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INVESTIGATION OF BRAZED AND  
WELDED CONNECTIONS

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Summary Report

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## SUMMARY

An investigation of brazed and welded tube connections for space vehicle use was conducted. Three connection types (Aeroquip brazed, GE brazed, and MSFC welded) were subjected to a series of environmental tests. Sizes tested ranged from 1/4-inch diameter to 1 1/2-inch diameter tubing. A total of 416 specimens were subjected to 2,395 tests.

All three connection types met test procedure requirements when subjected to the Proof Pressure, Leak, Storage, Extended Pressurization, LN<sub>2</sub> Temperature Soak, +500 °F Temperature Soak, Impulse, Tensile, and Burst Pressure Tests. All of the brazed connections and none of the welded connections exhibited corrosion due to the Corrosion Test. Acceptable stress levels were tabulated for connections subjected to Vibration Tests at room, LN<sub>2</sub>, and +500 °F temperatures. A number of discrepancies in fabrication were found.

All three types of semipermanent connections, with stricter manufacturing quality control, appear to be equally suitable for space vehicles. The limitations found in the corrosion and vibration testing should be taken into consideration in application of the connections.

## SECTION I. INTRODUCTION

This test program was initiated to investigate the ability of the semipermanent tube connections, as fabricated by R-ME-MW, to meet space vehicle requirements (Ref. 1). Three types of connections (Aeroquip brazed, GE brazed, and MSFC welded) were subjected to a variety of environmental tests. The following definitions will be used in this report: the "fitting" is the outer sleeve or connecting member, and the "connection" is the assembly, consisting of the two tubes and the fitting.

All of the assembly, welding, and brazing operations on the connections were performed by the Manufacturing Engineering Laboratory, R-ME-MW, of the Marshall Space Flight Center. The Aeroquip fittings were designed and supplied by Aeroquip, using production tools. The GE fittings were designed by GE and made in small quantities with short-run tooling by outside suppliers. Aeroquip (commercial) and GE (development contract) brazing tools were used to join the brazed connections (Refs. 2 and 3). R-ME-MW designed the MSFC welded tube connections and used TIG welding tools to join the connections with a single-pass weld (Ref. 3). The automatic TIG welding tools (Orbit-Arc or Astro-Arc) utilized an electric arc which rotated about the fittings. Diametral tolerances on commercial stainless steel tubing are normally too loose for good semipermanent joints. The ends of the tubing in both the brazed and welded connections were sized with expansion and swaging tools before being joined.

Cross sectional views and major dimensions for each connection are shown in Figures 1 through 4. Typical connections are shown in Figures 5 and 6.

Each test connection was subjected to a designated schedule of tests, which were basically divided into two different sequences. The detailed test program is shown in Table I (Aeroquip), Table II (GE), and Table III (MSFC). Explanations of the test specimen identification code and of the details of each test and test sequence are given in the test procedure (Appendix A). All tables and figures which have the prefix A are located in Appendix A.

The bulk of the testing was performed by R-P&VE-PE. The vibration test on the 3/4 inch size was accomplished by R-QUAL-ATE. The corrosion testing was done by R-P&VE-MMC, the tensile testing by R-P&VE-MMM, and the metallographic examinations by R-P&VE-MMA.

## SECTION II. DESCRIPTION OF TESTS

The tests, in general, were performed in accordance with the test procedure (Appendix A). A few test sequences were revised because some of the test specimens originally programmed were not manufactured. Actual test sequence of each connection is displayed in Tables I through III. Deviations from the test procedure are listed in Paragraph B.

### A. Tests

1. Corrosion Test. The specimens were subjected to salt water corrosion by R-P&VE-MMC in an alternate immersion tester. This immersion test in a 3.5 per cent salt water solution was judged to be much more severe than the atmospheric corrosion to which these connections would normally be exposed. In order to fit into the tester, the tubing specimen ends were cut off, resulting in contact of both the inside and outside surfaces of the connections with the saline solution.

2. Proof Pressure Test. Pressure was supplied by a pneumatic pressure pump. The unit was a Futurecraft Corporation "Port-a-Pump," Model No. 90105, Serial No. 104, with a range of 0 - 8000 psi delivery pressure (Fig. A-3).

3. Leak Test. Tests were performed with the Consolidated Electrodynamic Corporation "CEC Leak Detector," Type 24-120B, Serial No. 9525 (Figs. 7 and A-4).

4. Storage Test. The specimens were clamped in racks and exposed to atmosphere on the roof of Building 4619 (Fig. 8).

5. Extended Pressurization Test. Gaseous nitrogen was used for pressurization (Fig. A-3).

6. LN<sub>2</sub> Temperature Soak Test. The specimens were pressurized using 3000 psi helium and were submerged in liquid nitrogen contained in a double-walled tank (Fig. A-5).

7. 500 °F Temperature Soak Test. The specimens were placed in an oven (temperature range 0 - 600 °F) and were pressurized with helium (Fig. A-6).

8. Vibration Test At Room Temperature. The majority of the specimens were vibrated on either the MB Model 025H or the Ling Model L-200 machine (Figs. 9, 10, 16, and A-7).

9. Vibration Test At LN<sub>2</sub> Temperature. The same vibration equipment which was used in the room temperature test was also used in this test. Gaseous nitrogen was used for pressurization of the connections which were submerged in liquid nitrogen while being vibrated (Figs. 11, 12, 15, and A-10).

10. Vibration Test At 500 °F Temperature. The same vibration equipment which was used in the room temperature test was also used in this test. Gaseous nitrogen was used for pressurization. Heat was applied by a 500-watt tubular quartz lamp with reflector, Model HTL3558, made by Heat Technology, Inc. The power to the lamp was controlled by an R. I. Controls Co. "Thermac Controller," Model TC 5192. The thermocouple output was read from a "MiniMite" instrument made by Thermo Electric Co. (Figs. 13, 14, 16, and A-11).

11. Impulse Test. Impulse tests were performed utilizing Pump and Reservoir Unit Model 9555DX from Cox Instrument Co. for filling and circulating oil through the specimen; a hydraulic pump unit from Sun Electric Co. as the power source; a piston-type actuator with servo valve to drive the 1 1/4-inch diameter piston in the hydraulic cylinder, and the signal generator, Stata-Trak Model FGE 5124, from R. I. Controls Co. The impulse wave was measured with a Dynisco pressure transducer and was recorded by Honeywell Visicorder Model No. 906A-25800H (Figs. 17, A-8, and A-9).

12. Tensile Test. Tensile testing was performed by R-P&VE-MMM on a Riehle tensile tester.

13. Metallographic Examination. Metallographic examination was performed by R-P&VE-MMA with the American Optical Metallograph.

14. Burst Test. This test was performed with a 125 - 30,000 psi Sprague Hydrostatic Pump, Type S216C-300. The pressure transducer used was a Dynisco Model PT119B-20M, Serial No. 25310 (Fig. A-12).

#### B. Deviations From Tests

1. Corrosion Test. Test specimens QA10601, QA30601, QA10808, QA30801, QA11601, QA31601, and QA32401 were corrosion tested for a period of 120 days. The other 59 test specimens were subjected to the corrosion test for the standard period of 180 days.

2. Storage Test. Test specimens QA10403, QA10404, QA30403, QA30404, QG30403, and QG30404 were subjected to the + 500 °F vibration test after completion of two years in storage. The other 60 test specimens underwent the standard test sequence.

3. Vibration Test At Room Temperature. Initially, testing commenced with a stress, as measured by the unidirectional strain gages, of 22,500 psi (117 specimens). This represented the stress level in the outer surface fibers of the tubing due to vibration, but did not include the stress due to internal pressurization. Failures in testing brought a decision to reduce the measured stress to 20,000 psi (3 specimens) and then to 18,000 psi (67 specimens).

4. Vibration Test At LN<sub>2</sub> Temperature. Testing started with a vibration stress, as measured by the strain gages, of 33,200 psi (32 specimens). The stress was later reduced to 26,500 psi (10 specimens).

5. Vibration Test At + 500 °F Temperature. Testing started with a vibration stress, as measured by the strain gages, of 19,500 psi (20 specimens). The stress was reduced to 17,600 psi (1 specimen), 16,300 psi (3 specimens), 15,000 psi (23 specimens), 14,600 psi (5 specimens), 13,000 psi (1 specimen), and 12,000 psi (4 specimens).

### SECTION III. TEST RESULTS

Results of the individual tests are summarized in this section. The tests are listed in the order shown in Tables I through XVI.

#### A. Corrosion Test

Sixty-seven specimens were subjected to the 3.5 per cent salt water alternate immersion test (26 Aeroquip, 12 GE, and 29 MSFC specimens, Tables I through III). All of the Aeroquip and GE specimens corroded at the interface between the braze alloy and the fitting/tubing (Figs. 18, 19, and 20). Seven of the twenty-six Aeroquip specimens were tested for only 120 days instead of the standard 180 days. The extent of corrosion of the seven specimens was not consistent with the ratio of 120 to 180 days (exposure duration). None of these seven leaked after the test. Two of the remaining nineteen Aeroquip (180-day) specimens corroded sufficiently to leak after the corrosion test. None of the 12 GE (180-day) specimens leaked. There was no evidence that the MSFC welded (180-day) connections corroded. Two of the twenty-nine welded specimens leaked, but this was attributed to porous welds, not corrosion. This corrosion test is probably much more severe than the connections will experience in actual service.

#### B. Proof Pressure Test

There were no failures among the 350 specimens which underwent the proof pressure test (Tables I through III).

#### C. Leak Test

Two 1/4-inch size MSFC welded connections leaked when received. These were replaced with two new specimens which were assigned the original identification code numbers of the two which leaked. There were no other failures among the remaining 348 specimens which underwent the leak test (Tables I through III).

#### D. Storage Test

There were no leaks, evidence of damaging corrosion, or any other detrimental effects noted on the 66 specimens (Tables I through III) subjected to the two-year outdoor storage test (Fig. 8).

#### E. Extended Pressurization Test

There were no failures among the 194 specimens which underwent the extended pressurization test (Tables I through III).

#### F. LN<sub>2</sub> Temperature Soak Test

There were no failures among the 194 specimens which underwent the LN<sub>2</sub> temperature soak test (Tables I through III).

#### G. + 500 °F Temperature Soak Test

There were no failures among the 193 specimens which underwent the + 500 °F temperature soak test (Tables I through III).

#### H. Vibration Test At Room Temperature

The room temperature vibration test was conducted on 193 specimens (Tables IV through VI). A summary of the test data is shown in Figures 39, 40, and 41. Photographs of specimens which were subjected to this test are shown in Figures 22, 23, 24, 30, 31, 33, and 34. Metal hardness (after the vibration test) at various locations in the cross sections of three connections is shown in Figure 37.

An objective of the vibration test was the determination of a stress value to which the tube connections could be subjected successfully for 300,000 cycles. The number of cycles was based on an arbitrarily chosen resonant frequency of 1000 Hz for a vehicle flight duration of 5 minutes (300 seconds) at the resonant frequency. When failures occurred at a selected stress value, subsequent tests were performed at a lower stress value. Because of the limited number of test specimens and the long time required for the vibration tests and failure analysis, the difference between the stress value at which specimens failed and the new selected stress value was sometimes larger than desired.

The recommended vibration design stress limits for 300,000 cycles, effective for all three types of connections are listed on the following page:

| O.D.<br>Tube<br>(in.) | Temperature                         | Thin Wall - 1500 psi                     |                                           |                                   | Thick Wall - 3000 psi                    |                                           |                                   |
|-----------------------|-------------------------------------|------------------------------------------|-------------------------------------------|-----------------------------------|------------------------------------------|-------------------------------------------|-----------------------------------|
|                       |                                     | Vibration<br>Stress,<br>Bending<br>(psi) | Pressure<br>Stress,<br>Longitud.<br>(psi) | Total<br>Stress<br>Limit<br>(psi) | Vibration<br>Stress,<br>Bending<br>(psi) | Pressure<br>Stress,<br>Longitud.<br>(psi) | Total<br>Stress<br>Limit<br>(psi) |
| 1/4                   | LN <sub>2</sub><br>Room<br>+ 500 °F | 30,000                                   | 3,900                                     | 33,900                            | 30,000                                   | 5,800                                     | 35,800                            |
|                       |                                     | 20,000                                   | 3,900                                     | 23,900                            | 20,000                                   | 5,800                                     | 25,800                            |
|                       |                                     | 11,000                                   | 3,900                                     | 14,900                            | 11,000                                   | 5,800                                     | 16,800                            |
| 3/8                   | LN <sub>2</sub><br>Room<br>+ 500 °F | 30,000                                   | 4,300                                     | 34,300                            | 30,000                                   | 5,900                                     | 35,900                            |
|                       |                                     | 20,000                                   | 4,300                                     | 24,300                            | 20,000                                   | 5,900                                     | 25,900                            |
|                       |                                     | 11,000                                   | 4,300                                     | 15,300                            | 11,000                                   | 5,900                                     | 16,900                            |
| 1/2                   | LN <sub>2</sub><br>Room<br>+ 500 °F | 30,000                                   | 4,600                                     | 34,600                            | 30,000                                   | 5,900                                     | 35,900                            |
|                       |                                     | 20,000                                   | 4,600                                     | 24,600                            | 20,000                                   | 5,900                                     | 25,900                            |
|                       |                                     | 11,000                                   | 4,600                                     | 15,600                            | 11,000                                   | 5,900                                     | 16,900                            |
| 3/4                   | LN <sub>2</sub><br>Room<br>+ 500 °F | 30,000                                   | 5,000                                     | 35,000                            | 30,000                                   | 6,000                                     | 36,000                            |
|                       |                                     | 20,000                                   | 5,000                                     | 25,000                            | 20,000                                   | 6,000                                     | 26,000                            |
|                       |                                     | 11,000                                   | 5,000                                     | 16,000                            | 11,000                                   | 6,000                                     | 17,000                            |
| 1                     | LN <sub>2</sub><br>Room<br>+ 500 °F | 25,000                                   | 5,000                                     | 30,000                            | 25,000                                   | 6,200                                     | 31,200                            |
|                       |                                     | 17,000                                   | 5,000                                     | 22,000                            | 17,000                                   | 6,200                                     | 23,200                            |
|                       |                                     | 11,000                                   | 5,000                                     | 16,000                            | 11,000                                   | 6,200                                     | 17,200                            |
| 1 1/4                 | LN <sub>2</sub><br>Room<br>+ 500 °F | 25,000                                   | 4,900                                     | 29,900                            | 25,000                                   | 6,200                                     | 31,200                            |
|                       |                                     | 17,000                                   | 4,900                                     | 21,900                            | 17,000                                   | 6,200                                     | 23,200                            |
|                       |                                     | 11,000                                   | 4,900                                     | 15,900                            | 11,000                                   | 6,200                                     | 17,200                            |
| 1 1/2                 | LN <sub>2</sub><br>Room<br>+ 500 °F | 25,000                                   | 5,200                                     | 30,200                            | 25,000                                   | 8,500                                     | 33,500                            |
|                       |                                     | 17,000                                   | 5,200                                     | 22,200                            | 17,000                                   | 8,500                                     | 25,500                            |
|                       |                                     | 11,000                                   | 5,200                                     | 16,200                            | 11,000                                   | 8,500                                     | 19,500                            |

The strain measured by the strain gages was converted into stress as shown in Figures 39, 40, and 41. The measured stress values were decreased by approximately 10 - 20 per cent and listed in the above table under "Vibration Stress." The values were decreased as a safety factor because some stress values were obtained by interpolation (since no test data were available) and in some cases the number of specimens tested at the chosen stress levels was rather small. The "Vibration Stress" listed is due to bending only, because the strain gages were zeroed after pressurizing the connections. The longitudinal stress, due to pressure acting on the ends of a closed cylinder, was calculated (varying with pressure, wall thickness, and diameter) and listed under "Pressure Stress." The "Vibration Stress," and "Pressure Stress" values were added together, with the results listed under "Total Stress." The resulting data are conservative. The influence of Poisson's ratio is neglected. The highest stress is at the junction of the outside diameter of the tube and the end of the fitting, due to the discontinuity at the abrupt change in cross section. The strain gages were located as closely as possible to the fitting (Fig. 9), but could not measure the peak stress at the change in cross section, where the stress is greatest and the vibration fatigue cracks started.

#### I. Vibration Test At $\text{LN}_2$ Temperature

The  $\text{LN}_2$  temperature vibration test was conducted on 45 specimens (Tables IV through VI). A summary of the test data is shown in Figures 39, 40, and 41. A photograph of a specimen which was subjected to this test is shown in Figure 21. Results of the  $\text{LN}_2$  temperature test are combined with the results of the vibration test at room temperature in Section III.H.

#### J. Vibration Test At + 500 °F Temperature

The + 500 °F temperature vibration test was conducted on 57 specimens (Tables IV through VI). A summary of the test data is shown in Figures 39, 40, and 41. Photographs of specimens which were subjected to this test are shown in Figures 25 - 29, 32, and 35. Results of the + 500 °F temperature test are combined with the results of the vibration test at room temperature in Section III.H.

#### K. Impulse Test

There were no failures among the 194 specimens which underwent the impulse test (Tables I through III).

## L. Tensile Test

A tensile test was conducted, after the vibration test, on 95 specimens (Tables VII through IX). Results of tensile tests on control specimens and one-piece straight tubing sections (neither type subjected to vibration tests) are listed in Table X. Photographs of six test connections after completion of the tensile test are shown in Figure 36. Tensile test results are summarized in Figures 42, 43, and 44. The test connection specimens in all cases failed at a lower tensile stress than the average of the straight tubes without connections. The wide "scatter" between individual connection tensile stress results is believed to be caused by discrepancies in fabrication. No significant difference was noted in results of tensile tests conducted on connections which were vibrated and those which were not vibrated.

## M. Metallographic Examination

A metallographic examination was conducted on 195 specimens (Tables XI through XIII). Photographs from the metallographic examinations are shown in Figures 18 through 35. Under "Results" in the tables, it may be seen that all of the Aeroquip and GE brazed connections which were subjected to the corrosion test did corrode, but the MSFC welded connections did not corrode. Also indicated under "Results" are the specimens in which a fatigue crack was detected. Discrepancies in fabrication are noted in the tables. Figures 30 and 31 illustrate apparent weak spots in the wall thickness of the fitting. The specimen in Figure 30 appears to have been made according to the dimensional table of Figure 2, where the one-inch size is unique in having Dimension "B" larger than Dimension "G." The specimen in Figure 31 was assembled with a larger gap (Dimension "B") between the ends of the tubes than specified in the table of Figure 2.

## N. Burst Pressure Test

A burst pressure test was conducted on 141 specimens (Tables XIV through XVI). All specimens successfully passed the burst pressure test.

#### SECTION IV. CONCLUSIONS

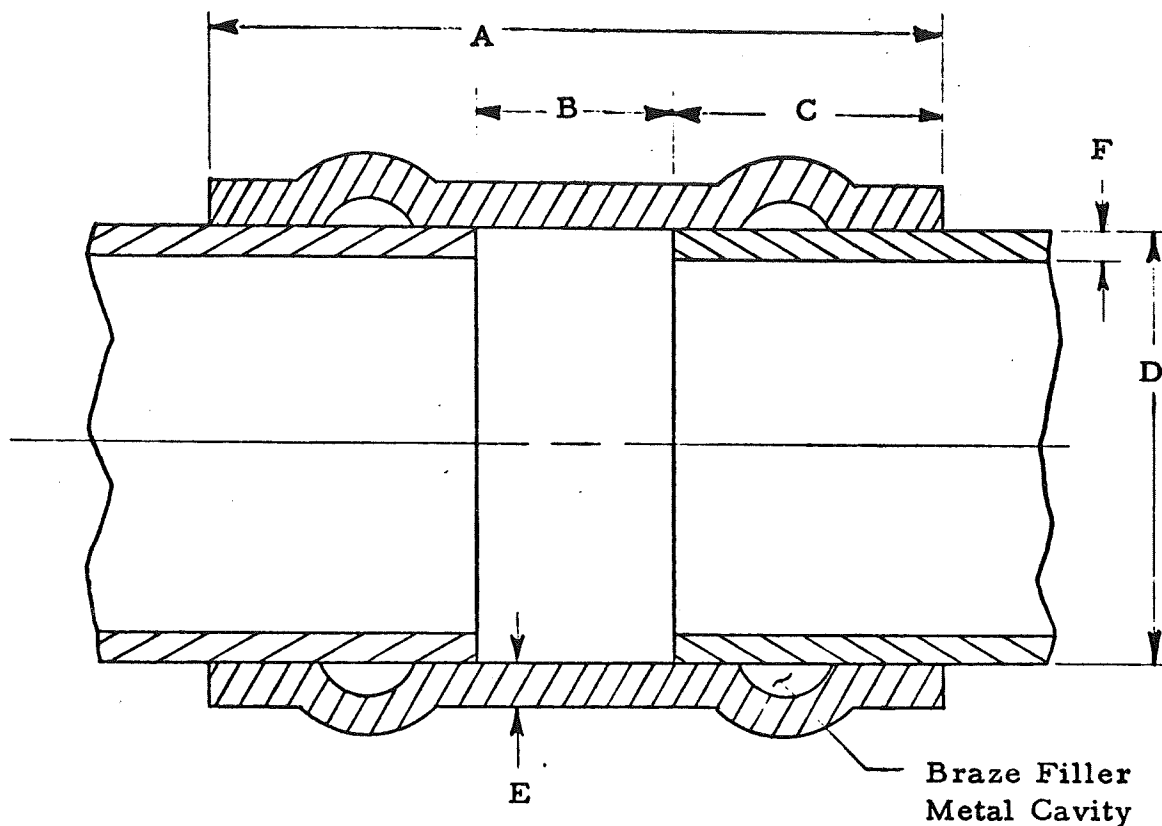
All three types of semipermanent tube connections (Aeroquip and GE brazed, and MSFC welded) gave good results during the following tests: Proof Pressure, Leak, Storage, Extended Pressurization, LN<sub>2</sub> Temperature Soak, + 500 °F Temperature Soak, Impulse, Tensile, and Burst Pressure.

In the corrosion test all of the brazed connections were corroded after the alternate immersion test in salt water; however, they did not corrode during the two-year outdoor storage test. The welded connections were not corroded after the alternate immersion test in salt water. This test is more severe than normally encountered by the connections in service.

In the three vibration tests at room, LN<sub>2</sub>, and + 500 °F temperatures, values for allowable stresses for the different sizes and environmental conditions were tabulated. However, by testing more specimens manufactured under more closely controlled conditions, and especially other sizes which were not available during this test program, it may be possible to allow higher stress values during vibration.

In the metallographic examination, several discrepancies in fabrication were discovered. These included improper insertion depth of tube into fitting, improper clearance between tube and fitting, improper braze flow (probably because of insufficient heat during brazing or lack of cleanliness), nonuniform or off-center welding seams, etc. Some of these discrepancies are not readily detected after fabrication; therefore, it is mandatory that the manufacturing process be controlled very closely.

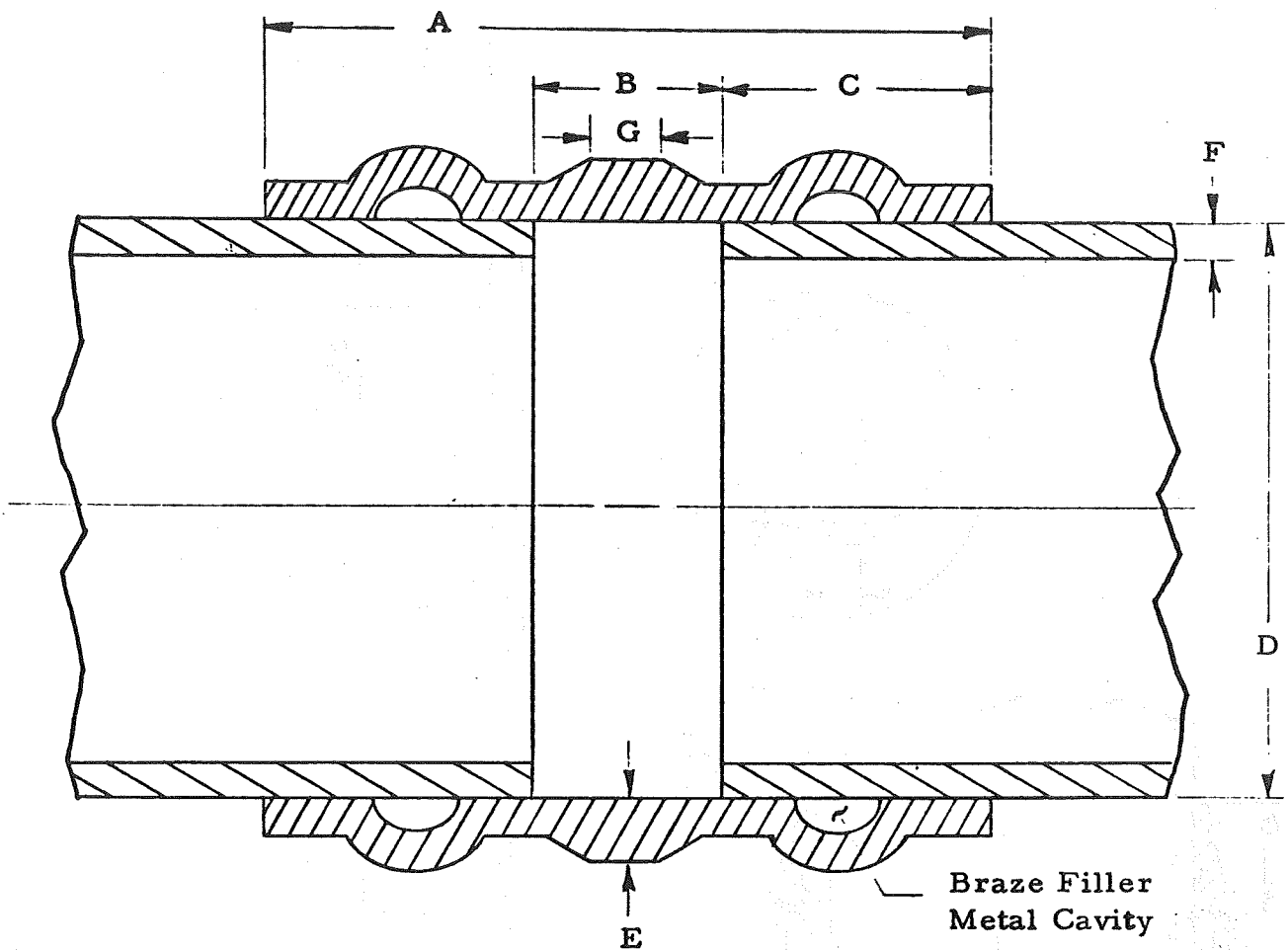
All three types of semipermanent connections, with strict manufacturing quality control, appear to be equally suitable for space vehicles. The limitations found in the corrosion and vibration testing should be taken into consideration in application of these connections.



| Part        | Material                 |
|-------------|--------------------------|
| Tube        | Type 321 Stainless Steel |
| Fitting     | Type 321 Stainless Steel |
| Braze Alloy | 80% gold - 20% nickel    |

| Tube           |                          |                                               | Connection Dimension (in.) |       |       |       |             |       |
|----------------|--------------------------|-----------------------------------------------|----------------------------|-------|-------|-------|-------------|-------|
| O. D.<br>(in.) | Oper.<br>Press.<br>(psi) | Cross<br>Sect.<br>Area<br>(in. <sup>2</sup> ) | A                          | B     | C     | D     | E<br>(min.) | F     |
| 1/4            | 1500                     | 0.0144                                        | 1.250                      | 0.350 | 0.450 | 0.250 | 0.025       | 0.020 |
| 1/4            | 3000                     | 0.0183                                        | 1.250                      | 0.350 | 0.450 | 0.250 | 0.025       | 0.026 |
| 3/8            | 1500                     | 0.0305                                        | 1.250                      | 0.350 | 0.450 | 0.375 | 0.036       | 0.028 |
| 3/8            | 3000                     | 0.0402                                        | 1.250                      | 0.350 | 0.450 | 0.375 | 0.036       | 0.038 |
| 1/2            | 1500                     | 0.0511                                        | 1.250                      | 0.350 | 0.450 | 0.500 | 0.047       | 0.035 |
| 1/2            | 3000                     | 0.0719                                        | 1.250                      | 0.350 | 0.450 | 0.500 | 0.047       | 0.051 |
| 3/4            | 1500                     | 0.108                                         | 1.250                      | 0.350 | 0.450 | 0.750 | 0.070       | 0.049 |
| 3/4            | 3000                     | 0.159                                         | 1.250                      | 0.350 | 0.450 | 0.750 | 0.070       | 0.075 |

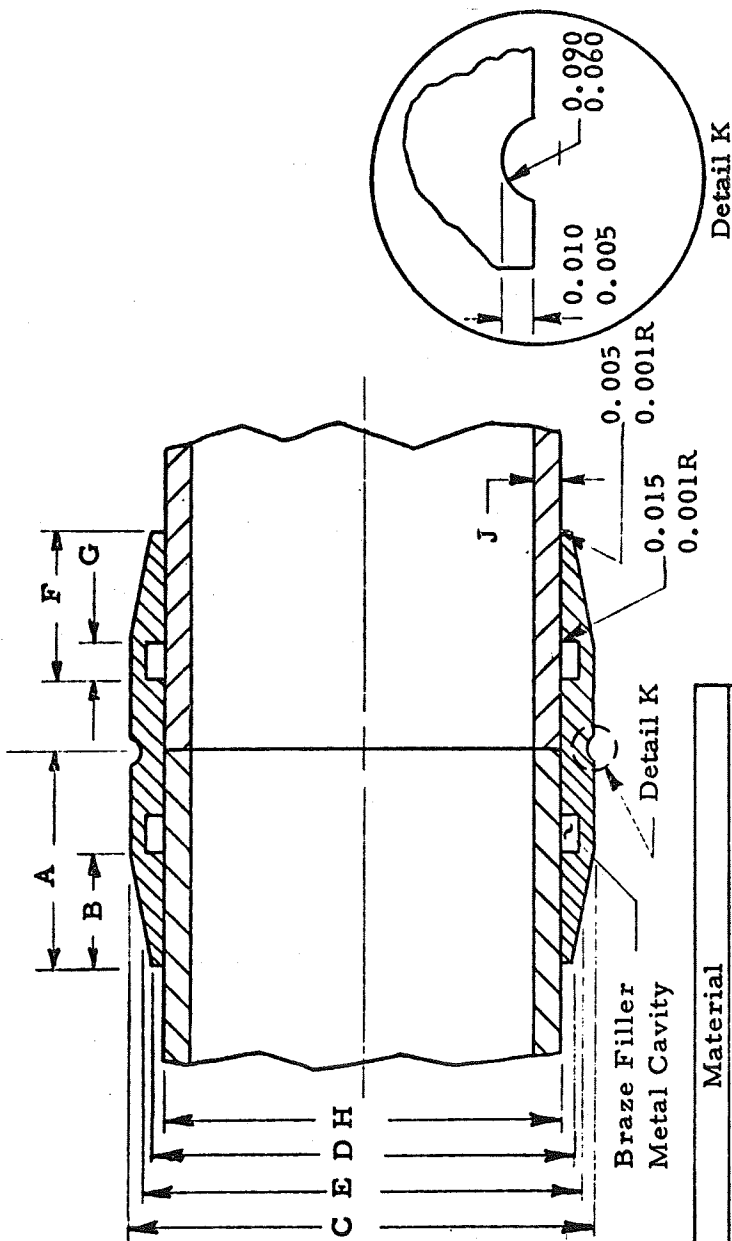
FIGURE 1 DIMENSIONAL SKETCH OF AEROQUIP BRAZED 1/4" TO 3/4"  
TUBE CONNECTION



| Part        | Material                 |
|-------------|--------------------------|
| Tube        | Type 321 Stainless Steel |
| Fitting     | Type 321 Stainless Steel |
| Braze Alloy | 80% gold - 20% nickel    |

| Tube           |                          |                                                 | Connection Dimension (in.) |       |       |       |             |       |       |
|----------------|--------------------------|-------------------------------------------------|----------------------------|-------|-------|-------|-------------|-------|-------|
| O. D.<br>(in.) | Oper.<br>Press.<br>(psi) | Cross<br>Section<br>Area<br>(in. <sup>2</sup> ) | A                          | B     | C     | D     | E<br>(min.) | F     | G     |
| 1              | 1500                     | 0.191                                           | 1.250                      | 0.350 | 0.450 | 1.000 | 0.092       | 0.065 | 0.125 |
| 1              | 3000                     | 0.278                                           | 1.250                      | 0.350 | 0.450 | 1.000 | 0.092       | 0.098 | 0.125 |
| 1 1/4          | 1500                     | 0.304                                           | 1.500                      | 0.400 | 0.550 | 1.250 | 0.114       | 0.083 | 0.500 |
| 1 1/4          | 3000                     | 0.432                                           | 1.500                      | 0.400 | 0.550 | 1.250 | 0.114       | 0.122 | 0.500 |
| 1 1/2          | 1500                     | 0.419                                           | 1.500                      | 0.400 | 0.550 | 1.500 | 0.090       | 0.095 | 0.500 |
| 1 1/2          | 3000                     | 0.492                                           | 1.500                      | 0.400 | 0.550 | 1.500 | 0.090       | 0.113 | 0.500 |

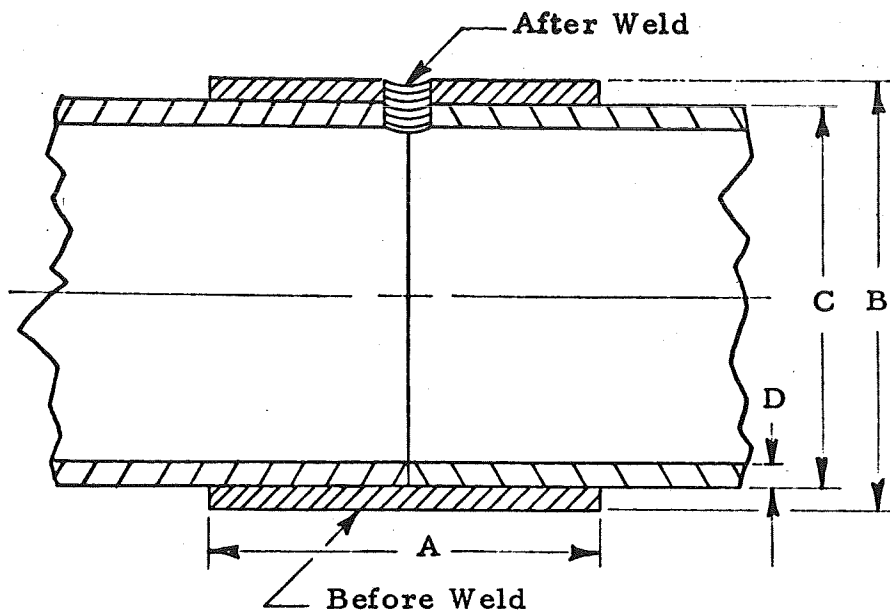
FIGURE 2 DIMENSIONAL SKETCH OF AEROQUIP BRAZED 1" to 1 1/2" TUBE  
CONNECTION



| Part        | Material                 |
|-------------|--------------------------|
| Tube        | Type 321 Stainless Steel |
| Fitting     | Type 321 Stainless Steel |
| Braze Alloy | 80% gold - 20% nickel    |

| Tube       |                   | Connection Dimension (in.)            |       |       |       |       |       |       |       |       |       |
|------------|-------------------|---------------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| O.D. (in.) | Oper. Press (psi) | Gross Sect. Area. (in. <sup>2</sup> ) | A     | B     | C     | D     | E     | F     | G     | H     | J     |
| 1/4        | 1500              | 0.0144                                | 0.322 | 0.083 | 0.352 | 0.287 | 0.297 | 0.138 | 0.058 | 0.250 | 0.020 |
| 1/4        | 3000              | 0.0184                                | 0.332 | 0.103 | 0.357 | 0.307 | 0.302 | 0.158 | 0.063 | 0.251 | 0.026 |
| 3/4        | 1500              | 0.108                                 | 0.390 | 0.193 | 0.872 | 0.787 | 0.817 | 0.272 | 0.087 | 0.750 | 0.049 |
| 3/4        | 3000              | 0.159                                 | 0.400 | 0.213 | 0.877 | 0.807 | 0.822 | 0.292 | 0.092 | 0.751 | 0.075 |
| 1 1/4      | 1500              | 0.304                                 | 0.547 | 0.310 | 1.400 | 1.287 | 1.317 | 0.425 | 0.080 | 1.250 | 0.083 |
| 1 1/4      | 3000              | 0.433                                 | 0.557 | 0.330 | 1.405 | 1.307 | 1.322 | 0.445 | 0.085 | 1.251 | 0.122 |

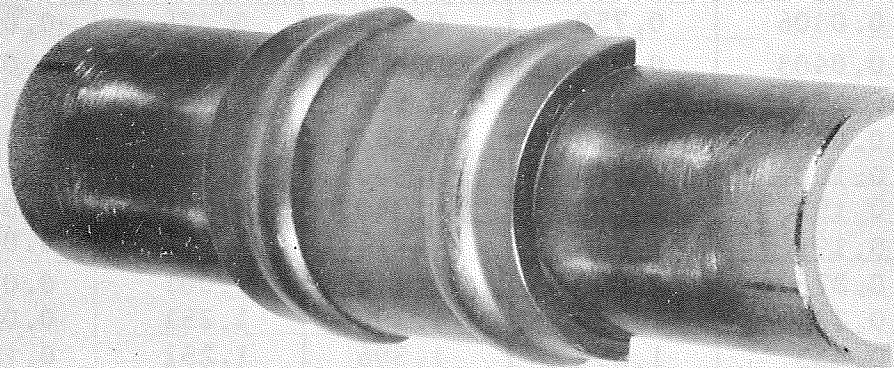
FIGURE 3 DIMENSIONAL SKETCH OF GE BRAZED 1/4" TO 1 1/4" TUBE CONNECTION



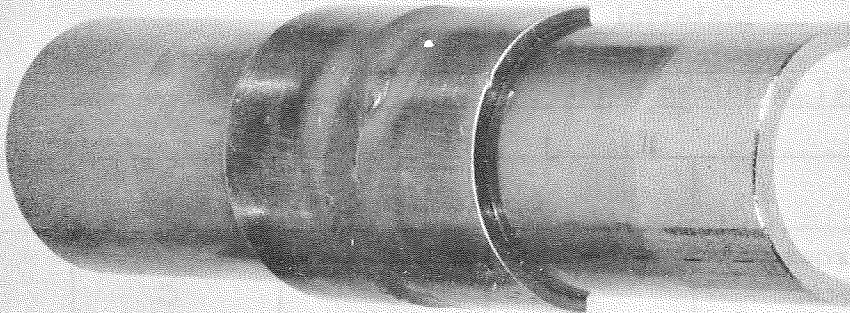
| Part    | Material                 |
|---------|--------------------------|
| Tube    | Type 321 Stainless Steel |
| Fitting | Type 347 Stainless Steel |

| Tube           |                          |                                               | Connection Dimension (in.) |            |            |       |
|----------------|--------------------------|-----------------------------------------------|----------------------------|------------|------------|-------|
| O. D.<br>(in.) | Oper.<br>Press.<br>(psi) | Cross<br>Sect.<br>Area<br>(in. <sup>2</sup> ) | A<br>±.015                 | B<br>±.002 | C<br>±.001 | D     |
| 1/4            | 1500                     | 0.0145                                        | 0.750                      | 0.286      | 0.251      | 0.020 |
|                | 3000                     | 0.0184                                        | 0.750                      | 0.286      | 0.251      | 0.026 |
| 3/8            | 1500                     | 0.0306                                        | 0.750                      | 0.425      | 0.376      | 0.028 |
|                | 3000                     | 0.0403                                        | 0.750                      | 0.425      | 0.376      | 0.038 |
| 1/2            | 1500                     | 0.0512                                        | 0.750                      | 0.562      | 0.501      | 0.035 |
|                | 3000                     | 0.0721                                        | 0.750                      | 0.562      | 0.501      | 0.051 |
| 3/4            | 1500                     | 0.108                                         | 1.000                      | 0.840      | 0.751      | 0.049 |
|                | 3000                     | 0.159                                         | 1.000                      | 0.840      | 0.751      | 0.075 |
| 1              | 1500                     | 0.191                                         | 1.000                      | 1.116      | 1.001      | 0.065 |
|                | 3000                     | 0.278                                         | 1.000                      | 1.116      | 1.001      | 0.098 |
| 1 1/4          | 1500                     | 0.305                                         | 1.250                      | 1.396      | 1.251      | 0.083 |
|                | 3000                     | 0.433                                         | 1.250                      | 1.396      | 1.251      | 0.122 |
| 1 1/2          | 1500                     | 0.420                                         | 1.250                      | 1.636      | 1.501      | 0.095 |
|                | 3000                     | 0.493                                         | 1.250                      | 1.636      | 1.501      | 0.113 |

