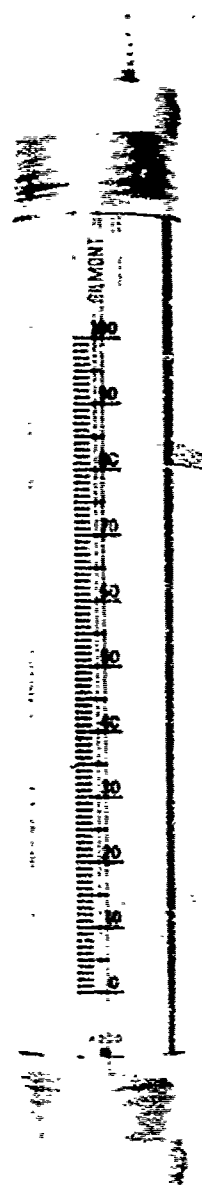


Figure 4. Gilmont Microflowmeter

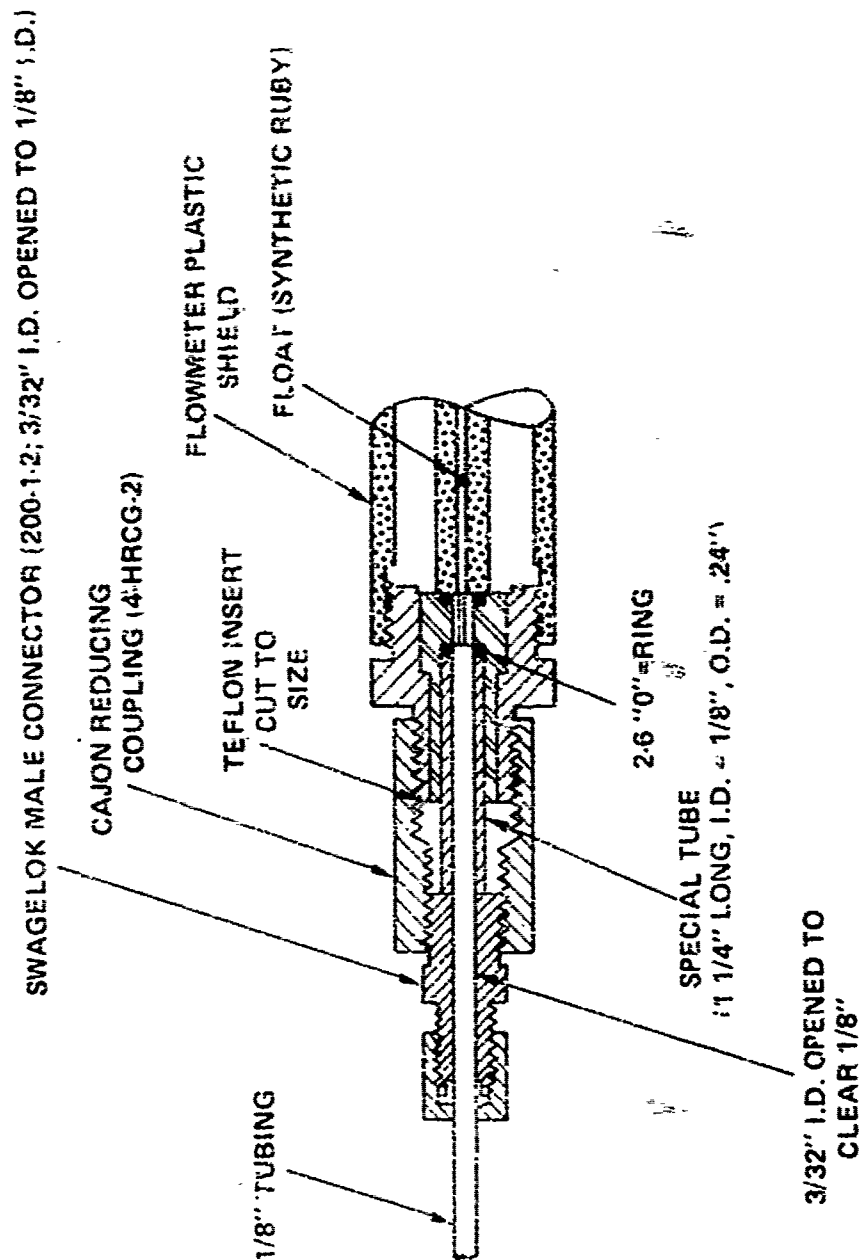


Figure 5. Gilmont Microflowmeter High Pressure Fitting Arrangement

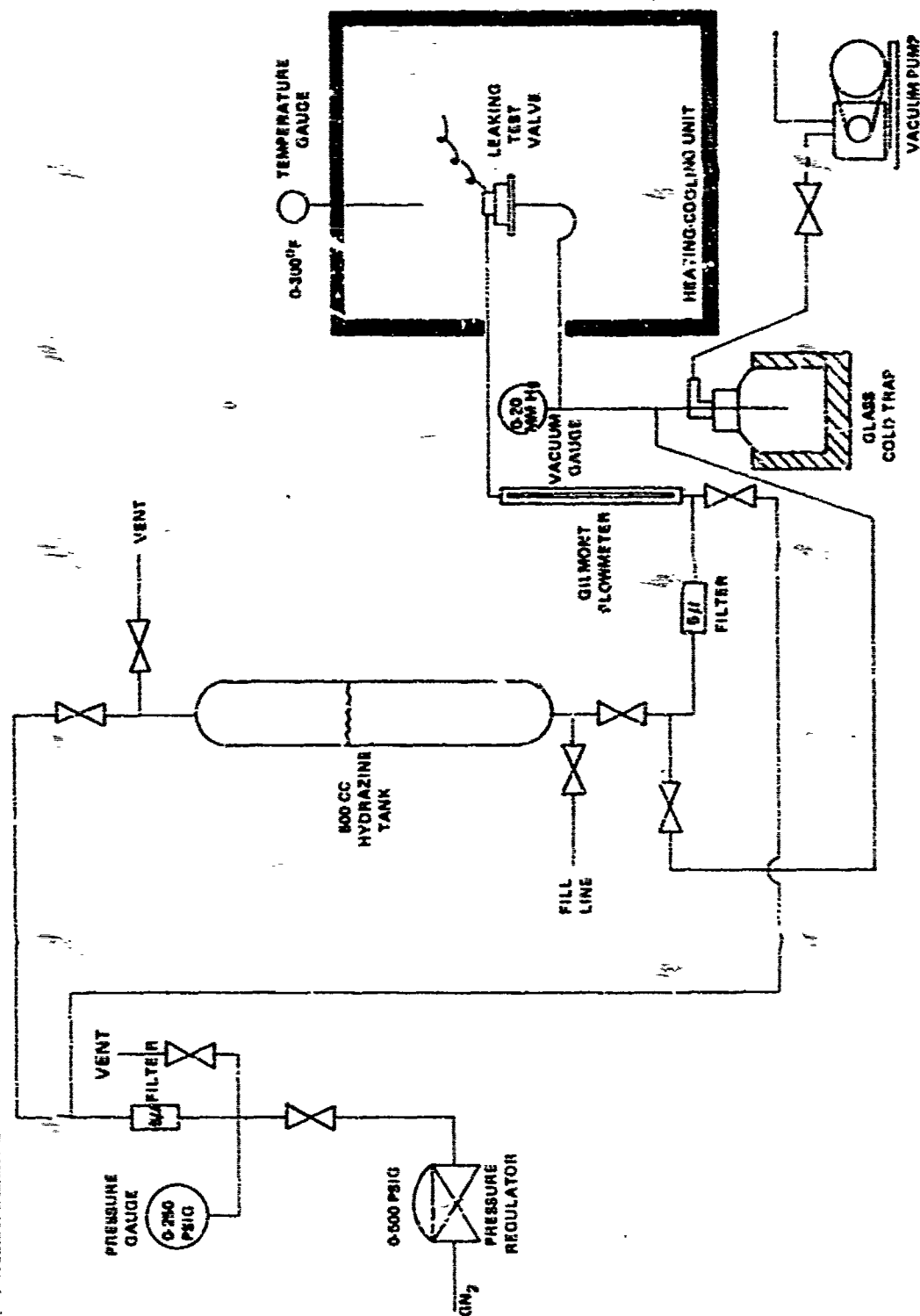


Figure 6. Hydrazine Leak Measurement System

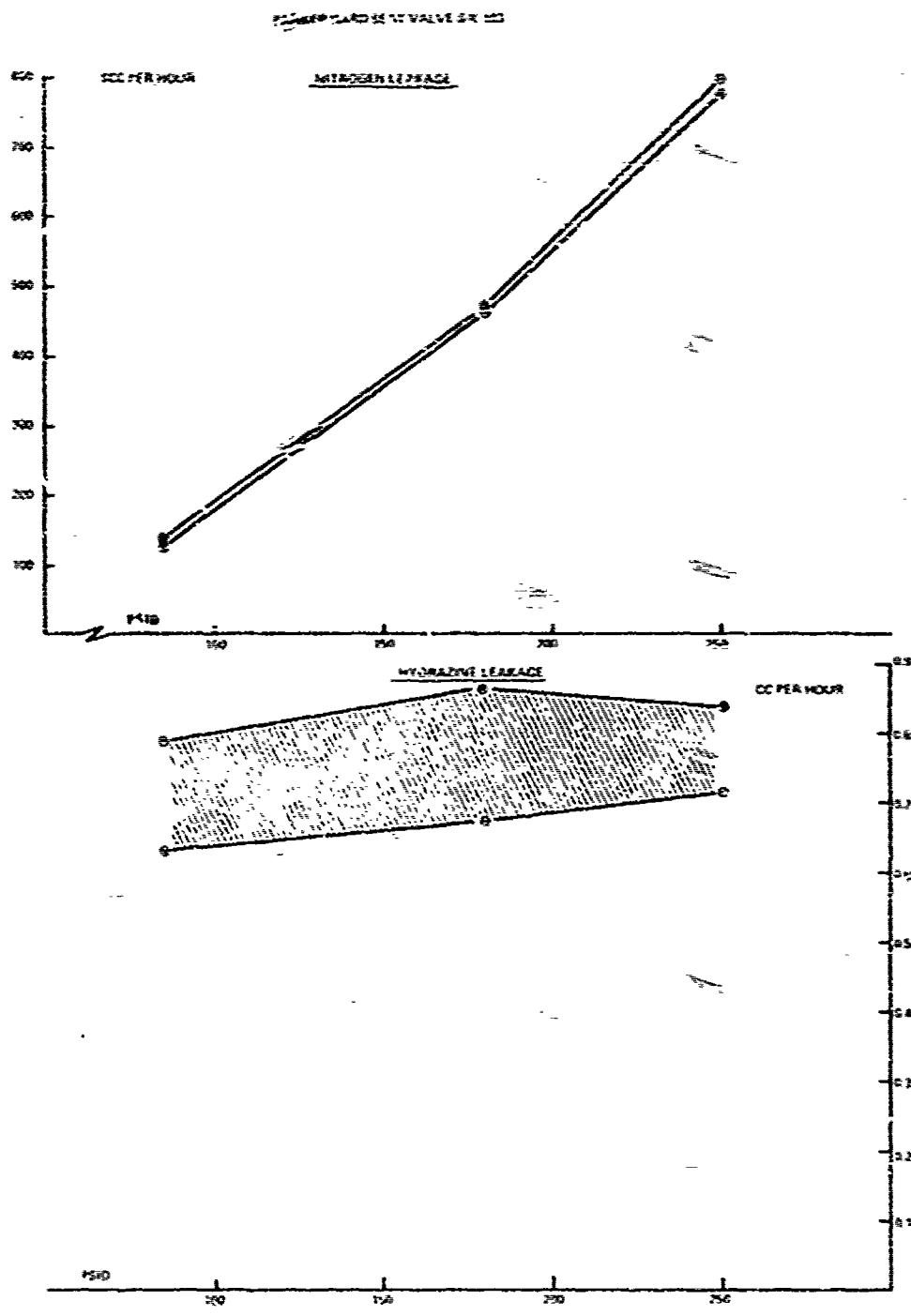


Figure 7. Leakage versus Pressure

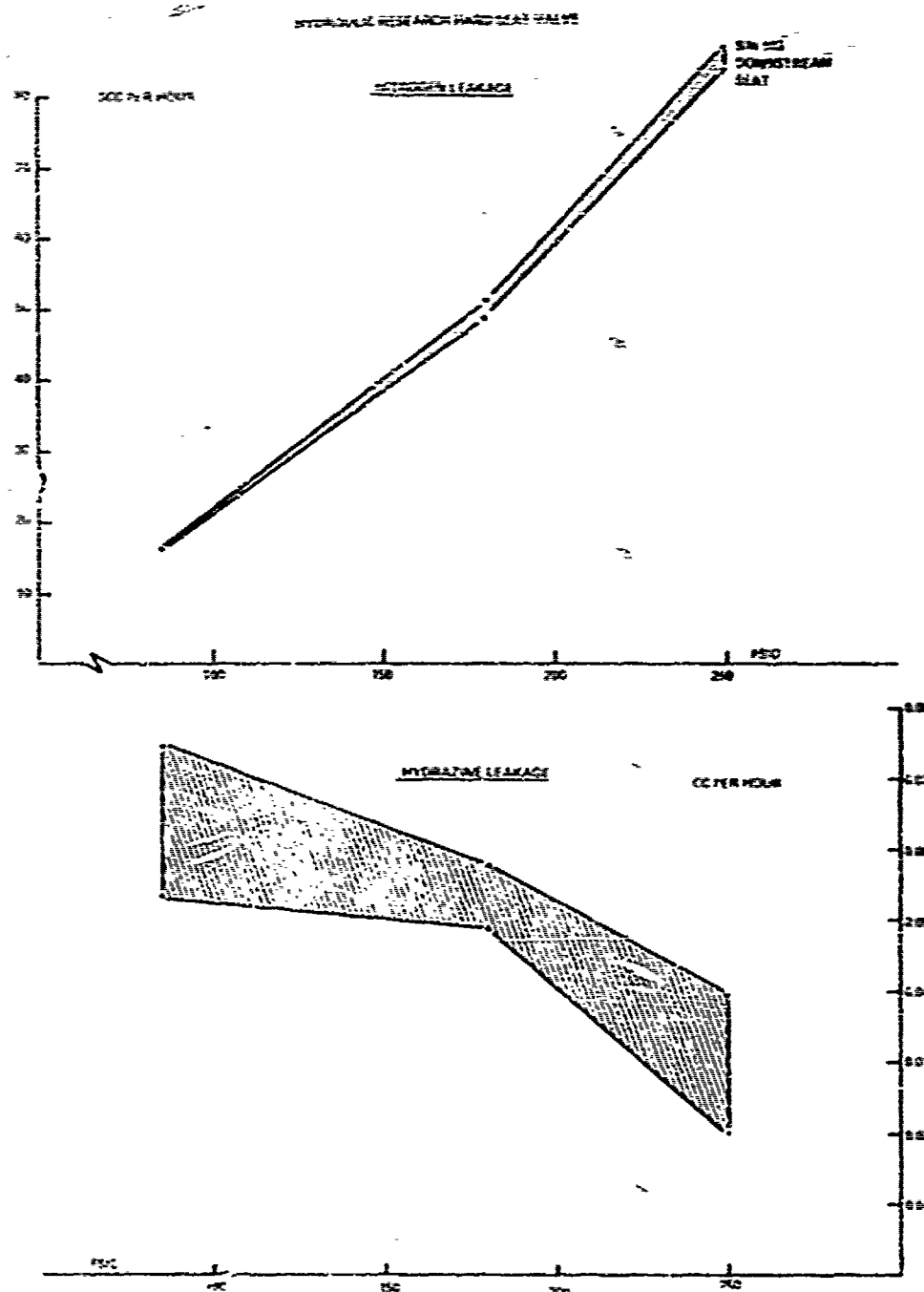


Figure 8. Leakage versus Pressure

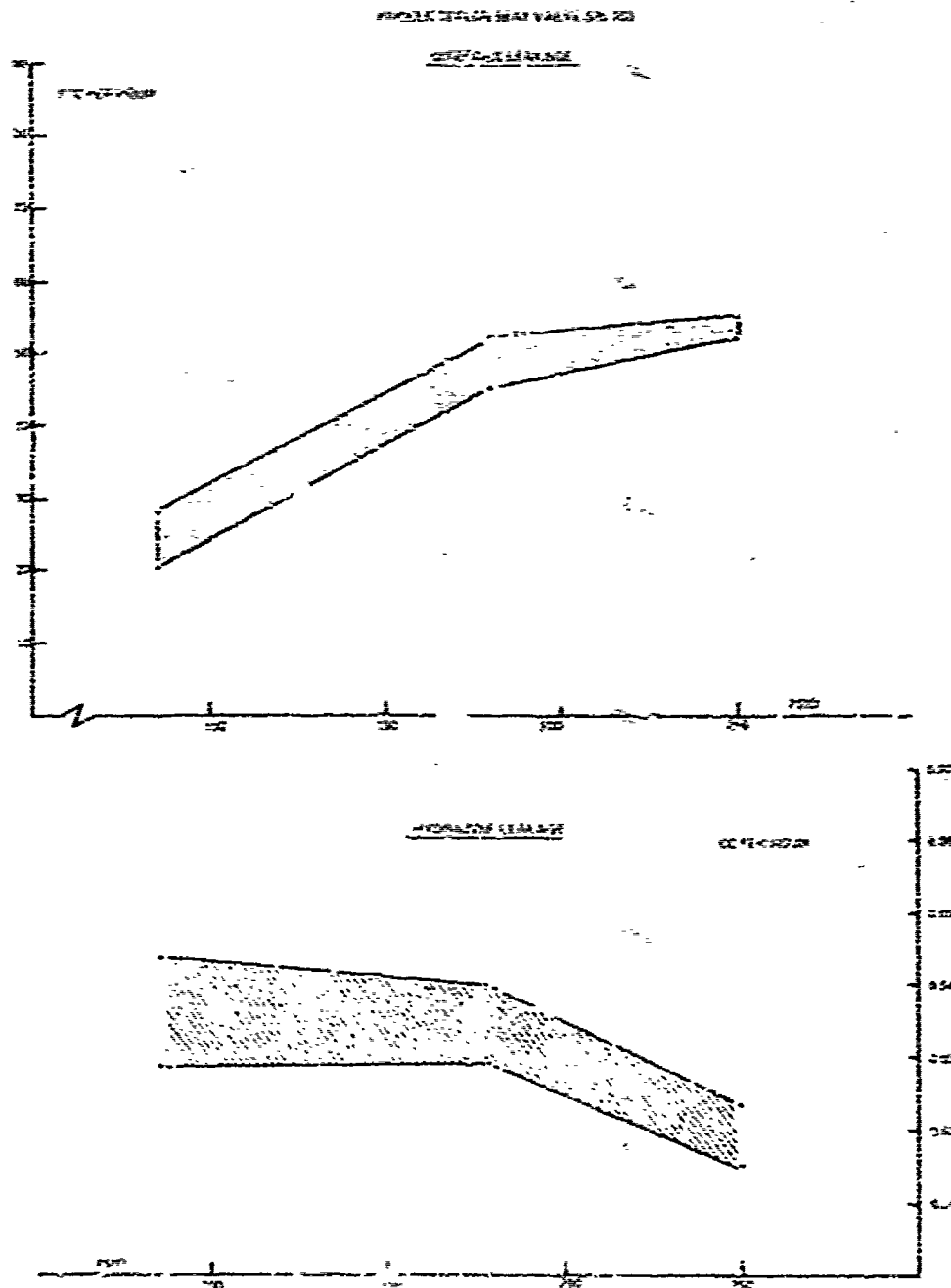


Figure 9. Leakage versus Pressure

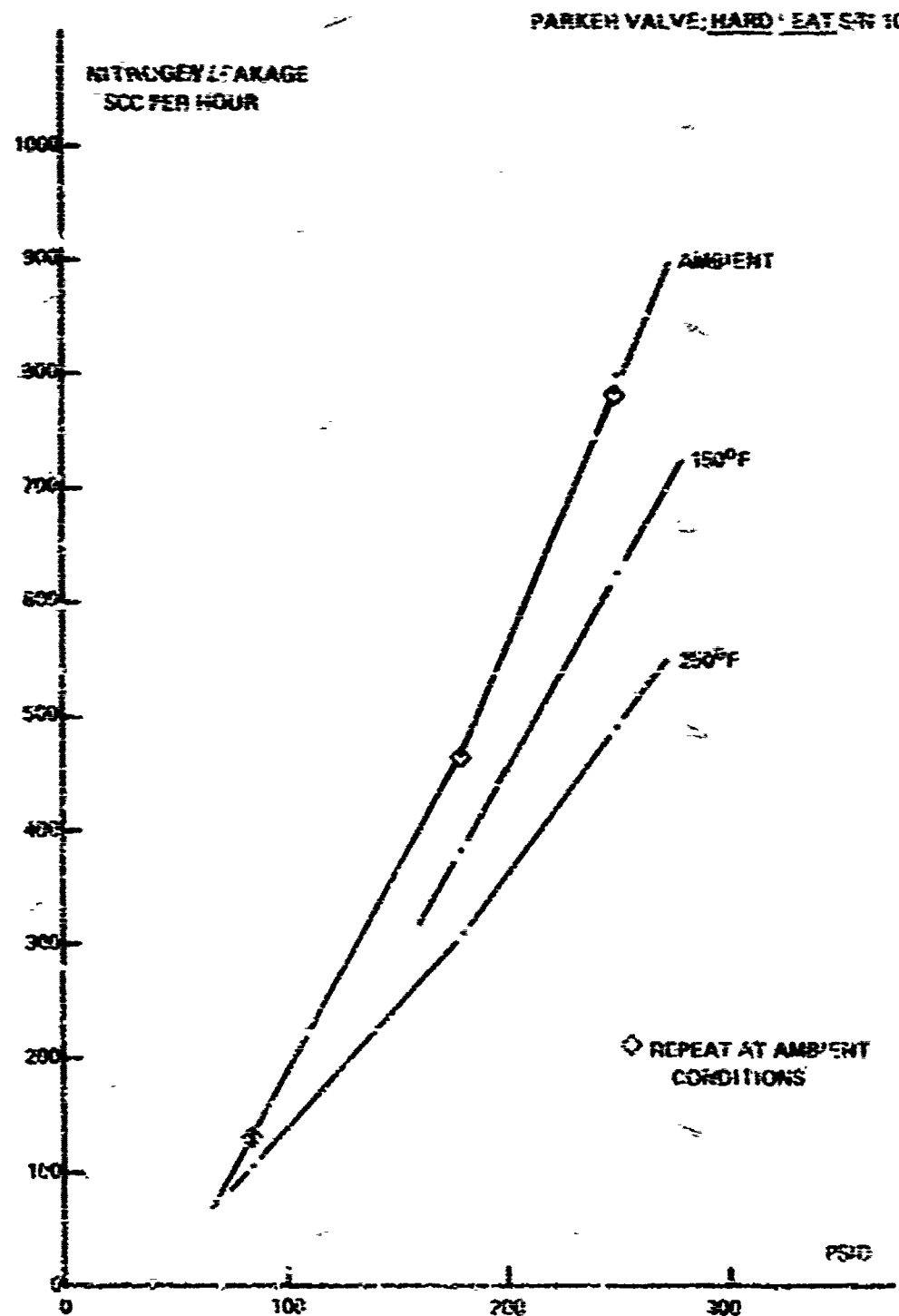


Figure 10. Temperature Effect on Leakage

PARKER VALVE: TEFLON SEAT 5W 102

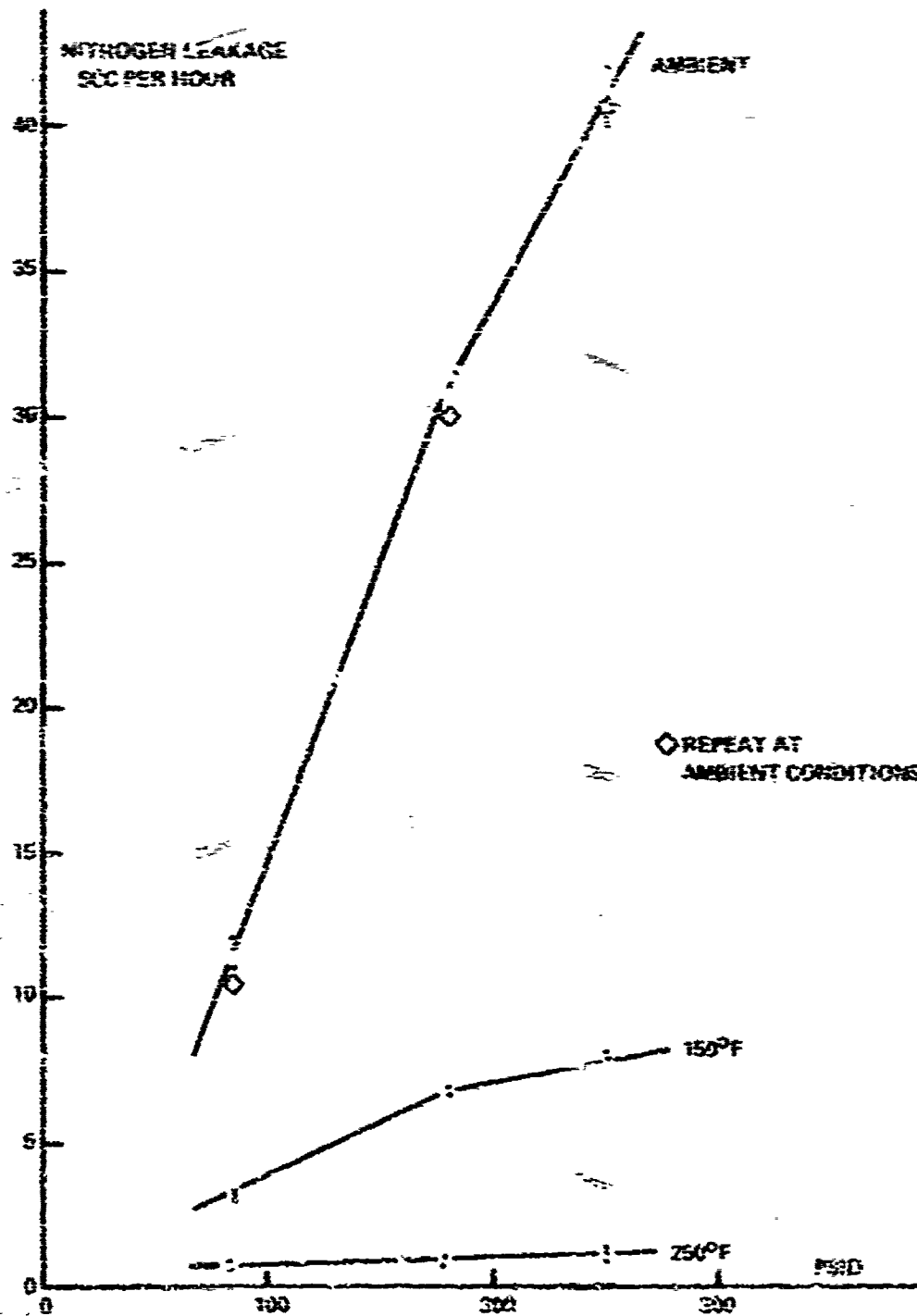


Figure 11. Temperature Effect on Leakage

