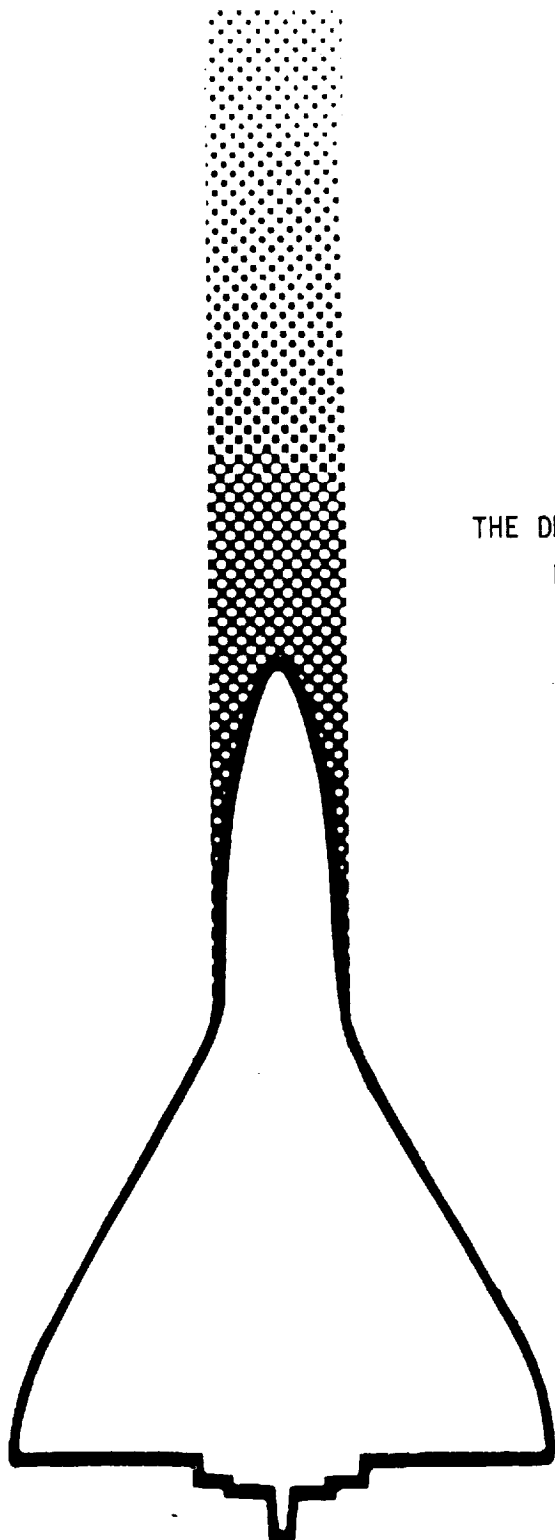


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## TEST REPORT

THE DETERMINATION OF THE HELIUM SATURATION  
LEVEL OF MONOMETHYLHYDRAZINE AND  
MON-3 NITROGEN TETROXIDE

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## 1.0 INTRODUCTION

During the Apollo Program WSTF developed a technique for helium saturation of Aerozine-50 and nitrogen tetroxide. These procedures and actual test data are described in NASA Technical Note TN D-6249.

The procedures described in this document were recently implemented to provide helium saturated monomethylhydrazine and MON-3  $N_2O_4$  in support of Space Shuttle testing of the Reaction Control and Orbital Maneuvering Systems.

This report describes the technical procedures followed to measure the helium saturation level of monomethylhydrazine and MON-3 nitrogen tetroxide.

## 2.0 HELIUM SATURATION PROCEDURE

To promote rapid absorption of helium by the propellant, equipment was designed to expose a large surface area of the propellant to a helium atmosphere. Figure 1 is a schematic of the Auxiliary Conditioning Unit (ACU) that was built to perform this operation. The fuel and oxidizer units are identical. The basic design of the equipment evolved as a result of the Apollo Program.

The ACU tank is loaded with propellant and is pressurized to the desired level with gaseous helium. Saturation is accomplished by pumping the propellant from the bottom of the ACU tank through the top-mounted nozzles, which inject fine sprays of propellant into the helium atmosphere. Each ACU is equipped with a heat exchanger to permit temperature conditioning of the propellants while circulating.

To ensure 100 percent helium saturation of the propellant at the desired pressure, an over saturation/degas procedure was used for the preparation of the propellants for a test. In a typical test, the propellants were prepared as follows: (1) the ACU was loaded with propellant, the ullage was pressurized with gaseous helium to 300 psia; (2) the propellant was circulated, and temperature conditioned until a bubble point determination indicated the helium saturation level was above the desired value (the equilibrium saturation-level value at a given temperature and at a pressure of 250 psia); (3) the ACU ullage pressure was readjusted to the desired saturation pressure (250 psia); (4) the propellant was allowed to continue circulating in order to degas to the desired saturation pressure (250 psia); (5) the circulation was discontinued, and the ACU ullage pressure was maintained to allow any excess helium to come out of the propellant; (6) the propellant tank (test article) was pressurized to the pressure necessary (250 psia) to maintain the desired helium saturation level and was maintained at  $250 \pm 5$  psia throughout the propellant loading in order to minimize helium desaturation.

## 3.0 BUBBLE POINT PROCEDURE

At a specific temperature and pressure, any liquid will hold a given quantity of gas in solution. Increasing the gas pressure will increase the quantity of gas that can be held by the liquid. Under any set of conditions of pressure and temperature, a liquid that holds the maximum quantity of gas in solution is

said to be gas saturated. If the pressure is reduced while all other conditions remain the same, the quantity of gas that can be held in solution is reduced and the liquid then contains more gas than it can hold in solution at the new lower pressure and is over saturated. The excess dissolved gas will come out of solution; and if the pressure is reduced sufficiently, the excess gas may be observed as small bubbles.

The bubble point technique was developed to provide an on-the-spot method for determining when the propellant is saturated with helium. The bubble point, for this application, is defined as the pressure at which gas coming out of solution can be visually detected. For any set of liquid conditions, the bubble point will always occur at some pressure below the pressure at which the liquid is saturated.

The bubble point measurement panel, which taps into the discharge propellant line in the ACU is shown schematically in Figure 2. The fuel and oxidizer panels differ in several respects. The fuel panel features a clear see-through sight glass to provide a brightly lighted white background for viewing of the bubbles entrained in the fuel.

The oxidizer panel features a sight glass that is equipped with a serrated glass on the side facing the viewer. To permit lighting of the serrations in the glass, approximately one-half of one side of the sight glass retention device has been cut away with minimal loss of structural integrity. A fluorescent light tube is mounted adjacent to the cut out area to light the sight glass. The lighted portion of the sight glass is positioned at the top of the sight glass. In both the fuel and oxidizer panels the sight glass is mounted at an angle to force the bubbles to travel up the inside surface of the glass nearest the viewer.

The bubble point measurement panel is initially prepared for use by closing the propellant inlet valve (V-4), the propellant outlet valve (V-3), and the vent needle valve (NV-1). The system is then pressurized with gaseous helium to approximately the helium saturation pressure by opening and then closing the gaseous helium supply valve (V-2). The helium trapped in the pneumatic reservoir enables the pressure on the trapped fluid to be vented slowly and, thus improves the bubble point resolution.

Valves V-3 and V-4 are opened to circulate propellant through the sight glass. To isolate the propellant for a reading, valves V-3 and V-4 are closed. This traps a sample of helium-saturated propellant under pressure in the sight glass. Approximately one minute is allowed to elapse for the entrained bubbles to settle out and then the pressure on the entrapped sample is vented through the vent needle valve (NV-1) to a pre-selected target bubble point pressure as observed on the pressure gage (G-1).