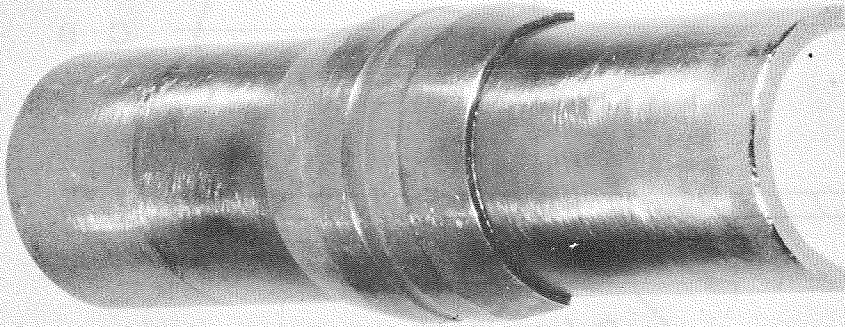
FIGURE 4 DIMENSIONAL SKETCH OF MSFC WELDED 1/4" TO 1 1/2" TUBE CONNECTION



Aeroquip (Brazed)



MSFC (Welded)



GE (Brazed)

FIGURE 5 EXTERIOR VIEW - THREE TYPES OF 3/4" TUBE CONNECTIONS

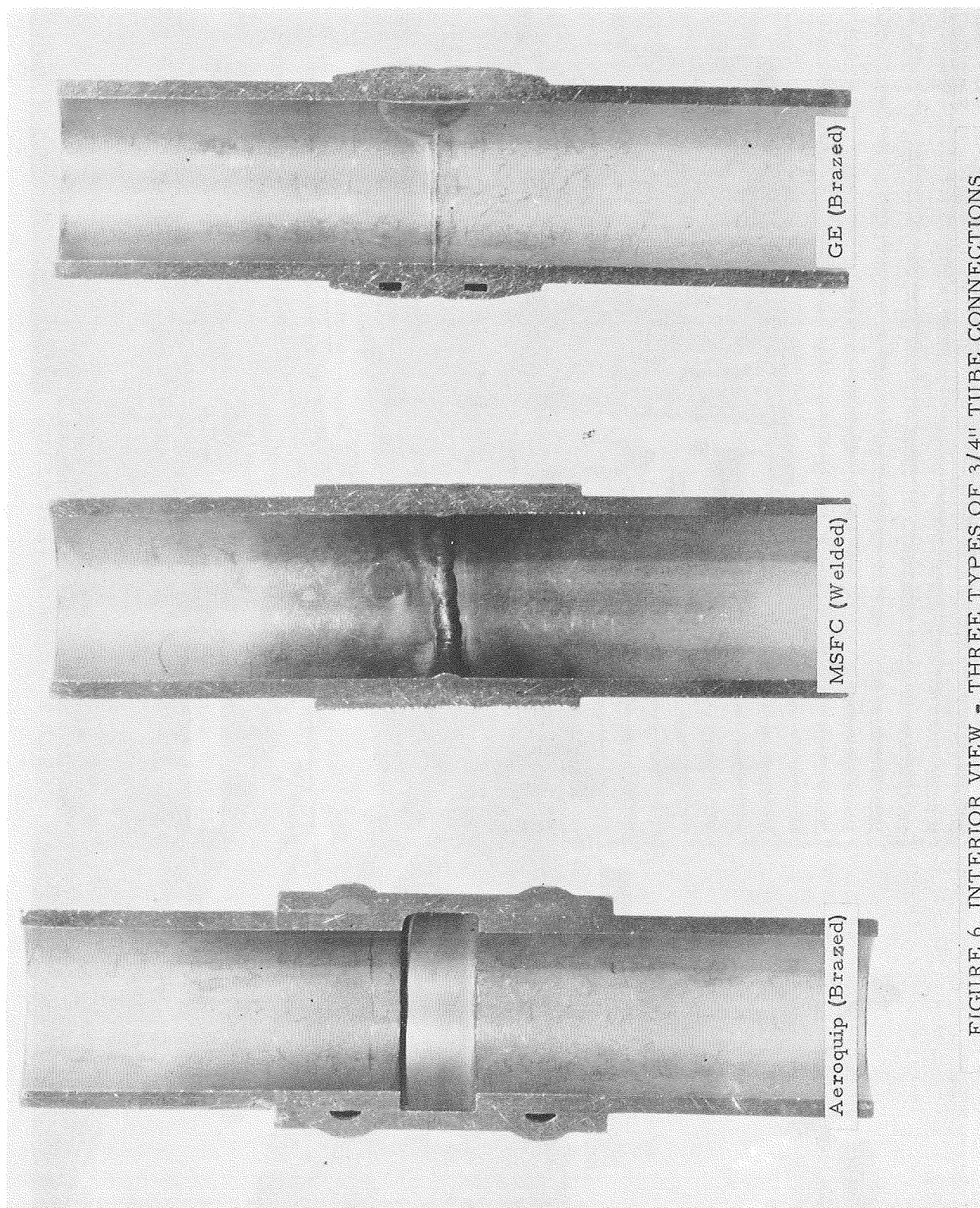




FIGURE 7 LEAKAGE TEST SETUP



FIGURE 8 BRAZED AND WELDED CONNECTIONS IN 24 MONTHS STORAGE TEST

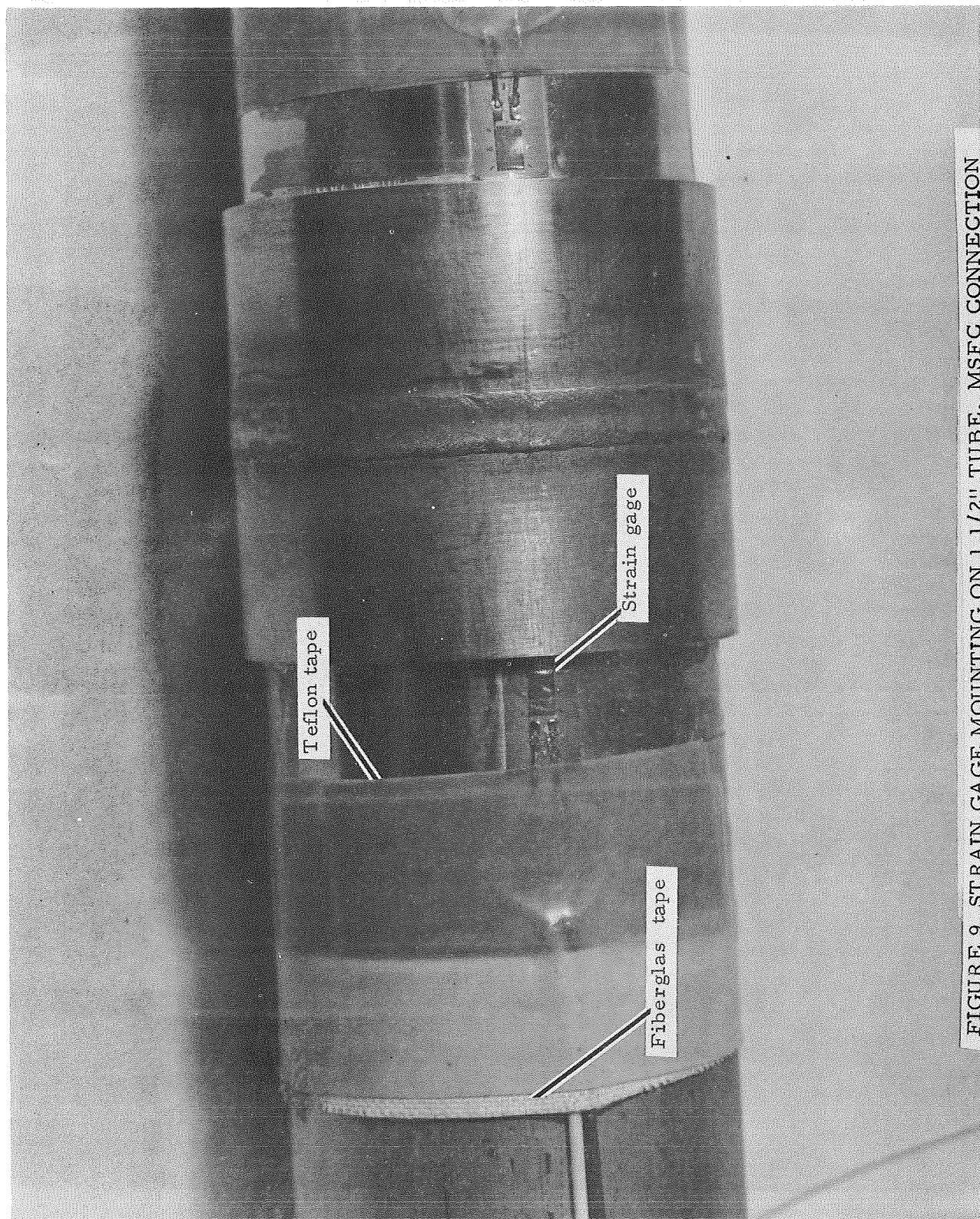


FIGURE 9 STRAIN GAGE MOUNTING ON 1 1/2" TUBE. MSFC CONNECTION

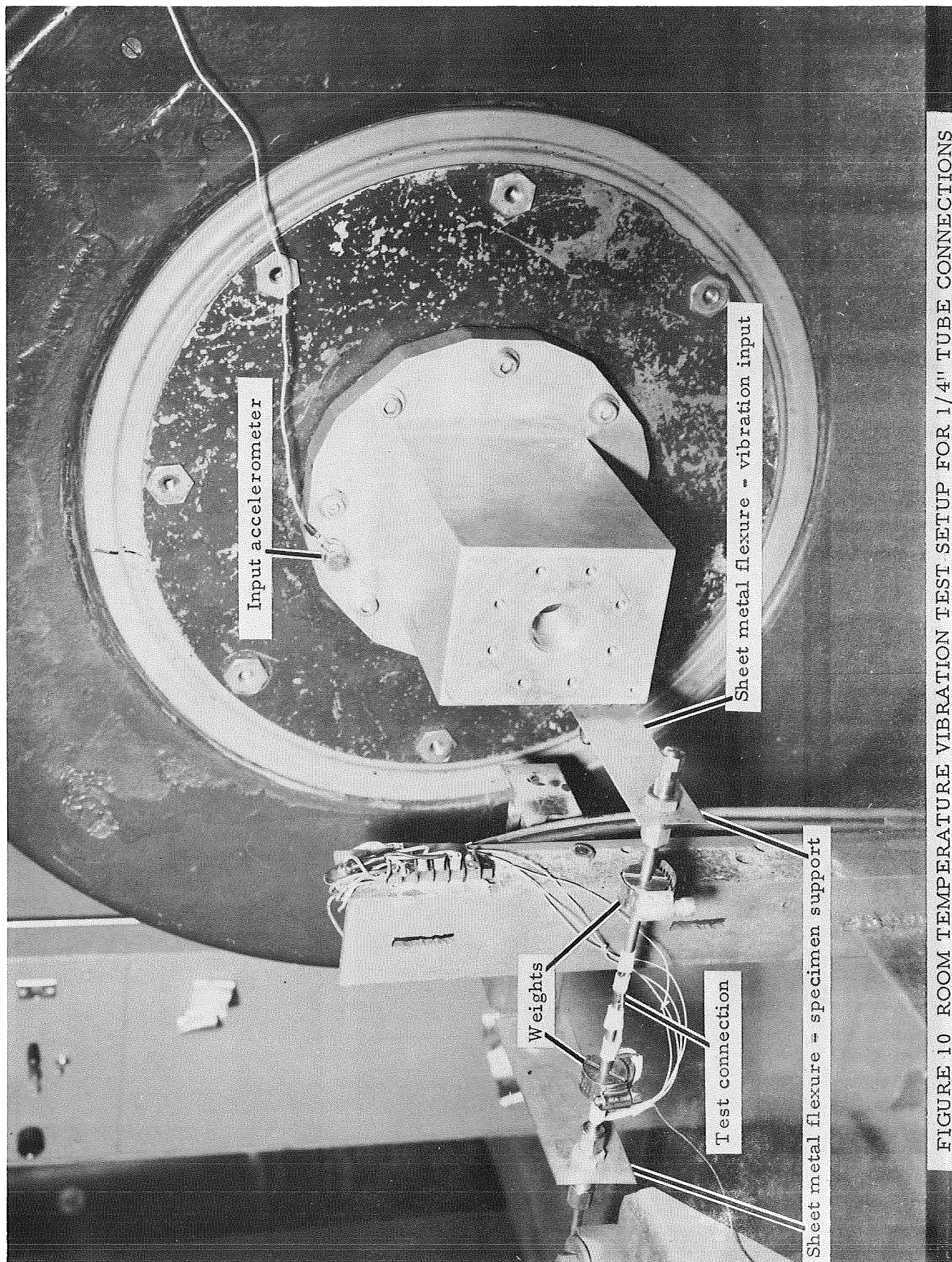


FIGURE 10 ROOM TEMPERATURE VIBRATION TEST SETUP FOR 1/4" TUBE CONNECTIONS

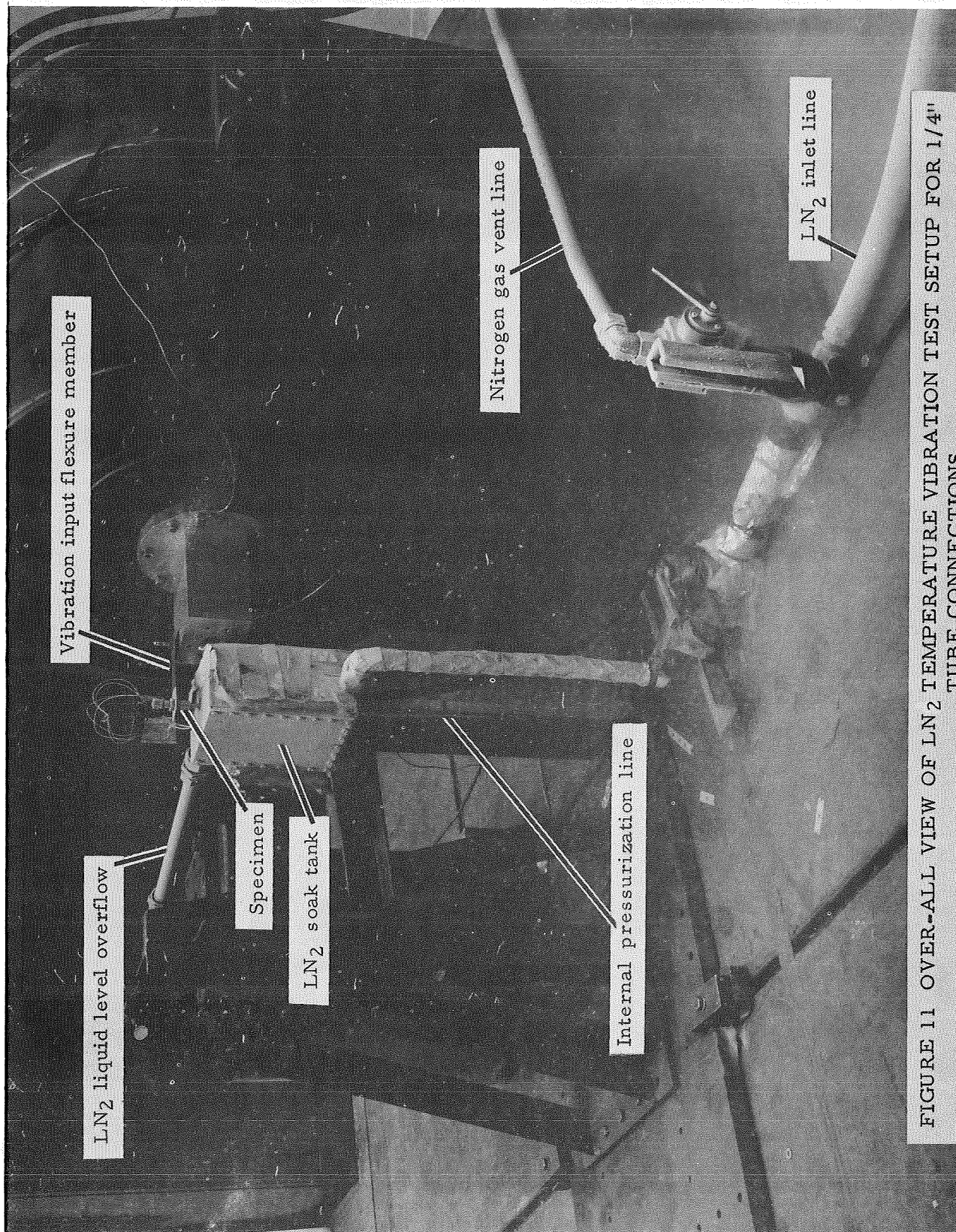
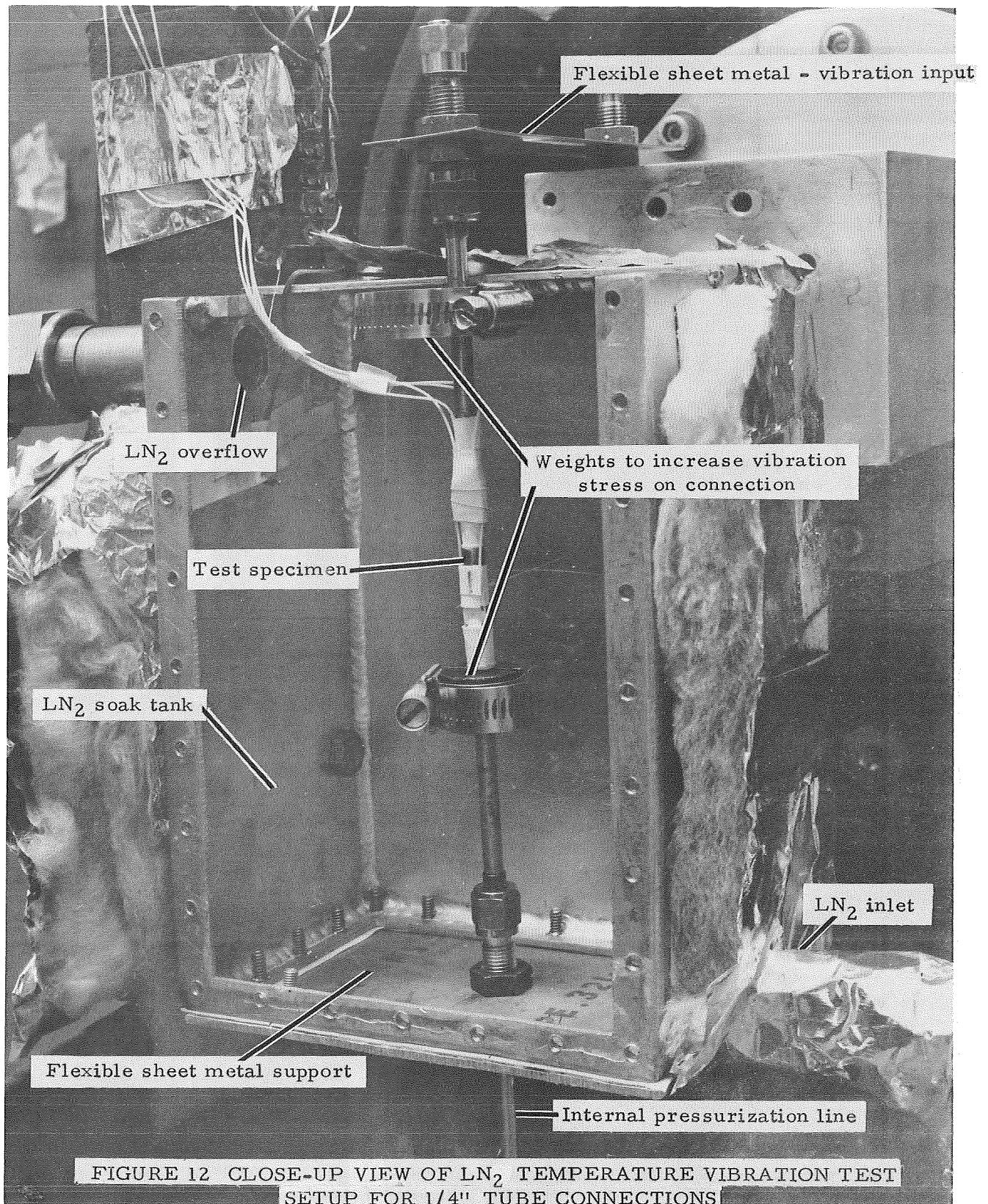


FIGURE 11 OVER-ALL VIEW OF LN<sub>2</sub> TEMPERATURE VIBRATION TEST SETUP FOR 1/4" TUBE CONNECTIONS



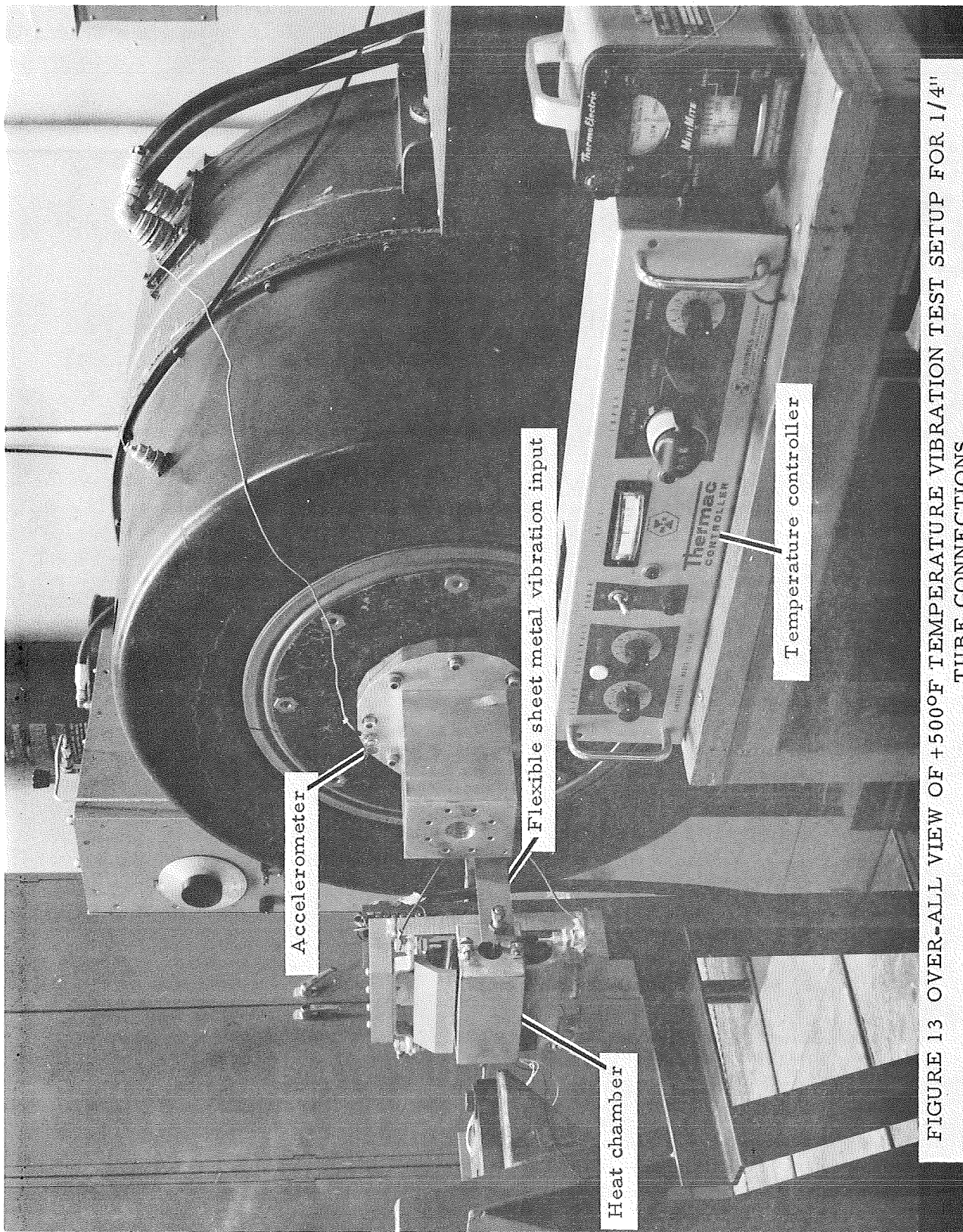


FIGURE 13 OVER-ALL VIEW OF +500°F TEMPERATURE VIBRATION TEST SETUP FOR 1/4" TUBE CONNECTIONS

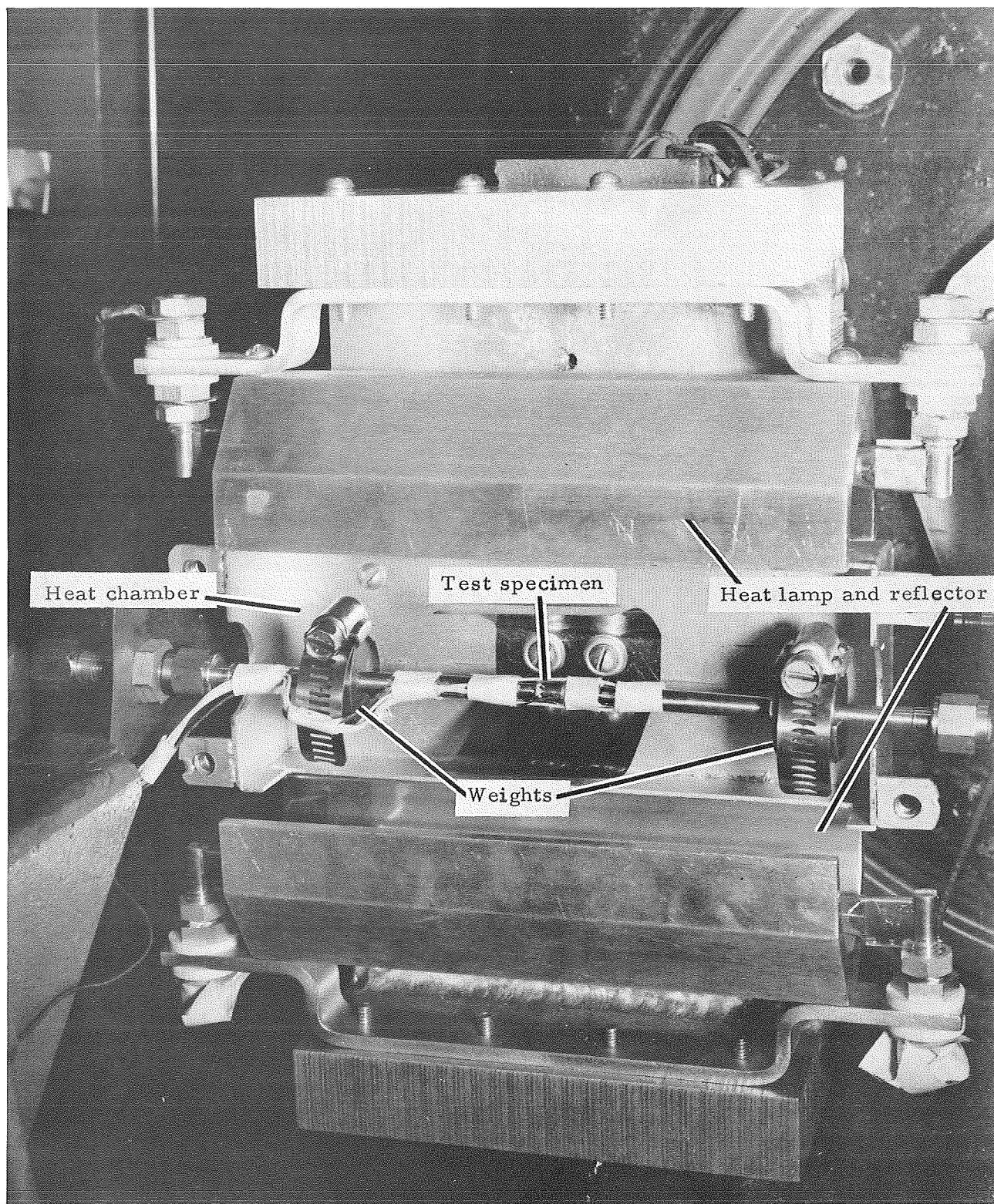


FIGURE 14 CLOSE-UP VIEW OF +500°F TEMPERATURE VIBRATION TEST SETUP FOR 1/4" TUBE CONNECTIONS

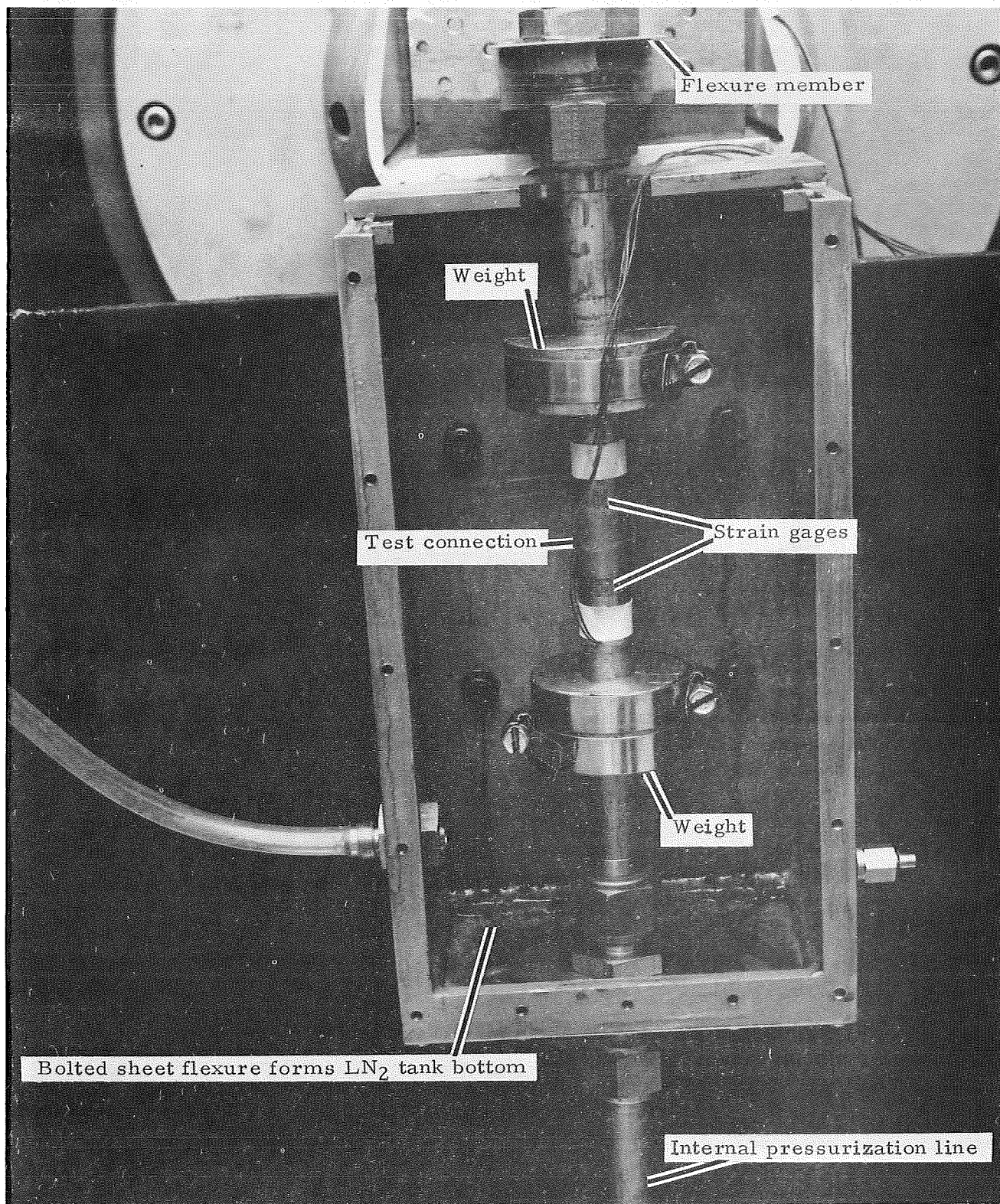


FIGURE 15 CLOSE-UP VIEW OF LN<sub>2</sub> TEMPERATURE VIBRATION TEST SETUP FOR 3/4" TUBE CONNECTIONS

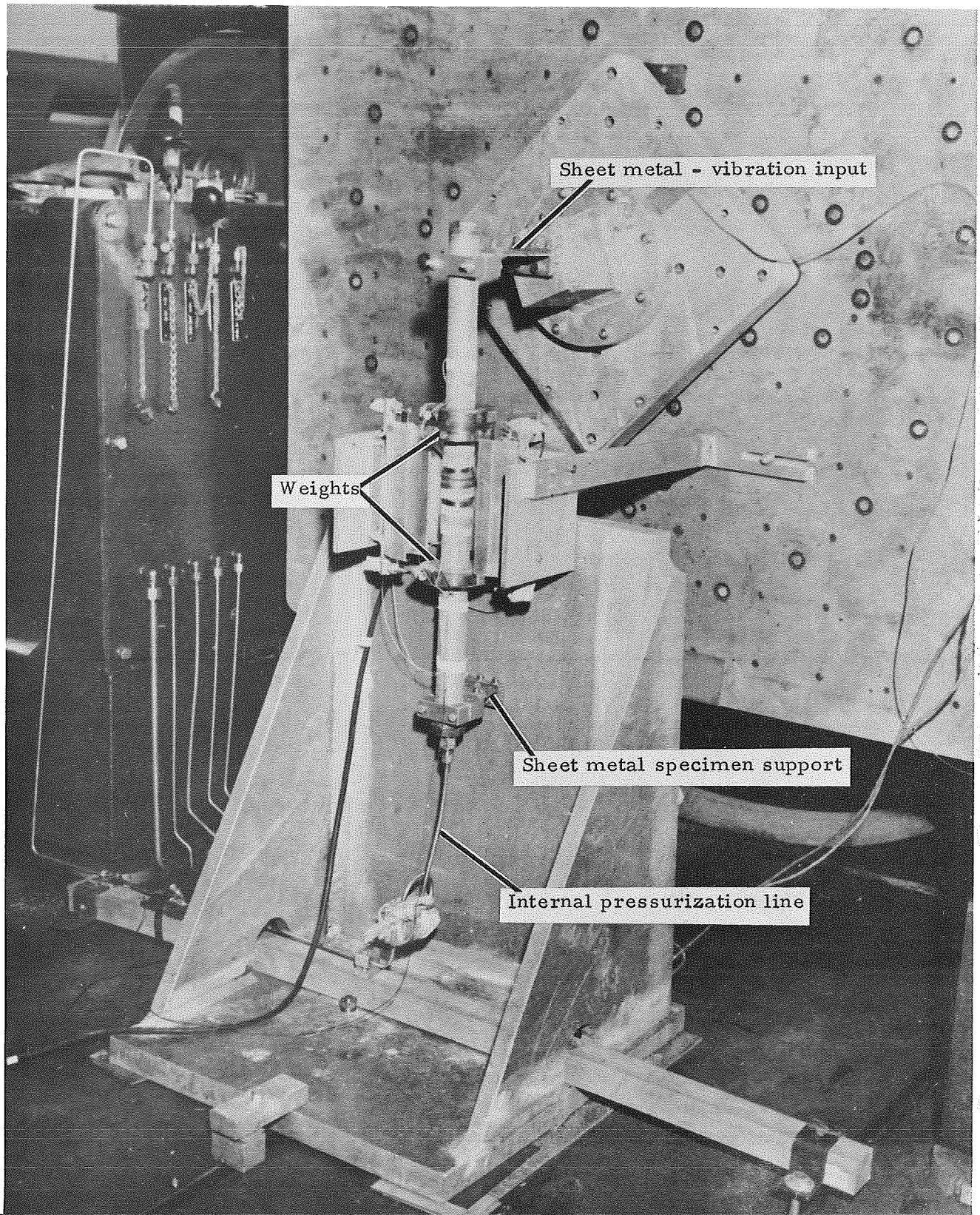


FIGURE 16 ROOM TEMPERATURE AND +500°F TEMPERATURE VIBRATION TEST SETUP FOR 1 1/2" TUBE CONNECTIONS

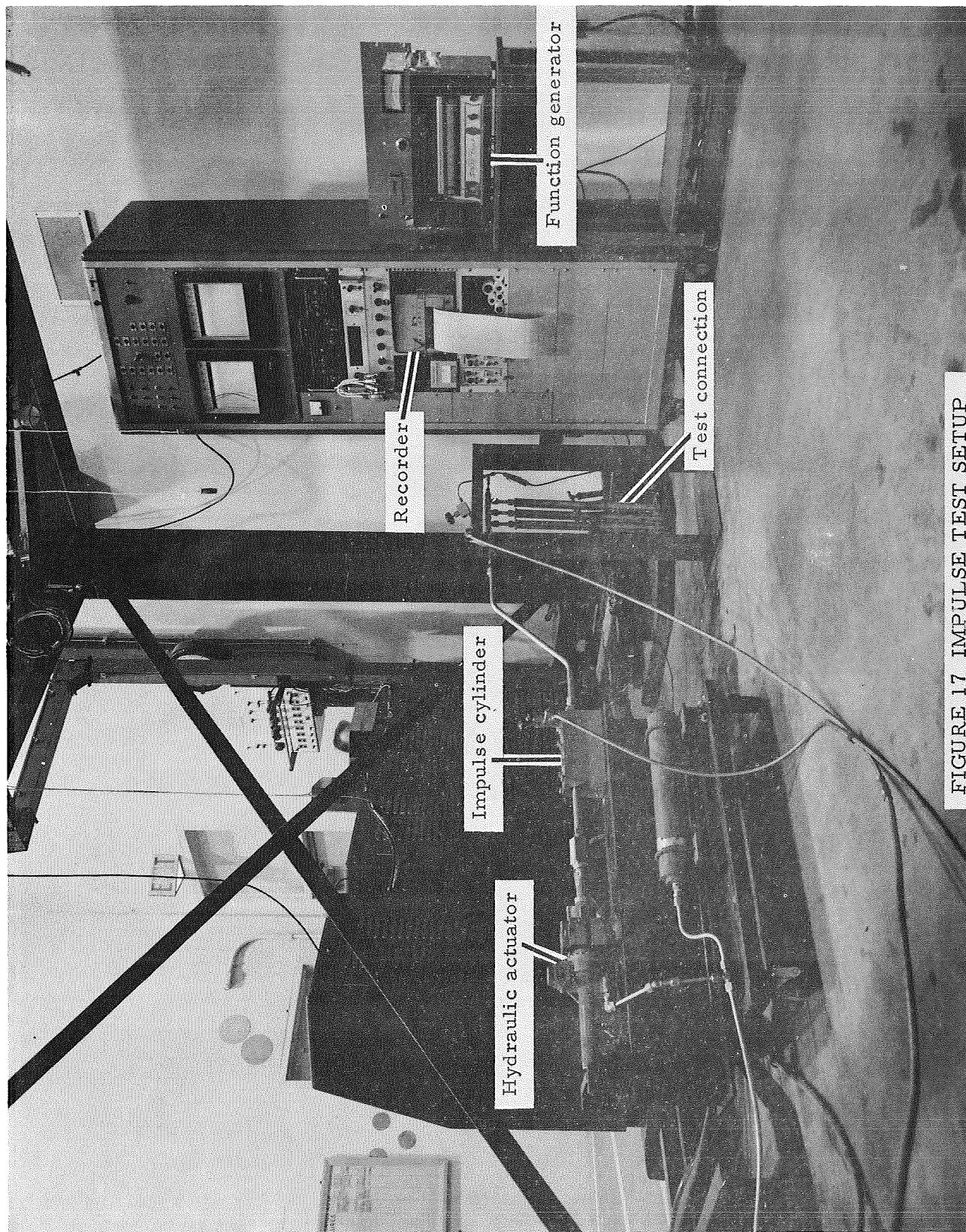


FIGURE 17 IMPULSE TEST SETUP

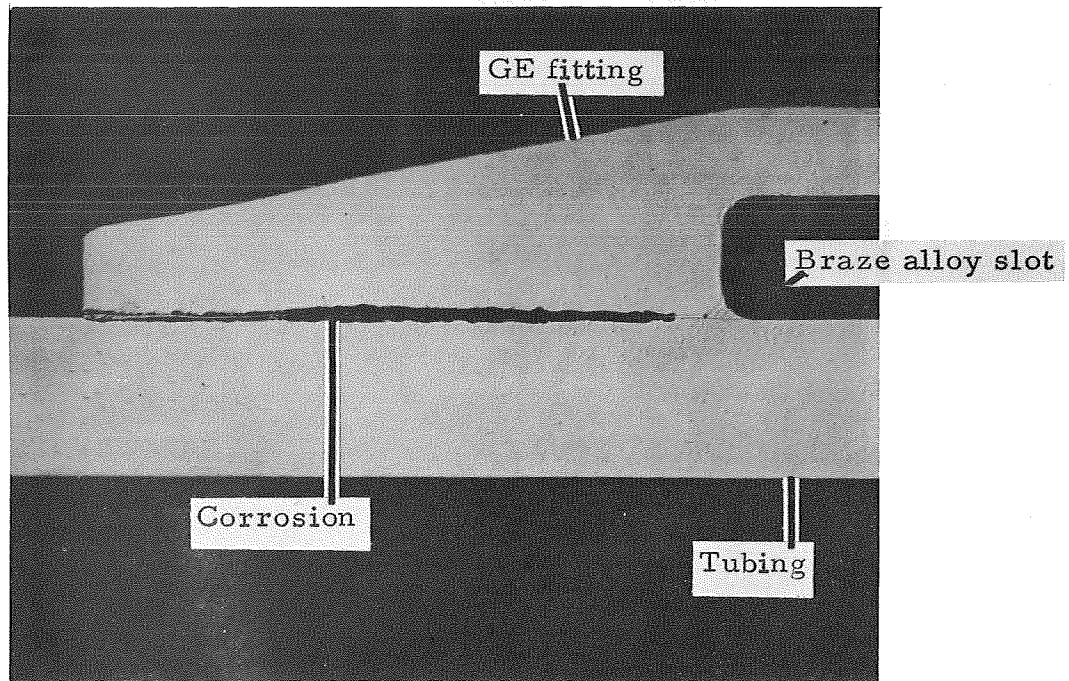


FIGURE 18 CORROSION AT BRAZE ON 3/4" TUBE,  
GE CONNECTION QG 11201 (15X)