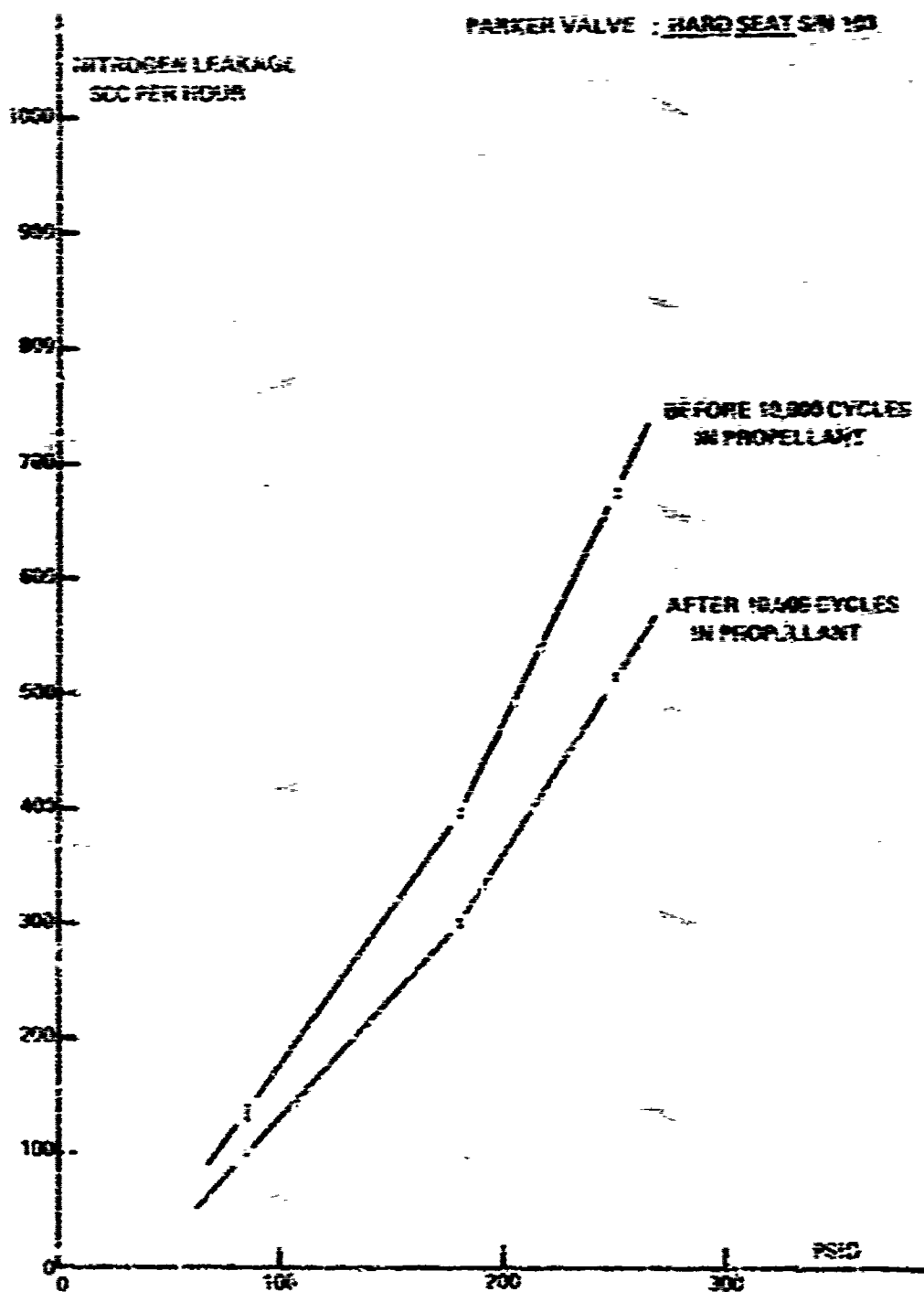


Figure 12. Cycling Effect on Leakage

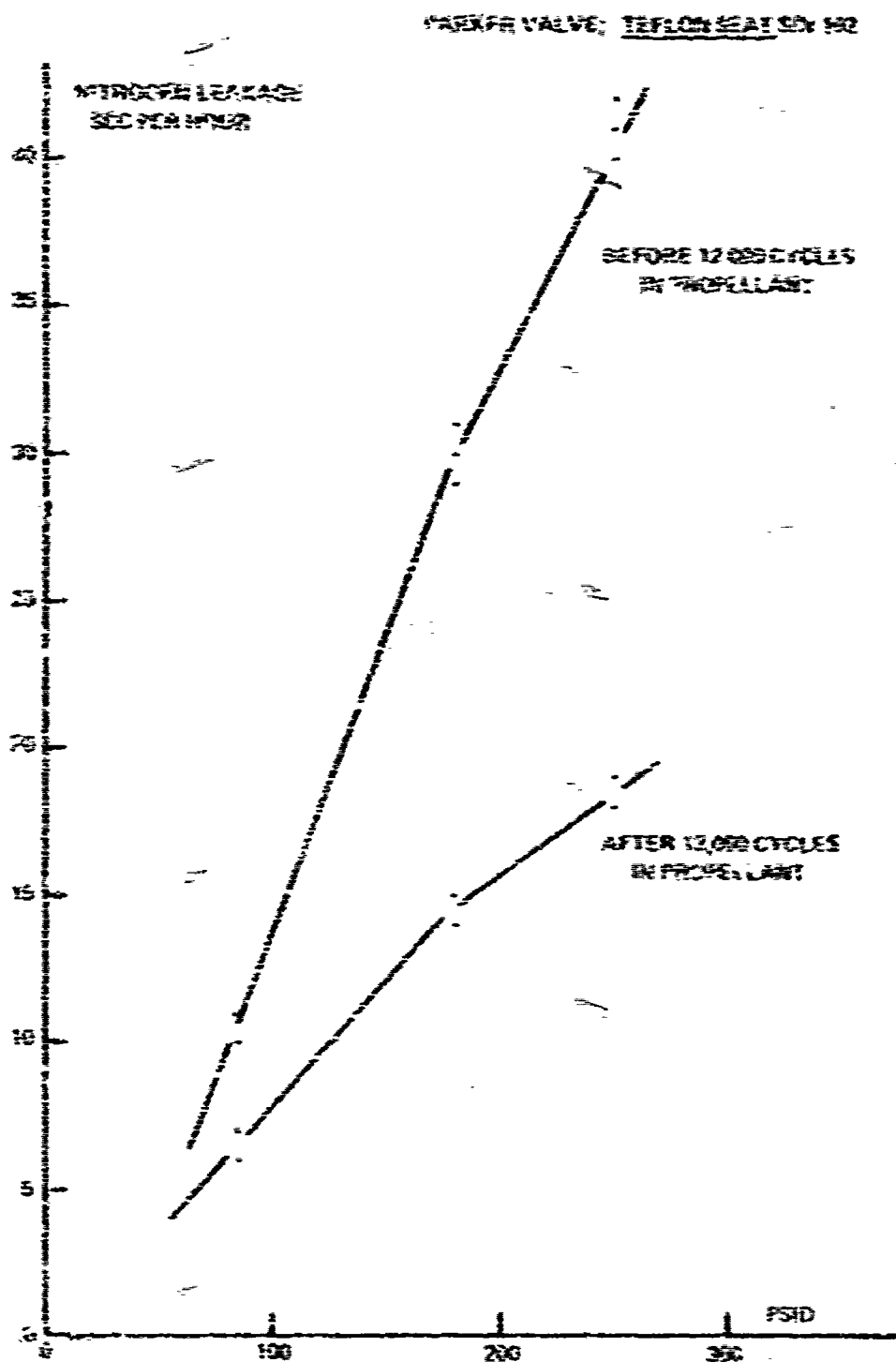


Figure 13. Cycling Effect on Leakage

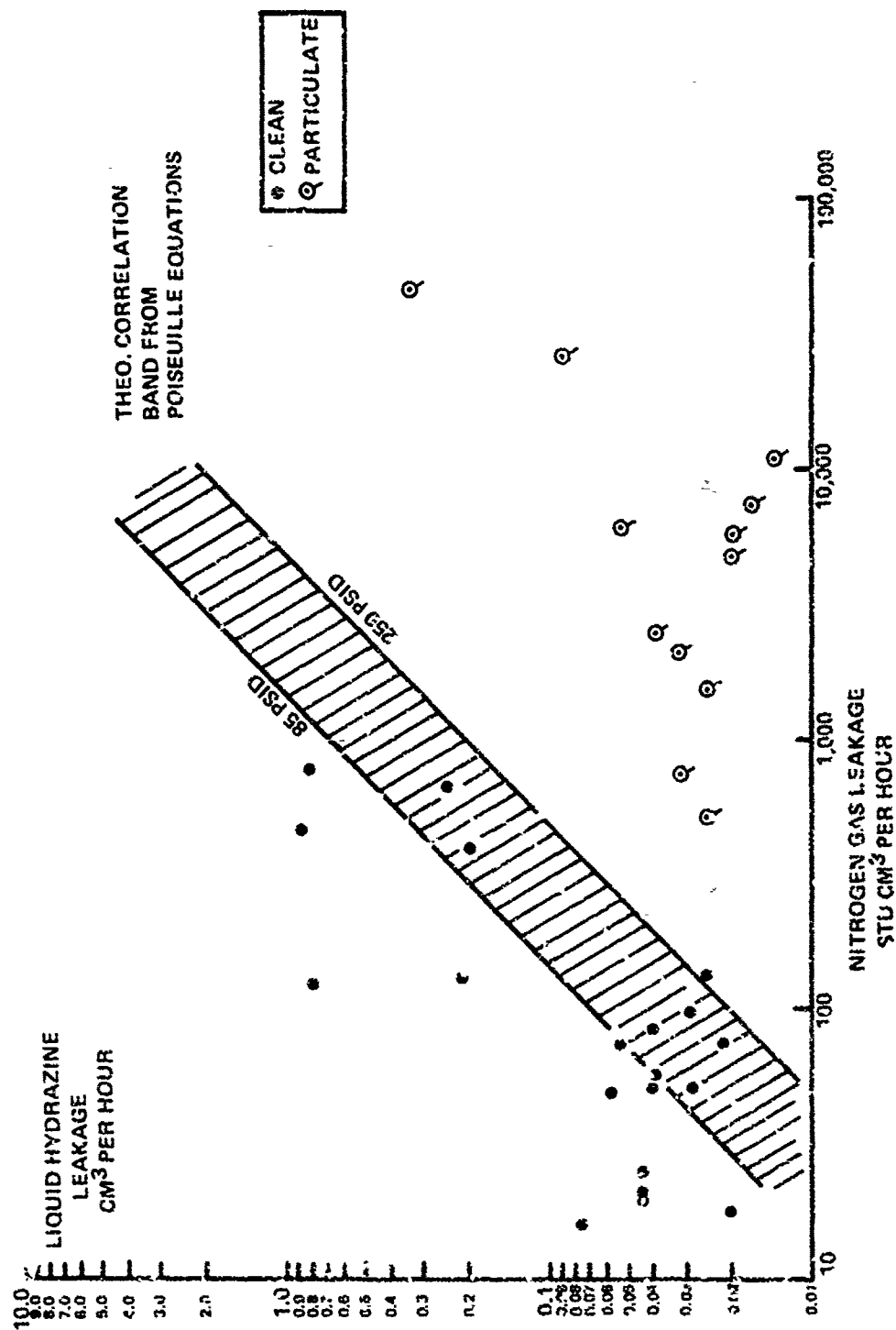


Figure 14. Liquid versus Gas Leakage.

TABLE I. LEAKAGE DATA

TEST ITEM: PARKER VALVE/HARD SEAT, 103

Test No.	Fluid	Valve Temp °F	Inlet Pressure psig	Leakage cc per hr	Remarks
1	Nitrogen	Ambient	85 psig	131	acc/hr
2				125	
3				138	
4				137	
5				138	
6				136	
7				135	
8				135	
9				136	
10				135	
11				128	
12				156	
13				136	
14				136	
15				136	
16			180 psig	469	
17				472	
18				470	
19				471	
20				471	
21		150°F	250 psig	800	
22				786	
23				756	
24				786	
25				627	
26			180 psig	627	
27				625	