After an additional one minute wait period, the sight glass is observed for one minute for the presence of rising gas bubbles. The bubble point is obtained if a continuous production of gas bubbles is observed during the one minute observation period. If during a one minute observation period only very few or no bubbles are observed, the target bubble point pressure is too high, and a new determination must be made on a new sample of propellant at a target bubble point pressure 5 to 10 psi lower. If a very large quantity of bubbles

are observed immediately, the target bubble point pressure is too low. A new sample of propellant should be obtained in the panel and the determination repeated at a pressure 5 psi higher. All observations of the sight glass for bubbles are made using a black cloth to exclude extraneous light.

Operationally, obtaining an accurate bubble point reading depends upon the technique used. The bubbles are small and difficult to detect. The configuration of the bubble point measurement panels and the procedure described above are improvements on those used during the Apollo Program.

#### 4.0 MMH BUBBLE POINT DATA

In all tabulations and plots of data, the propellant was assumed to be saturated at the ACU pressure.

Table I is a tabulation of the ACU pressure and corresponding observed bubble point pressures over the ACU pressure range 30 to 280 psig. These data were least squared to obtain the following equation relating bubble point pressure as a function of ACU pressure:

$$\text{Bubble Point Pressure (PSIG)} = -7.450475 + 0.957524 (\text{ACU Pressure (PSIG)})$$

$$\text{Sigma} = 4.1$$

The table also lists the calculated bubble point data and the difference between the actual (observed) and the calculated values.

Figure 3 is a plot of the equation relating bubble point pressure as a function of ACU pressure over the ranges 20 to 280 psig.

Tests were not performed to evaluate the influence of temperature on the relationship between ACU pressure and bubble point pressure. Tests conducted on Aerozine-50 in the 1960's and discussed in NASA TN D-6249 indicated that temperature has no significant effect on this relationship. It is assumed that the helium saturation properties of monomethylhydrazine and Aerozine-50 are similar because of the similar chemical nature of these materials.

#### 5.0 N<sub>2</sub>O<sub>4</sub> BUBBLE POINT DATA

Table II is a tabulation of the ACU pressure and corresponding observed bubble point pressures over the ACU pressure range 100 to 280 psig. The NO content of the oxidizer was 1.5 percent by weight. The average temperature of the oxidizer was 55°F. These data were least squared to obtain the following equation relating bubble point pressure as a function of ACU pressure:

$$\text{Bubble Point Pressure (PSIG)} = -8.829432 + 0.933971 (\text{ACU Pressure (PSIG)})$$

$$\text{Sigma} = 6.2$$

The table also lists the calculated bubble point data and the difference between the actual (observed) and the calculated values.

Figure 4 is a plot of the equation relating bubble point pressure as a function of ACU pressure over the range 25 to 280 psig.

Table III is a tabulation of helium saturation data obtained using oxidizer with an NO content of 2.3 percent by weight and at 440F. This data compares favorably with that given in Table II and indicates that the fundamental relationship between ACU pressure and bubble point is not significantly influenced by NO concentration or propellant temperature.

## 6.0 OBSERVATION OF THE DESATURATION PHENOMENON

A simple test was conducted to provide some insight into what happens to helium saturated propellants when they are suddenly depressurized. The test performed on both fuel and oxidizer consisted of the following steps: (1) temperature condition the propellant to  $70 \pm 50$ F; (2) saturate the propellant with GHe at  $250 \pm 5$  psig; (3) load the bubble point sight glass with saturated propellant at  $250 \pm 5$  psig; (4) isolate the sight glass and allow 2-minutes for the entrained bubbles to settle out; (5) rapidly reduce the pressure on the propellant in the sight glass to  $200 \pm 5$  psig; and (6) observe the sight glass for the formation of bubbles.

Approximately 15 seconds were required for the formation and observation of gas bubbles in both fuel and oxidizer. The test was repeated with the pressure reduced to 150 psig in lieu of 200 psig with the same result.

In another test performed using the fuel ACU set-up, the propellant was saturated at an ACU pressure of 250 psig and isolated in the bubble panel sight glass. After approximately one minute of stabilization, the pressure in the sight glass was dropped to 100 psig. A large number of (1) very, very fine bubbles and (2) larger bubbles were observed within 10 seconds. After one minute the very, very fine bubbles dissipated. The number of large bubbles continued to diminish in number so that after approximately nine minutes only 1/3 as many were still present. In other tests very, very fine bubbles were found to be produced when the fuel is subjected to very rapid depressurization. They were observed when the pressure change is as small as 15 psi. This condition can occur when the ACU pump is running and the fluid is isolated in the bubble panel by rapidly closing the 1/4-inch ball valves on the ACU lines between the ACU and the bubble panel instead of the valves on the bubble panel. A similar phenomenon is not observed with N<sub>2</sub>O<sub>4</sub> due to the dark red-brown color of the oxidizer and the differences in the test set-up.

Based upon these limited tests, it may be concluded that the helium begins to come out of solution immediately when the pressure is reduced below the saturation-equilibrium pressure.

## 7.0 Evaluation of the effect of rapid depressurization and subsequent repressurization on the helium saturation level.

This group of tests was performed to measure the influence of an inadvertent reduction of propellant tank pressure on the helium saturation level of MMH and MON-3  $N_2O_4$ . The tests were performed using propellant at  $70 \pm 10^\circ F$  and with the 2,000 gallon ACU 3/4 full. The actual test sequence consisted of the following steps:

- a) Helium saturate the propellants at an ACU pressure of  $250 \pm 5$  psig.
- b) Verify saturation through four consecutive bubble point readings.
- c) Rapidly reduce the pressure in the ACU to 200, 150, 100 or  $50 \pm 5$  psig.
- d) After 2, 5, or 10 minutes repressurize the ACU to  $250 \pm 5$  psig as rapidly as possible.
- e) Operate the ACU pump for the minimum time possible to refill the bubble panel sight glass and determine the bubble point of the propellant.

Tables IV and V are tabulations of the MMH and MON-3  $N_2O_4$  data obtained in this series of tests. Figure 5 is a plot of the MMH data showing the bubble point obtained on repressurization after the various depressurization time intervals. The bubble point of MMH saturated at the various test pressures is shown as a short line on the right hand side of the figure. The data indicates that after approximately two minutes at reduced pressure the MMH has a bubble point that approaches that of propellant saturated at the reduced pressure. After 5 minutes at the reduced pressure the propellant has for all practical purposes degassed to the lower level.

Figure 6 is a plot of the MON-3  $N_2O_4$  data showing the bubble point obtained on repressurization after various depressurization time intervals. The bubble point of  $N_2O_4$  saturated at these test pressures is shown as a short line on the right hand side of the figure.

Comparison of Figures 5 and 6 indicates that saturated MMH and  $N_2O_4$  respond differently to rapid depressurization. The data indicates that  $N_2O_4$  depressurized from 250 to 200 psig will, after 5 minutes at the lower pressure, exhibit a bubble point close to that of propellant saturated at the lower pressure. This behavior is similar to that exhibited by MMH. At depressurization pressures below 200 psig the bubble point of the  $N_2O_4$  does not approach the bubble point value for the depressurization pressure. This behavior may be related to the total quantity of helium in the propellant. Table VI is a tabulation of the amount of helium dissolved in saturated  $N_2O_4$  and MMH. These data were computed from the helium solubility data tabulated in Appendix A. The data indicates that  $N_2O_4$  will hold 4-5 times more helium than MMH on an equal volume of propellant basis.

