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The report details the application of a portable ultrasonic method to accurately check the pressure in a helium bottle. The subject helium bottle provides an initial launch boost to the Short Range Attack Missile's (SRAM-A, or AGM-69A) hydraulic flight control system.
The method described would apply to any pressure vessel, with minor variations from those procedures and equipments detailed in the report. to p. 3

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## FOREWORD

This final Engineering Report contains the complete technical account of the data gathered by the Short Range Attack Missile (SRAM) support program of Boeing Aerospace, Seattle, Washington, started under Engineering Assignment (EA) Number 87-7-1-12, and suspended by Oklahoma City Air Logistics Center (OC-ALC), Tinker Air Force Base, Oklahoma, due to lack of funds. The report was completed under Recurring Engineering Assignment Numbers 88-7-5 and 89-1.

## ABSTRACT

A series of tests was conducted at the Boeing Aerospace facility in Kent, Washington on a SRAM-A helium gas bottle ~~(APCO bottle S/N 5016)~~, to determine the feasibility of measuring gas pressure within the helium bottle by ultrasonic technique. The method, based on measurement of the speed of ultrasonic waves transmitted through a medium at constant pressure and temperature, provides the ability to determine bottle pressure without the necessity of removing the bottle from the missile. This bottle had previously been used for pressurizing the Flight Control Actuation System.

The ultrasonic waves were introduced into the bottle by a transducer attached to one side of the gas bottle and received by a transducer attached 180° directly opposite the input transducer. The amplitude of the ultrasonic signal decreased with decreasing pressure, proving that the method was feasible. It was later determined that the simplest and most accurate method of calibration was to measure the elapsed time between the sound wave first ~~entering the gas medium until~~ it was detected leaving the gas medium at constant pressure and temperature. The process was further developed leading to the successful use of a single ultrasonic transducer placed on the side of the bottle, at any convenient location, to transmit and receive the ultrasonic signals passing through the medium. Only the shroud around the aft end of the SRAM-A missile requires removal to provide access for measurement. Calibration curves were developed ~~for Boeing and APCO bottles~~ at 40°F, 70°F, and 100°F.

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## ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| AFB | Air Force Base |
| APCO | Accessory Products Company, Division of H. R. Textron Corp. |
| ASAT | Antisatellite Missile |
| BA | Boeing aerospace |
| EA | Engineering Assignment |
| EMC | Electromagnetic Compatibility |
| EMI | Electromagnetic Interference |
| °F | Degrees Fahrenheit |
| FCAA | Flight Control Actuator Assembly |
| GFE | Government Furnished Equipment |
| He | Helium |
| MHz | Megahertz |
| OC-ALC | Oklahoma City - Air Logistics Center |
| PE | Pulse Echo |
| PPM | Parts Per Million |
| PSI | Pounds per Square Inch |
| PSIG | Pounds per Square Inch Gage |
| SIL | System Integration Laboratory |
| S/N | Serial Number |
| SOP | Safety Operating Procedures |
| SRAM | Short Range Attack Missile |
| TT | Through Transmission |
| USAF | United States Air Force |
| TIM | Technical Interchange Meeting |

## 1.0 INTRODUCTION AND BACKGROUND

Flight test telemetry data from a successful Antisatellite Missile (ASAT) flight in August, 1986, indicated a low pressure (1020 psig) in the hydraulic control system. The ASAT missile used the SRAM-A Flight Control Actuation Assembly (FCAA). Normal pressure is near 3000 psig. The low hydraulic pressure was attributed to a loss of pressure with time in the helium bottle used to pressurize the hydraulic system in flight. This led to a need to measure the bottle pressure while on the missile but not by the existing method of removing the bottle and weighing it. Both ASAT and SRAM-A flight actuation systems utilize the same components, except that SRAM-A fins are smaller, and a 3000 psig hydraulic system pressure is required by the SRAM-A missile. Because the ASAT missile flies at higher altitudes with lower Q loads, successful flights may be obtained with lower hydraulic system pressure.

The hydraulic system accumulator/regulator is pressurized from a 5000 psig gaseous helium bottle. The most probable cause for low system pressure is a low bottle pressure. The present method of determining the amount of helium in a SRAM-A bottle requires removing the bottle from the missile hydraulic system, scraping and cleaning the bottle, weighing the bottle to determine the mass of gas present, comparing the measured weight to the weight in the initially filled bottle, preparing and applying adhesive, reinstalling the bottle on the missile, purging the hydraulic system and checking the helium system for leaks. This procedure suffers from many disadvantages, including difficulty of performing this procedure in the field, the necessity of skilled, trained personnel to do the bottle removal/ reinstalling, the necessity of a calibrated balance, the time and cost involved in removing and reinstalling the bottle and the required purging and pressure leak test of the system.

A portable method to determine the feasibility of measuring helium bottle pressure by ultrasonic technique without removal of the bottle from the missile was proposed by this Engineering Authorization (EA). Successful results would provide easy identification of low pressure bottles in the SRAM fleet.

An acoustic technique to determine content levels of gas or liquid in storage containers was originally developed at Boeing. This technique addresses a perceived need for a simple, reliable, accurate, and non-invasive method for orbiting spacecraft and space platforms. In this EA, following a successful proof of principle test, a simplified version of one acoustic gage method was adapted. These tests, results, and test hardware required are described and presented in this report.

# 2.0 DISCUSSION

## 2.1 Engineering Assignment (EA) Tasks

The tasks required by EA 87-7-1-12 and 12A are listed below. A copy of the EA and the revision are contained in Appendix A.

A. Obtain suitable SRAM helium bottle for testing.

B. Formulate test plan and procedures from inputs.

C. Prepare test setup.

D. Conduct test in laboratory taking ultrasonic measurements and weighing the gas in the bottle at known pressure decrements.

E. Evaluate the test data and document results.

F. Measure pressure in Boeing helium bottle S/N 3841.

G. Perform EMI test of ultrasonic equipment to verify squib safety.

H. Calibrate measurements of two Boeing bottles and two APCO bottles (Government Furnished Equipment; GFE).

J. Design and build a prototype test fixture and provide instructions for use.

K. Verify test with production bottles, at least four (4) of each kind.

L. Host a Technical Interchange Meeting (TIM) in Kent, Wa.

M. Prepare a final report, covering both original EA 87-7-1-12 and its revision, EA 87-7-1-12A.

## 2.2 Description of Work Done

All of the tasks listed above have been accomplished, with the exception of the Boeing bottle final calibration curve in Item 2.1H The second Boeing test article (GFE) was not provided in time to complete the testing and to construct a final calibration curve before work was suspended. However,a calibration curve of the single Boeing bottle is included in this report and labeled "Preliminary".

### 2.2.1 Test Procedure

The first test article, an APCO-built SRAM-A helium bottle (S/N 5016), was thoroughly cleaned, inspected, and subjected to a proof pressure test with water at about 7500 psig. The bottle was then assembled into the test configuration shown in the schematic diagram in Figure 1. The bottle was connected to a pressurized helium storage bottle by a tube with appropriate valves and fittings to allow filling the test bottle to about 4500 psig, venting where required and then disconnecting the line. A calibrated pressure transducer (accurate to 0.5% at full scale) was placed in the line on the test bottle side of the gas line disconnect valve to allow continuous monitoring of the test bottle internal pressure (see Figure 1A). A burst of ultrasonic waves was then injected into the metal wall of the bottle through the ultrasonic input transducer attached to one side of the bottle. Part of the signal followed the metal path of the cylinder wall and was sensed by the ultrasonic output transducer placed 180° opposite the input transducer as shown in Figure 1B. The signal also passed through the helium gas and was sensed by the output transducer on the other side of the bottle. Since sound travels faster in the metal path than the gas path, the signal passing through the gas lags behind the signal passing through the metal path by a finite time. Density of the gas increases with increased pressure and the ultrasonic pressure measuring technique is based on the interpretation of the time it takes for the ultrasonic signal to pass through the gas at different pressures.

Output signals from the pressure transducer and a standard thermocouple taped to the test bottle were connected to a data recorder/display unit shown in Figure 2. During the initial tests two ultrasonic transducers were mounted in a silicone rubber sleeve which fit securely over the end of the APCO bottle and precisely positioned the transducers 180 degrees opposite one another (Figure 3). A small amount of silicone based coupling gel was placed on the transducers before each test run to ensure good coupling between the transducers and the bottle surface. The transducers were connected by cables to a Nortec NDT 150 ultrasonic transmitter/receiver unit (Figure 2) to introduce and record the signals. The initial transducer tried with the APCO bottle operates at a frequency of 5 MHz. This provided a clear, strong signal with clear separation between the metal bottle response and the gas response to the applied ultrasonic signal. It was found later, when the Boeing bottle (S/N 3841) was tested, that a 10 MHz transducer was required to detect the signal passing through the gas and separate it from the signal passing through the metal path. This 10 MHz transducer was tried successfully on the APCO bottle and was used for all tests thereafter.

The acoustic signal, after travelling through the metal bottle and the gas,was displayed on the Nortec oscilloscope screen where it was photographed. A typical signal trace through helium gas at 4560 psig showing separation of gas and metal responses is shown in Figure 4. At the far left of the figure is the introduction of the signal. The damped metal bottle response is shown in the middle, and the gas response is shown to the right. The bottle response shows the "ringing" in the metal wall from the input ultrasonic signal, which reflects internally through the wall. Constructive and destructive interference between these multiple reflections results in a series of peaks of different amplitudes in response to a single incident peak.

The velocity of the acoustic signal is proportional to the density of the media in which it is travelling. It is much slower passing through the helium than through the steel bottle wall because of the density difference. The sound response from traversing the gas appears later and to the right of the bottle response on the time axis shown in Figure 4. The bottle response in this test configuration was damped by the silicone rubber sleeve in which the transducers were mounted and by the gel placed on the interface between the transducers and the bottle.

The oscillograph screen was normally set to display the full-wave rectified gas response seen in Figure 4. The series of peaks of the gas straight-through acoustic signal and the time difference between each peak is directly related to the bottle wall thickness. Velocity and amplitude of the peaks increases as pressure is increased (with temperature held constant). Variations in these peaks are caused by constructive/destructive interferences between these multiple reflections. A 0.05 microsecond wide "gate", as shown in Figure 4 , and the time based capabilities of the Nortec unit to separate the gas from the helium signal provide direct measurement of "time-to-first-peak". This is defined as the difference in microseconds between the incident signal and first peak of the gas response series. The amplitude of each peak of the gas response series was read off a digital voltmeter interfaced to the gate output of the Nortec. This response time is calibrated versus helium pressure.

Detailed test procedure is described in the test plan and procedures in 2-3631-GKD7-017, Appendix B. A condensed, general description of the test procedure for the initial tests is as follows:

The empty APCO bottle and its mount, along with the transducers/sleeve mount, pressure transducer, thermocouple, vent valve and line with quick disconnects uncoupled were weighed on a balance scale shown in Figure 4A to provide a tare value. The bottle had been previously purged with helium gas and had an internal helium pressure of about 15 psig. The bottle was then re-connected to the source gas line and pressurized to about 4500 psig, or as high as the available pressure in the helium source supply bottle. Quality of the helium was the same as the originally filled bottle (impurities less than 1ppm). The bottle was then disconnected from the source gas line and was allowed to stabilize for one hour to reach thermal equilibrium at the laboratory ambient temperature (70°F). The test article was weighed again to obtain the helium gas weight in the fully pressurized bottle. The various transducers and sensors were then re-connected, gas pressure and temperature measured and recorded, and the initial observed ultrasonic signal traces were photographically and numerically recorded (peak amplitude voltage and time to peak for the seven strongest peaks in the gas response). After this data was recorded, helium pressure was reduced in the test article by approximately 300 psig. The test article was allowed to equilibrate for a few minutes until bottle temperature and pressure stabilized and another set of data was taken at this new, lower pressure. All connectors were then removed and the test article was weighed to obtain change in gas weight. This was repeated in decrements of 300 psig until either the helium pressure was at laboratory ambient or until the gas response peaks were indistinguishable from the baseline system noise. The numerical data was then plotted as (1) average time-to-peak versus pressure, (2) average peak amplitude versus pressure, (3) normalized peak area versus pressure and (4) time-to-first peak versus pressure. Eight initial test runs were performed to evaluate repeatability, precision, and effects of gas contamination level. Helium samples with total impurities less than 10 PPM (including water impurities less than 1.5 PPM), as well as with total impurities less than 1 PPM, were tested to ascertain if these impurities affected the ultrasound measurements but no significant differences were detected. The bottles were originally filled with helium containing total impurities less than 1.0 PPM at the time of delivery.

Later, a single ultrasonic transducer was applied to the surface of the bottle and was used for the input signal as well as the receiver for the output signal. Initial results were so promising that the calibrations were rerun for each bottle using the single transducer. These produced the final calibration curves. Test procedure was the same as that used with two transducers except that data was obtained at three different temperatures (40°F, 70°F, 100°F) and it was no longer necessary to weigh the gas in the bottle.

The test article was filled with helium gas to approximately 5000 psig at 70°F and placed in an environmental chamber at room temperature (70°F). Bottle temperature, gas pressure and time- to- first- peak were recorded, and the bottle temperature was then lowered to 40°F. After bottle temperature and pressure reached equilibrium and were recorded, time-to-first-peak was recorded and the bottle was warmed to 100°F and again allowed to reach equilibrium. Data was recorded as above and bottle pressure was then reduced 300 psig. After reaching equilibrium, data was recorded as above and the bottle temperature was reduced to 70°F. After reaching equilibrium, data was recorded as above and bottle temperature was reduced to 40°F. Data was recorded as before after equilibrium was reached and bottle pressure was then reduced 300 psig. The cycle was repeated at each 300 psig decrement until the ultrasonic signal was no longer clearly distinguishable above the electronic noise level of the system. Data was obtained in this manner for developing the final calibration curves at 40°F, 70°F, and 100°F temperatures to allow interpolation for testing at ambient temperature.

## 2.2.2 Results

### 2.2.2.1 APCO Bottle

The initial test article was APCO bottle S/N 5016. The first series of test runs, identified as tests named He-1 through He-8, were conducted at a nominal temperature of 70°F. The first run (He-1) was a limited exploratory experiment to determine the appropriate transducer frequency to be used. Gas response peak amplitudes were directly related to magnitude of the helium pressure. This data is included in Appendix E. Results from the second to the eighth test runs are shown in Figures 5 through 7. The second run (He-2) was a more detailed test in which data on gas weight (Figure 5), average time-to-peak (Figure 6) and peak sound wave amplitude (maximum voltage, Figure 7) were plotted as a function of helium pressure. Bottle weight was measured on the balance scale shown in Figure 4A. Runs He-3 through He-6 were performed to evaluate the repeatability of the measurements and refine the experimental procedure. Results are shown in Figures 8 through 17. Runs He-1 through He-6 were conducted using grade 6 helium (1 ppm impurities), while runs He-7 and He-8 were performed with a lower grade of helium (grade 5; 10 ppm impurities) to evaluate any possible effects of a higher contaminant level on the acoustic gage technique. The small differences in impurities had no significant affect on the ultrasound measurements.

Early in this series of tests, it became apparent that the time-to-peak data was the most accurate, reliable, simple and reproducible. This data is essentially a measure of the velocity of sound through the pressurized helium gas as a function of gas pressure at constant temperature. Figure 8 shows the results of averaged time-to-peak data plotted against measured helium pressure for runs He-2, -3 and -4. Figure 9 shows similar data for He-4,-5,-6, and Figure 10 shows similar data for He-6,-7 and-8. Over the range of pressures of about 2000 to 4700 psig the plots for each test run are similar and overlap, with very similar slopes. Below 2000 psig some deviations were observed, primarily for He-2 and He-3 (Figure 8). These deviations are attributed to an insufficient waiting period between gas venting (i.e., reducing the bottle's internal helium pressure) and recording test data. Additional time was required between these steps to allow internal gas turbulence to subside and for the gas/bottle system to thermally equilibrate. This equilibration time was 4 to 5 minutes. Figure 11 shows the data spread for all average time-to-peak data points collected for runs He-2 to He-8. Linear least squares regression analysis of this combined data gives a slope of $-1.45 \times 10^{-3} \pm 0.03 \times 10^{-3}$ with an intercept of 66.9 ± 0.1 microseconds.

Figures 12 and 13 show analogous plots of gas response peak amplitudes (volts) for runs He-2 through He-6. These plots are also consistent from run to run.

The normalized peak area of the gas response as a function of pressure for a test run was determined by manually cutting out the gas response peak envelope from copies of the photographed signal traces, weighing the traces, and dividing each weight by the largest weighing value (which was invariably the trace taken at the highest gas pressure used in each run). Figure 16 shows the resulting data spread for He-2 through He-6 for this measurement. Use of electronic digitizing methods to determine peak area more precisely would reduce the spread of the data, but would require more equipment to do the digitizing as compared to the time-of-peak measurement method.

Figure 17 is a plot of the weighed mass of the helium gas as a function of the gas pressure for runs where gas weight data was recorded (He-1, He-2, He-7). In the first run ( He-1) the gas weight plotted against pressure resulted in the expected near linear relationship. The plots for later test runs (He-2, He-7) are off-set from the results of He-1 and may indicate the true reliability and consistency of the weighing method previously and presently used to determine the weight of helium gas in SRAM-A bottles. Figure 17A shows this significant data spread of gas weight at measured pressure for several test runs of the APCO and Boeing bottles.

2.2.2.2 Boeing Bottle

The first Boeing test article (S/N 3841) was a bottle taken from the ten year bottle surveillance program at Boeing Aerospace. In the 1987 Final Letter Report EA-87-7-1-3, this bottle indicated a possible 14% low helium weight. The initial ultrasonic measurement with this bottle was taken before the bottle seal had been opened and the pressure transducer inserted. The initial bottle pressure reading by pressure transducer was not obtained at this data point. The test procedure was the same as previously used for the APCO bottle except that the bottle was not weighed at each pressure decrement to obtain the mass of gas. All tests were conducted at a nominal ambient temperature of 70°F.

Three additional runs were made in which the weight of gas was also taken at each pressure. Time-to-first-peak versus bottle pressure for these three runs and the initial run is shown in Figure 18. The last run (8/7/87) shows an increase in time to reach first peak at the measured higher pressures compared to the previous runs. This increase in time gradually diminished as the test run proceeded and became imperceptible. An operational checkout of the electronic test equipment later revealed that a warm-up time of approximately 20 minutes is required to reach steady state operating temperature. It is seen that a composite of the data produces a curve that is almost linear within the pressure range of interest for this application (4000-5100 psig). Test results show that bottle S/N 3841 must have been initially between 4900 and 5100 psig as measured by the ultrasonic technique. The bottle, therefore, must have been full pressure instead of 14% low by weight.

Production bottles, (S/N 3316, 3195, 3095, 3466, 3251 and 3597), are all more than 10 years old. As measured by ultrasonic technique, all appear to be within the same pressure range (4900-5100 psig) and indicate a full or near full condition. Figure 19 illustrates the time-to-first-peak versus gas pressure for the APCO and Boeing bottles and illustrates the differences in the ultrasonic signatures of the two bottles. The gap between the two curves is caused by a difference in bottle wall thickness (Boeing bottle is 0.1 inch thicker than APCO bottle) and alloy microstructure. This illustrates the necessity for separate calibration curves for the Boeing and APCO bottles. Subsequent examination showed that the weighing data was probably in error-a small screw was not accounted for.

2.2.2.3 Single Ultrasonic Transducer Measurements

Following the initial successful demonstration of pressure measurement with a single transducer to Boeing Management (Appendix F), several test runs were conducted at room temperature (70°F ±2°F) using a single transducer. This is referred to as the "pulse-echo" method. The test procedure was the same as that used previously except that mass of the helium gas was not weighed. Raw data from six runs with Boeing bottle S/N 3841 is plotted in Figure 20 to demonstrate the consistency of results with this method. The time-to-first-peak is approximately twice that measured with two transducers (Figure 18). Since the single transducer operates as the transmitter and receiver, the induced signal is transmitted to and reflected from the opposite side of the bottle and travels approximately twice the distance of the signal introduced with two transducers.

Simplicity of measurement technique and portability of the test equipment were two major objectives. The relative ease of measuring pressure by ultrasonic technique with a single transducer, and the relative inconsistency in determining the quantity of gas in the bottles by the weighing method, led to a technique of normalizing the measured pressure (by ultrasonic technique) to the original filled bottle weight/pressure at the original filling temperature (70°F). Tests were conducted in a temperature controlled chamber at 40° F, 70°F and 100°F with two government furnished (GFE) APCO bottles (S/N 5016 and 5128) and one Boeing bottle (S/N 3841). A second GFE Boeing bottle was to be tested but was not available in time to complete the tests. Two runs were conducted on each of the APCO bottles using the same test procedures as before except weight measurement of the mass of gas in the bottle and each ultrasonic measurement was preceded by taking a reading from an ultrasonic calibration reference standard to compensate for possible small null shifts in the instruments. The bottle was filled to 5000 psig at room temperature, placed in the environmental chamber at 70°F and bottle temperature, pressure, and time-to-first-peak were recorded after reaching equilibrium. The chamber temperature was decreased to 40°F and bottle temperature, pressure, and time-to-first -peak were recorded after reaching equilibrium. Chamber temperature was then increased to 100°F and data was recorded as above after equilibrium was reached. Bottle pressure was reduced by approximately 300 psig and data was recorded as above after equilibrium was reached. The temperature was decreased to 70°F and then to 40°F with the same data recorded as above after equilibrium was reached. This was followed by decreasing bottle pressure by approximately 300 psig and the cycle was repeated. This procedure provided data for ultrasonic pressure measurements for a constant volume and mass of gas at three temperature isotherms. All of the test data was reduced and normalized and the calibration curve for the APCO bottle is presented as Figure 21. Figure 22 is a preliminary calibration curve based on the one Boeing bottle available.

The temperature limit (40°F to 100°F) was selected as the minimum and maximum laboratory temperature range in which a missile would be serviced. Minimum bottle pressure of 4750 psig, normalized to 70°F, is shown on each of the calibration curves as an "accept" or "reject" gage and may be considered as the preliminary minimum allowable pressure for bottle use on a SRAM-A flight at this time. This value was obtained by calculating the pressure using a gas leakage rate of $2.0 \times 10^{-4}$ lbs/year for a minimum period of 10 years (Reference 1). This curve may be used as a "Go/No-Go" curve such that if the measured time-to-first-peak results in a bottle pressure less than 4750 psig when normalized to 70°F, the bottle is unacceptable for use and should be removed from the missile. The finalized minimum acceptable bottle pressure will be determined from the results of a study detailed in reference 2. An example of the use of the curve is shown in Appendix D.

2.2.2.4 EMI Test

One of the tasks to be accomplished in this EA was to perform an EMI test of the ultrasonic equipment to verify safety of use in the immediate vicinity of a SRAM-A missile. An EMI/EMC analysis was conducted in lieu of a test and it was concluded that the energy levels generated by the ultrasonic test equipment (Nortec NDT-150 unit) are 70 to 100 times less than the squib qualification level. There is no danger of EMI firing a squib on the missile. A shorting plug for the helium bottle should be installed before using the helium bottle ultrasonic test equipment as a precautionary measure and is in the instructions in Appendix D. It was concluded that safety margins are sufficiently high to safely operate the equipment on a complete missile.

The full EMI analysis is included in Appendix C.

2.2.2.5 Technical Interchange Meeting (TIM) at Boeing

A Technical Interchange Meeting was held at Boeing Aerospace in Kent, Washington, on 16 September 1987, as part of the OC-ALC Quarterly Review. The ultrasonic measuring technique was demonstrated to Boeing and OC-ALC personnel during the review in the SRAM-A Systems Integration Laboratory (SIL). A bottle with a live squib (Boeing S/N 3749) installed on a production configured ground test missile was used. The measurement technique was also demonstrated to Boeing management on 1 October 1987 in the SRAM-A SIL. Pressure was also measured on a bottle with a live squib (APCO S/N 5045) installed on a ground test missile using a single ultrasonic transducer as a transmitter and receiver. This illustrated successful pressure measurement with a single transducer. Only the missile shroud required removal from the missile for taking a pressure measurement.

2.2.2.6 Prototype Test Fixture and Instructions for Use

A molded plastic prototype test fixture with the specified single ultrasonic transducer was designed, built and tested and is illustrated in Figure 23. The fixture, with its transducer, may be attached to either the APCO bottle or the BOEING bottle at any convenient location and held in place by two small magnets imbedded in the fixture. Installation of the test fixture on a bottle installed on a missile is shown in Figure 24. This frees the operator to manipulate the portable electronic equipment required to detect and readout the ultrasonic pressure signals. No perceptible differences in readout were noted when placing the fixture at different locations on the bottles. A sketch of the original concept of the test fixture is shown in Figure 25.

The electronic equipment, which is used to process and readout the ultrasonic signal, may be mounted in a 35 to 40 pound metal case the size of a large breadbox (8 3/4"wide x11 1/2"high x23"deep) and can be easily transported on a small cart as shown in Figure 26. The measurement system meets the objective of portability. The electronic equipment is standard off-the-shelf laboratory equipment which is illustrated in Appendix D. Instructions for measuring pressure with the necessary electronic equipment used in these tests as well as an example for its use are contained in Appendix D. An early model of the recommended NDT-150 equipment is shown in Figure 27. Components used in the tests and the recommended components are listed below:

| COMPONENT | USED IN TEST | RECOMMENDED |
|---|---|---|
| 1. Ultrasonic instrument system with CRT display | NORTEC NDT 150 | NORTEC NDT 150 |
| Pulser/receiver | NORTEC NDT 153P | NORTEC NDT 153P |
| Gate module | NORTEC NDT 158P | NORTEC NDT 154 |
| Sweep/time base | NORTEC NDT 151P | NORTEC NDT 151P |
| 2. Transducer, 10 MHZ, 1/4" flat | Panametrics V312 | Panametrics V312 |
| 3. Cable | Endevco 3090c | Endevco 3090c |
| 4. Transducer fixture | see Appendix D | see Appendix D |
| 5. Couplant | Ultragel II | Ultragel II |
| 6. Reference standard | see Appendix D | see Appendix D |

### 2.2.2.7 Measurement of Pressure in Production Bottles

Six Boeing production bottles and seven APCO production bottles were measured for pressure using the ultrasonic technique. This was performed with a single transducer system as well as with the two transducers for comparative purposes. The values of these tests are shown in Table 1. Values of time-to first-peak among all Boeing production bottles and among all APCO production bottles are very consistent. When these values, measured with the single transducer, are translated to the calibration curves on Figures 21 and 22 it is seen that pressures are all very close to 5000 psig (at 70°F).

## 3.0 SUMMARY AND CONCLUSION

The flight occurrence of a possible low pressure helium bottle on a flight vehicle (ASAT) and possible indications of low pressure bottles in the Boeing and Hill AFB surveillance program make it imperative that helium pressure be known. SRAM-A must have a pressurized helium bottle to fly its mission.

The two main objectives of this EA were:

1. Determine feasibility of a portable ultrasonic technique for measuring the pressure inside a sealed SRAM helium bottle without removal from the missile.

2. Develop calibration curves and prototype hardware to measure bottle pressure on missiles in the field.

Both objectives were met.

The following conclusions have been drawn from the test results:

A. The non-intrusive ultrasonic technique has proven to be a viable method of measuring pressure inside a sealed SRAM-A helium bottle without removing it from the missile. It is a preferred alternative to the present gravimetric (weighing) method of measuring helium gas pressure in SRAM-A bottles.

B. Measurement of the time for ultrasonic waves to travel from transmitter to receiver (across the helium bottle and back) as a function of gas pressure (time-to-first-peak) is the most accurate, precise, and reproducible of the acoustic gage methods evaluated.

C. Helium bottle pressure may be determined with the use of a single transducer on either APCO or Boeing bottles without removing any parts or components from the missile hydraulic system.

D. A calibration curve has been developed for the APCO bottle and a preliminary curve for the Boeing bottle. Finalized calibration for the Boeing bottle requires one additional bottle be tested for calibration. Separate calibration curves are required for the bottle design of each of the two manufacturers because of the physical differences of wall thickness and alloy microstructure.

E. Procedures for measuring helium pressure have been developed.

F. Prototype hardware has been developed for measuring helium gas pressure in a SRAM-A bottle in the field.

G. The acoustic gage measuring technique can be easily performed in the field by maintenance personnel in a relatively short time. This should result in significantly lower overall costs than weighing the bottles.

H. Impurity levels in the helium gas, up to 10 ppm, do not affect the results for this time-to-first-peak method of determining helium pressure.

I. Presently used weighing methods of determining helium weight are not as accurate as the acoustic gage techniques.

J. Labor involved in the current method of removing the helium bottle for weighing, and cleaning, weighing, mixing and applying adhesive, reinstalling the bottle, purging, and leak-checking the hydraulic system is significantly higher than using the ultrasonic technique.

K. Helium bottle S/N 3841, thought previously to be 14% low, was found to be approximately 5000 psig.

## 4.0 RECOMMENDATIONS

A. OC-ALC should approve a follow-on EA for testing the second Boeing helium bottle to provide a finalized calibration curve for the Boeing bottles. A TIM to Hill AFB to demonstrate the ultrasonic measuring technique on a missile in the field should be included.

B. Conduct an ultrasonic pressure measurement of the helium bottle during scheduled Level One tests.

C. Conduct an ultrasound pressure measurement of the helium bottle on the missile whenever the aft cover is removed.

D. OC-ALC/Hill AFB/BAFB should acquire the recommended components listed in paragraph 2.2.2.6 for ultrasonic pressure measurement and ultrasound all FCAA's in overhaul at Hill AFB.

E. OC-ALC should recommend to the Air Force to procure the necessary equipment to perform the tests described in RECOMMENDATIONS B and C.

