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FINAL REPORT
ION PUMP AND LEAK LIFE TEST

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TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (Cont)

SUMMARY

This report describes the fabrication and long term testing of a flight type ion pump and sintered inlet leak.

These tests were conducted over a period of one year at an ion pump pressure of approximately 1×10^{-6} torr. These long term tests were conducted to investigate aging of ion pumps and leaks under continuous use.

Pumping speed and leak conductance, as well as other parameters, were measured on a weekly basis with ion pump start tests conducted on a monthly basis.

INTRODUCTION

NASA Contract NAS9-9799 defines the development and production of flight magnetic mass spectrometer systems for use in the NASA Skylab program. In any mass spectrometer system, a means has to be provided to allow sample gases to enter the mass spectrometer for analysis. A pump is also provided to maintain the system at the high vacuum required for mass spectrometer operation.

In this mass spectrometer system the Skylab atmosphere is sampled by using a stainless steel sintered leak which, through its small conductance, only allows a minute quantity of gas to enter the mass spectrometer for analysis. To maintain the required high vacuum within the mass spectrometer an ion pump is utilized which continually and permanently removes the sampled gas after it is analyzed.

Considerable sintered leak and ion pump operational data had been accumulated prior to the decision for their use in the mass spectrometer system. These data were, however, for short term operation and although studies indicated that both the inlet leak and ion pump would operate satisfactorily over long periods of time, there was no direct empirical evidence.

To obtain the required empirical data an Engineering Change Proposal (ECP 609) was approved on 15 June 1970 to build and test, for a prolonged duration, an ion pump and a sintered inlet leak.

ECP 609 authorized the construction and testing of a system comprised of the flight ion pump and sintered leak developed for use on the Mass Spectrometer Atmospheric Sensor System. The test system consisted of the pump, leak and associated test equipment to allow the testing, monitoring and measuring of characteristic parameters of both the ion pump and the sintered leak during the life test duration of one year.

Within the test period, data was taken at predetermined intervals, concerning pumping speed, pump starting characteristics, ion pump running current and voltage and leak conductances.

TEST CONDITIONS

The life testing of the flight ion pump and leak was undertaken under the following conditions:

(1) The flight ion pump and leak tests lasted for the duration of one year to determine the characteristics of these two components over the expected flight hardware life of operation.

(2) The test environments were room ambient temperature and pressure with air as the test gas was continually being circulated past the leak (at the high pressure side of leak) by a mechanical circulating pump.

Chronological Events

In order to test the ion pump and sintered leak a test vacuum system was constructed, as shown in Figure 1, to allow both the testing of the ion pump and the sintered inlet leak.

The test vacuum system consists of two ion gauges, a bypass valve, a roughing valve, and a known conductance orifice through which the speed of the pump or the conductance of the leak is measured.

The pumping speed of the ion pump is measured by the two gauge method which is governed by the following relation:

$$S_P = \frac{P_1 - P_2}{P_2} \qquad (1)$$

where S_P = pump speed (ℓ/s)

P_1 = pressure of high side of known conductance (torr)

P_2 = pressure of low side of known conductance (torr)

C = known conductance orifice (ℓ/s)

The pressures, P_1 and P_2, are measured with the bypass valve closed after the two gauges are checked for tracking each other. The background pressure reading of both gauges should also be checked prior to making speed and conductance measurements. This is to eliminate errors due to the inability of having zero pressure inside a test vacuum system with no inlet flow from the outside. There is always a residual pressure in any system which is proportional to the cleanliness of the system. Whenever possible, the actual and running pressures utilized for speed or conductance measurements should be at least a decade above the background pressure. Also, the background pressure must be subtracted from the test pressure. In actuality, Equation (1) should be rewritten as:

$$S_P = \frac{\Delta P_1 - \Delta P_2}{\Delta P_2} C \qquad (2)$$

where:

ΔP is the test pressure minus the background pressure of that gauge.

To measure the conductance of the leak the following relationship is utilized:

$$C_L = \frac{\Delta P_1 - \Delta P_2}{P_o} C \qquad (3)$$

where: C_L = conductance of sintered leak (ℓ/s)

P_o = the pressure on the high pressure side of the leak (torr)

The test vacuum system also included a Residual Gas Analyzer (RGA) to analyze the possible regurgitated gases, if any, of the pump. RGA measurements were discontinued shortly after the life test started because of the inability of the RGA to provide repeatable data, numerous RGA malfunctions and most important, the RGA in operation outgassed more constituents than the ion pump could ever contribute to the system.

In order to assemble the components of the test system a drawing (344033) of the ion pump was made to eliminate the complex valve and tube configuration of the flight system and replace the weldable flight flange with a commercial Varian Associates rotatable flange.

Leak number 19 from the flight program was reworked to reduce its conductance from approximately 2.5×10^{-5} cubic centimeters per second to approximately 5.2×10^{-6} cubic centimeters per second. The leak was electron beam welded in a valve assembly (344063). The pump was constructed and connected to the NAS9-9799 ion pump breadboard power supply. The ion pump magnet was stabilized at 1100 gauss and on 23 October 1970 the system was connected and a pump down for the start of the test was attempted.

In attempting to pump down the system, several leaks were discovered in the associated equipment. After the leaks were corrected, an ion pump start was attempted, but the ion pump pulsed and outgassed severely. The entire system was baked to over 200°C for several hours without the ion pump running. After several hours (at ambient temperature) the ion pump was finally started, but showed pressure fluctuations indicating severe contamination. Apparently, baking out the RGA without the ion pump running severely contaminated the ion pump cathodes.

On 27 October 1970 (12 hours after ion pump stabilization) the RGA was operated to obtain a partial pressure spectrum. Useful data was not obtained, however, because of severe outgassing from the RGA unit. At this point it was noted that the test sintered leak was plugged. After considerable effort to bake open (to 400°C) the leak and circulating oxygen at high temperature, it was determined that the system should be vented and the leak replaced with another sintered leak (leak No. 3). By 10 December 1970, a new leak had been welded on the inlet valve and the system was assembled as shown in Figure 2, ready for pump down and bakeout. During this bakeout, the test pump as well as a laboratory pump were both on. The bakeout temperature was 250°C for four hours at which time the current of the test pump dropped from 290 to 30 microamperes. The current of the laboratory pump dropped from 800 to 235 microamperes. This reduction in current of both pumps indicated that the system was relatively clean and testing could start.

After the system was returned to room temperature, a preliminary check was made of the leak conductance and pumping speed. The pumping speed of the test pump was somewhat lower than expected and the conductance of the leak was about a factor of three higher than that measured during the conductance modification. Examination of prior data showed that an error had been made during the conductance modification phase and that the leak conductance was higher.

This higher leak conductance presented a problem in the operation of the system. With the calculated conductance, the system was to operate at a pump pressure of approximately 1 to 2 x 10^{-6} torr (with an external pressure of one atmosphere). The higher leak conductance forced the pump pressure to about 8 x 10^{-6} torr with one atmosphere on the high side of the leak. This pump pressure was unacceptably high for a continual run of one year; thus, the inlet pressure had to be reduced so that the pump would run at approximately 1 x 10^{-6} torr. This was accomplished by inserting a needle valve in the inlet system as shown in Figure 3.

With the test system operation stabilized, data was taken on a weekly basis, with more extensive monthly tests according to the test procedure presented in Appendix B. The test system was operated normally, according to the procedure until the 21st week when a special pumping speed test with nitrogen was conducted. Prior to the 22nd week of testing, the test ion pump experienced pulsing phenomena which lasted for several days. During the 22nd week, the pumping speed was running approximately 30 percent lower than the previous week. During the 23rd week of testing the pumping speed returned to normal.

Between the 29th and 30th week, a request was made to determine if the ion pump would start at pressures up to 7 x 10^{-3} torr. Several high pressure tests were conducted with air as the test gas and it was found that it takes approximately one hour to pump a volume of 2 liters from about 7 x 10^{-3} torr to 2 x 10^{-6} torr (with the flight breadboard supply). Since the high pressure starting tests mentioned above, the pump speed increased and remained consistently higher throughout the remainder of the life test. No other unusual events or deviations were experienced during the remainder of the life test.

Test Results

Both the test ion pump and sintered leak operated normally throughout the life test. The only exception was several days of ion pump pulsing after the special nitrogen (N_2) testing which resulted in a reduced pumping speed. This reduced speed is not an unusual phenomenon in ion pumps which are outgassing during pulsing periods. The mechanism for pulsing is not precisely known, but always occurs simultaneously with an ion pump current pulse. Figure 4 is an X-Y plot of the pressure pulses of the ion pump with time during the pulsing period. The Y-axis is the pressure pulse amplitude while the X-axis is time. Figure 5 is a similar plot showing considerable decrease in pulse amplitude. An ion pump normally shows pressure (or current) pulses of up to 20 percent of its running base pressure. This is due to variations of inlet pressure, discharge variations within the pump or variations of gas homogeneity.

The ion pump current-to-pressure ratio (I/P) appears fairly stable at approximately 70 amperes per torr, as shown in Figures 6 and 7, for the entire life test. A constant I/P ratio indicates a constant pumping speed as given by the relationship:

$$S_P = \Psi \, I/P \, A_a \qquad (4)$$

where: S_P = pumping speed (ℓ/s)

Ψ = the efficiency coefficient of the ion pump (torr-M/coulomb)

A_a = total anode area (M^2)

The actual pumping speeds over the duration of the test period are shown in Table 1 for a pressure of approximately 5 x 10^{-7} torr; Table 2 for a pump pressure of approximately 1 x 10^{-6} torr; and Table 3 for pump pressures of approximately 5 x 10^{-6} torr and 0.8 to 1 x 10^{-5} torr.

TABLE 1.- Pumping Speed

At ∿ 5 x 10^{-7} Torr Pump Pressure

Speed ℓ/s	Date	Monthly Test
3.01	3-3-71	2
3.08	4-12-71	3
2.90	5-11-71	4
	5-21 to 5-26	Pulsing
2.44	6-21-71	5
3.22	7-9-71	6
High Pressure Start Tests		
3.47	8-6-71	7
3.5	9-9-71	8
3.72	10-11-71	9
3.48	11-14-71	10
3.11	12-8-71	11
3.55	12-30-71	12

Average pumping speed before high pressure start tests: 2.93 ℓ/s.

Average pumping speed after high pressure start tests: 3.47 ℓ/s, or 0.54 ℓ/s higher than before.

Total average: 3.20 ℓ/s.

TABLE 2.- Pumping Speed

At ∿ 1.0 x 10^{-6} Torr Pump Pressure

Speed ℓ/s	Date	
2.19	12-14-70	
3.08	1-22-71	
2.47	1-29-71	
2.50	1-30-71	
3.02	2-5-71	
2.97	2-13-71	
2.82	3-3-71	
2.91	3-15-71	
3.12	3-19-71	
2.81	3-26-71	
2.69	4-2-71	
2.45	4-12-71	
2.76	4-16-71	
2.52	4-23-71	
2.64	4-30-71	
2.92	5-7-71	
2.65	5-14-71	
1.86	5-26-71	Pulsing
2.98	6-4-71	
2.30	6-11-71	Spikes on Pressure
2.86	6-18-71	Pulsing
2.19	6-21-71	
2.51	6-28-71	
2.62	7-2-71	
2.90	7-9-71	
2.82	7-13-71	High Pressure Starts
3.64	7-16-71	
3.50	7-23-71	
3.17	7-30-71	

TABLE 2.- (Concluded)

Speed ℓ/s	Date	
3.18	8-6-71	
3.43	8-13-71	
3.15	8-20-71	
3.19	9-9-71	
3.39	9-17-71	
3.14	9-24-71	
2.96	10-1-71	
3.35	19-8-71	
4.03	10-11-71	
3.20	10-19-71	
2.95	10-29-71	
2.97	11-4-71	
3.05	11-19-71	
3.21	11-29-71	
3.18	12-8-71	
3.18	12-22-71	
3.30	12-30-71	

Average pumping speed before high pressure start tests: 2.67 ℓ/s

Average pumping speed after high pressure start tests: 3.26 ℓ/s or 0.59 ℓ/s higher

Total average speed: 2.96 ℓ/s.