28				625	
29				625	
30				385	
31				385	
32				384	
33				383	

TABLE 1. LEAKAGE DATA (Cont'd)

Test No.	Fluid	Valve Temp °F	Inlet Pressure ±2 psig	Leakage cc per hour	Remarks
34	Nitrogen	150°F	180 psig	384 scc per hour	
35		250°F	250 psig	492	
36				492	
37				492	
38				491	
39				491	
40			180 psig	509	
41				308	
42				308	
43				307	
44				308	
45			85 psig	107	
46				105	
47				105	
48				105	
49				105	
50		Ambient		134	
51				135	
52				134	
53				136	
54				137	
55			180 psig	466	
56				466	
57				462	
58				469	
59				471	
60			250 psig	720	
61				779	
62				781	
63				786	
64				789	
65	Hydrazine	Ambient	85 psig	1,798 cc per hour	Begin N ₂ H ₄ Tests
66	Hydrazine	Ambient	85 psig	1,740	

TABLE I. Ist : GE DATA (Cont'd)

Test No.	Fluid	Valve Temp °F	Inlet Pressure ±2 psig	Leakage cc per hr	Remarks
67	Hydrazine	Ambient	65 psig	.717 cc per hour	
68				.650	
69				.620	
70				.672	
71				.672	
72			180 psig	.788	
73				.863	
74				.863	
75				.815	
76				.788	
77				.788	
78				.788	
79				.764	
80			250 psig	.704	
81				.740	
82				.740	
83				.717	Isolated in N ₂ H ₄ @ 85 psig for 16 hrs
84				.717	
85			250 psig	.674	
86				.674	
87				.674	
88				.681	Vacuum Saked 13 hrs
89	Nitrogen	Ambient	85 psig	140 cc per hour	
90				133	
91				137	
92				135	
93				136	
94				134	
95				135	
96				130	
97				134	
98				134	

TABLE I. LEAKAGE DATA (Cont'd)

Test No.	Fluid	Valve Temp °F	Inlet Pressure ±2 psig	Leakage cc per hr	Remarks
99	Nitrogen	Ambient	180 psig	400 sec per hour	
100				399	
101				403	
102				397	
103				396	
104			250 psig	674	
105				674	
106				674	
107				679	
108				672	Repeat N ₂ H ₄ Tests
109	Hydrazine	Ambient	85 psig	.211 cc per hr	
110				.200	
111				.179	
112			180 psig	.200	
113				.200	
114				.200	
115			250 psig	.211	
116				.200	
117				.179	Isolated in N ₂ H ₄ @ 85 psig for 64 hrs
118	Hydrazine	Ambient	250 psig	.246	
119				.141	
120				.081	
121				.064	
122				.058	Isolated in N ₂ H ₄ @ 85 psig for 18 hrs
123			85 psig	.037	
124				.036	
125			180 psig	.063	
126				.058	
127			250 psig	.075	
128				.069	
129				.049	Cycle 10,000 times in Propellant

TABLE I. LEAKAGE DATA (Cont'd)