## REFERENCES

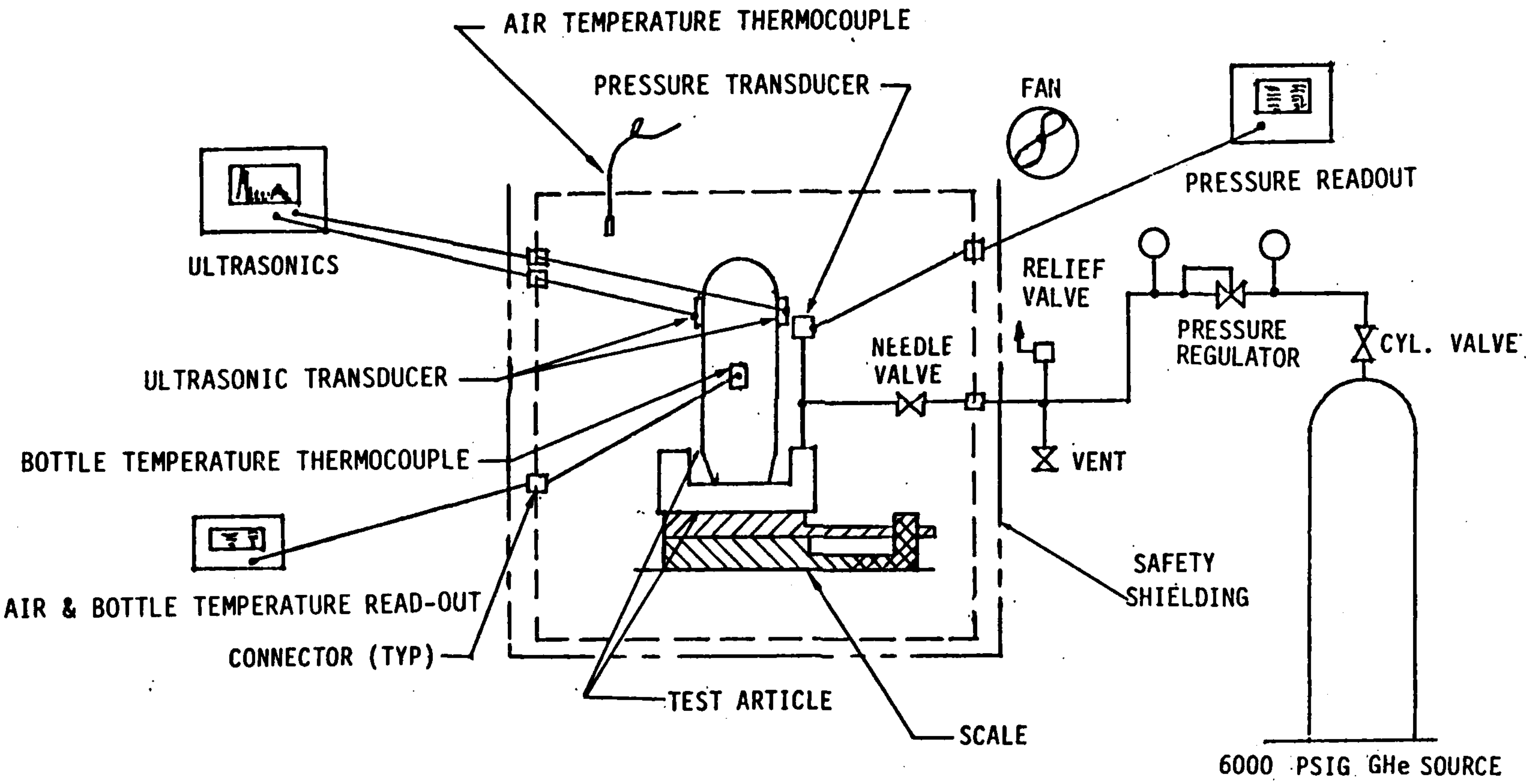
1. Technical Order T.O. 9H2-8-5-3, OVERHAUL INSTRUCTIONS-FLIGHT CONTROL ACTUATOR ASSEMBLY (ELECTRICAL, HYDRAULIC, AND PNEUMATIC), P/N 25A43111, Section 3-13

2. EA 87-7-1-24, HELIUM BOTTLE AND ACCUMULATOR/REGULATOR ASSEMBLY ANALYSIS AND PRESSURIZATION TESTING

3. Patent Disclosure A88-057, ULTRASONIC MEASUREMENT OF GAS PRESSURE IN SEALED PRESSURE VESSEL

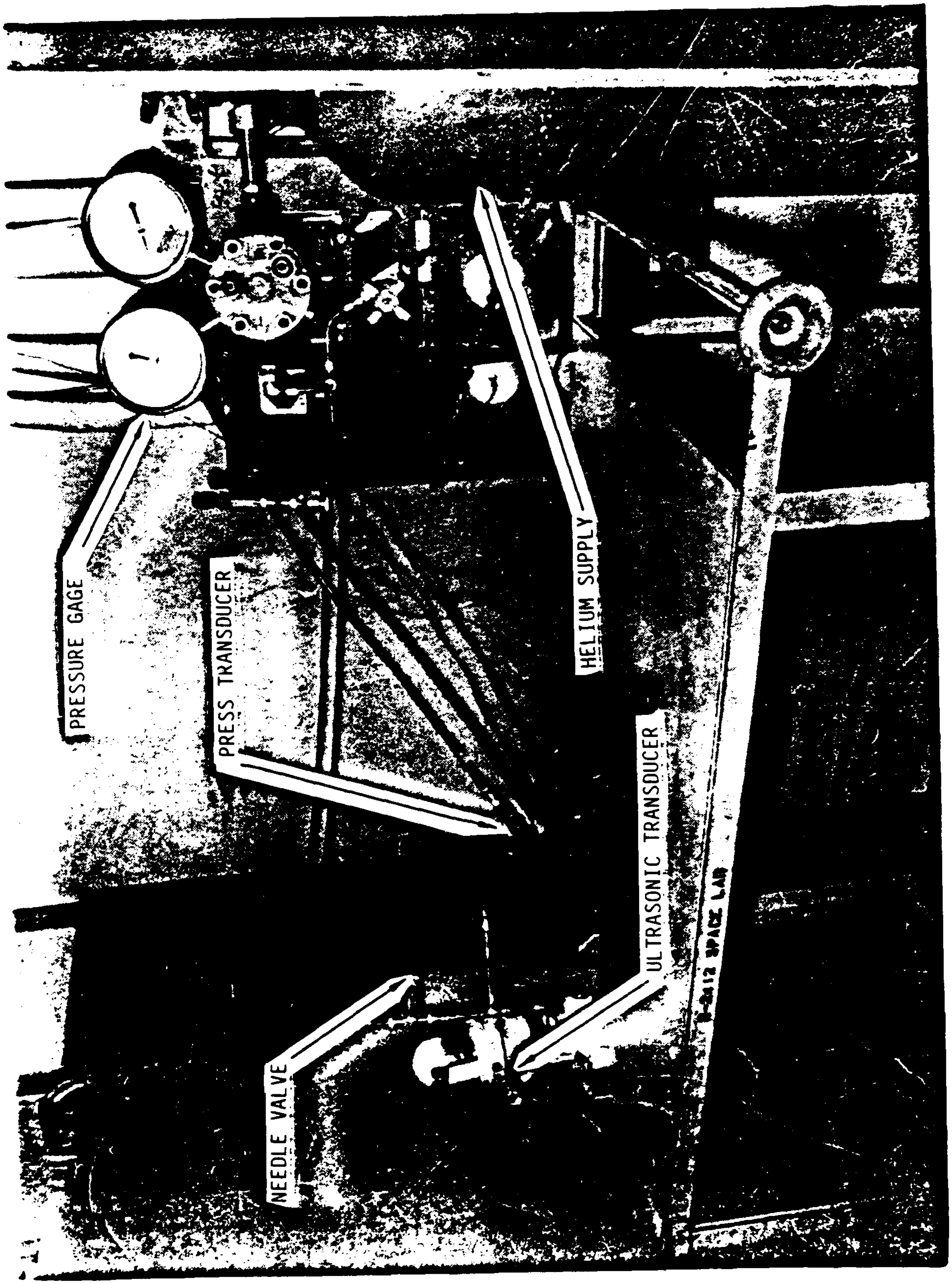
4. EA 87-7-1-3 Final Letter Report, FCAA HELIUM BOTTLE 10-YEAR SUSTAINED PRESSURE LOAD, SURVEILLANCE TESTING