Table VII is a tabulation of the percent helium lost upon depressurization and indicates that both propellants will for similar pressure drops lose similar volumetric percentages of helium. Based upon these observations the quantities of helium evolved on a volumetric basis may be a factor in the speed of desaturation.

Observation of the helium bubbles in depressurized MMH trapped in a sight glass indicates that the bubbles rise very slowly to the top of the sight glass. When the propellant is repressurized the helium appears to go back into solution. These observations suggest that another factor influencing the speed of desaturation may be the rate of bubble formation and rate at which they rise in a tank or line.

In summary, rapid depressurization of saturated MMH will, after a couple of minutes, reduce the saturation level to near that of the depressurization pressure.  $N_2O_4$  at pressures below 200 psig will not be as severely effected by rapid depressurization, i.e., the bubble point of the  $N_2O_4$  does not drop to the value for oxidizer at the depressurization pressure even after 10 minutes at the reduced pressure.

## 8.0 CONCLUSIONS

Helium saturation data were obtained on monomethylhydrazine and MON-3 nitrogen tetroxide to provide curves relating helium saturation bubble point pressure (in psig) as a function of ACU pressure (in psig). The MMH data is similar to that obtained in the late 1960's on Aerozine-50 and reported in NASA TN D-6249.

The oxidizer data in the NASA report is for MON-1 oxidizer and differs from that observed in this study. The MON-3 data obtained in this study does not indicate the need for separate curves relating bubble point pressure as a function of ACU pressure for different temperatures as reported in TN D-6249 for MON-1 oxidizer.

Data were also obtained to indicate the effect of rapid depressurization on the observed bubble point pressure of the propellants. The MMH data indicated that the bubble point pressure was reduced to the equilibrium value for the depressurization pressure after two minutes at the lower pressure. Oxidizer behaved differently in that the observed bubble point pressure was reduced but not to the equilibrium value for the depressurization pressure even after 10 minutes at the lower pressure. This observation may be related to the quantity of helium gas in saturated oxidizer.



9.0 DISTRIBUTION

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TABLE I. MMH HELIUM SATURATION DATA

<u>ACU PROPELLANT TEMPERATURE (°F)</u>	<u>ACU PRESSURE (PSIG)</u>	<u>OBSERVED BUBBLE POINT PRESSURE (PSIG)</u>	<u>CALCULATED* BUBBLE POINT PRESSURE (PSIG)</u>	<u>DIFFERENCE (OBSERVED- CALCULATED) (PSI)</u>
49	280.0	260.0	260.7	- 0.7
49	280.0	260.0	260.7	- 0.7
49	280.0	260.0	260.7	- 0.7
49	280.0	260.0	260.7	- 0.7
53	280.0	268.0	260.7	7.3
53	280.0	268.0	260.7	7.3
53	280.0	270.0	260.7	9.3
53	280.0	269.0	260.7	8.3
53	260.0	240.0	241.5	- 1.5
53	260.0	245.0	241.5	3.5
53	260.0	245.0	241.5	3.5
53	260.0	244.0	241.5	2.5
49	260.0	235.0	241.5	- 6.5
49	260.0	235.0	241.5	- 6.5
49	260.0	235.0	241.5	- 6.5
49	260.0	235.0	241.5	- 6.5
53	240.0	225.0	222.4	2.6
53	240.0	225.0	222.4	2.6
53	240.0	227.0	222.4	4.6
49	225.0	205.0	208.0	- 3.0
49	225.0	205.0	208.0	- 3.0
49	225.0	205.0	208.0	- 3.0
49	225.0	210.0	208.0	2.0
56	220.0	200.0	203.2	- 3.2
56	220.0	200.0	203.2	- 3.2
56	220.0	203.0	203.2	- 0.2
56	220.0	200.0	203.2	- 3.2
56	200.0	190.0	184.1	5.9
57	200.0	190.0	184.1	5.9
57	200.0	190.0	184.1	5.9
57	200.0	190.0	184.1	5.9

TABLE I. MMH HELIUM SATURATION DATA (CONT)

<u>ACU PROPELLANT TEMPERATURE (°F)</u>	<u>ACU PRESSURE (PSIG)</u>	<u>OBSERVED BUBBLE POINT PRESSURE (PSIG)</u>	<u>CALCULATED* BUBBLE POINT PRESSURE (PSIG)</u>	<u>DIFFERENCE (OBSERVED- CALCULATED) (PSI)</u>
49	200.0	185.0	184.1	0.9
49	200.0	185.0	184.1	0.9
49	200.0	185.0	184.1	0.9
49	200.0	185.0	184.1	0.9
50	175.0	160.0	160.1	- 0.1
50	175.0	160.0	160.1	- 0.1
50	175.0	160.0	160.1	- 0.1
50	175.0	160.0	160.1	- 0.1
57	175.0	150.0	160.1	-10.1
57	175.0	150.0	160.1	-10.1
58	175.0	150.0	160.1	-10.1
58	175.0	150.0	160.1	-10.1
58	150.0	135.0	136.2	- 1.2
58	150.0	135.0	136.2	- 1.2
58	150.0	135.0	136.2	- 1.2
58	150.0	135.0	136.2	- 1.2
50	150.0	140.0	136.2	3.8
50	150.0	140.0	136.2	3.8
50	150.0	140.0	136.2	3.8
50	150.0	140.0	136.2	3.8
50	125.0	110.0	112.2	- 2.2
50	125.0	110.0	112.2	- 2.2
50	125.0	110.0	112.2	- 2.2
50	125.0	110.0	112.2	- 2.2
58	125.0	109.0	112.2	- 3.2
58	125.0	105.0	112.2	- 7.2
58	125.0	107.0	112.2	- 5.2
58	125.0	110.0	112.2	- 2.2
58	125.0	110.0	112.2	- 2.2
58	125.0	110.0	112.2	- 2.2

TABLE I. MMH HELIUM SATURATION DATA (CONT)

<u>ACU PROPELLANT TEMPERATURE (°F)</u>	<u>ACU PRESSURE (PSIG)</u>	<u>OBSERVED BUBBLE POINT PRESSURE (PSIG)</u>	<u>CALCULATED* BUBBLE POINT PRESSURE (PSIG)</u>	<u>DIFFERENCE (OBSERVED- CALCULATED) (PSI)</u>
58	100.0	90.0	88.3	1.7
58	100.0	90.0	88.3	1.7
58	100.0	90.0	88.3	1.7
58	100.0	90.0	88.3	1.7
52	100.0	85.0	88.3	- 3.3
52	100.0	87.0	88.3	- 1.3
52	100.0	87.0	88.3	- 1.3
52	100.0	89.0	88.3	0.7
52	75.0	69.0	64.4	4.6
52	75.0	70.0	64.4	5.6
52	75.0	70.0	64.4	5.6
52	75.0	70.0	64.4	5.6
58	75.0	65.0	64.4	0.6
58	75.0	65.0	64.4	0.6
58	75.0	60.0	64.4	- 4.4
58	75.0	65.0	64.4	0.6
58	75.0	60.0	64.4	- 4.4
58	75.0	65.0	64.4	0.6
52	50.0	40.0	40.4	- 0.4
52	50.0	40.0	40.4	- 0.4
52	50.0	40.0	40.4	- 0.4
52	50.0	40.0	40.4	- 0.4
58	50.0	40.0	40.4	- 0.4
58	50.0	40.0	40.4	- 0.4
58	50.0	42.0	40.4	1.6
58	50.0	42.0	40.4	1.6
52	30.0	25.0	21.3	3.7
52	30.0	25.0	21.3	3.7
52	30.0	25.0	21.3	3.7
52	30.0	25.0	21.3	3.7