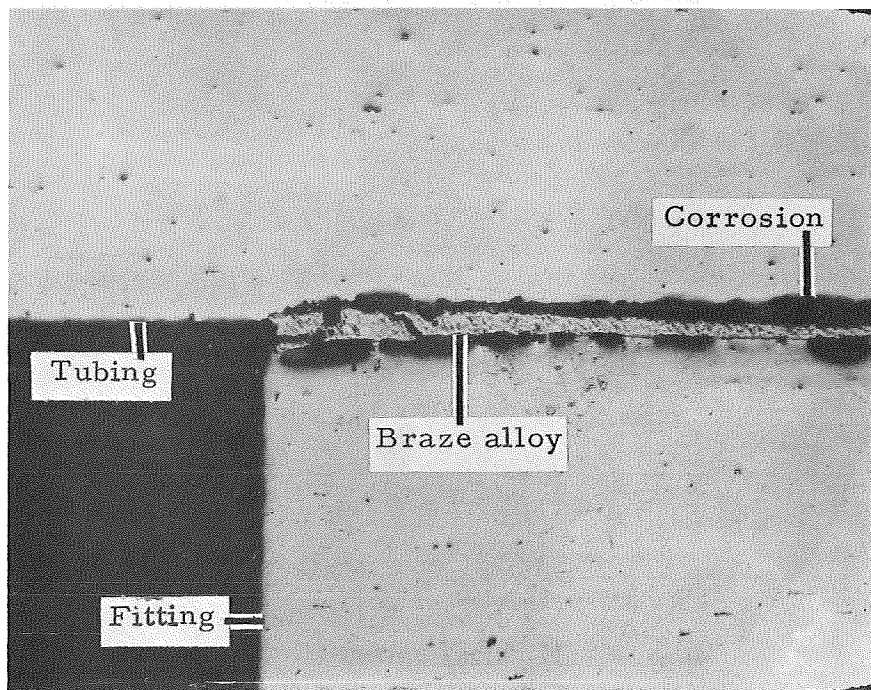


FIGURE 19 CORROSION - OUTER END OF BRAZE ON 3/4" TUBE,  
GE CONNECTION QG11201 (100X)

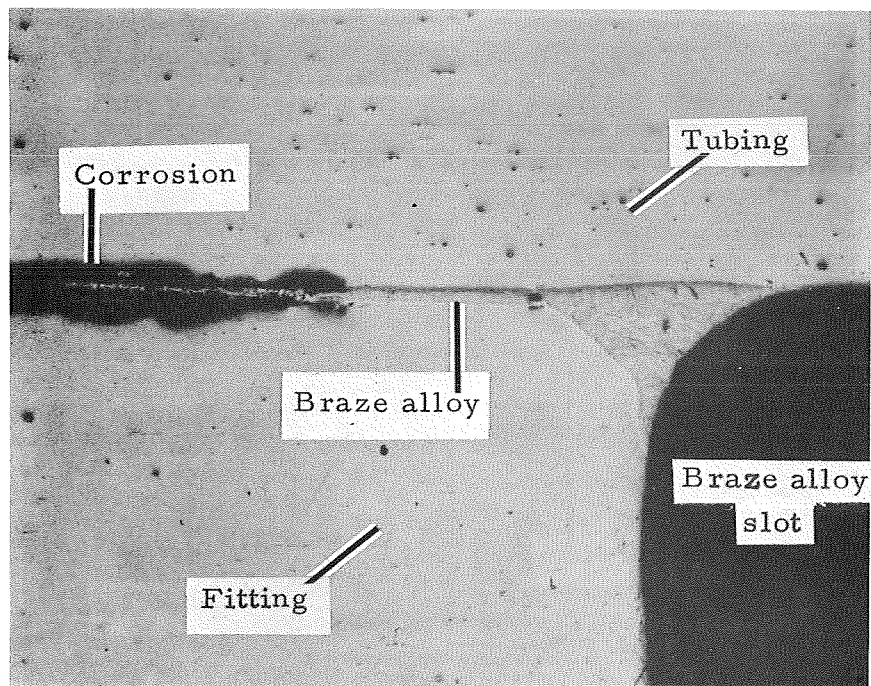


FIGURE 20 CORROSION - INNER END OF BRAZE ON 3/4" TUBE,  
GE CONNECTION QG 11201 (100X)

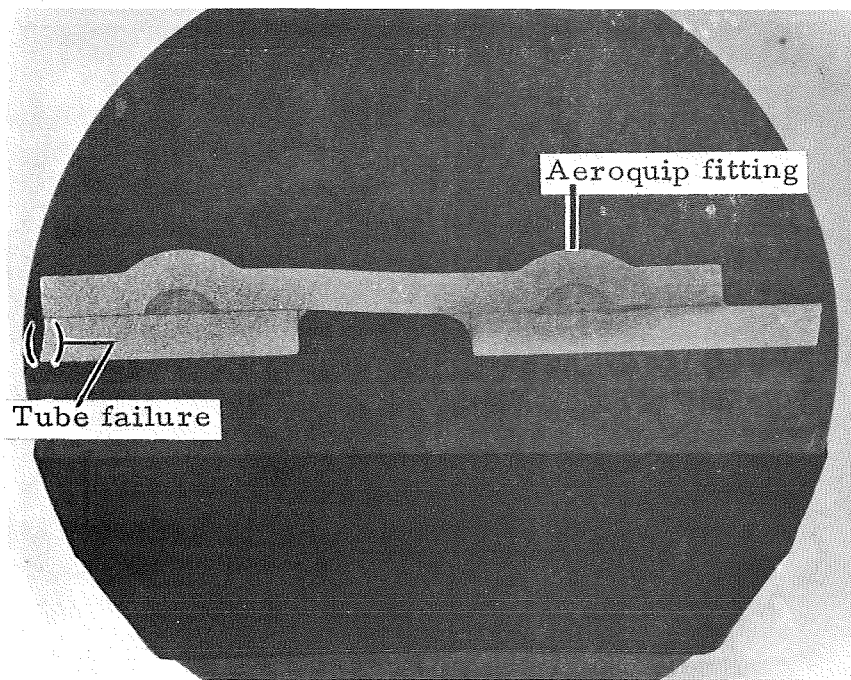


FIGURE 21 BENT AEROQUIP CONNECTION FAILURE ON 3/4" TUBE,  
CA 31202 (2 1/2 X)

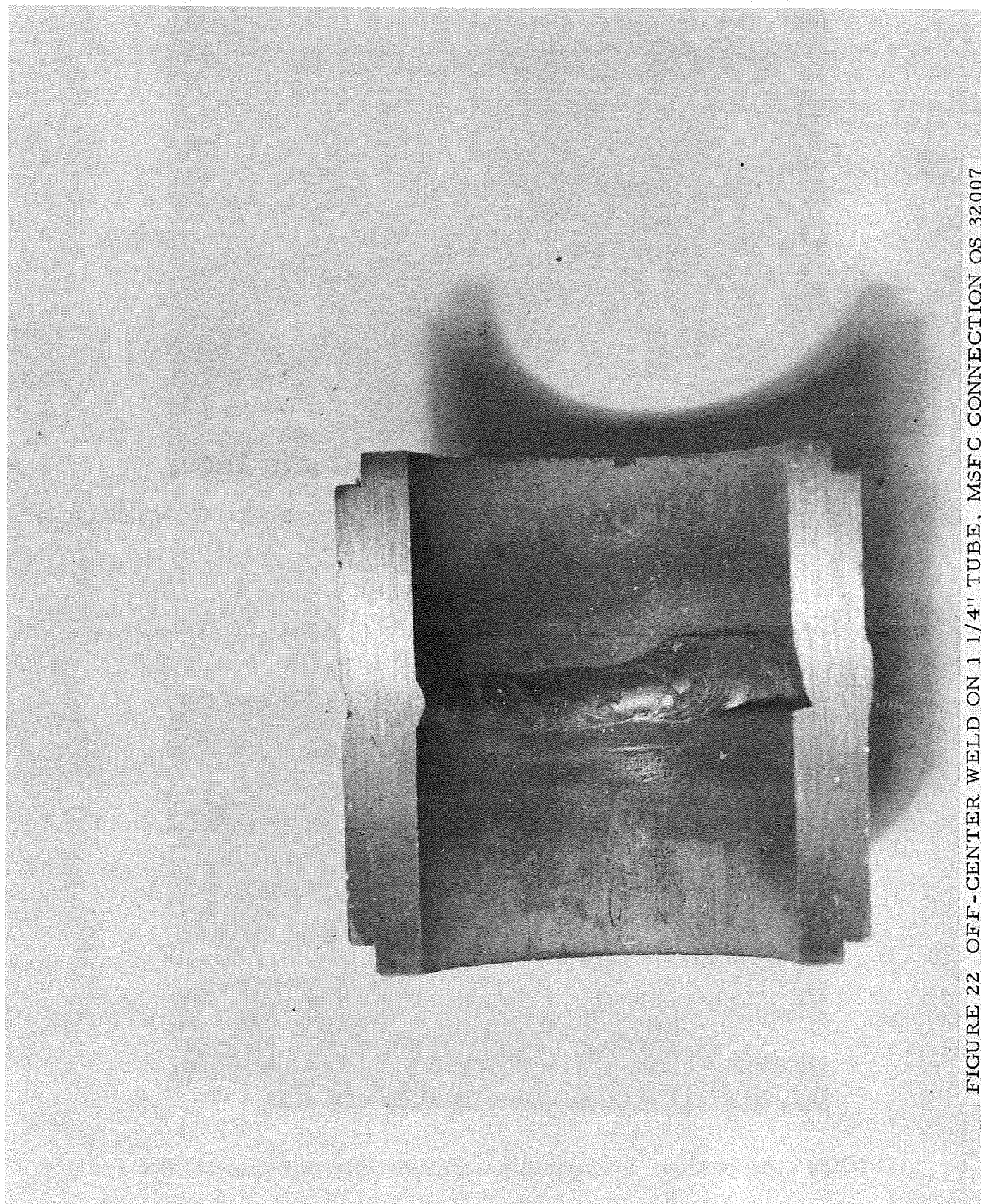


FIGURE 22 OFF-CENTER WELD ON 1 1/4" TUBE, MSFC CONNECTION QS 32007

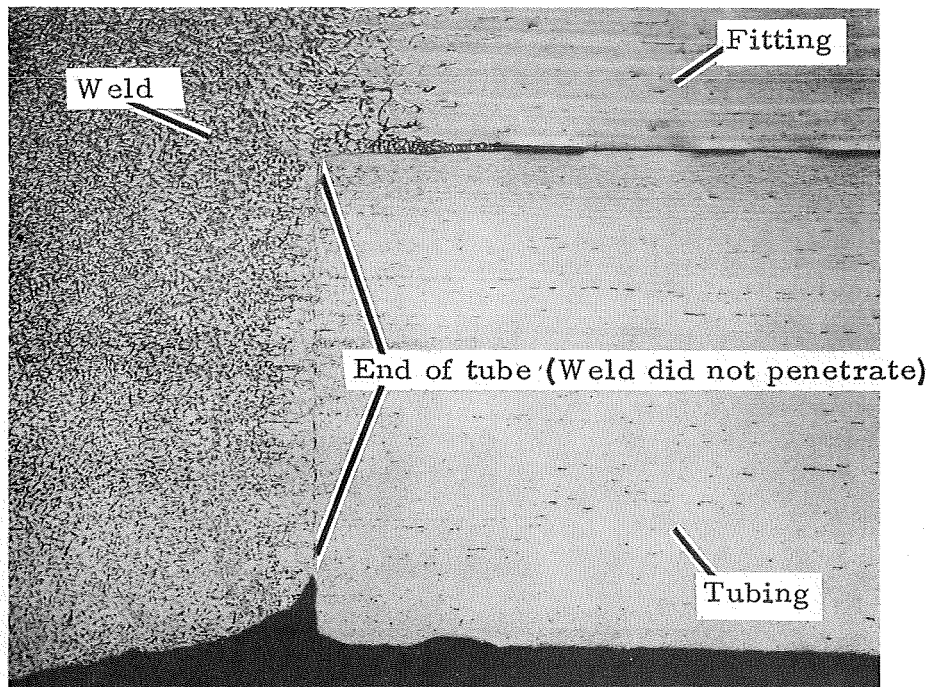
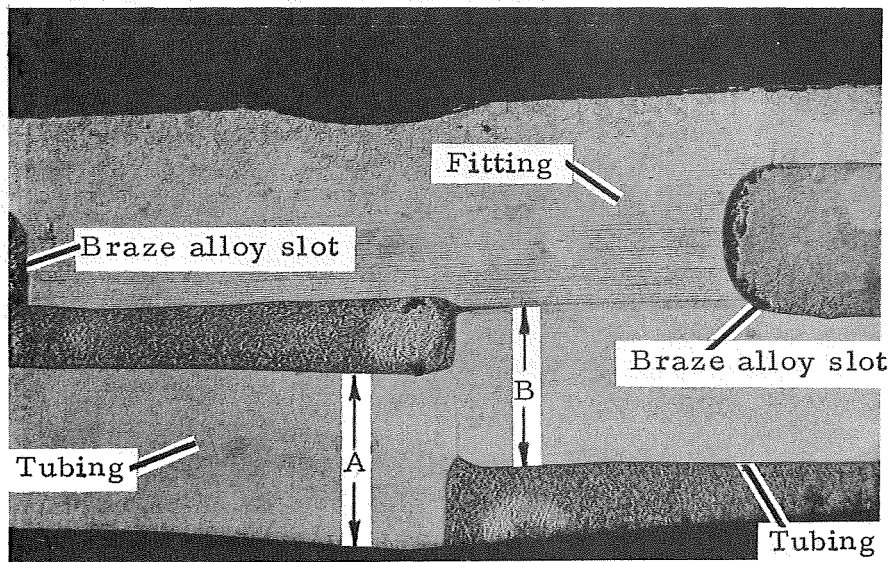


FIGURE 23 OFF-CENTER WELD ON 3/4" TUBE, MSFC CONNECTION  
QS11207 (50X)



NOTE: Dimension "A" should be aligned with dimension "B".

FIGURE 24 BRAZED TUBING MISFIT ON 3/4" TUBE,  
GE CONNECTION QG 11208 (15X)

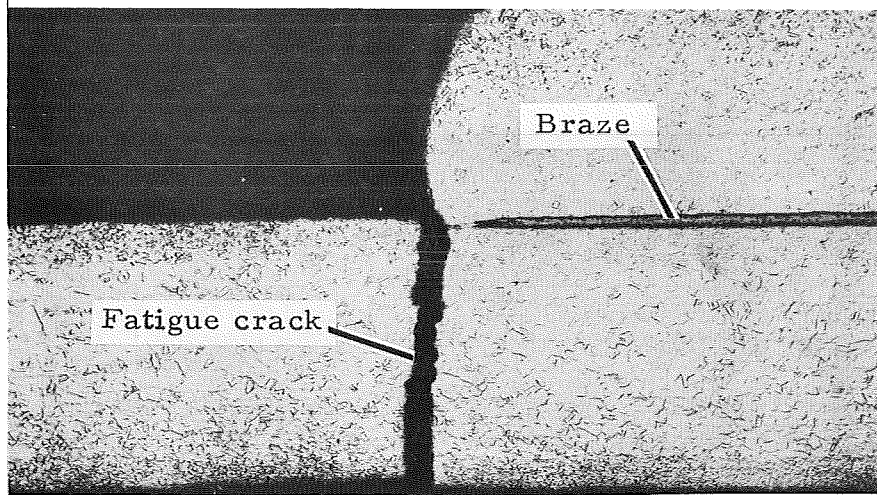


FIGURE 25 FATIGUE CRACK FAILURE AFTER VIBRATION,  
1/4" AEROQUIP CONNECTION CA30406 (50X)

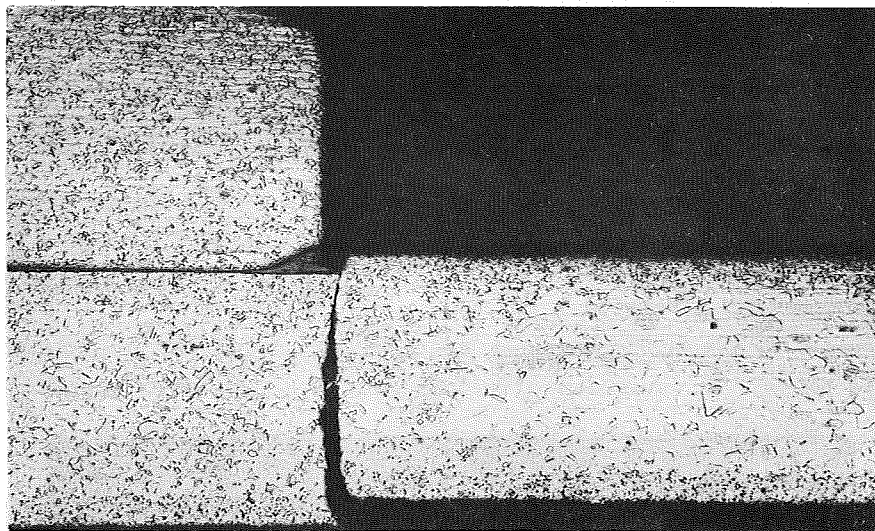


FIGURE 26 FATIGUE CRACK FAILURE AFTER VIBRATION,  
1/4" GE CONNECTION CG 30406 (50X)

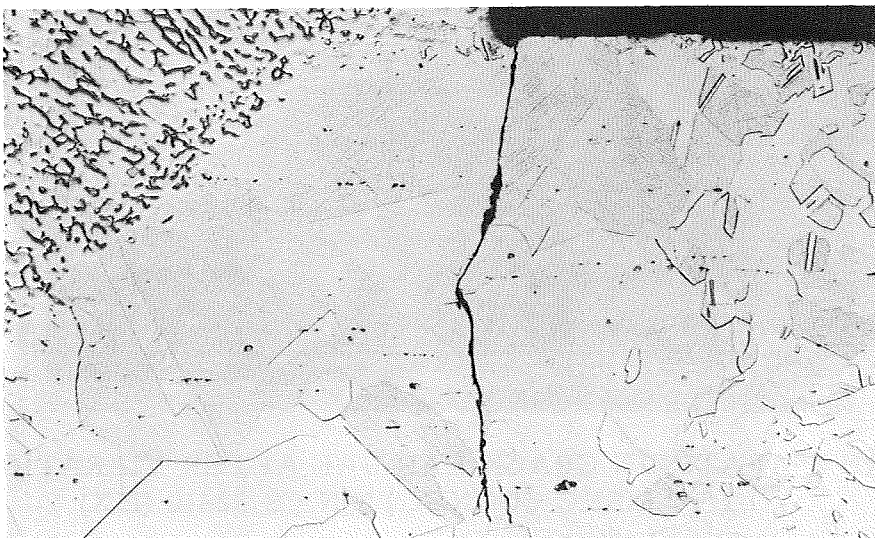


FIGURE 27 FATIGUE CRACK INITIATION AFTER VIBRATION,  
1/4" MSFC CONNECTION CS 30419 (500X)

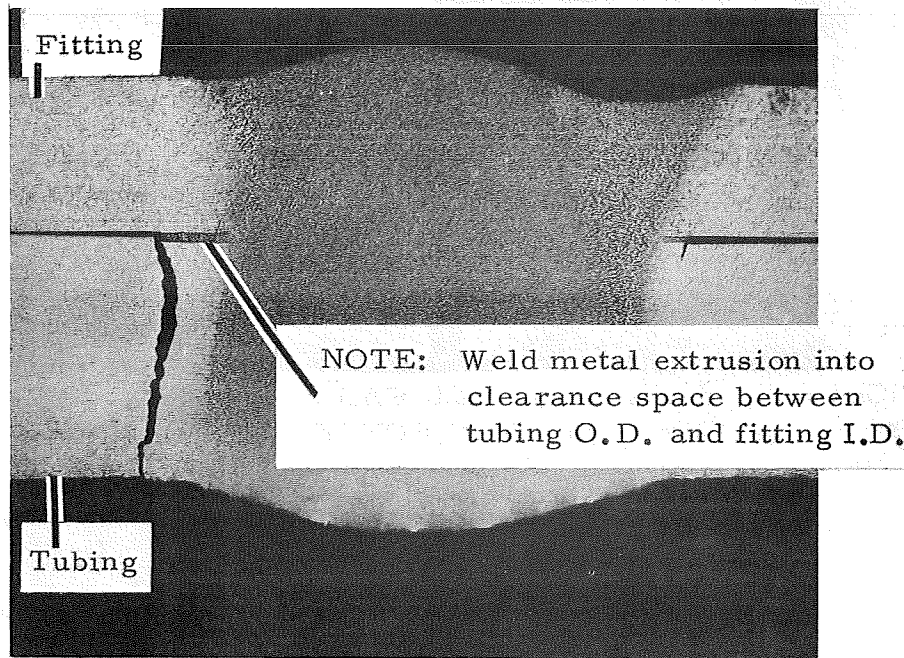


FIGURE 28 FATIGUE CRACK FAILURE AFTER VIBRATION,  
1 1/2" MSFC CONNECTION CS 32407 (15X)

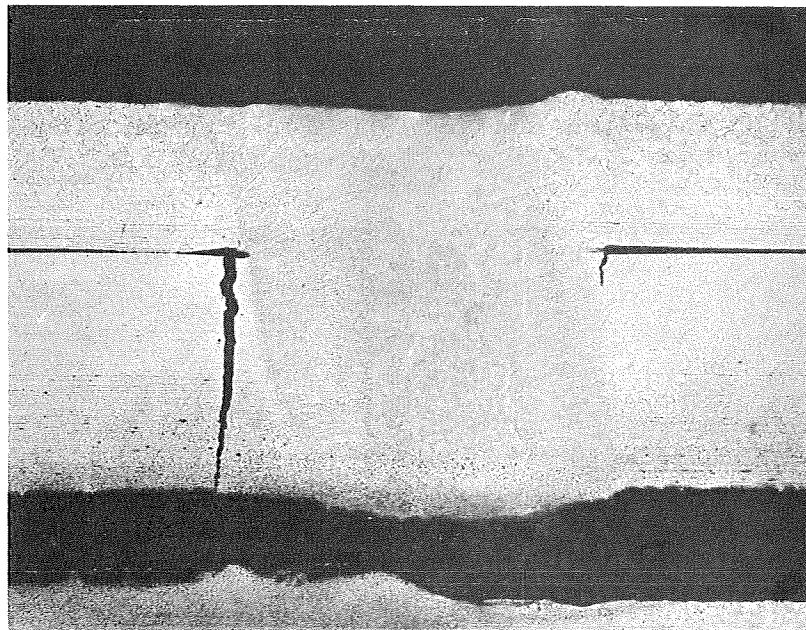


FIGURE 29 FATIGUE CRACK FAILURE AFTER VIBRATION,  
1 1/2" MSFC CONNECTION CS 32410 (15X)