# FIGURES



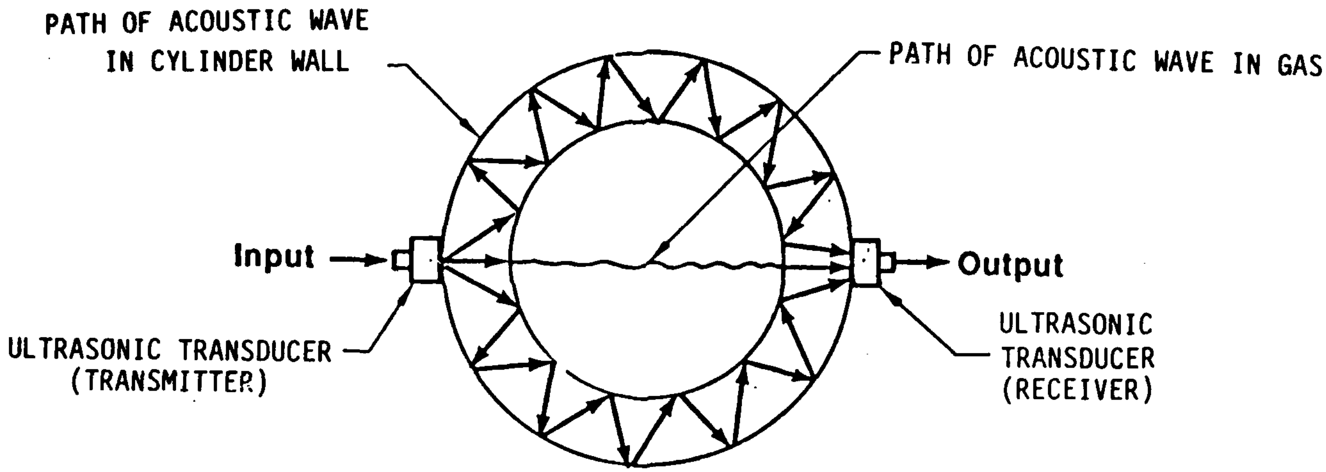

TEST CONFIGURATION
FIGURE 1

**BOEING**




HELIUM BOTTLE IN TEST SET-UP

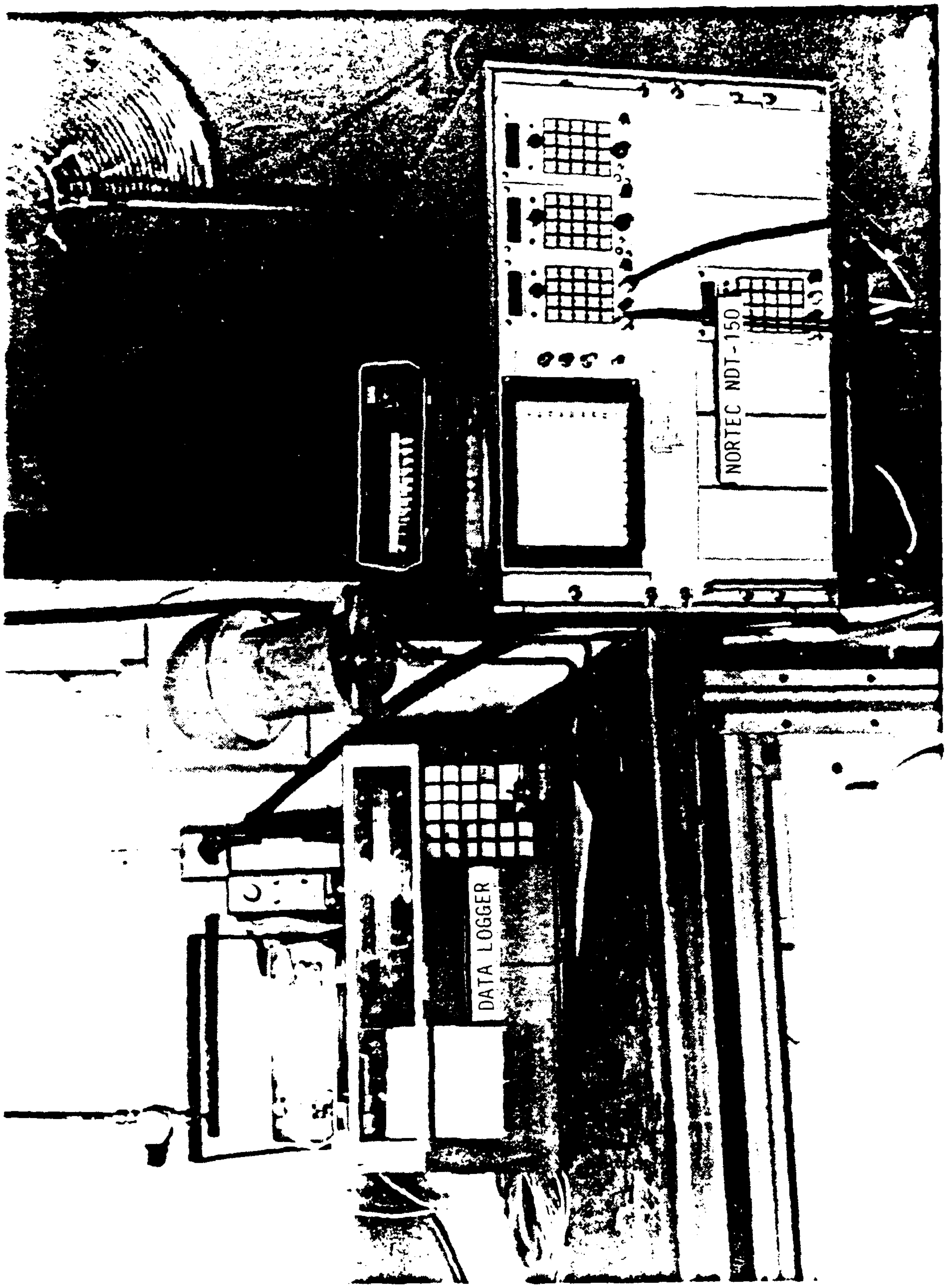
FIGURE 1A



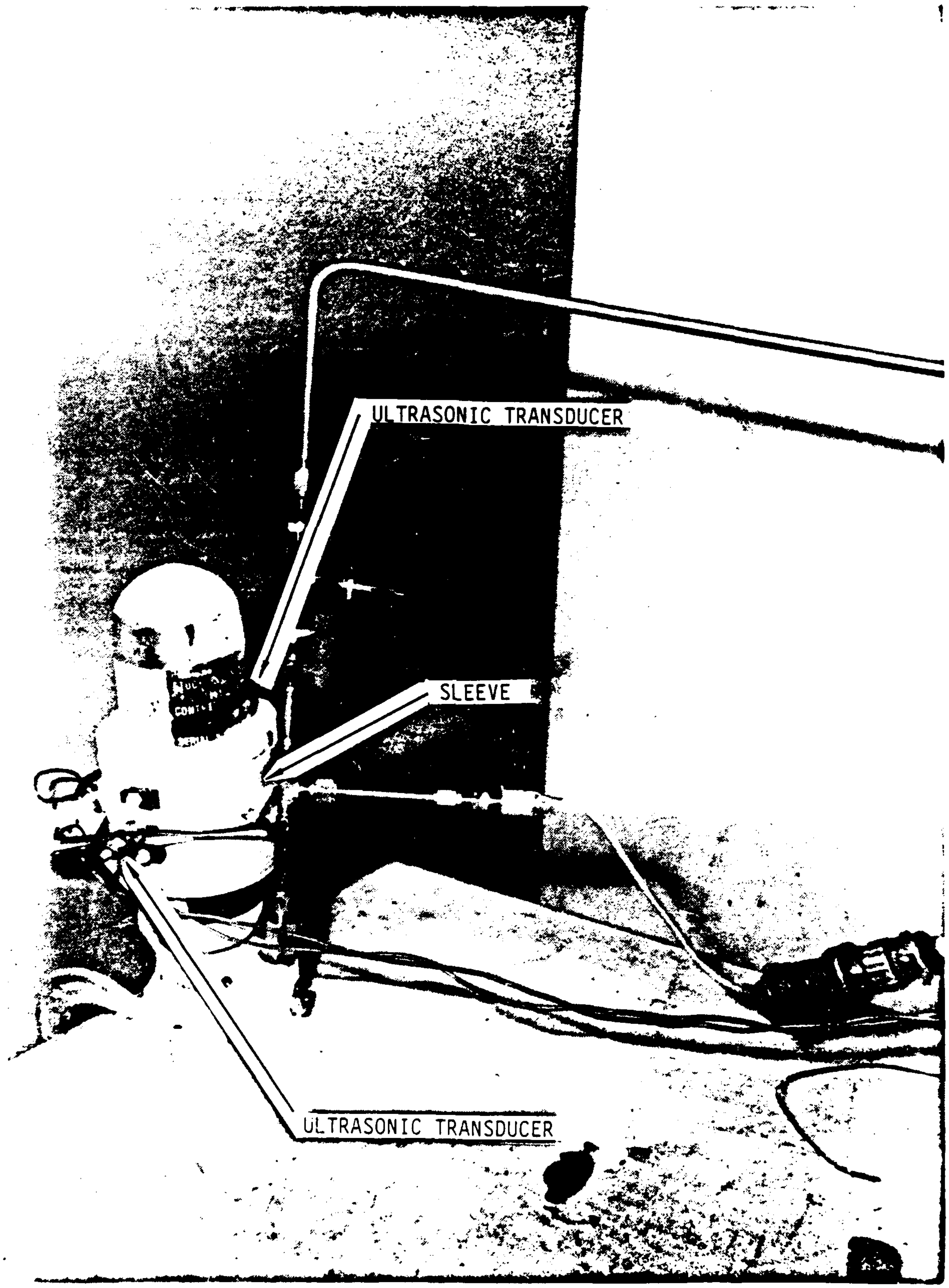

VARIABLES AFFECTING ACOUSTIC SIGNATURE:
- WALL THICKNESS
- ALLOY (MICROSTRUCTURE)
- BOEING/APCO DIFFERENCES

**ULTRASONIC TECHNIQUE APPROACH**

**FIGURE 1B**

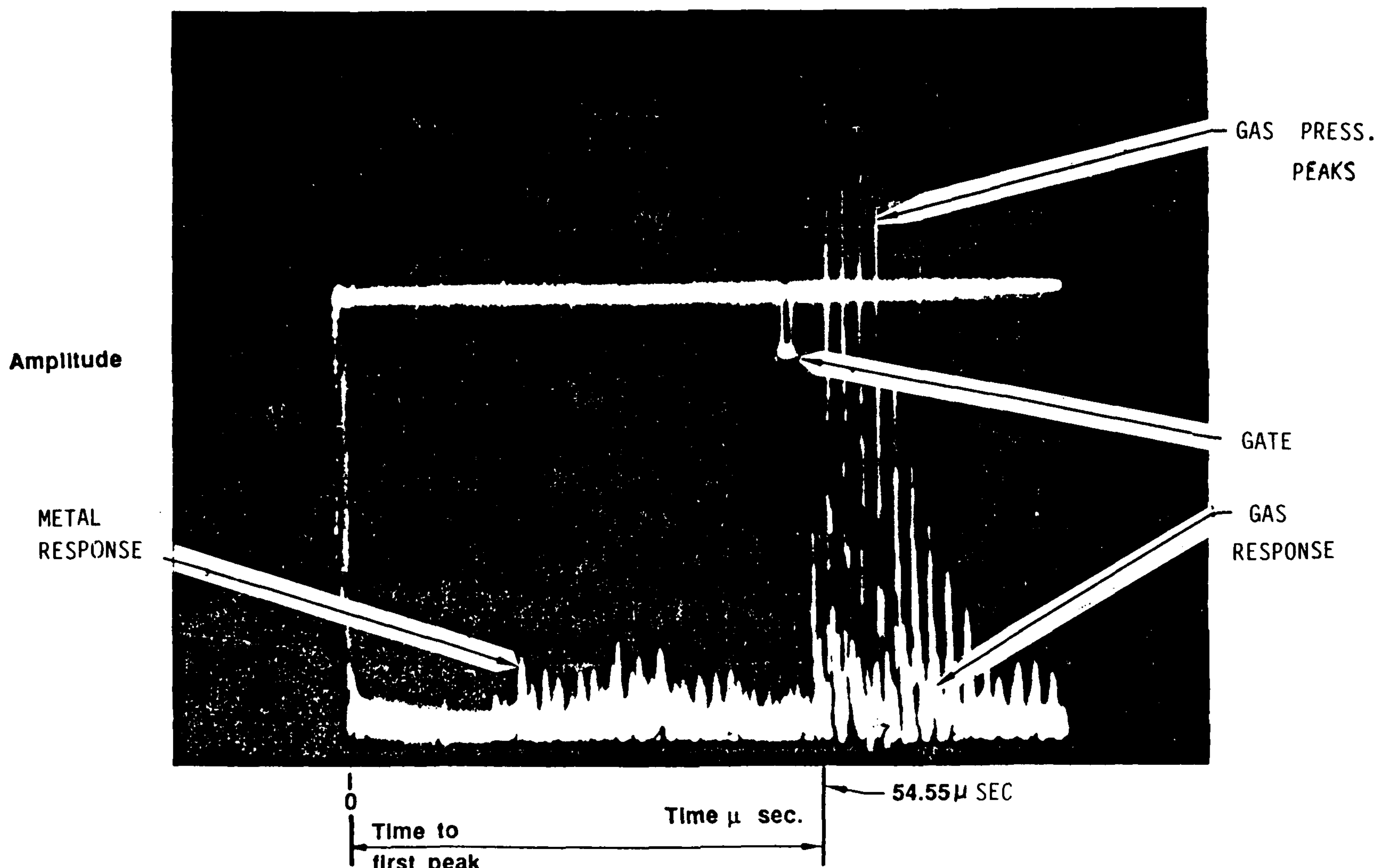



MONITORING EQUIPMENT




TEST ARTICLE WITH TWO TRANSDUCERS INSTALLED

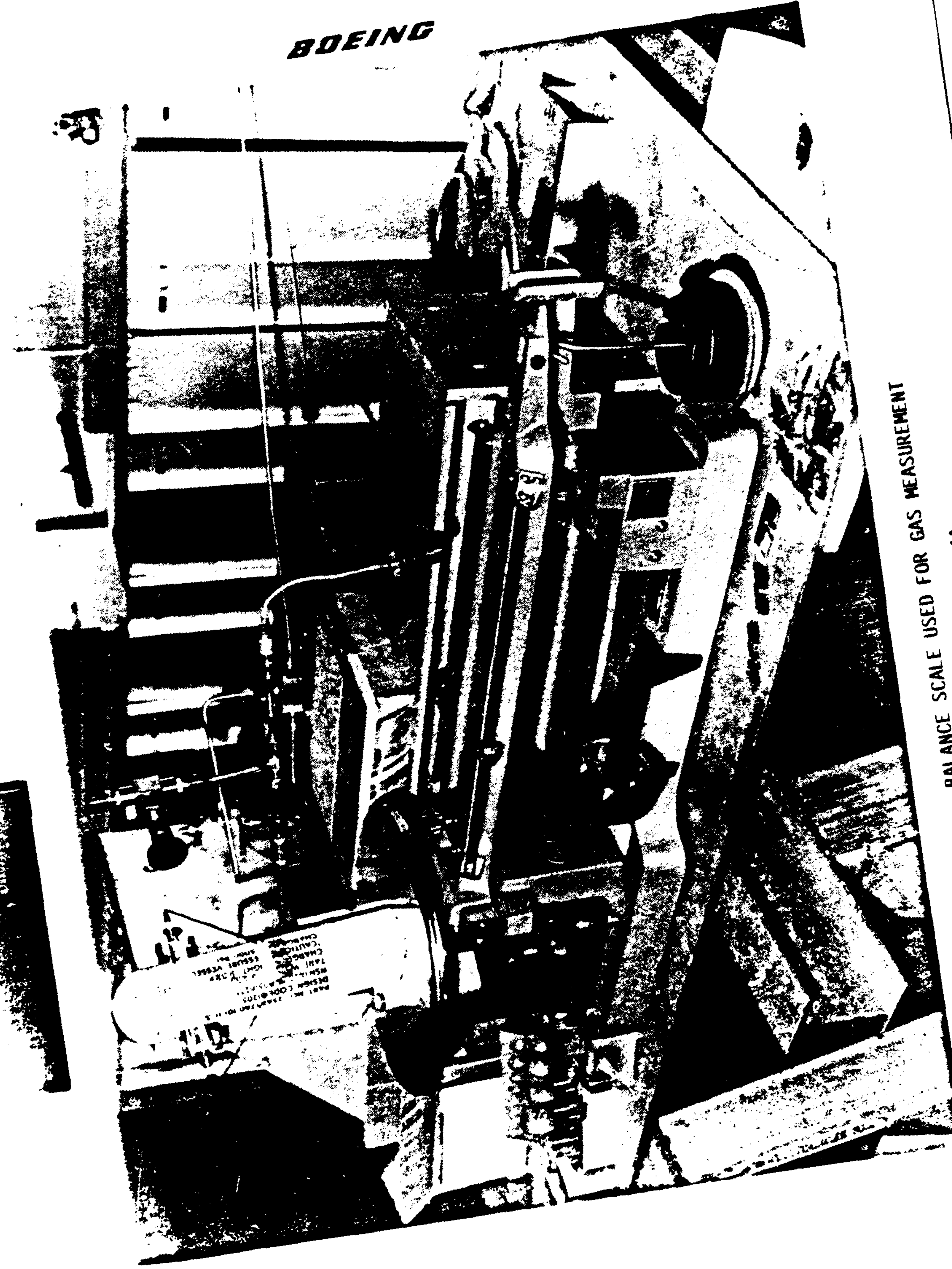
FIGURE 3




4,560 PSIG Helium
f=5MHZ INPUT
APCO BOTTLE S/N 5016
ULTRASONIC SIGNAL TRAVEL TIMES

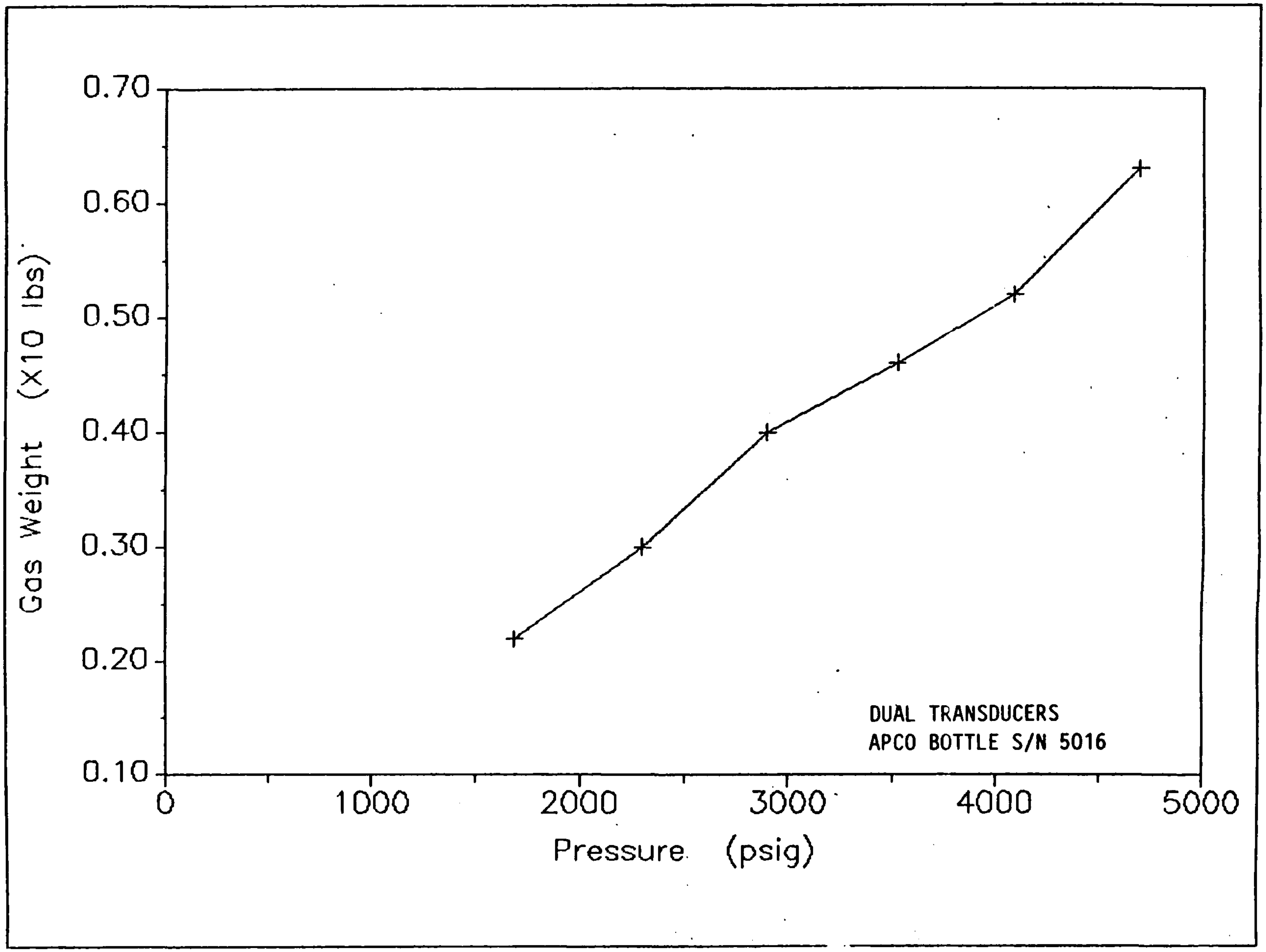
FIGURE 4

BOEING

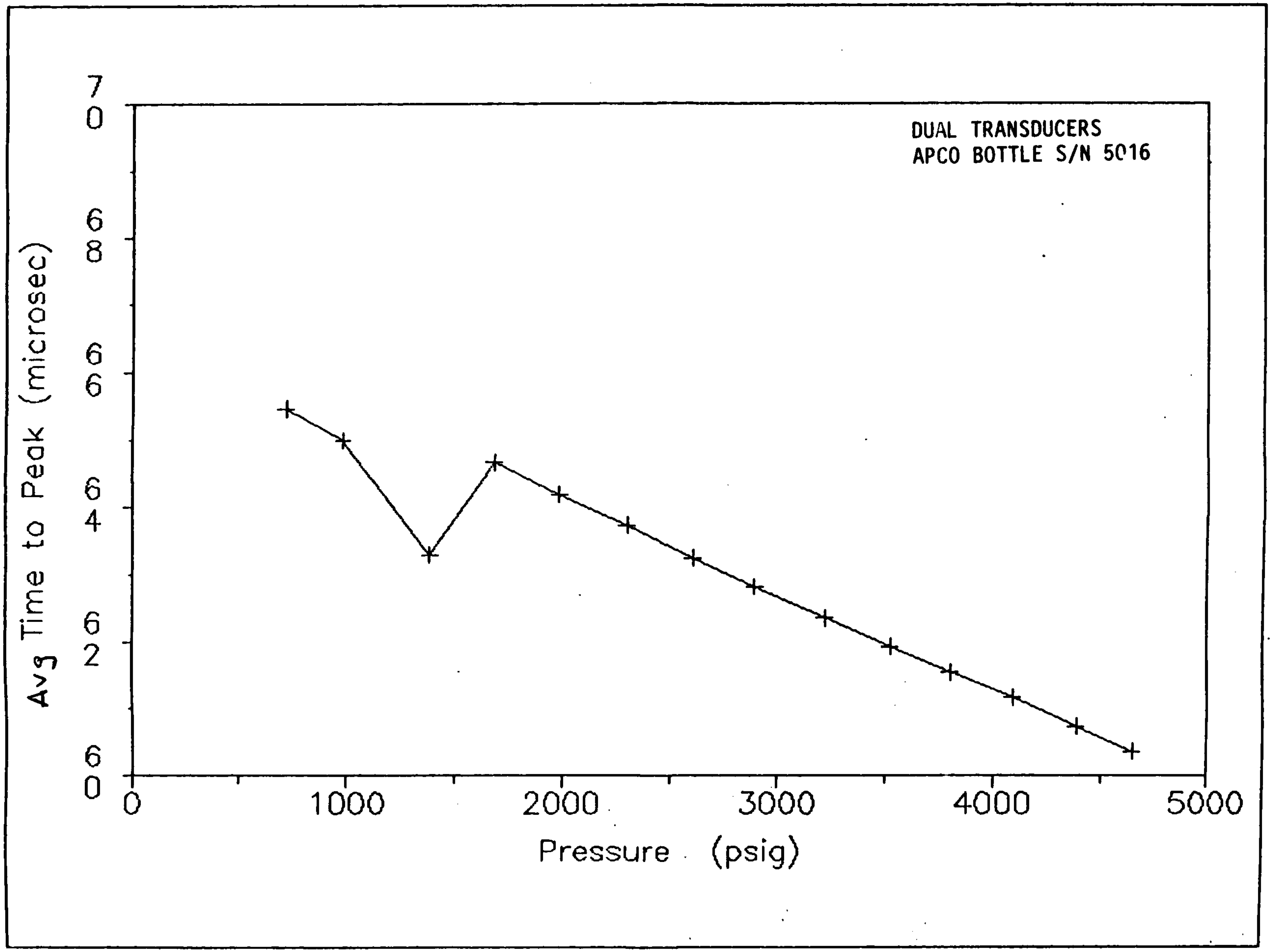


BALANCE SCALE USED FOR GAS MEASUREMENT

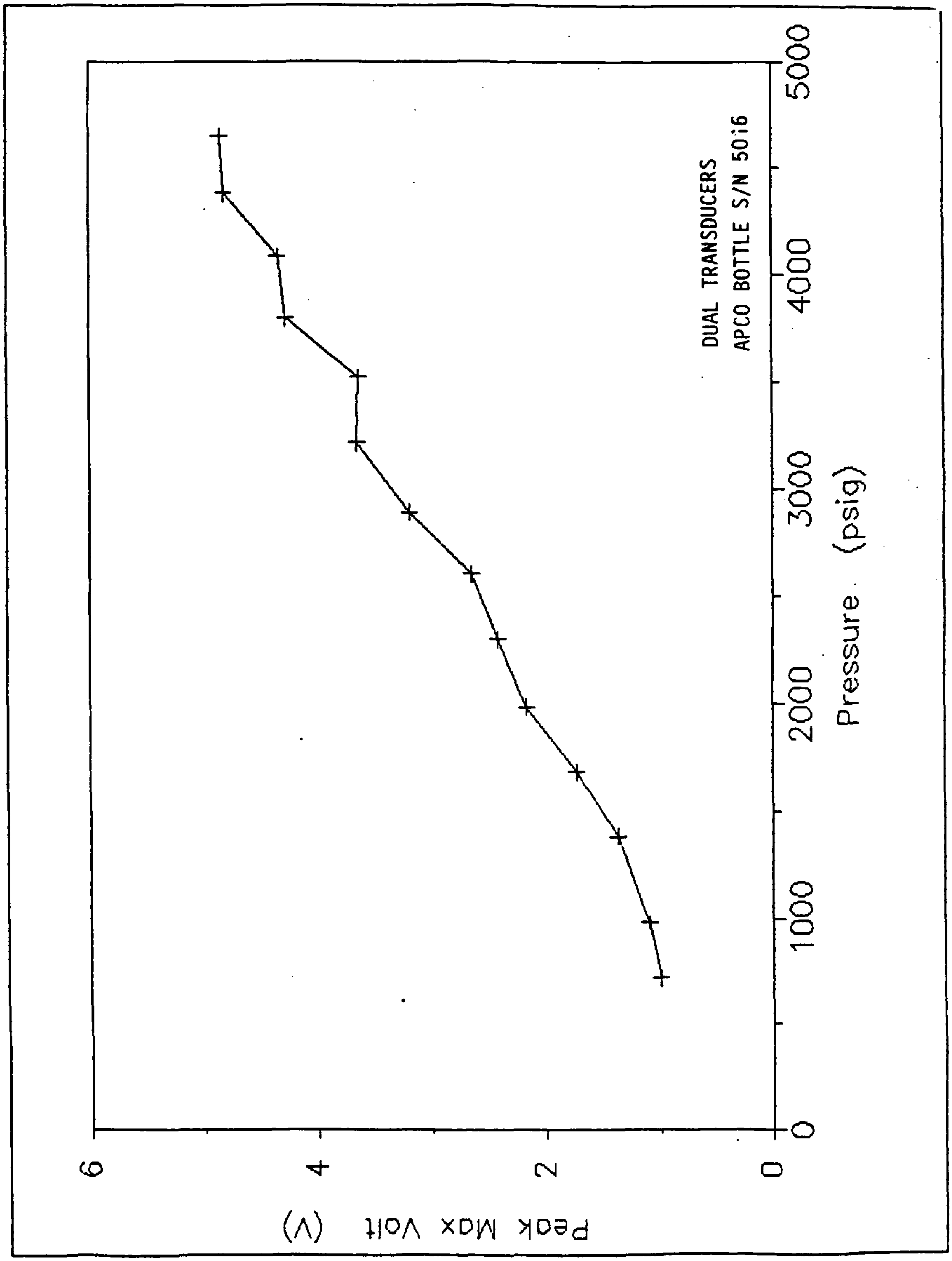
FIGURE 4A



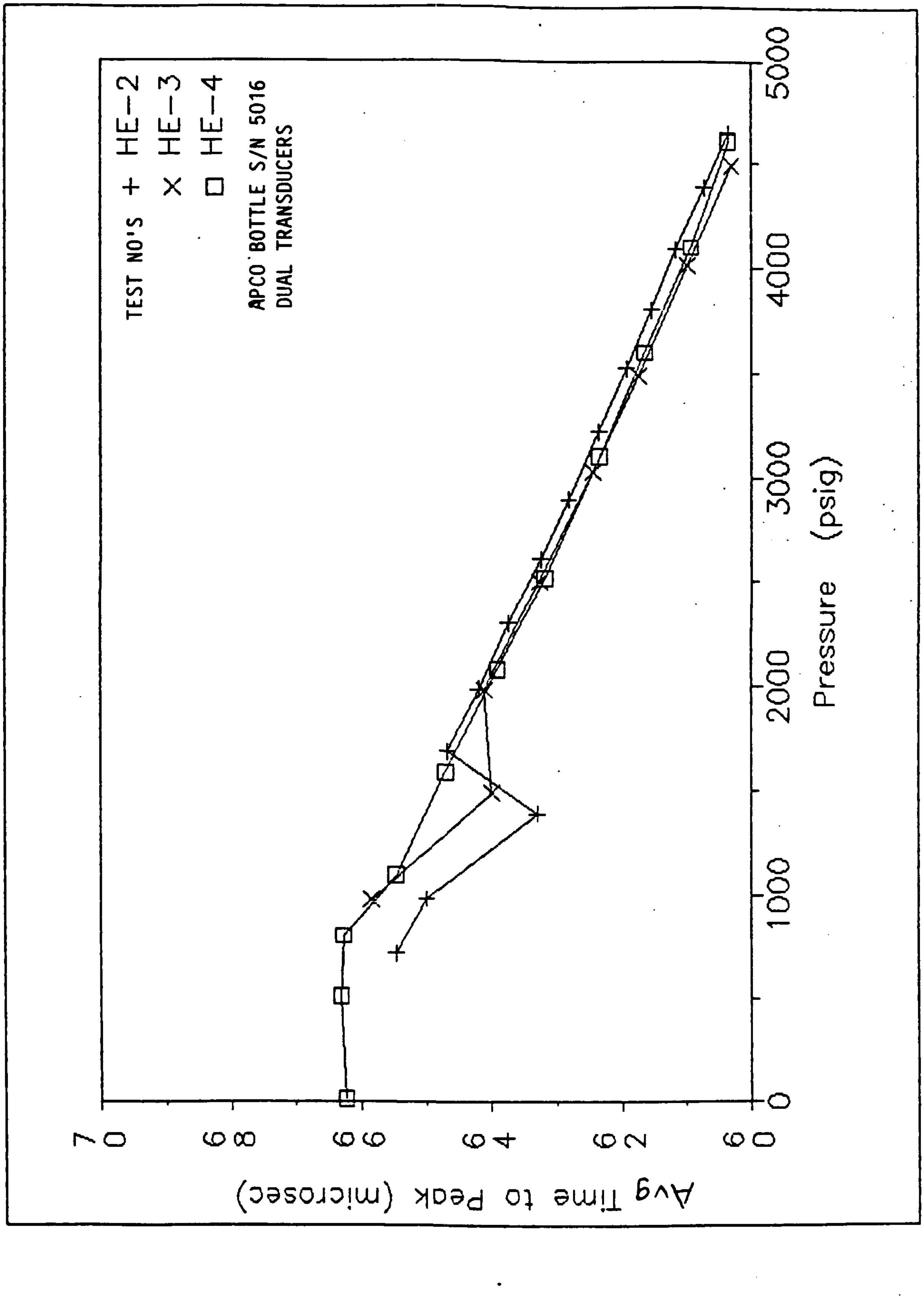

**HELIUM WEIGHT VS PRESSURE (He-2)**
**FIGURE 5**



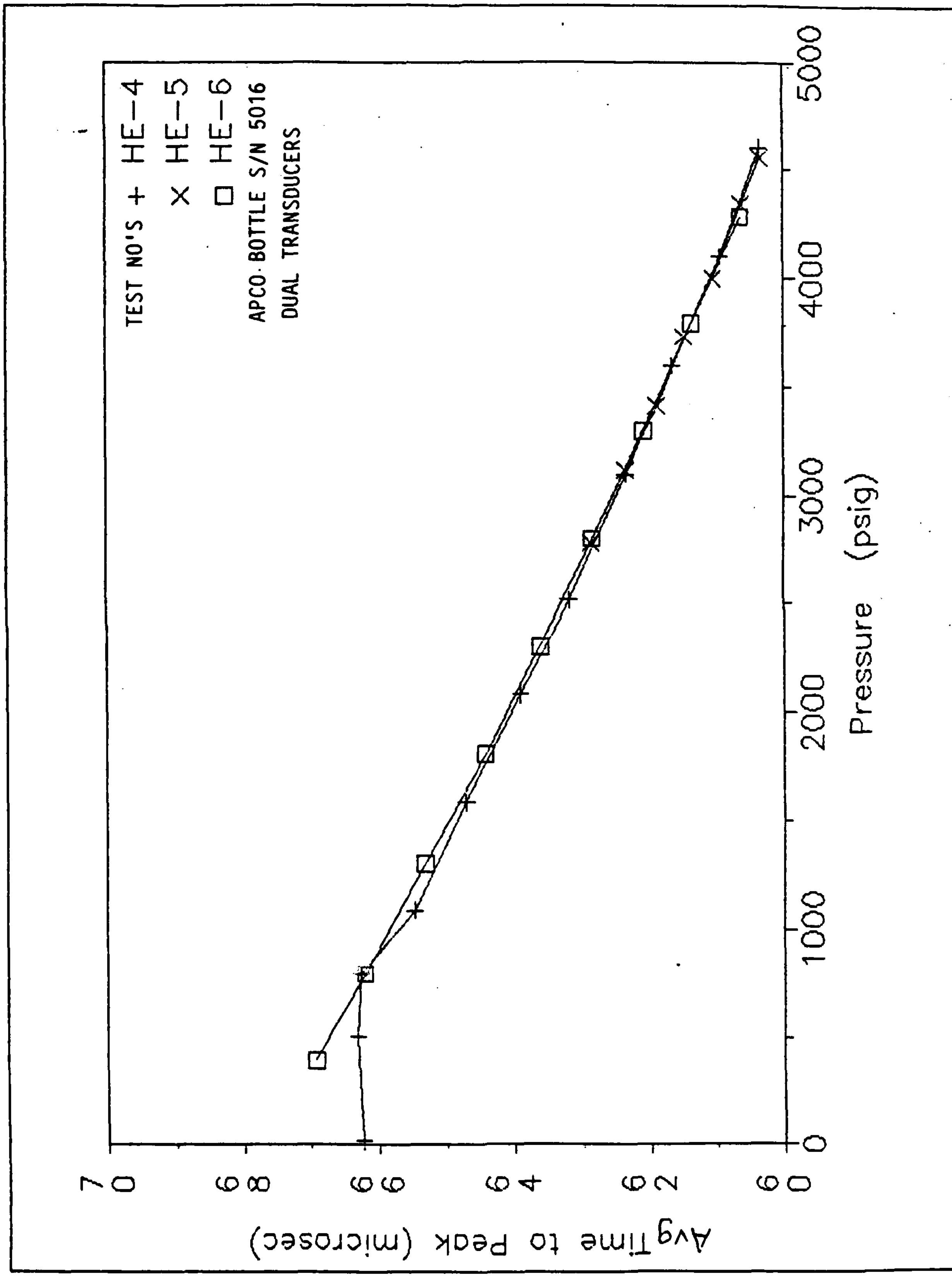

**PRESSURE VS TIME TO PEAK (He-2)**
**FIGURE 6**



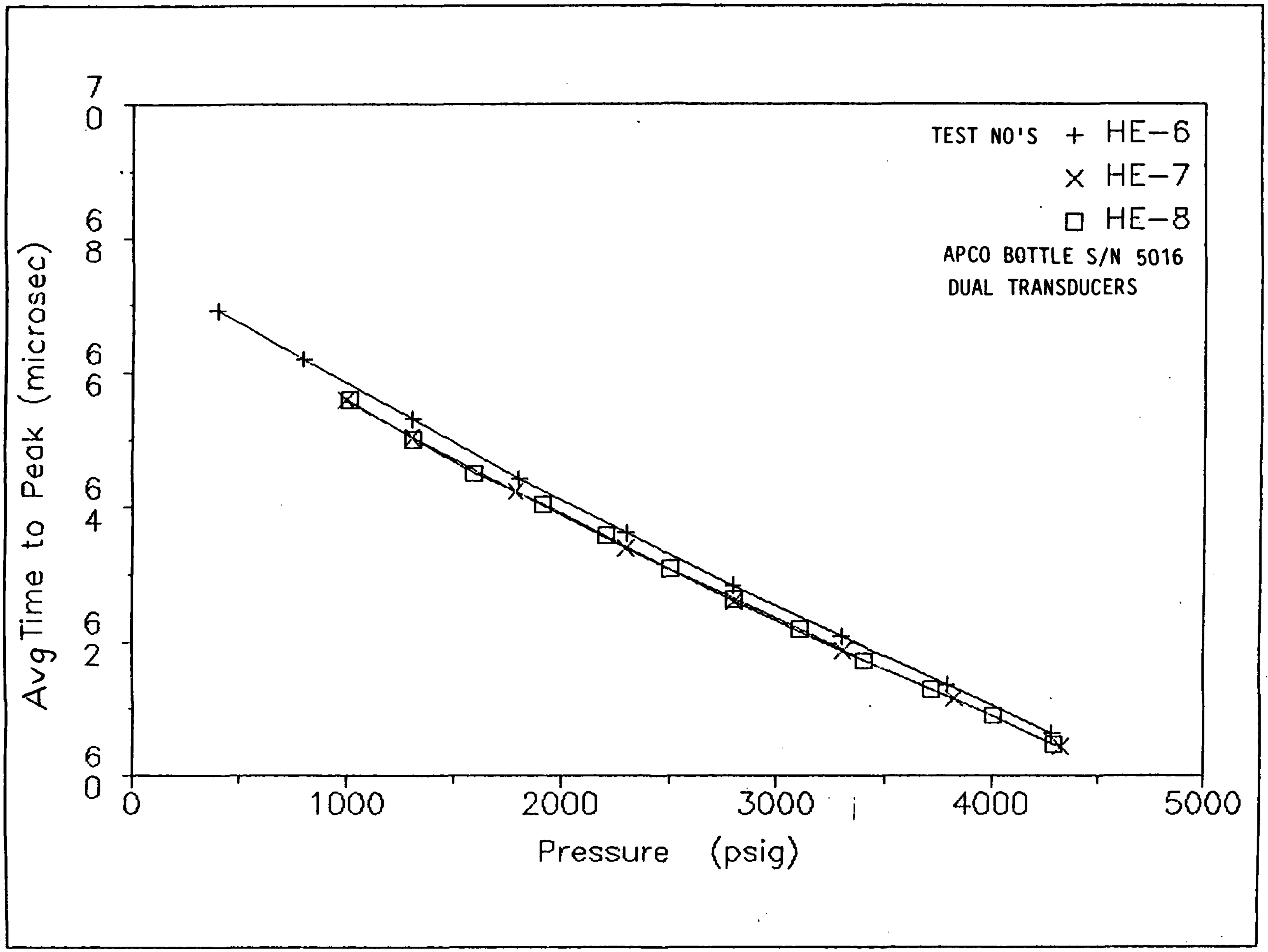

PRESSURE VS PEAK MAX VOLTAGE (He-2)
FIGURE 7



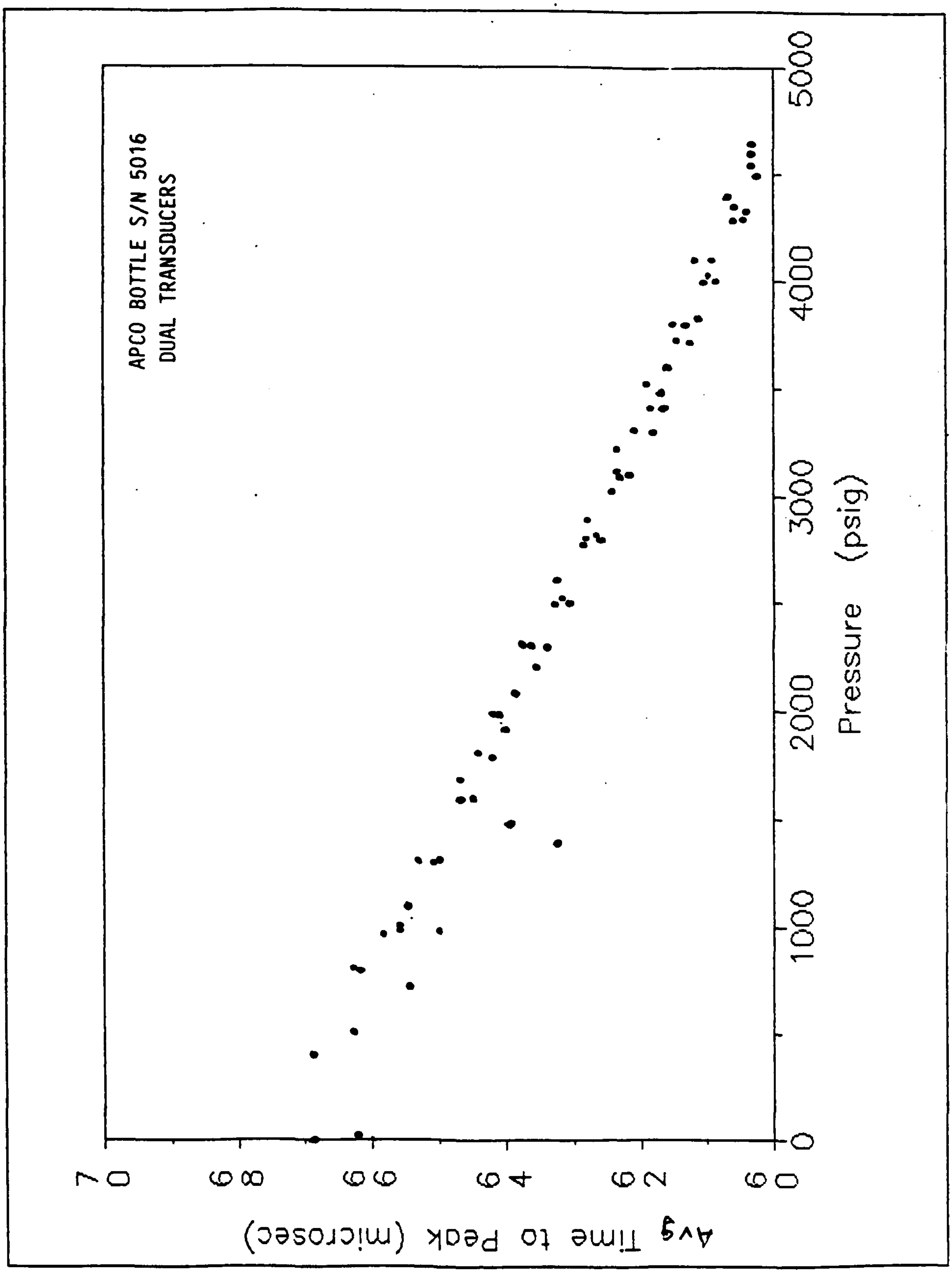

**PRESSURE VS TIME TO PEAK (He-2, -3, -4)**
**FIGURE 8**



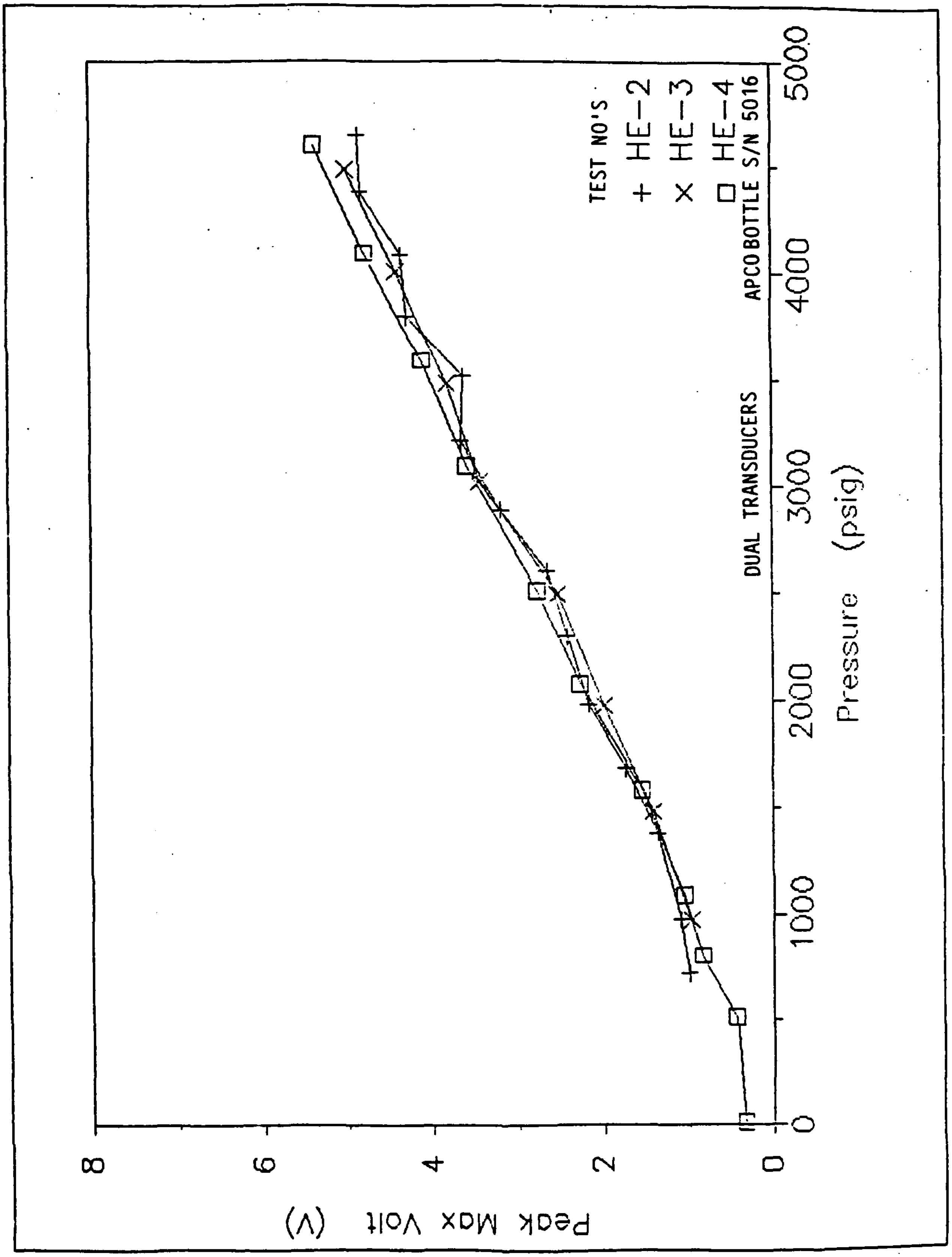

PRESSURE VS TIME TO PEAK (He-4, -5, -6)
FIGURE 9



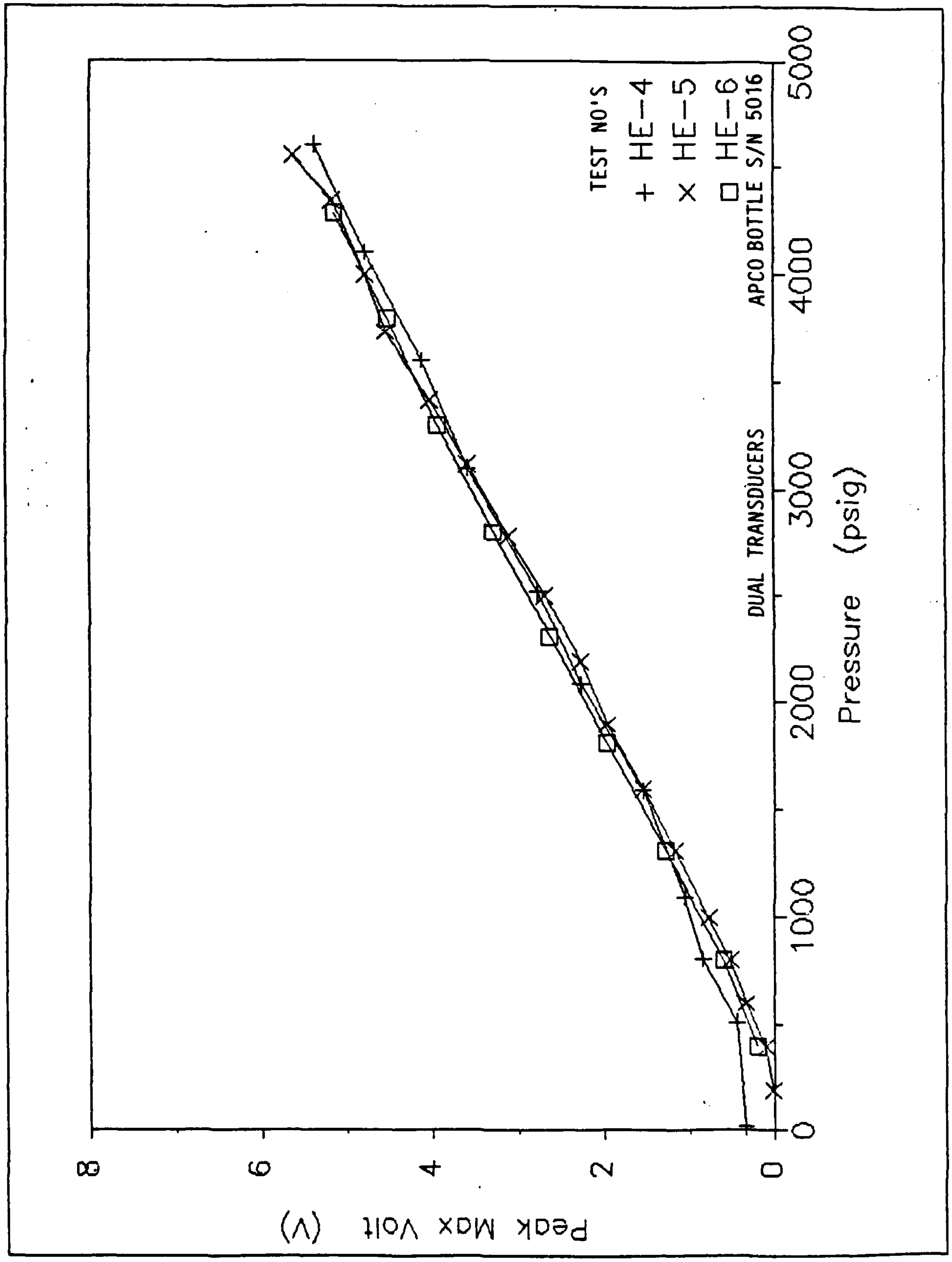

**PRESSURE VS TIME TO PEAK (He-6, -7, -8)**
**FIGURE 10**




**PRESSURE VS TIME TO PEAK (He-2, -3, -4, -5, -6, -7, -8)**
**FIGURE 11**




PRESSURE VS PEAK MAX VOLTAGE (He-2, -3, -4)
FIGURE 12




**PRESSURE VS PEAK MAX VOLTAGE (He-4, -5, -6)**
**FIGURE 13**

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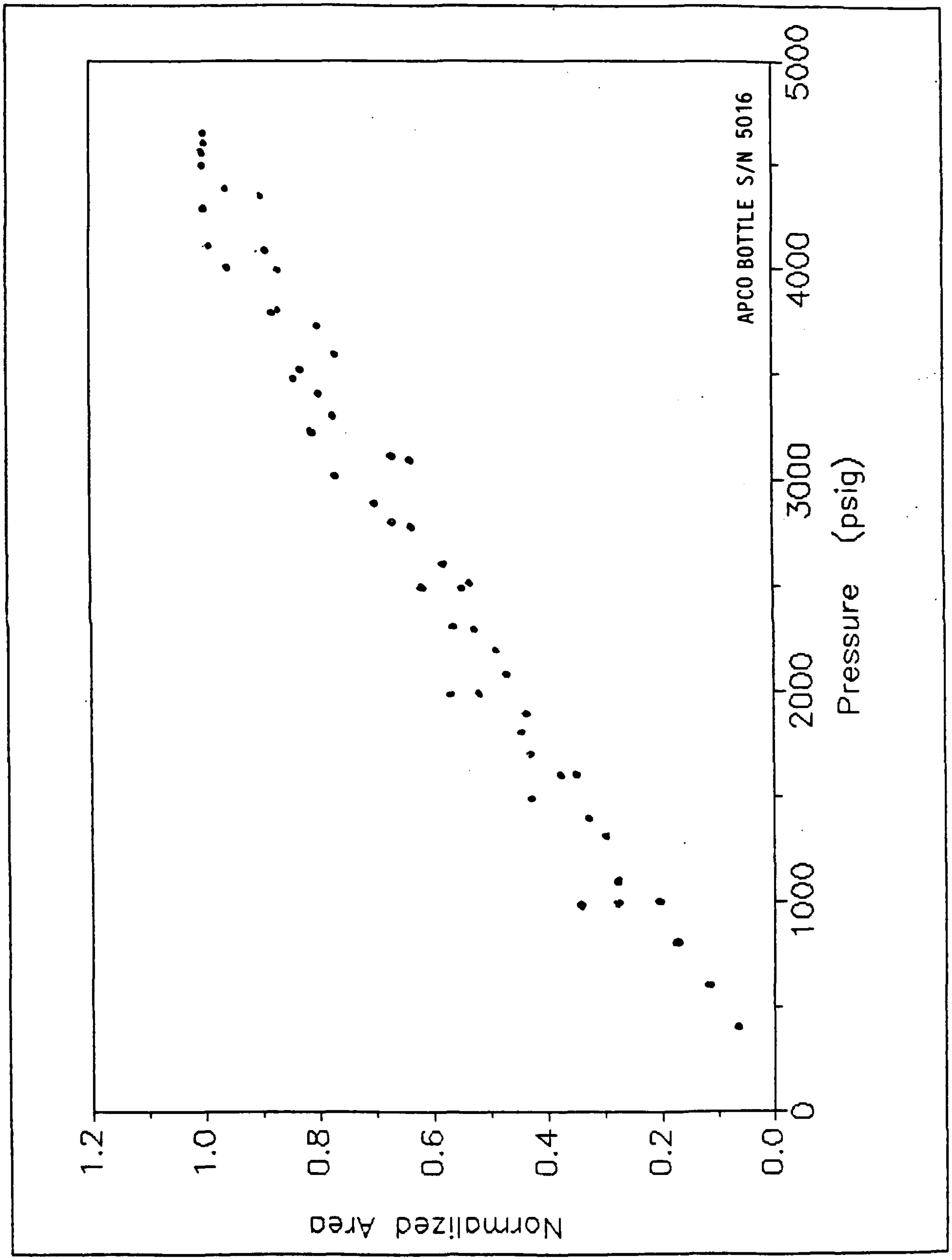
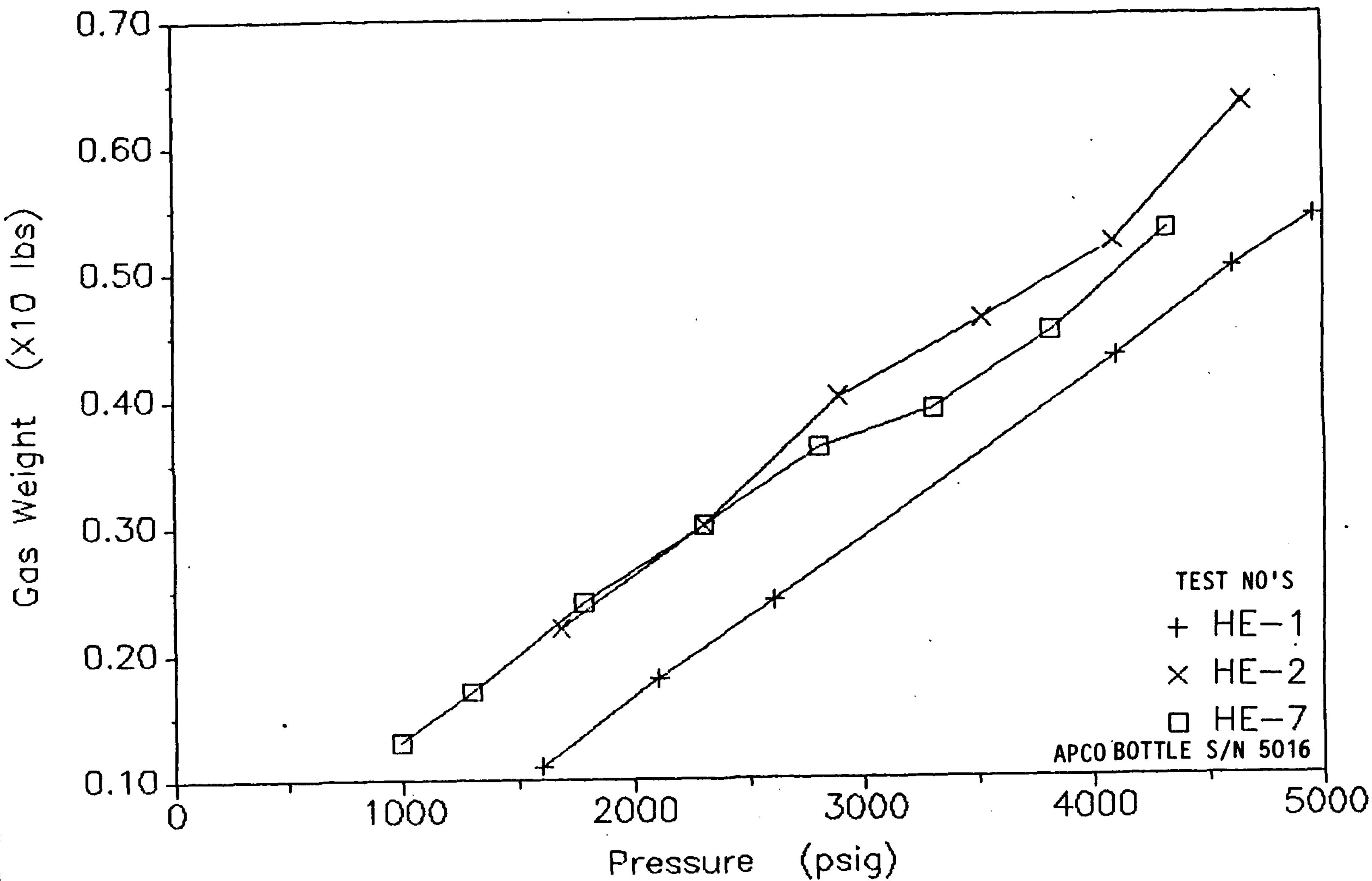
Figure 14