TABLE I. MMH HELIUM SATURATION DATA (CONT)

<u>ACU PROPELLANT TEMPERATURE (°F)</u>	<u>ACU PRESSURE (PSIG)</u>	<u>OBSERVED BUBBLE POINT PRESSURE (PSIG)</u>	<u>CALCULATED* BUBBLE POINT PRESSURE (PSIG)</u>	<u>DIFFERENCE (OBSERVED- CALCULATED) (PSI)</u>
58	30.0	22.0	21.3	0.7
58	30.0	20.0	21.3	- 1.3
58	30.0	20.0	21.3	- 1.3
58	30.0	20.0	21.3	- 1.3

AVG = 53.5 +3.5

\*Calculated Bubble Point Pressure (PSIG) =  $-7.450475 + 0.957524$  (ACU  
Pressure [PSIG])

Sigma = 4.1

TABLE II. N<sub>2</sub>O<sub>4</sub> (1.5% NO) HELIUM SATURATION DATA

<u>ACU PROPELLANT TEMPERATURE (°F)</u>	<u>ACU PRESSURE (PSIG)</u>	<u>OBSERVED BUBBLE POINT PRESSURE (PSIG)</u>	<u>CALCULATED* BUBBLE POINT PRESSURE (PSIG)</u>	<u>DIFFERENCE (OBSERVED- CALCULATED) (PSI)</u>
48	280.0	245.0	252.7	- 7.7
48	280.0	240.0	252.7	-12.7
49	280.0	250.0	252.7	- 2.7
49	280.0	250.0	252.7	- 2.7
49	280.0	260.0	252.7	7.3
49	280.0	255.0	252.7	2.3
51	280.0	255.0	252.7	2.3
51	280.0	255.0	252.7	2.3
51	280.0	255.0	252.7	2.3
51	260.0	230.0	234.0	- 4.0
51	260.0	229.0	234.0	- 5.0
51	260.0	229.0	234.0	- 5.0
51	260.0	229.0	234.0	- 5.0
57	253.0	225.0	227.5	- 2.5
57	253.0	225.0	227.5	- 2.5
57	253.0	235.0	227.5	7.5
57	253.0	225.0	227.5	- 2.5
57	253.0	225.0	227.5	- 2.5
57	253.0	235.0	227.5	7.5
57	253.0	225.0	227.5	- 2.5
52	250.0	212.0	224.7	-12.7
56	250.0	231.0	224.7	6.3
56	250.0	233.0	224.7	8.3
56	250.0	231.0	224.7	6.3
56	250.0	231.0	224.7	6.3
54	240.0	210.0	215.3	- 5.3
57	240.0	215.0	215.3	- 0.3
57	240.0	218.0	215.3	2.7
57	240.0	215.0	215.3	- 0.3
57	240.0	218.0	215.3	2.7
59	240.0	217.0	215.3	1.7
59	225.0	200.0	201.3	- 1.3

TABLE II. N<sub>2</sub>O<sub>4</sub> (1.5% NO) HELIUM SATURATION DATA (CONT)

<u>ACU PROPELLANT TEMPERATURE (°F)</u>	<u>ACU PRESSURE (PSIG)</u>	<u>OBSERVED BUBBLE POINT PRESSURE (PSIG)</u>	<u>CALCULATED* BUBBLE POINT PRESSURE (PSIG)</u>	<u>DIFFERENCE (OBSERVED- CALCULATED) (PSI)</u>
59	225.0	200.0	201.3	- 1.3
59	225.0	196.0	201.3	- 5.3
59	225.0	204.0	201.3	2.7
59	225.0	196.0	201.3	- 5.3
59	225.0	200.0	201.3	- 1.3
62	200.0	170.0	178.0	- 8.0
62	200.0	174.0	178.0	- 4.0
50	200.0	186.0	178.0	8.0
50	200.0	185.0	178.0	7.0
54	200.0	185.0	178.0	7.0
54	200.0	187.0	178.0	9.0
56	200.0	178.0	178.0	0.0
56	200.0	179.0	178.0	1.0
56	200.0	179.0	178.0	1.0
56	200.0	180.0	178.0	2.0
54	175.0	162.0	154.6	7.4
54	175.0	160.0	154.6	5.4
54	175.0	161.0	154.6	6.4
54	175.0	160.0	154.6	5.4
56	150.0	136.0	131.3	4.7
56	150.0	136.0	131.3	4.7
56	150.0	135.0	131.3	3.7
56	150.0	136.0	131.3	4.7
56	150.0	120.0	131.3	-11.3
56	150.0	120.0	131.3	-11.3
56	150.0	120.0	131.3	-11.3
56	150.0	119.0	131.3	-12.3
58	125.0	115.0	107.9	7.1
58	125.0	115.0	107.9	7.1
58	125.0	114.0	107.9	6.1
58	125.0	113.0	107.9	5.1

TABLE II. N<sub>2</sub>O<sub>4</sub> (1.5% NO) HELIUM SATURATION DATA (Cont)

<u>ACU PROPELLANT TEMPERATURE (°F)</u>	<u>ACU PRESSURE (PSIG)</u>	<u>OBSERVED BUBBLE POINT PRESSURE (PSIG)</u>	<u>CALCULATED* BUBBLE POINT PRESSURE (PSIG)</u>	<u>DIFFERENCE (OBSERVED- CALCULATED) (PSI)</u>
58	100.0	89.0	84.6	4.4
58	100.0	89.0	84.6	4.4
58	100.0	87.0	84.6	2.4
58	100.0	87.0	84.6	2.4
57	100.0	76.0	84.6	- 8.6
57	100.0	75.0	84.6	- 9.6
57	100.0	75.0	84.6	- 9.6
57	100.0	75.0	84.6	- 9.6

AVG = 55.4 +1.6

\*Calculated Bubble Point Pressure (PSIG) = -8.829432 + 0.933971 (ACU  
Pressure [PSIG])

Sigma = 6.2



TABLE III.  $N_2O_4$  (2.3% NO) HELIUM SATURATION DATA

<u>ACU PROPELLANT TEMPERATURE (°F)</u>	<u>ACU PRESSURE (PSIG)</u>	<u>OBSERVED BUBBLE POINT PRESSURE (PSIG)</u>	<u>CALCULATED* BUBBLE POINT PRESSURE (PSIG)</u>	<u>DIFFERENCE (OBSERVED- CALCULATED) (PSI)</u>
44	250	235	224.7	10.3
44	250	240	224.7	15.3
44	250	239	224.7	14.3
44	250	240	224.7	15.3
44	185	160	163.9	- 3.9
44	185	160	163.9	- 3.9
44	185	160	163.9	- 3.9
44	185	160	163.9	- 3.9
44	100	70	84.6	-14.6
44	100	73	84.6	-11.6
44	100	70	84.6	-14.6
44	100	73	84.6	-11.6

AVG=44

\*Calculated Bubble Point Pressure (PSIG) =  $-8.829432 + 0.933971$  (ACU  
Pressure [PSIG])