Test No.	Fluid	Valve Temp °F	Inlet Pressure ±2 psig	Leakage cc per hr	Remarks
130	Hydrazine	Ambient	85 psig	.189 cc per hour	
131				.150	
132				.124	
133			130 psig	.141	
134				.124	
135				.094	
136			250 psig	.088	
137				.081	
138				.069	
139				.058	
140				.049	
141				.044	Isolated in N ₂ H ₄ @ 85 psig for 16 hrs
142			250 psig	.069	
143				.058	
144				.053	
145				.053	
146			180 psig	.049	
147				.036	
148				.029	
149			85 psig	.058	
150				.053	
151				.049	
152				.044	
153			250 psig	.040	
154				.075	
155				.069	
156				.054	
157				.053	
158				.053	Vacuum Bake 16 hrs
159	Nitrogen	Ambient	85 psig	100 sec per hr	
160				100	
161				100	

TABLE I. LEAKAGE DATA (Cont'd)

Test No.	Fluid	Valve Temp °F	Inlet Pressure ± 2 psig	Leakage cc per hr	Remarks
162	Nitrogen	Ambient	85 psig	99	Into Ambient Storage
163				99	
164				100	
165				100	
166				100	
167				100	
168				99	
169			180 psig	302	
170				302	
171				302	
172				300	
173			250 psig	302	
174				517	
175				517	
176				514	
177				517	
178				514	
179	Nitrogen	Ambient	85 psig	103	Contaminated with Tungsten particles
180				105	
181				101	
182			180 psig	277	
183				277	
184				277	
185			250 psig	424	
186				419	
187				424	
188	Nitrogen	Ambient	85 psig	541	
189				534	
190				522	
191			180 psig	1525	
192				1525	

TABLE I. LEAKAGE DATA (Cont'd)

Test No.	Fluid	Valve Temp °F	Inlet Pressure ±2 psig	Leakage cc per hr	Remarks
193	Nitrogen	Ambient	180 psig	1525 scc per hr	
194			250 psig	2504	
195				2549	
196				2549	Begin N ₂ H ₄ Tests
197	Hydrazine	Ambient	85 psig	.025 cc per hr	
198				.020	
199				.015	
200			180 psig	.025	
201				.020	
202			250 psig	.040	
203				.036	
204				.029	
205				.025	
206				.025	
207				.022	
208				.020	
209				.015	
210				.015	
211				.012	
212				.010	Isolated in N ₂ H ₄ @ 85 psig for 38 hrs
213	Hydrazine	Ambient	250 psig	Not Measurable	Vacuum Baked 30 hrs
214	Nitrogen	Ambient	55 psig	2118 scc per hr	
215				2118	
216				2093	
217			160 psig	4500	
218				4390	
219				4390	
220			185 psig	4737	
221				4737	
222				4865	
223	Nitrogen	Ambient	250 psig	6000 scc per hour	
224				6000	
225				6207	

TABLE I. LEAKAGE DATA (Cont'd)

Test No.	Fluid	Valve Temp °F	Inlet Pressure ± 2 psig	Leakage cc per hr	Remarks
226	Hydr: ine	Ambient	85 psig	.032 cc per hour	
227				.029	
228				.025	
229				.022	
230				.020	
231			180 psig	.015	
232				.020	
233				.015	
234			250 psig	.053	
235				.049	
236				.044	
237				.040	
238				.036	
239				.036	
240				.032	
241				.029	
242				.022	
243				.022	
244				.020	
245				.020	
246				.020	Vacuum Bake 18 hrs
247	Nitrogen	Ambient	85 psig	2466 cc per hr	
248				2432	
249				2466	
250			180 psig	6667	
251				6420	
252				6420	
253			250 psig	10,000	
254				10,588	
255				10,000	Final Test

TABLE II. LEAKAGE DATA

TEST ITEM: PARKER VALVE/TEFLON SE.T, 102

Test No.	Fluid	Valve Temp °F	Inlet Pressure ±2 psig	Leakage cc per hr	Remarks
1	Nitrogen	Ambient	85 psig	12 cc per hour	
2				12	
3				12	
4				12	
5				12	
6				12	
7				11	
8				11	
9				12	
10				12	
11				12	
12				11	
13				11	
14				12	
15				12	
16				12	
17				12	
18				12	
19				12	
20			150 psig	31	
21				31	
22				31	
23				31	
24				31	
25				31	
26				31	
27			250 psig	31	
28				42	
29				42	
30				40	
31				40	
32				7.8	
33				7.9	

TABLE II. LEAKAGE DATA (Cont'd)

Test No.	Fluid	Valve Temp °F	Inlet Pressure psig	Leakage cc per hr	Remarks
34	Nitrogen	150°F	350 psig	7.7 sec per hour	
35				7.7	
36				7.7	
37			180 psig	6.7	
38				6.7	
39				6.7	
40				6.7	
41				6.6	
42			85 psig	3.3	
43				3.2	
44				3.2	
45				3.3	
46				3.3	
47		250°F	350 psig	1.1	
48				1.1	
49				0.9	
50			160 psig	1.1	
51				1.0	
52				0.9	
53				0.8	
54			85 psig	0.8	
55				0.7	
56				0.8	
57				0.8	
58	Nitrogen	Ambient	85 psig	10	
59				11	
60				1	
61				10	
62				10	
63			180 psig	31	
64				30	
65				20	
66				20	

TABLE II. LEAKAGE DATA (Cont'd)

Test No.	Fluid	Valve Temp °F	Inlet Pressure ±2 psig	Leakage cc per hr	Remarks
67	Nitrogen	Ambient	150 psig	30 sec per hour	
68				31	
69			250 psig	32	
70				40	
71				41	
72				37	
73				42	
74	Hydrazine	Ambient	85 psig	Not Measurable	Begin N_2H_4 Tests
75			150 psig	Not Measurable	
76			250 psig	Not Measurable	Cycle 12,000 times in Propellant
77	Hydrazine	Ambient	85 psig	Not Measurable	
78			150 psig	Not Measurable	
79			250 psig	Not Measurable	Vacuum Bake 18 hrs
80	Nitrogen	Ambient	85 psig	7	
81				7	
82				6	
83				5	
84				5	
85			150 psig	15	
86				15	
87				15	
88				15	
89				15	
90			250 psig	15	
91				15	
92				14	
93				13	
94				12	Final Test

TABLE III LEAKAGE DATA

TEST ITEM: PARKER VALVE/HARD SEAT, 102

Test No.	Fluid	Valve Temp °F	Inlet Pressure ±2 psig	Leakage cc per hr	Remarks
1	Nitrogen	Ambient	85 psig	25 cc per hr	
2				25	
3				25	
4			180 psig	52	
5				52	
6				50	
7			250 psig	74	
8				74	
9				74	
10			180 psig	74	
11				55	
12				53	
13			85 psig	52	
14				51	
15				52	
16			85 psig	26	
17				26	
18				26	
19			85 psig	25	
20				26	
21	Hydrazine	Ambient	85 psig	.044 cc per hr	Begin N_2H_4 Tests
22				.040	
23				.036	
24			180 psig	.036	
25				.032	
26				.029	
27			85 psig	.025	
28				.040	
29				.036	
30			180 psig	.032	
31				.029	
32				.029	
33			85 psig	.025	

TABLE III. LEAKAGE DATA (Cont'd)

Test No.	Fluid	Valve Temp °F	Inlet Pressure ±2 psig	Leakage cc per hr	Remarks
34	Hydrazine	Ambient	250 psig	.003 cc per hr	
35				.040	
36				.040	
37				.040	
38				.034	
39				.032	
40				.032	
41				.032	
42				.032	
43				.032	
44				.032	
45				.032	Vacuum Bake 18 hrs
46	Nitrogen	Ambient	95 psig	22 sec per hr	
47				24	
48				25	
49				22	
50				22	
51			120 psig	51	
52				50	
53				55	
54				50	
55				52	
56			250 psig	70	
57				69	
58				69	
59				71	
60				73	
61			180 psig	48	
62				48	
63				50	
64				49	
65				58	

TABLE III. LEAKAGE DATA (Cont'd)

Test No.	Fluid	Valve Temp °F	Inlet Pressure ±2 psig	Leakage cc per hr	Remarks
66	Nitrogen	Ambient	85 psig	22 sec per hr	
67				22	
68				22	
69				23	
70				24	Contaminated with aluminum
71	Nitrogen	Ambient	85 psig	.5	
72				9	
73				769	
74			180 psig	5737	
75				5757	
76				5772	
77			250 psig	12,536	
78				12,562	
79				12,562	
80				11,240	
81				11,219	
82				11,398	
83			180 psig	5742	
84				5680	
85			85 psig	1207	
86				1175	
88				1168	
89	Hydrazine	Ambient	85 psig	.032 cc per hr	Begin N_2H_4 Tests
90				.025	
91				.020	
92				.015	
93			180 psig	.020	
94				.017	
95				.017	
96				.015	

TABLE III. LEAKAGE DATA (Cont'd)