THIS FIGURE DELETED

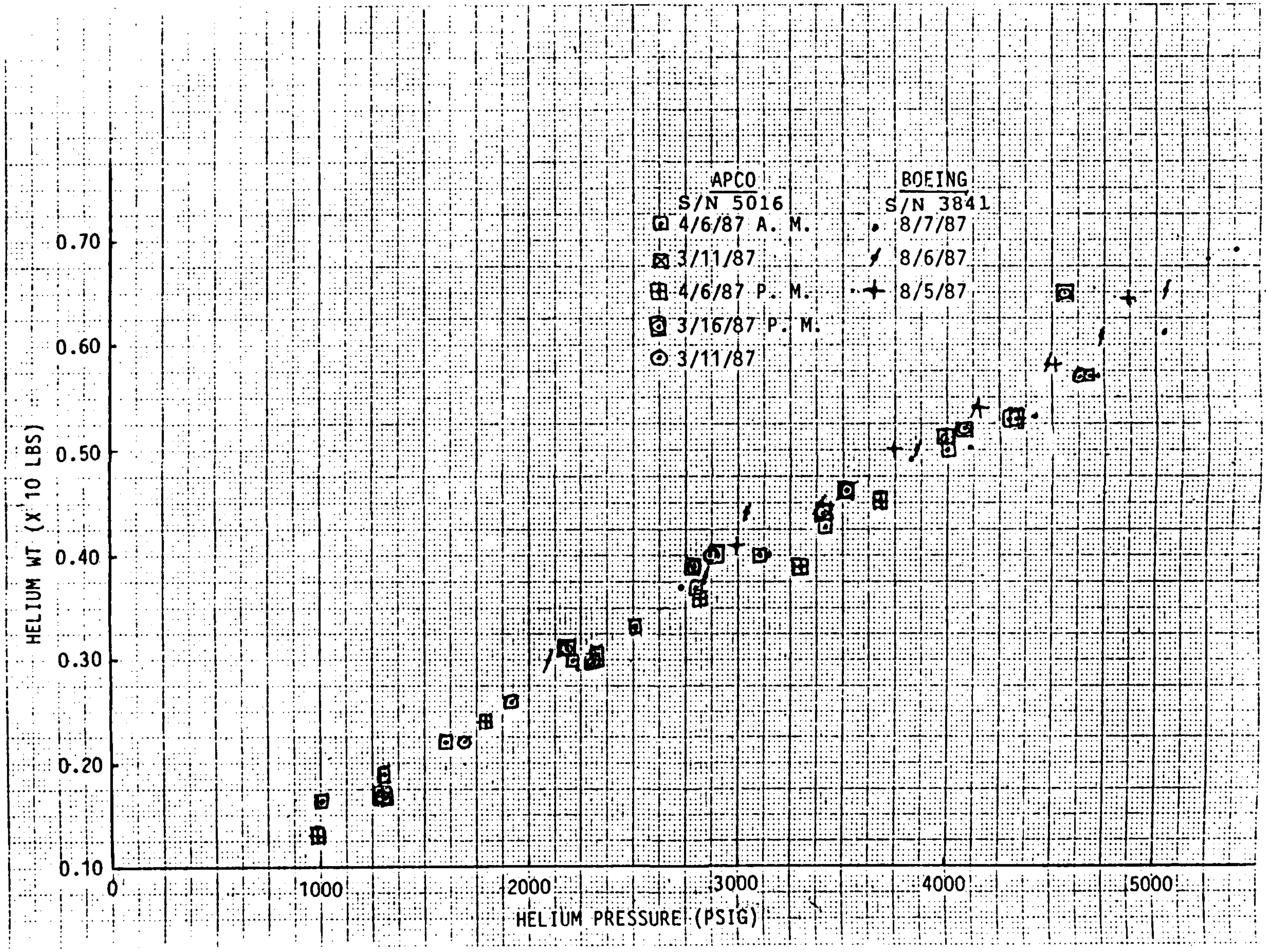
Figure 15



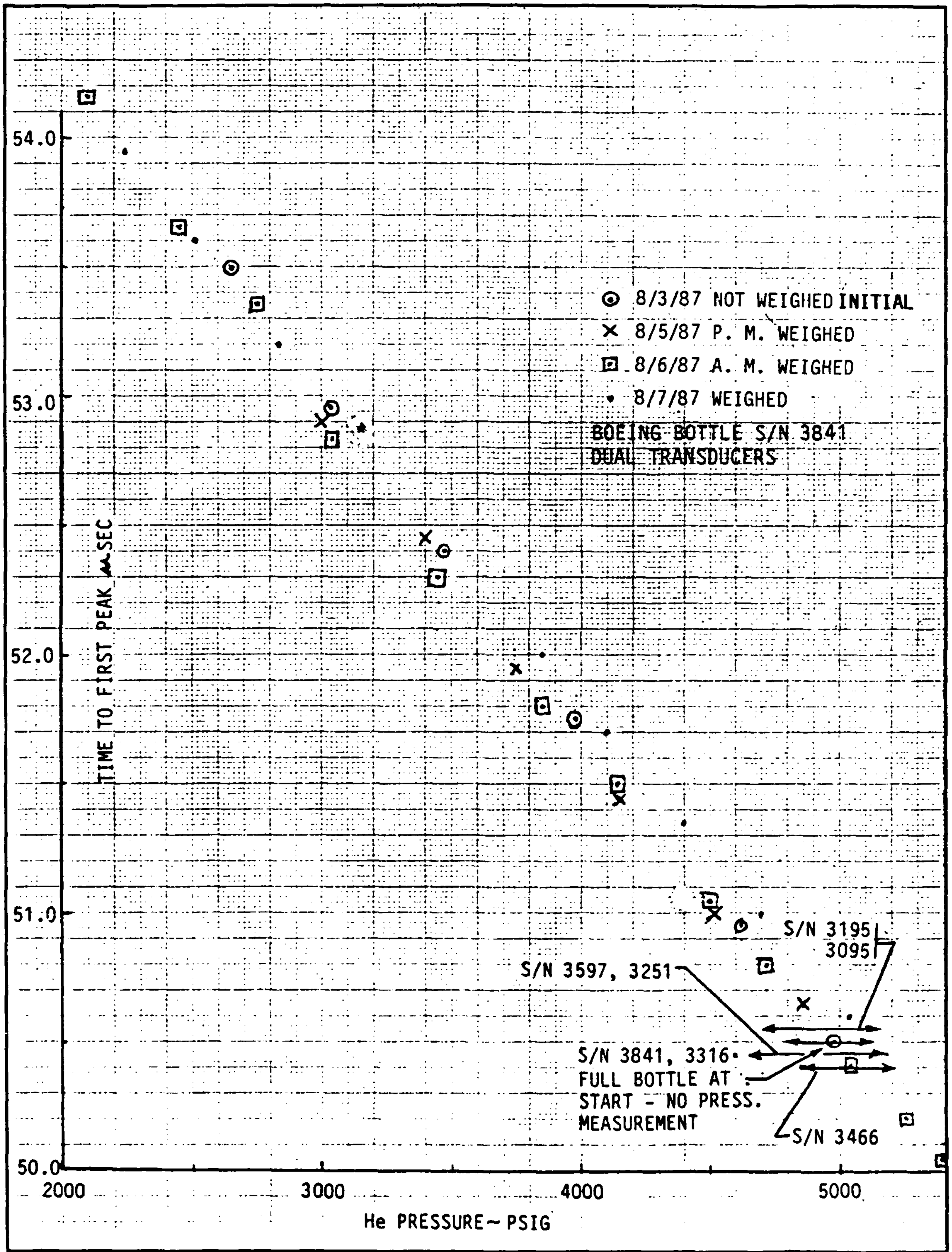

NORMALIZED PEAK AREA VS PRESSURE (He-2, -3, -4, -5, -6)
FIGURE 16




**HELIUM WEIGHT VS PRESSURE (He-1, -2, -7)**
**FIGURE 17**

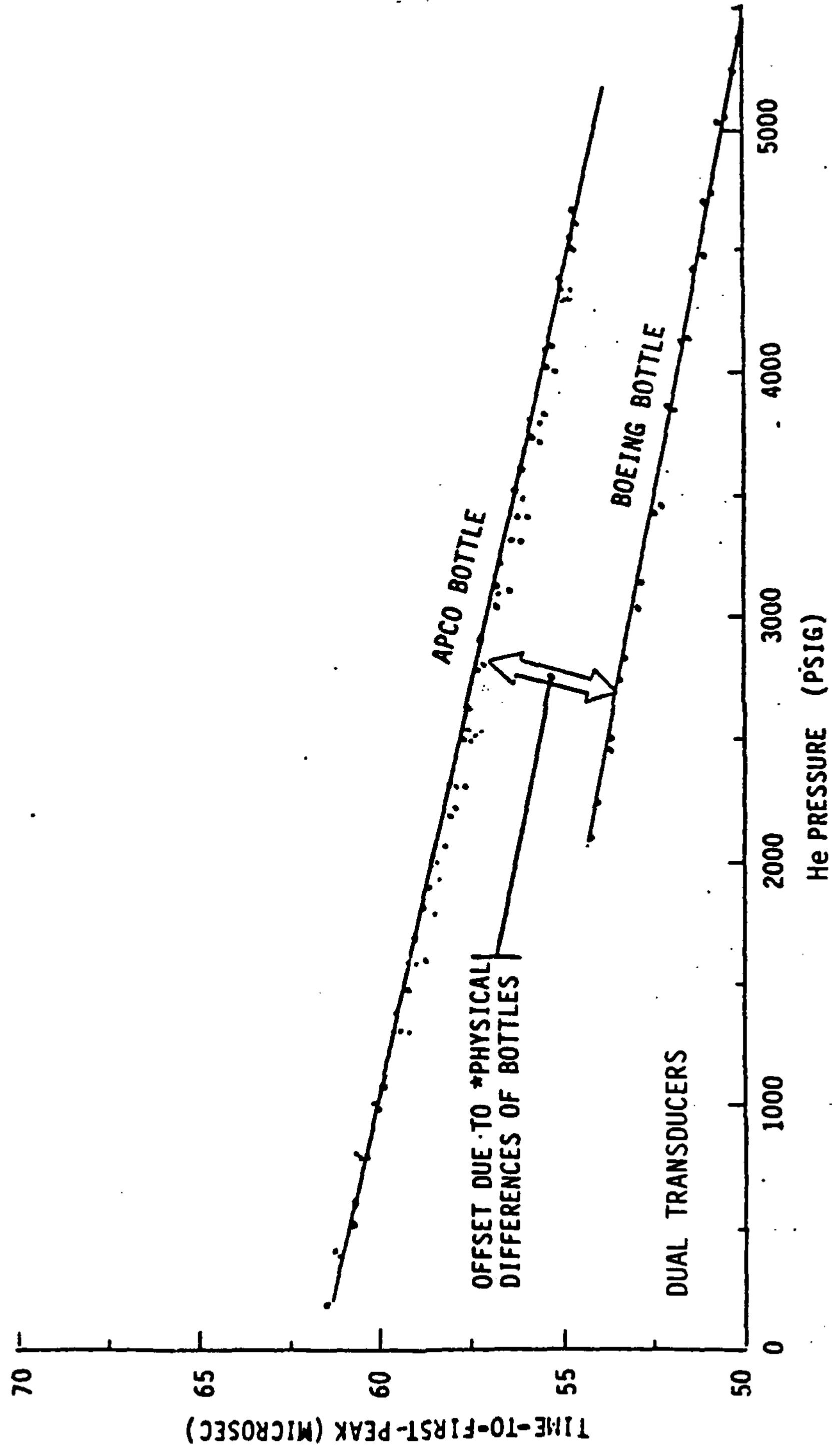



HELIUM WEIGHT VS PRESSURE - APCO & BOEING CALIBRATION DATA
FIGURE 17A



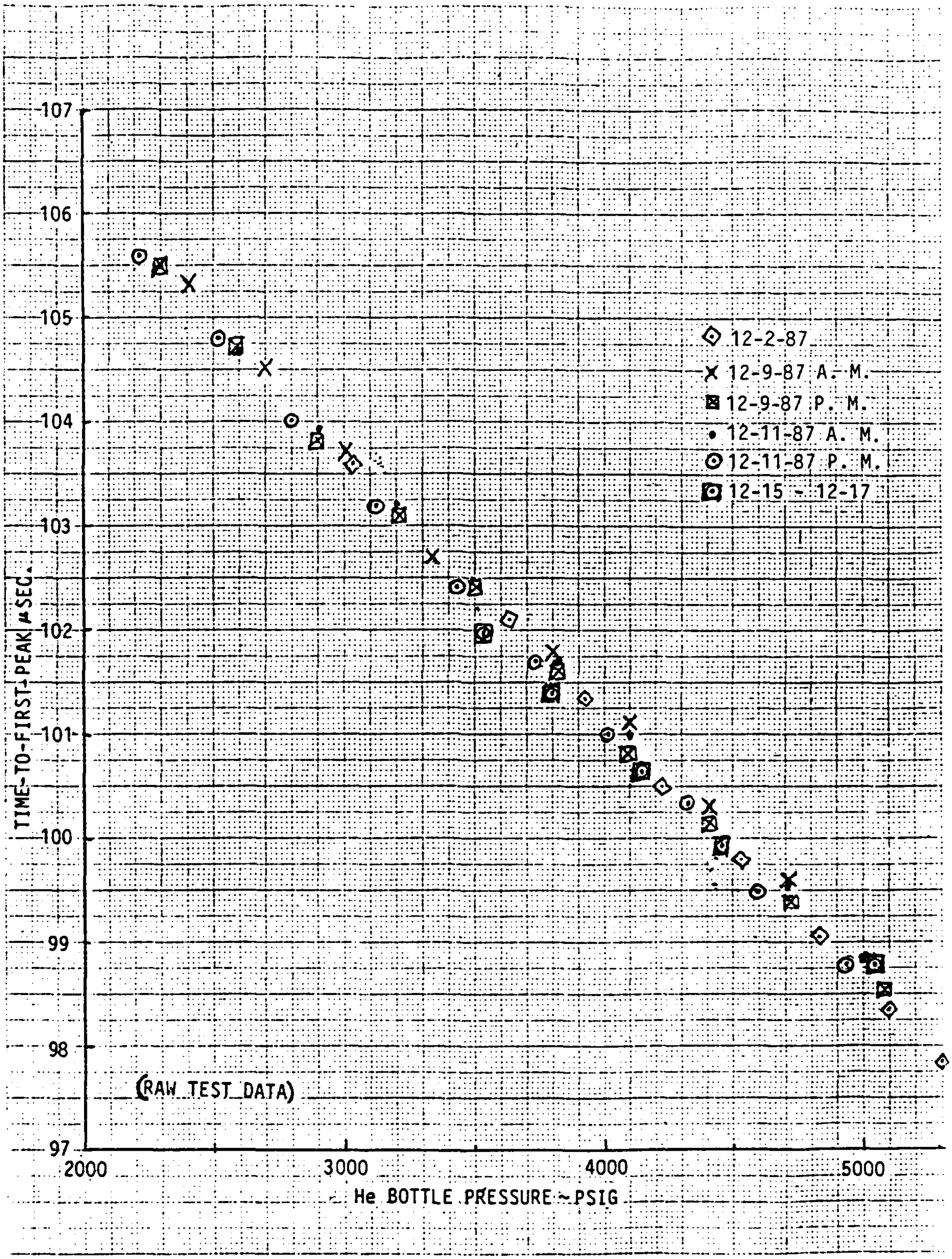

TIME-TO-FIRST-PEAK VS He PRESSURE, ULTRASONIC MEASUREMENT, S/N 3841

FIGURE 18

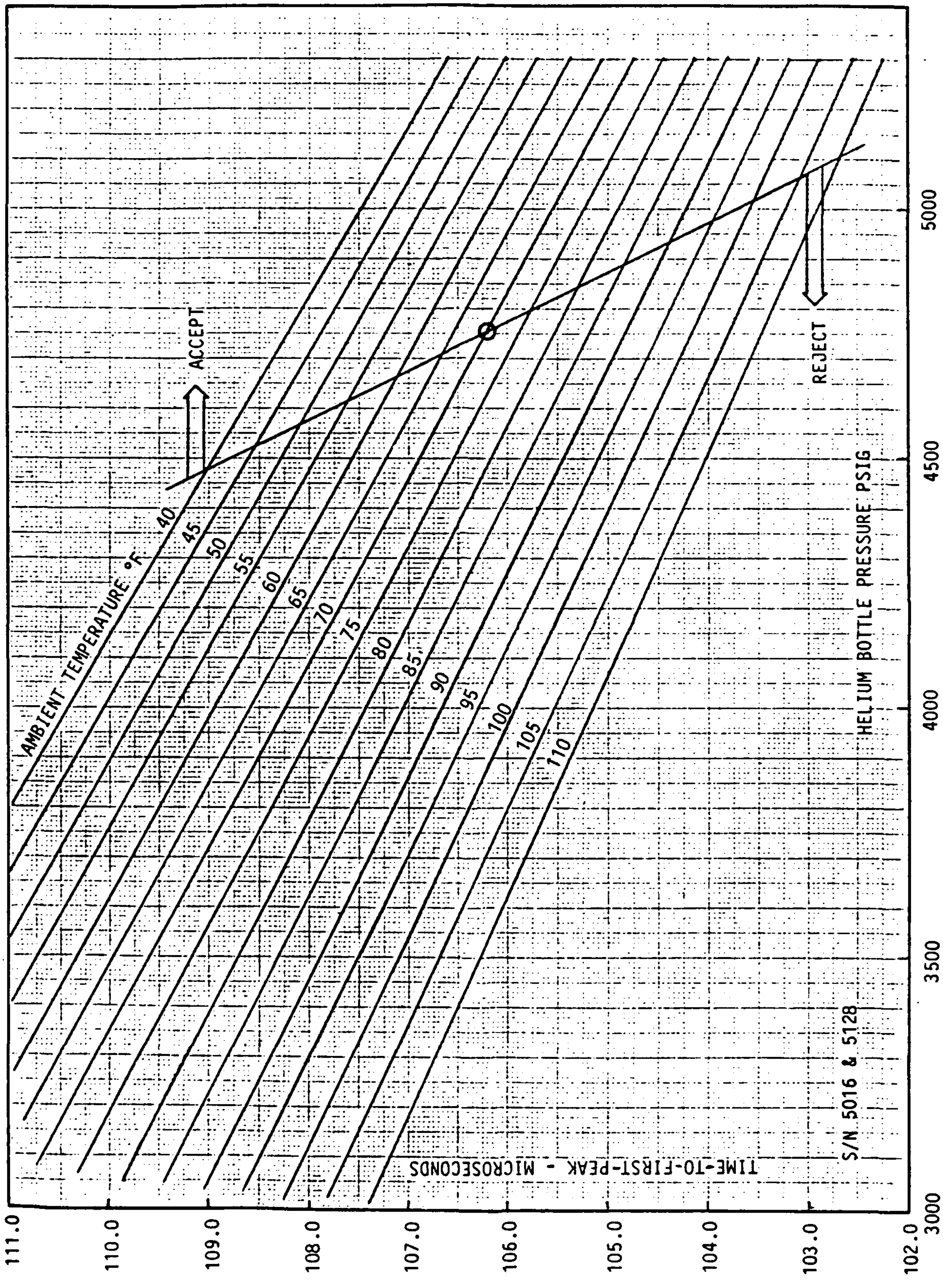



*WALL THICKNESS, ALLOY MICROSTRUCTURE

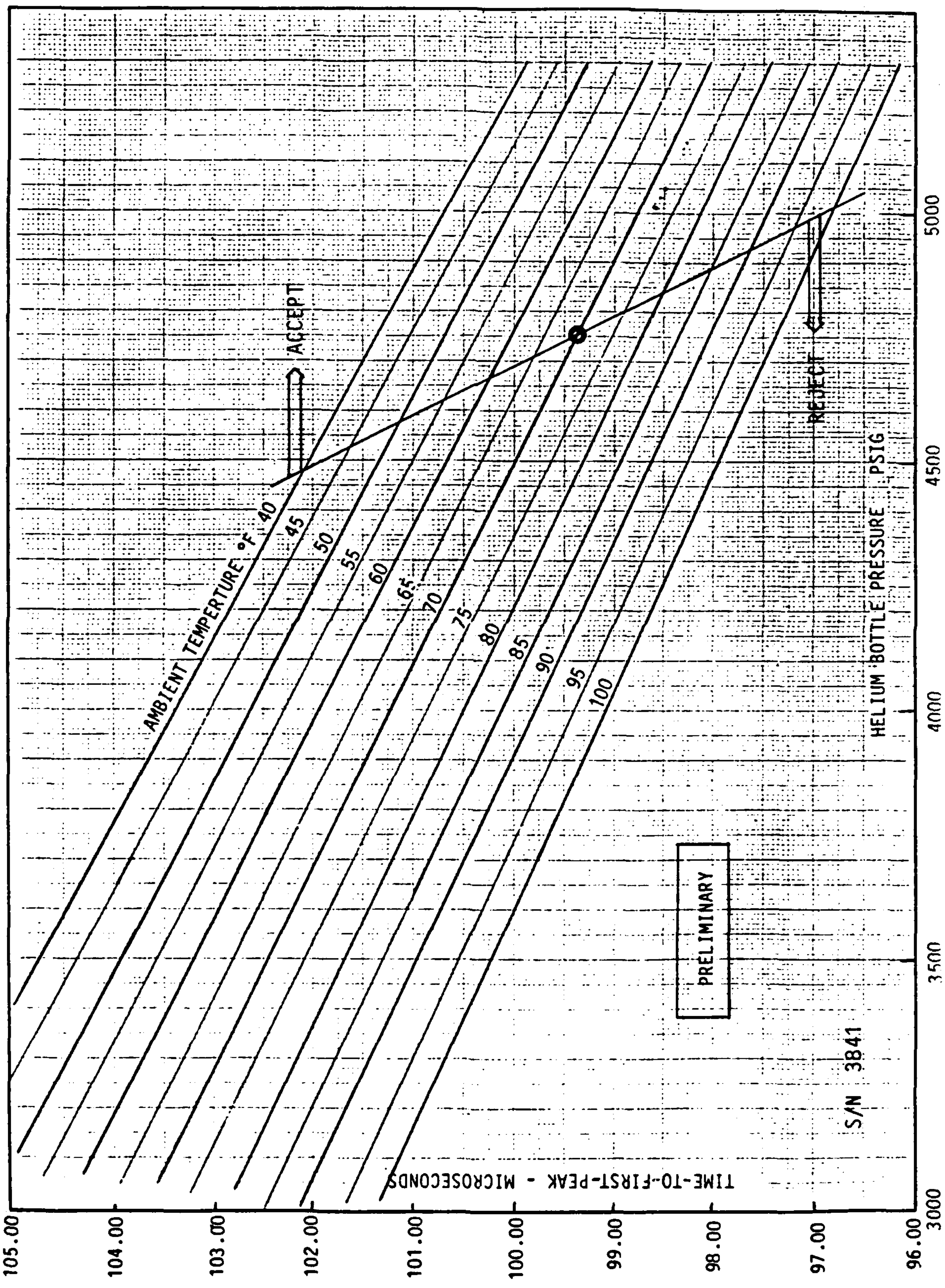
DIFFERENCES BETWEEN APCO AND BOEING BOTTLES
FIGURE 19



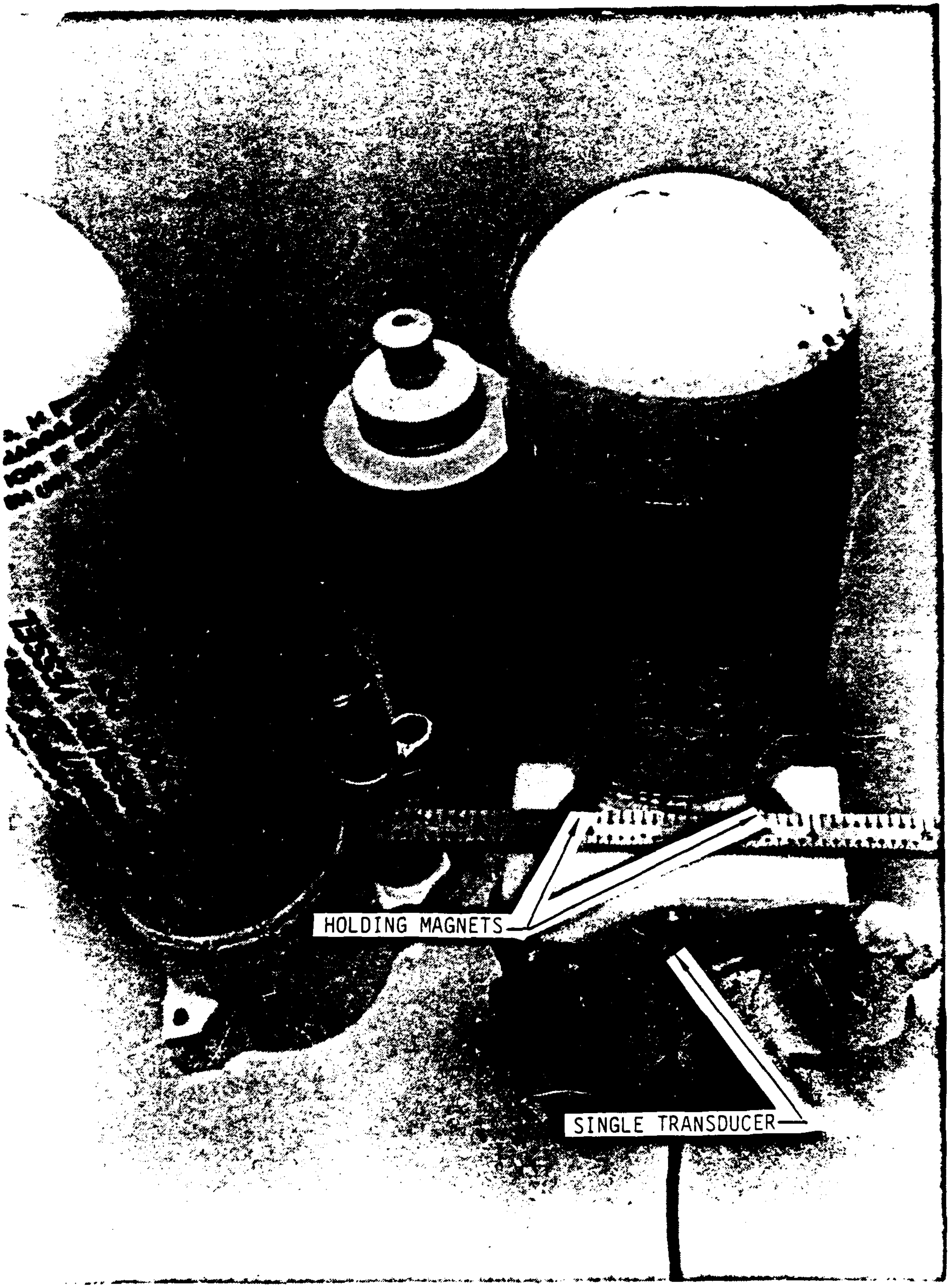

TIME-TO-FIRST-PEAK VS PRESSURE - BOEING BOTTLE S/N 3841, SINGLE TRANSDUCER
FIGURE 20




CALIBRATION CURVE FOR APCO HELIUM BOTTLE USING ULTRASONICS
FIGURE 21




CALIBRATION CURVE FOR BOEING HELIUM BOTTLE USING ULTRASONICS
FIGURE 22

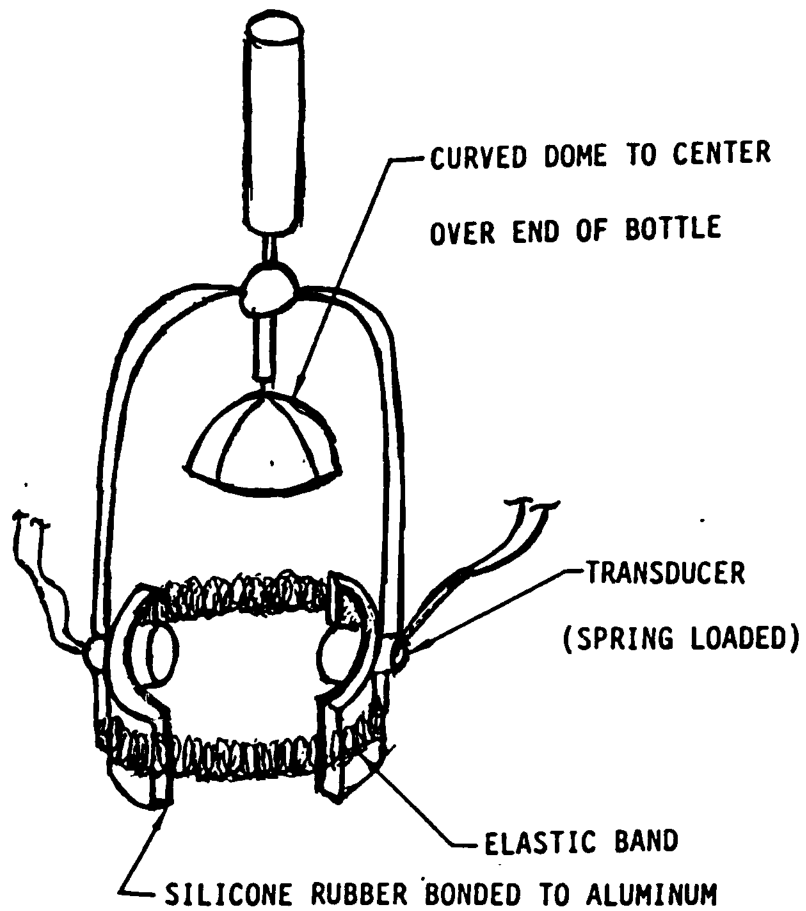



PROTOTYPE ULTRASONIC SINGLE TRANSDUCER TEST FIXTURE
FIGURE 23

BOEING

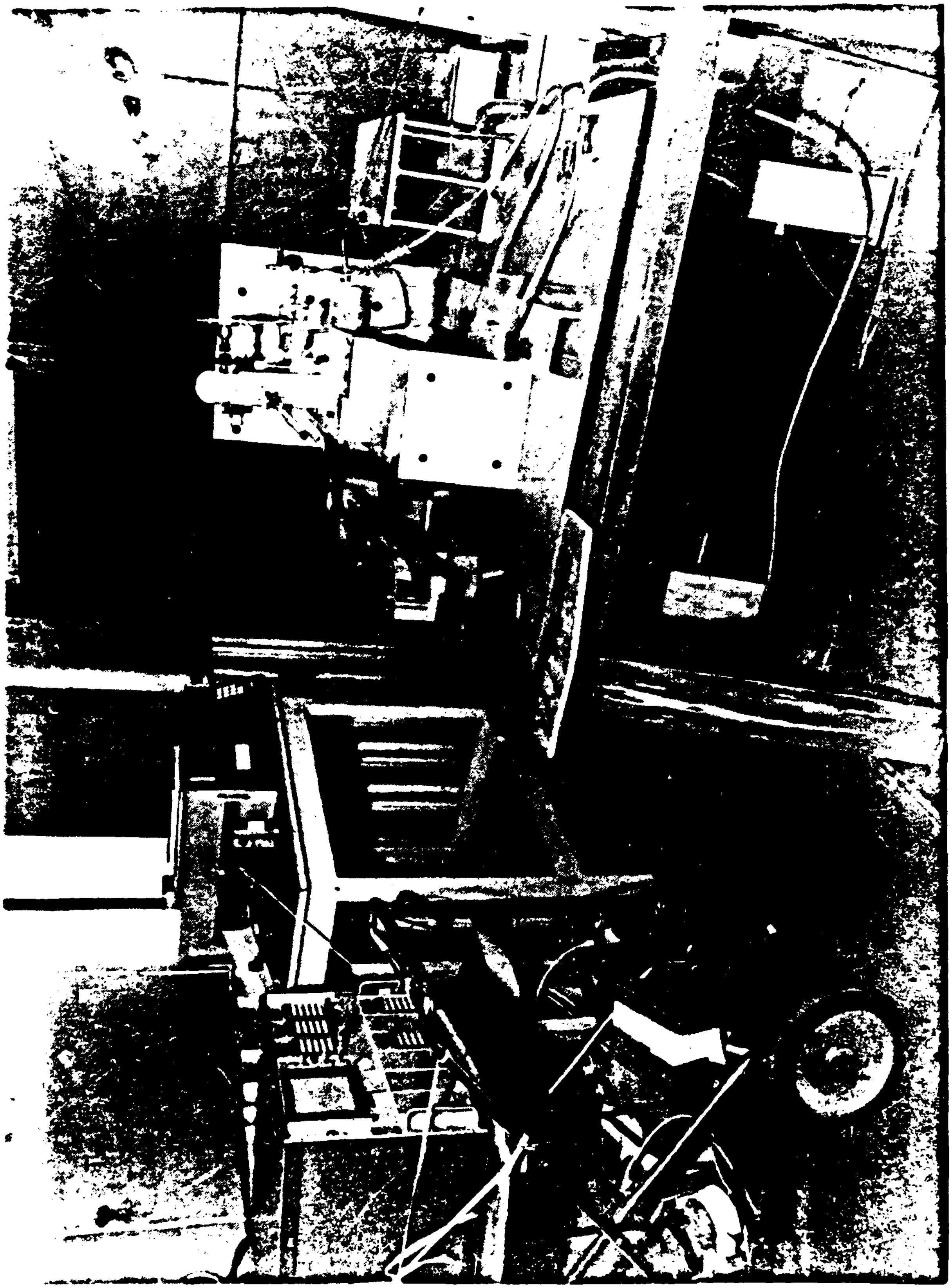
PROTOTYPE ULTRASONIC TEST FIXTURE INSTALLED ON BOTTLE

FIGURE 24



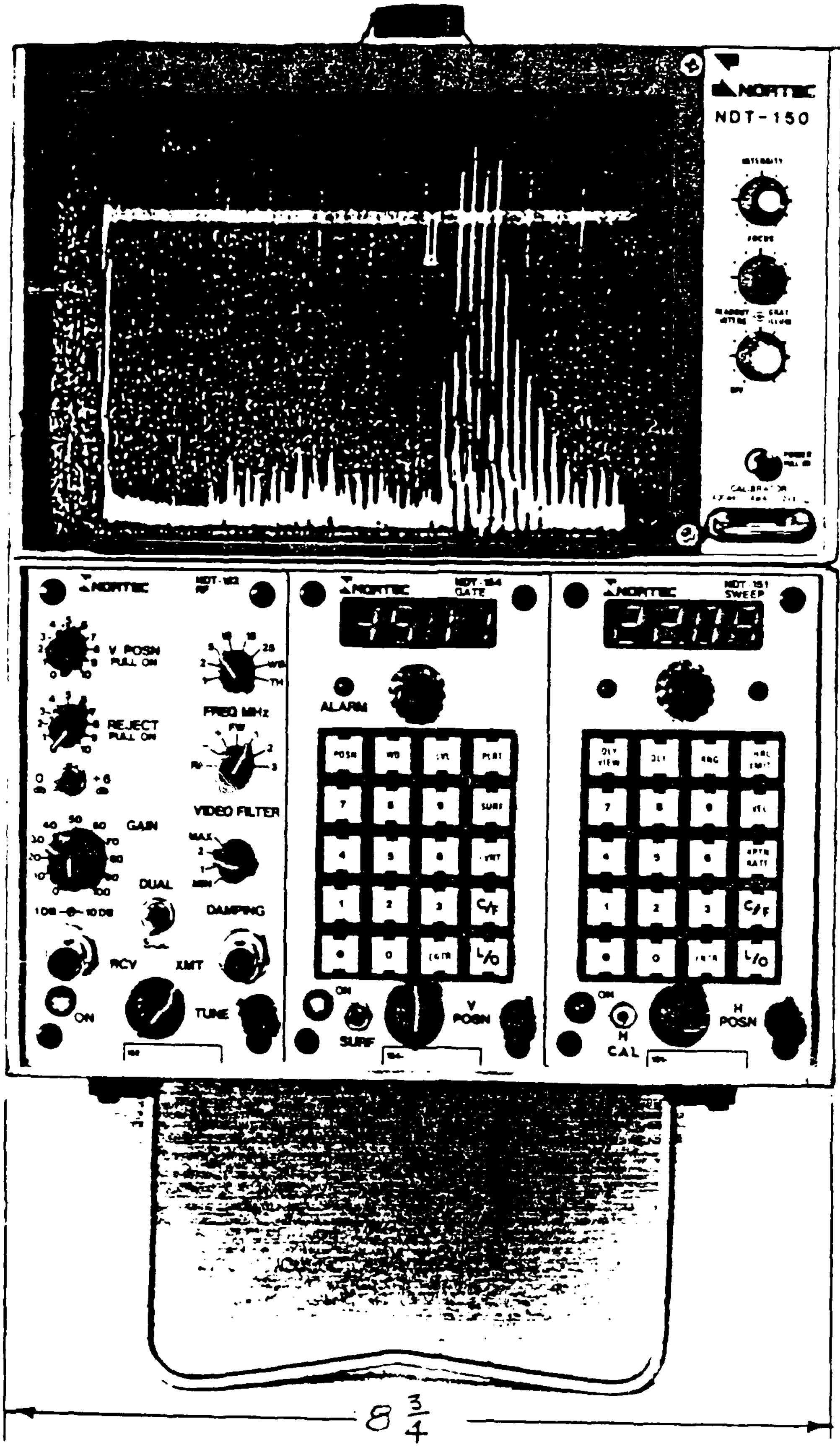

ORIGINAL CONCEPT OF TEST FIXTURE

FIGURE 25



TEST SET-UP SHOWING PORTABILITY OF EQUIPMENT ON SMALL CART

FIGURE [illegible]6




11 1/2

23" DEEP
WT = 35 TO 40 LBS
COST ~ $22,000

TYPICAL SINGLE CHANNEL PORTABLE NDT-150

FIGURE 27

# TABLES

TABLE 1

TABULATION OF RESULTS OF ULTRASONIC TESTS OF
SRAM-A PRODUCTION HELIUM BOTTLES

5000 SERIES = APCO
3000 SERIES = BOEING

| S/N | STAMPED GROSS BOTTL WT(LBS) | DATE | GROSS BOTTLE WT(LBS) | TEST DATE | Δ WT LBS | WT He-LBS | CAL MICRO SEC | TIME OF FLT (2 XDUCERS) MICRO SEC | TIME OF FLT (1 XDUCER ) MICRO SEC | COMMENTS/PRESSURE (PSIG) |
|---|---|---|---|---|---|---|---|---|---|---|
| 3841 | | | | 8/3/87 | | .058 | N/A | 50.50 | N/A | Data before bottle opened |
| 3195 | 9.325 | 7/18/75 | 9.326 | *12/21/87 | +.001 | | 51.50 | 50.55 | 98.55 | Green tag (reparable)/5025 |
| 3597 | 9.293 | 11/20/75 | 9.292 | *12/21/87 | -.001 | .066 | 51.50 | 50.45 | 98.30 | In ASAT SIL storage /5130 |
| 3466 | 9.266 | 10/10/75 | 9.266 | *12/21/87 | 0 | .064 | 51.50 | 50.40 | 98.25 | Green tag (reparable) /5170 |
| 3251 | 9.259 | 9/15/75 | 9.257 | *12/21/87 | -.002 | | 51.50 | 50.45 | 98.30 | Green tag (reparable) /5130 |
| 3095 | 9.339 | 5/12/76 | 9.340 | *12/21/87 | +.001 | .064 | 51.50 | 50.55 | 98.50 | From surveillance /5050 |
| 3316 | 9.272 | 9/26/75 | 9.274 | *12/21/87 | +.002 | .064/.062 | 51.50 | 50.50 | 98.45 | Green tag (reparable) /5070 |
| 3749 | | | | 9/16/87 | | | N/A | 50.45 | N/A | On SRAM SIL during demo -- (Quarterly Review) |
| 3096 | | | | 9/25/87 | | | N/A | 50.45 | 98.35 | From surveillance /5110 |
| 5696 | 9.303 | 4/26/76 | 9.304 | *12/21/87 | +.001 | .063/.062 | 51.50 | 53.75 | 105.5 | Serviceable /4960 |
| 5731 | 9.277 | 4/26/76 | 9.277 | *12/21/87 | 0 | .063 | 51.50 | 53.80 | 105.75 | Serviceable /4870 |
| 5723 | 9.254 | 4/26/76 | 9.254 | *12/21/87 | 0 | .063 | 51.50 | 53.75 | 105.60 | Serviceable /4920 |
| 5694 | 9.274 | 4/20/76 | 9.274 | *12/21/87 | 0 | .062/.062 | 51.50 | 53.75 | 105.55 | Serviceable /4950 |
| 5695 | 9.237 | 4/26/76 | 9.238 | *12/21/87 | +.001 | .062/.063 | 51.50 | 53.90 | 105.80 | Serviceable /4850 |
| 5726 | 9.247 | 4/26/76 | 9.247 | *12/21/87 | 0 | .062 | 51.50 | 53.70 | 105.50 | Serviceable /4960 |
| 5721 | 9.272 | 4/22/76 | 9.275 | *12/21/87 | +.003 | .063/.066 | 51.50 | 53.80 | 105.80 | Serviceable /4850 |
| 5763 | | | | | | | | 53.80 | N/A | From surveillance -- |
| 5045 | .064 LBS He | | | 10/1/87 | N/A | N/A | N/A | 53.55 | 105.15 | Demo to Mgmt SIL Lab -- (on demo. missile) |

*Temp = 72°F

# APPENDICES

# APPENDIX A

## ENGINEERING ASSIGNMENT 12 and 12A

EA 87-7-1-12
Page A-2

**ENGINEERING ASSIGNMENT**

DATE: 15 Jan 87

TO: Boeing Aerospace Company, SRAM-A Program, Seattle WA

FROM: OC-ALC/MMIRMD

| CONTRACT NO | ORDER NO | ASSIGNMENT NO | PRIORITY | ESTIMATED MANHOURS |
|---|---|---|---|---|
| F34601-84-C-1068 | | 87-7-1-12 | ROUTINE | 1068* |

| ENGINEERING PROJECT NO | MIP NO | DEFICIENCY DOCUMENT NO | SYSTEM APPLICATION FSC |
|---|---|---|---|
| | | | AGM-69A |

TITLE

Helium Bottle Pressure Measurement by Portable Ultrasonic Technique

PROBLEM

Recent ASAT test flight telemetry data (flight test 510L) indicates Low Hydraulic Control System Pressure. The most probable cause is Low Helium Bottle Pressure. Current method of determining pressure is to remove and weigh the bottle. A portable ultrasonic method needs to be studied to determine feasibility of measuring pressure of helium bottles without removal from the missile.