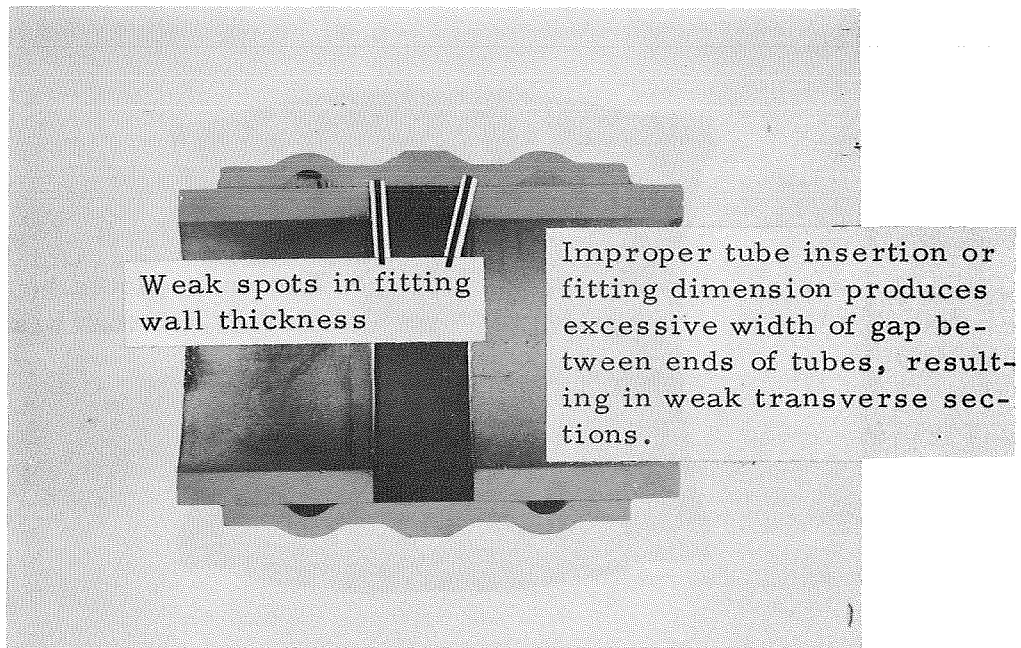


FIGURE 30 CROSS SECTION OF 1" AEROQUIP CONNECTION, QA 31608

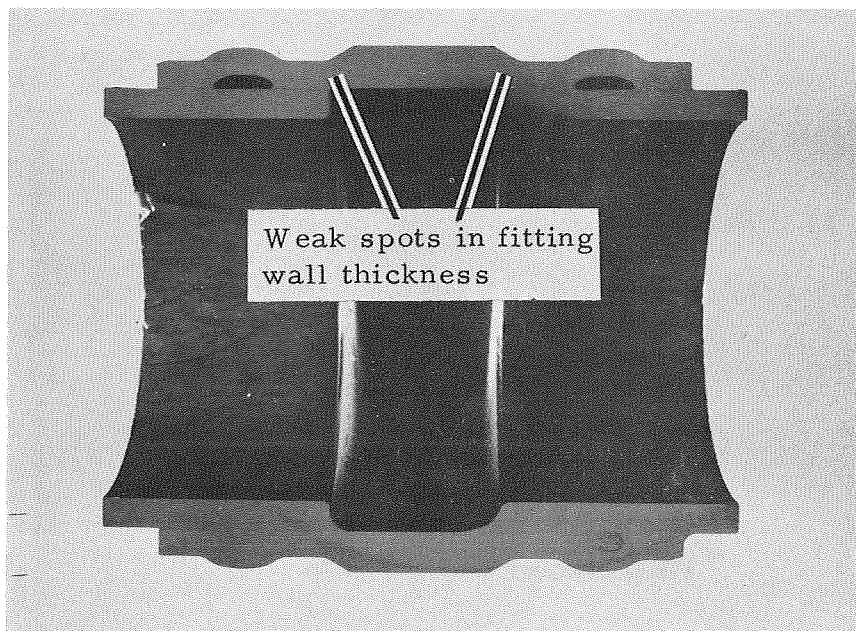


FIGURE 31 CROSS SECTION OF 1 1/4" AEROQUIP CONNECTION, QA 12007

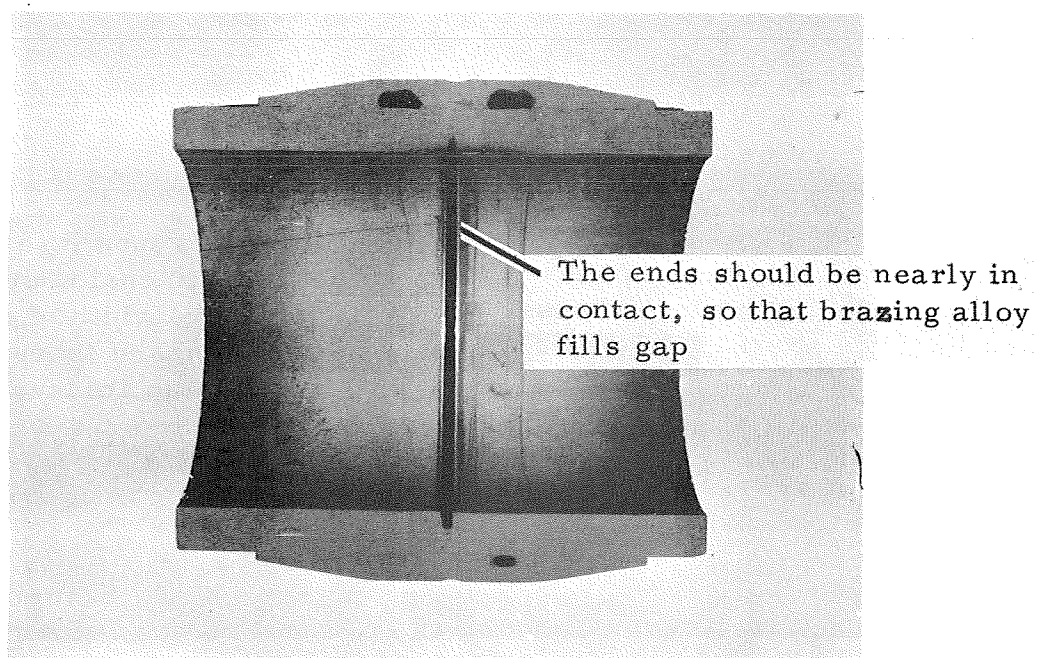


FIGURE 32 CROSS SECTION OF 1 1/4" GE CONNECTION, QG 32007

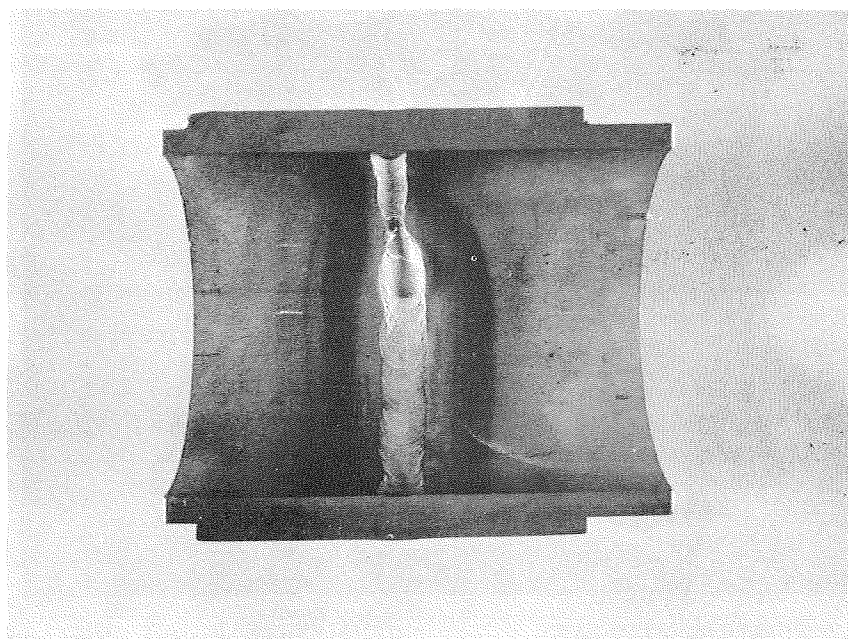


FIGURE 33 CROSS SECTION OF 1 1/2" MSFC CONNECTION, QS 12408

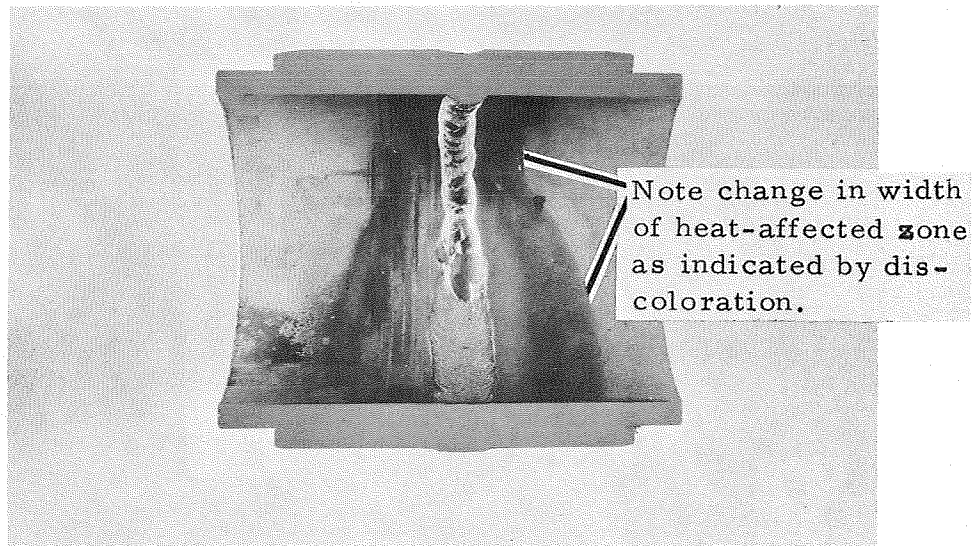


FIGURE 34 CROSS SECTION OF 1 1/4" MSFC CONNECTION, QS 12008

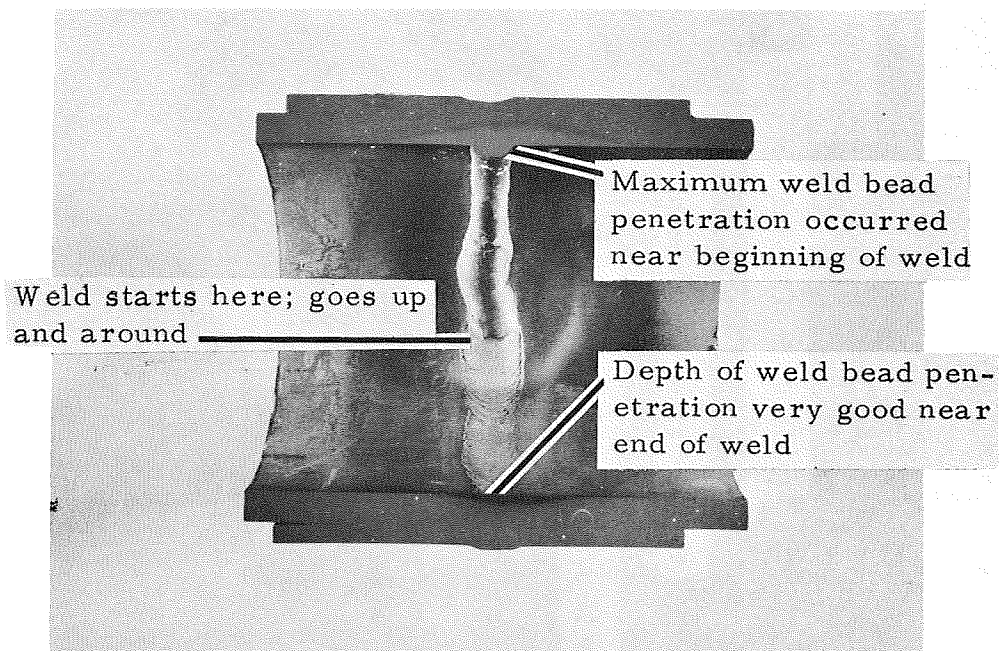


FIGURE 35 CROSS SECTION OF 1 1/2" MSFC CONNECTION, CS 32406

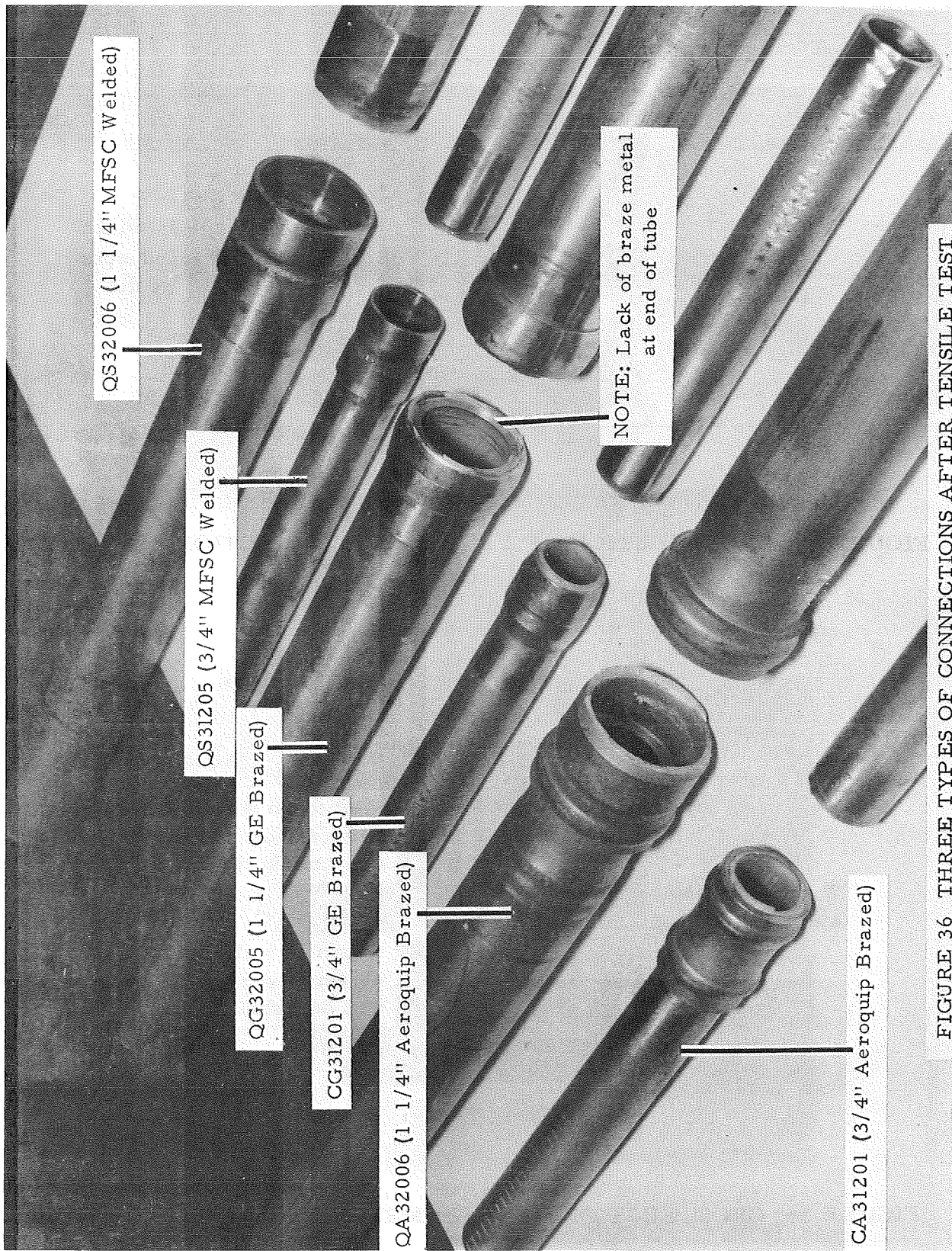


FIGURE 36 THREE TYPES OF CONNECTIONS AFTER TENSILE TEST

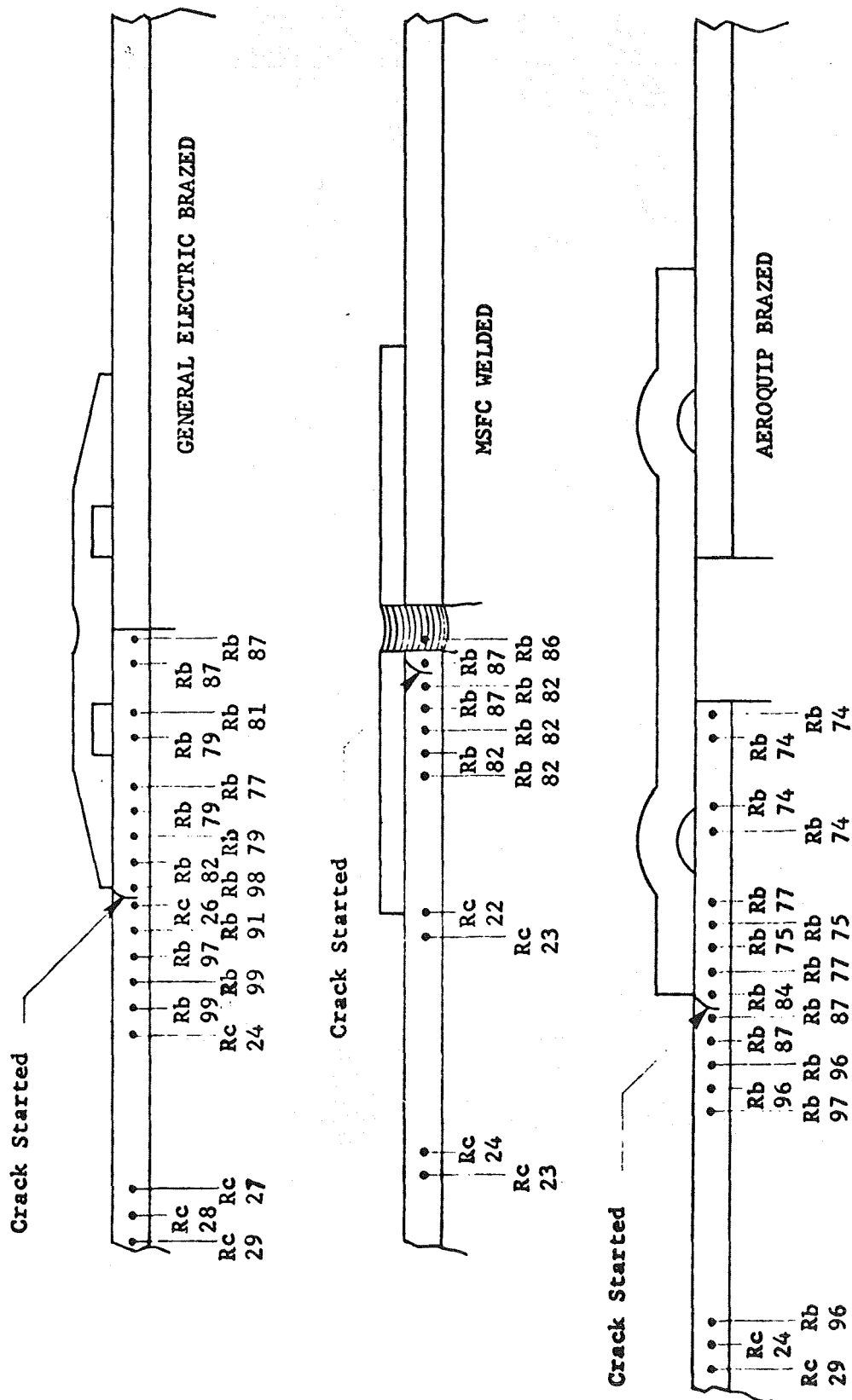


FIGURE 37 HARDNESS DISTRIBUTION ON 1/4" TUBE CONNECTION CROSS SECTION  
AFTER VIBRATION TESTING

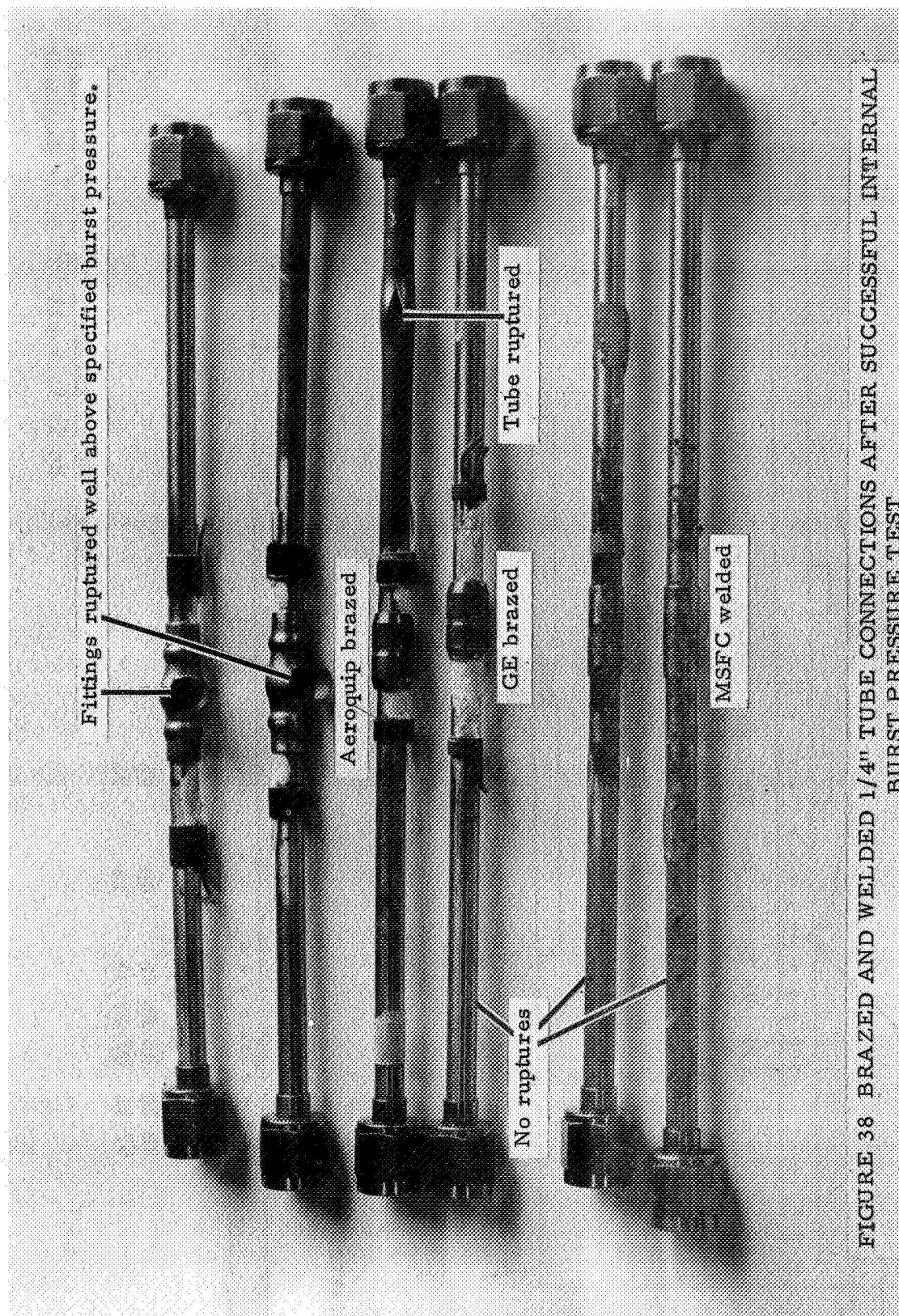


FIGURE 38 BRAZED AND WELDED 1/4" TUBE CONNECTIONS AFTER SUCCESSFUL INTERNAL BURST PRESSURE TEST

Experimental results of vibration test; completion of 300,000 cycles of alternating tensile and compressive stresses as shown, measured by strain gages mounted parallel to the tubing axis. Tubes pressurized to 1500 or 3000 psig.

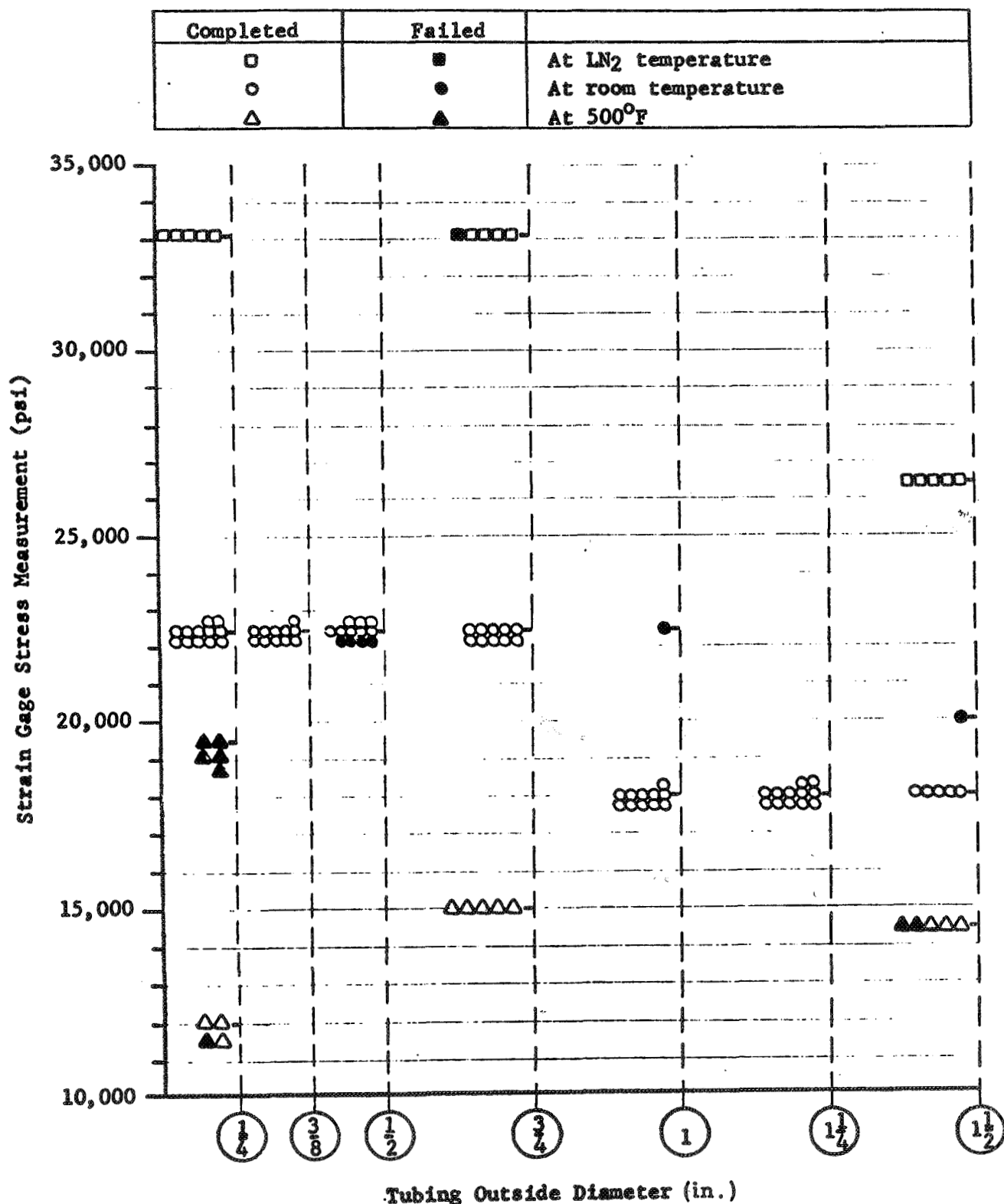


FIGURE 39. SUMMARY OF AEROQUIP BRAZED CONNECTION VIBRATION TESTS

Experimental results of vibration test; completion of 300,000 cycles of alternating tensile and compressive stresses as shown, measured by strain gages mounted parallel to the tubing axis. Tubes pressurized to 1500 or 3000 psig.

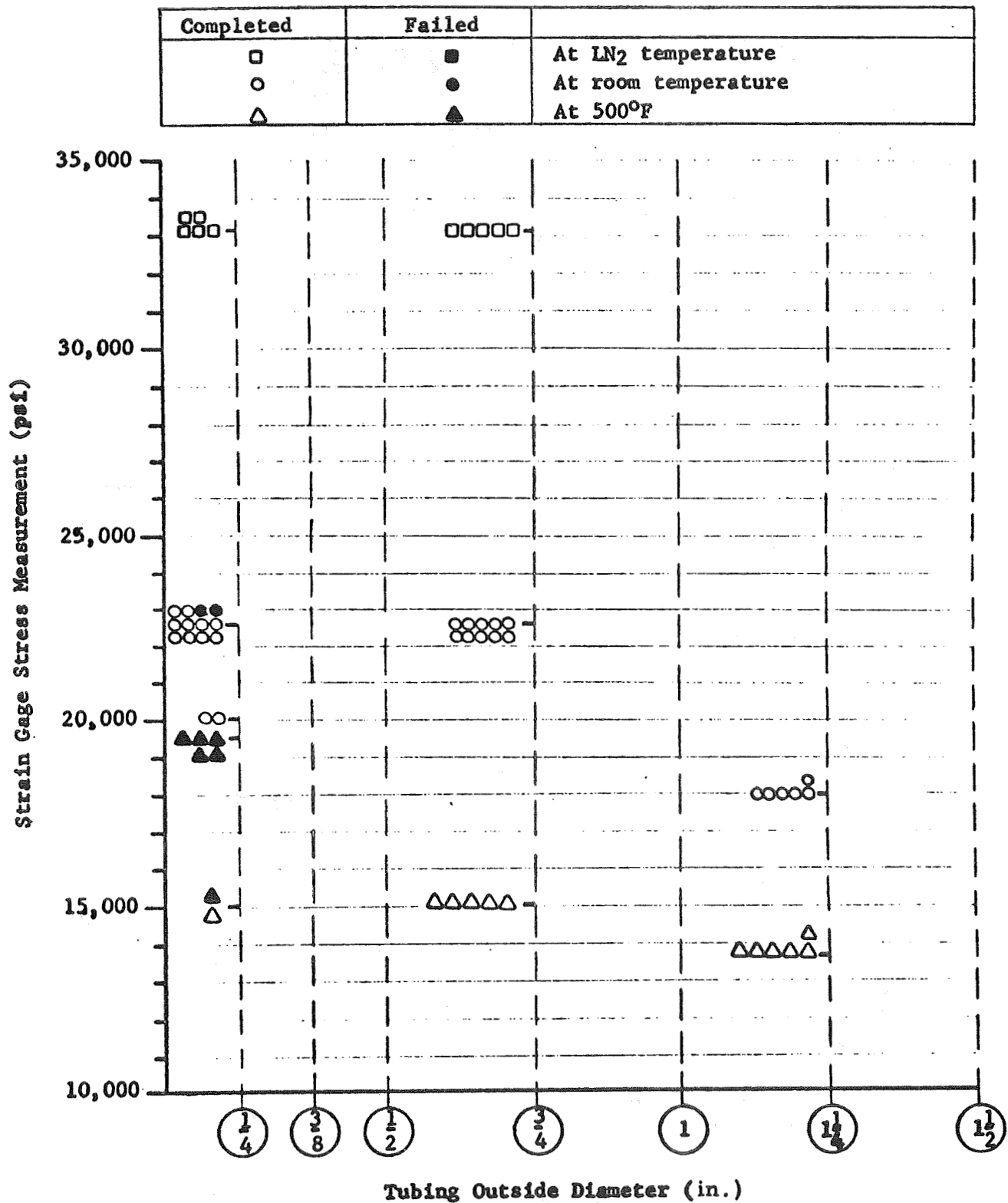


FIGURE 40. SUMMARY OF G.E. BRAZED CONNECTION VIBRATION TESTS

Experimental results of vibration test; completion of 300,000 cycles of alternating tensile and compressive stresses as shown, measured by strain gages mounted parallel to the tubing axis. Tubes pressurized to 1500 or 3000 psig.

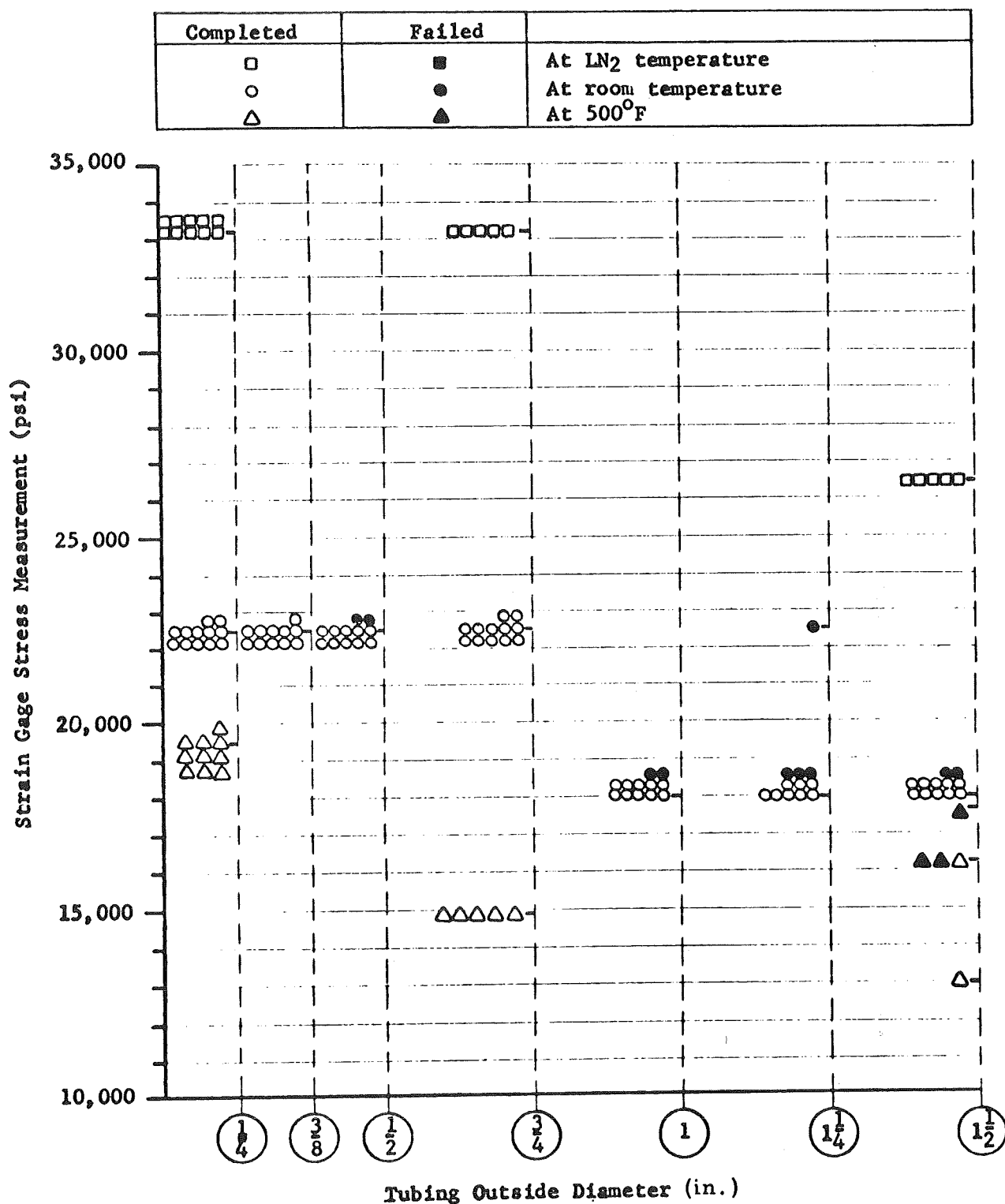


FIGURE 41. SUMMARY OF MSFC WELDED CONNECTION VIBRATION TESTS.

Experimental results of ultimate tensile tests from Tables VII and X

○ Individual connections after vibration tests.

10 Average of designated number of connections which were not subjected to vibration test.

3 Average of designated number of straight tubes (no connections).

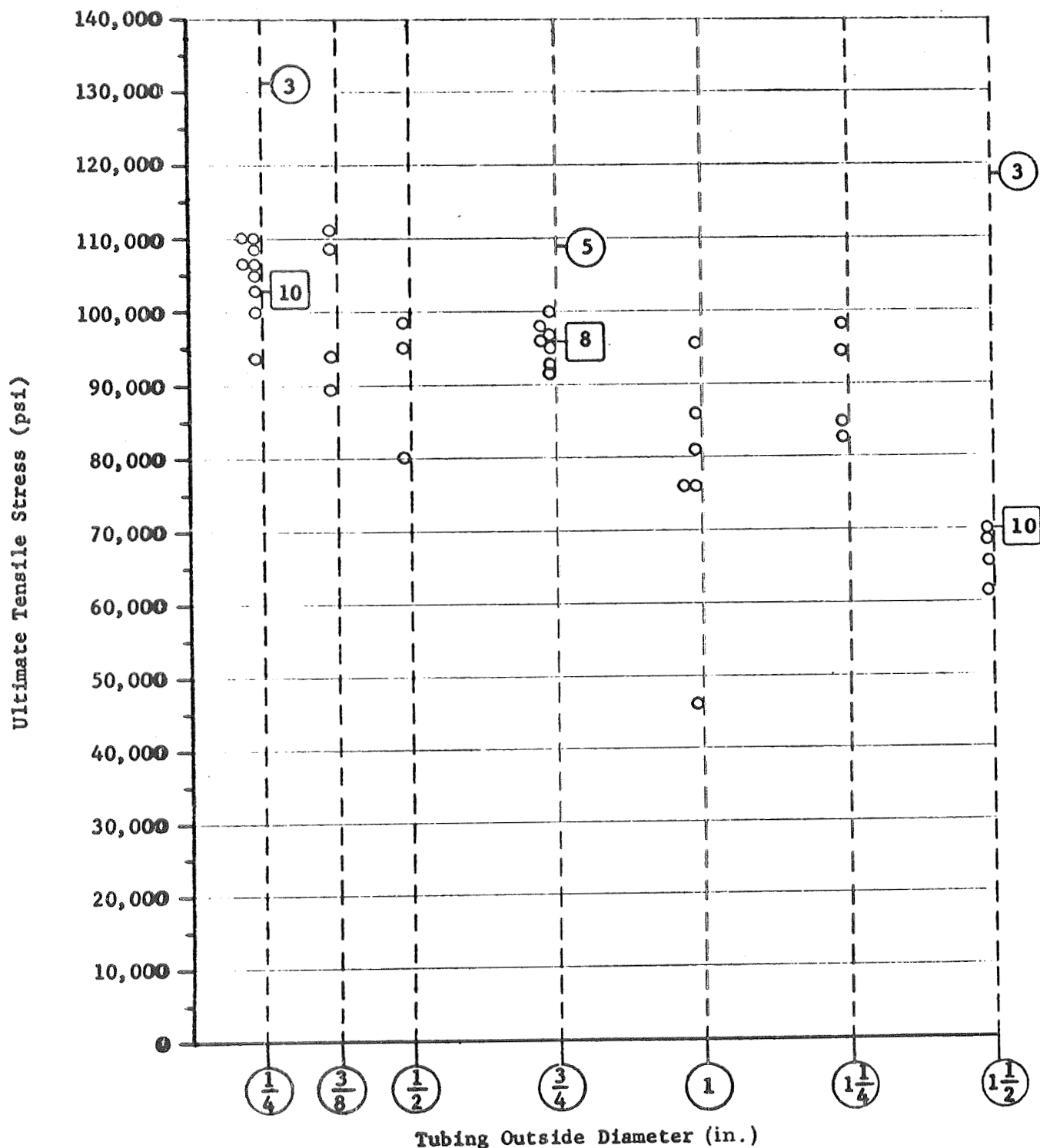


FIGURE 42 SUMMARY OF AEROQUIP BRAZED CONNECTION TENSILE TESTS

Experimental results of ultimate tensile tests from Tables VIII and X

○ Individual connections after vibration test.

□ 5 Average of designated number of connections which were not subjected to vibration test.

○ 3 Average of designated number of straight tubes (no connections).

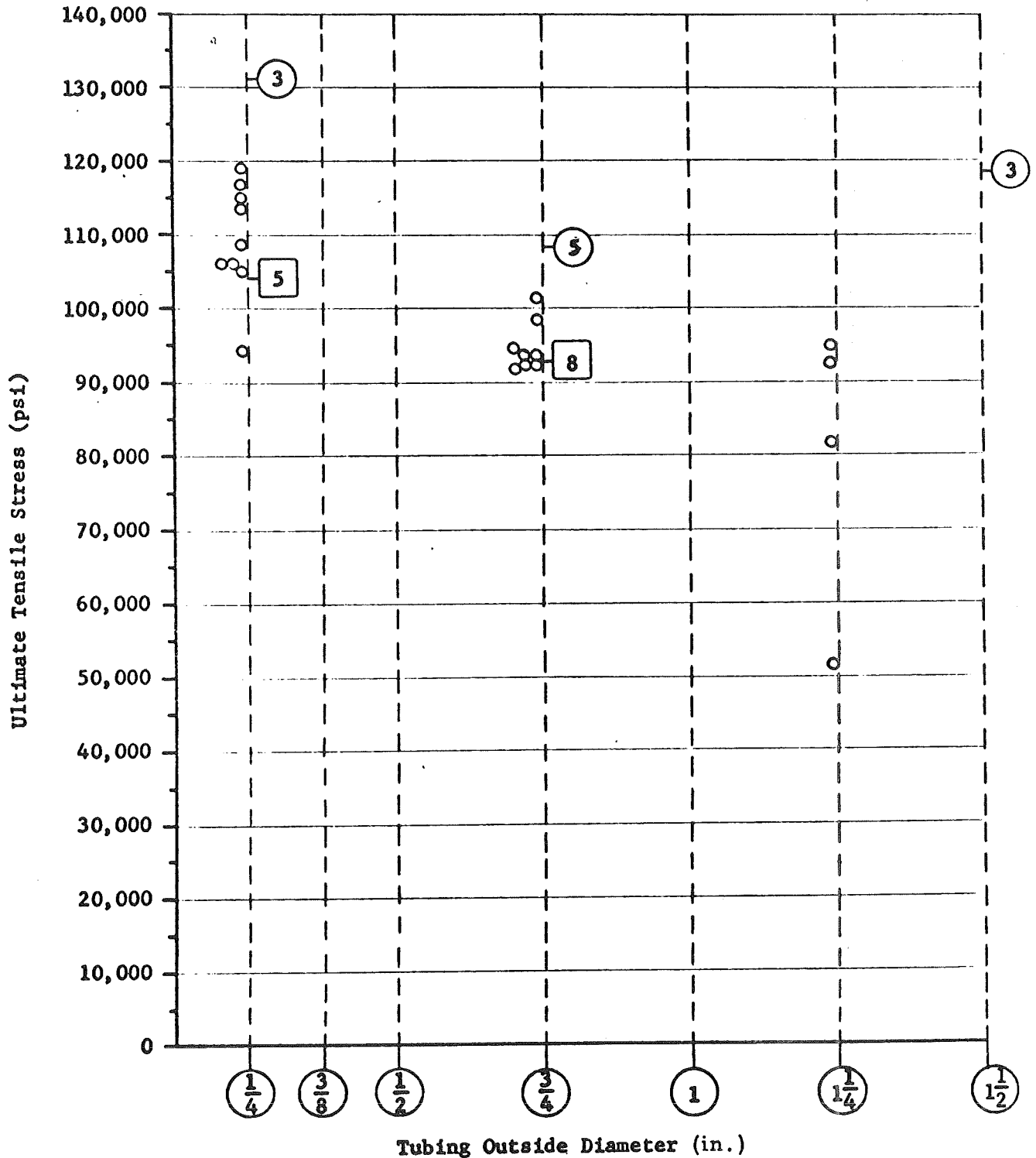


FIGURE 43 SUMMARY OF G.E. BRAZED CONNECTION TENSILE TESTS

Experimental results of ultimate tensile tests from Tables IX and X

○ Individual connections after vibration test..

9 Average of designated number of connections which are not subjected to vibration.

3 Average of designated number of straight tubes (no connections).

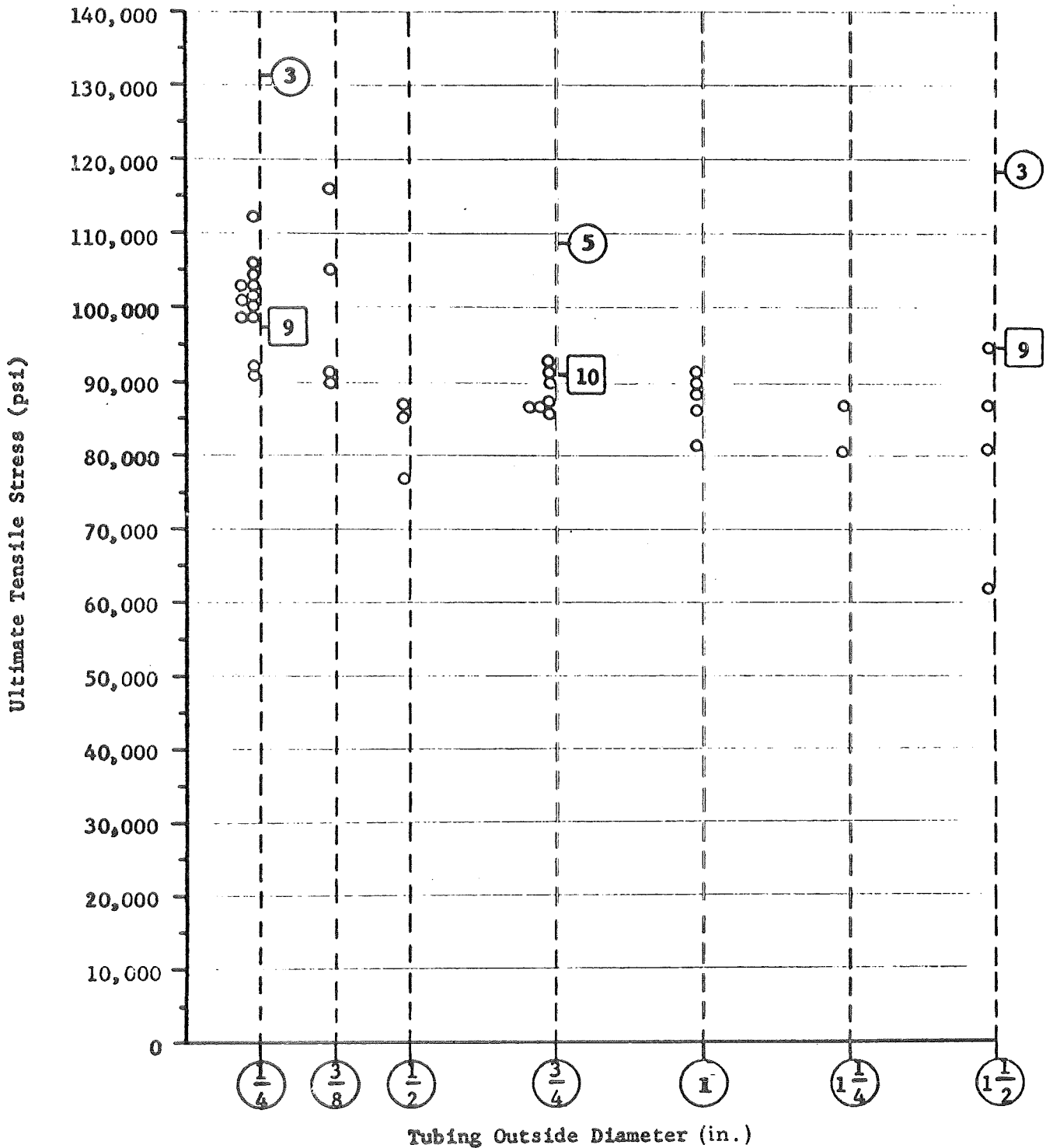


FIGURE 44 SUMMARY OF MFSC WELDED CONNECTION TENSILE TESTS

TABLE I  
Aeroquip Brazed Connections Test Program Data

| O.D. Tube (in.) | Tube Wall Designation | Test Sequence (See procedure, Figs. 1B and 2B) | Serial Number | Corrosion | Proof Pressurization | Leakage | 12 Months Storage | 12 Months Storage | Extended Pressurization | LN <sub>2</sub> Temperature Soak | +500°F Temperature Soak | Vibration, Room Temperature | Vibration, LN <sub>2</sub> Temperature | Vibration, +500°F Temperature | Impulse | Tensile | Metallographic Examination | Burst |
|-----------------|-----------------------|------------------------------------------------|---------------|-----------|----------------------|---------|-------------------|-------------------|-------------------------|----------------------------------|-------------------------|-----------------------------|----------------------------------------|-------------------------------|---------|---------|----------------------------|-------|
| 1/4             | Thin                  | "Q"                                            | QA10401       | X         |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA10402       | X         |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA10403       |           | X                    | X       |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA10404       |           | X                    | X       |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA10405       |           | X                    | X       |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA10406       |           | X                    | X       |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA10407       |           | X                    | X       |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA10408       |           | X                    | X       |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA10409       |           | X                    | X       |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA10410       |           | X                    | X       |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 | Thin                  | "Q"                                            | QA30401       | X         |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA30402       | X         |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA30403       |           | X                    | X       |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA30404       |           | X                    | X       |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA30405       |           | X                    | X       |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA30406       |           | X                    | X       |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA30407       |           | X                    | X       |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA30408       |           | X                    | X       |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA30409       |           | X                    | X       |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA30410       |           | X                    | X       |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 | Thick                 | "C"                                            | CA30401       |           | X                    | X       |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | CA30402       |           | X                    | X       |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | CA30403       |           | X                    | X       |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | CA30404       |           | X                    | X       |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | CA30405       |           | X                    | X       |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | CA30406       |           | X                    | X       |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | CA30407       |           | X                    | X       |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | CA30408       |           | X                    | X       |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | CA30409       |           | X                    | X       |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | CA30410       |           | X                    | X       |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
| 1/4             | Thick                 | "C"                                            | QA10601       |           | X                    | X       |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
| 3/8             | Thin                  |                                                | QA10602       |           | X                    | X       |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA10603       |           | X                    | X       |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA10604       |           | X                    | X       |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA10605       |           | X                    | X       |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
| 3/8             | Thin                  | "Q"                                            |               |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |

TABLE I (Continued)

## Aeroquip Brazed Connections Test Program Data

| O.D. Tube (in.) | Tube Wall Designation | Test Sequence (See procedure, Figs. 1B and 2B) | Serial Number | Corrosion | Proof Pressurization | Leakage | 12 Months Storage | 12 Months Storage | Extended Pressurization | LN <sub>2</sub> Temperature Soak | +500°F Temperature Soak | Vibration, Room Temperature | Vibration, LN <sub>2</sub> Temperature | Vibration, +500°F Temperature | Impulse | Tensile | Metallographic Examination | Burst |
|-----------------|-----------------------|------------------------------------------------|---------------|-----------|----------------------|---------|-------------------|-------------------|-------------------------|----------------------------------|-------------------------|-----------------------------|----------------------------------------|-------------------------------|---------|---------|----------------------------|-------|
| 3/8             | Thin                  | "Q"                                            | QA10606       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA10607       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA10608       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA10609       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA10610       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 | Thick                 |                                                | QA30601       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA30602       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA30603       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA30604       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA30605       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA30606       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA30607       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA30608       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA30609       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA30610       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
| 3/8             | Thick                 |                                                |               |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
| 1/2             | Thin                  |                                                | QA10801       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA10802       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA10803       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA10804       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA10805       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA10806       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA10807       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA10808       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA10809       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA10810       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
| 1/2             | Thick                 |                                                | QA30801       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA30802       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA30803       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA30804       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA30805       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA30806       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA30807       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA30808       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA30809       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA30810       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
| 1/2             | Thick                 | "Q"                                            |               |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |

TABLE I (Continued)  
Aeroquip Brazed Connections Test Program Data

| O.D. Tube (in.) | Tube Wall Designation | Test Sequence (See procedure, Figs. 1B and 2B) | Serial Number | Corrosion | Proof Pressurization | Leakage | 12 Months Storage | 12 Months Storage | Extended Pressurization | LN <sub>2</sub> Temperature Soak | +500°F Temperature Soak | Vibration, Room Temperature | Vibration, LN <sub>2</sub> Temperature | Vibration, +500°F Temperature | Impulse | Tensile | Metallographic Examination | Burst |
|-----------------|-----------------------|------------------------------------------------|---------------|-----------|----------------------|---------|-------------------|-------------------|-------------------------|----------------------------------|-------------------------|-----------------------------|----------------------------------------|-------------------------------|---------|---------|----------------------------|-------|
| 3/4             | Thin                  | "Q"                                            | QA11201       | X         |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA11202       | X         |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA11203       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA11204       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA11205       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA11206       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA11207       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA11208       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA11209       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA11210       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
| 3/4             | Thick                 | "Q"                                            | QA31201       | X         |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA31202       | X         |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA31203       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA31204       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA31205       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA31206       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA31207       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA31208       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | CA31201       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | CA31202       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
| 3/4             | Thick                 | "C"                                            | CA31203       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | CA31204       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | CA31205       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | CA31206       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | CA31207       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | CA31208       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | CA31209       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | CA31210       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA11601       | X         |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA11602       | X         |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
| 1               | Thin                  | "Q"                                            | QA11603       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA11604       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA11605       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA11606       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA11607       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA11607       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |

TABLE I (Continued)  
Aeroquip Brazed Connections Test Program Data

| O.D. Tube (in.) | Tube Wall Designation | Test Sequence (See procedure, Figs. 1B and 2B) | Serial Number | Corrosion | Proof Pressurization | Leakage | 12 Months Storage | 12 Months Storage | Extended Pressurization | LN <sub>2</sub> Temperature Soak | +500°F Temperature Soak | Vibration, Room Temperature | Vibration, LN <sub>2</sub> Temperature | Vibration, +500°F Temperature | Impulse | Tensile | Metallographic Examination | Burst |
|-----------------|-----------------------|------------------------------------------------|---------------|-----------|----------------------|---------|-------------------|-------------------|-------------------------|----------------------------------|-------------------------|-----------------------------|----------------------------------------|-------------------------------|---------|---------|----------------------------|-------|
| 1               | Thin                  | "Q"                                            | QA11608       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 | Thin                  |                                                | QA11609       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 | Thin                  |                                                | QA11610       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 | Thick                 |                                                | QA31601       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA31602       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA31603       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA31604       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA31605       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA31606       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA31607       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
| 1 1/4           | Thick                 | "Q"                                            | QA31608       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA31609       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA31610       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 | Thin                  |                                                | QA12001       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA12002       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA12003       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA12004       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA12005       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA12006       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA12007       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
| 1 1/4           | Thin                  | "Q"                                            | QA12008       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA12009       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA12010       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 | Thick                 |                                                | QA32001       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA32002       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA32003       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA32004       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA32005       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA32006       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA32007       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
| 1 1/4           |                       |                                                | QA32008       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QA32009       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 | Thick                 |                                                | QA32010       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |

TABLE I (Concluded)  
Aeroquip Brazed Connections Test Program Data

| O.D. Tube (in.) | Tube Wall Designation | Test Sequence (See procedure, Figs. 1B and 2B) | Serial Number | Corrosion | Proof Pressurization | Leakage | 12 Months Storage | 12 Months Storage | Extended Pressurization | LN <sub>2</sub> Temperature Soak | +500°F Temperature Soak | Vibration, Room Temperature | Vibration, LN <sub>2</sub> Temperature | Vibration, +500°F Temperature | Impulse | Tensile | Metallographic Examination | Burst |
|-----------------|-----------------------|------------------------------------------------|---------------|-----------|----------------------|---------|-------------------|-------------------|-------------------------|----------------------------------|-------------------------|-----------------------------|----------------------------------------|-------------------------------|---------|---------|----------------------------|-------|
| 1 1/2           | Thick                 | "Q"                                            | QA32401       | X         |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         | X                          |       |
|                 |                       |                                                | QA32402       | X         |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         | X                          |       |
|                 |                       |                                                | QA32403       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            | X     |
|                 |                       |                                                | QA32404       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            | X     |
|                 |                       |                                                | QA32405       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            | X     |
|                 |                       |                                                | QA32406       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            | X     |
|                 |                       |                                                | QA32407       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            | X     |
|                 |                       |                                                | QA32408       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            | X     |
|                 |                       |                                                | QA32409       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            | X     |
|                 |                       |                                                | QA32410       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            | X     |
|                 | Thick                 | "C"                                            | CA32401       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | CA32402       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | CA32403       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | CA32404       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | CA32405       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | CA32406       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | CA32407       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | CA32408       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | CA32409       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | CA32410       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |

TABLE II  
GE Brazed Connections Test Program Data

| O.D. Tube (in.) | Tube Wall Designation | Test Sequence (See procedure, Figs. 1B and 2B) | Serial Number | Corrosion | Proof Pressurization | Leakage | 12 Months Storage | 12 Months Storage | Extended Pressurization | LN <sub>2</sub> Temperature Soak | +500°F Temperature Soak | Vibration, Room Temperature | Vibration, LN <sub>2</sub> Temperature | Vibration, +500°F Temperature | Impulse | Tensile | Metallographic Examination | Burst |
|-----------------|-----------------------|------------------------------------------------|---------------|-----------|----------------------|---------|-------------------|-------------------|-------------------------|----------------------------------|-------------------------|-----------------------------|----------------------------------------|-------------------------------|---------|---------|----------------------------|-------|
| 1/4             | Thin                  | "Q"                                            | QG10401       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QG10402       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QG10403       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QG10404       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QG10405       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QG10406       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QG10407       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QG10408       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QG10409       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QG10410       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 | Thin                  | "Q"                                            | QG30401       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QG30402       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QG30403       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QG30404       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QG30405       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QG30406       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QG30407       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QG30408       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QG30409       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QG30410       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 | Thick                 | "C"                                            | CG30401       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | CG30402       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | CG30403       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | CG30404       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | CG30405       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | CG30406       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | CG30407       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | CG30408       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | CG30409       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | CG30410       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
| 1/4             | Thin                  | "Q"                                            | QG11201       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QG11202       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QG11203       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QG11204       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
| 3/4             | Thin                  | "Q"                                            | QG11205       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |

TABLE II (Continued)  
Test Program Data

GE Brazed Connections

| O.D. Tube (in.) | Tube Wall Designation | Test Sequence (See procedure, Figs. 1B and 2B) | Serial Number | Corrosion | Proof Pressurization | Leakage | 12 Months Storage | 12 Months Storage | Extended Pressurization | LN <sub>2</sub> Temperature Soak | +500°F Temperature Soak | Vibration, Room Temperature | Vibration, LN <sub>2</sub> Temperature | Vibration, +500°F Temperature | Impulse | Tensile | Metallographic Examination | Burst |
|-----------------|-----------------------|------------------------------------------------|---------------|-----------|----------------------|---------|-------------------|-------------------|-------------------------|----------------------------------|-------------------------|-----------------------------|----------------------------------------|-------------------------------|---------|---------|----------------------------|-------|
| 3/4             | Thin                  | "Q"                                            | QG11206       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QG11207       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QG11208       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QG11209       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QG11210       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 | Thick                 | "Q"                                            | QG31201       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QG31202       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QG31203       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QG31204       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QG31205       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
| 3/4             | Thick                 | "Q"                                            | QG31206       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QG31207       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QG31208       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | CG31201       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | CG31202       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 | Thin                  | "C"                                            | CG31203       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | CG31204       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | CG31205       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | CG31206       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | CG31207       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
| 1 1/4           | Thick                 | "Q"                                            | CG31208       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | CG31209       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | CG31210       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QG12001       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QG12002       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 | Thin                  | "Q"                                            | QG12003       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QG12004       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QG12005       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QG12006       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QG12007       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
| 1 1/4           | Thin                  | "Q"                                            | QG12008       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QG12009       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QG12010       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |

## GE Braze Connections

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TABLE III  
MSFC Welded Connections Test Program Data

| O.D. Tube (in.) | Tube Wall Designation | Test Sequence (See procedure, Figs. 1B and 2B) | Serial Number | Corrosion | Proof Pressurization | Leakage | 12 Months Storage | 12 Months Storage | Extended Pressurization | LN <sub>2</sub> Temperature Soak | +500°F Temperature Soak | Vibration, Room Temperature | Vibration, LN <sub>2</sub> Temperature | Vibration, +500°F Temperature | Impulse | Tensile | Metallographic Examination | Burst |
|-----------------|-----------------------|------------------------------------------------|---------------|-----------|----------------------|---------|-------------------|-------------------|-------------------------|----------------------------------|-------------------------|-----------------------------|----------------------------------------|-------------------------------|---------|---------|----------------------------|-------|
| 1/4             | Thin                  | "Q"                                            | QS10401       | X         |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QS10402       | X         |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QS10403       |           | X                    | X       | X                 | X                 |                         |                                  |                         |                             |                                        |                               |         |         |                            | X     |
|                 |                       |                                                | QS10404       |           | X                    | X       | X                 | X                 |                         |                                  |                         |                             |                                        |                               |         |         |                            | X     |
|                 |                       |                                                | QS10405       |           | X                    | X       | X                 | X                 |                         |                                  |                         |                             |                                        |                               |         |         |                            | X     |
|                 |                       |                                                | QS10406       |           | X                    | X       | X                 | X                 |                         |                                  |                         |                             |                                        |                               |         |         |                            | X     |
|                 |                       |                                                | QS10407       |           | X                    | X       | X                 | X                 |                         |                                  |                         |                             |                                        |                               |         |         |                            | X     |
|                 |                       |                                                | QS10408       |           | X                    | X       | X                 | X                 |                         |                                  |                         |                             |                                        |                               |         |         |                            | X     |
|                 |                       |                                                | QS10409       |           | X                    | X       | X                 | X                 |                         |                                  |                         |                             |                                        |                               |         |         |                            | X     |
|                 |                       |                                                | QS10410       |           | X                    | X       | X                 | X                 |                         |                                  |                         |                             |                                        |                               |         |         |                            | X     |
|                 | Thin                  | "Q"                                            | QS30401       | X         |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QS30402       | X         |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QS30403       |           | X                    | X       | X                 | X                 |                         |                                  |                         |                             |                                        |                               |         |         |                            | X     |
|                 |                       |                                                | QS30404       |           | X                    | X       | X                 | X                 |                         |                                  |                         |                             |                                        |                               |         |         |                            | X     |
|                 |                       |                                                | QS30405       |           | X                    | X       | X                 | X                 |                         |                                  |                         |                             |                                        |                               |         |         |                            | X     |
|                 |                       |                                                | QS30406       |           | X                    | X       | X                 | X                 |                         |                                  |                         |                             |                                        |                               |         |         |                            | X     |
|                 |                       |                                                | QS30407       |           | X                    | X       | X                 | X                 |                         |                                  |                         |                             |                                        |                               |         |         |                            | X     |
|                 |                       |                                                | QS30408       |           | X                    | X       | X                 | X                 |                         |                                  |                         |                             |                                        |                               |         |         |                            | X     |
|                 |                       |                                                | QS30409       |           | X                    | X       | X                 | X                 |                         |                                  |                         |                             |                                        |                               |         |         |                            | X     |
|                 |                       |                                                | QS30410       |           | X                    | X       | X                 | X                 |                         |                                  |                         |                             |                                        |                               |         |         |                            | X     |
|                 | Thick                 | "C"                                            | CS30401       | X         |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | CS30402       | X         |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | CS30403       |           | X                    | X       | X                 | X                 |                         |                                  |                         |                             |                                        |                               |         |         |                            | X     |
|                 |                       |                                                | CS30404       |           | X                    | X       | X                 | X                 |                         |                                  |                         |                             |                                        |                               |         |         |                            | X     |
|                 |                       |                                                | CS30405       |           | X                    | X       | X                 | X                 |                         |                                  |                         |                             |                                        |                               |         |         |                            | X     |
|                 |                       |                                                | CS30406       |           | X                    | X       | X                 | X                 |                         |                                  |                         |                             |                                        |                               |         |         |                            | X     |
|                 |                       |                                                | CS30407       |           | X                    | X       | X                 | X                 |                         |                                  |                         |                             |                                        |                               |         |         |                            | X     |
|                 |                       |                                                | CS30408       |           | X                    | X       | X                 | X                 |                         |                                  |                         |                             |                                        |                               |         |         |                            | X     |
|                 |                       |                                                | CS30409       |           | X                    | X       | X                 | X                 |                         |                                  |                         |                             |                                        |                               |         |         |                            | X     |
|                 |                       |                                                | CS30410       |           | X                    | X       | X                 | X                 |                         |                                  |                         |                             |                                        |                               |         |         |                            | X     |
|                 |                       | "C"                                            | CS30411       |           | X                    | X       | X                 | X                 |                         |                                  |                         |                             |                                        |                               |         |         |                            | X     |
|                 |                       |                                                | CS30412       |           | X                    | X       | X                 | X                 |                         |                                  |                         |                             |                                        |                               |         |         |                            | X     |
|                 |                       |                                                | CS30413       |           | X                    | X       | X                 | X                 |                         |                                  |                         |                             |                                        |                               |         |         |                            | X     |
|                 |                       |                                                | CS30414       |           | X                    | X       | X                 | X                 |                         |                                  |                         |                             |                                        |                               |         |         |                            | X     |
|                 |                       |                                                | CS30415       |           | X                    | X       | X                 | X                 |                         |                                  |                         |                             |                                        |                               |         |         |                            | X     |

TABLE III (Continued)

## MSFC Welded Connections Test Program Data

| O.D. Tube (in.)      | Tube Wall Designation    | Test Sequence (See procedure, Figs. 1B and 2B) | Serial Number | Corrosion | Proof Pressurization | Leakage | 12 Months Storage | 12 Months Storage | Extended Pressurization | LN <sub>2</sub> Temperature Soak | +500°F Temperature Soak | Vibration, Room Temperature | Vibration, LN <sub>2</sub> Temperature | Vibration, +500°F Temperature | Impulse | Tensile | Metallographic Examination | Burst |
|----------------------|--------------------------|------------------------------------------------|---------------|-----------|----------------------|---------|-------------------|-------------------|-------------------------|----------------------------------|-------------------------|-----------------------------|----------------------------------------|-------------------------------|---------|---------|----------------------------|-------|
| 1/4<br>↑<br>↓<br>1/4 | Thick<br>↑<br>↓<br>Thick | "C"<br>↑<br>↓<br>"C"                           | CS30416       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        | X                             |         |         |                            | X     |
|                      |                          |                                                | CS30417       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        | X                             |         |         |                            | X     |
|                      |                          |                                                | CS30418       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        | X                             |         |         |                            | X     |
|                      |                          |                                                | CS30419       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        | X                             |         |         |                            | X     |
|                      |                          |                                                | CS30420       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        | X                             |         |         |                            | X     |
| 3/8<br>↑<br>↓<br>3/8 | Thin<br>↑<br>↓<br>Thin   | "Q"<br>↑<br>↓<br>"Q"                           | QS10601       | X         |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            | X     |
|                      |                          |                                                | QS10602       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            | X     |
|                      |                          |                                                | QS10603       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            | X     |
|                      |                          |                                                | QS10604       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            | X     |
|                      |                          |                                                | QS10605       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            | X     |
|                      |                          |                                                | QS10606       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            | X     |
|                      |                          |                                                | QS10607       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            | X     |
|                      |                          |                                                | QS10608       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            | X     |
|                      |                          |                                                | QS10609       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            | X     |
|                      |                          |                                                | QS10610       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            | X     |
| 3/8<br>↑<br>↓<br>3/8 | Thick<br>↑<br>↓<br>Thick |                                                | QS30601       | X         |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            | X     |
|                      |                          |                                                | QS30602       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            | X     |
|                      |                          |                                                | QS30603       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            | X     |
|                      |                          |                                                | QS30604       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            | X     |
|                      |                          |                                                | QS30605       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            | X     |
|                      |                          |                                                | QS30606       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            | X     |
|                      |                          |                                                | QS30607       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            | X     |
|                      |                          |                                                | QS30608       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            | X     |
|                      |                          |                                                | QS30609       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            | X     |
|                      |                          |                                                | QS30610       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            | X     |
| 1/2<br>↑<br>↓<br>1/2 | Thin<br>↑<br>↓<br>Thin   |                                                | QS10801       | X         |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            | X     |
|                      |                          |                                                | QS10802       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            | X     |
|                      |                          |                                                | QS10803       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            | X     |
|                      |                          |                                                | QS10804       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            | X     |
|                      |                          |                                                | QS10805       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            | X     |
|                      |                          |                                                | QS10806       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            | X     |
|                      |                          |                                                | QS10807       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            | X     |
|                      |                          |                                                | QS10808       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            | X     |
|                      |                          |                                                | QS10809       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            | X     |
|                      |                          |                                                | QS10810       |           | X                    |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            | X     |

TABLE III (Continued)  
MSFC Welded Connections Test Program Data

| O.D. Tube (in.) | Tube Wall Designation | Test Sequence (See procedure, Figs. 1B and 2B) | Serial Number | Corrosion | Proof Pressurization | Leakage | 12 Months Storage | 12 Months Storage | Extended Pressurization | LN <sub>2</sub> Temperature Soak | +500°F Temperature Soak | Vibration, Room Temperature | Vibration, LN <sub>2</sub> Temperature | Vibration, +500°F Temperature | Impulse | Tensile | Metallographic Examination | Burst |
|-----------------|-----------------------|------------------------------------------------|---------------|-----------|----------------------|---------|-------------------|-------------------|-------------------------|----------------------------------|-------------------------|-----------------------------|----------------------------------------|-------------------------------|---------|---------|----------------------------|-------|
| 1/2             | Thick                 | "Q"                                            | QS30801       | ✗         |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QS30802       | ✗         |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QS30803       |           | ✗                    | ✗       |                   | ✗                 |                         |                                  |                         |                             |                                        |                               |         |         |                            | ✗     |
|                 |                       |                                                | QS30804       |           | ✗                    | ✗       |                   | ✗                 |                         |                                  |                         |                             |                                        |                               |         |         |                            | ✗     |
|                 |                       |                                                | QS30805       |           | ✗                    | ✗       |                   | ✗                 |                         |                                  |                         |                             |                                        |                               |         | ✗       | ✗                          |       |
|                 |                       |                                                | QS30806       |           | ✗                    | ✗       |                   | ✗                 |                         |                                  |                         |                             |                                        |                               |         | ✗       | ✗                          |       |
|                 |                       |                                                | QS30807       |           | ✗                    | ✗       |                   | ✗                 |                         |                                  |                         |                             |                                        |                               |         | ✗       | ✗                          |       |
|                 |                       |                                                | QS30808       |           | ✗                    | ✗       |                   | ✗                 |                         |                                  |                         |                             |                                        |                               |         | ✗       | ✗                          |       |
|                 |                       |                                                | QS30809       |           | ✗                    | ✗       |                   | ✗                 |                         |                                  |                         |                             |                                        |                               |         | ✗       | ✗                          |       |
|                 |                       |                                                | QS30810       |           | ✗                    | ✗       |                   | ✗                 |                         |                                  |                         |                             |                                        |                               |         | ✗       | ✗                          |       |
| 1/2             | Thick                 |                                                | QS11201       | ✗         |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QS11202       | ✗         |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QS11203       |           | ✗                    | ✗       |                   | ✗                 |                         |                                  |                         |                             |                                        |                               |         |         |                            | ✗     |
|                 |                       |                                                | QS11204       |           | ✗                    | ✗       |                   | ✗                 |                         |                                  |                         |                             |                                        |                               |         |         |                            | ✗     |
|                 |                       |                                                | QS11205       |           | ✗                    | ✗       |                   | ✗                 |                         |                                  |                         |                             |                                        |                               |         | ✗       | ✗                          |       |
|                 |                       |                                                | QS11206       |           | ✗                    | ✗       |                   | ✗                 |                         |                                  |                         |                             |                                        |                               |         | ✗       | ✗                          |       |
|                 |                       |                                                | QS11207       |           | ✗                    | ✗       |                   | ✗                 |                         |                                  |                         |                             |                                        |                               |         | ✗       | ✗                          |       |
|                 |                       |                                                | QS11208       |           | ✗                    | ✗       |                   | ✗                 |                         |                                  |                         |                             |                                        |                               |         | ✗       | ✗                          |       |
|                 |                       |                                                | QS11209       |           | ✗                    | ✗       |                   | ✗                 |                         |                                  |                         |                             |                                        |                               |         | ✗       | ✗                          |       |
|                 |                       |                                                | QS11210       |           | ✗                    | ✗       |                   | ✗                 |                         |                                  |                         |                             |                                        |                               |         | ✗       | ✗                          |       |
| 3/4             | Thin                  |                                                | QS11201       | ✗         |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QS11202       | ✗         |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QS11203       |           | ✗                    | ✗       |                   | ✗                 |                         |                                  |                         |                             |                                        |                               |         |         |                            | ✗     |
|                 |                       |                                                | QS11204       |           | ✗                    | ✗       |                   | ✗                 |                         |                                  |                         |                             |                                        |                               |         |         |                            | ✗     |
|                 |                       |                                                | QS11205       |           | ✗                    | ✗       |                   | ✗                 |                         |                                  |                         |                             |                                        |                               |         | ✗       | ✗                          |       |
|                 |                       |                                                | QS11206       |           | ✗                    | ✗       |                   | ✗                 |                         |                                  |                         |                             |                                        |                               |         | ✗       | ✗                          |       |
|                 |                       |                                                | QS11207       |           | ✗                    | ✗       |                   | ✗                 |                         |                                  |                         |                             |                                        |                               |         | ✗       | ✗                          |       |
|                 |                       |                                                | QS11208       |           | ✗                    | ✗       |                   | ✗                 |                         |                                  |                         |                             |                                        |                               |         | ✗       | ✗                          |       |
|                 |                       |                                                | QS11209       |           | ✗                    | ✗       |                   | ✗                 |                         |                                  |                         |                             |                                        |                               |         | ✗       | ✗                          |       |
|                 |                       |                                                | QS11210       |           | ✗                    | ✗       |                   | ✗                 |                         |                                  |                         |                             |                                        |                               |         | ✗       | ✗                          |       |
| 3/4             | Thick                 | "Q"                                            | QS31201       | ✗         |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QS31202       | ✗         |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QS31203       |           | ✗                    | ✗       |                   | ✗                 |                         |                                  |                         |                             |                                        |                               |         |         |                            | ✗     |
|                 |                       |                                                | QS31204       |           | ✗                    | ✗       |                   | ✗                 |                         |                                  |                         |                             |                                        |                               |         |         |                            | ✗     |
|                 |                       |                                                | QS31205       |           | ✗                    | ✗       |                   | ✗                 |                         |                                  |                         |                             |                                        |                               |         |         |                            | ✗     |
|                 |                       |                                                | QS31206       |           | ✗                    | ✗       |                   | ✗                 |                         |                                  |                         |                             |                                        |                               |         | ✗       | ✗                          |       |
|                 |                       |                                                | QS31207       |           | ✗                    | ✗       |                   | ✗                 |                         |                                  |                         |                             |                                        |                               |         | ✗       | ✗                          |       |
|                 |                       |                                                | QS31208       |           | ✗                    | ✗       |                   | ✗                 |                         |                                  |                         |                             |                                        |                               |         | ✗       | ✗                          |       |
|                 |                       |                                                | QS31209       |           | ✗                    | ✗       |                   | ✗                 |                         |                                  |                         |                             |                                        |                               |         | ✗       | ✗                          |       |
|                 |                       |                                                | QS31210       |           | ✗                    | ✗       |                   | ✗                 |                         |                                  |                         |                             |                                        |                               |         | ✗       | ✗                          |       |
| 3/4             | Thick                 | "C"                                            | CS31201       | ✗         |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | CS31202       | ✗         |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | CS31203       |           | ✗                    | ✗       |                   | ✗                 |                         |                                  |                         |                             |                                        |                               |         |         |                            | ✗     |
|                 |                       |                                                | CS31204       |           | ✗                    | ✗       |                   | ✗                 |                         |                                  |                         |                             |                                        |                               |         |         |                            | ✗     |
|                 |                       |                                                | CS31205       |           | ✗                    | ✗       |                   | ✗                 |                         |                                  |                         |                             |                                        |                               |         |         |                            | ✗     |
| 3/4             | Thick                 | "G"                                            | CS31201       | ✗         |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | CS31202       | ✗         |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | CS31203       |           | ✗                    | ✗       |                   | ✗                 |                         |                                  |                         |                             |                                        |                               |         |         |                            | ✗     |
|                 |                       |                                                | CS31204       |           | ✗                    | ✗       |                   | ✗                 |                         |                                  |                         |                             |                                        |                               |         |         |                            | ✗     |
|                 |                       |                                                | CS31205       |           | ✗                    | ✗       |                   | ✗                 |                         |                                  |                         |                             |                                        |                               |         |         |                            | ✗     |

TABLE III (Continued)  
MSFC Welded Connections Test Program Data

| O.D. Tube (in.) | Tube Wall Designation | Test Sequence (See procedure, Figs. 1B and 2B) | Serial Number | Corrosion | Proof Pressurization | Leakage | 12 Months Storage | 12 Months Storage | Extended Pressurization | LN <sub>2</sub> Temperature Soak | +500°F Temperature Soak | Vibration, Room Temperature | Vibration, LN <sub>2</sub> Temperature | Vibration, +500°F Temperature | Impulse | Tensile | Metallographic Examination | Burst |
|-----------------|-----------------------|------------------------------------------------|---------------|-----------|----------------------|---------|-------------------|-------------------|-------------------------|----------------------------------|-------------------------|-----------------------------|----------------------------------------|-------------------------------|---------|---------|----------------------------|-------|
| 3/4             | Thick                 | "C"                                            | CS31206       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | CS31207       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | CS31208       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | CS31209       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
| 3/4             | Thick                 | "C"                                            | CS31210       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
| 1               | Thin                  | "Q"                                            | QS11601       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QS11602       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QS11603       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QS11604       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QS11605       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QS11606       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QS11607       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QS11608       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QS11609       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 | Thin                  |                                                | QS11610       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 | Thick                 |                                                | QS31601       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QS31602       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QS31603       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QS31604       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QS31605       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QS31606       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QS31607       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QS31608       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QS31609       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
| 1               | Thick                 |                                                | QS31610       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
| 1 1/4           | Thin                  |                                                | QS12001       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QS12002       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QS12003       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QS12004       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QS12005       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QS12006       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QS12007       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QS12008       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QS12009       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
| 1 1/4           | Thin                  | "Q"                                            | QS12010       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |

TABLE III (Continued)

## MSFC Welded Connections Test Program Data

| O.D. Tube (in.) | Tube Wall Designation | Test Sequence (See procedure, Figs. 1B and 2B) | Serial Number | Corrosion | Proof Pressurization | Leakage | 12 Months Storage | 12 Months Storage | Extended Pressurization | LN <sub>2</sub> Temperature Soak | +500°F Temperature Soak | Vibration, Room Temperature | Vibration, LN <sub>2</sub> Temperature | Vibration, +500°F Temperature | Impulse | Tensile | Metallographic Examination | Burst |
|-----------------|-----------------------|------------------------------------------------|---------------|-----------|----------------------|---------|-------------------|-------------------|-------------------------|----------------------------------|-------------------------|-----------------------------|----------------------------------------|-------------------------------|---------|---------|----------------------------|-------|
| 1 1/4           | Thick                 | "Q"                                            | QS32001       | X         |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QS32002       | X         |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QS32003       |           | X                    | X       | X                 | X                 |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QS32004       |           | X                    | X       | X                 | X                 |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QS32005       |           | X                    | X       | X                 | X                 |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QS32006       |           | X                    | X       | X                 | X                 |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QS32007       |           | X                    | X       | X                 | X                 |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QS32008       |           | X                    | X       | X                 | X                 |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QS32009       |           | X                    | X       | X                 | X                 |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QS32010       |           | X                    | X       | X                 | X                 |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
| 1 1/4           | Thick                 |                                                | QS12401       | X         |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
| 1 1/2           | Thin                  |                                                | QS12402       | X         |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QS12403       |           | X                    | X       | X                 | X                 |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QS12404       |           | X                    | X       | X                 | X                 |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QS12405       |           | X                    | X       | X                 | X                 |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QS12406       |           | X                    | X       | X                 | X                 |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QS12407       |           | X                    | X       | X                 | X                 |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QS12408       |           | X                    | X       | X                 | X                 |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QS12409       |           | X                    | X       | X                 | X                 |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QS12410       |           | X                    | X       | X                 | X                 |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 | Thin                  |                                                | QS32401       | X         |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 | Thick                 |                                                | QS32402       | X         |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QS32403       |           | X                    | X       | X                 | X                 |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QS32404       |           | X                    | X       | X                 | X                 |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QS32405       |           | X                    | X       | X                 | X                 |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QS32406       |           | X                    | X       | X                 | X                 |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QS32407       |           | X                    | X       | X                 | X                 |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QS32408       |           | X                    | X       | X                 | X                 |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QS32409       |           | X                    | X       | X                 | X                 |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | QS32410       |           | X                    | X       | X                 | X                 |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       | "Q"                                            | CS32401       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
| 1 1/2           | Thick                 | "C"                                            | CS32402       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | CS32403       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | CS32404       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | CS32405       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |
|                 |                       |                                                | CS32405       |           |                      |         |                   |                   |                         |                                  |                         |                             |                                        |                               |         |         |                            |       |

## MSFC Welded Connections

[illegible]

# Vibration Test Data

Tables IV through VI

Requirement: Completion of 300,000 cycles of vibration while subjected to the internal operating pressure and temperature listed. The stress level listed is the stress in the outer surface fibers of the tubing due to vibration, but not including stress due to internal pressurization, as measured by the two strain gages. The strain gages were mounted parallel to the tubing axis, as closely as practical to each end of the fitting. The stress registered by both gages was "balanced" by moving the lead weights which were clamped around the tubing.

TABLE IV  
VIBRATION TEST DATA

| Aeroquip Brazed       |                  | Connections                     |               | Total<br>No. of<br>Cycles | Stress<br>Level<br>(psi) | Remarks                       |
|-----------------------|------------------|---------------------------------|---------------|---------------------------|--------------------------|-------------------------------|
|                       |                  | Operating<br>Pressure<br>(psig) | Test<br>Temp. |                           |                          |                               |
| O.D.<br>Tube<br>(in.) | Serial<br>Number | 1500                            | 3000          |                           |                          |                               |
| 1/4                   | QA10403          | x                               | +500°F        | 300,000                   | 12,000                   |                               |
| ↑                     | QA10404          | x                               | +500°F        | ▲                         | 12,000                   |                               |
|                       | QA10405          | x                               | Room          |                           | 22,500                   |                               |
|                       | QA10406          | x                               | ▲             |                           | ▲                        |                               |
|                       | QA10407          | x                               |               |                           |                          |                               |
|                       | QA10408          | x                               |               |                           |                          |                               |
|                       | QA10409          | x                               | ▼             |                           | ▼                        |                               |
|                       | QA10410          | x                               | Room          | ▼                         | 22,500                   |                               |
|                       | QA30403          |                                 | +500°F        | 300,000                   | 12,000                   |                               |
|                       | QA30404          | x                               | +500°F        | 98,000                    | 12,000                   | Failed, could not be balanced |
|                       | QA30405          | x                               | Room          | 300,000                   | 22,500                   |                               |
|                       | QA30406          | x                               | ▲             | ▲                         | ▲                        |                               |
|                       | QA30407          | x                               |               |                           |                          |                               |
|                       | QA30408          | x                               |               |                           |                          |                               |
|                       | QA30409          | x                               | ▼             |                           | ▼                        |                               |
|                       | QA30410          | x                               | Room          |                           | 22,500                   |                               |
|                       | CA30401          | x                               | LN2           |                           | 33,200                   |                               |
|                       | CA30402          | x                               | LN2           | ▼                         | 33,200                   |                               |
| 1/4                   | CA30403          | x                               | LN2           | 300,000                   | 33,200                   |                               |

TABLE IV (Continued)  
VIBRATION TEST DATA

| Aeroquip Brazed Connections |               | Operating Pressure (psig) |      | Test Temp. | Stress Level (psi) | Total No. of Cycles | Remarks                                                                                                                                                                                                   |
|-----------------------------|---------------|---------------------------|------|------------|--------------------|---------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| O.D. Tube (in.)             | Serial Number | 1500                      | 3000 |            |                    |                     |                                                                                                                                                                                                           |
| 1/4                         | CA30404       |                           | x    | LN2        | 33,200             | 300,000             |                                                                                                                                                                                                           |
|                             | CA30405       |                           | x    | LN2        | 33,200             | 300,000             |                                                                                                                                                                                                           |
|                             | CA30406       |                           | x    | +500°F     | 19,500             | 18,000              |                                                                                                                                                                                                           |
|                             | CA30407       |                           | x    | ↑          | ↑                  | 68,600              | Failed - five specimens at the number of cycles indicated. The stress level was considered too high and was lowered to 12,900 psi, resulting in a reduced rate of failures.<br>CA 30406 shown in Fig. 25. |
|                             | CA30408       |                           | x    | ↑          | ↑                  | 133,800             |                                                                                                                                                                                                           |
|                             | CA30409       |                           | x    | ↓          | ↓                  | 25,500              |                                                                                                                                                                                                           |
| 1/4                         | CA30410       |                           | x    | +500°F     | 19,500             | 117,800             |                                                                                                                                                                                                           |
| 3/8                         | QA10605       | x                         |      | Room       | 22,500             | 300,000             |                                                                                                                                                                                                           |
|                             | QA10606       | x                         |      | ↑          | ↑                  | ↑                   |                                                                                                                                                                                                           |
|                             | QA10607       | x                         |      |            |                    |                     |                                                                                                                                                                                                           |
|                             | QA10608       | x                         |      |            |                    |                     |                                                                                                                                                                                                           |
|                             | QA10609       | x                         |      |            |                    |                     |                                                                                                                                                                                                           |
|                             | QA30605       |                           | x    |            |                    |                     |                                                                                                                                                                                                           |
|                             | QA30606       |                           | x    |            |                    |                     |                                                                                                                                                                                                           |
|                             | QA30607       |                           | x    |            |                    |                     |                                                                                                                                                                                                           |
|                             | QA30608       |                           | x    |            |                    |                     |                                                                                                                                                                                                           |
|                             | QA30609       |                           | x    |            |                    |                     |                                                                                                                                                                                                           |
| 3/8                         | QA30610       |                           | x    |            |                    |                     |                                                                                                                                                                                                           |
| 1/2                         | QA10805       | x                         |      |            |                    |                     |                                                                                                                                                                                                           |
|                             | QA10806       | x                         |      |            |                    | 300,000             |                                                                                                                                                                                                           |
|                             | QA10807       | x                         |      |            |                    | 273,000             | Failed.                                                                                                                                                                                                   |
|                             | QA10808       | x                         |      |            |                    | 300,000             |                                                                                                                                                                                                           |
|                             | QA10809       | x                         |      |            |                    | 207,000             | Failed                                                                                                                                                                                                    |
|                             | QA10810       | x                         |      |            |                    | 46,000              | Failed                                                                                                                                                                                                    |
|                             | QA30805       |                           | x    |            |                    | 269,000             | Failed                                                                                                                                                                                                    |
|                             | QA30806       |                           | x    |            |                    | 300,000             |                                                                                                                                                                                                           |
|                             | QA30807       |                           | x    |            |                    | ↑                   |                                                                                                                                                                                                           |
|                             | QA30808       |                           | x    |            |                    | ↑                   |                                                                                                                                                                                                           |
| 1/2                         | QA30809       |                           | x    | Room       | 22,500             | 300,000             |                                                                                                                                                                                                           |

TABLE IV (Continued)  
VIBRATION TEST DATA

| Aeroquip Brazed Connections |                  |                                 |      |                       |                          |                           |         |  |  |
|-----------------------------|------------------|---------------------------------|------|-----------------------|--------------------------|---------------------------|---------|--|--|
| O.D.<br>Tube<br>(in.)       | Serial<br>Number | Operating<br>Pressure<br>(psig) |      | Test<br>Temp.<br>(°F) | Stress<br>Level<br>(psi) | Total<br>No. of<br>Cycles | Remarks |  |  |
|                             |                  | 1500                            | 3000 |                       |                          |                           |         |  |  |
| 1/2                         | QA30810          |                                 | x    | Room                  | 22,500                   | 300,000                   |         |  |  |
| 3/4                         | QA11205          | x                               |      | Room                  | 22,500                   | 300,000                   |         |  |  |
|                             | QA11206          | x                               |      |                       |                          |                           |         |  |  |
|                             | QA11207          | x                               |      |                       |                          |                           |         |  |  |
|                             | QA11208          | x                               |      |                       |                          |                           |         |  |  |
|                             | QA11209          | x                               |      |                       |                          |                           |         |  |  |
|                             | QA11210          | x                               |      |                       |                          |                           |         |  |  |
|                             | QA31205          |                                 | x    |                       |                          |                           |         |  |  |
|                             | QA31206          |                                 | x    |                       |                          |                           |         |  |  |
|                             | QA31207          |                                 | x    |                       |                          |                           |         |  |  |
|                             | QA31208          |                                 | x    | Room                  | 22,500                   | 300,000                   |         |  |  |
|                             | CA31201          | x                               |      | LN2                   | 33,200                   | 300,000                   |         |  |  |
|                             | CA31202          | x                               |      | Room                  | 22,500                   | 300,000                   |         |  |  |
|                             | CA31203          | x                               |      | LN2                   | 33,200                   | 300,000                   |         |  |  |
|                             | CA31204          | x                               |      | Room                  | 22,500                   | 300,000                   |         |  |  |
|                             | CA31205          | x                               |      | LN2                   | 33,200                   | 300,000                   |         |  |  |
|                             | CA31206          | x                               |      | +500°F                | 15,000                   | 300,000                   |         |  |  |
|                             | CA31207          | x                               |      | Room                  | 18,000                   | 300,000                   |         |  |  |
|                             | CA31208          | x                               |      | Room                  | 18,000                   | 300,000                   |         |  |  |
|                             | CA31209          | x                               |      | Room                  | 18,000                   | 300,000                   |         |  |  |
| 3/4                         | CA31210          | x                               |      | +500°F                | 15,000                   | 300,000                   |         |  |  |
| 1                           | QA11605          | x                               |      | Room                  | 18,000                   | 300,000                   |         |  |  |
|                             | QA11606          | x                               |      | Room                  | 18,000                   | 300,000                   |         |  |  |
|                             | QA11607          | x                               |      | Room                  | 18,000                   | 300,000                   |         |  |  |
|                             | QA11608          | x                               |      | Room                  | 18,000                   | 300,000                   |         |  |  |
|                             | QA11609          | x                               |      | Room                  | 18,000                   | 300,000                   |         |  |  |
|                             | QA11610          | x                               |      | Room                  | 18,000                   | 300,000                   |         |  |  |
| 1                           | QA31605          | x                               |      | Room                  | 18,000                   | 300,000                   |         |  |  |
| 1                           | QA31606          | x                               |      | Room                  | 18,000                   | 300,000                   |         |  |  |

Failed in setup check. Bent connection. Fig. 21.