TABLE 3.- Pumping Speed

Pump Pressure At ∿ 5.0×10^{-6} Torr ℓ/s	Date	Pump Pressure At ∿ 8.0×10^{-6} Torr ℓ/s
2.58	2-12-71	2.23
2.22	3-3-71	2.54
2.48	3-15-71	2.28
2.49	3-19-71	2.13
2.48	3-26-71	2.26
2.34	4-2-71	2.25
1.60	4-12-71	1.55
2.31	4-16-71	2.25
1.85	4-23-71	1.67
2.33	4-30-71	2.10
2.51	5-7-71	2.25
2.38	5-14-71	2.18
1.70	5-26-71 Pulsing	1.36
2.45	6-4-71	2.19
0.74	6-11-71 Pulsing	1.17
2.31	6-18-71	2.1
2.14	6-28-71	2.07
2.22	7-2-71	2.17
2.55	7-9-71	2.55
	7-13-71 High Pressure Starts	
2.97	7-16-71	2.65
2.68	7-23-71	2.80
2.37	7-30-71	2.80
2.55	8-6-71	2.80
1.65	8-13-71	2.34
2.74	8-20-71	3.19
2.64	9-9-71	2.82
2.72	9-17-71	2.80
2.55	9-24-71	2.80

TABLE 3.- (Concluded)

Pump Pressure At ∿ 5.0 x 10^{-6} Torr ℓ/s	Date	Pump Pressure At ∿ 8.0 x 10^{-6} Torr ℓ/s
2.55	10-1-71	2.77
2.52	10-11-71	2.48
2.52	10-19-71	2.55
2.47	10-29-71	2.81
2.60	11-4-71	2.80
2.53	11-19-71	2.82
2.46	11-29-71	2.82
2.72	12-8-71	3.07
2.51	12-22-71	2.80
2.58	12-30-71	2.82

Average speed at ∿ 5 x 10^{-6} torr prior to high pressure start tests: 2.19 ℓ/s.

Average speed at ∿ 5 x 10^{-6} torr after high pressure start tests: 2.54 ℓ/s.

Total average speed at ∿ 5 x 10^{-6} torr: 2.37 ℓ/s.

Average speed at ∿ 8 x 10^{-6} torr prior to high pressure start tests: 2.07 ℓ/s.

Average speed at ∿ 8 x 10^{-6} torr after high pressure start tests: 2.78 ℓ/s.

Total average speed at ∿ 8 x 10^{-6} torr: 2.42 ℓ/s.

From the data in Tables 1, 2 and 3, note that the special high pressure air starts of the ion pump resulted in higher subsequent pumping speeds. A higher pumping speed is expected immediately after high pressure running of an ion pump, because such starts clean the cathodes allowing better sputtering. This increase in pumping speed is, however, normally a temporary phenomenon. In this case, a consistently higher pumping speed resulted for approximately six months, as shown in the above tables and Figure 8. In general, the speed apparently increased by 0.5 liters per second or about 20 to 25 percent. Figure 9 shows the average pumping speed with the mean of the deviations, for all pressures tested for the test duration prior to the high pressure start tests. The mean deviations are calculated by adding all deviations higher than the average value of the speed or leak conductance, and then determine the average of these deviations. Similarly, the lower mean of the deviations is calculated by adding all deviations which are lower than the average value and then determine the average of those values. Figure 10 shows the ion pump speed for the test duration after high pressure testing. The pumping speed (Figure 11) shows the average pumping speeds over the entire life test. The above figures show that the ion pump speed has not been degraded with time during the life test (54 weeks of operation) and approximately 75 starts at various pressures ranging from 10^{-8} to 10^{-3} torr.

During the test periods, when pump data was taken, data was also taken for measuring the characteristics of the inlet leak. The leak parameters measured were leak conductances at various pressures and also to determine if the leak changed from molecular flow to viscous flow. Tables 4 and 5 provide the conductance of the leak for the shown pressures for the duration of the test.

The average conductance of the sintered leak prior to the high pressure starts at a pump pressure of 5×10^{-7} torr (external leak pressure of approximately 50 to 60 torr) is 2.01×10^{-8} liters per second. At pump pressures of approximately 1×10^{-6} torr (external pressure from 100 to 150 torr) the average conductance is 2.0×10^{-8} liters per second. At pressures of approximately 5×10^{-6} torr (external pressure of 260 to 500 torr) the average conductance is 2.25×10^{-8} liters per second; while the average conductance at 0.8 -1 x 10^{-5} torr (external pressure of 400 to 700 torr) is 2.41×10^{-8} liters per second.

The conductance of the leak shows an increase of approximately 15 percent for the entire duration after the high pressure starting tests. Figure 12 shows the conductance variations of the leak over the entire duration of the test for pump pressures of approximately 1×10^{-6} torr, or a 100 to 150 torr external pressure. In this figure the lines show the average conductance prior to and after the high pressure starting tests. There is no known physical cause for the conductance of the leak to increase after high pressure starting of the ion pump. One possible cause for the data to read higher is the possible effect of high pressure on the ion gauges. The possible data corrections will be discussed in the following section. Figure 13 shows the leak conductance as a function of pump operating pressure for the duration of testing prior to the high pressure starts. Similarly, Figure 14 shows the leak conductance for

TABLE 4.- Sintered Leak Conductances
Prior to High Pressure Starts Testing
at Shown Pump Pressures

At 5 x 10^{-7} torr	At 1 x 10^{-6} torr	At 5 x 10^{-6} torr	At 0.8 -1 x 10^{-5} torr
1.99 x 10^{-8} ℓ/s	2.06 x 10^{-8}	2.41 x 10^{-8}	2.48 x 10^{-8}
	2.02	1.89	3.1
	2.05	2.49	2.52
	2.04	2.33	2.50
	1.97	2.29	2.50
	2.29	2.53	1.73
1.87	1.79	2.11	2.27
	1.82	2.27	2.51
	1.92	2.19	2.36
	1.86	2.26	2.46
1.98	1.98	2.35	2.54
	2.07	2.34	2.46
	1.98	2.19	2.33
	2.07	2.55	2.56
2.19	2.05	1.37	2.43
	1.95	2.33	2.53
	1.89	2.29	2.53
	1.89	2.3	2.55
	2.22	2.27	2.64

TABLE 5.- Sintered Leak Conductances
After High Pressure Starts Testing

At 5 x 10^{-7} Torr	At 1 x 10^{-6} Torr	At 5 x 10^{-6} Torr	At 0.8 -1 x 10^{-5} Torr
	2.50 x 10^{-8} ℓ/s	2.77 ℓ/s	3.01 ℓ/s
	2.32	2.58	3.21
	1.68	2.58	3.20
2.24 ℓ/s	2.24	2.54	3.21
	2.20	1.92	3.06
	2.33	2.74	3.19
2.28	2.53	2.62	3.35
	2.39	2.66	3.29
	2.27	2.55	3.31
	2.37	2.61	3.27
	2.37	2.60	3.1
	2.39	2.58	3.37
2.35	2.24	2.62	3.29
	2.3	2.56	3.28
	2.28	2.55	3.35
2.47	2.48	2.70	3.63
	2.30	2.59	3.30
2.15	2.26	2.62	3.32

the duration of testing after the high pressure starts. In both of these figures the positive and negative mean of all the deviations at a given pressure are shown at the test points. Figure 15 is a combination of the above two figures as well as showing the total life test average conductance.

Figure 16 shows the conductance of the sintered leak as a function of outside pressure for two typical monthly readings. One before the high pressure start tests and one after those tests. From this figure, note that the conductance remains approximately constant up to an external pressure of 500 torr and then begins to rise with external pressure. A constant conductance, with respect to outside pressure, indicates molecular flow of the leak while an increasing conductance with outside pressure indicates a viscous flow of gas through the leak.

The pressure dependence of the flow can be shown by simplifying Knudsen's[1] general equation of flow through long circular tubes, by which a sintered leak can be approximated. The realtionship for gas flow through long tubes is:

$$Q = \frac{K_1 D^4 \left(P_1^2 - P_2^2\right)}{L} + \frac{K_2 D^3 \left(P_1 - P_2\right)}{L} \qquad (5)$$

where:

Q = mass flow

K_1 and K_2 = constants for a given gas

D = diameter of tubes

L = length of tubes

P_1 = pressure at the tube inlet and outlet

P_2 = pressure at the tube outlet

The first term of the above equation depicts viscous flow, while the second shows molecular flow.

By expanding:

$$P_1^2 - P_2^2 \approx 2P\,\Delta P \quad \text{for } P_1 \approx P_2$$

[1] L.B. Loeb, "Kinetic Theory of Gases", McGraw-Hill, Inc. New York, 1934

Substituting this approximation back into Equation (5) and also knowing that the conductance (C) of a tube is:

$$C = \frac{Q}{\Delta P} \tag{6}$$

then the relationship for conductance is:

$$C = \frac{K_1 D^4}{L} 2P + \frac{K_2 D^3}{L} \tag{7}$$

Since the first term is the viscous term, a conductance using viscous flow is proportional to external pressure, while a conductance using a molecular flow is independent of external pressure. From Figure 16 note that the leak is molecular at the flight mass spectrometer operating pressures, which are below 330 torr.

Data Evaluation and Data Correction

The results of this life test indicate that making measurements of the pumping speeds of small ion pumps and measuring the conductances of small leak rates is not a very exacting empirical science. This is due primarily to the inconsistencies of pressure measurements by ion gauges which can vary from time to time. Also, these gauges in general, do not track each other exactly. Nontracking of gauges will definitely cause speed and conductance errors in any given experiment.

In general, the error in measuring the pumping speed of a small ion pump is higher than ten percent.

In reviewing this data, it can be stated that the ion pump speed did not change within experimental errors with time, except for the change occurring after the high pressure starting tests which probably cleaned the pump. This change appeared as a pumping speed increase of approximately 25 percent. An increase of approximately 15 percent also appeared in the conductance of the leak. This indicates an ion gauge tracking variation which should be subtracted from the pumping speed change. The pumping speed for the duration of the test, after the high pressure starts, should only show a ten percent increase rather than 25 percent.

A second test data error is the value of the known conductance. This was thought to be 205 cubic centimeters, but subsequent measurements at the conclusion of the test period showed that this was 225 cubic centimeters per second, or approximately ten percent higher. Therefore, all pumping speeds and conductance measurements should reflect an increase of ten percent. The life test average pumping speed of 1×10^{-6} torr should then be approximately 3.3 rather than 3.0 liters per second. Similarly, the leak conductance should be approximately 2.4×10^{-8} rather than the 2.2×10^{-8} liters per second shown in the data at 1×10^{-6} torr pressure.