DESCRIPTION

Tasks required are:

1. Obtain suitable SRAM helium bottle for testing.
2. Formulate test plan and procedures from inputs.
3. Prepare test set-up.
4. Conduct test in laboratory taking ultrasonic measurements and weighing the gas in the bottle at known pressure increments.
5. Evaluate the test data and document results.
6. Measure pressure in Boeing helium bottle S/N 3841.
7. Prepare final letter report.

* Denotes: CLIN 0020 - 740 MHRs TECHNOLOGY
- 328 MHRs ENGINEERING (TEST & QUALITY)
1068 MHRs TOTAL

CLIN 0017 - MATERIALS, $300.00 AUTHORIZED

TOTAL MHRs SHALL NOT EXCEED 1068
TOTAL COST OF THIS EA SHALL NOT EXCEED $86,000.00

Victor B. Dannevik 2 Jan 87
PE DATE

PE

| DUE DATE | PROJECT ENGINEER | OFFICE SYMBOL | EXT |
|---|---|---|---|
| 31 Jul 87 | KELVIN E. HALE | MMIRMD | 63972 |

COORDINATION

| UNIT CHIEF | DATE | SECTION CHIEF | DATE |
|---|---|---|---|
| Roy Hawkins ROY E. HAWKINS | 15 Jan 87 | T. Jack Jones T. JACK JONES | 16 Jan 87 |
| **STAFF ENGINEER** | **DATE** | **BRANCH CHIEF** | **DATE** |
| Eugene F. Arnold EUGENE F. ARNOLD | 15 Jan 87 | T. Jack Jones C. L. TACKER | 20 Jan 87 |

AFLC Form 2813, Jan 69 PREVIOUS EDITION WILL BE USED

EA 87-7-1-12
Page A-3

# ENGINEERING ASSIGNMENT

| TO | FROM | DATE |
|---|---|---|
| Boeing Aerospace Company<br>SRAM Program, Seattle WA | OC-ALC/MMHRMB | 24 Apr 87 |

| CONTRACT NO. | ORDER NO. | ASSIGNMENT NO. | PRIORITY | ESTIMATED MANHOURS |
|---|---|---|---|---|
| F34601-84-C-1068 | | 87-7-1-12A | ROUTINE | 1575* |

| ENGINEERING PROJECT NO. | MIP NO. | DEFICIENCY DOCUMENT NO. | SYSTEM APPLICATION/FSC |
|---|---|---|---|
| | | | AGM-69A (SRAM) |

**TITLE**

Helium Bottle Pressure Measurement by Portable Ultrasonic Technique

**PROBLEM**

This EA revises EA 87-7-1-12 by adding new tasks. Recent ASAT test flight telemetry data (flight test 510L) indicates Low Hydraulic Control System Pressure. The most probable cause is Low Helium Bottle Pressure. Current method of determining pressure is to remove and weigh the bottle. A portable ultrasonic method has been studied under EA 87-7-1-12 and this revision extends the study to include EMI testing, and development of a prototype tester.

**DESCRIPTION**

The Contractor shall:

1. Perform EMI test of ultrasonic equipment to verify squib safety.
2. Calibrate measurements of two Boeing bottles and one Apco bottle (GFB).
3. Design and build a prototype test fixture, and provide instructions for use.
4. Verify test with production bottles, at least four (4) of each kind.
5. Host a Technical Interchange Meeting (TIM) in Seattle.
6. Prepare a final report, covering both original EA 87-7-1-12 and it's revision EA 87-7-1-12A.

*Denotes: CLIN 0020

| | | |
|---|---|---|
| - 1360 MHRs | TECHNOLOGY | @ 68.870 |
| - 69 MHRs | ENGINEERING | @ 75.860 |
| - 146 MHRs | DEVELOPMENTAL SHOP | @ 109.46 |
| 1575 MHRs | TOTAL | |

PCO

TOTAL MANHOURS ON THIS REVISION SHALL NOT EXCEED 1575

CLIN 0017 - MATERIALS, $700.00 AUTHORIZED

TOTAL COST OF THIS EA REVISION SHALL NOT EXCEED $140,000.00

David T. Howe
MMH
David T. Howe Col USAF
Chief, B-52 Missiles [illegible]
Directorate Materiel Management

29 Apr 87
DATE

NOTE: per Hilsinger this is all additive
M. [signature] 5/5/87

[illegible] 25 Apr 87

| DUE DATE | PROJECT ENGINEER | OFFICE SYMBOL | EXT |
|---|---|---|---|
| 30 Sep 87 | KELVIN E. HALE | MMHRMB | 63972 |

**COORDINATION**

| UNIT CHIEF | DATE | SECTION CHIEF | DATE |
|---|---|---|---|
| [signature] ... HAWKINS | 24 Apr 87 | T. JACK JONES | 27 Apr 87 |

| STAFF ENGINEER | DATE | BRANCH CHIEF | DATE |
|---|---|---|---|
| Eugene F. Arnold<br>EUGENE F. ARNOLD | 24 April 87 | C.L. VACHE | 5 May 87 |

AFLC Form 2813, Jan 69 PREVIOUS EDITION WILL BE USED Air Force OC, [illegible]

mff 05 May

2/3

# APPENDIX B

## TEST PLAN AND TEST PROCEDURE

# COORDINATION SHEET

FROM M/S 8J-96

| | | | |
|---|---|---|---|
| TO: | C. E. Hilsinger | 8J-70 | NO: 2-3631-GKD7-017 |
| | R. R. Martin | 86-14 | ITEM NO: |
| CC: | R. A. Burns | 73-09 | DATE: February 27, 198 |
| | F. J. Crotty | 8J-98 | |
| | J. H. Gosse | 8Y-70 | MODEL: SRAM-A |
| | L. R. Hause | 8W-11 | |
| | J .C. Johnson | 8Y-70 3-5611 | |
| | M. W. Johnson | 8Y-78 | |
| | T. J. Kramer | 82-23 | |
| | J. C. Mendez/ | 3A-52 | |
| | J. L. Gruber | | |
| | T. S. O'Neill | 8J-91 | |
| | L. P. Torre | 8Y-70 | |
| | W. L. Wilson | 82-21 | |

GROUP INDEX: SRAM-A Technology Staff

SUBJECT: Test Plan and Procedures to Measure Helium Bottle Pressure by Portable Ultrasonic Technique

REFERENCE: Engineering Assignment 87-7-1-12 dated 15 January 1987 Subject: Feasibility of Portable Ultrasonic Method to Measure Pressure of a SRAM-A FCAA Bottle Without Removal from the Missile

A test plan and procedure has been developed to perform a test to evaluate the feasibility of measuring helium gas pressure in a SRAM-A bottle which pressurizes the FCAA hydraulic accumulator/regulator. This is in response to the reference which describes the problem of a low hydraulic system pressure during a flight test and the tasks which are to be accomplished. The test plan and detailed test procedures are contained in the attachment.

A. G. Olson 2/26/87
A. G. Olson
SRAM-A Technology

George K Dragseth 2/27
G. K. Dragseth
SRAM-A Technology Manager

Attachments (2)

Attachment 1 to:
2-3631-GKD7-017

# TEST PLAN FOR HELIUM BOTTLE PRESSURE MEASUREMENT BY PORTABLE ULTRASONIC TECHNIQUE

## 1. Introduction

Tests will be conducted to determine feasibility and method of measuring helium gas pressure within a sealed pressurized bottle using ultrasonic technique. A successful technique will make it possible to measure the pressure within the helium bottle installed on a SRAM missile without requiring its removal from the missile and the man-hours required to accomplish the task and subsequent reinstallation and purging tasks.

## 2. Test Plan

The test article will be an expended SRAM-A helium gas bottle manufactured by APCO. The test article will be thoroughly cleaned, examined, and subjected to a proof pressure test before being assembled into the test configuration shown in Figure 1.

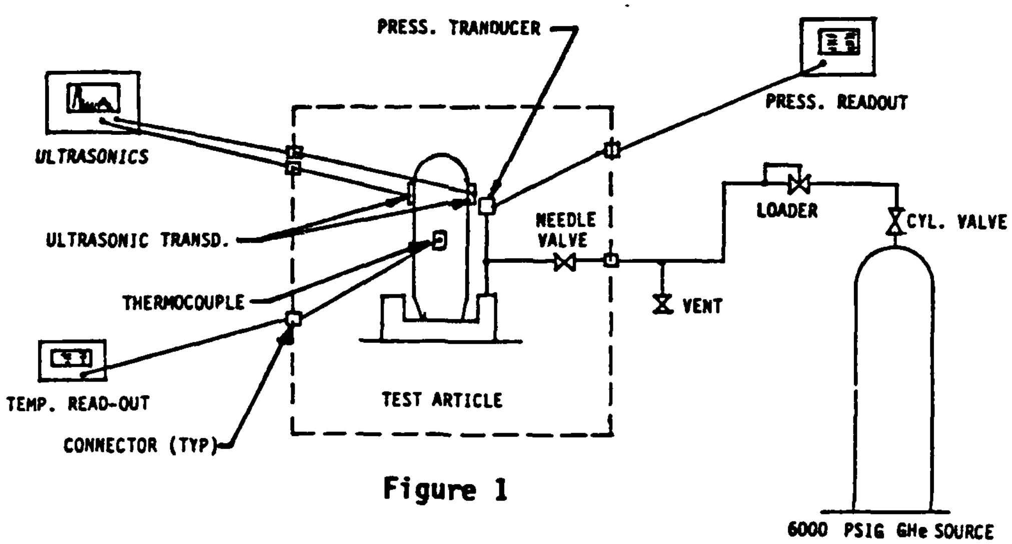



**Figure 1**

After assembly into the test configuration of Figure 1, tare weight of the test article will be determined. The bottle will then be filled with helium gas to 5000 psig and the test article will be weighed to determine the initial quantity of gas in the bottle.

Ultrasonics will be applied to the gas bottle at pressure decrements and parameters in gas and bottle will be recorded (weight, pressure, temperature). A calibration curve will then be plotted from selected parameters which will enable the mass of helium in the bottle to be determined from measured ultrasonic parameters, and converted to pressure using the perfect gas law equation.

Repeatability of results will be verified by conducting several runs. This will be followed by applying ultrasonics to low weight Boeing helium bottle S/N 3841 in surveillance to evaluate accuracy and repeatability of the technique.

Attachment 2 to:
2-3631-GKD7-017

# TEST PROCEDURES FOR HELIUM BOTTLE PRESSURE MEASUREMENT BY PORTABLE ULTRASONIC TECHNIQUE

## 1. Introduction

The test procedure below will be followed when conducting the test with the test article configuration and instrumentation specified herein. Tests will be conducted in the centrifuge room in the basement of building 18-24 of The Boeing Space Center complex in Kent, WA.

## 2. Objective

The test objective is to obtain sufficient test data from an ultrasonic technique to construct a test article calibration curve from which helium gas weight and pressure may be obtained, using measured ultrasonic parameters of production bottles installed on SRAM-A missiles.

## 3. Instrumentation and Equipment

The instrumentation and equipment required to perform the test are listed as follows:

- APCO helium bottle, S/N 5016
- Pressure transducer 0-7500 psig
- Power supply & Digital volt meter
- Thermocouple 50° - 125°F, and read-out
- Pressurized He gas source 6000 psig
- Precision balance scale (weigh to 0.001 lb.).
- Hand shut-off needle valve (fine thread)
- ~3 ft. SS - 7500 proof pressure tubing
- Vent valve
- Shut-off valve on He gas source
- Hand Loader

- Fixture to secure equipment to floor/bench
- Ultrasonic pulser/receiver
- Ultrasonic transducers (3 sets)
- Spectrum analyzer (range of 0.5 Mhz - 5 Mhz)
- Camera
- Peak/hold digital volt meter to measure peak wave amplitude

4. Test Procedure

4.1 Preparation of test article (Figure 1).

4.1.1 Proof pressure test the bottle to 7500 psig using water. Measure and record volume within bottle. Dry out moisture.

4.1.2 Install tubing, hand valve, pressure transducer, coupling.

4.1.3 Install thermocouple on bottle.

4.1.4 Install ultrasonic transducers on bottle.

4.2 Weigh test article.

This procedure shall be accomplished under clean handling conditions.

4.2.1 Weigh empty test article configured according to Figure 1 on precision balance scale to closest 0.001 lb. This is tare weight.

NOTE: Be sure to disconnect thermocouple and ultrasonic lines before weighing.

4.3 Baseline Ultrasonic response of empty gas bottle at ambient pressure and temperature.

4.3.1 Connect lines to ultrasonic pulser/receiver, thermocouple read-out and pressure transducer.

4.3.2 Check correct operation of ultrasonic equipment. Record each set of transducers being used.

4.3.3 Take ultrasonic measurements at three frequencies and different locations on the bottle:

1.0 Mhz

2.25 Mhz

5 Mhz

Record gains, time display, etc. on data sheet.

4.4 Pressurize test article (at room temperature 70°F).

4.4.1 Connect and tighten the pressure coupling between the bottle and the 6000 psi He pressure source.

4.4.2 Open the shut-off needle valve, close vent valve and check hand loader valve to assure it is closed.

4.4.3 Open hand loader valve to obtain full test article bottle pressure of 5000 psig.

4.4.4 Record pressure transducer reading at test article.

4.4.5 Close shut-off needle valve and hand loader valve. Vent the line between coupling and pressure source to the atmosphere.

4.4.6 Disconnect pressure source at coupling. Disconnect thermocouple, ultrasonics and pressure transducer. Check test article for leaks with sniffer at all joints and fittings. No leaks are permitted.

4.4.7 Weigh test article (Fig. 1) on precision balance scale to nearest 0.001 lb. This is full bottle weight.

4.4.8 Re-connect thermocouple, pressure transducer and ultrasonic lines and allow temperature to stabilize at room temperature.

4.4.9 Subtract tare weight in 4.2.1 from full bottle weight. This is weight of He in bottle (approx. 0.07 lbs). Calculate He volume in tubing and add to volume of bottle found in 4.1.1. This is total pressurized volume of helium.

4.5 Ultrasonic application

4.5.1 Check to verify connection of lines to ultrasonic pulser/receiver.

4.5.2 Check operation of ultrasonic equipment. Record the set of transducers being used.

4.5.3 Take ultrasonic measurements at three frequencies at different locations on the bottle:

1.0 Mhz

2.25 Mhz

5 Mhz

Record gains, time display, etc., on data sheet.

4.6 Pressure reduction

4.6.1 Disconnect ultrasonics from test article at connector.

4.6.2 Carefully crack open the hand shut-off needle valve and reduce pressure by 500 psig on pressure transducer.

4.6.3 Allow temperature to stabilize. Record temperature and pressure.

4.6.4 Disconnect thermocouple and pressure transducer lines and weigh test article (Fig. 1) on precision balance scale to nearest 0.001 lbs.

4.6.5 Subtract tare weight found in 4.2.1. This is gas weight in bottle at pressure and temperature in 4.6.3.

4.6.6 Reconnect all transducers and repeat steps in Section 4.5.

4.6.7 Repeat steps 6 through 6.6 with pressure reduced in 500 psig decrements down to a bottle pressure of 2000 psig.

4.7 Disposition of gas bottle

After all test points have been obtained, slowly open hand needle valve and reduce pressure to atmospheric. Purge bottle several times with air and weigh again. Compare with tare weight. Disassemble test configuration and return test article to storage.

4.8 Data Reduction

4.8.1 Identify bottle and gas response on oscilloscope traces. If the responses were recorded digitally upon collection, prepare difference plots of pressurized responses minus the empty (baseline) response using digital subtraction of Fourier analysis as applicable and time permitting.

Plot:

(a) Gas response peak amplitude vs gas weight.

(b) Gas response peak amplitude vs. gas pressure.

(c) Gas response peak area vs gas weight.

(d) Gas response peak area vs. gas pressure.

(e) Gas response peak Q (half-height peak width) vs gas weight

(f) Ratio of gas peak amplitude to bottle peak amplitude vs specific wt. of gas in bottle.

4.8.2 If possible, repeat steps 4.2 through 4.7 to evaluate repeatability ten times.

4.9 Production bottle

4.9.1 Obtain production Boeing bottle S/N 3841 and weigh on the precision balance scale. Subtract stamped tare weight to obtain weight of gas in bottle.

4.9.2 Apply and connect thermocouple and ultrasonic transducer(s) to gas bottle. Record temperature and apply ultrasonics to bottle.

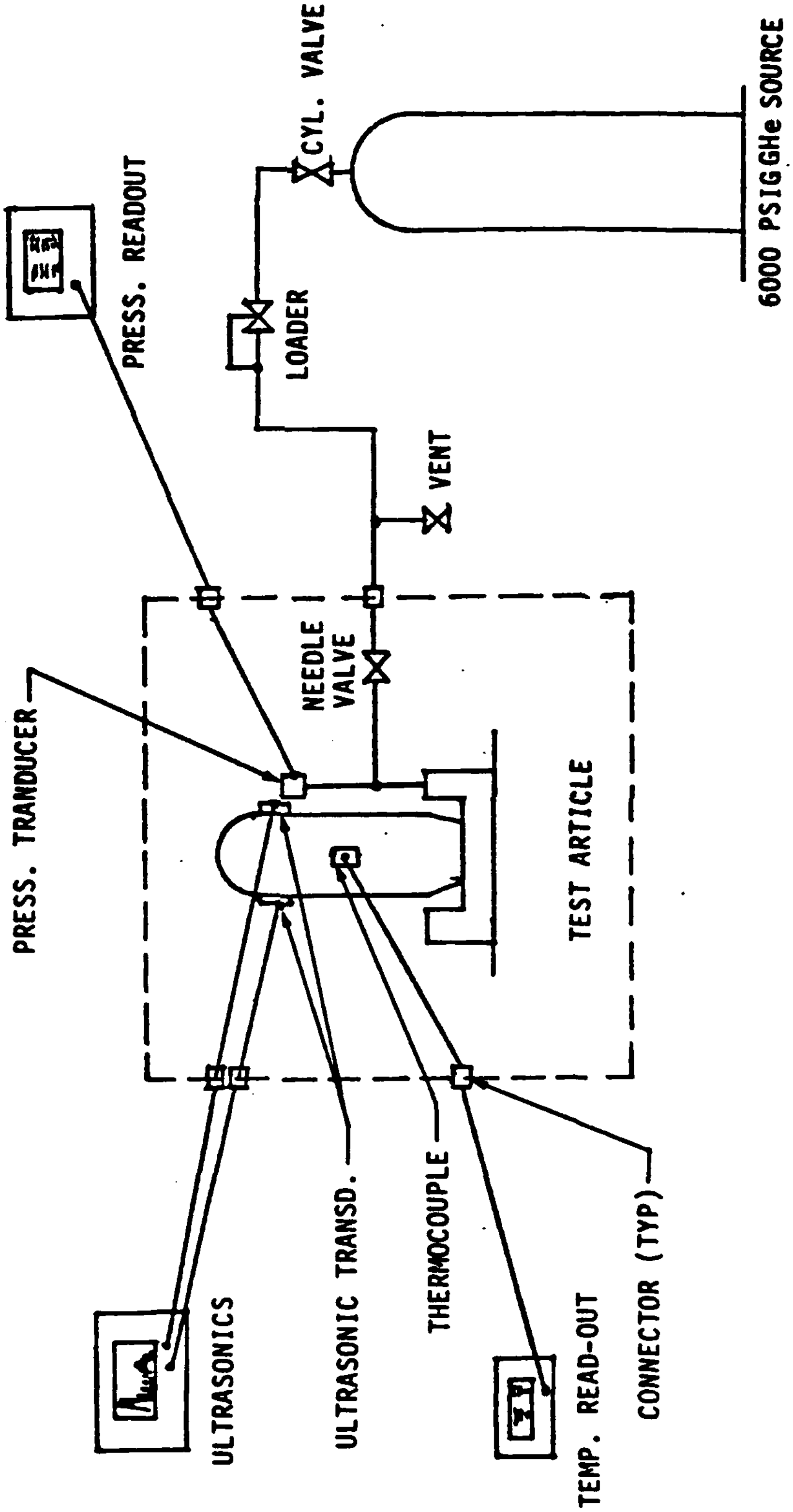
4.9.3 Record temperature, bottle and gas responses to ultrasonic inputs in the same manner as the test article. Calculate gas weight and pressure from test article calibration curve.

4.9.4 Compare weight of gas determined by ultrasonic method to direct weight method. Compare corresponding pressure calculated from perfect gas low equation. If time permits, apply ultrasonic technique to low weight helium bottles in Boeing surveillance program.

4.9.5 If correlations and repeatability are acceptable, prepare transducer sleeve/fitting for off-line demonstration.

Attachment 2 to:
2-3631-GKD7-017

EA 87-7-1-12
Page B-9




TEST CONFIGURATION

FIGURE 1

# APPENDIX C

# EMI ANALYSIS

28 August 1987
2-1305-2-0087-032 Rev 1

To: G. K. Dragseth 8J-96

cc: A. G. Olson 8J-96
R. W. Lane 81-15

Subject: EA87-7-1-12A
EMI/EMC Analysis of SRAM Helium Bottle Test Set

The electrical characteristics of the NORTEC test equipment was reviewed to determine if the signal characteristics could potentially impact the EED circuits in the SRAM FAS. The test equipment consists of a NORTEC NDT-150 unit which generates a short pulse of energy to activate an ultrasonic transducer.

The pulse is about 250 volts peak and about 100 nanoseconds in length with a pulse repetition frequency (PRF) of 1500 pulses per second (PPS).

Since the helium bottle squib is qualified to withstand a 25000 volt discharge from the pins to the case, the 250 volt pulse is a factor of 100 below the transient qualification level. The squib is also qualified to withstand a 1 amp/1 watt power applied to the bridgewires. The tester pulse of 250 volts for 100 ns at 1500 pps has an average value of 250v x 100ns x 1500pps = .0375 volts. If this average voltage were applied to the nominal 1 ohm bridgewire, the average power would be about 1.4 milliwatts, which is about 70 times smaller than the qualification level.

These calculations are based on a worst case scenario which assumes no isolation between the squib and the pulser output voltage, therefore, since large safety margins exist, no additional EMC tests are considered necessary to determine actual levels coupled into the EED.

As an extra safety margin, it is recommended that the shorting plug for the helium bottle EED be installed before using the helium bottle test equipment.

Note: This analysis is applicable for the helium bottle standing alone, in the SRAM FAS, or in a production configured missile.

Prepared By: Dean R Boston OMS
D. R. Boston

Approved By: Chuck E Hilsinger
C. E. Hilsinger

Concurrence: Jack V. Eisaman
J. V. Eisaman,
Ordnance Engineering

EQUIPMENT USED FOR ULTRASONIC

PRESSURE MEASURING TECHNIQUE :

NORTEC NDT-150
ULTRASONIC FREQUENCY = 5 MHZ

TRANSDUCERS: AUTOMATION INDUSTRIES
.5 IN. DIA., 5 MHZ

DIGITAL VOLTMETER: KEITHLY 173

# APPENDIX D

## DESIGN OF TEST FIXTURE

## AND INSTRUCTIONS FOR USE

# ACOUSTIC MEASUREMENT OF HELIUM PRESSURE IN SRAM HELIUM PRESSURE BOTTLES

1.0 Background: This test procedure describes the test equipment and test method for determining the pressure of the helium gas contained in SRAM-A helium pressure bottles. This procedure was designed to perform the pressure measurement without requiring removal of the bottle from the missile.

2.0 Equipment required: (or equal)

| | | |
|---|---|---|
| 1. | Single Channel Ultrasonic Instrument | NORTEC NDT 150 |
| | Pulser/Receiver | NORTEC NDT 153P |
| | Gate | NORTEC NDT 154 |
| | Sweep/Time Base | NORTEC NDT 151P |
| 2. | Transducer, 10 MHz, 1/4", Flat | Panametrics V312 |
| 3. | Cable | Endevco 3090C |
| 4. | Transducer Fixture | (Per Drawing) |
| 5. | Couplant | Ultragel II, or Equiv. |
| 6. | Reference Standard | (Per Drawing) |

3.0 * Test Procedure:

1. Connect ultrasonic instrument (NORTEC NDT 150) to 110/120V line power and pull power switch to turn on. Allow 30 minutes of warm-up time before data recording.

2. Sweep module programming: NDT-151P (Fig. 1A)

| | | | |
|---|---|---|---|
| Depress | $\boxed{\text{RPTN RATE}}$, | Keypad 3.000, | $\boxed{\text{ENTR}}$ |
| Depress | $\boxed{\text{DLY}}$, | Keypad 810.0 | $\boxed{\text{ENTR}}$ |
| Depress | $\boxed{\text{RNG}}$, | Keypad 70.0 | $\boxed{\text{ENTR}}$ |
| Depress | $\boxed{\text{DLY VIEW}}$, | To select either compressed or expanded view. | |

Any necessary adjustments of the delay $\boxed{\text{DLY}}$ or range $\boxed{\text{RNG}}$ may be made by depressing that function key and rotating the control under the digital display. Depressing $\boxed{\text{C/F}}$ allows coarse or fine control of the above adjustments.

* WHEN MEASURING He PRESSURE IN A BOTTLE WITH A "LIVE" SQUIB, INSTALL A SHORTING PLUG IN THE SQUIB BEFORE USING THE HELIUM BOTTLE ULTRASONIC TEST EQUIPMENT AS A PRECAUTIONARY MEASURE

3.0 Test Procedure (Continued)

3. Gate module programming: NDT-158P (Figure 1B) pull V pos control and rotate to position trace at top of screen.

   Depress $\boxed{\text{SURF}}$ to obtain $\boxed{-}$ readout

   Depress $\boxed{\text{WD}}$, keypad 0.050, $\boxed{\text{ENTR}}$

   Depress $\boxed{\text{POSN}}$, keypad 98.00, $\boxed{\text{ENTR}}$

   A vertical spike will appear in the trace which may be moved to the left or right by rotating the control knob under the digital display. Depressing $\boxed{\text{C/F}}$ allows coarse or fine control of the spike position.

4. Pulser-Receiver programming: NDT-153P (Figure 1C)

   Pull V pos control and rotate to position trace at bottom of screen.

   Depress $\boxed{\text{L/O SHF}}$, to obtain illuminated "lower" green light.

   Depress $\boxed{\text{TUNE PWR}}$, to obtain $\boxed{\text{H -- P}}$ on display

   Depress $\boxed{\text{L/O SHF}}$, to obtain illuminated "upper" green light

   Depress $\boxed{\text{FREQ AGC}}$, to obtain $\boxed{\text{15.00}}$ on display

   Depress $\boxed{\text{MODE SEG}}$, to obtain $\boxed{\text{0}}$ on display

   Depress $\boxed{\text{TUNE POWER}}$, rotate control knob to obtain $\boxed{\text{40}}$ on display

   Depress $\boxed{\text{GAIN}}$, rotate control knob to obtain $\boxed{\text{70.0}}$ on display

   Connect transducer cable to "XDCR" connector. Mount transducer in fixture and connect transducer to cable microdot connector.

5. Pulse-Echo transit time measurement:

   Assure that the transducer moves freely in the holding fixture. Clean and wipe transducer face and curved surface of fixture. apply a bead of couplant to transducer face and curved surface of fixture, Figure 2. If the helium pressure vessel to be tested is an APCO bottle (bonded metal identification plates), position the transducer fixture forward of the holding strap, with the curved surface groove on the transducer fixture facing forward, away from the holding strap. Slide the fixture so that it butts up against the holding strap, Figure 3, and adjust for maximum amplitude pulses on the display screen. A periodic series of pulses should appear on the display screen as in Figure 4, which shows an earlier model of the NDT-150. If the vessel to be tested is a Boeing bottle (painted identification) the fixture may be located just aft of the holding strap.

3.0 Test Procedure (Continued)

5. Pulse-Echo transit time measurement: (Continued)

Adjust the pulser-receiver gain by rotating the control knob to obtain a first peak signal amplitude of approximately 75% screen height. Assure that the first peak is viewed on the screen by depressing [DLY] on the sweep module and slowly rotating the control knob to shift the series of pulses left and right on the screen display. Depress the gate module [POSN] and rotate the control knob to position the vertical spike of the top trace directly over the peak of the first pulse of the lower trace. Note the indication on the gate module digital display and record this number on the data sheet "Pulse-Echo Time" entry.

Remove the fixture from the test vessel and clean couplant from the test vessel. Slide the transducer out of the test fixture, apply couplant to the transducer face and position the transducer on the marked surface of the reference standard, adjusting pulser-receiver gain and sweep position to view the first pulse of the pulse train on-screen. Rotate the gate control knob to position the vertical spike directly over the peak of the first pulse. Note the indication on the gate module digital display and record this number on the data sheet "standard" entry. Note temperature and record on the data sheet "temperature" entry.

6. Pressure Calculation.

Enter the measured standard time under the "Reference Standard" reading. Enter the difference in the "Standard Correction" entry. If the measured standard time is larger than the reference standard time, subtract the standard correction from the measured vessel pulse-echo time and enter the result in the "corrected pulse-echo time" entry. If the measured standard time is smaller than the reference standard time, add the standard correction to the measured vessel pulse-echo time and enter the result in the "Corrected Pulse-Echo Time" entry.

Select the appropriate graph (APCO or Boeing) and mark the "Corrected Pulse-Echo Time" on the vertical time scale of the chart. With a straight-edged ruler, extend this line horizontally until it intersects the appropriate temperature line from the "Temperature" entry. From this intersecting point, draw a line vertically down to obtain the pressure reading. Record this reading in the "vessel pressure" entry.

If the point of intersection of the time-temperature lines is to the right of the line A-A, the vessel pressure is acceptable.