TABLE IV (Continued)  
VIBRATION TEST DATA

Aeroquip Brazed Connections

| O.D.<br>Tube<br>(in.) | Serial<br>Number | Operating<br>Pressure<br>(psig) |      | Test<br>Temp. | Stress<br>Level<br>(psi) | Total<br>No. of<br>Cycles | Remarks                                                       |
|-----------------------|------------------|---------------------------------|------|---------------|--------------------------|---------------------------|---------------------------------------------------------------|
|                       |                  | 1500                            | 3000 |               |                          |                           |                                                               |
| 1                     | QA31607          |                                 | x    | Room          | 22,500                   | 206,000                   | Failed                                                        |
| 1                     | QA31608          |                                 | x    |               | 18,000                   | 300,000                   | Fig. 30                                                       |
| 1                     | QA31609          |                                 | x    |               |                          |                           |                                                               |
| 1                     | QA31610          |                                 | x    |               |                          |                           |                                                               |
| 1 1/4                 | QA12005          | x                               |      |               |                          |                           |                                                               |
| 1                     | QA12006          | x                               |      |               |                          |                           |                                                               |
| 1                     | QA12007          | x                               |      |               |                          |                           | Fig. 31                                                       |
| 1                     | QA12008          | x                               |      |               |                          |                           |                                                               |
| 1                     | QA12009          | x                               |      |               |                          |                           |                                                               |
| 1                     | QA12010          | x                               |      |               |                          |                           |                                                               |
| 1                     | QA32005          |                                 | x    |               |                          |                           |                                                               |
| 1                     | QA32006          |                                 | x    |               |                          |                           |                                                               |
| 1                     | QA32007          |                                 | x    |               |                          |                           |                                                               |
| 1                     | QA32008          |                                 | x    |               |                          |                           |                                                               |
| 1                     | QA32009          |                                 | x    |               |                          |                           |                                                               |
| 1 1/4                 | QA32010          |                                 | x    |               | 18,000                   | 300,000                   |                                                               |
| 1 1/2                 | QA32405          |                                 | x    |               | 20,000                   | 152,000                   | Failed. Braze void at fitting end.                            |
| 1                     | QA32406          |                                 | x    |               | 18,000                   | 300,000                   |                                                               |
| 1                     | QA32407          |                                 | x    |               |                          |                           |                                                               |
| 1                     | QA32408          |                                 | x    |               |                          |                           |                                                               |
| 1                     | QA32409          |                                 | x    |               |                          |                           |                                                               |
| 1                     | QA32410          |                                 | x    | Room          | 18,000                   |                           |                                                               |
| 1                     | CA32401          |                                 | x    | LN2           | 26,500                   |                           |                                                               |
| 1                     | CA32402          |                                 | x    |               |                          |                           |                                                               |
| 1                     | CA32403          |                                 | x    |               |                          |                           |                                                               |
| 1                     | CA32404          |                                 | x    |               |                          |                           |                                                               |
| 1                     | CA32405          |                                 | x    | LN2           | 26,500                   | 300,000                   |                                                               |
| 1                     | CA32406          |                                 | x    | +500°F        | 14,600                   | 154,000                   | Failed. Several braze voids, some at fitting end.             |
| 1 1/2                 | CA32407          |                                 | x    | +500°F        | 14,600                   | 143,000                   | Failed. Tubing did not extend far enough into failed fitting. |

TABLE IV (Concluded)  
VIBRATION TEST DATA

Aeroquip Brazed Connections

| O.D. Tube (in.) | Serial Number | Operating Pressure (psig) |      | Test Temp. | Stress Level (psi) | Total No. of Cycles | Remarks |
|-----------------|---------------|---------------------------|------|------------|--------------------|---------------------|---------|
|                 |               | 1500                      | 3000 |            |                    |                     |         |
| 1 1/2           | CA32408       |                           | x    | +500°F     | 14,600             | 300,000             |         |
| 1 1/2           | CA32409       |                           | x    | +500°F     | 14,600             | 300,000             |         |
| 1 1/2           | CA32410       |                           | x    | +500°F     | 14,600             | 300,000             |         |

TABLE V  
VIBRATION TEST DATA

GE Brazed Connections

| O.D. Tube (in.) | Serial Number | Operating Pressure (psig) |      | Test Temp. | Stress Level (psi) | Total No. of Cycles | Remarks                                                     |
|-----------------|---------------|---------------------------|------|------------|--------------------|---------------------|-------------------------------------------------------------|
|                 |               | 1500                      | 3000 |            |                    |                     |                                                             |
| 1/4             | QG10403       | x                         |      | Room       | 20,000             | 300,000             |                                                             |
|                 | QG10404       | x                         |      |            | 20,000             |                     |                                                             |
|                 | QG10405       | x                         |      |            | 22,500             |                     |                                                             |
|                 | QG10406       | x                         |      |            |                    |                     |                                                             |
|                 | QG10407       | x                         |      |            |                    |                     |                                                             |
|                 | QG10408       | x                         |      |            |                    | 300,000             |                                                             |
|                 | QG10409       | x                         |      |            |                    | 125,000             | Failed. Inspection did not reveal any fault in fabrication. |
|                 | QG10410       | x                         |      |            | 22,500             | 300,000             |                                                             |
|                 | QG30403       |                           | x    | Room       | 15,000             | 300,000             |                                                             |
|                 | QG30404       |                           | x    | 500°F      | 15,000             | 133,000             | Failed.                                                     |
|                 | QG30405       |                           | x    | 500°F      | 15,000             | 300,000             |                                                             |
|                 | QG30406       |                           | x    | Room       | 22,500             | 300,000             |                                                             |
|                 | QG30407       |                           | x    |            |                    | 300,000             |                                                             |
|                 | QG30408       |                           | x    |            |                    | 300,000             |                                                             |
|                 | QG30409       |                           | x    |            |                    | 210,000             | Failed.                                                     |
|                 | QG30410       |                           | x    |            |                    | 300,000             |                                                             |
| 1/4             | QG30410       |                           | x    | Room       | 22,500             | 300,000             |                                                             |

TABLE V (Continued)  
VIBRATION TEST DATA

CE Brazed Connections

| O.D.<br>Tube<br>(in.) | Serial<br>Number | Operating<br>Pressure<br>(psig) |      | Test<br>Temp. | Stress<br>Level<br>(psi) | Total<br>No. of<br>Cycles | Remarks                                                    |
|-----------------------|------------------|---------------------------------|------|---------------|--------------------------|---------------------------|------------------------------------------------------------|
|                       |                  | 1500                            | 3000 |               |                          |                           |                                                            |
| 1/4                   | CG30401          | x                               |      | LN2           | 33,200                   | 300,000                   |                                                            |
|                       | CG30402          | x                               |      |               |                          |                           |                                                            |
|                       | CG30403          | x                               |      |               |                          |                           |                                                            |
|                       | CG30404          | x                               |      |               |                          |                           |                                                            |
|                       | CG30405          | x                               |      | LN2           | 33,200                   | 300,000                   |                                                            |
|                       | CG30406          | x                               |      | +500°F        | 19,500                   | 277,700                   |                                                            |
|                       | CG30407          | x                               |      |               |                          | 63,000                    | Failed - five specimens at the number of cycles indicated. |
|                       | CG30408          | x                               |      |               |                          | 59,000                    | The stress level was considered too high and was lowered   |
|                       | CG30409          | x                               |      |               |                          | 63,600                    | to 12,000 psi, resulting in a reduced rate of failures.    |
| 1/4                   | CG30410          | x                               |      | +500°F        | 19,500                   | 40,000                    | CG 30406 shown in Fig. 26.                                 |
| 3/4                   | QG11205          | x                               |      | Room          | 22,500                   | 300,000                   |                                                            |
|                       | QG11206          | x                               |      |               |                          |                           |                                                            |
|                       | QG11207          | x                               |      |               |                          |                           | Tubing misfit.                                             |
|                       | QG11208          | x                               |      |               |                          |                           | Poor fabrication. Fig. 24.                                 |
|                       | QG11209          | x                               |      |               |                          |                           |                                                            |
|                       | QG11210          | x                               |      |               |                          |                           |                                                            |
|                       | QG31205          | x                               |      |               |                          |                           |                                                            |
|                       | QG31206          | x                               |      |               |                          |                           |                                                            |
|                       | QG31207          | x                               |      |               |                          |                           | String of braze defects.                                   |
|                       | QG31208          | x                               |      | Room          | 22,500                   |                           |                                                            |
|                       | CG31201          | x                               |      | LN2           | 33,200                   |                           |                                                            |
|                       | CG31202          | x                               |      |               |                          |                           |                                                            |
|                       | CG31203          | x                               |      |               |                          |                           |                                                            |
|                       | CG31204          | x                               |      |               |                          |                           |                                                            |
|                       | CG31205          | x                               |      | LN2           | 33,200                   |                           |                                                            |
|                       | CG31206          | x                               |      | +500°F        | 15,000                   |                           |                                                            |
|                       | CG31207          | x                               |      |               |                          |                           |                                                            |
| 3/4                   | CG31208          | x                               |      | +500°F        | 15,000                   | 300,000                   |                                                            |
|                       | CG31209          | x                               |      |               |                          |                           |                                                            |

TABLE V (Concluded)  
VIBRATION TEST DATA

GE Brazed Connections

| O.D.<br>Tube<br>(in.) | Serial<br>Number | Operating<br>Pressure<br>(psig) |      | Test<br>Temp.<br>Temp. | Stress<br>Level<br>(psi) | Total<br>No. of<br>Cycles | Remarks   |
|-----------------------|------------------|---------------------------------|------|------------------------|--------------------------|---------------------------|-----------|
|                       |                  | 1500                            | 3000 |                        |                          |                           |           |
| 3/4                   | CG31210          | x                               | x    | +500°F                 | 15,000                   | 300,000                   |           |
| 1 1/4                 | QG12005          | x                               |      | Room                   | 18,000                   | ↑                         |           |
| ↑                     | QG12006          | x                               |      | ↑                      | ↑                        |                           |           |
|                       | QG12007          | x                               |      |                        |                          |                           |           |
|                       | QG12008          | x                               |      |                        |                          |                           |           |
|                       | QG12009          | x                               |      |                        |                          |                           |           |
|                       | QG12010          | x                               |      | Room                   | 18,000                   |                           |           |
|                       | QG32005          | x                               |      | +500°F                 | 15,000                   |                           |           |
|                       | QG32006          | x                               |      | ↑                      | ↑                        |                           |           |
|                       | QG32007          | x                               |      |                        |                          |                           | Figure 32 |
|                       | QG32008          | x                               |      |                        |                          |                           |           |
| ↑                     | QG32009          | x                               |      | ↑                      | ↑                        |                           |           |
| 1 1/4                 | QG32010          | x                               |      | +500°F                 | 15,000                   | 300,000                   |           |

TABLE VI  
VIBRATION TEST DATA

MSFC Welded Connections

| O.D.<br>Tube<br>(in.) | Serial<br>Number | Operating<br>Pressure<br>(psig) |      | Test<br>Temp. | Stress<br>Level<br>(psi) | Total<br>No. of<br>Cycles | Remarks |
|-----------------------|------------------|---------------------------------|------|---------------|--------------------------|---------------------------|---------|
|                       |                  | 1500                            | 3000 |               |                          |                           |         |
| 1/4                   | QS10405          | x                               |      | Room          | 22,500                   | 300,000                   |         |
| ↑                     | QS10406          | x                               |      | ↑             | ↑                        | ↑                         |         |
|                       | QS10407          | x                               |      |               |                          |                           |         |
|                       | QS10408          | x                               |      |               |                          |                           |         |
|                       | QS10409          | x                               |      |               |                          |                           |         |
| ↑                     | QS10410          | x                               |      | ↑             | ↑                        |                           |         |
| 1/4                   | QS30405          |                                 | x    | Room          | 22,500                   | 300,000                   |         |

TABLE VI (Continued)  
VIBRATION TEST DATA

| MSFC Welded           |                  | Connections                     |      |                        |                          | Total<br>No. of<br>Cycles | Remarks |
|-----------------------|------------------|---------------------------------|------|------------------------|--------------------------|---------------------------|---------|
| O.D.<br>Tube<br>(in.) | Serial<br>Number | Operating<br>Pressure<br>(psig) |      | Test<br>Temp.<br>Temp. | Stress<br>Level<br>(psi) |                           |         |
|                       |                  | 1500                            | 3000 |                        |                          |                           |         |
| 1/4                   | QS30406          |                                 | x    | Room                   | 22,500                   | 300,000                   |         |
|                       | QS30407          |                                 | x    | ↑                      | ↑                        | ↑                         |         |
|                       | QS30408          |                                 | x    |                        |                          |                           |         |
|                       | QS30409          |                                 | x    | ↓                      | ↓                        |                           |         |
|                       | QS30410          |                                 | x    | Room                   | 22,500                   |                           |         |
|                       | CS30401          |                                 | x    | LN2                    | 33,200                   |                           |         |
|                       | CS30402          |                                 | x    | ↑                      | ↑                        |                           |         |
|                       | CS30403          |                                 | x    |                        |                          |                           |         |
|                       | CS30404          |                                 | x    |                        |                          |                           |         |
|                       | CS30405          |                                 | x    |                        |                          |                           |         |
|                       | CS30406          |                                 | x    |                        |                          |                           |         |
|                       | CS30407          |                                 | x    |                        |                          |                           |         |
|                       | CS30408          |                                 | x    |                        |                          |                           |         |
|                       | CS30409          |                                 | x    | ↓                      | ↓                        |                           |         |
|                       | CS30410          |                                 | x    | LN2                    | 33,200                   |                           |         |
|                       | CS30411          |                                 | x    | +500°F                 | 19,500                   |                           |         |
|                       | CS30412          |                                 | x    | ↑                      | ↑                        |                           |         |
|                       | CS30413          |                                 | x    |                        |                          |                           |         |
|                       | CS30414          |                                 | x    |                        |                          |                           |         |
|                       | CS30415          |                                 | x    |                        |                          |                           |         |
|                       | CS30416          |                                 | x    |                        |                          |                           |         |
|                       | CS30417          |                                 | x    |                        |                          |                           |         |
|                       | CS30418          |                                 | x    |                        |                          |                           |         |
|                       | CS30419          |                                 | x    | ↓                      | ↓                        |                           |         |
|                       | CS30420          |                                 | x    | +500°F                 | 19,500                   |                           |         |
|                       | QS10605          | x                               |      | Room                   | 22,500                   |                           |         |
|                       | QS10606          | x                               |      | ↑                      | ↑                        |                           |         |
|                       | QS10607          | x                               |      | ↓                      | ↓                        |                           |         |
|                       | QS10608          | x                               |      | Room                   | 22,500                   | 300,000                   |         |

Fig. 27

TABLE VI (Continued)  
VIBRATION TEST DATA

MSFC Welded Connections

| O.D.<br>Tube<br>(in.) | Serial<br>Number | Operating<br>Pressure<br>(psig) |      | Test<br>Temp. | Stress<br>Level<br>(psi) | Total<br>No. of<br>Cycles | Remarks                        |
|-----------------------|------------------|---------------------------------|------|---------------|--------------------------|---------------------------|--------------------------------|
|                       |                  | 1500                            | 3000 |               |                          |                           |                                |
| 3/8                   | QS10609          | x                               |      | Room          | 22,500                   | 300,000                   |                                |
|                       | QS10610          | x                               |      |               |                          |                           |                                |
|                       | QS30605          |                                 | x    |               |                          |                           |                                |
|                       | QS30606          |                                 | x    |               |                          |                           |                                |
|                       | QS30607          |                                 | x    |               |                          |                           |                                |
|                       | QS30609          |                                 | x    |               |                          |                           |                                |
| 3/8                   | QS30610          |                                 | x    |               |                          |                           |                                |
| 1/2                   | QS10805          | x                               |      |               |                          |                           |                                |
|                       | QS10806          | x                               |      |               |                          |                           |                                |
|                       | QS10807          | x                               |      |               |                          | 300,000                   |                                |
|                       | QS10808          | x                               |      |               |                          | 265,000                   | Failed.                        |
|                       | QS10809          | x                               |      |               |                          | 300,000                   |                                |
|                       | QS10810          | x                               |      |               |                          | 300,000                   |                                |
|                       | QS30805          |                                 | x    |               |                          | 269,000                   | Failed.                        |
|                       | QS30806          |                                 | x    |               |                          | 300,000                   |                                |
|                       | QS30807          |                                 | x    |               |                          |                           |                                |
|                       | QS30808          |                                 | x    |               |                          |                           |                                |
|                       | QS30809          |                                 | x    |               |                          |                           |                                |
| 1/2                   | QS30810          |                                 | x    |               |                          |                           |                                |
| 3/4                   | QS11205          | x                               |      |               |                          |                           |                                |
|                       | QS11206          | x                               |      |               |                          |                           |                                |
|                       | QS11207          | x                               |      |               |                          |                           | Off-center weld. Fig. 23.      |
|                       | QS11208          | x                               |      |               |                          |                           |                                |
|                       | QS11209          | x                               |      |               |                          |                           |                                |
|                       | QS11210          | x                               |      |               |                          |                           |                                |
|                       | QS31205          |                                 | x    |               |                          |                           |                                |
|                       | QS31206          |                                 | x    |               |                          |                           |                                |
|                       | QS31207          |                                 | x    |               |                          |                           |                                |
| 3/4                   | QS31208          |                                 | x    | Room          | 22,500                   | 300,000                   | Poor weld fusion - misaligned. |

TABLE VI (Continued)  
VIBRATION TEST DATA

| MSFC Welded     |               | Connections               |   | Test Temp. | Stress Level (psi) | Total No. of Cycles | Remarks                                |
|-----------------|---------------|---------------------------|---|------------|--------------------|---------------------|----------------------------------------|
| O.D. Tube (in.) | Serial Number | Operating Pressure (psig) |   |            |                    |                     |                                        |
| 3/4             | QS31209       | 1500 3000                 | x | Room       | 22,500             | 300,000             |                                        |
|                 | QS31210       |                           | x | Room       | 22,500             |                     |                                        |
|                 | CS31201       |                           | x | LN2        | 33,200             |                     |                                        |
|                 | CS31202       |                           | x |            |                    |                     |                                        |
|                 | CS31203       |                           | x |            |                    |                     |                                        |
|                 | CS31204       |                           | x |            |                    |                     |                                        |
|                 | CS31205       |                           | x | LN2        | 33,200             |                     |                                        |
|                 | CS31206       |                           | x | +500°F     | 15,000             |                     | Poor weld fusion - misaligned.         |
|                 | CS31207       |                           | x |            |                    |                     |                                        |
|                 | CS31208       |                           | x |            |                    |                     |                                        |
|                 | CS31209       |                           | x |            |                    |                     |                                        |
| 3/4             | CS31210       |                           | x | +500°F     | 15,000             | 300,000             |                                        |
| 1               | QS11605       | x                         |   | Room       | 18,000             | 259,000             | Failed.                                |
|                 | QS11606       | x                         |   |            |                    | 300,000             |                                        |
|                 | QS11607       | x                         |   |            |                    | 300,000             |                                        |
|                 | QS11608       | x                         |   |            |                    | 300,000             |                                        |
|                 | QS11609       | x                         |   |            |                    | 269,000             | Failed.                                |
|                 | QS11610       | x                         |   |            |                    | 300,000             |                                        |
|                 | QS31605       |                           | x |            |                    |                     |                                        |
|                 | QS31606       |                           | x |            |                    |                     |                                        |
|                 | QS31607       |                           | x |            |                    |                     |                                        |
|                 | QS31608       |                           | x |            |                    |                     |                                        |
|                 | QS31609       |                           | x |            |                    |                     |                                        |
| 1               | QS31610       |                           | x |            |                    | 300,000             |                                        |
| 1 1/4           | QS12005       | x                         |   |            | 18,000             | 251,000             | Failed. Crack started at weld overlap. |
|                 | QS12006       | x                         |   |            | 22,500             | 180,000             | Failed. Crack started at weld overlap. |
|                 | QS12007       | x                         |   |            | 18,000             | 300,000             |                                        |
| 1 1/4           | QS12008       | x                         |   | Room       | 18,000             | 300,000             | Fig. 34.                               |
|                 | QS12009       | x                         |   |            | 18,000             | 300,000             |                                        |

TABLE VI (Concluded)  
VIBRATION TEST DATA

MSFC Welded Connections

| O.D.<br>Tube<br>(in.) | Serial<br>Number | Operating<br>Pressure<br>(psig) |      | Test<br>Temp. | Stress<br>Level<br>(psi) | Total<br>No. of<br>Cycles | Remarks                                                   |
|-----------------------|------------------|---------------------------------|------|---------------|--------------------------|---------------------------|-----------------------------------------------------------|
|                       |                  | 1500                            | 3000 |               |                          |                           |                                                           |
| 1 1/4                 | QS12010          | x                               |      | Room          | 18,000                   | 238,000                   | Failed. Two cracks, misaligned.                           |
|                       | QS32005          |                                 | x    |               |                          | 300,000                   |                                                           |
|                       | QS32006          |                                 | x    |               |                          |                           | Lack of fusion in weld - 3 places.                        |
|                       | QS32007          |                                 | x    |               |                          |                           | Off-center weld. Fig. 22.                                 |
|                       | QS32008          |                                 | x    |               |                          | 300,000                   |                                                           |
|                       | QS32009          |                                 | x    |               |                          | 147,000                   | Failed. Poor weld.                                        |
| 1 1/4                 | QS32010          |                                 | x    |               |                          | 300,000                   |                                                           |
| 1 1/2                 | QS12405          | x                               |      |               |                          | 75,000                    | Failed. Tubing misaligned, crack started at weld overlap. |
|                       | QS12406          | x                               |      |               |                          | 300,000                   |                                                           |
|                       | QS12407          | x                               |      |               |                          |                           |                                                           |
|                       | QS12408          | x                               |      |               |                          |                           |                                                           |
|                       | QS12409          | x                               |      |               |                          |                           |                                                           |
|                       | QS12410          | x                               |      |               |                          | 300,000                   |                                                           |
|                       | QS32405          |                                 | x    |               |                          | 135,000                   | Failed. Weld misaligned, lacked fusion.                   |
|                       | QS32406          |                                 | x    |               |                          | 300,000                   | Off-center weld.                                          |
|                       | QS32407          |                                 | x    |               |                          |                           |                                                           |
|                       | QS32408          |                                 | x    |               |                          |                           | Tubing misaligned, crack started at weld overlap.         |
|                       | QS32409          |                                 | x    |               |                          |                           |                                                           |
|                       | QS32410          |                                 | x    | Room          | 18,000                   |                           |                                                           |
|                       | CS32401          |                                 | x    | LN2           | 26,500                   |                           | Off-center weld.                                          |
|                       | CS32402          |                                 | x    |               |                          |                           | Off-center weld.                                          |
|                       | CS32403          |                                 | x    |               |                          |                           |                                                           |
|                       | CS32404          |                                 | x    |               |                          |                           |                                                           |
|                       | CS32405          |                                 | x    | LN2           | 26,500                   |                           | Minor misaligned weld and minor lack of fusion.           |
|                       | CS32406          |                                 | x    | +500°F        | 13,000                   | 300,000                   | Fig. 35.                                                  |
|                       | CS32407          |                                 | x    |               | 17,600                   | 159,000                   | Failed. Fig. 28.                                          |
|                       | CS32408          |                                 | x    |               | 16,300                   | 135,000                   | Failed.                                                   |
|                       | CS32409          |                                 | x    |               | 16,300                   | 300,000                   |                                                           |
| 1 1/2                 | CS32410          |                                 | x    | +500°F        | 16,300                   | 88,000                    | Failed. Fig. 29.                                          |

# Tensile Test Data

Tables VII through X

## Requirements:

Determine the tensile stress of test connections after they have been subjected to vibration tests. The yield stress data (0.2% strain) was not available for all sizes. The maximum tensile load is the fracture load. The ultimate and yield stress are calculated by dividing the load by the tubing original cross-sectional area, which is shown on dimensional sketches, Figs. 1 thru 4. Tensile tests of control specimens, which were not subjected to any previous environmental tests, are also listed at the end of this section.

\*NOTE: Fracture Location: (T) indicates fracture in tube and (F) indicates fracture in fitting.

TABLE VII  
TENSILE TEST DATA (At Room Temperature)

## Aeroquip Brazed Connections

| O.D. Tube (in.) | Serial Number | Operating Pressure (psig) |      | Tensile Load (Lbs) |       | Tensile Stress (psi) |        | Previous Vibration Test Stress (psi) |          | Remarks                | #Fracture Location |
|-----------------|---------------|---------------------------|------|--------------------|-------|----------------------|--------|--------------------------------------|----------|------------------------|--------------------|
|                 |               | 1500                      | 3000 | Maximum to break   | Yield | Ultimate to break    | Yield  | +500°F                               | Room LN2 |                        |                    |
| 1/4             | QA10403       | x                         |      | 1,502              | - - - | 103,945              | - - -  | 12,000                               |          |                        |                    |
|                 | QA10404       | x                         |      | 1,445              | - - - | 100,000              | - - -  | 12,000                               |          |                        |                    |
|                 | QA10405       | x                         |      | 1,590              | - - - | 110,034              | - - -  |                                      | 22,500   |                        |                    |
|                 | QA10406       | x                         |      | 1,574              | - - - | 108,927              | - - -  |                                      | 22,500   |                        |                    |
|                 | QA30403       |                           | x    | 1,710              | - - - | 93,442               | - - -  | 12,000                               |          |                        |                    |
|                 | QA30405       |                           | x    | 1,958              | - - - | 106,994              | - - -  |                                      | 22,500   |                        |                    |
|                 | QA30406       |                           | x    | 1,928              | - - - | 105,355              | - - -  |                                      | 22,500   |                        |                    |
|                 | CA30401       |                           | x    | 1,965              | - - - | 107,377              | - - -  |                                      |          |                        |                    |
|                 | CA30402       |                           | x    | 2,020              | - - - | 110,382              | - - -  |                                      |          |                        |                    |
| 1/4             | QA10605       | x                         |      | 3,325              | 1,700 | 108,945              | 55,701 |                                      |          |                        |                    |
| 3/8             | QA10606       | x                         |      | 3,385              | 1,700 | 110,911              | 55,701 |                                      |          |                        |                    |
|                 | QA30605       |                           | x    | 3,620              | 1,675 | 89,983               | 41,636 |                                      | 22,500   |                        |                    |
| 3/8             | QA30606       |                           | x    | 3,815              | 2,075 | 94,830               | 51,578 |                                      |          |                        |                    |
| 1/2             | QA10805       | x                         |      | 4,850              | - - - | 94,856               | - - -  |                                      |          |                        |                    |
| 1/2             | QA10806       | x                         |      | 5,045              | - - - | 98,670               | - - -  |                                      |          |                        |                    |
| 1/2             | QA30806       |                           | x    | 5,750              | - - - | 79,939               | - - -  |                                      |          |                        |                    |
| 3/4             | QA11205       | x                         |      | 10,590             | 6,420 | 98,137               | 59,444 |                                      | 22,500   |                        |                    |
| 3/4             | QA11206       | x                         |      | 10,800             | 5,700 | 100,083              | 52,778 |                                      | 22,500   |                        |                    |
|                 |               |                           |      |                    |       |                      |        |                                      |          | Fatigue crack started. | T                  |

TABLE VII (Concluded)  
TENSILE TEST DATA (At Room Temperature)

Aeroquip Brazed Connections

| O.D.<br>Tube<br>(in.) | Serial<br>Number | Operating<br>Pressure<br>(psig) |      | Tensile Load<br>(Lbs) |        | Tensile Stress<br>(psi) |        | Previous Vibration<br>Test Stress (psi) |        | Remarks |                        |
|-----------------------|------------------|---------------------------------|------|-----------------------|--------|-------------------------|--------|-----------------------------------------|--------|---------|------------------------|
|                       |                  | 1500                            | 3000 | Maximum<br>to break   | Yield  | Ultimate<br>to break    | Yield  | +500°F                                  | Room   | LN2     | *Fracture<br>Location  |
| 3/4                   | QA31205          |                                 | x    | 14,800                | 7,650  | 93,058                  | 47,547 |                                         | 22,500 |         | Fatigue crack started. |
|                       | QA31206          |                                 | x    | 14,750                | 7,080  | 92,744                  | 44,528 |                                         | 22,500 |         |                        |
|                       | CA31201          |                                 | x    | 15,350                | 8,120  | 96,516                  | 51,069 |                                         |        | 33,200  | Fig. 36                |
|                       | CA31207          |                                 | x    | 15,250                | 9,540  | 95,888                  | 60,000 | 15,000                                  |        |         |                        |
| 3/4                   | CA31208          |                                 | x    | 15,525                | 7,800  | 97,617                  | 49,056 | 15,000                                  |        |         | Fatigue crack started. |
|                       | QA11605          | x                               |      | 15,425                | 8,280  | 80,789                  | 43,351 |                                         | 18,000 |         |                        |
| 1                     | QA11606          | x                               |      | 16,325                | 9,390  | 85,502                  | 49,162 |                                         |        |         |                        |
|                       | QA11610          | x                               |      | 18,150                | 7,830  | 95,061                  | 40,995 |                                         |        |         |                        |
|                       | QA31605          |                                 | x    | 21,050                | 8,910  | 75,801                  | 32,050 |                                         |        |         | Fatigue crack started. |
|                       | QA31606          |                                 | x    | 21,100                | 9,450  | 75,981                  | 33,993 |                                         | 18,000 |         |                        |
| 1                     | QA31607          |                                 | x    | 12,850                | 7,830  | 46,273                  | 28,165 |                                         | 22,500 |         | Fatigue crack started. |
|                       | QA12005          | x                               |      | 29,900                | 12,000 | 98,258                  | 39,473 |                                         | 18,000 |         |                        |
|                       | QA12006          | x                               |      | 28,550                | 14,700 | 93,822                  | 48,355 |                                         |        |         |                        |
|                       | QA32005          |                                 | x    | 35,650                | 13,500 | 82,460                  | 31,250 |                                         |        |         | Fatigue crack started. |
| 1 1/4                 | QA32006          |                                 | x    | 36,400                | 16,350 | 84,195                  | 37,847 |                                         |        |         | Fig. 36                |
|                       | QA32406          |                                 | x    | 30,650                | 18,700 | 62,247                  | 38,008 |                                         | 18,000 |         | Fatigue crack started  |
|                       | CA32401          |                                 | x    | 34,000                | 19,800 | 69,051                  | 40,244 |                                         |        | 26,500  |                        |
|                       | CA32402          |                                 | x    | 34,650                | 18,480 | 70,371                  | 37,561 |                                         |        | 26,500  |                        |
| 1 1/2                 | CA32408          |                                 | x    | 32,300                | 18,000 | 65,598                  | 36,585 | 15,000                                  |        |         | Fatigue crack started  |

TABLE VIII  
TENSILE TEST DATA (At Room Temperature)

GE Braze Connections

| O.D.<br>Tube<br>(in.) | Serial<br>Number | Operating<br>Pressure<br>(psig) |      | Tensile Load<br>(Lbs) |        | Tensile Stress<br>(psi) |        | Previous Vibration<br>Test Stress (psi) |        | Remarks |                        |
|-----------------------|------------------|---------------------------------|------|-----------------------|--------|-------------------------|--------|-----------------------------------------|--------|---------|------------------------|
|                       |                  | 1500                            | 3000 | Maximum<br>to break   | Yield  | Ultimate<br>to break    | Yield  | +500°F                                  | Room   | LN2     | *Fracture<br>Location  |
| 1/4                   | QG10403          | x                               |      | 1,690                 | -      | 116,955                 | -      |                                         | 20,000 |         | Fatigue crack started. |
|                       | QG10404          | x                               |      | 1,515                 | -      | 104,844                 | -      |                                         | 20,000 |         | Fatigue crack started. |
|                       | QG10405          | x                               |      | 1,720                 | -      | 119,031                 | -      |                                         | 22,500 |         |                        |
|                       | QG10406          | x                               |      | 1,573                 | -      | 108,858                 | -      |                                         | 22,500 |         | Fatigue crack started. |
| 3/4                   | QG30403          |                                 | x    | 1,935                 | -      | 105,277                 | -      | 12,000                                  |        |         |                        |
|                       | QG30405          |                                 | x    | 1,715                 | -      | 93,308                  | -      |                                         | 22,500 |         |                        |
|                       | QG30406          |                                 | x    | 1,935                 | -      | 105,277                 | -      |                                         | 22,500 |         |                        |
|                       | CG30401          |                                 | x    | 2,090                 | -      | 113,710                 | -      |                                         |        | 33,200  |                        |
| 1/4                   | CG30402          |                                 | x    | 2,115                 | -      | 115,070                 | -      |                                         |        | 33,200  |                        |
| 3/4                   | QG11205          | x                               |      | 10,630                | 5,580  | 98,508                  | 51,667 |                                         | 22,500 |         | Fatigue crack started. |
|                       | QG11206          | x                               |      | 10,930                | 5,880  | 101,288                 | 54,444 |                                         |        |         |                        |
|                       | QG31205          |                                 | x    | 14,750                | 7,440  | 92,604                  | 46,792 |                                         |        |         |                        |
|                       | QG31206          |                                 | x    | 14,850                | 7,740  | 93,232                  | 48,679 |                                         | 22,500 |         |                        |
| 3/4                   | CG31201          |                                 | x    | 14,950                | 7,860  | 93,860                  | 49,434 |                                         |        | 33,200  | Fig. 36                |
|                       | CG31202          |                                 | x    | 14,950                | 7,740  | 93,860                  | 48,679 |                                         |        | 33,200  |                        |
|                       | CG31207          |                                 | x    | 14,975                | 7,800  | 94,017                  | 49,056 | 15,000                                  |        |         |                        |
|                       | CG31208          |                                 | x    | 14,850                | 7,560  | 93,232                  | 47,547 | 15,000                                  |        |         |                        |
| 1 1/4                 | QG12005          | x                               |      | 28,700                | 13,200 | 94,315                  | 43,421 |                                         | 18,000 |         |                        |
|                       | QG12006          | x                               |      | 28,000                | 14,400 | 92,014                  | 47,368 |                                         | 18,000 |         | Fatigue crack started  |
|                       | QG32005          |                                 | x    | 22,500                | 17,400 | 51,996                  | 40,185 | 15,000                                  |        |         | Fig. 36                |
|                       | QG32006          |                                 | x    | 35,900                | 18,000 | 82,963                  | 41,570 | 15,000                                  |        |         | Poor braze fabrication |

TABLE IX  
TENSILE TEST DATA (At Room Temperature)

MSFC Welded Connections

| O.D. Tube (in.) | Serial Number | Operating Pressure (psig) |      | Tensile Load (Lbs) |        | Tensile Stress (psi) |        | Previous Vibration Test Stress (psi) |        | Remarks | *Fracture Location     |
|-----------------|---------------|---------------------------|------|--------------------|--------|----------------------|--------|--------------------------------------|--------|---------|------------------------|
|                 |               | 1500                      | 3000 | Maximum to break   | Yield  | Ultimate to break    | Yield  | +500°F                               | Room   |         |                        |
| 1/4             | QS10405       | x                         |      | 1,630              | - - -  | 112,336              | - - -  |                                      | 22,500 |         | Fatigue crack started. |
|                 | QS10406       | x                         |      | 1,507              | - - -  | 103,859              | - - -  |                                      |        |         |                        |
|                 | QS30405       |                           | x    | 1,950              | - - -  | 106,093              | - - -  |                                      |        |         |                        |
|                 | QS30406       |                           | x    | 1,860              | - - -  | 101,197              | - - -  |                                      | 22,500 |         | Fatigue crack started. |
|                 | CS30401       |                           | x    | 1,875              | - - -  | 102,013              | - - -  |                                      | 33,200 |         |                        |
|                 | CS30402       |                           | x    | 1,905              | - - -  | 103,645              | - - -  |                                      |        |         |                        |
|                 | CS30403       |                           | x    | 1,920              | - - -  | 104,461              | - - -  |                                      |        |         | Fatigue crack started. |
|                 | CS30404       |                           | x    | 1,710              | - - -  | 93,036               | - - -  |                                      | 33,200 |         |                        |
|                 | CS30411       |                           | x    | 1,825              | - - -  | 99,293               | - - -  | 19,500                               |        |         | Fatigue crack started. |
|                 | CS30412       |                           | x    | 1,825              | - - -  | 99,293               | - - -  |                                      |        |         |                        |
|                 | CS30413       |                           | x    | 1,700              | - - -  | 92,492               | - - -  |                                      |        |         |                        |
| 1/4             | CS30414       |                           | x    | 1,835              | - - -  | 99,837               | - - -  | 19,500                               |        |         |                        |
| 3/8             | QS10605       | x                         |      | 3,555              | 2,740  | 116,176              | 89,542 |                                      | 22,500 |         |                        |
|                 | QS10606       | x                         |      | 3,230              | 1,840  | 105,555              | 60,131 |                                      |        |         |                        |
|                 | QS30605       |                           | x    | 3,645              | 1,955  | 90,334               | 48,511 |                                      |        |         |                        |
| 3/8             | QS30606       |                           | x    | 3,735              | 2,365  | 92,565               | 58,685 |                                      |        |         |                        |
|                 |               |                           | x    | 4,485              | - - -  | 87,529               | - - -  |                                      |        |         |                        |
| 1/2             | QS10805       | x                         |      | 5,575              | - - -  | 77,323               | - - -  |                                      |        |         | Fatigue crack started. |
| 1/2             | QS30805       |                           | x    |                    | - - -  |                      | - - -  |                                      |        |         |                        |
| 1/2             | QS30806       |                           | x    | 6,135              | - - -  | 85,090               | - - -  |                                      |        |         |                        |
| 3/4             | QS11205       | x                         |      | 9,950              | 5,430  | 92,078               | 50,278 |                                      |        |         | Poor weld fabrication. |
|                 | QS11206       | x                         |      | 9,450              | 5,940  | 87,451               | 55,000 |                                      |        |         | Poor weld fabrication. |
|                 | QS31205       |                           | x    | 13,775             | 7,440  | 86,483               | 46,792 |                                      |        |         | Fig. 36                |
|                 | QS31206       |                           | x    | 14,075             | 7,320  | 88,366               | 46,038 |                                      | 22,500 |         | Fatigue crack started. |
|                 | CS31202       |                           | x    | 13,900             | 7,020  | 87,268               | 44,151 |                                      | 33,200 |         | Poor weld fabrication. |
|                 | CS31207       |                           | x    | 14,450             | 7,440  | 90,721               | 46,792 | 15,000                               |        |         |                        |
| 3/4             | CS31208       |                           | x    | 14,500             | 7,020  | 91,035               | 44,151 | 15,000                               |        |         |                        |
|                 | QS11605       | x                         |      | 17,425             | 9,150  | 91,168               | 47,906 |                                      | 18,000 |         |                        |
|                 | QS11606       | x                         |      | 15,750             | 10,380 | 82,405               | 54,345 |                                      |        |         |                        |
|                 | QS11609       | x                         |      | 17,200             | 13,980 | 89,991               | 73,194 |                                      |        |         |                        |
| 1               | QS31605       |                           | x    | 24,600             | 12,660 | 88,486               | 45,539 |                                      | 18,000 |         |                        |

TABLE IX (Concluded)  
TENSILE TEST DATA (At Room Temperature)

MSFC Welded Connections

| O.D. Tube (in.) | Serial Number | Operating Pressure (psig) |      | Tensile Load (Lbs) |        | Tensile Stress (psi) |        | Previous Vibration Test Stress (psi) |        |                 | Remarks                  |
|-----------------|---------------|---------------------------|------|--------------------|--------|----------------------|--------|--------------------------------------|--------|-----------------|--------------------------|
|                 |               | 1500                      | 3000 | Maximum to break   | Yield  | Ultimate to break    | Yield  | +500°F                               | Room   | LN <sub>2</sub> |                          |
| 1               | QS31606       |                           | x    | 24,100             | 11,220 | 86,687               | 40,360 |                                      | 18,000 |                 | Fatigue crack started. T |
| 1 1/4           | QS32005       |                           | x    | 37,650             | 17,400 | 87,008               | 40,185 |                                      |        |                 | Fatigue crack started. T |
| 1 1/4           | QS32006       |                           | x    | 35,300             | 17,400 | 81,577               | 40,185 |                                      |        |                 | Fig. 36                  |
| 1 1/2           | QS12406       | x                         |      | 39,750             | 20,400 | 94,728               | 48,571 |                                      |        |                 | Fatigue crack started. T |
|                 | QS32406       |                           | x    | 30,875             | 19,440 | 62,660               | 39,432 |                                      | 18,000 |                 | Off-center weld. T       |
|                 | CS32401       |                           | x    | 40,100             | 23,500 | 81,382               | 47,667 |                                      |        | 26,500          | Off-center weld. T       |
| 1 1/2           | CS32402       |                           | x    | 43,275             | 21,400 | 87,825               | 43,408 |                                      |        | 26,500          | Off-center weld. T       |

TABLE X  
TENSILE TEST DATA (At Room Temperature)  
Averaged Results of Control Specimens Which Were Not Subjected to Vibration Tests

| O.D. Tube (in.) | Type of Fitting | Operating Pressure (psig) |      | Tensile Load (Lbs) |        | Tensile Stress (psi) |         | Number of Specimens in Test Group | Remarks                                           |
|-----------------|-----------------|---------------------------|------|--------------------|--------|----------------------|---------|-----------------------------------|---------------------------------------------------|
|                 |                 | 1500                      | 3000 | Maximum to break   | Yield  | Ultimate to break    | Yield   |                                   |                                                   |
| 1/4             | Aeroquip        |                           | x    | 1,908              | 844    | 104,300              | 46,100  | 10                                |                                                   |
| 3/4             | Aeroquip        |                           | x    | 15,403             | 7,697  | 96,900               | 48,400  | 8                                 |                                                   |
| 1 1/2           | Aeroquip        |                           | x    | 33,915             | 16,966 | 70,300               | 35,200  | 10                                |                                                   |
| 1/4             | GE              |                           | x    | 1,910              | 1,340  | 104,400              | 73,200  | 5                                 |                                                   |
| 3/4             | GE              |                           | x    | 14,900             | 7,582  | 93,700               | 47,700  | 8                                 |                                                   |
| 1/4             | MSFC            |                           | x    | 1,778              | 1,014  | 97,100               | 55,400  | 9                                 |                                                   |
| 3/4             | MSFC            |                           | x    | 14,500             | 7,530  | 91,200               | 47,400  | 10                                |                                                   |
| 1 1/2           | MSFC            |                           | x    | 45,772             | 24,637 | 95,200               | 51,200  | 9                                 |                                                   |
| 1/4             | None            |                           | x    | 1,890              | 1,571  | 131,200              | 109,100 | 3                                 | Straight tubing sections without any connections. |
| 3/4             | None            |                           | x    | 17,210             | 14,940 | 108,200              | 94,000  | 5                                 |                                                   |
| 1 1/2           | None            |                           | x    | 57,300             | 48,400 | 119,100              | 100,600 | 3                                 |                                                   |

# Metallographic Examination Data

Tables XI through XIII

**Requirement:** Examination by the Engineering Materials Division of designated specimens after completion of a corrosion test or a series of tests which included vibration. The examination was performed by observing with a microscope the polished, sometimes etched, longitudinal cross section of the connection. Except where noted under "Remarks", the corrosion test was performed for a period of 180 days.