Also, the low known conductance (225 cc/s) value forces the ionization gauges to operate on two different decade ranges, which accentuates the tracking difficulties of the two gauges. After the test was concluded, the known conductance orifice was replaced with a larger orifice to allow the two gauges to operate within the same decade and pump speeds were again measured. Test results showed that the average pumping speed, of three readings at 1×10^{-6} torr pump pressure, is 4.5 liters per second. The conclusion is that another correction of 20 to 25 percent should be made to compensate the non-tracking gauge phenomenon. When all the corrections are taken into consideration, the pumping speed of the test pump is somewhere between 4 to 4.5 liters per second at 1×10^{-6} torr and the conductance of the leak is approximately 2.7×10^{-8} liters per second.

CONCLUSIONS AND RECOMMENDATIONS

The conclusions derived from more than 9000 hours of testing are that the flight sintered leak and the flight ion pump will operate consistently under normal ambient temperature operating conditions and pump pressures of approximately 1×10^{-6} torr. There is no evidence that either the leak or the pump shows any time degradation for the entire test duration. The life test indicates that the normal operating life of both the leak and the pump is in excess of 9000 hours. Perkin-Elmer recommends that the test ion pump be sectioned and examined to measure the amount of wear experienced at the cathodes so that an evaluation of the expected life of the pump can be made. At pressures of 1×10^{-6} torr the flight ion pump should have a normal estimated operating life in excess of 25,000 hours.

APPENDIX A

ILLUSTRATIONS

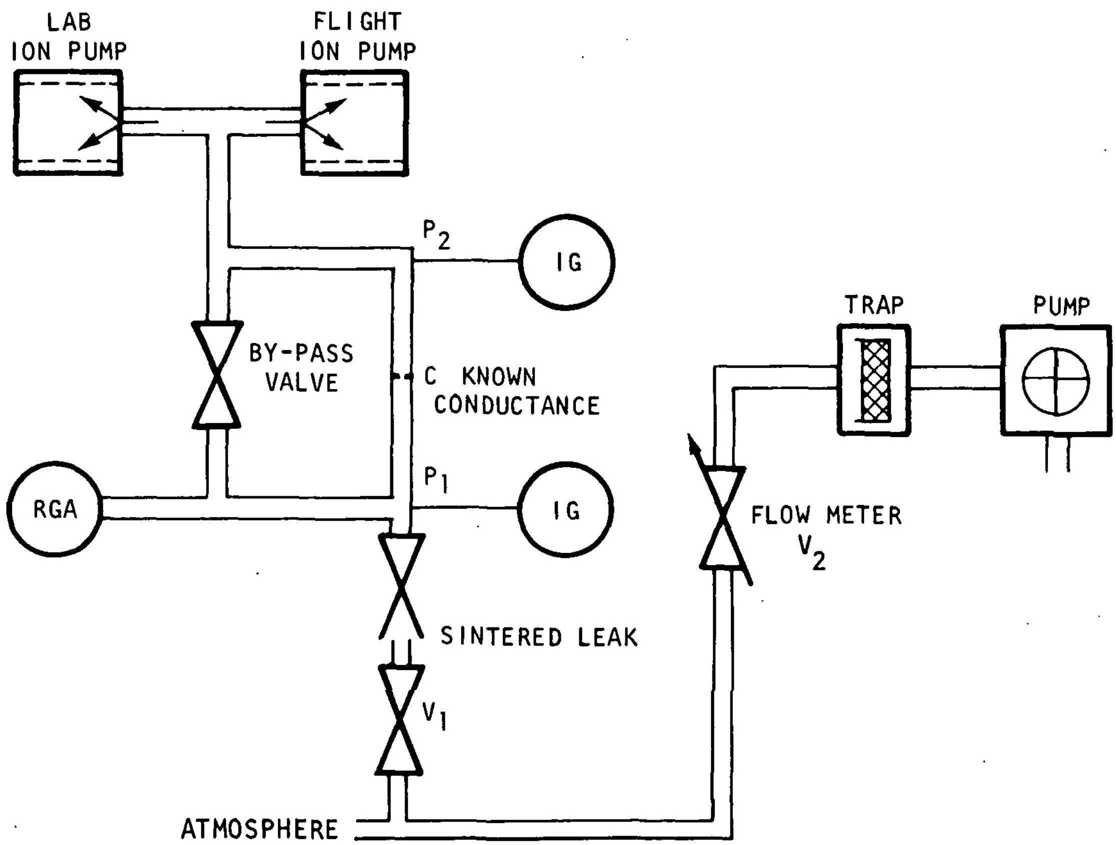


FIGURE 1. Test Vacuum System

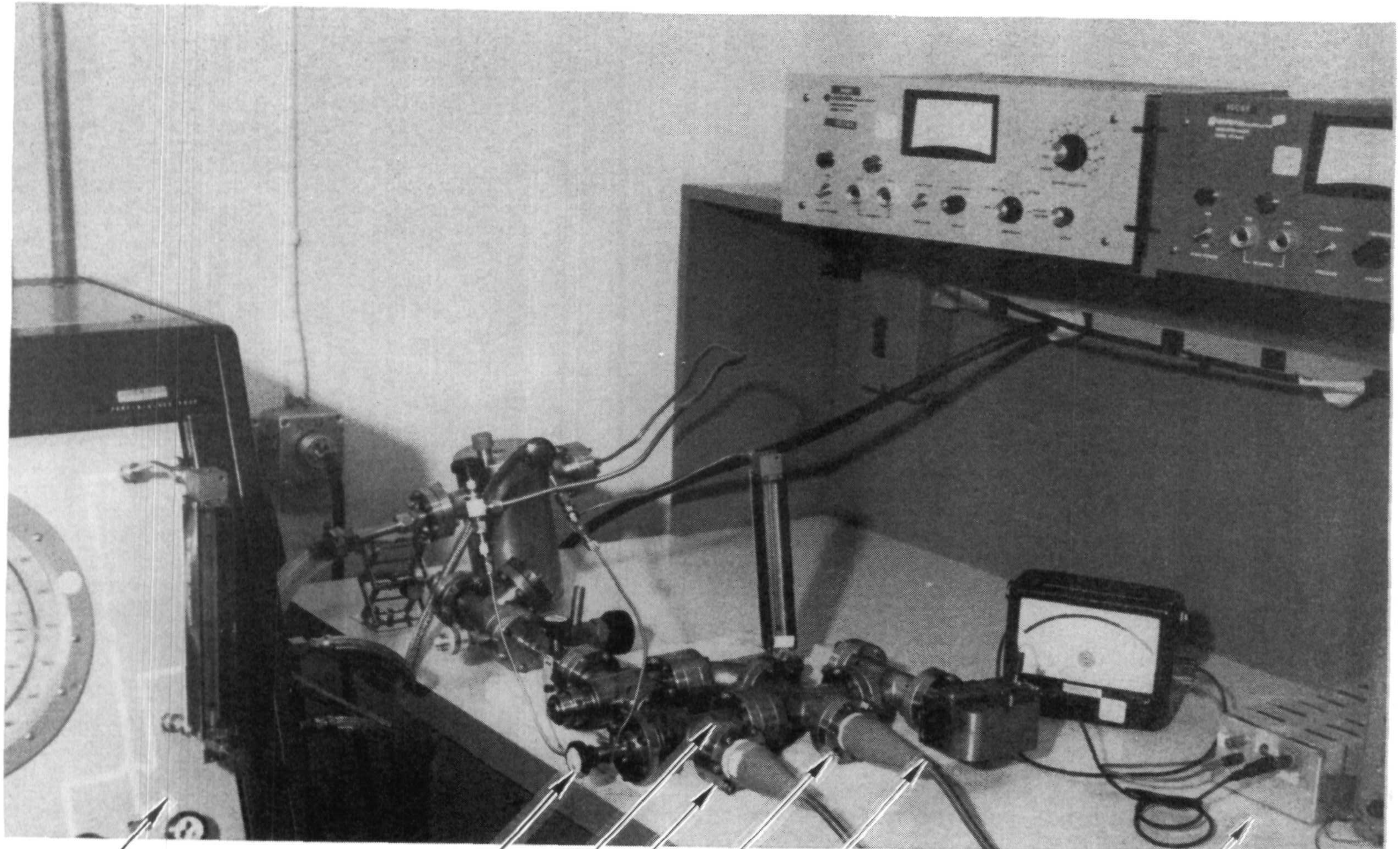
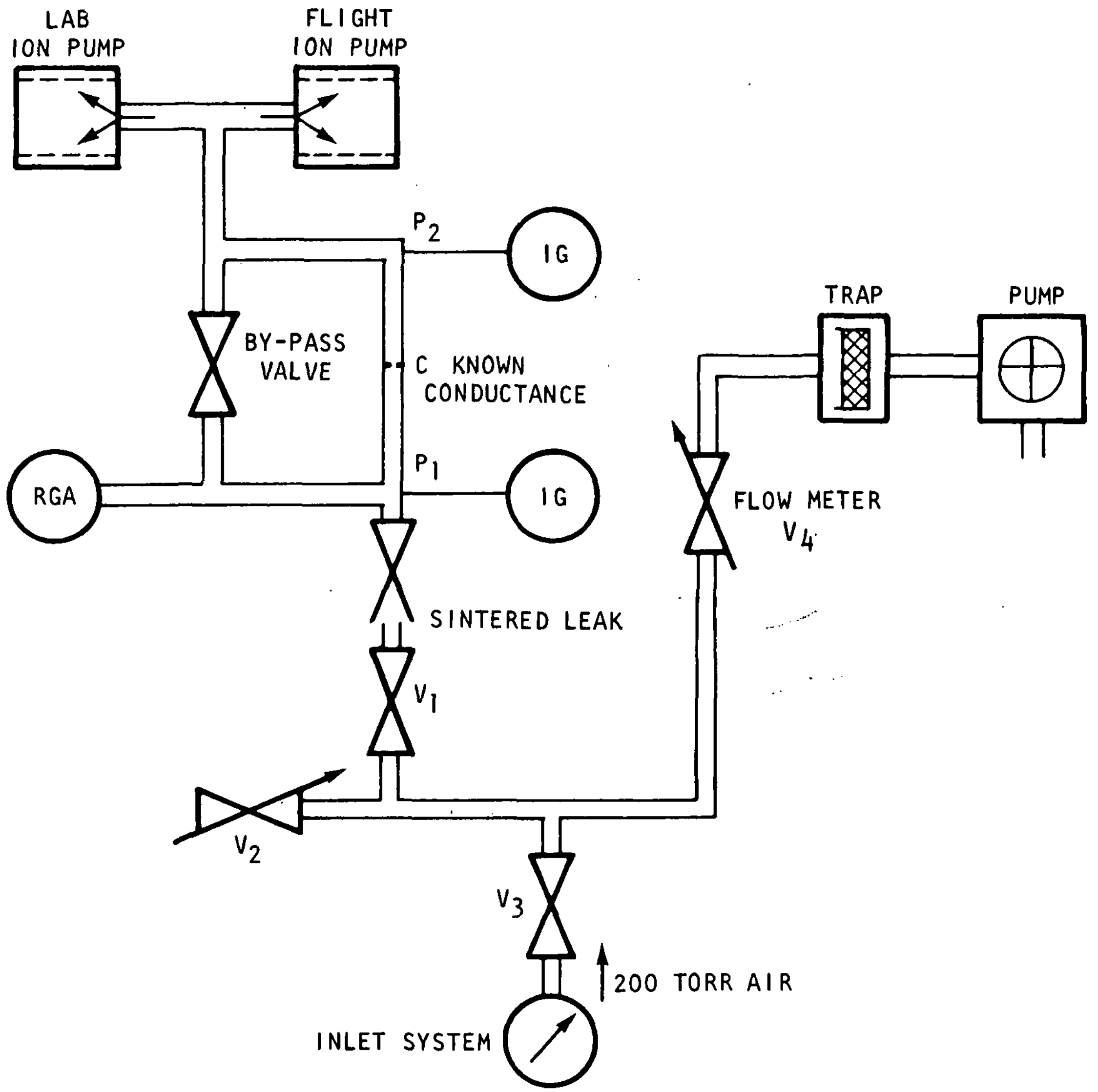