R. HAUSE 3/31/88

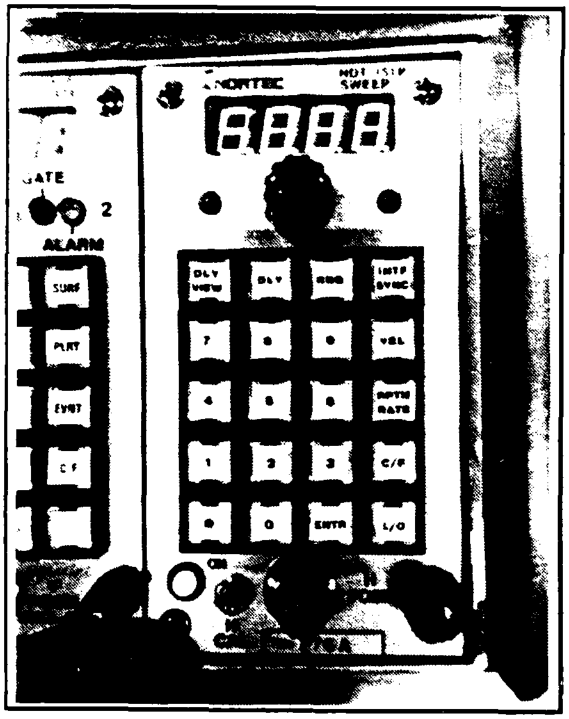



Figure 1A

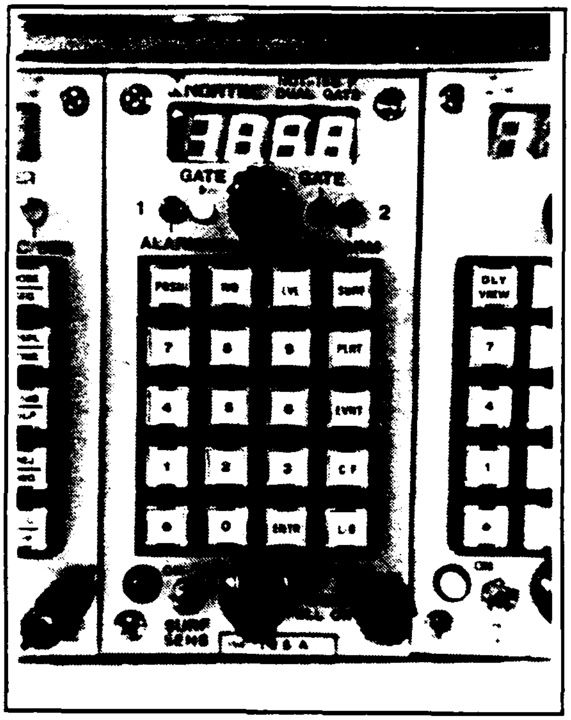



Figure 1B

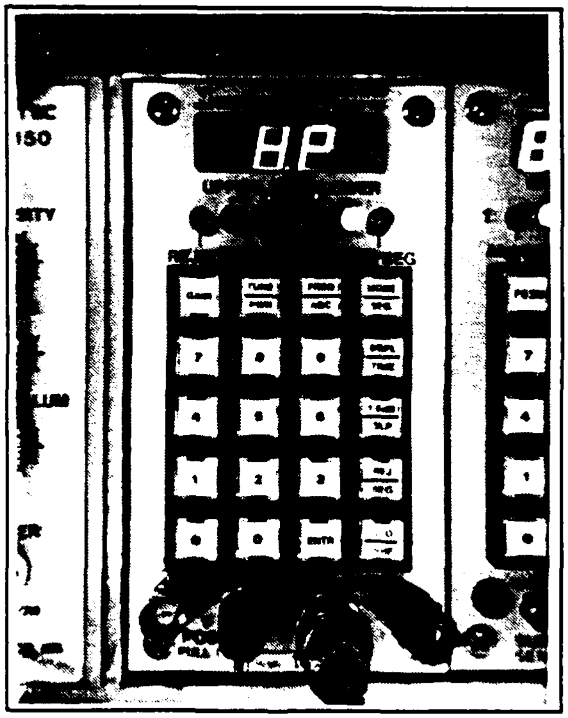



Figure 1C

**BOEING**

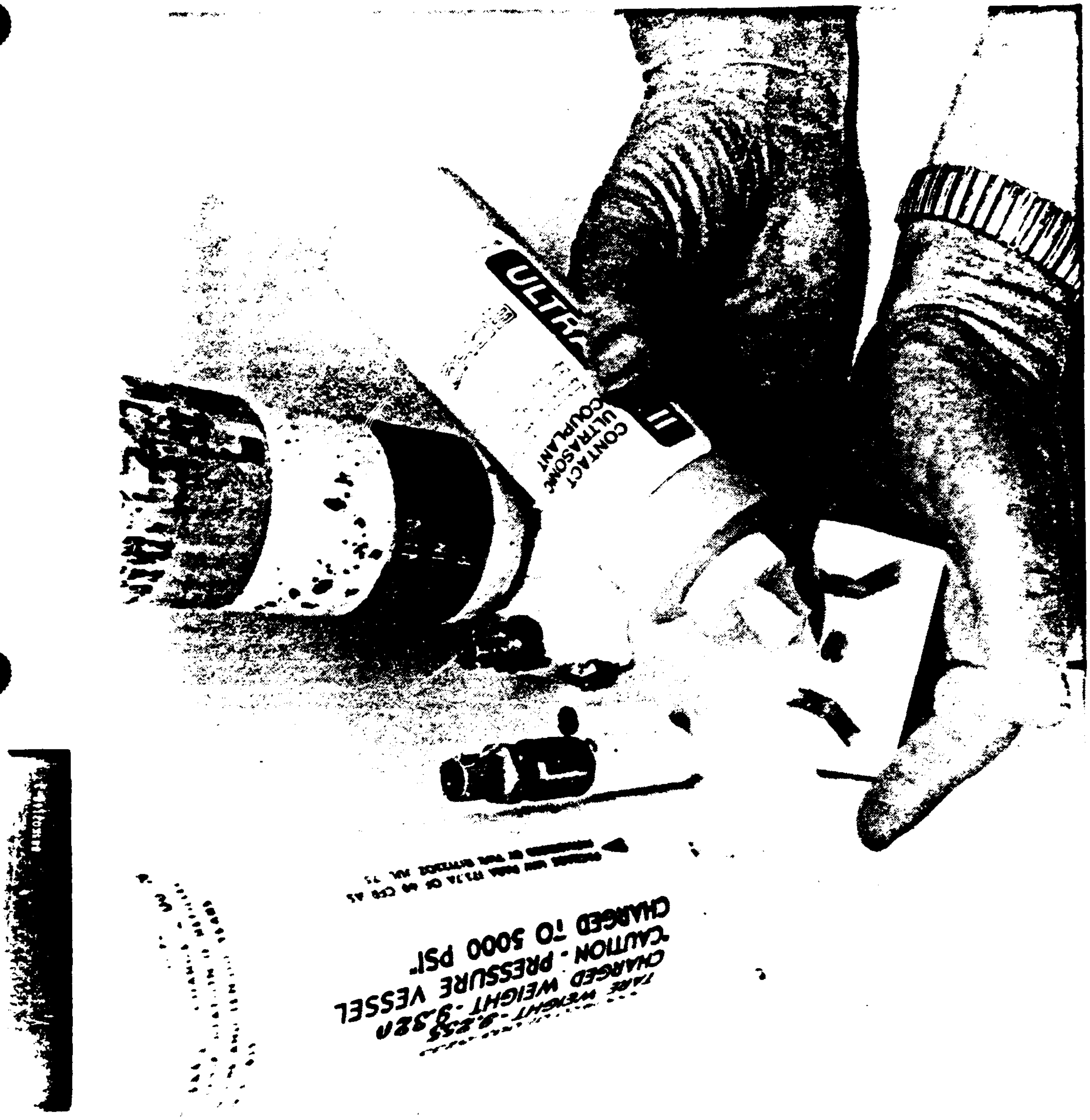



FIGURE 2

FIGURE 3

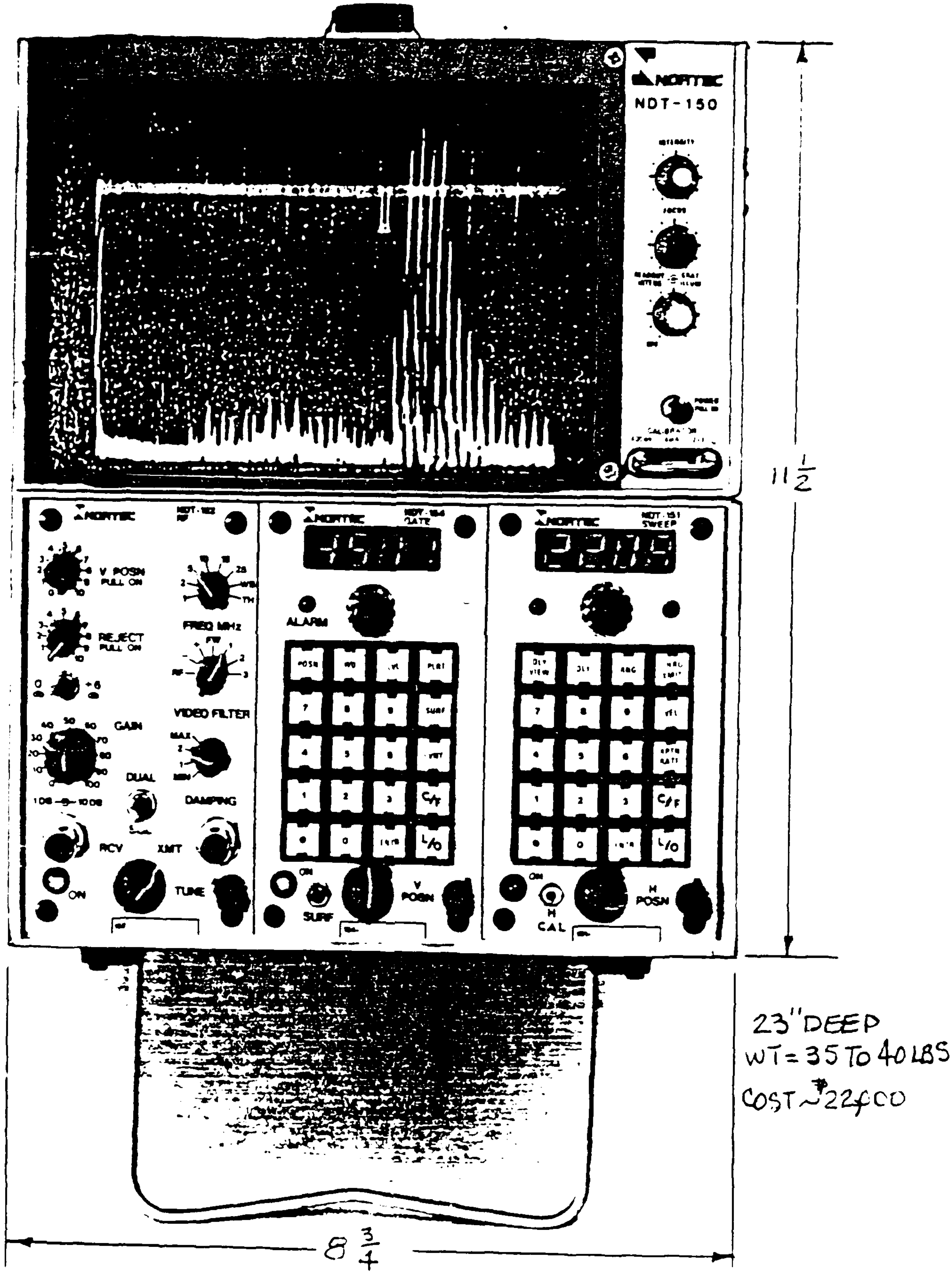
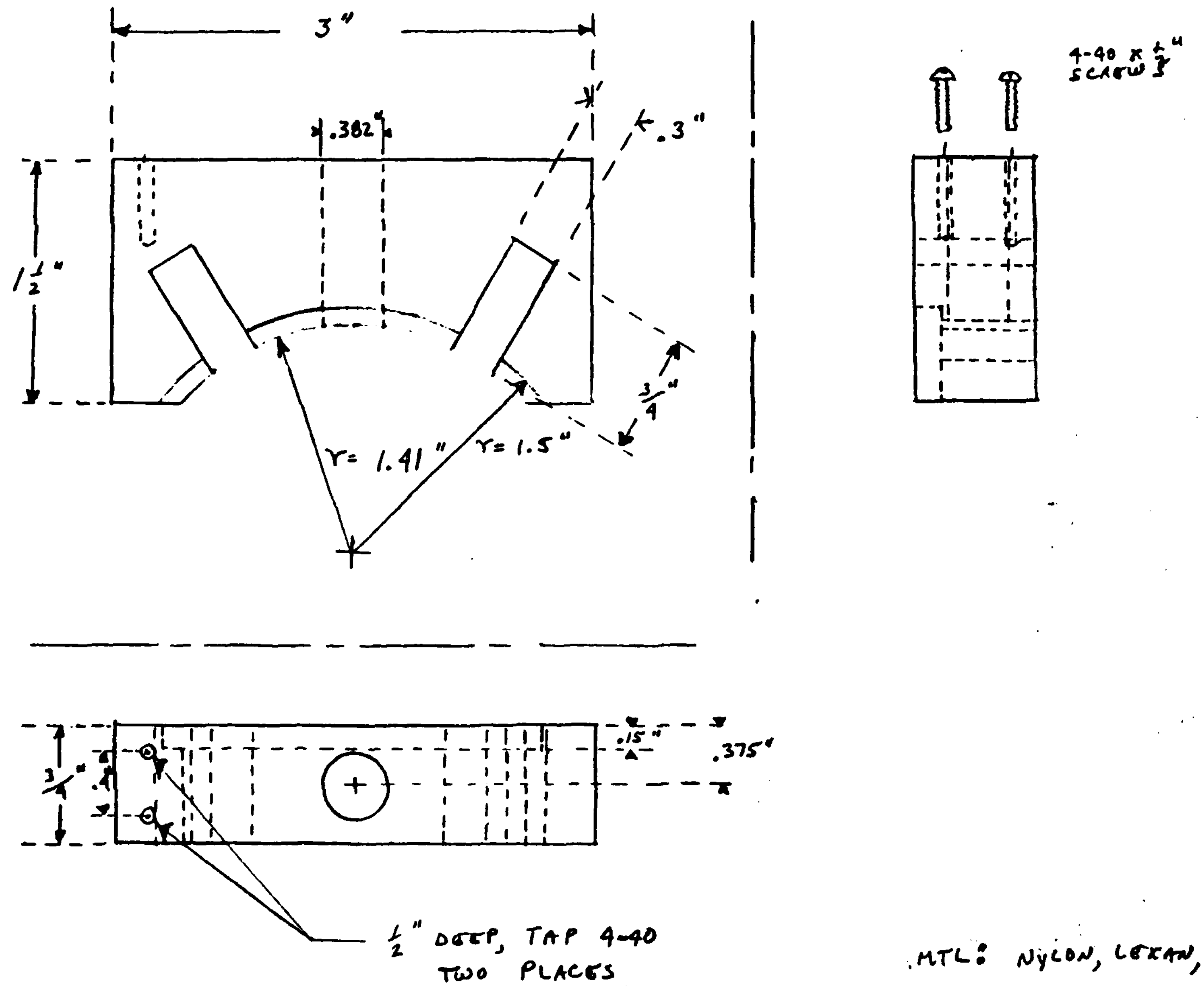



Figure 4. Single Channel Portable NDT-150 - Front Control Panels

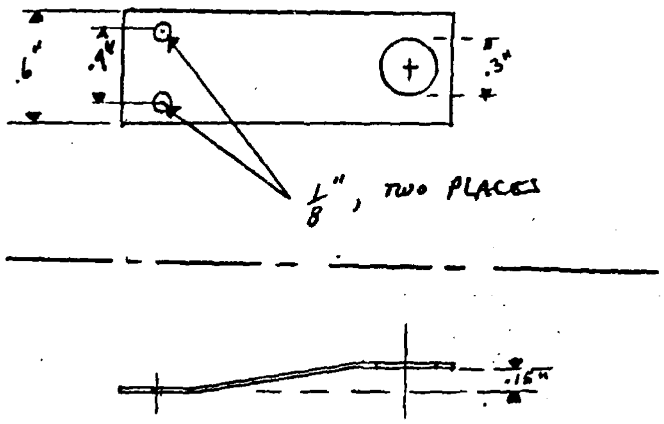



MTL: NYLON, LEXAN, OR EQ.

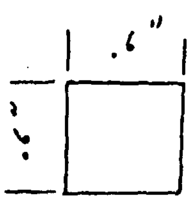
R. HAUSE 3/25/88

TEST FIXTURE FOR ULTRASONIC TRANSDUCER

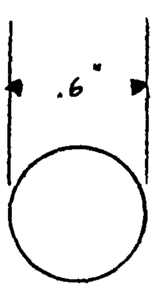
SH 1/3




SPRING, RETAINER




PLATE, MAGNET
SOFT IRON, t ≈ .040"
4 EACH




MAGNET, PERMANENT
.6"d x .2" t

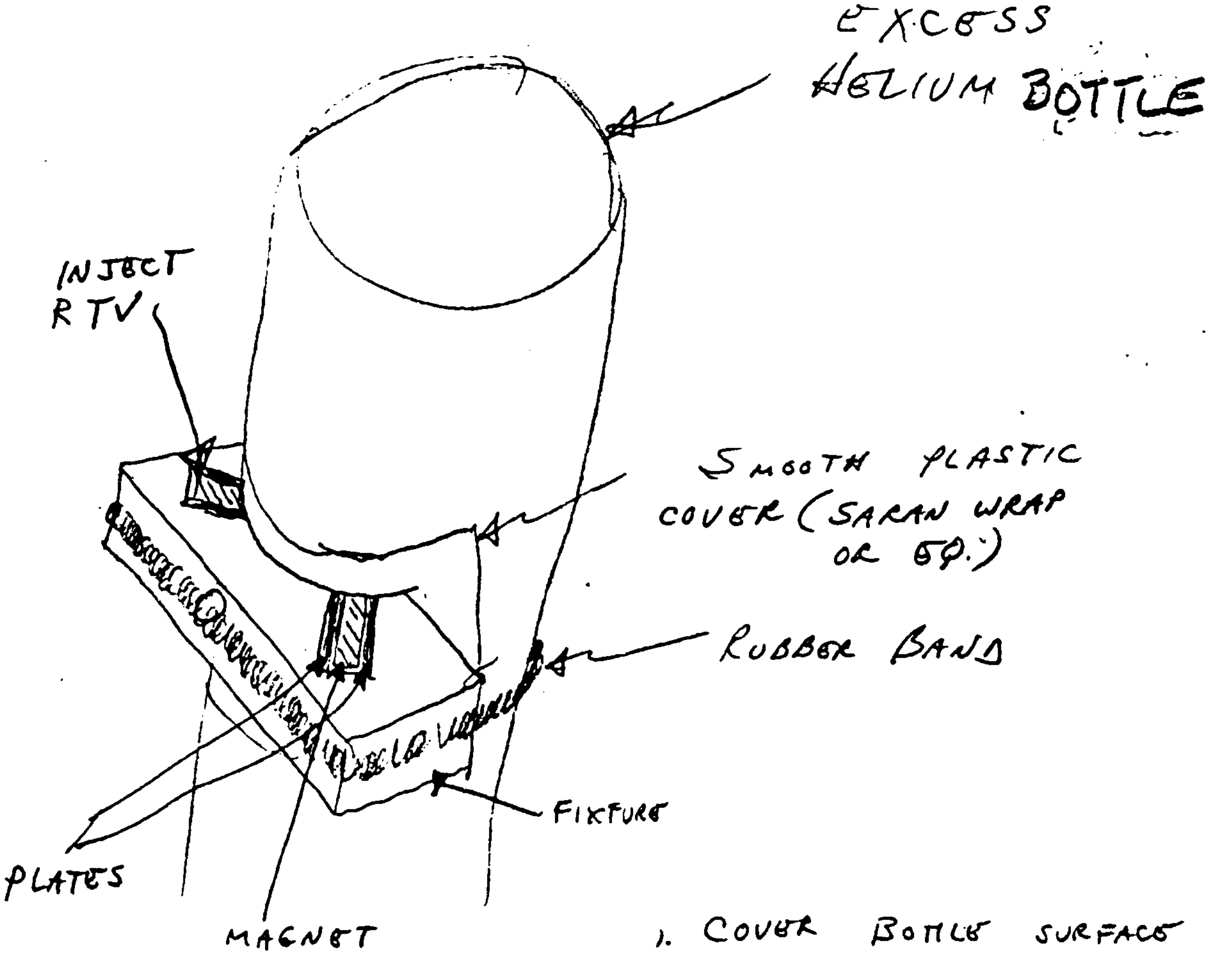
TEST FIXTURE FOR ULTRASONIC
TRANSDUCER

R. HAUSE 3/25/88

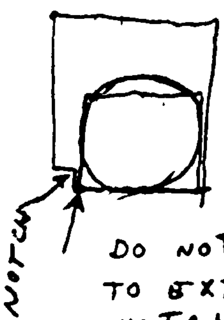
SH 2/3

R. HAUSE 3/25/88

# ASSY. OF TEST FIXTURE FOR ULTRASONIC TRANSDUCER




1. COVER BOTTLE SURFACE WITH TIGHT, WRINKLE-FREE PLASTIC COAT.
2. MOUNT FIXTURE WITH RUBBER BAND, ASSURING UNIFORM SURFACE CONTACT.
3. ATTACH PLATES TO SIDES OF MAGNETS AND SLIDE INTO SLOTS OF FIXTURE SUCH THAT PLATES ARE FLUSH WITH UN-NOTCHED SIDE OF FIXTURE.
4. INJECT RTV SILICONE RUBBER INTO VOID AROUND MAGNETS AND PLATES. WIPE OFF EXCESS AND ALLOW TO CURE 24 HRS.




DO NOT ALLOW PLATES TO EXTEND INTO NOTCH AREA.

DATA SHEET

MFG ____________________ S/N ____________________

DATE ____________________

PULSE-ECHO TIME ______________________ μs. 1

STANDARD ____________________________ μs. 2

TEMPERATURE _______________ °F

REFERENCE STANDARD 95.55 μs.

MEASURED STANDARD 2 _______________

MEASURED PULSE-ECHO TIME _____________ 1

STANDARD CORRECTION _________________ 3

CORRECTED PULSE-ECHO TIME ____________ 4

BOTTLE PRESSURE _____________________ 5

DATA SHEET

MFG APCO S/N - - -

DATE - - -

PULSE-ECHO TIME 105.3 µS. 1

STANDARD 95.65 µS. 2

TEMPERATURE 73 °F

REFERENCE STANDARD 95.55 µS.

MEASURED STANDARD 2 95.65

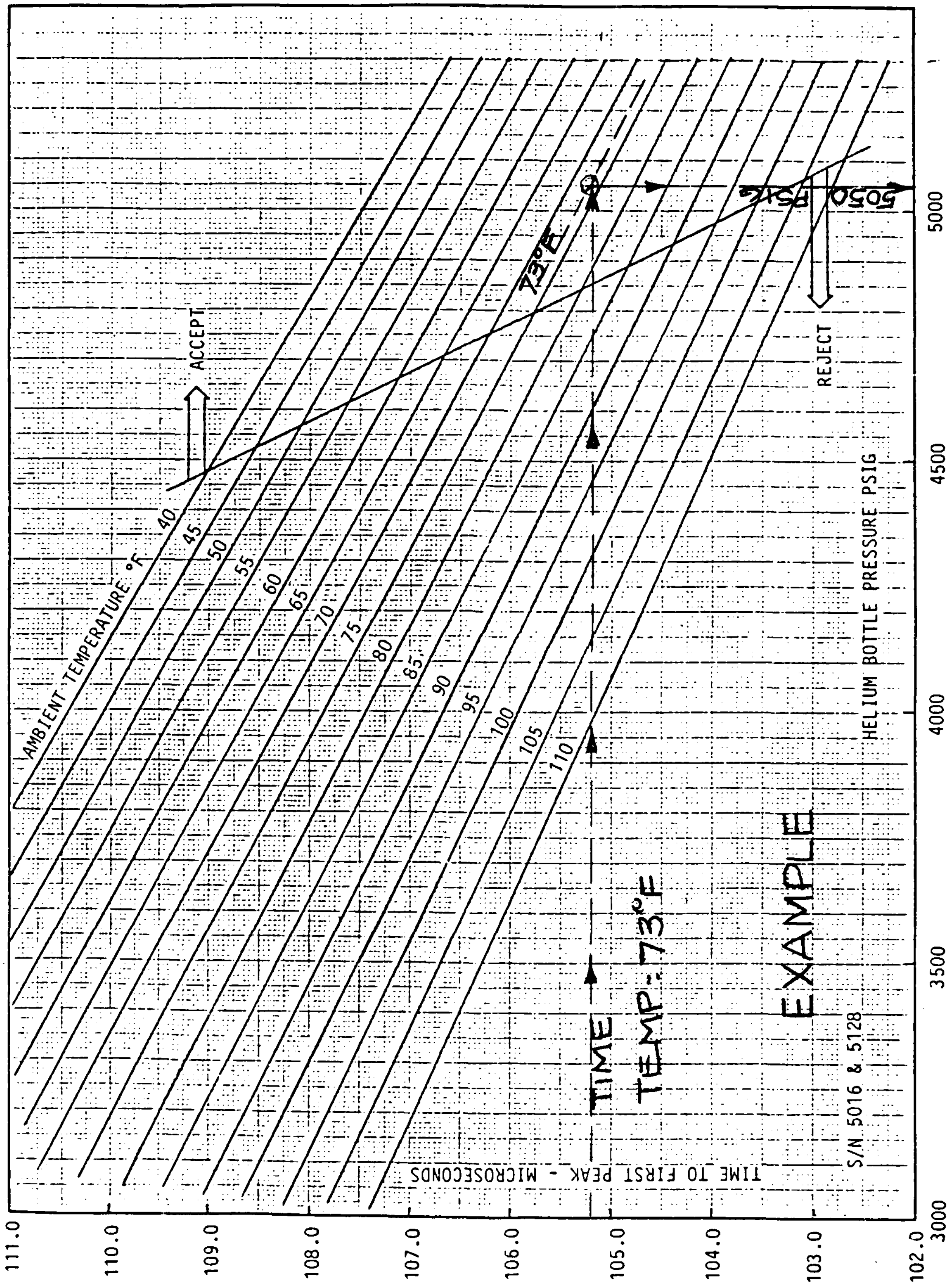
MEASURED PULSE-ECHO TIME 105.3 1

STANDARD CORRECTION -.10 3

CORRECTED PULSE-ECHO TIME 105.20 4

BOTTLE PRESSURE 5050 psi 5

**EXAMPLE**

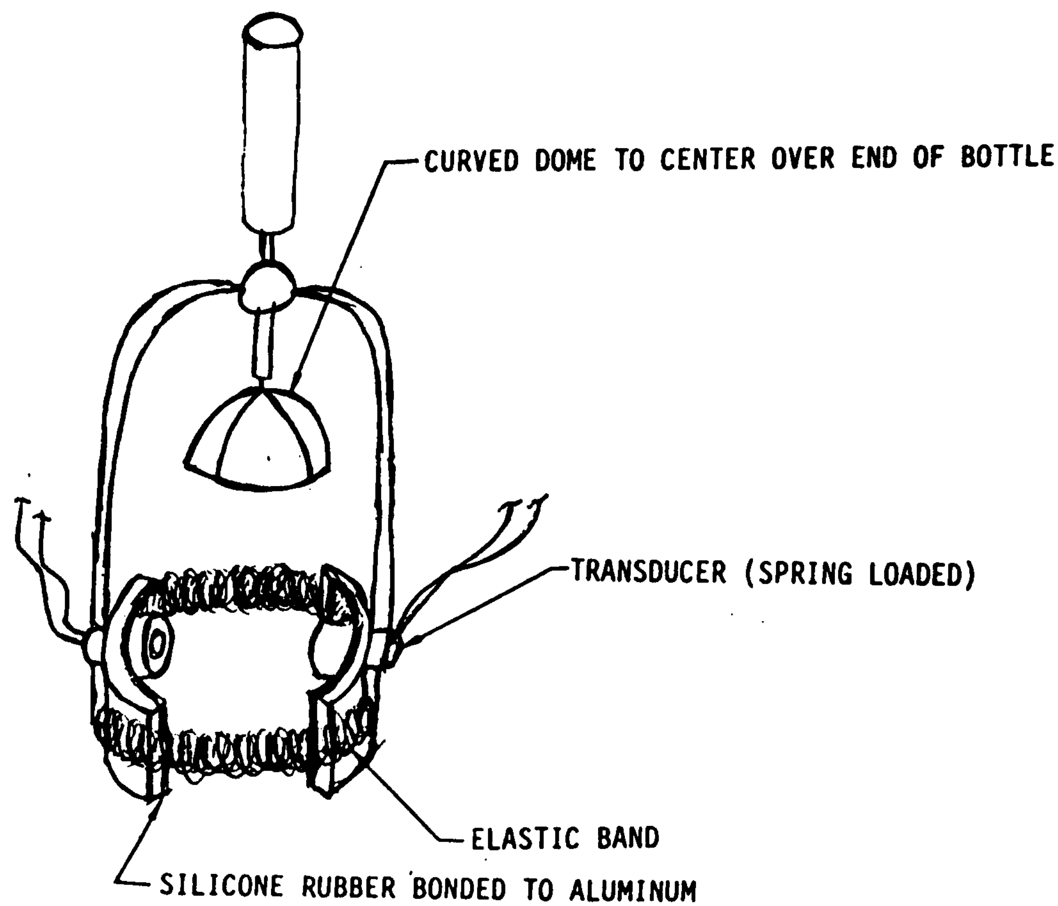



CALIBRATION CURVE FOR APCO HELIUM BOTTLE USING ULTRASONICS

HELIUM BOTTLE PRESSURE
MEASUREMENT BY PORTABLE
ULTRASONIC TECHNIQUE

Chart: 73
Speaker: A. G. Olson
Date: 15 September 1987

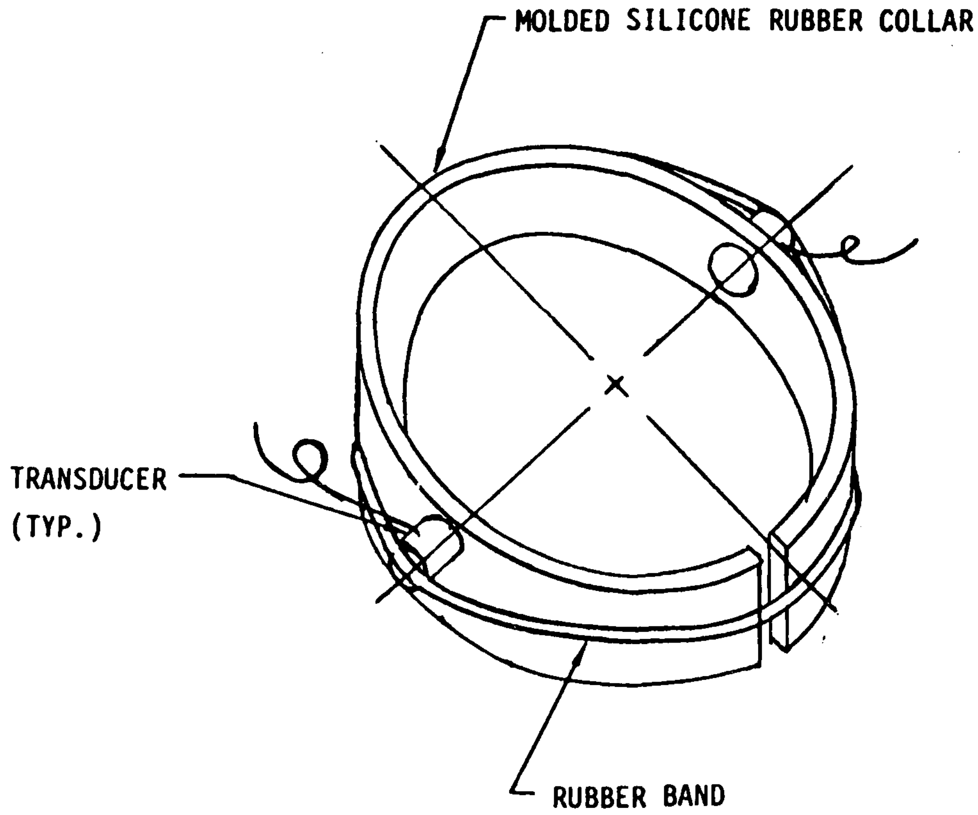
ORIGINAL TRANSDUCER TEST FIXTURE



HELIUM BOTTLE PRESSURE
MEASUREMENT BY PORTABLE
ULTRASONIC TECHNIQUE

Chart: 74
Speaker: A. G. Olson
Date: 15 September 1987

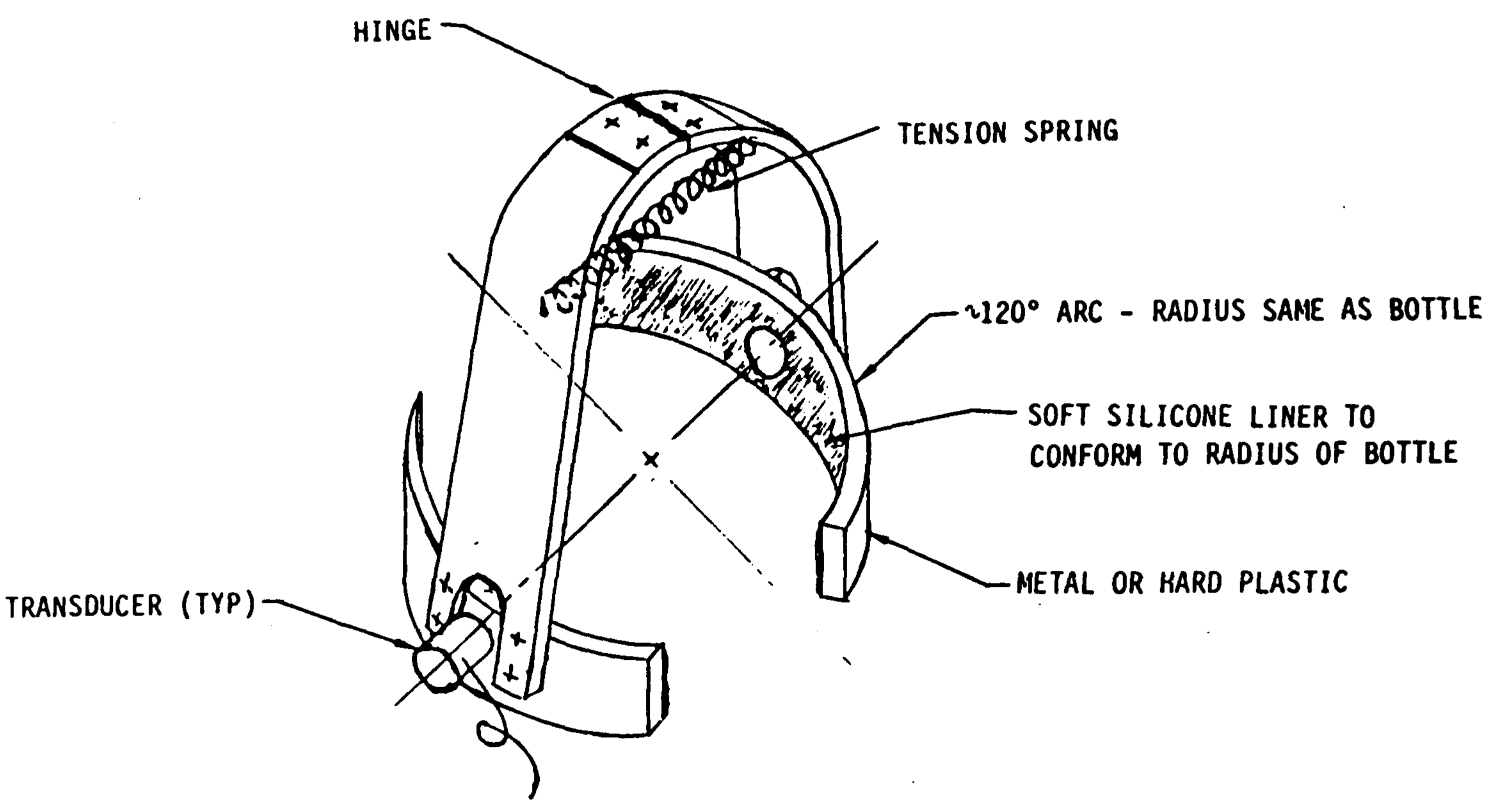
TRANSDUCER FIXTURE FIRST ITERATION



HELIUM BOTTLE PRESSURE
MEASUREMENT BY PORTABLE
ULTRASONIC TECHNIQUE

Chart: 75
Speaker: A. G. OLSON
Date: 15 SEPTEMBER 1987

TRANSDUCER FIXTURE SECOND ITERATION




• TRANSDUCERS <u>MUST</u> BE LOCATED 180° APART

## Equation Development

The task of developing an empirical equation to determine the pressure of helium at any given temperature knowing the ultrasonic longitudinal sound wave pulse echo time of flight was accomplished in the following manner.