TABLE XI  
METALLOGRAPHIC EXAMINATION DATA

## Aeroquip Brazed Connections

| O.D. Tube (in.) | Serial Number | Previous Tests |                |                                     | Results            |               |          |
|-----------------|---------------|----------------|----------------|-------------------------------------|--------------------|---------------|----------|
|                 |               | Cor- ro- sion  | Vibration Room | LN <sub>2</sub> +500°F Stress (psi) | Corrosion Occurred | Fatigue Crack | Remarks  |
| 1/4             | QA10401       | x              |                |                                     | x                  |               |          |
| ▲               | QA10402       | x              |                |                                     | x                  |               |          |
|                 | QA10403       |                |                | 12,000                              |                    | x             |          |
|                 | QA10404       |                |                | 12,000                              |                    | x             |          |
|                 | QA10407       |                | 22,500         |                                     |                    | x             |          |
|                 | QA10408       |                | 22,500         |                                     |                    |               |          |
|                 | QA30401       | x              |                |                                     | x                  |               |          |
|                 | QA30402       | x              |                |                                     | x                  |               |          |
|                 | QA30403       |                |                | 12,000                              |                    | x             |          |
|                 | QA30404       |                |                | 12,000                              |                    | x             |          |
|                 | QA30407       |                | 22,500         |                                     |                    |               |          |
|                 | QA30408       |                | 22,500         |                                     |                    |               |          |
|                 | QA30409       |                |                | 33,200                              |                    |               |          |
| ▼               | CA30406       |                |                | 19,500                              |                    | x             | Fig. 25. |
| 1/4             | CA30410       |                |                | 19,500                              |                    | x             |          |

TABLE XI (Continued)  
METALLOGRAPHIC EXAMINATION DATA

| Aeroquip Brazed Connections |               |           |                | Previous Tests  |              |             | Results   |                                   |
|-----------------------------|---------------|-----------|----------------|-----------------|--------------|-------------|-----------|-----------------------------------|
| O.D. Tube (in.)             | Serial Number | Corrosion | Vibration Room | LN <sub>2</sub> | Stress (psi) | Corro. Test | Mat. Def. | Remarks                           |
| 3/8                         | QA10601       | x         |                |                 |              | x           |           | Corrosion test duration 120 days. |
| ↑                           | QA10602       | x         |                |                 |              | x           |           |                                   |
|                             | QA10607       |           | 22,500         |                 |              |             |           |                                   |
|                             | QA10608       |           | 22,500         |                 |              |             |           |                                   |
| ↓                           | QA30601       | x         |                |                 |              | x           |           | Corrosion test duration 120 days. |
|                             | QA30602       | x         |                |                 |              | x           |           |                                   |
| ↓                           | QA30607       |           | 22,500         |                 |              |             |           |                                   |
| 3/8                         | QA30608       |           | 22,500         |                 |              |             |           |                                   |
| 1/2                         | QA10801       | x         |                |                 |              | x           |           | Corrosion test duration 120 days. |
| ↑                           | QA10802       | x         |                |                 |              | x           |           |                                   |
|                             | QA10806       |           | 22,500         |                 |              |             | x         |                                   |
|                             | QA10807       |           | 22,500         |                 |              |             | x         |                                   |
|                             | QA10808       |           | 22,500         |                 |              |             | x         |                                   |
|                             | QA30801       | x         |                |                 |              | x           |           | Corrosion test duration 120 days. |
|                             | QA30802       | x         |                |                 |              | x           |           |                                   |
|                             | QA30805       |           | 22,500         |                 |              |             | x         |                                   |
| ↓                           | QA30807       |           | 22,500         |                 |              |             | x         |                                   |
| 1/2                         | QA30808       |           | 22,500         |                 |              |             | x         |                                   |
| 3/4                         | QA11201       | x         |                |                 |              | x           |           |                                   |
| ↑                           | QA11202       | x         |                |                 |              | x           |           |                                   |
|                             | QA11207       |           | 22,500         |                 |              |             |           |                                   |
|                             | QA11208       |           | 22,500         |                 |              |             |           |                                   |
|                             | QA31201       | x         |                |                 |              | x           |           |                                   |
|                             | QA31202       | x         |                |                 |              | x           |           |                                   |
|                             | QA31207       |           | 22,500         |                 |              |             |           |                                   |
|                             | QA31208       |           | 22,500         |                 |              |             |           |                                   |
| ↓                           | CA31202       |           | 33,200         |                 |              |             | x         | Bent fitting. Fig. 21.            |
|                             | CA31205       |           | 33,200         |                 |              |             |           |                                   |
| 3/4                         | CA31206       |           |                |                 | 15,000       |             |           |                                   |

TABLE XI (Concluded)  
METALLOGRAPHIC EXAMINATION DATA

| Aeroquip Brazed Connections |                   |             |                            | Previous Tests         |      | Results           |                                                       |
|-----------------------------|-------------------|-------------|----------------------------|------------------------|------|-------------------|-------------------------------------------------------|
| O.D. Serial                 | Tube Number (in.) | Cor-ro-sion | Cor-Vibration Stress (psi) | LN <sub>2</sub> +500°F | Room | Corrosion Fatigue | Remarks                                               |
| 1                           | QA11601           | x           |                            |                        |      | x                 | Corrosion test duration 120 days.                     |
| 1                           | QA11602           | x           |                            |                        |      | x                 |                                                       |
| 1                           | QA11607           |             | 18,000                     |                        |      |                   |                                                       |
| 1                           | QA11608           |             | 18,000                     |                        |      |                   |                                                       |
| 1                           | QA31601           | x           |                            |                        |      | x                 | Corrosion test duration 120 days.                     |
| 1                           | QA31602           | x           |                            |                        |      | x                 | Leaked after corrosion test.                          |
| 1                           | QA31607           |             | 22,500                     |                        |      | x                 |                                                       |
| 1                           | QA31608           |             | 18,000                     |                        |      |                   | Fig. 30.                                              |
| 1 1/4                       | QA12001           | x           |                            |                        |      | x                 |                                                       |
| 1                           | QA12002           | x           |                            |                        |      | x                 |                                                       |
| 1                           | QA12005           |             | 18,000                     |                        |      |                   |                                                       |
| 1                           | QA12006           |             |                            |                        |      |                   | Braze voids. Fig. 31.                                 |
| 1                           | QA12007           |             |                            |                        |      |                   | Braze voids.                                          |
| 1                           | QA12008           |             | 18,000                     |                        |      |                   |                                                       |
| 1                           | QA32001           | x           |                            |                        |      | x                 |                                                       |
| 1                           | QA32002           | x           |                            |                        |      | x                 |                                                       |
| 1                           | QA32005           |             | 18,000                     |                        |      | x                 |                                                       |
| 1                           | QA32006           |             |                            |                        |      |                   |                                                       |
| 1                           | QA32007           |             |                            |                        |      |                   |                                                       |
| 1 1/4                       | QA32008           |             | 18,000                     |                        |      |                   |                                                       |
| 1 1/2                       | QA32401           | x           |                            |                        |      | x                 | Corrosion test duration 120 days.                     |
| 1                           | QA32402           | x           |                            |                        |      | x                 | Leaked after corrosion test.                          |
| 1                           | QA32405           |             | 20,000                     |                        |      | x                 | Braze void at fitting end.                            |
| 1                           | QA32406           |             | 18,000                     |                        |      |                   |                                                       |
| 1                           | QA32407           |             | 18,000                     |                        |      |                   |                                                       |
| 1                           | QA32408           |             | 18,000                     |                        |      |                   |                                                       |
| 1                           | CA32401           |             | 26,500                     |                        |      |                   |                                                       |
| 1                           | CA32402           |             | 26,500                     |                        |      |                   |                                                       |
| 1                           | CA32405           |             | 26,500                     |                        |      |                   |                                                       |
| 1                           | CA32406           |             |                            |                        |      |                   | Several braze voids, some at fitting end.             |
| 1                           | CA32407           |             |                            |                        |      | x                 | Tubing did not extend far enough into failed fitting. |
| 1 1/2                       | CA32408           |             |                            |                        |      |                   |                                                       |

TABLE XII  
METALLOGRAPHIC EXAMINATION DATA

GE Braze Connections

| O.D. Serial<br>Tube Number<br>(in.) | Previous Tests |                                |        | Results                 |         |                                                       |
|-------------------------------------|----------------|--------------------------------|--------|-------------------------|---------|-------------------------------------------------------|
|                                     | Cor-<br>rosion | Room<br>Vibration Stress (psi) | +500°F | Corrosion<br>Occurrence | Fatigue | Remarks                                               |
| 1/4 QG10401                         | x              |                                |        | x                       |         |                                                       |
| 1/4 QG10402                         | x              |                                |        | x                       |         |                                                       |
| 1/4 QG10403                         |                | 20,000                         |        |                         | x       |                                                       |
| 1/4 QG10404                         |                | 20,000                         |        |                         | x       |                                                       |
| 1/4 QG10405                         |                | 22,500                         |        |                         |         |                                                       |
| 1/4 QG10407                         |                |                                |        |                         | x       |                                                       |
| 1/4 QG10408                         |                |                                |        |                         |         |                                                       |
| 1/4 QG10409                         |                | 22,500                         |        |                         | x       |                                                       |
| 1/4 QG30401                         | x              |                                |        | x                       |         |                                                       |
| 1/4 QG30402                         | x              |                                |        | x                       |         |                                                       |
| 1/4 QG30403                         |                |                                | 15,000 |                         | x       |                                                       |
| 1/4 QG30404                         |                |                                | 15,000 |                         | x       |                                                       |
| 1/4 QG30407                         |                | 22,500                         |        |                         |         |                                                       |
| 1/4 QG30408                         |                | 22,500                         |        |                         | x       |                                                       |
| 1/4 CG30405                         |                | 33,200                         |        |                         | x       | Fig. 26.                                              |
| 1/4 CG30406                         |                |                                | 19,500 |                         | x       |                                                       |
| 1/4 CG30407                         |                |                                | 19,500 |                         | x       |                                                       |
| 1/4 CG30408                         |                |                                | 19,500 |                         | x       |                                                       |
| 3/4 QG11201                         | x              |                                |        | x                       |         | Figs. 18, 19, & 20.                                   |
| 3/4 QG11202                         | x              |                                |        | x                       |         |                                                       |
| 3/4 QG11207                         |                | 22,500                         |        |                         |         | Tubing misfit.                                        |
| 3/4 QG11208                         |                | 22,500                         |        |                         |         | Tubing misfit. Fig. 24.                               |
| 3/4 QG31201                         | x              |                                |        | x                       |         |                                                       |
| 3/4 QG31202                         | x              |                                |        | x                       |         |                                                       |
| 3/4 QG31207                         |                | 22,500                         |        |                         |         | String of braze defects.                              |
| 3/4 QG31208                         |                | 22,500                         |        |                         |         |                                                       |
| 3/4 CG31205                         |                | 33,200                         |        |                         |         |                                                       |
| 3/4 CG31206                         |                |                                | 15,000 |                         |         |                                                       |
| 1 1/4 QG12001                       | x              |                                |        | x                       |         |                                                       |
| 1 1/4 QG12002                       | x              |                                |        | x                       |         |                                                       |
| 1 1/4 QG12005                       |                | 18,000                         |        |                         |         |                                                       |
| 1 1/4 QG12006                       |                | 18,000                         |        |                         | x       | Tube separated from fitting at braze in tensile test. |

TABLE XII (Concluded)  
METALLOGRAPHIC EXAMINATION DATA

GE Brazed Connections

| O.D. Tube (in.) | Serial Number | Previous Tests |                |                                     | Results            |               |                            |
|-----------------|---------------|----------------|----------------|-------------------------------------|--------------------|---------------|----------------------------|
|                 |               | Corrosion      | Vibration Room | Stress (psi) LN <sub>2</sub> +500°F | Corrosion Occurred | Fatigue Crack | Remarks                    |
| 1 1/4           | QG12007       |                | 18,000         |                                     |                    |               |                            |
| ↑               | QG12008       |                | 18,000         |                                     |                    |               |                            |
|                 | QG32001       | x              |                |                                     | x                  |               |                            |
|                 | QG32002       | x              |                |                                     | x                  |               |                            |
|                 | QG32005       |                |                | 15,000                              |                    | x             |                            |
|                 | QG32006       |                |                | ↑                                   |                    |               | Had a braze void. Fig. 32. |
| ↓               | QG32007       |                |                | ↓                                   |                    |               |                            |
|                 | QG32008       |                |                |                                     |                    | x             |                            |
| 1 1/4           | QG32009       |                |                | 15,000                              |                    |               |                            |

TABLE XIII  
METALLOGRAPHIC EXAMINATION DATA

MSFC Welded Connections

| O.D. Tube (in.) | Serial Number | Previous Tests |                |                                     | Results            |               |          |
|-----------------|---------------|----------------|----------------|-------------------------------------|--------------------|---------------|----------|
|                 |               | Corrosion      | Vibration Room | Stress (psi) LN <sub>2</sub> +500°F | Corrosion Occurred | Fatigue Crack | Remarks  |
| 1/4             | QS10401       | x              |                |                                     |                    |               |          |
| ↑               | QS10402       | x              |                |                                     |                    |               |          |
|                 | QS10407       |                | 22,500         |                                     |                    |               |          |
|                 | QS10408       |                | 22,500         |                                     |                    |               |          |
|                 | QS30401       | x              |                |                                     |                    |               |          |
|                 | QS30402       | x              |                |                                     |                    |               |          |
|                 | QS30407       |                | 22,500         |                                     |                    |               |          |
|                 | QS30408       |                | 22,500         |                                     |                    |               |          |
|                 | CS30409       |                |                | 33,200                              |                    |               |          |
| ↓               | CS30410       |                |                | 33,200                              |                    |               |          |
|                 | CS30419       |                |                | 19,500                              |                    | x             | Fig. 27. |
| 1/4             | CS30420       |                |                | 19,500                              |                    | x             |          |
| 3/8             | QS10601       | x              |                |                                     |                    |               |          |
| 3/8             | QS10602       | x              |                |                                     |                    |               |          |
| 3/8             | QS10607       |                | 22,500         |                                     |                    |               |          |

TABLE XIII (Continued)  
METALLOGRAPHIC EXAMINATION DATA

| MSFC Welded Connections |               |           |        | Previous Tests         |                        | Results            |                                       |
|-------------------------|---------------|-----------|--------|------------------------|------------------------|--------------------|---------------------------------------|
| O.D. Tube (in.)         | Serial Number | Corrosion | Room   | Vibration Stress (psi) | LN <sub>2</sub> +500°F | Corrosion Occurred | Remarks                               |
| 3/8                     | QS10608       |           | 22,500 |                        |                        |                    |                                       |
|                         | QS30601       | x         |        |                        |                        |                    |                                       |
|                         | QS30602       | x         |        |                        |                        |                    |                                       |
|                         | QS30607       |           | 22,500 |                        |                        |                    |                                       |
| 1/2                     | QS10801       | x         |        |                        |                        |                    |                                       |
|                         | QS10802       | x         |        |                        |                        |                    |                                       |
|                         | QS10806       |           | 22,500 |                        |                        | x                  |                                       |
|                         | QS10807       |           | 22,500 |                        |                        | x                  |                                       |
|                         | QS10808       |           | 22,500 |                        |                        | x                  |                                       |
|                         | QS30801       | x         |        |                        |                        |                    |                                       |
|                         | QS30802       | x         |        |                        |                        |                    |                                       |
|                         | QS30807       |           | 22,500 |                        |                        | x                  |                                       |
| 1/2                     | QS30808       |           | 22,500 |                        |                        |                    |                                       |
|                         | QS11201       | x         |        |                        |                        |                    | Carbide precipitation at weld.        |
|                         | QS11202       | x         |        |                        |                        |                    | Off-center weld. Fig. 23.             |
|                         | QS11207       |           | 22,500 |                        |                        |                    |                                       |
| 3/4                     | QS11208       |           | 22,500 |                        |                        |                    |                                       |
|                         | QS31201       | x         |        |                        |                        |                    | Carbide precipitation at weld.        |
|                         | QS31202       | x         |        |                        |                        |                    | Weld defect.                          |
|                         | QS31207       |           | 22,500 |                        |                        | x                  |                                       |
|                         | QS31208       |           | 22,500 |                        |                        |                    | Poor weld fusion - misaligned.        |
|                         | CS31202       | x         |        |                        |                        |                    |                                       |
|                         | CS31205       |           | 33,200 |                        |                        | x                  |                                       |
|                         | CS31206       |           | 15,000 |                        |                        | x                  | Poor weld fusion - misaligned.        |
| 1                       | QS11601       | x         |        |                        |                        |                    | Small cracks in weld.                 |
|                         | QS11602       | x         |        |                        |                        |                    | Porous weld caused leak test failure. |
|                         | QS11607       |           | 18,000 |                        |                        |                    |                                       |
|                         | QS11608       |           | 18,000 |                        |                        |                    |                                       |
|                         | QS31601       | x         |        |                        |                        |                    | Small cracks in weld.                 |
|                         | QS31602       | x         |        |                        |                        |                    |                                       |
|                         | QS31607       |           | 18,000 |                        |                        |                    |                                       |
|                         | QS31608       |           | 18,000 |                        |                        |                    |                                       |

TABLE XIII (Concluded)  
METALLOGRAPHIC EXAMINATION DATA

| MSFC Welded Connections             |                     |                   | Previous Tests  |                        |                       | Results          |                                                          |
|-------------------------------------|---------------------|-------------------|-----------------|------------------------|-----------------------|------------------|----------------------------------------------------------|
| O.D. Serial<br>Tube Number<br>(in.) | Cor-<br>ro-<br>sion | Room<br>Vibration | LN <sub>2</sub> | +500°F<br>Stress (psi) | Corrosion<br>Occurred | Fatigue<br>Crack | Remarks                                                  |
| 11/4                                | QS12001             | x                 |                 |                        |                       |                  |                                                          |
| ↑                                   | QS12002             | x                 |                 |                        |                       |                  |                                                          |
|                                     | QS12005             |                   | 18,000          |                        |                       | x                | Crack started at weld overlap.                           |
|                                     | QS12006             |                   | 22,500          |                        |                       | x                | Crack started at weld overlap.                           |
|                                     | QS12007             |                   | 22,500          |                        |                       | x                |                                                          |
|                                     | QS12008             |                   | 18,000          |                        |                       |                  | Fig. 34.                                                 |
|                                     | QS12010             |                   | 18,000          |                        |                       | x                | Two cracks, misaligned.                                  |
|                                     | QS32001             | x                 |                 |                        |                       |                  |                                                          |
|                                     | QS32002             | x                 |                 |                        |                       |                  |                                                          |
|                                     | QS32005             |                   | 18,000          |                        |                       | x                |                                                          |
|                                     | QS32006             | ↑                 |                 |                        |                       |                  | Lack of fusion in weld - 3 places.                       |
|                                     | QS32007             |                   |                 |                        |                       | x                | Off-center weld, Fig. 22.                                |
| ↓                                   | QS32008             |                   |                 |                        |                       |                  |                                                          |
| 11/4                                | QS32009             |                   | 18,000          |                        |                       | x                | Poor weld.                                               |
| 11/2                                | QS12401             | x                 |                 |                        |                       | x                | Leaked after corrosion test - porous weld. Crater crack. |
| ↑                                   | QS12402             | x                 |                 |                        |                       |                  |                                                          |
|                                     | QS12405             |                   | 18,000          |                        |                       | x                | Tubing misaligned. Crack started at weld overlap.        |
|                                     | QS12407             |                   | 18,000          |                        |                       |                  |                                                          |
|                                     | QS12408             |                   | 18,000          |                        |                       |                  |                                                          |
|                                     | QS32401             | x                 |                 |                        |                       |                  | Weld cracks in fusion zone.                              |
|                                     | QS32402             | x                 |                 |                        |                       |                  |                                                          |
|                                     | QS32405             |                   | 18,000          |                        |                       | x                | Weld misaligned, lacked fusion.                          |
|                                     | QS32407             |                   | 18,000          |                        |                       |                  |                                                          |
|                                     | QS32408             |                   | 18,000          |                        |                       |                  | Tubing misaligned. Crack started at weld overlap.        |
|                                     | CS32401             |                   | 26,500          |                        |                       |                  | Off-center weld.                                         |
|                                     | CS32402             |                   | 26,500          |                        |                       |                  | Off-center weld.                                         |
|                                     | CS32405             |                   | 26,500          |                        |                       |                  | Minor misaligned weld and minor lack of fusion.          |
|                                     | CS32406             |                   | 13,000          |                        |                       |                  | Fig. 35.                                                 |
|                                     | CS32407             |                   | 17,600          |                        |                       | x                | Fig. 28.                                                 |
| ↓                                   | CS32408             |                   | 16,300          |                        |                       |                  |                                                          |
| 11/2                                | CS32410             |                   | 16,300          |                        |                       | x                | Fig. 29.                                                 |

Burst Pressure Test Data  
Tables XIV through XVI

Requirement:

Pressurization of the tube connections to four times the operating pressure without rupture (2.5 times operating pressure for 1 1/2 inch size). The maximum test pressure attainable with the equipment used was 20,000 psig. In many tests, leakage in the test equipment or the test specimen endplugs were the cause of test termination before reaching either 20,000 psig or the rupture pressure. No specimens failed.

TABLE XIV  
BURST PRESSURE TEST DATA (At Room Temperature)

Aeroquip Brazed Connections

| O.D.<br>Tube<br>(in.) | Serial<br>Number | Operating<br>Pressure<br>(psig) |      | Rupture<br>Pressure<br>(psig) | Max. Press.<br>Applied<br>(Did not burst) | Previous Vibration Test<br>Stress (psi) |                  | Location of Rupture |
|-----------------------|------------------|---------------------------------|------|-------------------------------|-------------------------------------------|-----------------------------------------|------------------|---------------------|
|                       |                  | 1500                            | 3000 |                               |                                           | None                                    | +500° F Room LN2 |                     |
| 1/4                   | QA10409          | x                               |      | 16,600                        |                                           |                                         | 22,500           | Fitting             |
| 1/4                   | QA10410          | x                               |      | 18,200                        |                                           |                                         |                  |                     |
| 3/8                   | QA30409          |                                 | x    | 18,000                        |                                           |                                         |                  |                     |
| 3/8                   | QA30410          |                                 | x    | 18,400                        |                                           |                                         | 22,500           |                     |
| 1/4                   | QA30403          |                                 | x    | 18,000                        |                                           |                                         | 33,200           |                     |
| 1/4                   | QA30404          |                                 | x    | 18,800                        |                                           |                                         | 33,200           | Fitting             |
| 3/8                   | QA10603          | x                               |      |                               | 17,400                                    |                                         |                  |                     |
| 3/8                   | QA10604          | x                               |      |                               | 20,000                                    | x                                       |                  |                     |
| 3/8                   | QA10609          | x                               |      |                               | 19,000                                    |                                         | 22,500           |                     |
| 3/8                   | QA30603          |                                 | x    |                               | 19,800                                    |                                         |                  |                     |
| 3/8                   | QA30604          |                                 | x    |                               | 20,000                                    | x                                       |                  |                     |
| 3/8                   | QA30609          |                                 | x    | 19,500                        |                                           |                                         | 22,500           | Fitting             |
| 1/2                   | QA10803          | x                               |      | 18,000                        |                                           |                                         |                  | Tubing              |
| 1/2                   | QA10804          | x                               |      | 18,000                        |                                           | x                                       |                  | Tubing              |
| 1/2                   | QA30803          |                                 | x    |                               | 19,000                                    | x                                       |                  |                     |
| 1/2                   | QA30804          |                                 | x    | 19,600                        |                                           | x                                       |                  | Fitting             |
| 1/2                   | QA30809          |                                 | x    | 19,500                        |                                           |                                         | 22,500           | Fitting             |
| 3/4                   | QA11203          | x                               |      |                               | 16,800                                    | x                                       | 22,500           |                     |
| 3/4                   | QA11204          | x                               |      |                               | 17,900                                    | x                                       |                  |                     |
| 3/4                   | QA11209          | x                               |      | 17,400                        |                                           |                                         | 22,500           | Tubing              |

TABLE XIV (Concluded)  
BURST PRESSURE TEST DATA (At Room Temperature)

Aeroquip Brazed Connections

| O.D.<br>Tube<br>(in.) | Serial<br>Number | Operating<br>Pressure<br>(psig) |      | Rupture<br>Pressure<br>(psig) | Max. Press.<br>Applied<br>(Did not burst)<br>(psig) | Previous Vibration Test<br>Stress (psi) |        |        | Location of Rupture               |
|-----------------------|------------------|---------------------------------|------|-------------------------------|-----------------------------------------------------|-----------------------------------------|--------|--------|-----------------------------------|
|                       |                  | 1500                            | 3000 |                               |                                                     | None                                    | +500°F | Room   |                                   |
| 3/4                   | QA11210          | x                               |      | 17,500                        |                                                     |                                         |        | 22,500 | Tubing                            |
|                       | QA31203          |                                 | x    |                               | 17,100                                              | x                                       |        |        |                                   |
|                       | QA31204          |                                 | x    |                               | 17,000                                              | x                                       |        |        |                                   |
|                       | CA31203          |                                 | x    |                               | 20,000                                              |                                         |        | 33,200 |                                   |
|                       | CA31204          |                                 | x    |                               |                                                     |                                         |        | 33,200 |                                   |
|                       | CA31209          |                                 | x    |                               |                                                     |                                         | 15,000 |        |                                   |
| 3/4                   | CA31210          |                                 | x    |                               | 20,000                                              |                                         | 15,000 |        |                                   |
| 1                     | QA11603          | x                               |      |                               | 9,400                                               | x                                       |        |        |                                   |
|                       | QA11604          | x                               |      |                               | 9,300                                               | x                                       |        |        |                                   |
|                       | QA11609          | x                               |      |                               | 12,000                                              |                                         |        | 18,000 |                                   |
|                       | QA31603          |                                 | x    |                               | 14,000                                              | x                                       |        |        |                                   |
|                       | QA31604          |                                 | x    |                               | 17,900                                              | x                                       |        |        |                                   |
|                       | QA31609          |                                 | x    |                               | 13,600                                              |                                         |        |        |                                   |
| 1                     | QA31610          |                                 | x    |                               | 12,000                                              |                                         |        |        |                                   |
| 1 1/4                 | QA12003          | x                               |      |                               | 10,400                                              | x                                       |        |        |                                   |
|                       | QA12004          | x                               |      |                               | 13,900                                              | x                                       |        |        |                                   |
|                       | QA12009          | x                               |      | 13,000                        |                                                     |                                         |        | 18,000 | End plug                          |
|                       | QA12010          | x                               |      | 13,250                        |                                                     |                                         |        | 18,000 | End plug                          |
|                       | QA32003          |                                 | x    |                               | 17,600                                              | x                                       |        |        |                                   |
|                       | QA32004          |                                 | x    |                               | 14,600                                              | x                                       |        |        |                                   |
|                       | QA32009          |                                 | x    |                               | 20,000                                              |                                         |        | 18,000 |                                   |
| 1 1/4                 | QA32010          |                                 | x    | 19,500                        |                                                     |                                         |        | 18,000 | End plug                          |
| 1 1/2                 | QA32403          |                                 | x    | -----                         |                                                     | x                                       |        |        | Burst pressure test not performed |
|                       | QA32404          | x                               |      | 14,300                        |                                                     | x                                       |        |        | End plug                          |
|                       | QA32409          | x                               |      | 13,600                        |                                                     |                                         |        | 18,000 | End plug                          |
|                       | QA32410          | x                               |      | 13,500                        |                                                     |                                         |        | 18,000 | End plug                          |
|                       | CA32403          | x                               |      | 15,400                        |                                                     |                                         |        | 26,500 | Fitting                           |
|                       | CA32404          | x                               |      | 14,600                        |                                                     |                                         |        | 26,500 | Fitting                           |
|                       | CA32409          | x                               |      | 15,100                        |                                                     |                                         | 15,000 |        | Fitting                           |
| 1 1/2                 | CA32410          | x                               |      | 14,600                        |                                                     |                                         | 15,000 |        | End plug                          |

TABLE XV  
BURST PRESSURE TEST DATA (At Room Temperature)

GE Brazed Connections

| O.D.<br>Tube<br>(in.) | Serial<br>Number | Operating<br>Pressure<br>(psig) |      | Rupture<br>Pressure<br>(psig) | Max. Press.<br>Applied<br>(Did not burst)<br>(psig) | Previous Vibration Test<br>Stress (psi) |                  | Location of Rupture |
|-----------------------|------------------|---------------------------------|------|-------------------------------|-----------------------------------------------------|-----------------------------------------|------------------|---------------------|
|                       |                  | 1500                            | 3000 |                               |                                                     | None                                    | +500° F Room LN2 |                     |
| 1/4                   | QG10410          | x                               |      | 20,000                        |                                                     |                                         | 22,500           | Tubing              |
|                       | QG30409          |                                 | x    |                               | 20,000                                              |                                         | 22,500           |                     |
|                       | QG30410          |                                 | x    |                               |                                                     |                                         | 22,500           |                     |
|                       | CG30403          |                                 | x    |                               |                                                     |                                         | 33,200           |                     |
| 1/4                   | CG30404          |                                 | x    |                               | 20,000                                              |                                         | 33,200           |                     |
| 3/4                   | QG11203          | x                               |      |                               | 15,000                                              | x                                       |                  |                     |
|                       | QG11204          | x                               |      |                               | 14,400                                              | x                                       |                  |                     |
|                       | QG11209          | x                               |      | 17,900                        |                                                     |                                         | 22,500           | Tubing              |
|                       | QG11210          | x                               |      | 17,500                        |                                                     |                                         | 22,500           | Tubing              |
|                       | QG31203          |                                 | x    | 15,300                        |                                                     | x                                       |                  |                     |
|                       | QG31204          |                                 | x    |                               | 15,900                                              | x                                       |                  |                     |
|                       | CG31203          |                                 | x    |                               | 20,000                                              |                                         | 33,200           |                     |
|                       | CG31204          |                                 | x    |                               |                                                     |                                         | 33,200           |                     |
| 3/4                   | CG31209          |                                 | x    |                               |                                                     |                                         | 15,000           |                     |
|                       | CG31210          |                                 | x    |                               | 20,000                                              |                                         | 15,000           |                     |
|                       | QG12003          | x                               |      |                               | 8,500                                               | x                                       |                  |                     |
|                       | QG12004          | x                               |      |                               | 8,500                                               | x                                       |                  |                     |
| 1 1/4                 | QG12009          | x                               |      | 14,200                        |                                                     |                                         | 18,000           | End plug            |
|                       | QG12010          | x                               |      | 13,800                        |                                                     |                                         | 18,000           | End plug            |
|                       | QG32003          |                                 | x    | 12,800                        |                                                     | x                                       |                  |                     |
|                       | QG32004          |                                 | x    |                               | 13,300                                              | x                                       |                  |                     |
| 1 1/4                 | QG32009          |                                 | x    | 18,500                        |                                                     |                                         | 15,000           | End plug            |
|                       | QG32010          |                                 | x    | 18,800                        |                                                     |                                         | 15,000           | End plug            |
|                       |                  |                                 |      |                               |                                                     |                                         |                  |                     |
|                       |                  |                                 |      |                               |                                                     |                                         |                  |                     |

TABLE XVI  
BURST PRESSURE TEST DATA (At Room Temperature)

| MSFC Welded Connections |               | Operating Pressure (psig) |      | Rupture Pressure (psig) | Max. Press. Applied (Did not burst) | Previous Vibration Test Stress (psi) |              |        | Location of Rupture |
|-------------------------|---------------|---------------------------|------|-------------------------|-------------------------------------|--------------------------------------|--------------|--------|---------------------|
| O.D. Tube (in.)         | Serial Number | 1500                      | 3000 |                         |                                     | None                                 | +500° F Room | LN2    |                     |
| 1/4                     | QS10403       | x                         |      |                         | 20,000                              | x                                    |              |        | Tubing              |
|                         | QS10404       | x                         |      | 20,000                  |                                     | x                                    |              |        |                     |
|                         | QS10409       | x                         |      |                         | 20,000                              |                                      | 22,500       |        |                     |
|                         | QS10410       | x                         |      |                         |                                     |                                      | 22,500       |        |                     |
|                         | QS30403       |                           | x    |                         |                                     | x                                    |              |        |                     |
|                         | QS30404       |                           | x    |                         |                                     | x                                    |              |        |                     |
|                         | QS30409       |                           | x    |                         |                                     |                                      | 22,500       |        |                     |
|                         | QS30410       |                           | x    |                         |                                     |                                      | 22,500       |        |                     |
|                         | CS30405       |                           | x    |                         |                                     |                                      |              | 33,200 |                     |
|                         | CS30406       |                           | x    |                         |                                     |                                      |              |        |                     |
|                         | CS30407       |                           | x    |                         |                                     |                                      |              |        |                     |
|                         | CS30408       |                           | x    |                         |                                     |                                      |              | 33,200 |                     |
|                         | CS30415       |                           | x    |                         |                                     |                                      | 19,500       |        |                     |
|                         | CS30416       |                           | x    |                         |                                     |                                      |              |        |                     |
|                         | CS30417       |                           | x    |                         |                                     |                                      |              |        |                     |
| 1/4                     | CS30418       |                           | x    |                         |                                     |                                      | 19,500       |        |                     |
| 3/8                     | QS10603       | x                         |      |                         |                                     | x                                    |              |        |                     |
|                         | QS10604       | x                         |      |                         |                                     | x                                    |              |        |                     |
|                         | QS10609       | x                         |      |                         |                                     |                                      | 22,500       |        |                     |
|                         | QS10610       | x                         |      |                         |                                     |                                      | 22,500       |        |                     |
|                         | QS30603       |                           | x    |                         |                                     | x                                    |              |        |                     |
|                         | QS30604       |                           | x    |                         |                                     | x                                    |              |        |                     |
|                         | QS30609       |                           | x    |                         | 20,000                              |                                      | 22,500       |        |                     |
| 3/8                     | QS30610       |                           | x    |                         | 19,000                              |                                      | 22,500       |        |                     |
|                         | QS10803       | x                         |      | 18,600                  |                                     | x                                    |              |        | Tubing              |
| 1/2                     | QS10804       | x                         |      | 18,400                  |                                     | x                                    |              |        | Tubing              |
|                         | QS10809       | x                         |      | 19,400                  |                                     |                                      | 22,500       |        |                     |
|                         | QS10810       | x                         |      | 19,200                  |                                     |                                      | 22,500       |        |                     |
|                         | QS30803       |                           | x    |                         | 20,000                              | x                                    |              |        |                     |
| 1/2                     | QS30804       |                           | x    |                         | 19,400                              | x                                    |              |        |                     |

TABLE XVI (Continued)  
BURST PRESSURE TEST DATA (At Room Temperature)

| MSFC Welded |         | Connections |   | O.D. Tube<br>(in.) | Serial<br>Number | Operating<br>Pressure<br>(psig) |        | Rupture<br>Pressure<br>(psig) | Max. Press.<br>Applied<br>(Did not burst)<br>(psig) | Previous Vibration Test<br>Stress (psi) |        |  | Location of Rupture |
|-------------|---------|-------------|---|--------------------|------------------|---------------------------------|--------|-------------------------------|-----------------------------------------------------|-----------------------------------------|--------|--|---------------------|
|             |         |             |   |                    |                  | None                            | +500°F |                               |                                                     | Room                                    | LN2    |  |                     |
|             |         |             |   |                    |                  |                                 |        |                               |                                                     |                                         |        |  |                     |
| 1/2         | QS30809 |             | x |                    |                  |                                 |        |                               | 20,000                                              |                                         | 22,500 |  |                     |
| 1/2         | QS30810 |             | x |                    |                  |                                 |        |                               | 20,000                                              |                                         | 22,500 |  |                     |
| 3/4         | QS11203 |             | x |                    |                  |                                 |        |                               | 16,100                                              | x                                       |        |  |                     |
|             | QS11204 |             | x |                    |                  |                                 |        |                               | 12,400                                              | x                                       |        |  |                     |
|             | QS11209 |             | x |                    |                  |                                 |        | 18,500                        |                                                     |                                         | 22,500 |  | Tubing              |
|             | QS11210 |             | x |                    |                  |                                 |        | 18,250                        |                                                     |                                         | 22,500 |  | Tubing              |
|             | QS31203 |             |   | x                  |                  |                                 |        |                               | 14,900                                              | x                                       |        |  |                     |
|             | QS31204 |             |   | x                  |                  |                                 |        |                               | 15,900                                              | x                                       |        |  |                     |
|             | QS31209 |             |   | x                  |                  |                                 |        |                               | 20,000                                              |                                         | 22,500 |  |                     |
|             | QS31210 |             |   | x                  |                  |                                 |        |                               |                                                     |                                         | 22,500 |  |                     |
|             | CS31203 |             |   | x                  |                  |                                 |        |                               |                                                     | x                                       |        |  |                     |
|             | CS31204 |             |   | x                  |                  |                                 |        |                               |                                                     | x                                       |        |  |                     |
|             | CS31209 |             |   | x                  |                  |                                 |        |                               |                                                     |                                         | 15,000 |  |                     |
| 3/4         | CS31210 |             |   | x                  |                  |                                 |        |                               | 20,000                                              |                                         | 15,000 |  |                     |
| 1           | QS11603 |             | x |                    |                  |                                 |        |                               | 10,200                                              | x                                       |        |  |                     |
|             | QS11604 |             | x |                    |                  |                                 |        |                               | 12,500                                              | x                                       |        |  |                     |
|             | QS11610 |             | x |                    |                  |                                 |        |                               | 17,200                                              |                                         | 18,000 |  |                     |
|             | QS31603 |             |   | x                  |                  |                                 |        |                               | 15,700                                              | x                                       |        |  |                     |
|             | QS31604 |             |   | x                  |                  |                                 |        |                               | 13,900                                              | x                                       |        |  |                     |
|             | QS31609 |             |   | x                  |                  |                                 |        |                               | 12,900                                              |                                         | 18,000 |  |                     |
| 1           | QS31610 |             |   | x                  |                  |                                 |        |                               | 17,000                                              |                                         | 18,000 |  |                     |
| 1 1/4       | QS12003 |             | x |                    |                  |                                 |        |                               | 12,400                                              | x                                       |        |  |                     |
|             | QS12004 |             | x |                    |                  |                                 |        |                               | 8,600                                               | x                                       |        |  |                     |
|             | QS12009 |             | x |                    |                  |                                 |        |                               | 17,200                                              |                                         | 18,000 |  |                     |
|             | QS32003 |             |   | x                  |                  |                                 |        |                               | 12,700                                              | x                                       |        |  |                     |
|             | QS32004 |             |   | x                  |                  |                                 |        |                               | 13,300                                              | x                                       |        |  |                     |
| 1 1/4       | QS32010 |             |   | x                  |                  |                                 |        |                               | 20,000                                              |                                         |        |  |                     |
| 1 1/2       | QS12403 |             | x |                    |                  |                                 |        |                               | 9,200                                               | x                                       |        |  |                     |
| 1 1/2       | QS12404 |             | x |                    |                  |                                 |        |                               | 6,800                                               | x                                       |        |  |                     |
| 1 1/2       | QS12409 |             | x |                    |                  |                                 |        | 14,500                        |                                                     |                                         |        |  | End plug            |

TABLE XVI (Concluded)  
BURST PRESSURE TEST DATA (At Room Temperature)

[illegible]

## APPENDIX A

### TEST PROCEDURE FOR BRAZED AND WELDED TUBE CONNECTION TEST PROGRAM

#### A. Purpose

Evaluate the ability of the brazed and welded tube connections to meet space vehicle requirements. Obtain a comparison of fabricating procedures developed by Aeroquip Corporation and General Electric Corporation (brazed connections) and by R-ME-MW (welded connections).