Sigma = 6.2

TABLE IV. MMH DEPRESSURIZATION - REPRESSURIZATION BUBBLE POINT DATA

BEFORE DEPRESSURIZATION			DEPRESSURIZATION		AFTER REPRESSURIZATION	
ACU PRESSURE (PSIG)	BUBBLE POINT (PSIG)	TEMP (°F)	TIME (MIN)	PRESSURE (PSIG)	ACU PRESSURE (PSIG)	BUBBLE POINT (PSIG)
250	223	75	2	200	245	210
250	228	77	5	200	245	187
250	225	73	10	200	250	185
250	225	72	2	150	250	160
250	230	65	5	150	250	145
250	235	72	10	150	250	135
250	229	66	2	100	250	115
250	232	66	5	100	250	112
250	225	71	10	100	250	90
250	235	69	2	50	250	100
250	230	65	5	50	250	60
250	230	65	10	50	250	65

AVG. 229      AVG 70

TABLE V. N<sub>2</sub>O<sub>4</sub> DEPRESSURIZATION - REPRESSURIZATION BUBBLE POINT DATA

BEFORE DEPRESSURIZATION			DEPRESSURIZATION		AFTER REPRESSURIZATION		
ACU	BUBBLE POINT (PSIG)	TEMP (°F)	TIME (MIN)	PRESSURE (PSIG)	ACU	PRESSURE (PSIG)	BUBBLE POINT (PSIG)
250	232	73	2	200	250	250	220
250	222	74	5	200	245	245	180
250	225	74	10	200	250	250	175
250	221	74	2	150	245	245	198
250	238	71	5	150	250	250	165
250	219	70	10	150	250	250	160
250	226	72	2	100	250	250	192
250	225	70	5	100	250	250	150
250	223	69	10	100	250	250	148
Avg.	226	Avg. 72					

TABLE VI. QUANTITY OF HELIUM IN PROPELLANTS AT 70°F

<u>PRESSURE</u> <u>(PSIG)</u>	<u>cc (STP)/cc</u> <u>OF PROPELLANT</u>		<u>RATIO OF N<sub>2</sub>O<sub>4</sub></u> <u>TO MMH He</u> <u>SOLUBILITY</u>
	<u>N<sub>2</sub>O<sub>4</sub></u> <u>(MON-1)</u>	<u>MMH</u>	
250	0.463	0.114	4.1
200	0.353	0.085	4.2
150	0.244	0.056	4.4
100	0.134	0.026	5.2

TABLE VII. PERCENT HELIUM LOST UPON DESATURATION

OXIDIZER INITIAL CONDITIONS: 70°F AND SATURATED AT 250 PSIG

<u>PRESSURE REDUCTION</u> <u>(PSIG)</u>		<u>PERCENT HELIUM LOST</u>	
<u>INITIAL</u>	<u>FINAL</u>	<u>N<sub>2</sub>O<sub>4</sub></u>	<u>MMH</u>
250	200	23.7	25.4
250	150	47.3	50.9
250	100	71.1	77.2