A linear regression analysis was preformed on the experimental data values. This analysis was preformed by examining the relationship between the dependent variable (y, time of flight) and the independent variable (x , bottle pressure) for each isothermal line. A straight line approximation was consider appropriate for this data because a least-squares linear regression analysis for each experimental isothermal data line correlation coefficient was found to be vary close to 1. See table 1 for results of the statistical analysis . A linear regression was preformed from a model of y= mx +b or Time Of Flight (TOF)= m Pressure(P) + b which is the equation for describing a straight line where m is the slope of the line and b is the y intercept.

Now that an equation was ascertained for each isothermal line the equation had to be modified to predict the time of flight from any temperature. A second linear regression was preformed on the slopes of each isothermal line. Again the correlation coefficient was close to one so a straight line equation was also appropriate.

The final equation now is of the form TOF=(m x temperature(T)+intercept) x P +intercept. A time of flight standard was used in the experiment to compensate for any electronic drift in the gate from the normalized 51.55 micro seconds and inserted into the equation . By inserting values into the equation and solving for pressure (since in the field the pressure is the unknown) the final equations for the Boeing and A.P.C.O. pressure bottles are obtained and shown below.

Apco. Bottle

P = (TOF + (51.55 - STD.TOF) + (T x .115) - 126.834) / (((9.887 x ~~10-6~~ $10^{-6}$)x T ) - 3.34x~~10-3~~ $10^{-3}$)

Boeing Bottle

P = (TOF + (51.55 -STD.TOF) + (T x 9.74 x 10-2) - 117.90) / (((6.5~~e-6~~ $\times 10^{-6}$) x T )-2.92 ~~10-3~~ $\times 10^{-3}$)

Note:
TOF=Pulse Echo Time of Flight in Microseconds
Pressure = Pounds per square inch gage
Temperature = Degrees Fahrenheit
STD = Standard Pulse Echo Time of Flight in Microseconds

Using the equations developed here the average deviation from actual data was only 37 psig and 45 psig for Apco and Boeing respectively. Now a programmable calculator can be used in the field to determine the pressure at any given temperature instead of using the less precise graphs.

J. LINN 3/31/88

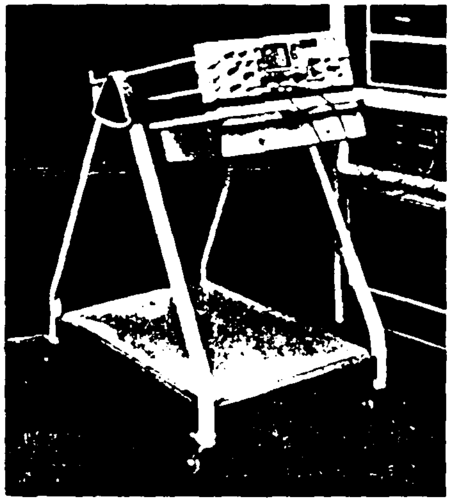
************************************************************

| Manufacture | Temperature (Deg.F) | Correlation |
|---|---|---|
| Apco | 40 | .993 |
| Apco | 70 | .996 |
| Apco | 100 | .995 |
| Apco slopes | | .993 |
| Boeing | 40 | .998 |
| Boeing | 70 | .998 |
| Boeing | 100 | .997 |
| Boeing slopes | | .998 |

************************************************************

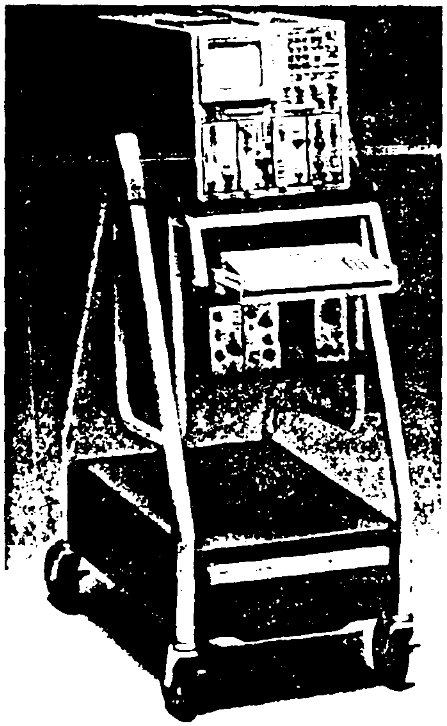
TABLE I
STATISTICAL ANALYSIS OF STRAIGHT LINE LEAST SQUARES FIT FOR EXPERIMENTAL ISOTHERMAL DATA

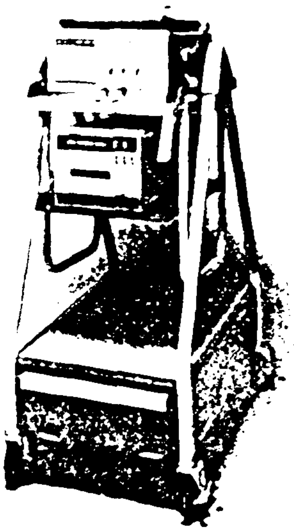
1986 TEKTRONIX CATALOG



K217

Recommended For





K210

Recommended For

ORDERING INFORMATION

ORDERING INFORMATION

$495

NC

OPTIONAL ACCESSORIES

OPTIONAL ACCESSORIES

Extra Shelf

Third Keyboard Drawer Kit

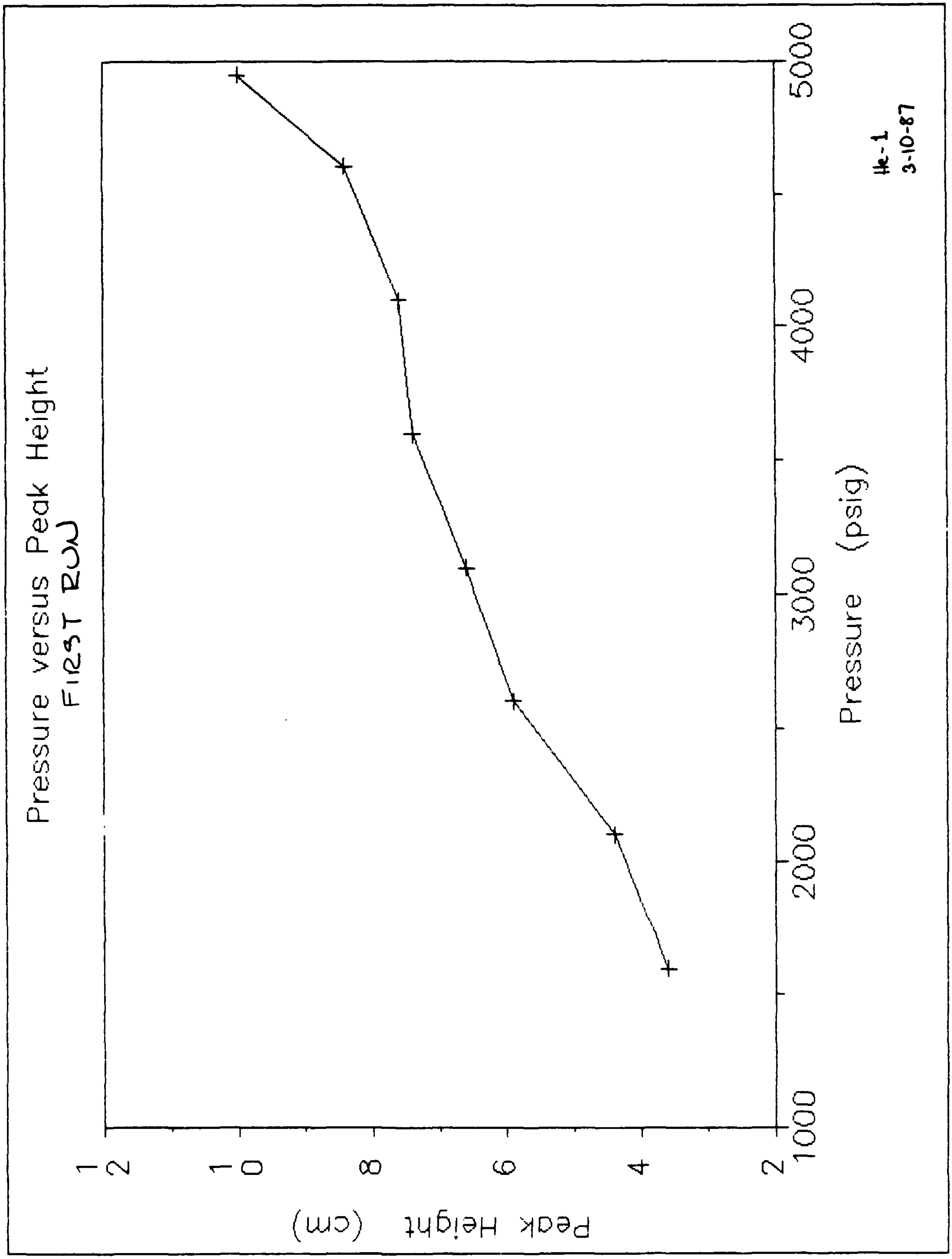
Plug-in Storage Cabinet Kit

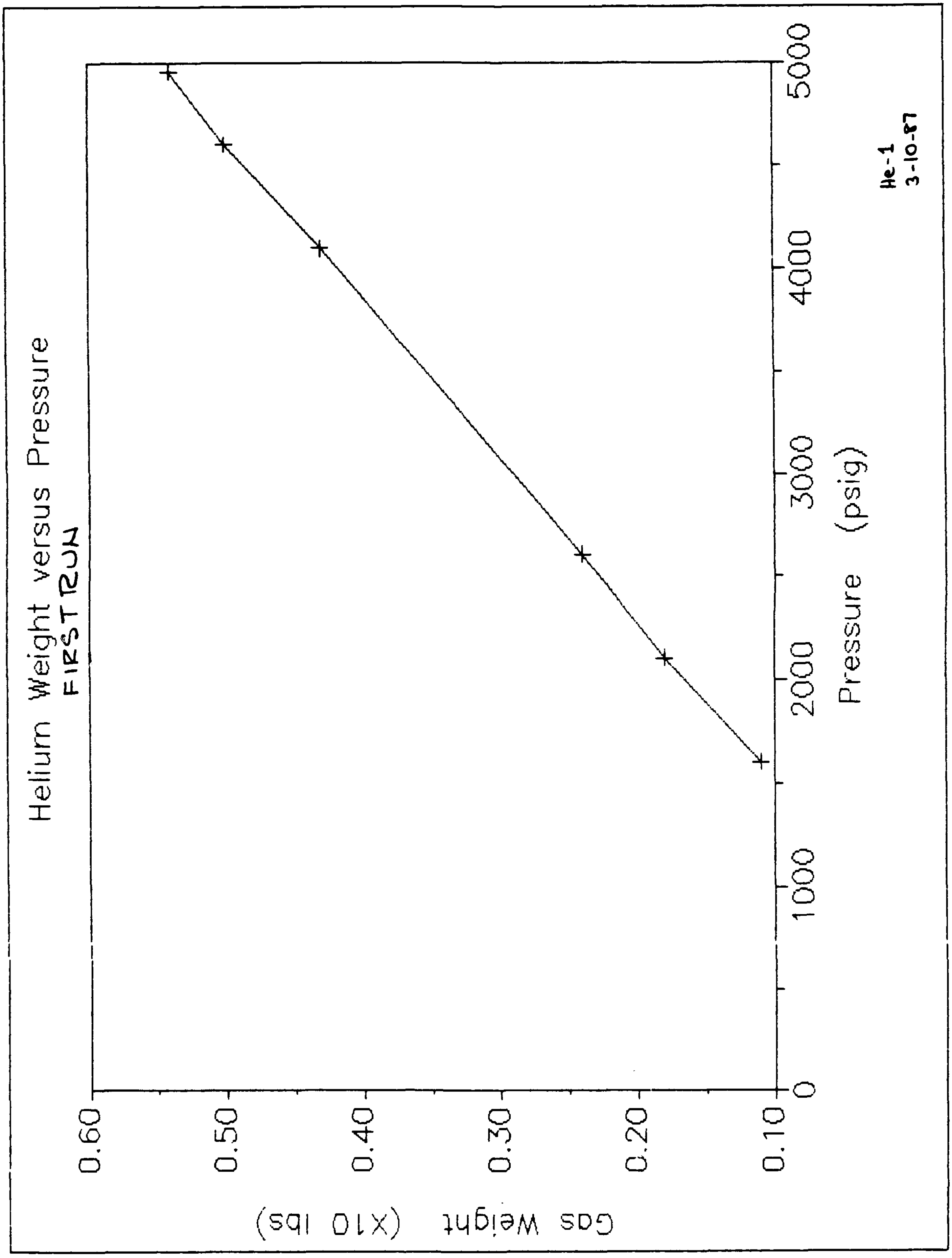
Retaining Bar

CARTS

# APPENDIX E

# TEST DATA


Pressure versus Peak Height
FIRST RUN
Peak Height (cm)
2
4
6
8
10
12
Pressure (psig)
1000
2000
3000
4000
5000
He-1
3-10-87


Helium Weight versus Pressure
FIRST RUN
Gas Weight (X10 lbs)
0.60
0.50
0.40
0.30
0.20
0.10
0
1000
2000
3000
4000
5000
Pressure (psig)
He-1
3-10-87

SUMMARY OF DATA FROM APCO BOTTLE
(S/N 5016) TESTS

(2 Transducers)

| Date | Measured Pressure psig | Time to First Peak Micro Sec |
|---|---|---|
| 3-11-87 | 4648 | 54.55 |
| | 4383 | 54.95 |
| | 4092 | 55.40 |
| | 3801 | 55.80 |
| | 3523 | 56.20 |
| | 3219 | 56.60 |
| | 2891 | 57.15 |
| | 2609 | 57.50 |
| | 2303 | 58.00 |
| | 1989 | 58.40 |
| | 1687 | 59.00 |
| | 1387 | 59.50 |
| 3-12-87 | 4493 | 54.55 |
| | 4016 | 55.30 |
| | 3487 | 56.00 |
| | 3020 | 56.70 |
| | 2501 | 57.50 |
| | 1983 | 58.40 |
| | 1485 | 59.20 |

TEMP ≈ 70°F

SUMMARY OF DATA FROM APCO BOTTLE
(S/N 5016) TESTS

(2 Transducers)

| Date | Measured Pressure psig | Time to First Peak Micro Sec |
|---|---|---|
| 3-16-87 (a.m.) | 4603 | 54.50 |
| | 4110 | 55.20 |
| | 3598 | 56.00 |
| | 3099 | 56.65 |
| | 2519 | 57.50 |
| | 2080 | 58.15 |
| | 1588 | 59.10 |
| | 1089 | 59.90 |
| | 800 | 60.70 |

| | | |
|---|---|---|
| 3-16-87 (p.m.) | 4558 | 54.70 |
| | 3999 | 55.40 |
| | 3418 | 56.15 |
| | 2790 | 57.20 |
| | 21.87 | 58.00 |
| | 1303 | 59.50 |

TEMP ≈ 70°F

# SUMMARY OF DATA FROM APCO BOTTLE (S/N 5016) TESTS

(2 Transducers)

| Date | Measured Pressure psig | Time to First Peak Micro Sec |
|---|---|---|
| 3-17-87 | 4284 | 54.85 |
| | 3794 | 55.60 |
| | 3300 | 56.35 |
| | 2800 | 57.05 |
| | 2305 | 57.85 |
| | 1808 | 58.70 |
| | 1304 | 59.60 |
| | 795 | 60.50 |
| | 394 | 61.15 |
| 4-6-87 (a.m.) | 4293 | 54.70 |
| | 4003 | 55.15 |
| | 3718 | --- |
| | 3406 | 55.95 |
| | 3106 | 56.40 |
| | 2804 | 56.90 |
| | 2507 | 57.35 |
| | 2211 | 57.85 |
| | 1918 | 58.25 |
| | 1597 | 58.70 |
| | 1309 | 59.20 |
| | 1008 | 60.15 |

TEMP ≈ 70°F

SUMMARY OF DATA FROM APCO BOTTLE
(S/N 5016) TESTS

(2 Transducers)

| Date | Measured Pressure psig | Time to First Peak Micro Sec |
|---|---|---|
| 4-6-87 (p.m.) | 4325 | 54.60 |
| | 3821 | 55.40 |
| | 3305 | 56.10 |
| | 2803 | 56.85 |
| | 2302 | 57.65 |
| | 1788 | 58.50 |
| | 1302 | 59.35 |
| | 992 | 60.00 |

TEMP ≈ 70°F

# DATA SHEET

## ULTRASONIC MEASUREMENT OF PRESSURE IN *APCO HELIUM BOTTLE 821100-103, S/N 5016

| Run No. | Date | Weight (Lb) | | | Pressure Gauge (psig) |
|---|---|---|---|---|---|
| | | Gross | Tare | Helium | |
| 2 | 3-11-87 | 11.503 | 11.446 | .057 | 4691 |
| | | 11.498 | 11.446 | .052 | 4087 |
| | | 11.492 | | .046 | 3523 |
| | | 11.486 | | .040 | 2898 |
| | | 11.476 | | .030 | 2303 |
| | | 11.468 | | .022 | 1689 |

TEMP ≈ 70°F

C. Brooks 3/11/87

*2 Transducers

# DATA SHEET

## ULTRASONIC MEASUREMENT OF PRESSURE IN *APCO HELIUM BOTTLE 821100-103, S/N 5016

| Run No. | Date | Weight (Lb) | | | Pressure Gauge (psig) |
|---|---|---|---|---|---|
| | | Gross | Tare | Helium | |
| 5 | 3-16-87 p.m. | 11.248 | 11.192 | .056 | 4558 |
| | | 11.243 | | .051 | 3999 |
| | | 11.236 | | .044 | 3418 |
| | | 11.231 | | .039 | 2790 |
| | | 11.223 | | .031 | 2187 |
| | | 11.209 | | .017 | 1303 |

C. Brooks 3/16/87

*2 Transducers

# DATA SHEET

## ULTRASONIC MEASUREMENT OF PRESSURE IN *APCO HELIUM BOTTLE 821100-103, S/N 5016

| Run No. | Date | Weight (Lb) | | | Pressure Gauge (psig) |
|---|---|---|---|---|---|
| | | Gross | Tare | Helium | |
| 8(a.m.) | 4-6-87 | 11.259 | 11.206 | .053 | 4299 |
| | | 11.256 | | .050 | 3990 |
| | | 11.256 | | -- | 3708 |
| | | 11.249 | | .043 | 3406 |
| | | 11.246 | | .040 | 3099 |
| | | 11.243 | | .037 | 2797 |
| | | 11.239 | | .033 | 2496 |
| | | 11.236 | | .030 | 2187 |
| | | 11.232 | | .026 | 1894 |
| | | 11.228 | | .022 | 1597 |
| | | 11.225 | | .019 | 1301 |
| | | 11.220 | | .014 | 998 |

C. Brooks 4/6/87

*2 Transducers

# DATA SHEET

## ULTRASONIC MEASUREMENT OF PRESSURE IN *APCO HELIUM BOTTLE 821100-103, S/N 5016

| Run No. | Date | Weight (Lb) | | | Pressure Gauge (psig) |
|---|---|---|---|---|---|
| | | Gross | Tare | Helium | |
| 7(p.m.) | 4-6-87 | 11.259 | 11.206 | .053 | 4325 |
| | | 11.251 | | .045 | 3821 |
| | | 11.245 | | .039 | 3305 |
| | | 11.242 | | .036 | 2816 |
| | | 11.236 | | .030 | 2302 |
| | | 11.230 | | .024 | 1788 |
| | | 11.223 | | .017 | 1302 |
| | | 11.219 | 11.206 | .013 | 989 |
| | | Cal Wts | Cal Wts | | |
| | | 11.222 | 11.211 | | |
| | Δ = | .003 | .005 | | |

TEMP ≈ 70°F

C. Brooks 4/6/87

*2 Transducers

Less than 10 PPM Impurities

# DATA SHEET

## BOEING HELIUM BOTTLE (S/N 3841); INITIAL RUN

(2 Transducers) 8-3-87

| Condition | Measured Pressure psig | Bottle Temp. °F | Time to First Peak Micro Sec. |
|---|---|---|---|
| Full | N/A | 72.2 | 50.50 |
| Pressure Decrements | 4620 | 72.9 | 50.95 |
| | 3979 | 71.6 | 51.75 |
| | 3466 | 70.9 | 52.40 |
| | 3030 | 70.3 | 52.95 |
| | 2639 | 69.8 | 53.50 |

TEMP ≈ 70°F

# DATA SHEET

## ULTRASONIC MEASUREMENT OF PRESSURE IN *BOEING HELIUM BOTTLE 25A45740-101-11, S/N 3841

| Run No. | Date | Weight (Lb) Gross | Weight (Lb) Tare | Weight (Lb) Helium | Pressure Gauge (psig) | Temp °F | Micro Sec. |
|---|---|---|---|---|---|---|---|
| 1 | 8-5-87 | 10.707 | 10.643 | .064 | 4887 | 79.2 | 50.45 |
| | | ⊙10.707 | 10.642 | .065 | | | |
| Repeat | | | | | 4869 | 77.7 | 50.55 |
| 2 | | 10.701 | | .058 | 4515 | 76.7 | 51.00 |
| | | ⊙ 10.697 | | .055 | | | |
| 3 | | 10.697 | | .054 | 4150 | 75.3 | 51.45 |
| | | ⊙ 10.694 | | .052 | | | |
| 4 | | 10.693 | | .050 | 3750 | 74.4 | 51.95 |
| | | ⊙ 10.691 | | .049 | | | |
| 5 | | 10.688 | | .045 | 3403 | 74.0 | 52.45 |
| | | ⊙ 10.685 | | .043 | | | |
| 6 | | 10.684 | | .041 | 3005 | 73.2 | 52.90 |
| | | ⊙ 10.681 | | .039 | | | |
| 7 | | 10.643 | | | 4.1 | 63.3 | |
| | | ⊙10.642 | | | | | |

* 2 Transducers

⊙ Checked with Calibrated Weights

APCO RUN 2 Final Press = 15 psi S/N 5016

| DATE | TIME | BOTTLE $T_B$ °F | AMBIENT $T_A$ °F | GAGE PRESS (PSI) | CAL STD μSEC | THRU TRANSMISSION TTU μSEC | PULSE ECHO PE μ SEC |
|---|---|---|---|---|---|---|---|
| 1-19-88 | 09:45 | 71.8 | 71.8 | 5097 | 51.55 | 53.70 | 105.3 |
| | 12:40 | 37.9 | 37.9 | 4777 | 51.60 | 55.30 | 108.5 |
| 1-20-88 | 06:52 | 100.9 | 101.1 | 5318 | 51.55 | 52.45 | 102.8 |
| | 07:07 | 100.4 | 101.2 | 4988 | 51.55 | 52.80 | 103.6 |
| | 09:36 | 72.4 | 72.1 | 4746 | 51.55 | 54.05 | 106.0 |
| | 12:06 | 38.4 | 38.7 | 4454 | 51.55 | 55.65 | 109.3 |
| | 12:16 | 37.8 | 38.2 | 4105 | 51.55 | 56.20 | 110.3 |
| | 14:25 | 64.5 | 65.1 | 4318 | 51.60 | 54.90 | 107.6 |
| 1-21-88 | 07:02 | 100.4 | 100.7 | 4586 | 51.55 | 53.25 | 104.5 |
| | 07.14 | 99.7 | 100.6 | 4243 | 51.55 | 53.70 | 105.3 |
| | 09:53 | 72.4 | 72.4 | 4043 | 51.60 | 54.95 | 107.9 |
| | 12:05 | 38.9 | 38.5 | 3795 | 51.60 | 56.65 | 111.2 |
| | 12:17 | 38.2 | 38.6 | 3490 | 51.60 | 57.10 | 112.1 |
| | 14:18 | 64.6 | 65.2 | 3671 | 51.60 | 55.75 | 109.5 |
| 1-22-88 | 08:01 | 100.9 | 101.1 | 3908 | 51.55 | 54.10 | 106.2 |
| | 08:10 | 100.0 | 101.1 | 3598 | 51.55 | 54.55 | 107.0 |
| | 09:58 | 71.8 | 72.4 | 3423 | 51.60 | 55.85 | 109.6 |
| Readjust X-ducers | | | | | | 55.85 | 109.7 |
| | 12:03 | 37.8 | 39.1 | 3214 | 51.60 | 57.60 | 113.1 |
| | 12:15 | 36.6 | 37.6 | 2874 | 51.60 | 58.15 | 114.2 |
| | 13:50 | 72.1 | 72.8 | 3073 | 51.65 | 56.30 | 110.5 |
| | 13:59 | 70.9 | 73.0 | 2500 | 51.65 | 57.15 | 112.3 |
| | 14:02 | 69.6 | 73.0 | 1984 | | 57.95 | 113.9 |
| | | 67.6 | 73.0 | 964 | | 59.70 | 117.4 |
| | | 67.4 | 73.1 | 460 | | 60.60 | 119.2 |

SINGLE TRANSDUCER

APCO RUN 2 Corrected +8.5 psi/$^{o}$F

S/N 5016 -.089 μsec/°F

| BOTTLE $T_B$ $^{o}$F | GAGE PRESS. P(PSI) | CAL STD μsec | -.089 s/$^{o}$F P.E. | CORRECTED PRESS Pc(PSI) | $PB_C$ | $STD_C$ |
|---|---|---|---|---|---|---|
| 71.8 | 5097 | 51.55 | 105.3 | 5082 | 105.46 | 105.46 |
| 32.9 | 4777 | 51.60 | 108.5 | 4795 | 108.30 | 108.30 |
| 00.9 | 5318 | .55 | 102.8 | 5310 | 102.88 | 102.88 |
| 00.4 | 4988 | .55 | 103.6 | 4984 | 103.65 | 103.65 |
| 72.4 | 4746 | .55 | 106.0 | 4726 | 106.2 | 106.20 |
| 38.4 | 4454 | .55 | 109.3 | 4468 | 109.12 | 109.12 |
| 37.8 | 4105 | .55 | 110.3 | 4124 | 110.1 | 110.10 |
| 64.5 | 4318 | .60 | 107.6 | 4365 | 107.11 | 107.05 |
| 00.4 | 4586 | .55 | 104.5 | 4582 | 104.54 | 104.54 |
| 99.7 | 4243 | .55 | 105.3 | 4245 | 105.3 | 105.30 |
| 72.4 | 4043 | .60 | 107.9 | 4023 | 108.11 | 108.05 |
| 38.9 | 3795 | .60 | 111.2 | 3804 | 111.10 | 111.05 |
| 38.2 | 3490 | .60 | 112.1 | 3505 | 111.94 | 111.89 |
| 64.6 | 3671 | .60 | 109.5 | 3717 | 109.02 | 108.97 |
| 00.9 | 3908 | .55 | 106.2 | 3900 | 106.28 | 106.28 |
| 00.0 | 3598 | .55 | 107.0 | 3598 | 107.00 | 107.01 |
| 71.8 | 3423 | .60 | 109.6 | 3408 | 109.76 | 109.71 |

SINGLE TRANSDUCER

RUN 3, APCO BOTTLE Final Press = 11.5 psi S/N 5016

| DATE | TIME | AMBIENT TEMP $T_A$ °F | BOTTLE TEMP $T_B$ °F | GAGE PRESS (PSI) | CAL STD SEC | THRU TRANSMISSION TTU μSEC | PULSE ECHO PE μ SEC |
|---|---|---|---|---|---|---|---|
| 2-2-88 | 08:19 | 70.2 | 70.1 | 5055 | 51.55 / 103.2 | 53.70 | 105.3 |
| | 09:50 | 40.1 | 40.3 | 4773 | 51.55 / 103.2 | 55.10 | 108.2 |
| | 12:49 | 101.3 | 101.8 | 5328 | 51.55 / 103.3 | 52.35 | 102.6 |
| | 13:01 | 101.8 | 101.0 | 5041 | 51.55 / 103.3 | 52.65 | 103.3 |
| | 14:21 | 68.7 | 69.1 | 4765 | 51.60 / 103.3 | 54.10 | 106.2 |
| 2-3-88 | 07:50 | 41.3 | 41.3 | 4510 | 51.60 / 103.3 | 55.45 | 108.7 |
| | 08:01 | 41.3 | 40.7 | 4193 | 103.3 / 51.60 | 55.90 | 109.7 |
| | 09:33 | 62.5 | 62.0 | 4367 | 51.55 / 103.2 | 54.80 | 107.5 |
| | 12:29 | 100.7 | 100.5 | 4672 | 51.65 / 103.4 | 53.25 | 104.4 |
| | 12:41 | 100.6 | 99.9 | 4347 | 51.65 / 103.4 | 53.60 | 105.1 |
| | 14:42 | 71.0 | 71.0 | 4129 | 51.60 / 103.4 | 54.85 | 107.6 |
| 2-4-88 | 07:36 | 41.5 | 41.5 | 3900 | 51.60 / 103.3 | 56.30 | 110.5 |
| | 07:47 | 41.7 | 40.9 | 3601 | 51.60 / 103.3 | 56.70 | 111.4 |
| | 08:56 | 62.7 | 61.9 | 3749 | 51.60 / 103.4 | 55.70 | 109.3 |
| | 10:43 | 100.6 | 10.2 | 4012 | 51.60 / 103.3 | 53.95 | 105.7 |
| | 10:54 | 100.9 | 100.0 | 3679 | 51.60 / 103.3 | 54.35 | 106.6 |
| | 12:37 | 71.7 | 71.8 | 3508 | 51.60 / 103.4 | 55.60 | 109.1 |
| 2-5-88 | 07:39 | 51.5 | 41.4 | 3309 | 51.65 / 103.3 | 57.15 | 112.1 |
| | 07:51 | 41.5 | 40.9 | 3009 | 51.60 / 103.3 | 57.60 | 113.2 |
| | 09:11 | 69.4 | 69.5 | 3176 | 51.55 / 103.3 | 56.15 | 110.2 |
| | 10:34 | 100.4 | 100.1 | 3351 | 51.55 / 103.2 | 54.65 | 107.2 |
| | 10:45 | 100.5 | 99.6 | 3007 | 51.55 / 103.2 | 55.10 | 108.2 |
| | 12:03 | 69.4 | 69.5 | 2854 | 51.60 / 103.3 | 56.65 | 111.2 |
| | 12:08 | | 68.2 | 2497 | | 57.25 | 112.3 |
| | 12:13 | | 67.1 | 1970 | | 58.00 | 114.0 |
| | 12:17 | | 66.0 | 1432 | | 58.90 | 115.7 |

SINGLE TRANSDUCER

RUN 3 APCO BOTTLE S/N 5016

| $T_B$ | PSI | TTU μSec | PE μSec |
|---|---|---|---|
| 64.1 | 815 | 60.05 | 118.1 |
| 64.8 | 455 | 60.65 | 119.2 |
| 64.8 | 297 | 61.00 | - |
| Stops at 11.5 psi | | | |

SINGLE TRANSDUCER

APCO RUN 3 Corrected S/N 5016

| BOTTLE TEMP $T_B$ °F | GAGE PRESS. P(PSI) | PULSE ECHO μ SEC | CAL STD μSec | CORRECTED PRESS Pc(PSI) | $PB_C$ μSec |
|---|---|---|---|---|---|
| 101.8 | 5328 | 102.6 | 51.55 | 5314 | 102.77 |
| 101.0 | 5041 | 103.3 | 51.55 | 5033 | 103.40 |
| 100.5 | 4672 | 104.4 | 51.65 | 4668 | 104.35 |
| 99.9 | 4347 | 105.1 | 51.65 | 4347 | 105.00 |
| 100.2 | 4012 | 105.7 | 51.60 | 4011 | 105.60 |
| 100.0 | 3679 | 106.6 | 51.60 | 3679 | 106.50 |
| 70.1 | 5055 | 105.3 | 51.55 | 5055 | 105.30 |
| 69.1 | 4765 | 106.2 | 51.60 | 4772 | 106.07 |
| 62.0 | 4367 | 107.5 | 51.55 | 4431 | 106.76 |
| 71.0 | 4129 | 107.6 | 51.60 | 4121 | 107.64 |
| 61.9 | 3749 | 109.3 | 51.60 | 3814 | 108.50 |
| 71.8 | 3508 | 109.1 | 51.60 | 3494 | 109.22 |
| 40.3 | 4773 | ·08.2 | 51.55 | 4771 | 108.20 |
| 41.3 | 4510 | 108.7 | 51.60 | 4500 | 108.77 |
| 40.7 | 4193 | 109.7 | 51.60 | 4188 | 109.71 |
| 41.5 | 3900 | 110.5 | 51.60 | 3888 | 110.59 |
| 40.9 | 3601 | 111.4 | 51.60 | 3594 | 111.40 |
| 41.4 | 3309 | 112.1 | 51.65 | 3298 | 112.13 |

SINGLE TRANSDUCER

BOEING BOTTLE RUN 2 Final Press = S/N 3841

| AMBIENT TEMP $T_A$ °F | BOTTLE TEMP $T_B$ °F | GAGE PRESS $P_B$(PSI) | TIME | CAL SEC | THRU TRANSMSN TTU µSEC | PULSE ECHO µSEC | DATE |
|---|---|---|---|---|---|---|---|
| 71.1 | 71.3 | 5027 | 7:09 | 51.60 | 50.65 | 98.75 | 01-05-88 |
| 39.6 | 39.7 | 4734 | 9:09 | 51.55 | 51.90 | 101.2 | 01-05-88 |
| 100.4 | 100.2 | 5284 | 11:33 | 51.50 | 49.40 | 96.15 | 01-05-88 |
| 100.5 | 99.8 | 5014 | 11:46 | 51.50 | 49.65 | 96.70 | 01-05-88 |
| 69.7 | 69.8 | 4755 | 13:34 | 57.55 | 50.90 | 99.25 | 01-05-88 |
| 38.4 | 38.6 | 4483 | 15:03 | 51.50 | 52.30 | 102.0 | 01-05-88 |
| 38.4 | 38.2 | 4212 | 15:17 | 51.50 | 52.60 | 102.80 | 01-05-88 |
| 68.9 | 68.7 | 4461 | 07:10 | 51.50 | 51.20 | 99.85 | 01-06-88 |
| 101.0 | 100.0 | 4722 | 09:11 | 51.50 | 49.90 | 97.30 | 01-06-88 |
| 101.1 | 100.5 | 4405 | 09:30 | 51.50 | 50.25 | 97.90 | 01-06-88 |
| 68.9 | 68.9 | 4165 | 12:02 | 51.55 | 51.65 | 100.7 | 01-06-88 |
| 37.7 | 38.0 | 3929 | 14:02 | 51.50 | 53.00 | 103.40 | 01-06-88 |
| 37.6 | 37.5 | 3636 | 14:13 | 51.50 | 53.40 | 104.20 | 01-06-88 |
| 71.8 | 71.6 | 3878 | 07:30 | 51.55 | 51.90 | 101.3 | 01-07-88 |
| 101.0 | 100.7 | 4082 | 09:27 | 51.60 | 50.70 | 98.80 | 01-07-88 |
| 101.0 | 100.2 | 3793 | 09:39 | 51.60 | 51.00 | 99.45 | 01-07-88 |
| 71.8 | 71.7 | 3607 | 13:09 | 51.60 | 52.25 | 101.90 | 01-07-88 |
| 38.1 | 38.4 | 3388 | 14:42 | 51.55 | 53.80 | 105.00 | 01-07-88 |
| 38.1 | 37.8 | 3102 | 14:52 | 51.55 | 54.20 | 105.80 | 01-07-88 |
| 80.1 | 80.0 | 3356 | 07:48 | 51.55 | 52.25 | 101.90 | 01-08-88 |
| 109.0 | 107.0 | 3479 | 10:59 | 51.60 | 51.40 | 100.20 | 01-08-88 |
| 100.8 | 100.1 | 3209 | 11:09 | 51.60 | 51.70 | 100.90 | 01-08-88 |
| 72.5 | 72.7 | 3059 | 01:28 | 51.55 | 52.90 | 103.20 | 01-08-88 |
| 38.5 | 38.8 | 2871 | 02:54 | 51.55 | 54.45 | 106.40 | 01-08-88 |
| 38.2 | 37.8 | 2531 | 03:03 | 51.55 | 55.05 | 107.50 | 01-08-88 |