Test No.	Fluid	Valve Temp °F	Inlet Pressure ±2 psig	Leakage cc per hr	Remarks
97	Hydrazine	Ambient	180 psig	.012 cc per hr	
98			250 psig	.012	
99				.014	
100				.012	
101				.016	
102				.010	Isolated in N_2H_4 @ 35 psig for 23 hrs
103			85 psig	Not measurable	
104			180 psig	Not measurable	
105			250 psig	Not measurable	Valve actuated once
106			250 psig	.029	
107				.029	
108				.029	
109				.025	
110				.025	
111				.022	
112				.020	
113				.017	
114				.012	Isolated in N_2H_4 @ 250 psig for 20 hrs
115	Nitrogen	Ambient	250 psig	Not measurable	Vacuum Bake 18 hrs
116			35 psig	7600 cc per hr	
117				7466	
118				7560	
119			180 psig	26,000	
120				26,000	
121				26,000	
122			250 psig	45,000	
123				45,000	
124				45,000	

TABLE III. LEAKAGE DATA (Cont'd)

Test No.	Fluid	Valve Temp °F	Inlet Pressure ±2 psig	Leakage cc per hr	Remarks
125	Hydrazine	Ambient	250 psig	.340 cc per hr	Begin N_2H_4 tests
126				.340	
127				.298	
128				.264	
129				.258	
130				.234	
131				.200	
132				.200	
133				.195	
134			180 psig	.088	
135				.088	
136				.081	
137				.081	
138				.075	
139				.075	
140				.075	
141				.075	
142				.075	
143			85 psig	.017	
144				.017	
145				.015	
146				.012	Isolated in N_2H_4 @ 85 psig for 16 hrs
147			85 psig	.017	
148			180 psig	.069	
149				.069	
150				.064	
151				.064	
152				.058	
153				.053	
154			250 psig	.081	
155				.075	
156				.075	

TABLE III. LEAKAGE DATA (Cont'd)

<u>Test No.</u>	<u>Fluid</u>	<u>Valve Temp °F</u>	<u>Inlet Pressure ±2 psig</u>	<u>Leakage cc per hr</u>	<u>Remarks</u>
157	Hydrazine	Ambient	250 psig	.075 cc per hour	
158				.069	
159				.064	Vacuum Bake 18 hrs
160	Nitrogen	Ambient	85 psig	804 cc per hour	
161				804	
162				811	
163				2169	
164			180 psig	2169	
165				2169	
166				3461	
167			250 psig	3273	
168				3529	
169				2100	
170				2096	
171			35 psig	2100	
172				796	
173				804	
174				804	Final Test

TABLE IV. LEAKAGE DATA

TEST ITEM: PARKER VALVE/TEFLON SEAT, 103

Test No.	Fluid	Valve Temp °F	Inlet Pressure ±2 psig	Leakage cc per hr	Remarks
1	Nitrogen	Ambient	85 psig	26 cc per hour	
2				27	
3				28	
4				28	
5				27	
6				28	
7				28	
8				28	
9				28	
10				28	
11			180 psig	52	
12				52	
13				52	
14				52	
15				52	
16			250 psig	54	
17				55	
18				54	
19				55	
20				55	
21			180 psig	52	
22				51	
23				52	
24				51	
25				51	
26			85 psig	25	
27				25	
28				26	
29				26	
30				26	
31			180 psig	45	
32				46	
33				46	

TABLE IV. LEAKAGE DATA (Cont'd)

Test No.	Fluid	Valve Temp °F	Inlet Pressure ±2 psig	Leakage cc per hr	Remarks
34	Nitrogen	Ambient	250 psig	53 sec per hour	
35				52	
36				52	
37				52	
38				52	
39				52	
40				52	
41				52	
42				51	
43			85 psig	21	
44				20	
45				21	
46				21	
47	Hydrazine	Ambient	55 psig	.044 cc per hour	Begin N ₂ H ₄ Tests
48				.040	
49				.040	
50				.036	
51			120 psig	.032	
52				.029	
53				.029	
54				.040	
55			250 psig	.040	
56				.036	
57				.040	
58				.024	
59			65 psig	.029	
60				.025	
61				.017	
62				.015	
63				.015	Vacuum Bake 18 hrs
64	Nitrogen	Ambient	65 psig	21 sec per hour	
65				20	
66				20	

TABLE IV. LEAKAGE DATA (Cont'd)

<u>Test No.</u>	<u>Fluid</u>	<u>Valve Temp °F</u>	<u>Inlet Pressure ±2 psig</u>	<u>Leakage cc per hr</u>	<u>Remarks</u>
67	Nitrogen	Ambient	85 psig	20 scc per hour	
68				21	
69				43	
70				42	
71				40	
72			250 psig	41	
73				41	
74				50	
75				51	
76				53	
77				50	
78				50	Final Test

TABLE V. LEAKAGE DATA

TEST ITEM: HYDRAULIC RESEARCH VALVE/UPSTREAM SEAT, 102

Test No.	Fluid	Valve Temp °F	Inlet Pressure ±2 psig	Leakage cc per hr	Remarks
1	Nitrogen	Ambient	85 psig	4.1 cc per hour	
2				4.0	
3				4.1	
4				4.1	
5				4.1	
6			180 psig	11.0	
7				10.9	
8				11.0	
9				10.9	
10				11.0	
11			250 psig	17.5	
12				17.2	
13				18.0	
14				18.1	
15				18.0	
16	Hydrazine	Ambient	85 psig	Not Measurable	Begin N ₂ H ₄ Tests
17			180 psig	Not Measurable	
18			250 psig	Not Measurable	Valve Actuated Once
19			85 psig	Not Measurable	
20			180 psig	Not Measurable	
21			250 psig	Not Measurable	Valve Actuated 10 times
22			85 psig	Not Measurable	
23			180 psig	Not Measurable	
24			250 psig	Not Measurable	
25		200°F	85 psig	Not Measurable	
26			180 psig	Not Measurable	
27			250 psig	Not Measurable	Vacuum Bake 18 hrs

TABLE V. LEAKAGE DATA (Cont'd)

Test No.	Fluid	Valve Temp °F	Inlet Pressure ± 2 psig	Leakage cc per hr	Remarks
28	Nitrogen	Ambient	85 psig	7.1 sec per hr	
29				7.1	
30				7.0	
31				7.0	
32				7.0	
33			150 psig	18.0	
34				18.6	
35				18.9	
36				17.5	
37				18.1	
38			250 psig	28.0	
39				29.1	
40				28.6	
41				28.0	
42				28.2	Final Test

TABLE VI. LEAKAGE DATA

TEST ITEM: HYDRAULIC RESEARCH VALVE/
DOWNSTREAM SEAT, 102

Test No.	Fluid	Valve Temp °F	Inlet Pressure ±2 psig	Leakage cc per hr	Remarks
1	Nitrogen	Ambient	85 psig	2.6 cc per hour	
2				2.6	
3				2.6	
4				2.6	
5				2.6	
6			180 psig	7.1	
7				7.1	
8				7.0	
9				7.0	
10				7.2	
11			250 psig	11.7	
12				11.8	
13				11.7	
14				11.6	
15				11.5	
16	Hydrazine	Ambient	85 psig	Not Measurable	Begin N_2H_4 Tests
17			180 psig	Not Measurable	
18			250 psig	Not Measurable	Valve Actuated Once
19			85 psig	Not Measurable	
20			180 psig	Not Measurable	
21			250 psig	Not Measurable	Valve Actuated 100 times
					Vacuum Bake 12 hrs
22	Hydrazine		85 psig	.004 cc per hour	Begin N_2H_4 Tests
23				.044	
24				.032	
25			180 psig	.036	
26				.038	
27				.074	
28			250 psig	.229	
29				.021	

TABLE VI. LEAKAGE DATA (Cont'd)

Test No.	Fluid	Valve Temp °F	Inlet Pressure ±2 psig	Leakage cc per hr	Remarks
30	Hydrazine	Ambient	250 psig	.017 cc per hr	Vacuum Bake 24 hrs
31	Nitrogen	Ambient	85 psig	21 cc per hr	
32				21	
33				21	
34				21	
35				21	
36			180 psig	60	
37				60	
38				58	
39				60	
40				61	
41			250 psig	98	
42				95	
43				95	
44				130	
45				97	Final Test

TABLE VII. LEAKAGE DATA

TEST ITEM: HYDRAULIC RESEARCH VALVE/
UPSTREAM SEAT, 103

Test No.	Fluid	Valve Temp °F	Inlet Pressure ±2 psig	Leakage cc per hr	Remarks
1	Nitrogen	Ambient	85 psig	10 sec per hour	
2				25	
3				25	
4				26	
5				25	
6			160 psig	54	
7				53	
8				53	
9				52	
10				52	
11				52	
12			250 psig	155	
13				155	
14				155	
15				155	
16				155	
17				155	
18				155	
19			325 psig	53	
20				53	
21				52	
22				51	
23				54	
24			50 psig	25	
25				25	
26				25	
27				25	
28				25	
29	Hydraulic	Ambient	85 psig	Not Measurable	Seals Used, Tests
30			140 psig	Not Measurable	
31			250 psig	Not Measurable	
32		250°F	85 psig	Not Measurable	
33			160 psig	Not Measurable	