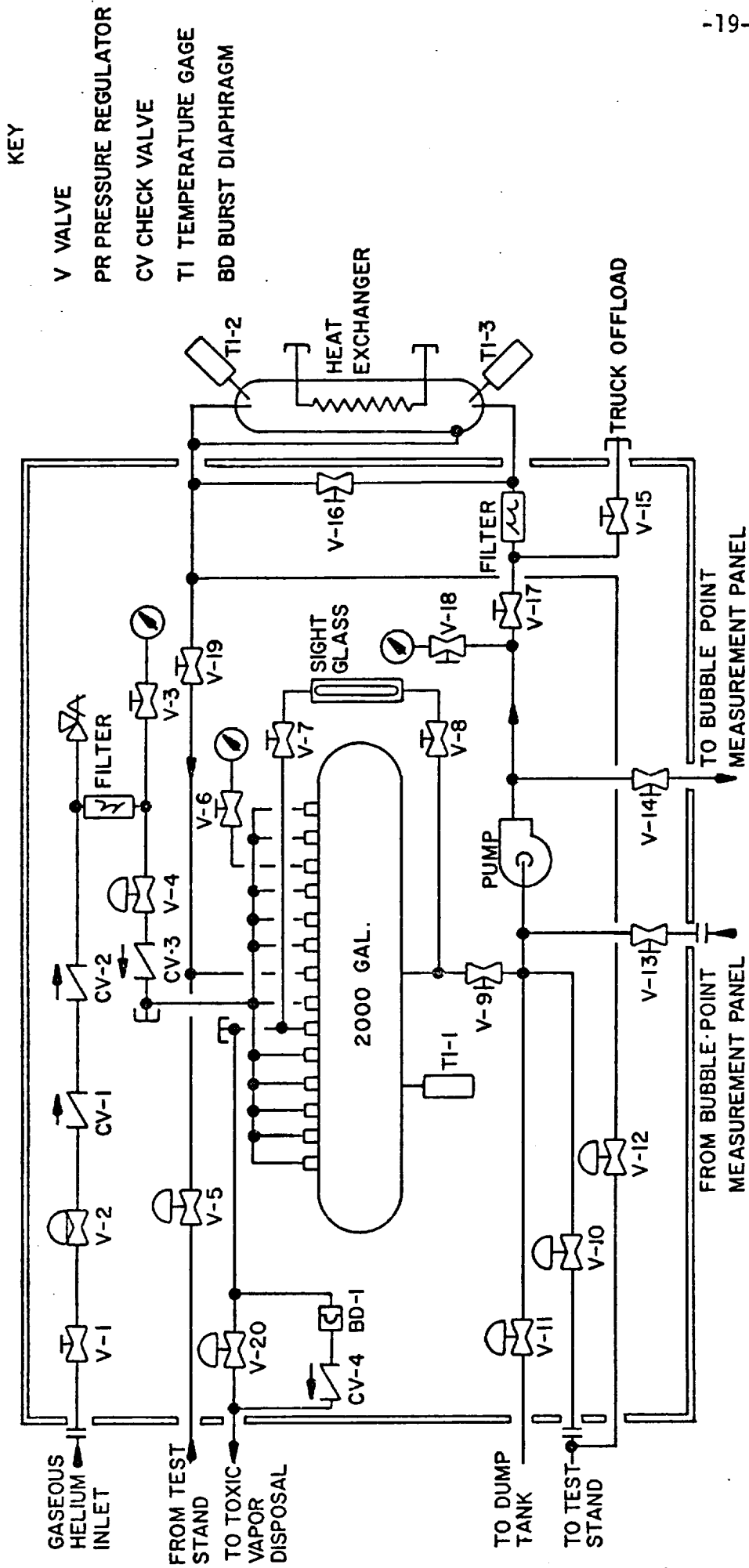


FIG 1.- AUXILIARY CONDITIONING UNIT SCHEMATIC

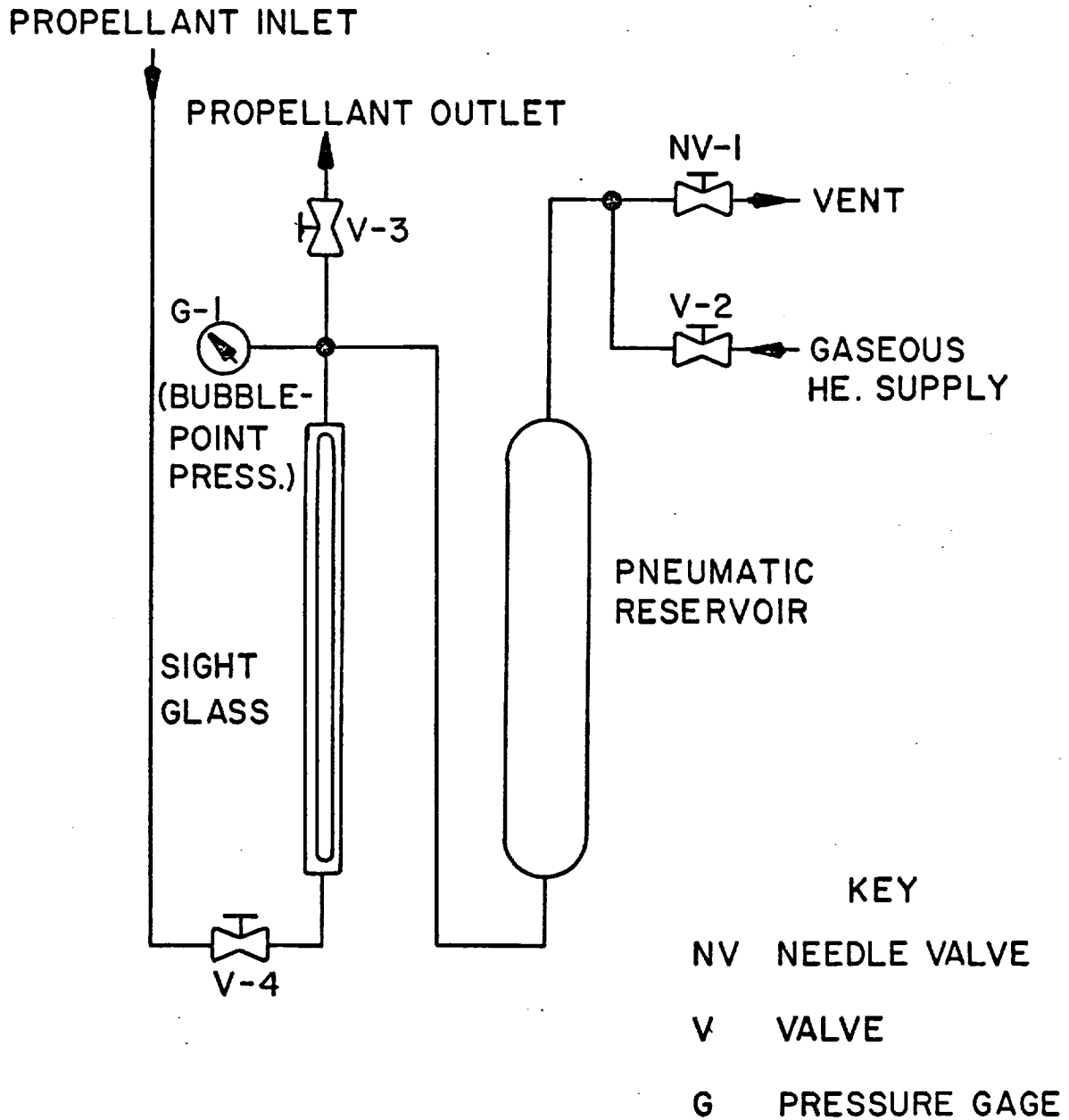


FIG. 2. - BUBBLE-POINT MEASUREMENT PANEL SCHEM.

FIGURE 3.

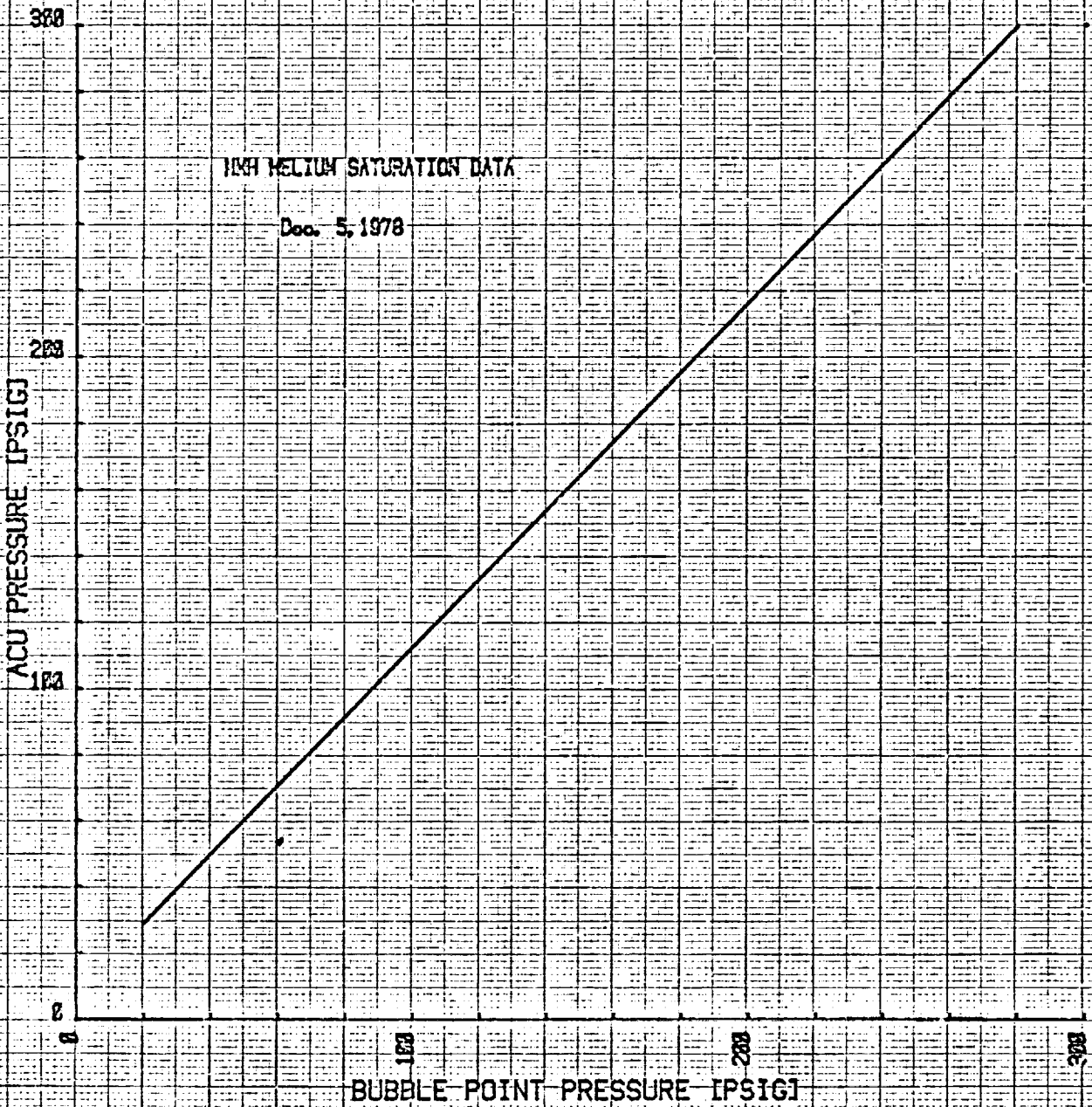


FIGURE 4.