FIGURE 2. Inlet Leak and Ion Pump Test Setup

APPENDIX A



NOTE

1. Close V_1 And V_2
2. Close V_4
3. Connect Inlet System to V_3
4. Pumpdown Inlet System
5. Open V_3
6. Obtain 200 torr (dead end)
7. Open V_1
8. Take Readings at Appropriate P_2

FIGURE 3. Test Vacuum System for Below Atmospheric Operation

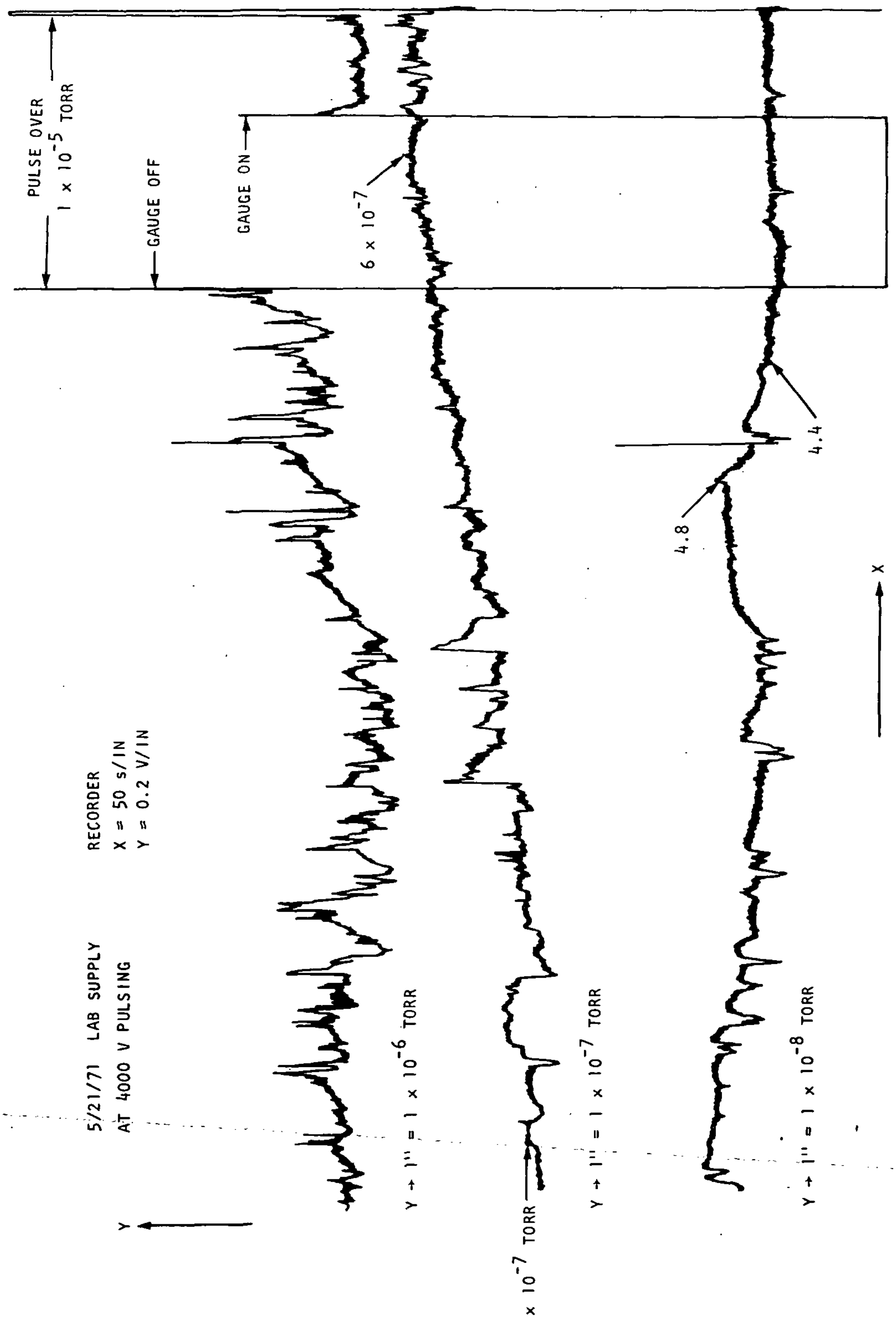


FIGURE 4. Typical Pump Pulsing at Given Pressures

APPENDIX A

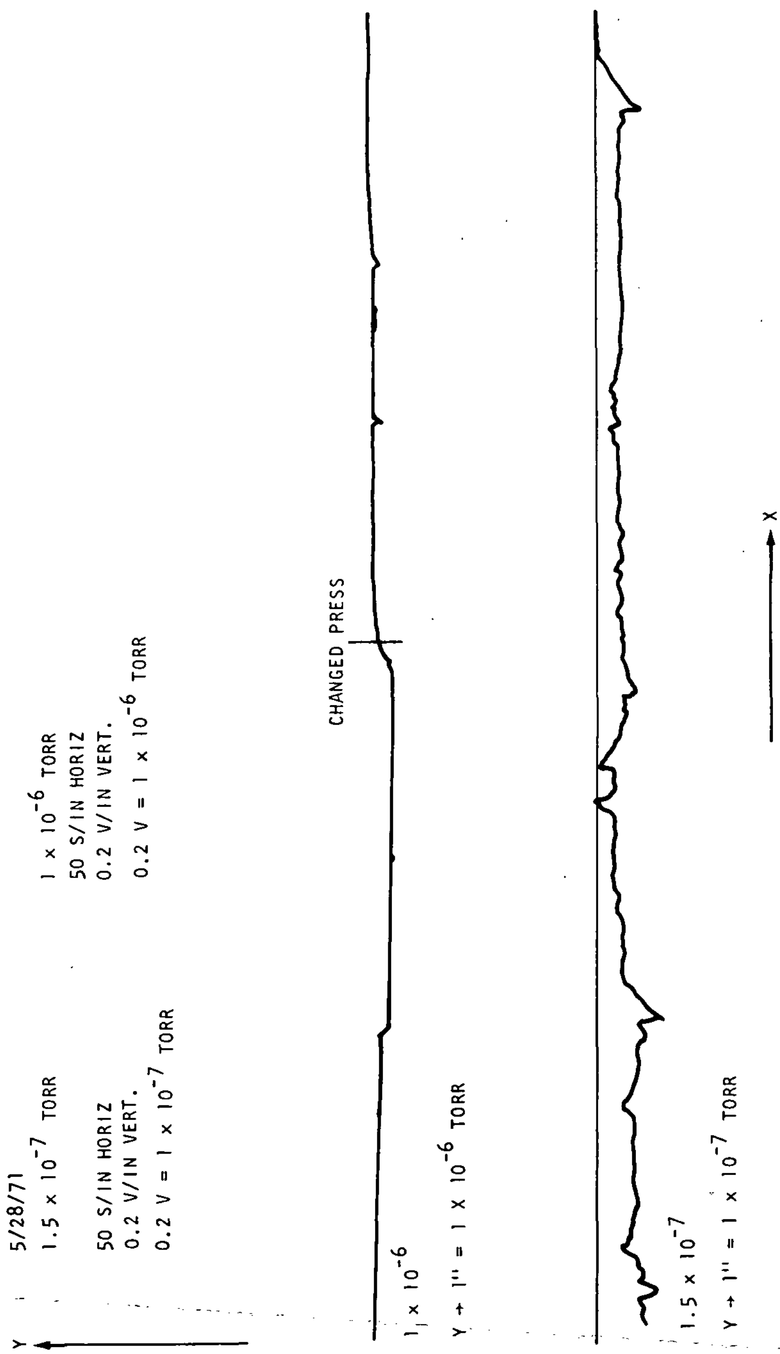


FIGURE 5

Reduced Pressure Pulsing of Ion Pump

APPENDIX A

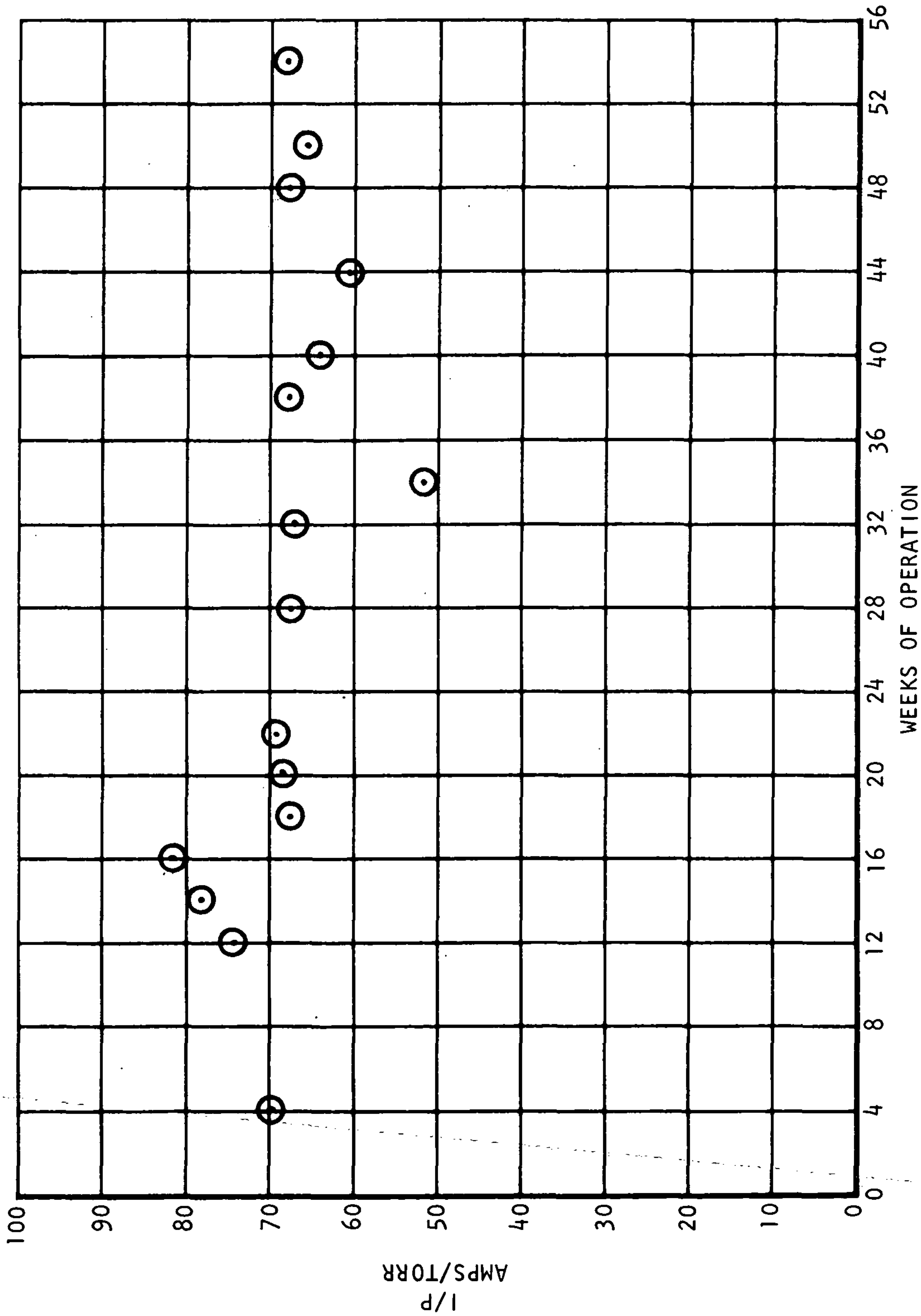


FIGURE 6.- I/P vs Time of Operation Pressure ∿ 5 x 10^{-6} Torr

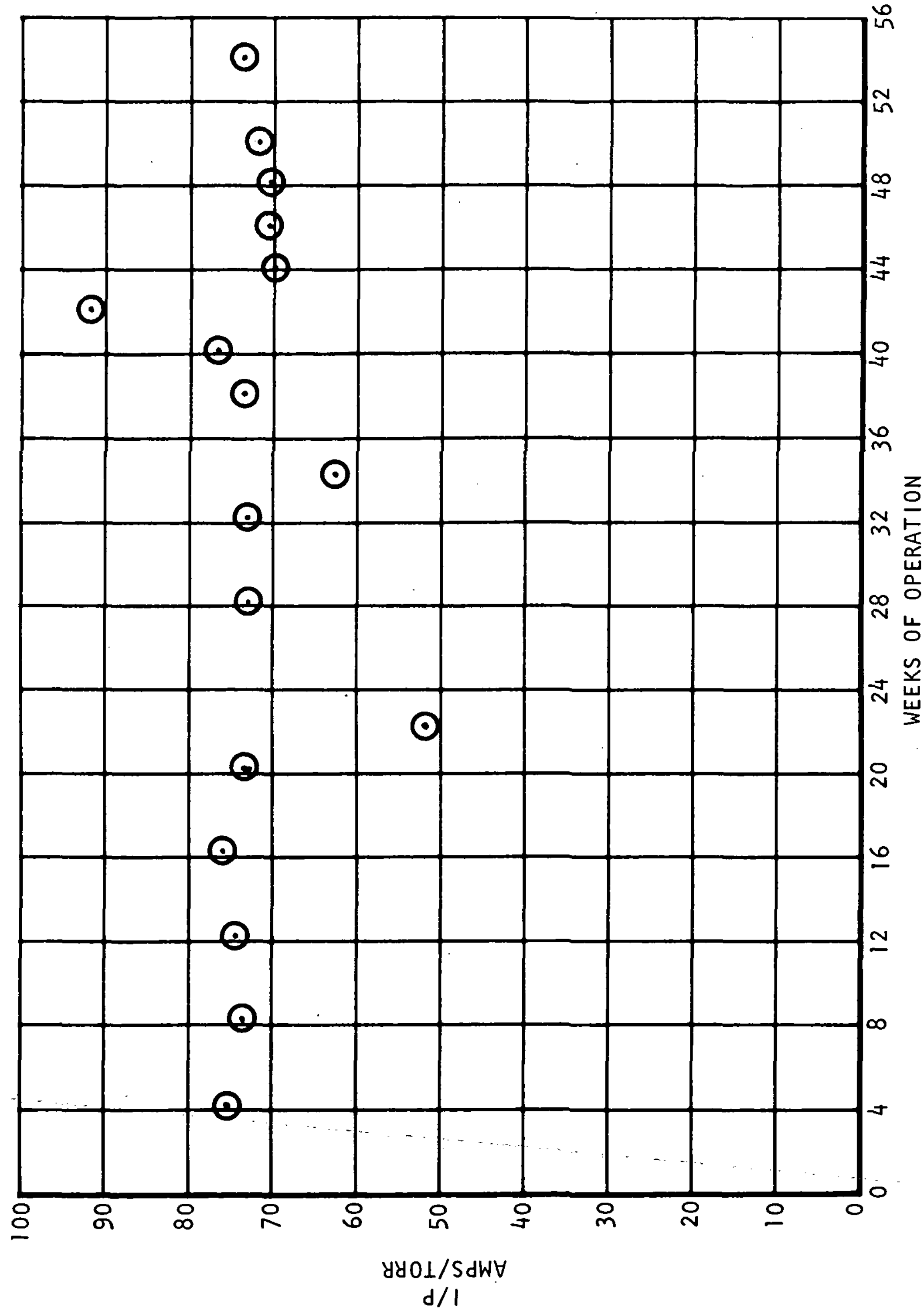


FIGURE 7.- I/P vs Time of Operation for P = 0.8 - 1.0 x 10^{-5} Torr

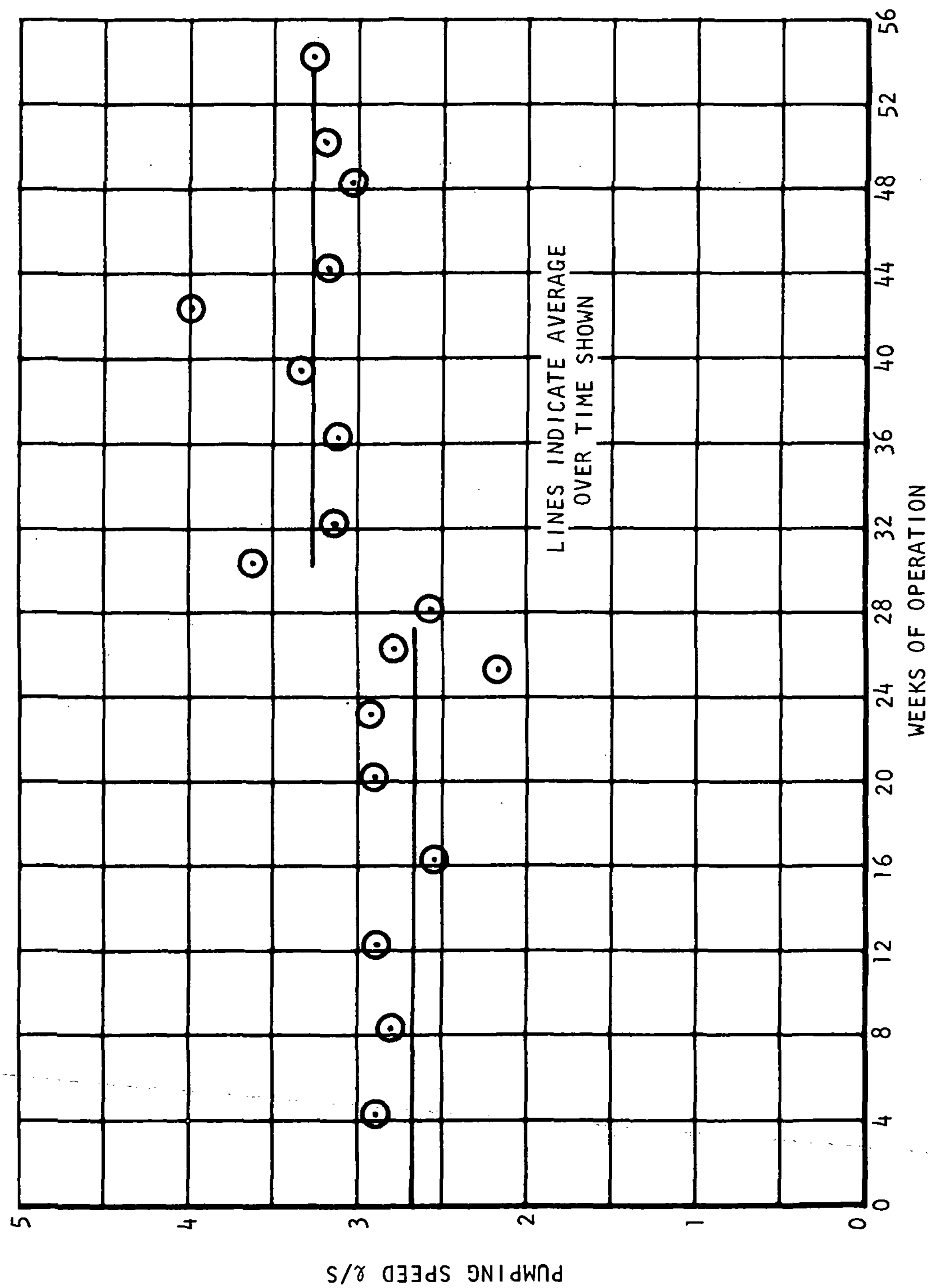