TABLE VII. LEAKAGE DATA (Cont'd)

Test No.	Fluid	Valve Temp °F	Inlet Pressure ± 2 psig	Leakage cc per hr	Remarks
34	Hydrazine	209°F	250 psig	Not Measurable	Valve Actuated Once
35		Ambient	85 psig	.020 cc per hour	
36				.020	
37				.020	
38				.017	
39				.017	
40			180 psig	.022	
41				.021	
42				.020	
43				.020	
44				.021	
45			150 psig	.025	
46				.022	
47				.022	
48				Not Measurable	
49				.021	
50				.021	
51				.021	
52				.020	
53			185 psig	.019	
54				.018	
55				.020	Vacuum Leak 26 hrs
56	Nitrogen	Ambient	85 psig	Not Measurable	
57			180 psig	65 sec per hour	
58				50	
59				44	Gas Leakage Erratic
60			150 psig	55	
61				68	
62				65	Erratic

TABLE VII. LEAKAGE DATA (Cont'd)

Test No.	Fluid	Valve Temp °F	Inlet Pressure psia	Leakage cc per hr	Remarks
63	Nitrogen	Ambient	150 psig	1.1 cc per hour	
64				1.0	
65				1.0	Erratic, increasing with time; possible due to seat/poppet Volume Rate 1.1 cc/hr
66	Nitrogen	Ambient	80 psig	1.0	
67				1.0	
68				1.1	
69			150 psig	1.1	
70				1.0	
71				1.1	
72			150 psig	1.1	
73				1.0	
74				1.0	Final Test

TABLE VIII. LEAKAGE DATA
TEST ITEM: HYDRAULIC RESEARCH VALVE/
DOWNSTREAM SEAT, 103

<u>Test No.</u>	<u>Fluid</u>	<u>Valve Temp °F</u>	<u>Inlet Pressure ±2 psig</u>	<u>Leakage cc per hr</u>	<u>Remarks</u>
1	Nitrogen	Ambient	85 psig	16 cc per hour	
2				16	
3				16	
4				16	
5				16	
6			180 psig	49	
7				50	
8				50	
9				49	
10				51	
11			250 psig	86	
12				87	
13				87	
14				87	
15				87	
16				87	
17				86	
18	Hydrazine	Ambient	85 psig	.075 cc per hour	Begin N ₂ H ₄ Tests
19				.075	
20				.069	
21				.053	
22			180 psig	.058	
23				.051	
24				.049	
25			250 psig	.040	
26				.040	
27				.036	
28				.029	
29				.022	
30				.020	
31		200°F	250 psig	.015	
32				.019	Vacuum Bake 18 hrs

TABLE VIII. LEAKAGE DATA (Cont'd)

Test No.	Fluid	Valve Temp °F	Inlet Pressure ±2 psig	Leakage cc per hr	Remarks
33	Nitrogen	Ambient	85 psig	1175 sec per hour	
34				1169	
35				1154	
36			180 psig	4186	
37				4186	
				4235	
39			250 psig	7385	
40				7200	
41				7385	Final Test

TABLE IX. PERFORMANCE CHARACTERISTICS
PARKER VALVES

PROPELLANT:	HYDRAZINE; 0.0117 LB/SEC @ 14.6 PSID MAX
TEMPERATURE:	
AMBIENT	+35°F TO +250°F
FLUID	+40°F TO +140°F
PURGE	+225°F
OPERATING PRESSURE:	0 TO 300 PSIG
PROOF PRESSURE:	600 PSIG
BURST PRESSURE:	1200 PSIG
OPENING RESPONSE:	7 MSEC MAX @ 24 VDC, 215 PSIG, +250°F
CLOSING RESPONSE:	7 MSEC MAX @ 56 VDC EXT VOLTAGE
REPEATABILITY:	± 0.5 MSEC AT 28 VDC, 215 PSIG, 70°F
INTERNAL LEAKAGE:	10 SCC PER HOUR GN_2 @ 300 PSIG
EXTERNAL LEAKAGE:	6×10^{-6} SCC PER SEC He @ 300 PSIG
WEIGHT:	0.41 LB MAX

TABLE X. PERFORMANCE CHARACTERISTICS
HYDRAULIC RESEARCH VALVES

PROPELLANT:	HYDRAZINE; 0.0224 LB/SEC @ 28 PSID MAX
TEMPERATURE:	
OPERATING	35°F TO 250°F
AMBIENT	-65°F TO 250°F
OPERATING PRESSURE:	335 PSIG
PROOF PRESSURE:	670 PSIG
BURST PRESSURE:	780 PSIG
OPENING RESPONSE:	17 MSEC
CLOSING RESPONSE:	8 MSEC
RESPONSE REPEATABILITY:	1 MSEC OPEN/CLOSE
INTERNAL LEAKAGE:	1 SCC PER HOUR GN ₂ @ 300 PSIG, 70°F
EXTERNAL LEAKAGE:	1 X 10 ⁻⁶ SCC PER SEC He @ 300 PSIG
WEIGHT:	0.47 LB MAX

TABLE XI. SUMMARY OF CORRELATION DATA

VALVE IDENTIFICATION	FLUID	LEAKAGE 485 PSIG	LEAKAGE 9180 PSIG	LEAKAGE 9250 PSIG	REMARKS
PARKER HARD SEAT 102	MIN. GN ₂	25	51	74	VAC. BAKE
	MAX. N ₂ H ₄	044	040	.053	
	MIN. GN ₂	22	48	68	CONTAMINATE
	MIN. GN ₂	745	5663	11,219	ACTUATE
	MAX. N ₂ H ₄	.032	.020	.014	
	MAX. N ₂ H ₄			.029	VAC. BAKE
	MIN. GN ₂	7466	26,000	45,000	VAC. BAKE
	MAX. N ₂ H ₄	.017	.068	.340	
	MIN. GN ₂	796	2006	3273	FINISH
PARKER HARD SEAT 103	MIN. GN ₂	125	462	739	VAC. BAKE
	MAX. N ₂ H ₄	.788	.953	.835	
	MIN. GN ₂	133	396	672	
	MAX. N ₂ H ₄	.211	.200	.246	10,000 CYCLES
	MAX. N ₂ H ₄	.189	.141	.028	VAC. BAKE
	MIN. GN ₂	99	300	514	STORAGE
	MIN. GN ₂	191	277	419	CONTAMINATE
	MIN. GN ₂	522	1525	2504	
	MAX. N ₂ H ₄	.025	.025	.040	VAC. BAKE
	MIN. GN ₂	2093	4737	6006	
	MAX. N ₂ H ₄	.032	.020	.053	VAC. BAKE
	MIN. GN ₂	2432	6429	10,000	FINISH
HYDRAULIC RESEARCH 102 UPSTREAM SEAT	MIN. GN ₂	40	11	18	ACTUATE
	MAX. N ₂ H ₄	0	0	0	VAC. BAKE
	MIN. GN ₂	70	18	26	FINISH
HYDRAULIC RESEARCH 102 DOWNSTREAM SEAT	MIN. GN ₂	26	75	12	100 CYCLES
	MAX. N ₂ H ₄	0	0	0	VAC. BAKE
	MAX. N ₂ H ₄	044	.035	.056	VAC. BAKE
	MIN. GN ₂	21	58	97	FINISH
HYDRAULIC RESEARCH 103 UPSTREAM SEAT	MIN. GN ₂	75	92	149	VAC. BAKE
	MAX. N ₂ H ₄	0	0	0	ACTUATE
	MAX. N ₂ H ₄	.029	.022	.025	VAC. BAKE
	MIN. GN ₂	18	76	133	FINISH
HYDRAULIC RESEARCH 103 DOWNSTREAM SEAT	MIN. GN ₂	15	49	91	
	MAX. N ₂ H ₄	.075	.058	.046	VAC. BAKE
	MIN. GAS	1154	4165	7200	FINISH
PARKER TEFLON SEAT 102	MIN. GN ₂	75	25	25	
	MAX. N ₂ H ₄	0	0	0	12,000 CYCLES
	MAX. N ₂ H ₄	0	0	0	VAC. BAKE
	MIN. GN ₂	6	12	13	FINISH
PARKER TEFLON SEAT 103	MIN. GN ₂	75	51	51	
	MAX. N ₂ H ₄	044	040	.025	VAC. BAKE
	MIN. GN ₂	20	46	50	FINISH

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