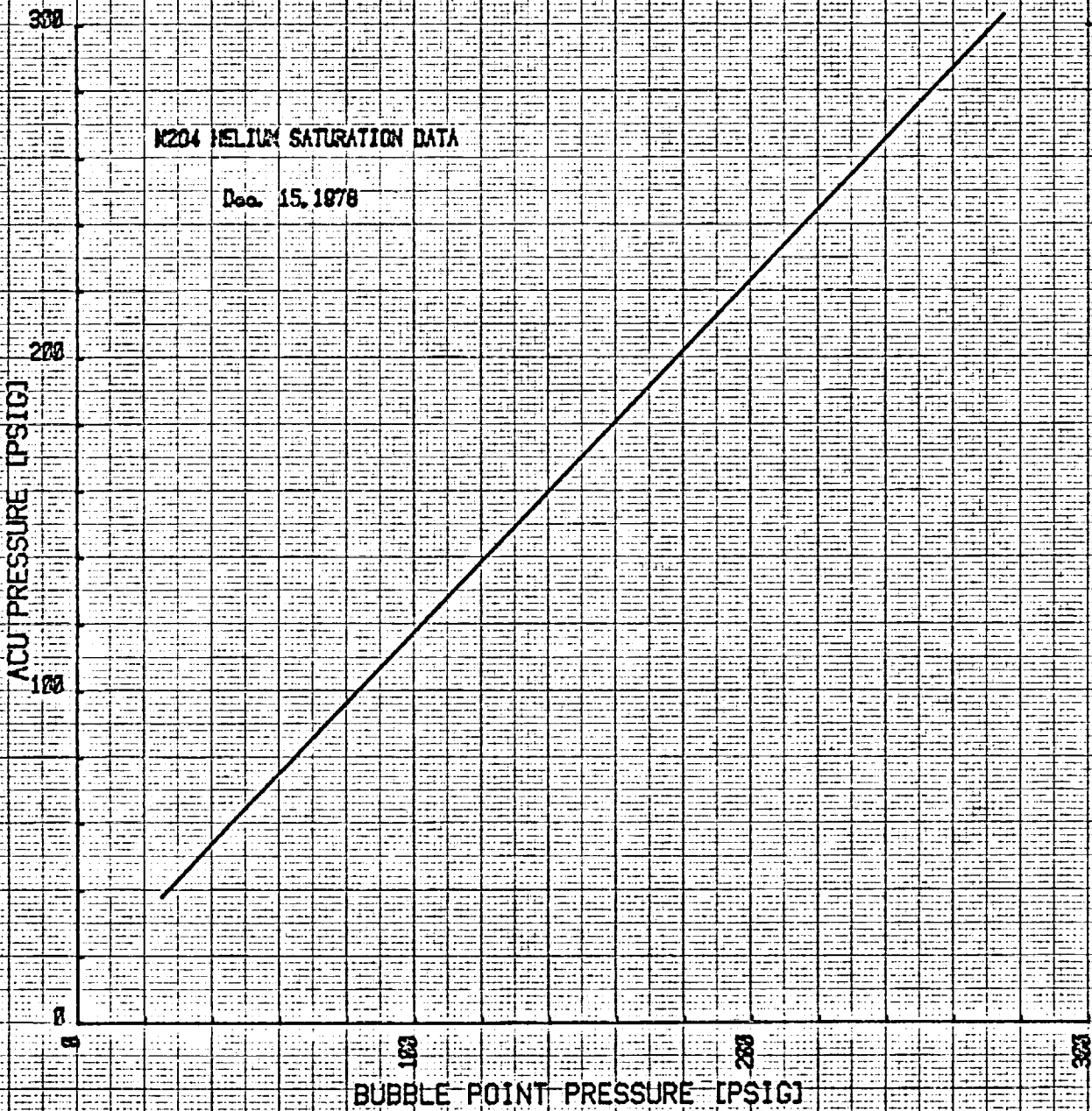
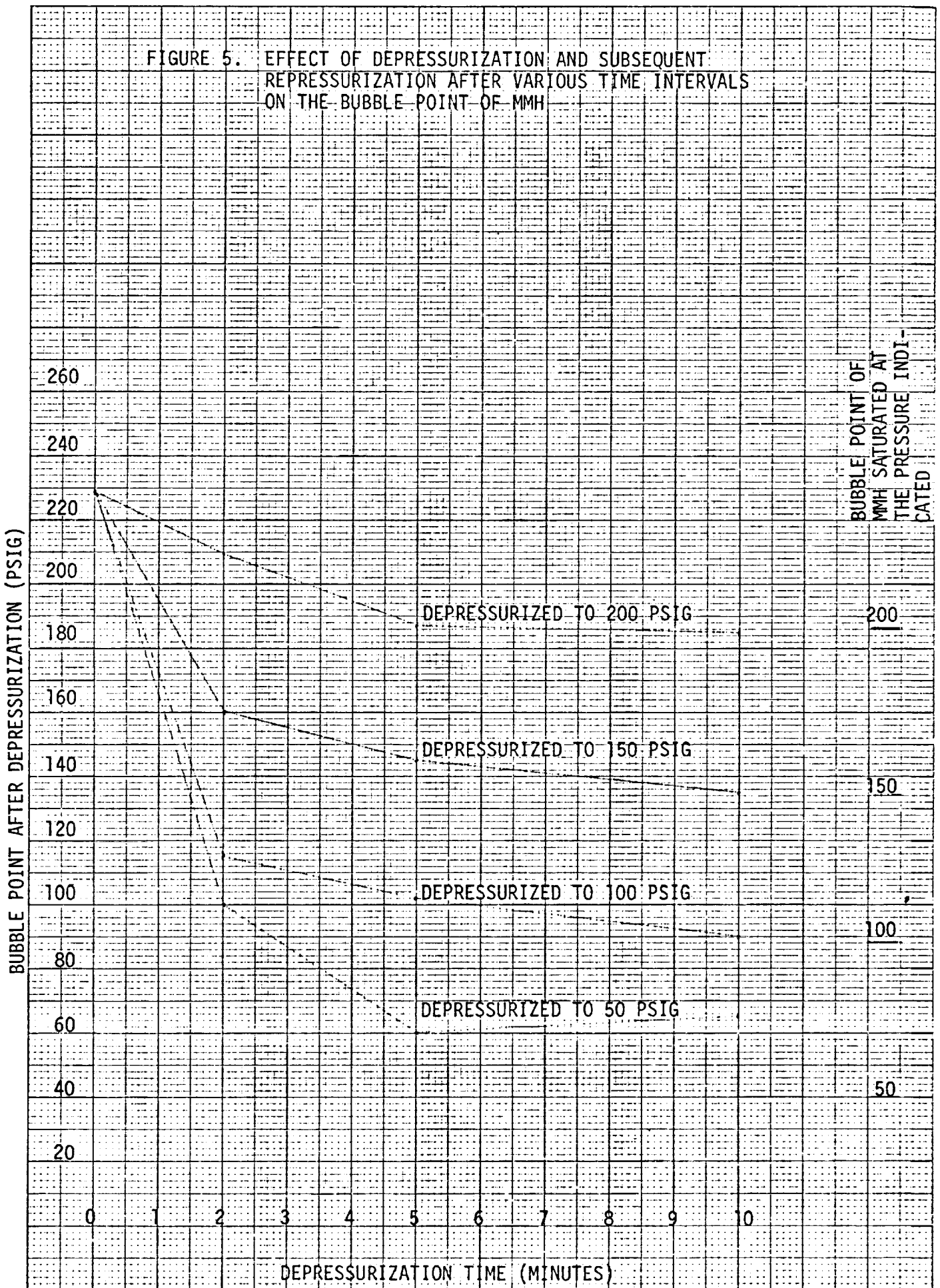