FIGURE 8.- Pumping Speed vs Time of Operation Pressure ~ 1 x 10^{-6} Torr

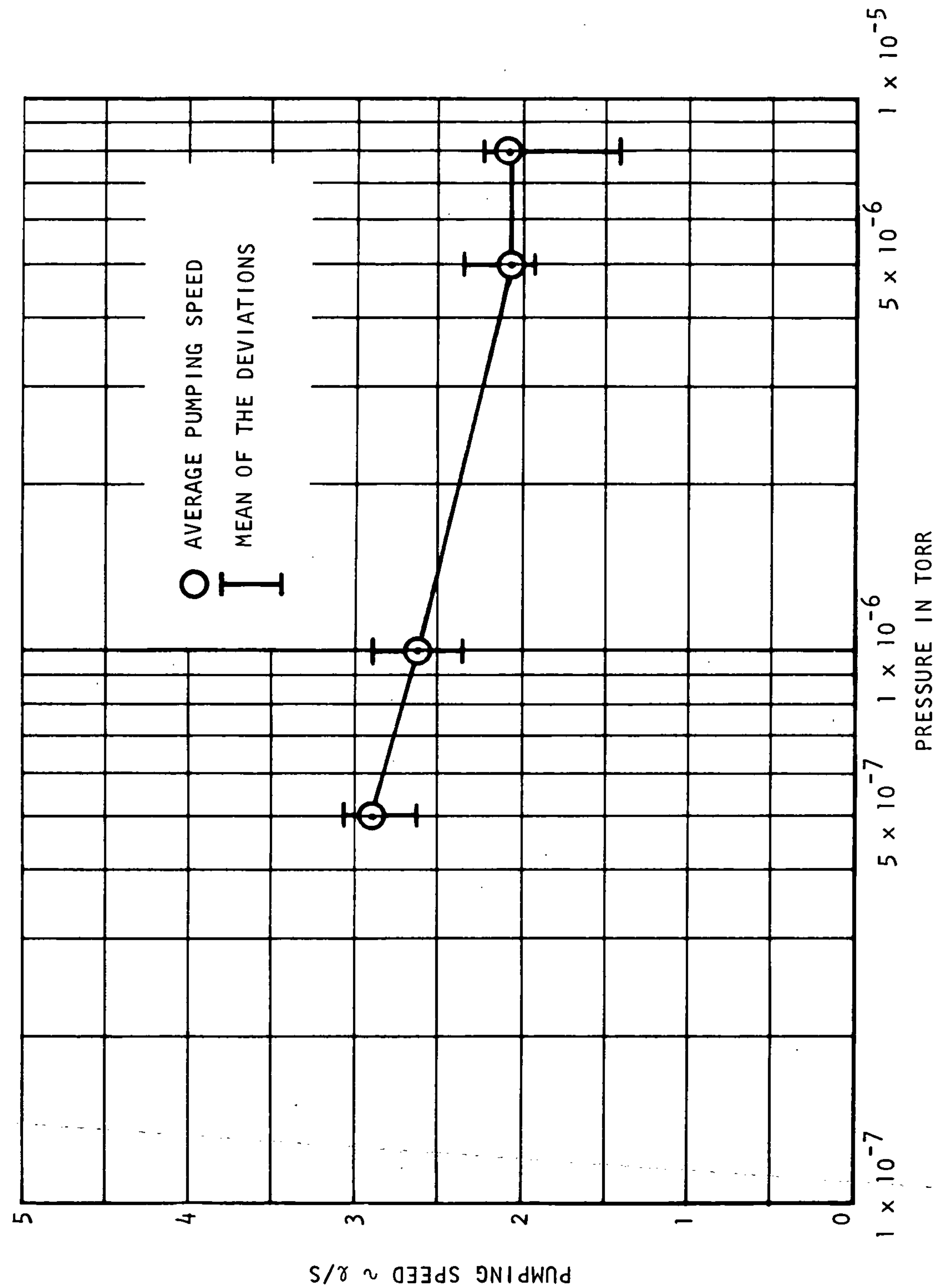


FIGURE 9.- Pumping Speed Before High Pressure Starts

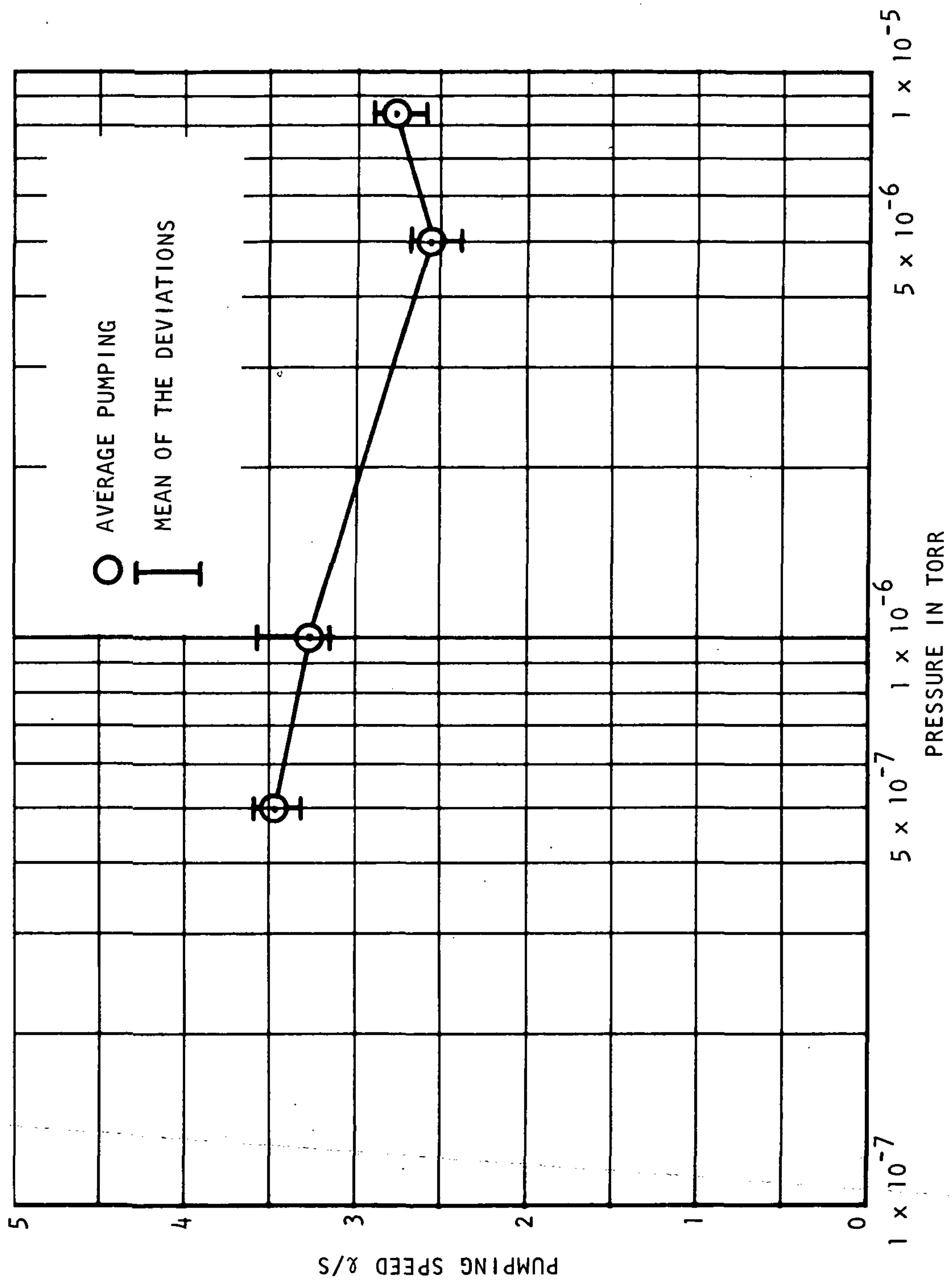


FIGURE 10.- Pumping Speed After High Pressure Starts

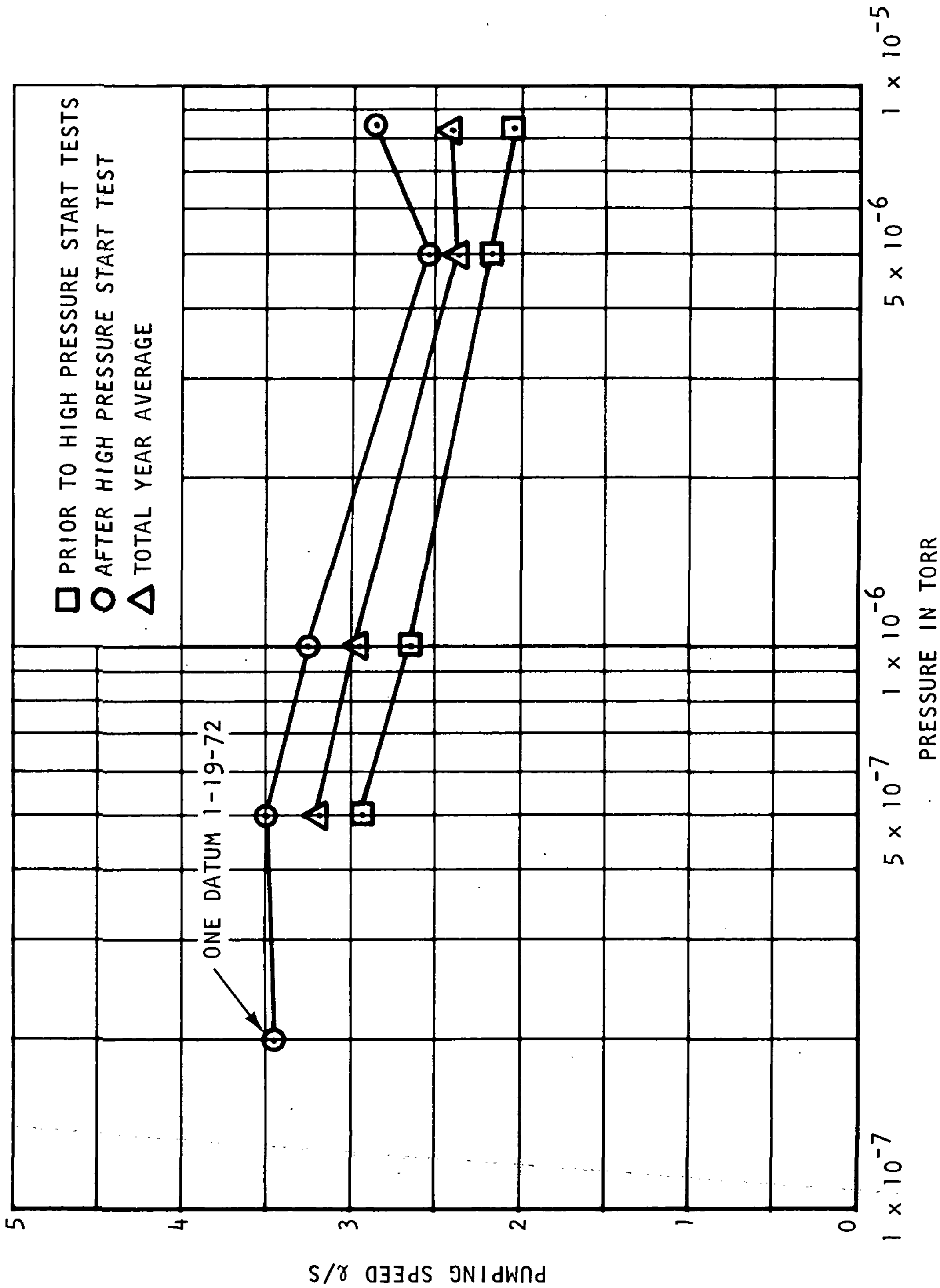


FIGURE 11.- Average Pumping Speed Over 54 Weeks of Testing

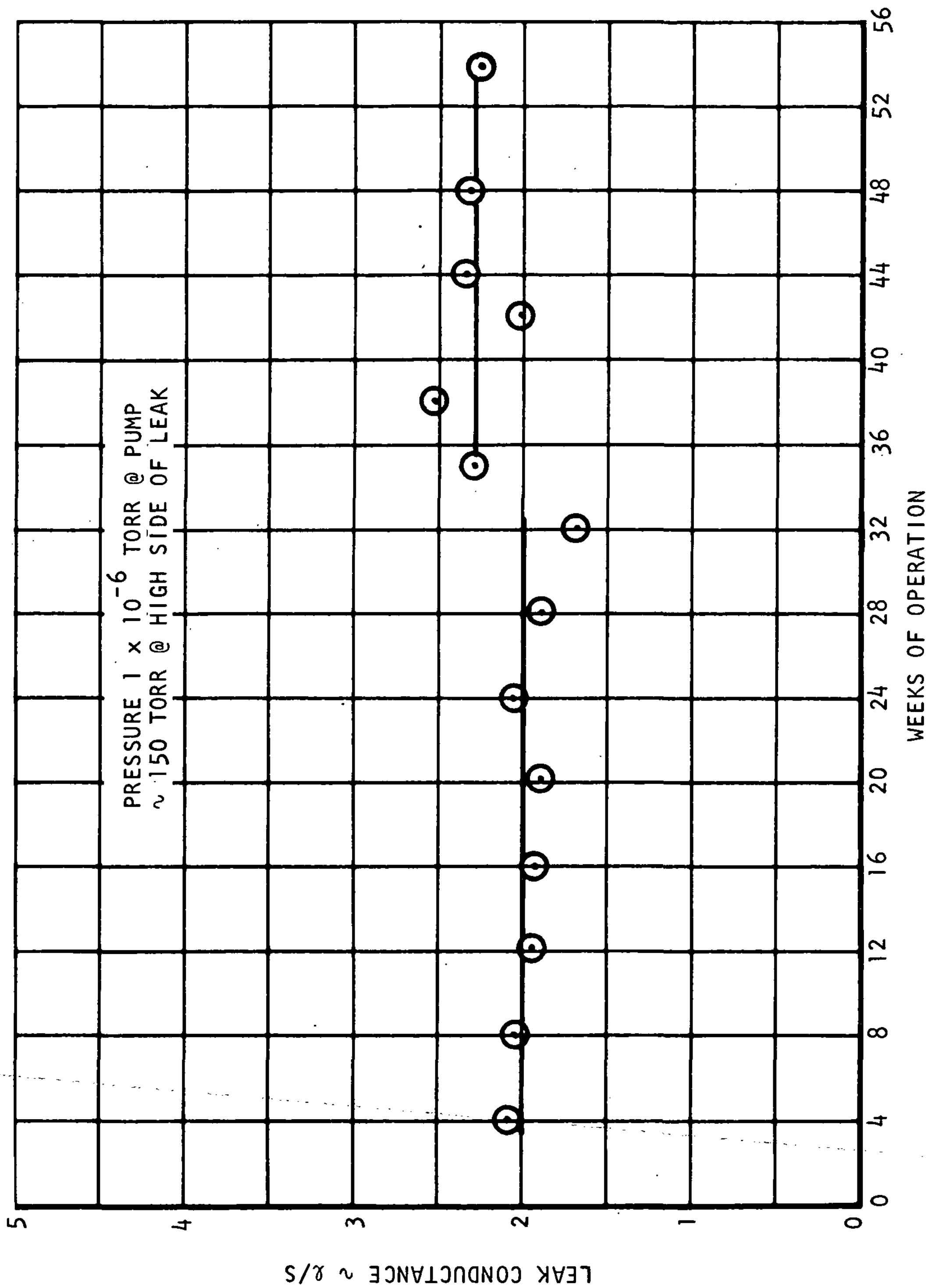


FIGURE 12.- Leak Conductance vs Time of Operation

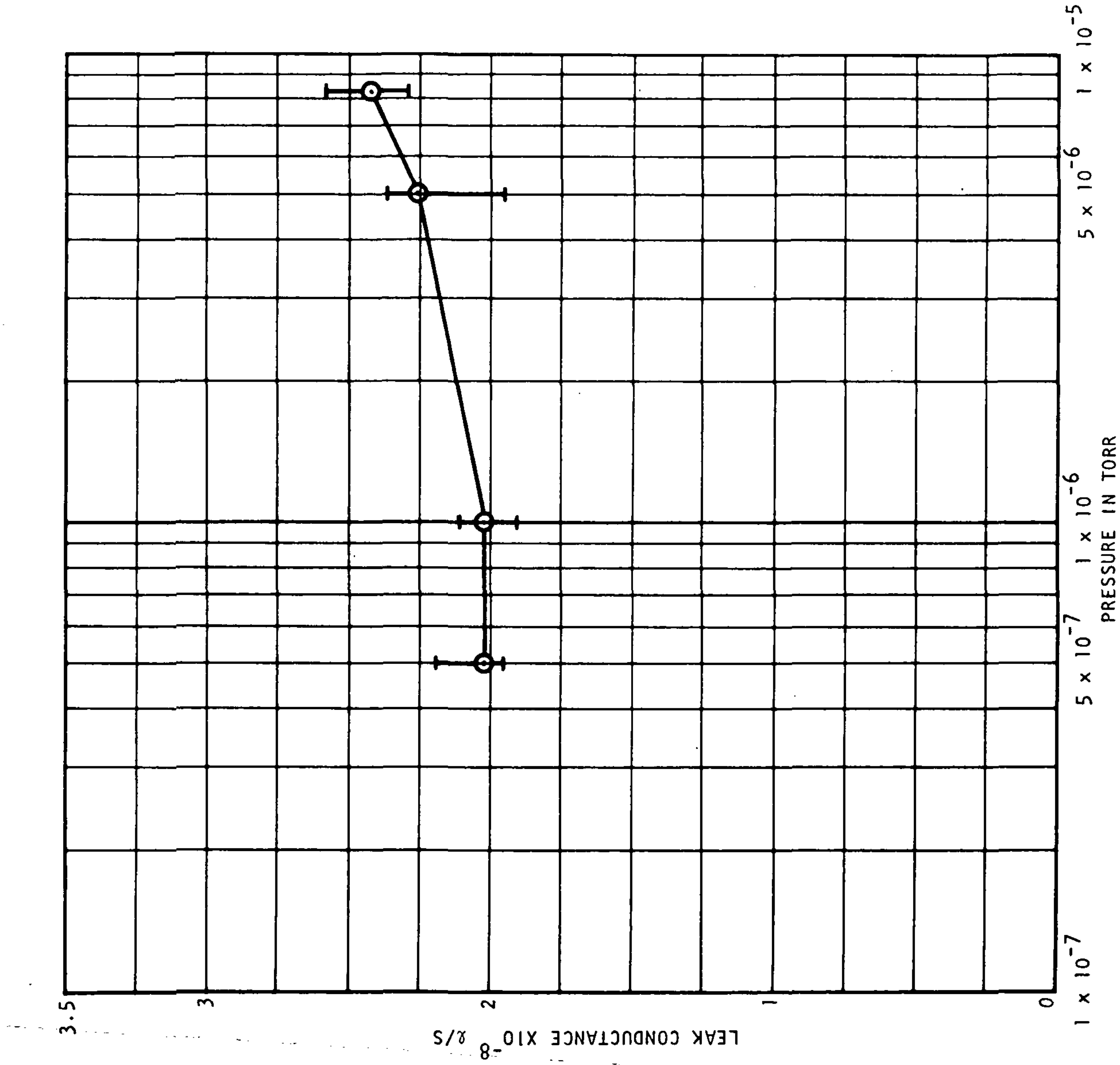


FIGURE 13. Leak Conductance Deviation Before High Pressure Test

APPENDIX A

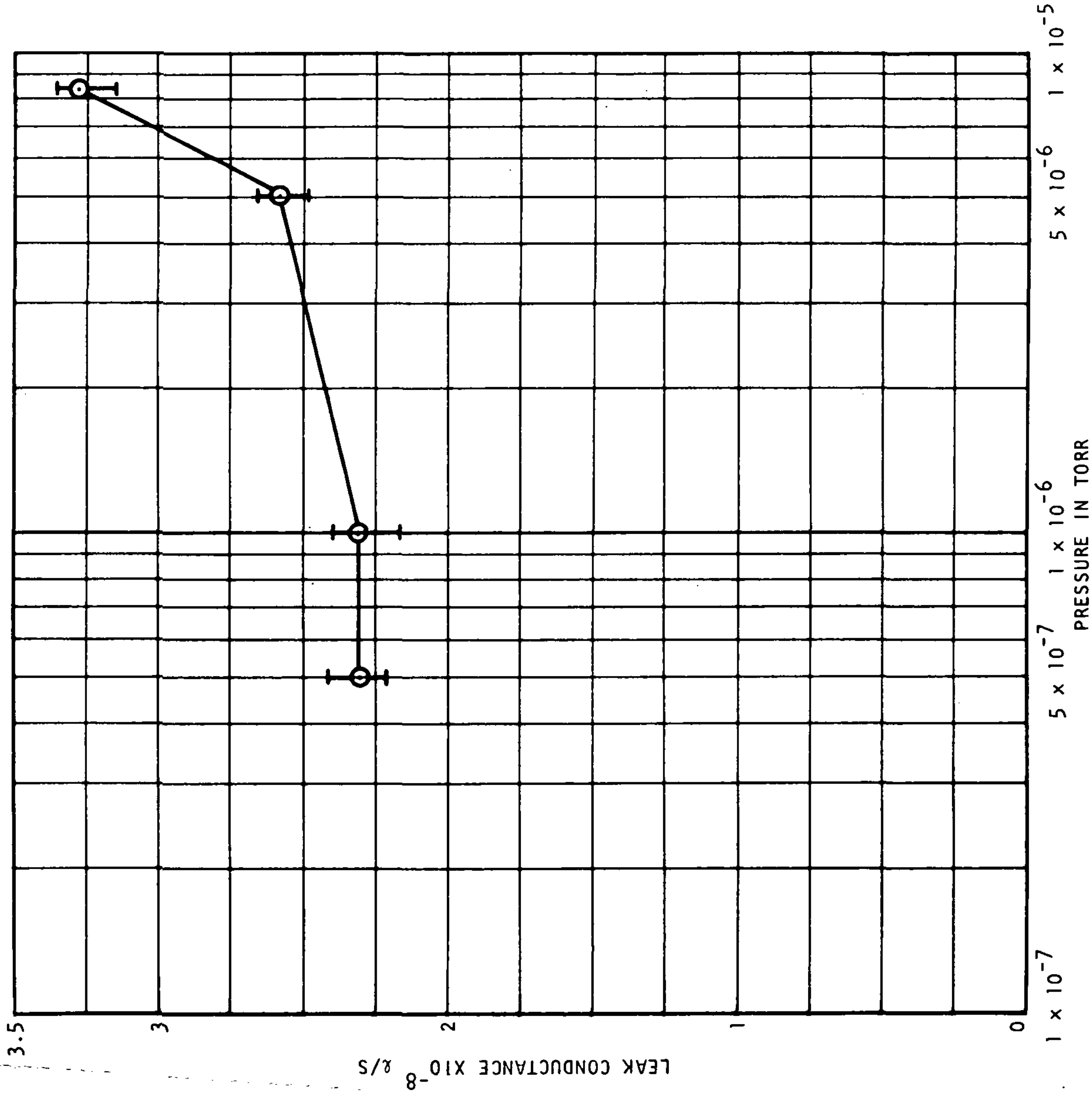


FIGURE 14. Leak Conductance Deviation After High Pressure Test

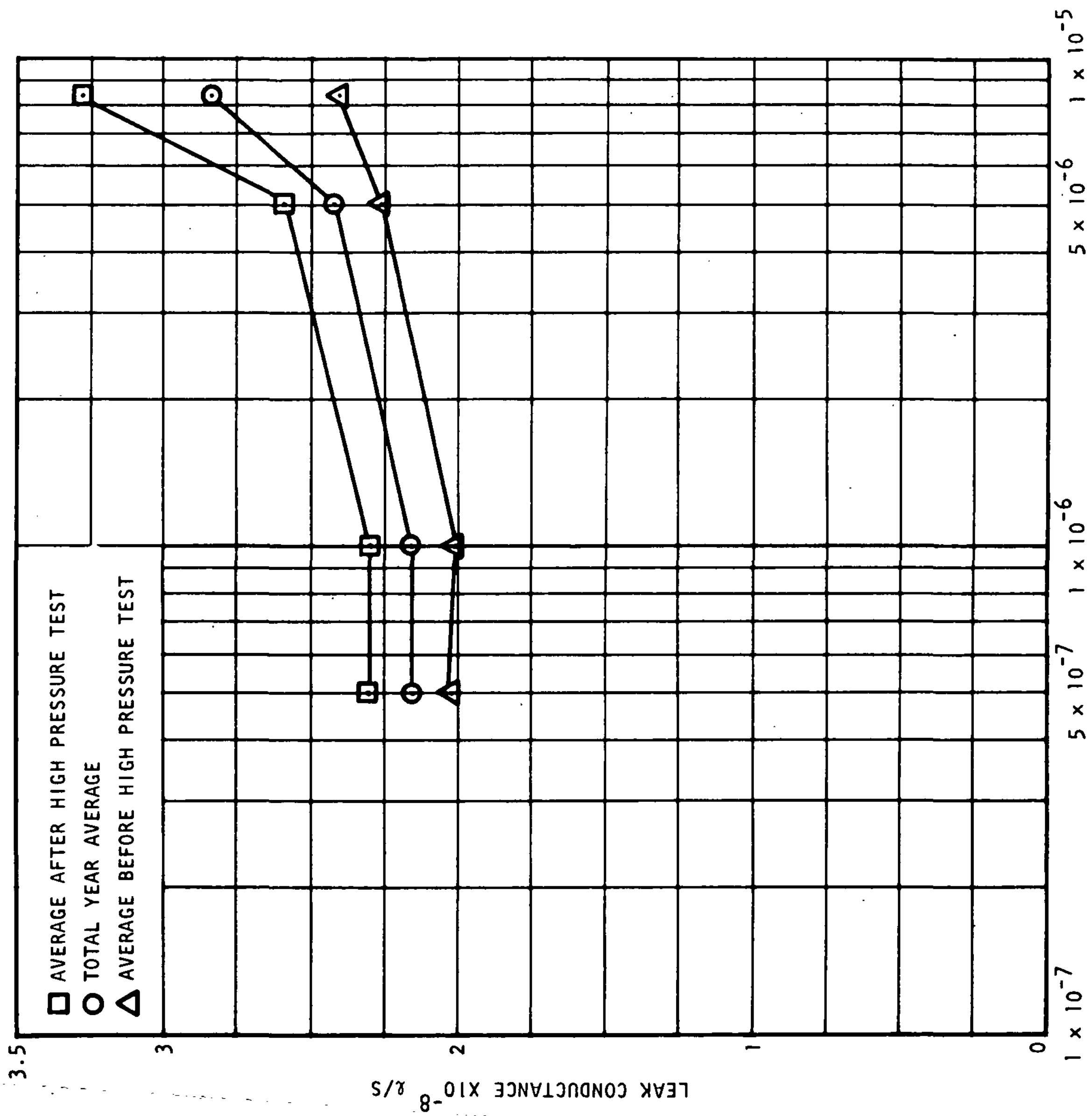


FIGURE 15. Average Conductance of Sintered Leak

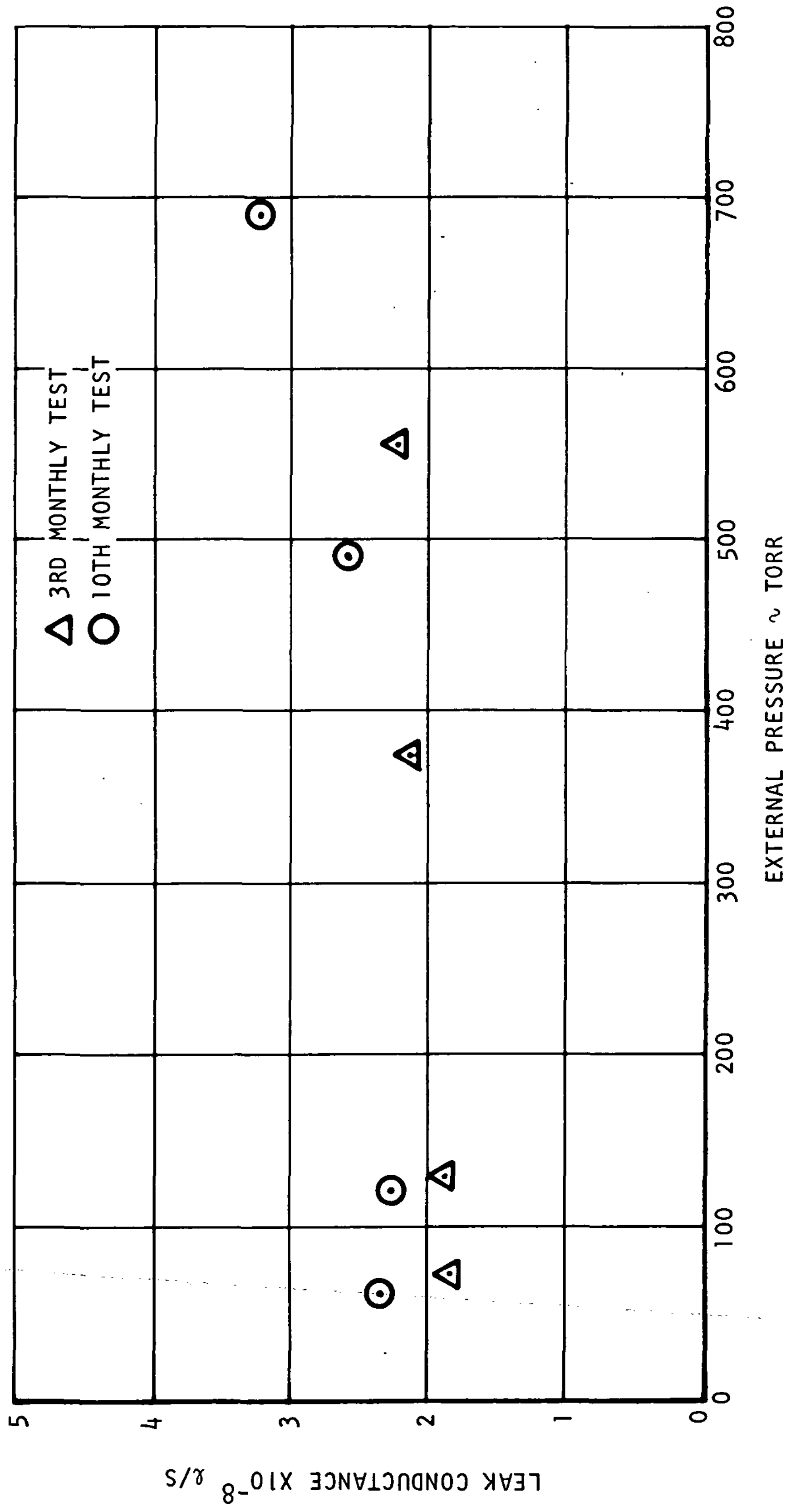