SINGLE TRANSDUCER

BOEING BOTTLE S/N 3841 RUN #1 Final Press =

| AMBIENT TEMP $T_A$ $^oF$ | BOTTLE TEMP $T_B$ $^oF$ | GAGE PRES. P (PSI) | PULSE ECHO P/E µS | THRU TRANSM. TTU µs | TIME | µ SEC CALBLOCK | DATE |
|---|---|---|---|---|---|---|---|
| 69.0 | 68.9 | 5039 | 98.80 | 50.70 | 13:22 | 51.60 | 12/14/87 |
| 100.3 | 99.8 | 5318 | 96.30 | 49.45 | 15:25 | 51.55 | 12/14/87 |
| 36.5 | 37.0 | 4737 | 101.60 | 52.15 | 07:10 | 51.65 | 12/15/87 |
| 37.0 | 36.4 | 4442 | 102.40 | 52.50 | 07:20 | 51.65 | 12/15/87 |
| 62.3 | 63.4 | 4677 | 99.95 | 51.25 | 09:23 | 51.35 | 12/15/87 |
| 100.7 | 100.1 | 4992 | 96.90 | 49.75 | 11:02 | 51.55 | 12/15/87 |
| 100.5 | 100.2 | 4696 | 97.50 | 50.05 | 11:37 | 51.55 | 12/15/87 |
| 71.0 | 71.0 | 4461 | 99.90 | 51.25 | 13:30 | 51.55 | 12/15/87 |
| 39.6 | 39.6 | 4206 | 102.80 | 52.65 | 15:10 | 51.55 | 12/15/87 |
| 38.3 | 38.9 | 3884 | 103.60 | 53.10 | 15:25 | 51.60 | 12/15/87 |
| 72.7 | 72.6 | 4137 | 100.60 | 51.55 | 07:27 | 51.55 | 12/16/87 |
| 99.5 | 99.5 | 4335 | 98.40 | 50.45 | 08:55 | 51.60 | 12/16/87 |
| 100.6 | 99.2 | 4008 | 99.10 | 50.80 | 09:10 | 51.60 | 12/17/87 |
| 73.7 | 72.1 | 3823 | 101.40 | — | 10:21 | — | 12/17/87 |
| 70.9 | 71.3 | 3817 | 101.40 | 51.95 | 11:34 | 51.65 | 12/17/87 |
| 39.1 | 39.4 | 3594 | 104.40 | 53.45 | 14:40 | 51.60 | 12/17/87 |
| 38.2 | 38.5 | 33097 | 105.20 | 53.90 | 14:51 | 51.55 | 12/17/87 |
| 73.4 | 73.3 | 3534 | 102.00 | 52.30 | 07:00 | 51.55 | 12/18/87 |
| 100.6 | 100.0 | 3703 | 99.75 | 51.15 | 09:26 | 51.55 | 12/18/87 |
| 100.7 | 99.7 | 3390 | 100.50 | 51.55 | 09:41 | 51.55 | 12/18/87 |
| 72.7 | 73.1 | 3235 | 102.80 | 52.65 | 13:23 | 51.55 | 12/18/88 |
| 39.6 | 39.5 | 3040 | 105.90 | 54.25 | 14:57 | 51.55 | 12/18/87 |
| 39.0 | 39.0 | 3810 | 106.60 | 54.55 | 15:09 | 51.55 SHUT OFF | 12/18/87 |
| 70.8 | 70.6 | 2180 | 103.70 | 53.10 | 09:41 | 51.55 | 12/21/87 |
| 99.3 | 99.2 | 3134 | 101.20 | 51.85 | 11:30 | 51.55 | 12/21/87 |
| 99.0 | 98.4 | 2821 | 101.90 | 52.25 | 11:43 | 51.55 | 12/21/87 |
| 72.4 | 72.2 | 2695 | 104.20 | 53.40 | 13:30 | 51.55 | 12/21/87 |

SINGLE TRANSDUCER

# DATA SHEET

## ULTRASONIC MEASUREMENT OF PRESSURE IN *BOEING HELIUM BOTTLE 25A45740-101-11, S/N 3841

| Run No. | Date | Weight (Lb) Gross | Weight (Lb) Tare | Weight (Lb) Helium | Pressure Gauge (psig) | Temp °F | Micro Sec. |
|---|---|---|---|---|---|---|---|
| 1 | 8-7-87 | 10.702 | 10.641 | .061 | 5034 | 72.3 | 50.60 |
| | | ⊙10.702 | 10.640 | .062 | | | |
| 2 | | 10.678 | 10.641 | .057 | 4708 | 72.4 | 51.00 |
| | | ⊙10.700 | 10.640 | .060 | | | |
| 3 | | 10.694 | 10.641 | .053 | 4412.8 | 72.4 | 51.35 |
| | | ⊙10.696 | 10.640 | .056 | | | |
| 4 | | 10.691 | 10.641 | .050 | 4112 | 72.3 | 51.70 |
| | | ⊙10.692 | 10.640 | .052 | | | |
| 5 | | 10.690 | 10.641 | .049 | 3853 | 72.6 | 52.00 |
| | | ⊙10.691 | 10.640 | .051 | | | |
| 6 | | 10.685 | 10.641 | .044 | 3437 | 72.3 | 52.45 |
| | | ⊙10.685 | 10.640 | .045 | | | |
| 7 | | 10.681 | 10.641 | .038 | 3146 | 73.3 | 52.80 |
| | | ⊙10.681 | 10.640 | .038 | | | |
| 8 | | 10.679 | 10.641 | .033 | 2836 | 73.6 | 53.20 |
| | | ⊙10.678 | 10.640 | .038 | | | |
| 9 | | 10.674 | 10.641 | .033 | 2512 | 73.6 | 53.60 |
| | | ⊙10.673 | 10.640 | .033 | | | |
| 10 | | 10.670 | 10.641 | .029 | 2234 | 73.9 | 53.95 |
| | | ⊙10.669 | 10.640 | .029 | | | |
| 11 | | 10.641 | 10.641 | 0 | 2.9 | 70.7 | -- |
| | | ⊙10.640 | 10.640 | 0 | | | |

*2 Transducers

⊙Checked with Calibrated Weights

APCO RUN 2 — Final Press = 19 psi — * S/N 5128

| DATE | TIME | BOTTLE $T_B$ °F | AMBIENT $T_A$ °F | GAGE 1 PRESS (PSI) | CAL STD μSEC | THRU TRANSMISSION TTU μSEC | PULSE ECHO PE μSEC |
|---|---|---|---|---|---|---|---|
| 2-22-88 | 07:28 | 70.7 | 70.8 | 51 47 | 51.55 | 53.50 | 105.2 |
| | 08:46 | 41.4 | 40.6 | 5856 | 51.60 | 54.95 | 108.0 |
| | 10:28 | 98.2 | 97.6 | 5390 | 51.60 | 52.40 | 102.9 |
| | 10:37 | 98.3 | 97.2 | 5063 | 51.55 | 52.80 | 103.6 |
| | 12:24 | 69.9 | 70.1 | 4824 | 51.60 | 54.05 | 106.1 |
| | 14:01 | 40.8 | 40.6 | 4561 | 51.60 | 55.45 | 108.9 |
| | 14:07 | 39.3 | 39.2 | 4243 | 51.60 | 55.90 | 109.8 |
| 2-23-88 | 07:32 | 67.6 | 67.7 | 4478 | 51.60 | 54.55 | 107.0 |
| | 08:59 | 99.0 | 98.0 | 4727 | 51.65 | 53.25 | 104.5 |
| | 09:07 | 98.5 | 97.3 | 4442 | 51.65 | 53.60 | 105.2 |
| | 10:45 | 69.8 | 70.4 | 4238 | 51.65 | 54.75 | 107.6 |
| | 12:04 | 41.1 | 40.1 | 4001 | 51.65 | 56.25 | 110.6 |
| | 12:10 | 39.1 | 38.9 | 3710 | 51.65 | 56.70 | 111.5 |
| | 13:25 | 69.9 | 69.2 | 3931 | 51.65 | 55.20 | 108.5 |
| | 14:41 | 100.2 | 99.8 | 4148 | 51.65 | 53.80 | 105.7 |
| | 14:47 | 100.3 | 99.0 | 3813 | 51.65 | 54.25 | 106.6 |
| 2-24-88 | 07:22 | 67.7 | 67.3 | 3605 | 51.65 | 55.70 | 109.5 |
| | 08:32 | 36.4 | 38.5 | 3415 | 51.65 | 57.20 | 112.4 |
| | 08:39 | 36.6 | 37.0 | 3083 | 51.65 | 57.75 | 113.5 |
| | 10:01 | 70.7 | 69.3 | 3278 | 51.65 | 56.10 | 110.2 |
| | 12:14 | 100.6 | 100.5 | 3465 | 51.70 | 54.70 | 107.4 |
| | 12:20 | 99.7 | 99.3 | 3153 | 51.70 | 55.15 | 108.3 |
| | 13:16 | 66.5 | 67.6 | 2982 | 51.65 | 56.60 | 111.3 |
| | 14:28 | 41.8 | 40.1 | 2831 | 51.65 | 58.00 | 114.1 |

SINGLE TRANSDUCER

*FROM ABORTED
MISSILE FLIGHT
ON 10/28/87

APCO RUN 1 Final Press = 20 psi *S/N 5128

| DATE | TIME | AIR °F $T_A$ °F | BTLE °F $T_B$ °F | GAGE PRESS (PSI) | CAL STD μSEC | THRU TRANSMISSION TTU μSEC | PULSE ECHO PE μ SEC |
|---|---|---|---|---|---|---|---|
| 2-15-88 | 08:37 | 71.0 | 70.8 | 5108 | 51.60 | 53.65 | 105.3 |
| | 09:59 | 38.0 | 39.0 | 4806 | 51.55 | 55.05 | 108.2 |
| | 12:12 | 100.9 | 100.1 | 5374 | 51.55 | 52.30 | 102.6 |
| | 12:19 | 100.8 | 99.0 | 5076 | 51.55 | 52.60 | 103.3 |
| | 13:21 | 70.5 | 72.0 | 4838 | 51.55 | 53.90 | 105.8 |
| | 14:36 | 36.9 | 37.2 | 4531 | 51.55 | 55.55 | 109.0 |
| | 14:42 | 36.1 | 36.3 | 4225 | 51.55 | 55.95 | 109.9 |
| 2-16-88 | 07:48 | 73.5 | 73.4 | 4528 | 51.60 | 54.25 | 106.6 |
| | 08:59 | 100.8 | 99.4 | 4742 | 51.60 | 53.10 | 104.2 |
| | 09:07 | 100.8 | 98.7 | 4376 | 51.60 | 53.60 | 105.1 |
| | 10:45 | 70.5 | 71.8 | 4173 | 51.60 | 54.70 | 107.5 |
| | 12:55 | 44.5 | 40.1 | 3935 | 51.65 | 56.30 | 110.6 |
| | 13:07 | 47.1 | 42.8 | 3660 | 51.65 | 56.60 | 111.2 |
| 2-17-88 | 07:30 | 67.1 | 67.1 | 3828 | 51.65 | 55.40 | 108.8 |
| | 09:00 | 101.7 | 100.9 | 4064 | 51.65 | 53.85 | 105.7 |
| | 09:08 | 101.7 | 99.6 | 3703 | 51.65 | 54.30 | 106.7 |
| | 10:35 | 72.4 | 74.0 | 3542 | 51.65 | 55.50 | 109.1 |
| | 11:45 | 38.6 | 38.1 | 3312 | 51.65 | 57.30 | 112.6 |
| | 11:57 | 36.4 | 37.5 | 2999 | 51.65 | 57.80 | 113.6 |
| | 13:42 | 68.4 | 67.6 | 3178 | 51.65 | 56.25 | 110.6 |
| | 14:54 | 100.2 | 99.0 | 3360 | 51.65 | 54.80 | 107.7 |
| | 15:03 | 100.0 | 98.2 | 3001 | 51.65 | 55.30 | 108.7 |
| 2-18-88 | 07:24 | 67.5 | 67.6 | 2842 | 51.65 | 56.75 | 111.6 |
| | 09:03 | 38.6 | 38.0 | 2688 | 51.65 | 58.30 | 114.6 |

SINGLE TRANSDUCER

*FROM ABORTED
MISSILE FLIGHT
ON 10/28/87

# DATA SHEET

## ULTRASONIC MEASUREMENT OF PRESSURE IN *BOEING HELIUM BOTTLE 25A45740-101-11, S/N 3841

| Run No. | Date | Weight (Lb) Gross | Tare | Helium | Pressure Gauge (psig) | Temp °F | Micro Sec. |
|---|---|---|---|---|---|---|---|
| 1 | 8-6-87 | 10.706 | 10.637 | .069 | 5386 | 77.8 | 50.05 |
| | | ⊙10.707 | | .068 | | | |
| 2 | | 10.705 | | .068 | 5252 | 77.3 | 50.20 |
| | | ⊙10.706 | | .067 | | | |
| 3 | | 10.702 | | .065 | 5050 | 76.8 | 50.40 |
| | | ⊙10.704 | | .065 | | | |
| 4 | | 10.698 | | .061 | 4731 | 76.2 | 50.80 |
| | | ⊙10.700 | | .061 | | | |
| 5 | | 10.695 | | .058 | 4487 | 75.9 | 51.05 |
| | | ⊙10.697 | | .058 | | | |
| 6 | | 10.691 | | .054 | 4134 | 75.1 | 51.50 |
| | | ⊙10.693 | | .054 | | | |
| 7 | | 10.687 | | .050 | 3849 | 75.0 | 51.80 |
| | | ⊙10.691 | | .052 | | | |
| 8 | | 10.687 | | .050 | 3442 | 74.5 | 52.30 |
| | | ⊙10.691 | | .048 | | | |
| 9 | | 10.681 | | .044 | 3034 | 74.0 | 52.85 |
| | | ⊙10.687 | | .043 | | | |
| 10 | | 10.674 | | .037 | 2736 | 73.9 | 53.35 |
| | | ⊙10.676 | | .037 | | | |
| 11 | | 10.673 | | .036 | 2443 | 73.8 | 53.65 |
| 12 | | 10.667 | | .030 | 2098 | 73.4 | 54.15 |
| | | ⊙10.668 | | .029 | | | |
| | | 10.637 | | 0 | 4.3 | 71.3 | |
| | | ⊙10.639 | | | | | |

*2 Trandsucers

⊙Checked with Calibrated Weights

| B.Pressure | B.Temp | STD. | PE. | Calc. P | Deviation | AVG.DEV. |
|---|---|---|---|---|---|---|
| 4225.00 | 36.30 | 51.55 | 109.90 | 4278.20 | 53.20 | 37.33 |
| 2874.00 | 36.60 | 51.60 | 114.20 | 2843.79 | 30.21 | |
| 3083.00 | 37.00 | 51.65 | 113.50 | 3084.25 | 1.25 | |
| 4531.00 | 37.20 | 51.55 | 109.00 | 4558.95 | 27.95 | |
| 2999.00 | 37.50 | 51.65 | 113.60 | 3036.32 | 37.32 | |
| 4105.00 | 37.80 | 51.55 | 110.30 | 4106.51 | 1.51 | |
| 3214.00 | 37.80 | 51.60 | 113.10 | 3179.41 | 34.59 | |
| 4777.00 | 37.90 | 51.60 | 108.50 | 4727.88 | 49.12 | |
| 3312.00 | 38.10 | 51.65 | 112.60 | 3356.54 | 44.54 | |
| 3490.00 | 38.20 | 51.60 | 112.10 | 3505.68 | 15.68 | |
| 4454.00 | 38.40 | 51.55 | 109.30 | 4429.20 | 24.80 | |
| 3415.00 | 38.50 | 51.65 | 112.40 | 3413.04 | 1.96 | |
| 3795.00 | 38.90 | 51.60 | 111.20 | 3791.15 | 3.85 | |
| 3710.00 | 38.90 | 51.65 | 111.50 | 3706.56 | 3.44 | |
| 4806.00 | 39.00 | 51.55 | 108.20 | 4787.03 | 18.97 | |
| 4243.00 | 39.20 | 51.60 | 109.80 | 4257.44 | 14.44 | |
| 2831.00 | 40.10 | 51.65 | 114.10 | 2791.25 | 39.75 | |
| 4001.00 | 40.10 | 51.65 | 110.60 | 3980.31 | 20.69 | |
| 3935.00 | 40.10 | 51.65 | 110.60 | 3980.31 | 45.31 | |
| 4773.00 | 40.30 | 51.55 | 108.20 | 4757.06 | 15.94 | |
| 4856.00 | 40.60 | 51.60 | 108.00 | 4835.18 | 20.82 | |
| 4561.00 | 40.60 | 51.60 | 108.90 | 4528.90 | 32.10 | |
| 4193.00 | 40.70 | 51.60 | 109.70 | 4254.18 | 61.18 | |
| 3009.00 | 40.90 | 51.60 | 113.20 | 3056.94 | 47.94 | |
| 3601.00 | 40.90 | 51.60 | 111.40 | 3670.10 | 69.10 | |
| 4510.00 | 41.30 | 51.60 | 108.70 | 4580.32 | 70.32 | |
| 3309.00 | 41.40 | 51.65 | 112.10 | 3434.85 | 125.85 | |
| 3900.00 | 41.50 | 51.60 | 110.50 | 3961.15 | 61.15 | |
| 3660.00 | 42.80 | 51.65 | 111.20 | 3704.43 | 44.43 | |
| 3749.00 | 61.90 | 51.60 | 109.30 | 3832.74 | 83.74 | |
| 4367.00 | 62.00 | 51.55 | 107.50 | 4471.64 | 104.64 | |
| 4318.00 | 64.50 | 51.60 | 107.60 | 4387.50 | 69.50 | |
| 3671.00 | 64.60 | 51.60 | 109.40 | 3718.49 | 47.49 | |
| 1432.00 | 66.00 | 51.60 | 115.70 | 1333.41 | 98.59 | |
| 1970.00 | 67.10 | 51.60 | 114.00 | 1926.64 | 43.36 | |
| 3828.00 | 67.10 | 51.65 | 108.80 | 3888.12 | 60.12 | |
| 3605.00 | 67.30 | 51.65 | 109.50 | 3620.66 | 15.66 | |
| 2982.00 | 67.60 | 51.65 | 111.30 | 2938.00 | 44.00 | |
| 4478.00 | 67.70 | 51.60 | 107.00 | 4526.16 | 48.16 | |
| 2497.00 | 68.20 | 51.60 | 112.30 | 2524.72 | 27.72 | |
| 4765.00 | 69.10 | 51.60 | 106.20 | 4790.18 | 25.18 | |
| 3931.00 | 69.20 | 51.65 | 108.50 | 3940.42 | 9.42 | |
| 3278.00 | 69.30 | 51.65 | 110.20 | 3297.20 | 19.20 | |
| 3176.00 | 69.50 | 51.55 | 110.20 | 3253.28 | 77.28 | |
| 2854.00 | 69.50 | 51.60 | 111.21 | 2891.03 | 37.03 | |
| 4824.00 | 70.10 | 51.60 | 106.10 | 4802.34 | 21.66 | |
| 5055.00 | 70.10 | 51.55 | 105.30 | 5085.70 | 30.70 | |
| 4238.00 | 70.40 | 51.65 | 107.60 | 4246.24 | 8.24 | |
| 5108.00 | 70.80 | 51.60 | 105.30 | 5087.43 | 20.57 | |
| 5147.00 | 70.80 | 51.55 | 105.20 | 5106.37 | 40.63 | |
| 4129.00 | 71.00 | 51.60 | 107.60 | 4210.64 | 81.64 | |
| 3508.00 | 71.80 | 51.60 | 109.10 | 3617.95 | 109.95 | |
| 4173.00 | 71.80 | 51.60 | 107.50 | 4226.30 | 53.30 | |
| 3423.00 | 71.80 | 51.60 | 109.60 | 3427.84 | 4.84 | |
| 5097.00 | 71.80 | 51.55 | 105.30 | 5043.76 | 53.24 | |
| 4838.00 | 72.00 | 51.55 | 105.80 | 4848.54 | 10.54 | |

1/2



APCO CAL. CURVE DATA

| | | | | | |
|---|---|---|---|---|---|
| 3073.00 | 72.10 | 51.65 | 110.50 | 3095.01 | 22.01 |
| 4043.00 | 72.40 | 51.60 | 107.90 | 4057.09 | 14.09 |
| 4746.00 | 72.40 | 51.55 | 106.00 | 4762.08 | 16.08 |
| 4528.00 | 73.40 | 51.60 | 106.60 | 4525.66 | 2.34 |
| 3542.00 | 74.00 | 51.65 | 109.10 | 3570.16 | 28.16 |
| 5063.00 | 97.20 | 51.55 | 103.60 | 5061.26 | 1.74 |
| 4442.00 | 97.30 | 51.65 | 105.00 | 4511.83 | 69.83 |
| 5390.00 | 97.60 | 51.60 | 102.90 | 5366.09 | 23.91 |
| 4727.00 | 98.00 | 51.65 | 104.50 | 4701.89 | 25.11 |
| 4376.00 | 98.70 | 51.60 | 105.10 | 4406.61 | 30.61 |
| 3813.00 | 99.00 | 51.65 | 106.60 | 3783.40 | 29.60 |
| 5076.00 | 99.00 | 51.55 | 103.30 | 5138.68 | 62.68 |
| 3153.00 | 99.30 | 51.70 | 108.30 | 3073.82 | 79.18 |
| 4742.00 | 99.40 | 51.60 | 104.20 | 4767.16 | 25.16 |
| 3703.00 | 99.60 | 51.65 | 106.70 | 3721.14 | 18.14 |
| 3007.00 | 99.60 | 51.55 | 108.20 | 3041.79 | 34.79 |
| 4243.00 | 99.70 | 51.55 | 105.30 | 4270.01 | 27.01 |
| 4148.00 | 99.80 | 51.65 | 105.70 | 4139.42 | 8.58 |
| 4347.00 | 99.90 | 51.65 | 105.10 | 4391.34 | 44.34 |
| 3598.00 | 100.00 | 51.55 | 107.00 | 3537.68 | 60.32 |
| 3679.00 | 100.00 | 51.60 | 106.60 | 3729.07 | 50.07 |
| 5374.00 | 100.10 | 51.55 | 102.60 | 5406.40 | 32.40 |
| 4012.00 | 100.20 | 51.60 | 105.70 | 4105.50 | 93.50 |
| 4988.00 | 100.40 | 51.55 | 103.60 | 4972.49 | 15.51 |
| 4586.00 | 100.40 | 51.55 | 104.50 | 4589.07 | 3.07 |
| 3465.00 | 100.50 | 51.70 | 107.40 | 3414.05 | 50.95 |
| 4672.00 | 100.50 | 51.65 | 104.40 | 4671.34 | 0.66 |
| 3908.00 | 100.90 | 51.55 | 106.20 | 3848.41 | 59.59 |
| 5318.00 | 100.90 | 51.55 | 102.80 | 5299.94 | 18.06 |
| 5041.00 | 101.00 | 51.55 | 103.30 | 5083.71 | 42.71 |
| 3351.00 | 101.10 | 51.55 | 107.20 | 3414.54 | 63.54 |
| 5328.00 | 101.80 | 51.55 | 102.60 | 5361.44 | 33.44 |
| 4064.00 | 101.90 | 51.65 | 105.70 | 4072.59 | 8.59 |

APCO CAL. CURVE DATA

APCO

3-18-88

| Temp | | Time | Press |
|---|---|---|---|
| 40.00 | 51.55 | 111.00 | 3813.07 |
| 40.00 | 51.55 | 106.50 | 5341.34 |
| 45.00 | 51.55 | 111.00 | 3679.29 |
| 45.00 | 51.55 | 106.50 | 5233.66 |
| 50.00 | 51.55 | 111.00 | 3540.87 |
| 50.00 | 51.55 | 106.00 | 5297.95 |
| 55.00 | 51.55 | 111.00 | 3397.55 |
| 55.00 | 51.55 | 106.00 | 5185.70 |
| 60.00 | 51.55 | 111.00 | 3249.07 |
| 60.00 | 51.55 | 105.50 | 5251.43 |
| 65.00 | 51.55 | 111.00 | 3095.15 |
| 65.00 | 51.55 | 105.50 | 5134.21 |
| 70.00 | 51.55 | 111.00 | 2935.48 |
| 70.00 | 51.55 | 105.00 | 5201.44 |
| 75.00 | 51.55 | 110.00 | 3154.58 |
| 75.00 | 51.55 | 104.50 | 5271.23 |
| 80.00 | 51.55 | 110.00 | 2989.87 |
| 80.00 | 51.55 | 104.50 | 5147.58 |
| 85.00 | 51.55 | 109.50 | 3018.68 |
| 85.00 | 51.55 | 104.00 | 5219.06 |
| 90.00 | 51.55 | 109.00 | 3048.65 |
| 90.00 | 51.55 | 103.50 | 5293.43 |
| 95.00 | 51.55 | 108.50 | 3079.86 |
| 95.00 | 51.55 | 103.50 | 5162.59 |
| 100.00 | 51.55 | 108.00 | 3112.38 |
| 100.00 | 51.55 | 103.00 | 5238.90 |
| 105.00 | 51.55 | 107.50 | 3146.29 |
| 105.00 | 51.55 | 103.00 | 5101.27 |
| 110.00 | 51.55 | 107.00 | 3181.70 |
| 110.00 | 51.55 | 102.50 | 5179.58 |
| 30.00 | 51.55 | 111.00 | 4067.59 |
| 30.00 | 51.55 | 107.00 | 5381.92 |

BOEING
3-18-88

| TEMP | | TIME | PRESS |
|---|---|---|---|
| 30.00 | 51.55 | 106.00 | 3294.68 |
| 30.00 | 51.55 | 101.00 | 5129.54 |
| 35.00 | 51.55 | 106.00 | 3153.57 |
| 35.00 | 51.55 | 101.00 | 5010.58 |
| 40.00 | 51.55 | 105.00 | 3384.96 |
| 40.00 | 51.55 | 98.00 | 6016.54 |
| 45.00 | 51.55 | 105.00 | 3241.48 |
| 45.00 | 51.55 | 99.00 | 5525.02 |
| 50.00 | 51.55 | 105.00 | 3094.41 |
| 50.00 | 51.55 | 99.30 | 5290.94 |
| 55.00 | 51.55 | 105.00 | 2943.61 |
| 55.00 | 51.55 | 99.00 | 5285.07 |
| 60.00 | 51.55 | 104.00 | 3184.19 |
| 60.00 | 51.55 | 98.50 | 5358.10 |
| 65.00 | 51.55 | 104.00 | 3030.63 |
| 65.00 | 51.55 | 98.00 | 5433.03 |
| 70.00 | 51.55 | 104.00 | 2873.02 |
| 70.00 | 51.55 | 98.00 | 5307.10 |
| 75.00 | 51.55 | 103.00 | 3122.30 |
| 75.00 | 51.55 | 98.00 | 5177.80 |
| 80.00 | 51.55 | 103.00 | 2961.67 |
| 80.00 | 51.55 | 97.50 | 5253.33 |
| 85.00 | 51.55 | 102.00 | 3219.01 |
| 85.00 | 51.55 | 97.00 | 5330.94 |
| 90.00 | 51.55 | 102.00 | 3055.25 |
| 90.00 | 51.55 | 97.00 | 5196.57 |
| 95.00 | 51.55 | 102.00 | 2886.86 |
| 95.00 | 51.55 | 96.00 | 5492.73 |
| 100.00 | 51.55 | 101.00 | 3154.19 |
| 100.00 | 51.55 | 96.00 | 5356.83 |
| 105.00 | 51.55 | 101.00 | 2982.35 |
| 105.00 | 51.55 | 96.00 | 5216.98 |

# APPENDIX F

## T.I.M. MEETING

## DEMONSTRATION TO BOEING MANAGEMENT

8J-96

TIM



DATE 14 SEPT 1987

TIME 0930 PDT

LOCATION SRAM-A SIL

Attachment to
2-6055-0087-091

ULTRASONIC HELIUM BOTTLE
PRESSURE MEASUREMENT CHECKLIST

1. Verify compliance with prerequisites per SOP 321D Addendum I, dated 8 Sept. 1987.

2. Locate test equipment required for test adjacent to GTM aft end and apply line power to test equipment for warmup.

3. Record SRAM Ground Test Missile (GTM) and Flight Control Actuator Assembly (FCAA) Part Numbers and Serial Numbers to be used for test:

   GTM P/N 25A43960-918-11 S/N 12

   FCAA P/N 25A43111-105-18 S/N 457

4. Verify Control Section fairing removal accomplished.

5. Remove clamp from Helium Storage Bottle if required (Reference T.O. 21M-AGM69A-4-1 Figure 18 - Index 34 and 39, respectively) *

6. Record Helium Storage Bottle Part and Serial Numbers

   Bottle P/N 25A45740-101-11 ** S/N 3749 (BOEING)

7. Install ultrasonic transducer test fixture on Helium Storage bottle per Test Conductor direction.

8. Acquire ultrasonic measurement test data as required, following sufficient test equipment warmup, per Test Conductor direction. 50.35 μSEC → 5050 PSI (APPROX, > 5000 PSI)

9. Upon completion of test activities, remove transducer test fixture and reinstall clamp per dwg.

** COMPLETE P/N OBTAINED FROM IPB T.O. (P/N PARTIALLY OBSCURED BY CLAMP).

* CLAMP REMOVAL NOT REQ'D FOR BOEING BOTTLE

ATTENDEES

R. HAUSE } TECHNOLOGY
A. OLSON }
J. EISAMAN ORDNANCE
E. CLAIBOURN ORD CERT TECH
J. MAYS } ALCM/SRAM-A SIL
L. MATTAUSCH } TEST ENGR.
L. JANKOWSKI SAFETY-NOTIFIED (UNABLE TO ATTEND)

September 19, 1987
2-3631-GKD7-088

| | | | | |
|---|---|---|---|---|
| To: | R. B. Cairns | 8K-70 | | |
| | R. L. Hanson | 82-21 | | |
| | J. T. Hoggatt | 2E-02 | | |
| | J. C. Johnson | ~~8J-75~~ | | |
| | M. W. Johnson | 8J-75 | | |
| | B. E. Keller | 8J-86 | | |
| | T. J. Kramer | 82-23 | | |
| | L. J. Mason | 85-03 | | |
| | T. K. Oswald | 3A-60 | | |
| cc: | J. L. Gruber | 3A-54 | A. G. Olson | 8J-96 |
| | J. S. Harbaugh | 8J-72 | | |
| | L. R. Hause | 8W-11 | | |
| | C. E. Hilsinger | 8J-82 | | |
| | R. W. Lane | 81-15 | | |
| | J. L. Mays | 81-15 | | |
| | L. P. Torre | 2E-01 | | |
| | G. H. Yamamoto | 8Y-86 | | |

Subject: Demonstration of SRAM-A Helium Bottle Pressure Measurement Using Ultrasound

Reference: EA 87-7-1-12A "Measurement of Gas Pressure Inside a Sealed Bottle by Ultrasound

A demonstration of the pressure measurement technique will be at 10:00, 1 October (Thursday) in the SRAM/ALCM SIL, 18-43 Bldg. The demonstration, on an unsquibbed Boeing helium bottle mounted on a production configuration ground test missile, will be similar to the demonstration to OC-ALC personnel during last week's quarterly review.

This issue has arisen because of indications of low helium bottle pressure on the fourth ASAT flight (uses SRAM-A FCAA), & past indications of a low bottle pressure at Hill AFB, & Boeing surveillance bottles. Current procedure is to determine helium bottle pressure by opening the hydraulic system & removing & weighing the bottle. Using ultrasound, the bottle pressure can be determined while on the FCAA--with a potential for significant reduction in work for Air Force personnel.

This gas pressure measurement technique is being developed by M&P (Larry Torre), ultrasonic test lab (Bob Hause), and our prime engineer (Alden Olson). It's the best thing I've seen since the invention of sliced bread. It has substantial potential for SRAM-A, ASAT, & other systems requiring knowledge of pressure in sealed containers--possibly some not of this world.

If you can make the demonstration, please call me (773-2717) or Alden Olson (773-4127).

George K. Dragseth

George K. Dragseth
SRAM/ALCM Technology Manager

FCAA P/N 2SA43111-105-18
S/N 227

APCO HELIUM STORAGE BOTTLE
PART NO. 821100-103
SERIAL NO. 5045
CHARGED WT 9,283
TARE WT 9,219
INSP. DATE 1-26-76

GTM P/N 2SA43960-916-11
S/N 10

[illegible] 2 OCT 87

SQUIB RESISTANCE
MEASUREMENT CHECK

RESISTANCE =

A TO C = 1.11 Ω
B TO C = 1.02 Ω

Check By
Gary E Hunt
Ordnance tech.
10/1/87 10:00 A.M.

INSPECTION TAG FOR SQUIB ON APCO
He BOTTLE - MGMT DEMO 10/1/87

BOEING


DEMONSTRATION TO BOEING MANAGEMENT

FIGURE 1

**BOEING**


DEMONSTRATION TO BOEING MANAGEMENT

FIGURE 2

**BOEING**

DEMONSTRATION TO BOEING MANAGEMENT

**BOEING**

DEMONSTRATION TO BOEING MANAGEMENT

FIGURE 4