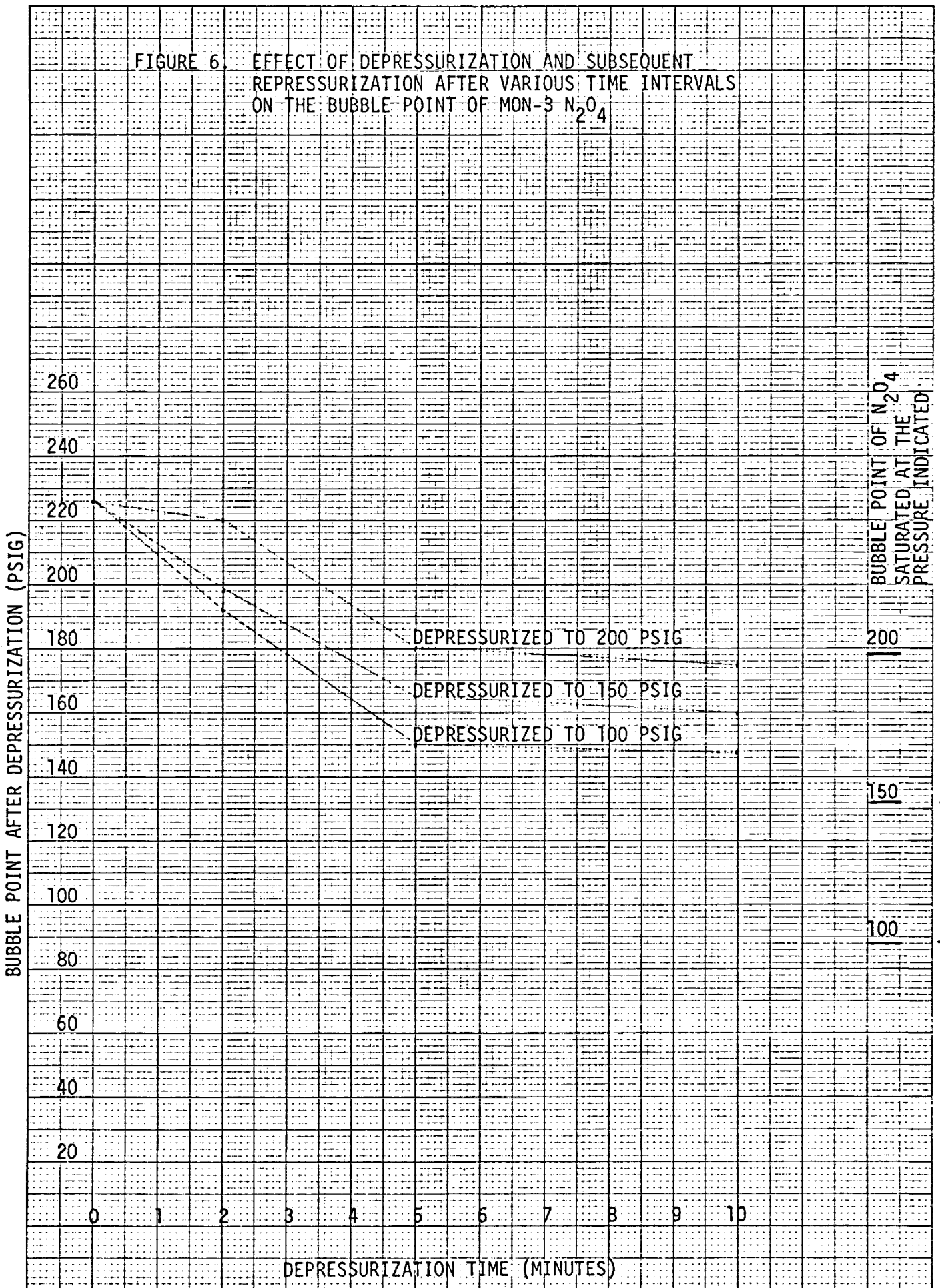
FIGURE 5. EFFECT OF DEPRESSURIZATION AND SUBSEQUENT REPRESSURIZATION AFTER VARIOUS TIME INTERVALS ON THE BUBBLE POINT OF MMH



46 1320

K&E 10 X 10 TO 1/2 INCH 7 X 10 INCHES KEUFFEL & ESSER CO. MADE IN U.S.A.

FIGURE 6. EFFECT OF DEPRESSURIZATION AND SUBSEQUENT REPRESSURIZATION AFTER VARIOUS TIME INTERVALS ON THE BUBBLE POINT OF MON-3 N<sub>2</sub>O<sub>4</sub>



46 1320

K&E 10 X 10 TO 1/4 INCH 7 X 10 INCHES KEUFFEL & ESSER CO. MADE IN U.S.A.

APPENDIX A  
MMH AND MON-1  $N_2O_4$   
HELIUM SOLUBILITY DATA

## MONOMETHYLHYDRAZINE HELIUM SOLUBILITY DATA

<u>TEMP (°F)</u>	<u>PRESSURE (PSIA)</u>	<u>MEASURED He CONCENTRATION cc (STP)/cc OF PROPELLANT</u>	<u>CALCULATED He CONCENTRATION cc (STP)/cc OF PROPELLANT</u>	<u>DIFFERENCE (MEASURED- CALCULATED)</u>
20 <sup>a</sup>	300	0.030	0.062	-0.032
68 <sup>a</sup>	300	0.131	0.131	0.000
122 <sup>a</sup>	300	0.204	0.209	-0.005
176 <sup>a</sup>	300	0.306	0.287	-0.019
32 <sup>b</sup>	202	0.050	0.023	+0.027
32 <sup>b</sup>	251	0.062	0.051	+0.011
80 <sup>b</sup>	101	0.045	0.033	+0.012
80 <sup>b</sup>	203	0.095	0.092	+0.003
80 <sup>b</sup>	251	0.123	0.120	+0.003
125 <sup>b</sup>	102	0.073	0.098	-0.025
125 <sup>b</sup>	204	0.146	0.157	-0.011
125 <sup>b</sup>	247	0.179	0.182	-0.003

Helium Content cc (STP)/cc of Propellant =  $-0.141215 + 0.000583$  (Pressure [PSIA]) +  $0.001437$  (Temperature [°F])

Sigma = 0.017

- Source: a - Solubility of Helium in Nitrogen Tetroxide, Aerozine -50, and Methyl Hydrazine---B. Foran and B.B. Williams, North American Aviation, Inc., 15 March 1963
- b - Solubility of Helium and Nitrogen in Liquid Propellants---Aerojet General Corp, Report No. LM 0696-03-7, May 6, 1966

NITROGEN TETROXIDE (MON-1) HELIUM SOLUBILITY DATA

<u>TEMP (°F)</u>	<u>PRESSURE (PSIA)</u>	<u>MEASURED He CONCENTRATION cc (STP)/cc OF PROPELLANT</u>	<u>CALCULATED He CONCENTRATION cc (STP)/cc OF PROPELLANT</u>	<u>DIFFERENCE (MEASURED- CALCULATED)</u>
55	234	0.395	0.394	+0.001
55	236	0.393	0.398	+0.005
62	228	0.365	0.396	-0.031
62	228	0.367	0.396	-0.029
78	234	0.455	0.446	+0.009
86	232	0.487	0.460	+0.027
95	92	0.182	0.174	+0.008
70	120	0.181	0.178	+0.003
70	120	0.168	0.178	-0.010
69	237	0.410	0.432	-0.022
69	237	0.451	0.432	+0.019
69	237	0.437	0.432	+0.005
102	235	0.494	0.504	-0.010
69	234	0.426	0.426	0.000
46	235	0.405	0.375	+0.030
46	235	0.385	0.375	+0.010
46	235	0.371	0.375	-0.004

$$\text{Helium Content (cc (STP)/cc of Propellant) = } -0.247401 + (0.002194 \times \text{pressure [PSIG]}) + (0.002313 \times \text{temperature [°F]})$$

$$\text{Sigma} = 0.017$$

Source: Determination of the Helium Saturation Level of Aerozine -50 and Nitrogen Tetroxide --- NASA TN D-6249