FIGURE 16.- Leak Conductance vs External Pressure

APPENDIX B

ION PUMP AND LEAK TEST

APPENDIX B

ION PUMP AND LEAK TEST

At one week intervals measure and record the following: (See Figure 17.)

(1) Equalize gauges and measure both pressures.

P_1 and P_2

(2) Ion pump running voltage.

(3) Ion pump running current.

(4) Close inlet and flowmeter valves and connect inlet system as shown below.

(5) With flowmeter valve, atmospheric flow control valve and inlet valve closed, pump down inlet system and insert air.

(6) Open inlet leak valve until $P_2 \approx 1 \times 10^{-6}$ torr and repeat measurements (1) through (3).

Calculate pumping speed and leak conductance.

$$S_P = \frac{\Delta P_1 - \Delta P_2}{\Delta P_2} C \qquad C = 0.205 \ \ell/s$$

$$C_L = \frac{\Delta P_1 - \Delta P_2}{P_o} C \qquad P_o \simeq \text{setting of outside pressure}$$

Repeat measurement for $P_2 \approx 5 \times 10^{-6}$ and $0.8 - 1 \times 10^{-5}$ torr. The following data shall be taken once every month.

(1) Close all inlet valves.

(2) Connect inlet system as above

(3) Open bypass valve.

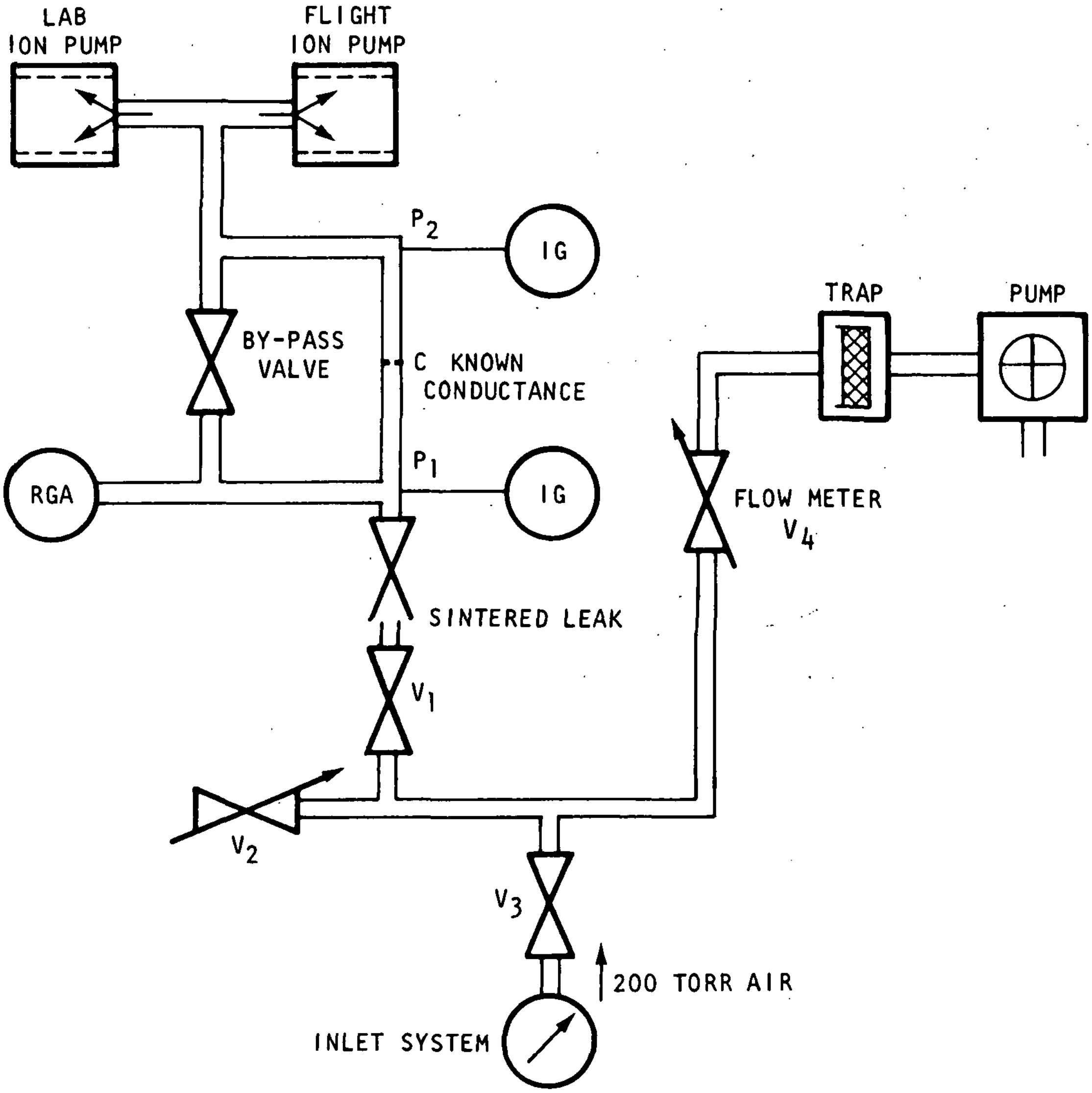


FIGURE 17

Test Setup for Ion Pump and Leak Test

APPENDIX B

(4) Pump out inlet system (equal p gauges).

(5) Open V_1. Close bypass valve.

(6) Turn pump off.

(7) Insert pressure from inlet system until P_2 reads:

a. Background

b. 5×10^{-7} torr

c. 1×10^{-6} torr

d. 5×10^{-6} torr

e. 1×10^{-5} torr

At each of the above pressures, start the flight ion pump:

(8) Measure the following:

a. Voltage of pump start

b. Pressure at start

c. Time required to reach stable pressure or 1×10^{-7} P_2

d. Current pulse at start

e. Running current (stable pressure)

f. Pumping speed

g. Leak conductance

When data is taken (finished)

(1) Close V_3

(2) Open V_4

(3) Remove inlet system

(4) Open V_1

(5) Open V_2 until P_2 reads $1 - 2 \times 10^{-6}$ torr

(6) Leave system running continually

APPENDIX B

Plot the following data as it becomes available:

S_p vs P_t	(1)	Pumping speed vs pressure at given time (new each month).
S_p vs t_p	(2)	Pumping speed vs time at given pressures.
I/P vs P_t	(3)	Pump current/pressure vs pressure at given time (new each month).
I/P_t vs t_p	(4)	I/P vs time at given pressures.
	(5)	Leak conductance vs pressure at given time (new each month).
	(6)	Leak conductance vs time at given pressure.