#### B. Test Hardware

Table A-I lists the test hardware. The connections will be fabricated by R-ME-MW. Divide the test hardware into two sections, thin wall for a working pressure of 1500 psig, and thick wall for a working pressure of 3000 psig. The tubing is 1/8 hard, Type 321 stainless steel.

#### C. Test Sequence

The test sequence is shown in Figures A-1 and A-2. The number of connections experiencing each test is also detailed. Test and analysis of all 1/4-inch connections (100 each) will be completed before testing other sizes.

#### D. Nomenclature

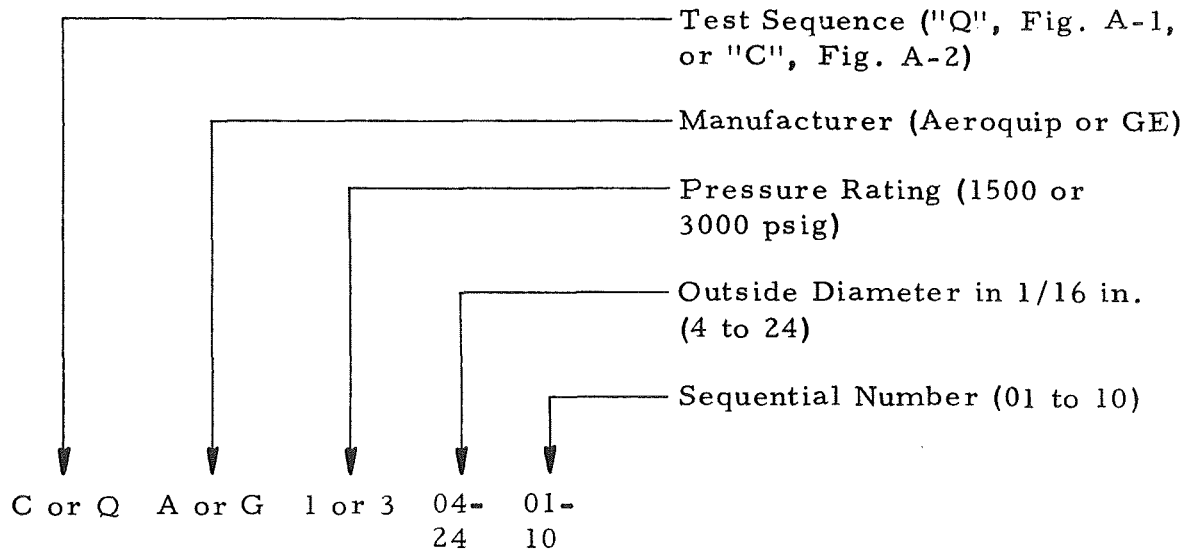
The following nomenclature for pressures will govern throughout this test:

| Nomenclature             | Connection Type         |                |                         |           |
|--------------------------|-------------------------|----------------|-------------------------|-----------|
|                          | Thin Wall               |                | Thick Wall              |           |
|                          | Under<br>1 1/2 in. Dia. | 1 1/2 in. Dia. | Under<br>1 1/2 in. Dia. | 1 1/2 in. |
| Working<br>Press. (psig) | 1500                    | 1500           | 3000                    | 3000      |
| Proof<br>Press. (psig)   | 3000                    | 2250           | 6000                    | 4500      |
| Burst<br>Press. (psig)   | 6000                    | 3750           | 12000                   | 7500      |

## E. Test Specimen Identification Code

Table A-I lists the quantity of connections of each size and wall thickness. The sequence of tests ("Q" or "C") of each connection group is also indicated. Each test connection will be identified as illustrated below:

### 1. Brazed Connections



Example: QA10801

Q - Test Per Test Sequence "Q"

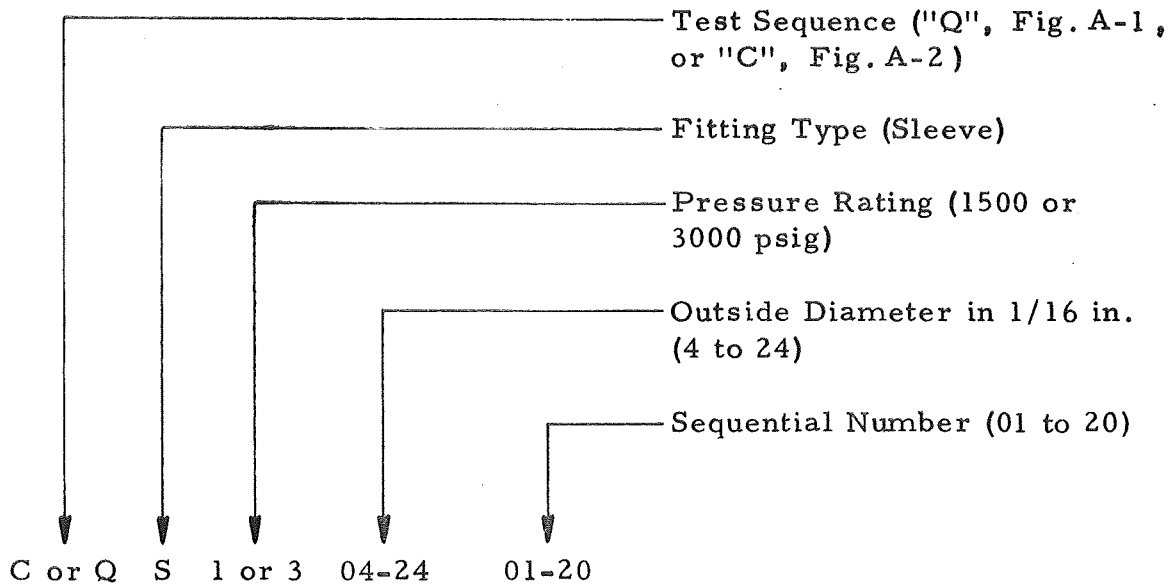
A - Aeroquip Fitting

1 - 1500 psig (thin wall)

08 - 1/2 in. O.D.

01 - First Specimen

## 2. Welded Connections



Example: CS31207

C - Test Per Test Sequence "C"

S - Sleeve Joint

3 - 3000 psig (Thick Wall)

12 - 3/4 in. O.D.

07 - Seventh Specimen

### F. Failure

1. A test connection will be considered to have failed if it leaks or if damage occurs (as a result of testing) that impairs its use as a tubing connection, except as a result of destructive test.

2. If a connection fails, remove it from test and subject it to visual and metallurgical inspections. Record findings of inspection, emphasizing any differences between failed and adequate connections.

### G. Assembly

1. Flare tube ends of each test connection (except as noted in G.3) with Leonard Flaring Machine or orbital adapter. Fittings may be welded to the ends of larger sizes.

2. Establish proper machine settings with non-test tubing prior to flaring test hardware.

3. Reserve connection No. 1 and No. 2 of each group scheduled for test per Figure A-1 for corrosion test. Do not flare tube ends of these connections. Cut to proper length as required by R-P&VE-MMC.

## H. Procedure

### 1. Corrosion Test (R-P&VE-MMC)

- a. Immerse connections in 3.5 per cent sodium chloride solution for 10 minutes.
- b. Withdraw connections from solution for 50 minutes.
- c. Repeat immersion-withdrawal cycle for 180 days.
- d. After completion of test, subject to metallographic inspection. (Paragraph H.13)

### 2. Storage Test

- a. Perform Proof Pressure Test of Paragraph H.3 and Leak Test of Paragraph H.4 on connection No. 3 and No. 4 of each group.
- b. Place connection No. 3 and No. 4 in outdoor storage.
- c. After 12 months, remove connections from storage, visually inspect and perform Leak Test per Paragraph H.4.
- d. Return connections to storage for remaining 12 months.
- e. At end of 24 months, remove connections from storage, visually inspect, perform Leak Test per Paragraph H.4 and then Burst Test per Paragraph H.14.

### 3. Proof Pressure Test

- a. Assemble connections of each test group in setup of Figure A-3.
- b. Pressurize with dry air of  $\text{GN}_2$  to proof pressure specified in Paragraph D.
- c. Monitor proof pressure for five minutes.
- d. Relieve pressure, inspect for distortion or physical damage.
- e. Perform Leak Test per Paragraph H.4.

4. Leak Test. This shall be performed per one of the test setups shown in Figure A-4 with (a) the Mass Spectrometer Method preferred, and (b) the Water Displacement Method used as an alternate method. Eliminate leakage of non-test joints by any means available, such as copper crush washers or Teflon dispersion sealing compound.

a. Mass Spectrometer Method

(1) Attach connection to mass spectrometer to subject tubing interior to high vacuum.

(2) Apply helium gas to exterior of each connection separately.

b. Water Displacement Method

(1) Pressurize connection assembly with helium to 10 psig and submerge in water.

(2) Increase pressure to value of Paragraph D (working pressure) and collect leakage bubbles from each connection for 20 minutes. Depressurize.

5. Extended Pressurization

a. Install connection in test setup per Figure A-3.

b. Pressurize connection to working pressure of Paragraph D and maintain for 72 hours. Depressurize.

c. Perform Leak Test per Paragraph H.4.

6. LN<sub>2</sub> Temperature Soak Test

a. Pressurize connection to 10 psig with helium and submerge in LN<sub>2</sub> tank as shown in Figure A-5.

b. Increase to value of working pressure in Paragraph D. Supply constant pressure to connection for 30 minutes while temperature stabilizes.

c. Maintain pressure for 30 additional minutes. Depressurize.

d. Perform Leak Test per Paragraph H.4.

## 7. 500 °F Temperature Soak Test

- a. Assemble setup of Figure A-6.
- b. Pressurize with helium to 500 psig and increase oven temperature to 500 °F.
- c. After oven temperature reaches 500 °F, pressurize to working pressure as shown in Paragraph D. Supply constant pressure (or vent) for 30 minutes while temperature stabilizes.
- d. Maintain pressure for 30 additional minutes. Depressurize.
- e. Perform Leak Test per Paragraph H.4.

## 8. Vibration Test At Room Temperature

- a. Install a single connection per one of the setups of Figure A-7.
- b. Subject the connection to sinusoidal vibration. Scan the frequency range at low level input to determine the primary resonant frequency.
- c. Slide the adjustable weights to obtain equal output from each of the two strain gages adjacent to the fitting.
- d. Pressurize with gaseous nitrogen to working pressure as shown in Paragraph D and lock in pressure.
- e. Start vibrator and monitor readout from strain gages. Increase force input from vibrator until a peak stress value of 22,500 psi is indicated on the strain gages. (Note: This is equivalent to 865 microinches/inch strain, using a value of 26,000,000 for the modulus of elasticity).
- f. Vibrate for a total of 300,000 cycles. Depressurize.
- g. Perform Leak Test per Paragraph H.4.

## 9. Impulse Test

- a. Assemble setup of Figure A-8.
- b. Using hydraulic oil, subject test assembly to 1000 impulse cycles at 35 cycles per minute (see Fig. A-9).

- c. Remove test assembly from setup.
- d. Clean specimen ultrasonically with F-113 Freon. Dry in oven at 150 °F for 2 hours.
- e. Perform Leak Test per Paragraph H.4.

#### 10. Vibration Test At LN<sub>2</sub> Temperature

- a. Install a single connection per one of the setups of Figure A-10.
- b. Subject the connection to sinusoidal vibration. Scan the frequency range at low level input to determine the primary resonant frequency.
- c. Slide the adjustable weights to obtain equal output from each of the two strain gages adjacent to the fitting.
- d. Pressurize with gaseous nitrogen to working pressure as shown in Paragraph D.
- e. Supply liquid nitrogen to test setup until liquid appears at cooldown valve outlet.
- f. Close cooldown valve, continue flow until liquid nitrogen appears at overflow valve. Adjust valve to maintain liquid nitrogen level at overflow level.
- g. After temperature stabilizes, lock in gaseous nitrogen to working pressure as shown in Paragraph D.
- h. Start vibrator and monitor readout from strain gages. Increase force input from vibrator until a peak stress value of 33,200 psi is indicated on the strain gages. (Note: This is equivalent to 1,125 microinches/inch strain, using a value of 29,500,000 for the modulus of elasticity).
- i. Vibrate for a total of 300,000 cycles. Depressurize.
- j. Perform Leak Test per Paragraph H.4.

#### 11. Vibration Test At 500 °F Temperature

- a. Install a single connection per one of the setups of Figure A-11. Shield thermocouples and strain gages from direct heat radiation.

b. Subject the connection to sinusoidal vibration. Scan the frequency range at low level input to determine the primary resonant frequency.

c. Slide the adjustable weights to obtain equal output from each of the two strain gages adjacent to the fitting.

d. Pressurize with gaseous nitrogen to working pressure as shown in Paragraph D.

e. Adjust electrical power to heat lamps to obtain + 500 °F temperature at test fitting.

f. After temperature stabilizes, lock in gaseous nitrogen working pressure as shown in Paragraph D.

g. Start vibrator and monitor readout from strain gages. Increase force input from vibrator until a peak stress value of 15,000 psi is indicated on the strain gages. (Note: This is equivalent to 640 microinches/inch strain, using a value of 23,400,000 for the modulus of elasticity).

h. Vibrate for a total of 300,000 cycles. Depressurize.

i. Perform Leak Test per Paragraph H.4.

#### 12. Tensile Test (R-P&VE-MMM)

a. Modify length and tube ends of specimens as requested by R-P&VE-MMM.

b. Establish stress-strain relationship to failure (rupture).

#### 13. Metallographic Examination (R-P&VE-MMA)

a. Inspect each connection for locations of gross failures.

b. Each connection will then be sectioned, polished, and mounted for microscopic examination by R-P&VE-MMA per standard procedures. The number of sections and location for each connection will, in general, be left to the discretion of R-P&VE-MMA.

#### 14. Burst Pressure Test

a. Assemble setup of Figure A-12.

b. During initial fill with water, eliminate all air from high pressure system.

c. Pressurize connection to proof pressure as listed in Paragraph D and hold for 5 minutes.

d. Increase pressure to burst pressure as listed in Paragraph D and hold for 5 minutes.

e. Increase pressure in 500 psi increments until rupture occurs or pressure limit of test equipment is reached. Record failure pressure.

TABLE A-I

| Tube Size (in.)       |               |        |             |             |                   | Total<br>Quantity |
|-----------------------|---------------|--------|-------------|-------------|-------------------|-------------------|
| O. D.                 | Wall<br>Thick | Length | Brazed      | Connections | Welded Connectors |                   |
|                       |               |        | Aeroquip    | GE          | R-ME-MW           |                   |
| THIN WALL - 1500 psig |               |        |             |             |                   |                   |
| 1/4                   | .020          | 9      | 10 (Seq. A) | 10 (Seq. A) | 10 (Seq. A)       | 30                |
| 3/8                   | .028          | 11     | 10 (Seq. A) | ---         | 10 (Seq. A)       | 20                |
| 1/2                   | .035          | 13     | 10 (Seq. A) | ---         | 10 (Seq. A)       | 20                |
| 3/4                   | .049          | 15     | 10 (Seq. A) | 10 (Seq. A) | 10 (Seq. A)       | 30                |
| 1                     | .065          | 19     | 10 (Seq. A) | ---         | 10 (Seq. A)       | 20                |
| 1 1/4                 | .083          | 22     | 10 (Seq. A) | 10 (Seq. A) | 10 (Seq. A)       | 30                |
| 1 1/2                 | .095          | 25     | 10 (Seq. A) | 10 (Seq. A) | 10 (Seq. A)       | 30                |
| THICK WALL - 3000     |               |        |             |             |                   |                   |
| 1/4                   | .026          | 9      | 10 (Seq. A) | 10 (Seq. A) | 10 (Seq. A)       | 70                |
|                       |               |        | 10 (Seq. B) | 10 (Seq. B) | 20 (Seq. B)       |                   |
| 3/8                   | .038          | 11     | 10 (Seq. A) | ---         | 10 (Seq. A)       | 20                |
| 1/2                   | .051          | 13     | 10 (Seq. A) | ---         | 10 (Seq. A)       | 20                |
| 3/4                   | .075          | 15     | 10 (Seq. A) | 10 (Seq. A) | 10 (Seq. A)       | 60                |
|                       |               |        | 10 (Seq. B) | 10 (Seq. B) | 10 (Seq. B)       |                   |
| 1                     | .098          | 19     | 10 (Seq. A) | ---         | 10 (Seq. A)       | 20                |
| 1 1/4                 | .122          | 22     | 10 (Seq. A) | 10 (Seq. A) | 10 (Seq. A)       | 30                |
| 1 1/2                 | .113          | 25     | 10 (Seq. A) | 10 (Seq. A) | 10 (Seq. A)       | 60                |
|                       |               |        | 10 (Seq. B) | 10 (Seq. B) | 10 (Seq. B)       |                   |

TABLE A-II

| TUBE O.D.<br>(in.) | SUPPORT DISTANCE, "D"<br>(in.) |
|--------------------|--------------------------------|
| 1/4                | 6                              |
| 3/8                | 8                              |
| 1/2                | 10                             |
| 3/4                | 12                             |
| 1                  | 15                             |
| 1 1/4              | 18                             |
| 1 1/2              | 21                             |

See Figure A-7 for support distance "D".

# TEST SEQUENCE "Q"

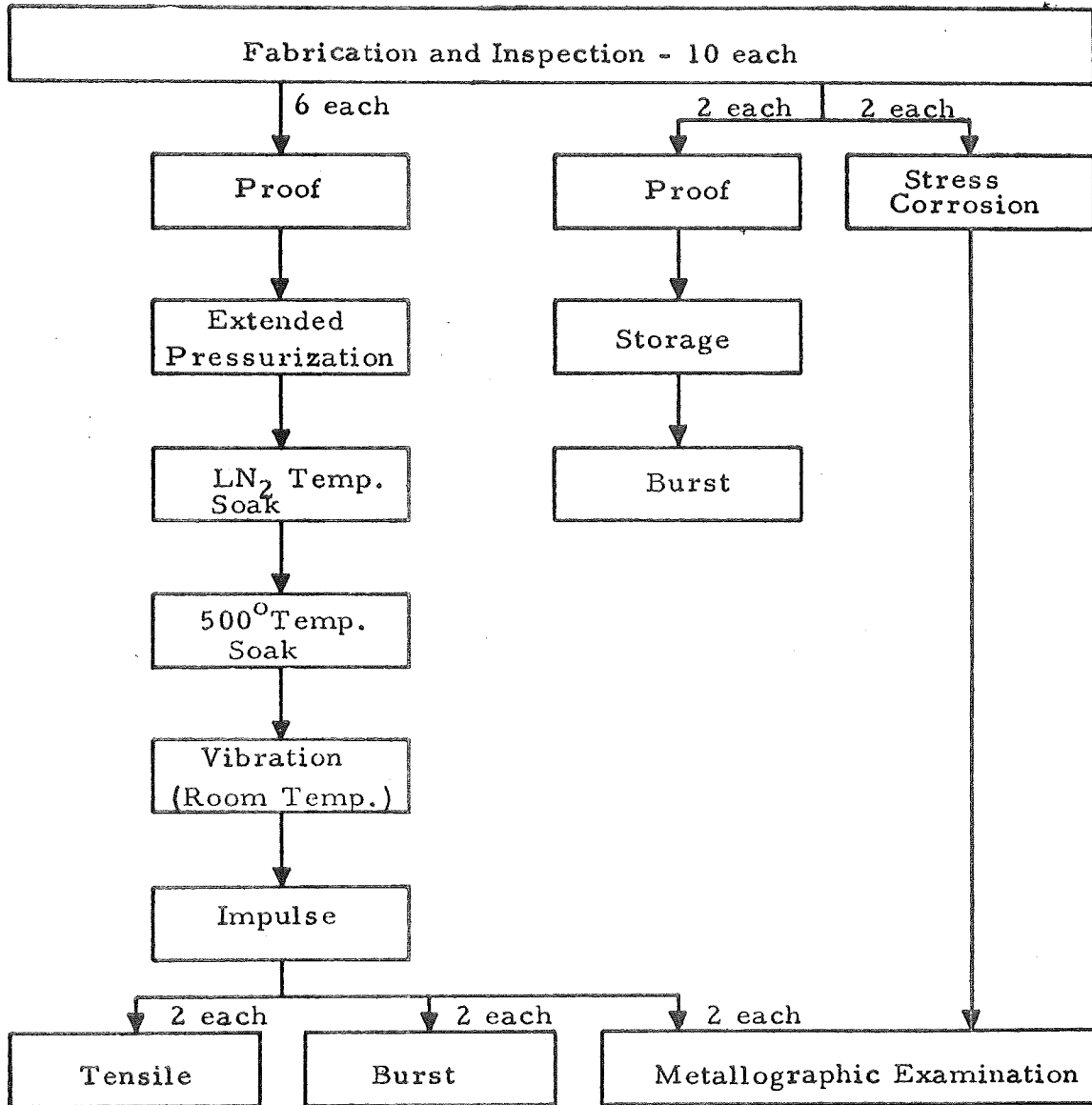
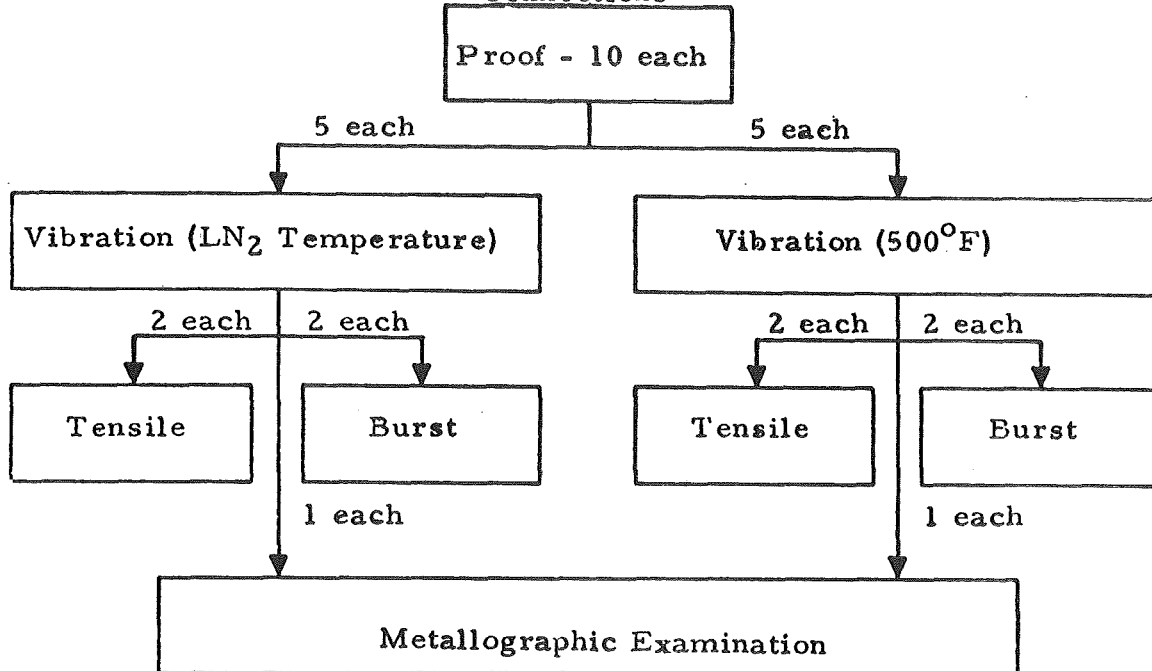


FIG. A-1 SEQUENCE OF TESTING FOR TEN SPECIMENS (BRAZED AND WELDED) OF EACH SIZE AND PRESSURE LEVEL, AS INDICATED IN TABLE A-I.

# TEST SEQUENCE "C"

3/4" and 1 1/2" Dia. Welded and 1/4", 3/4", and 1 1/2" Dia. Brazed Connections



1/4" Welded Connections

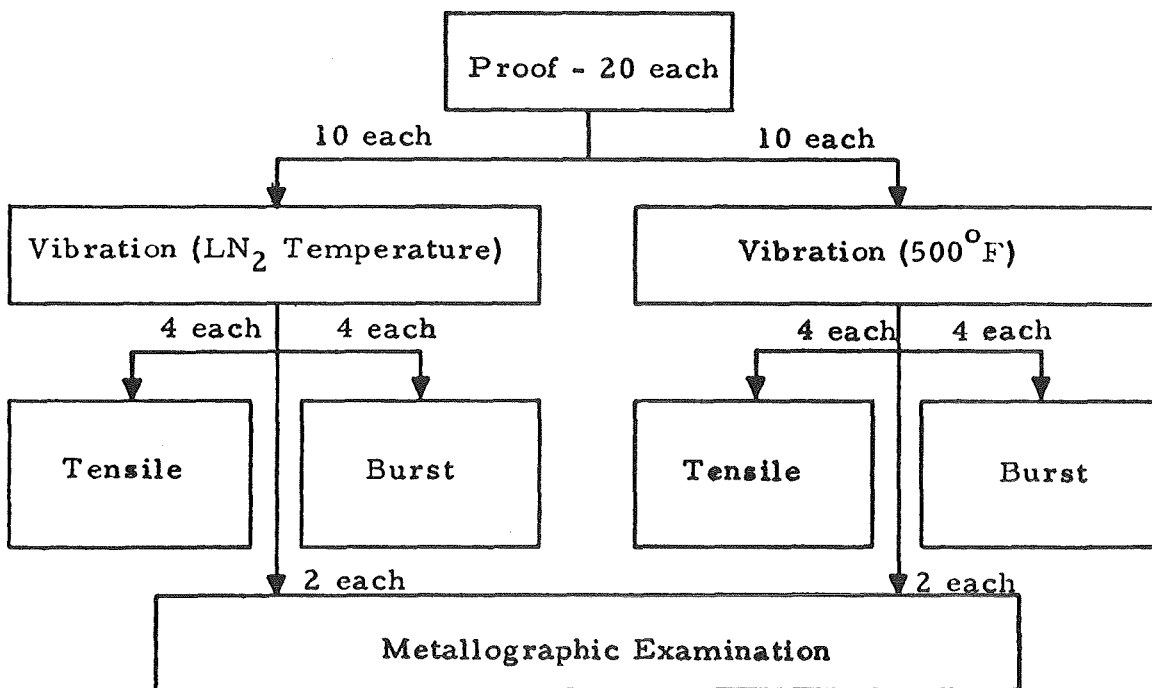


FIG. A-2 SEQUENCE OF TESTING FOR THE REMAINING BRAZED AND WELDED SPECIMENS AS INDICATED IN TABLE A-I

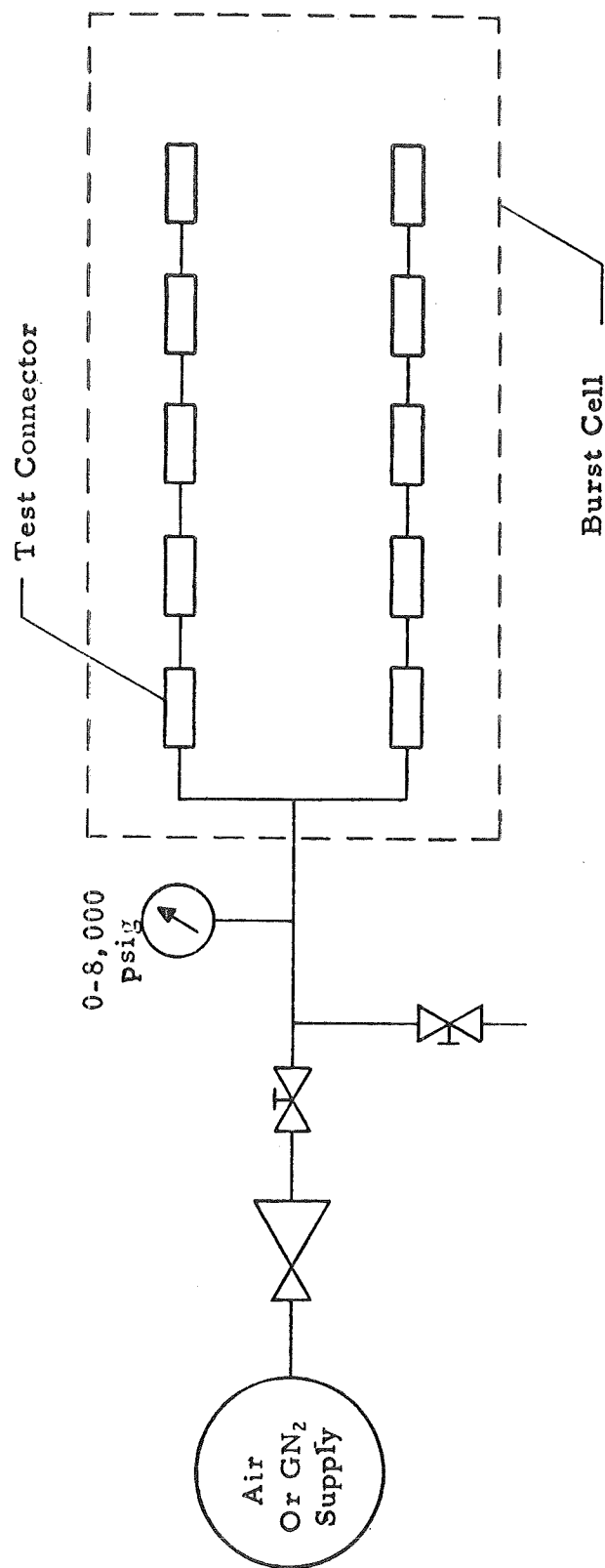
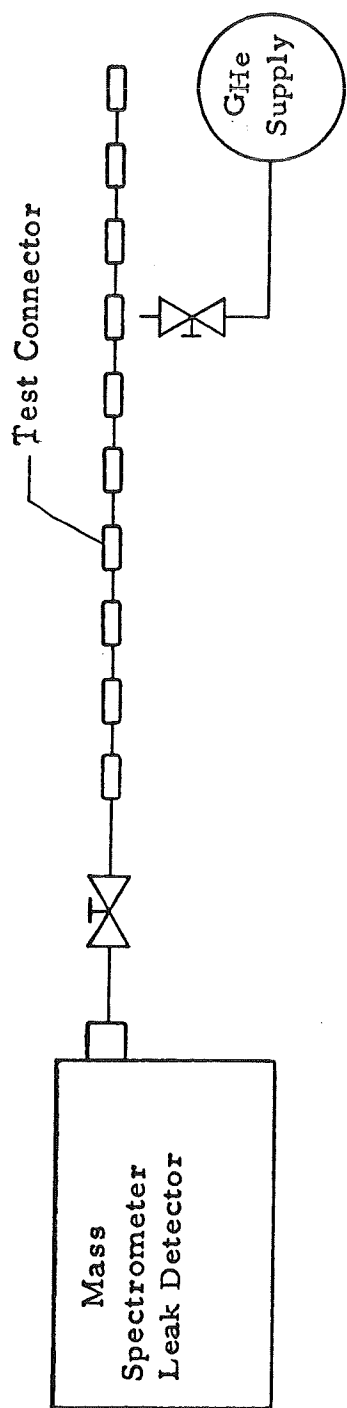
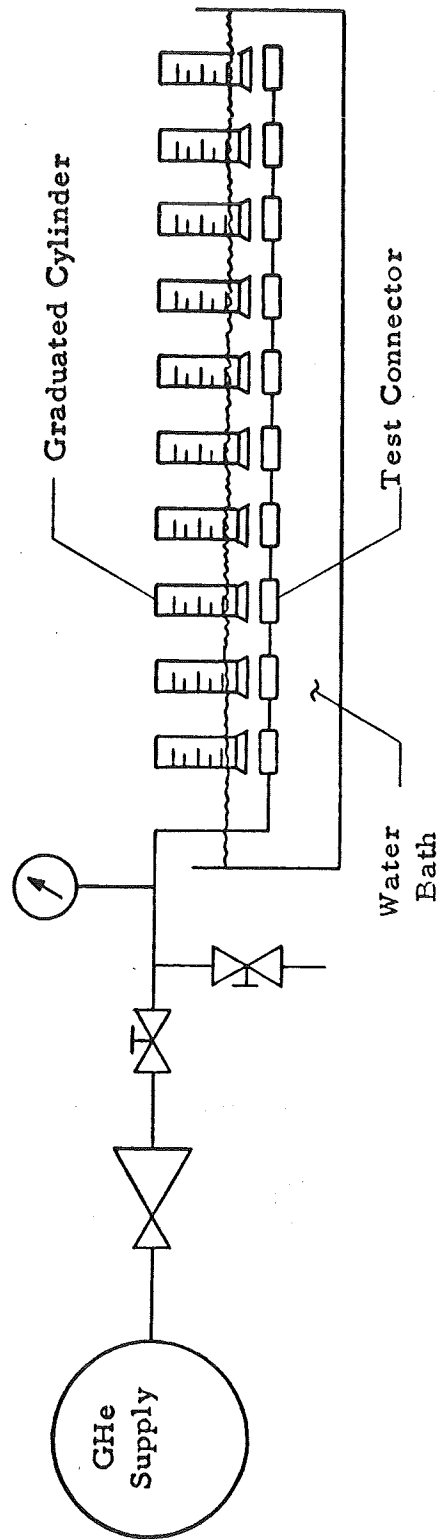


FIG. A-3 PROOF PRESSURE AND EXTENDED PRESSURIZATION TEST SETUP



A. Mass Spectrometer Method

0-5000psig



B. Water Displacement Method

FIG. A-4 LEAKAGE TEST SETUP

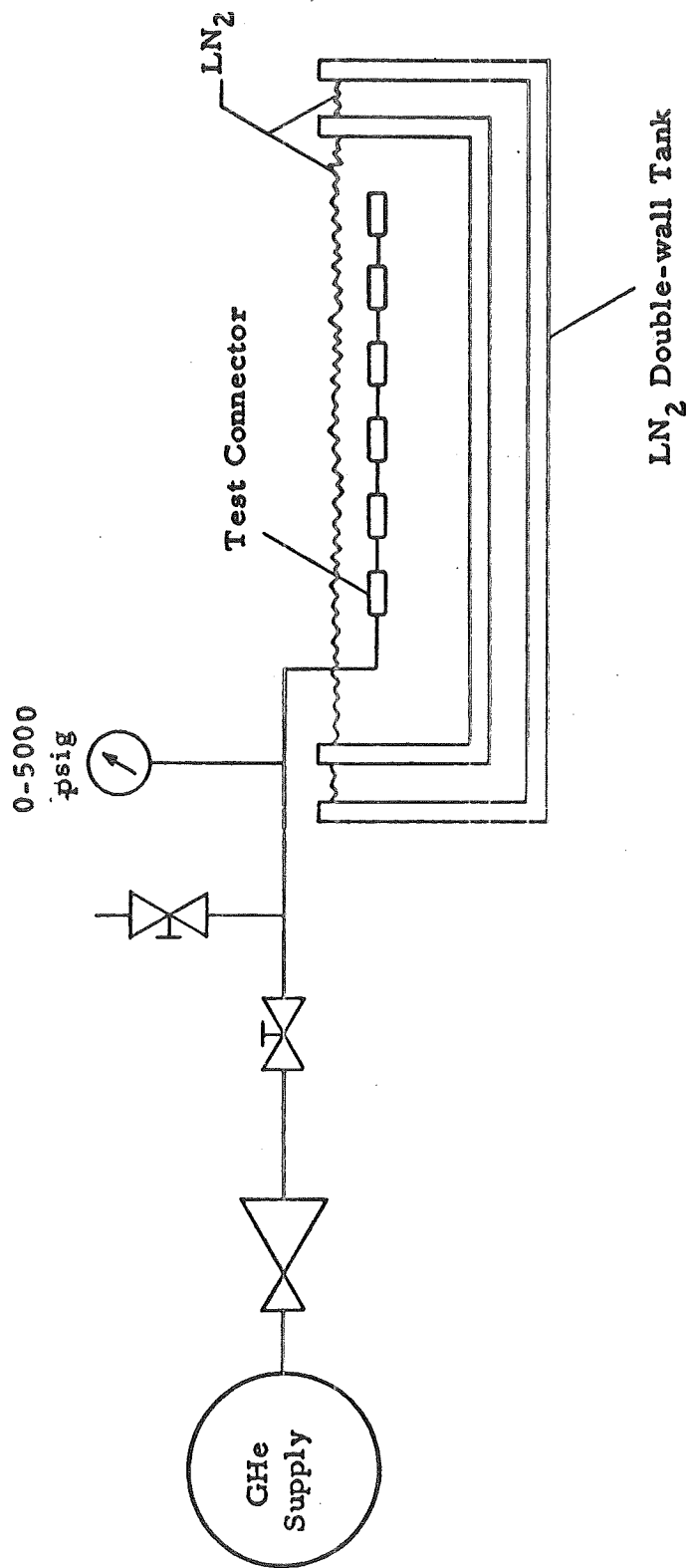


FIG. A-5 TEST SETUP FOR LN<sub>2</sub> TEMPERATURE SOAK TEST

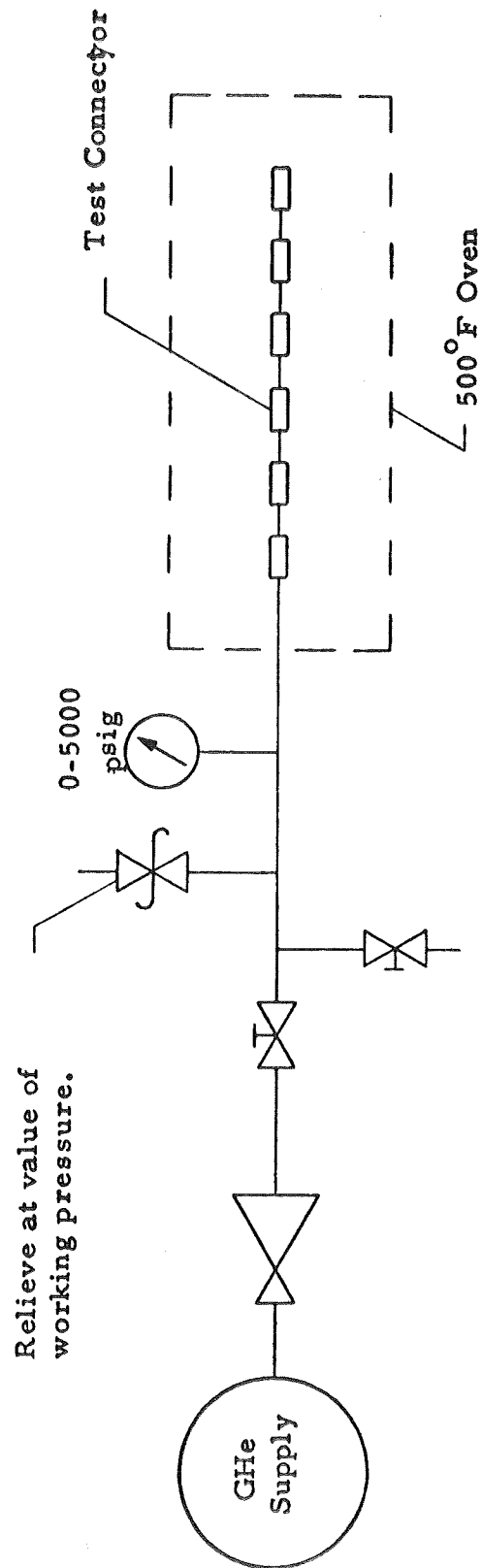
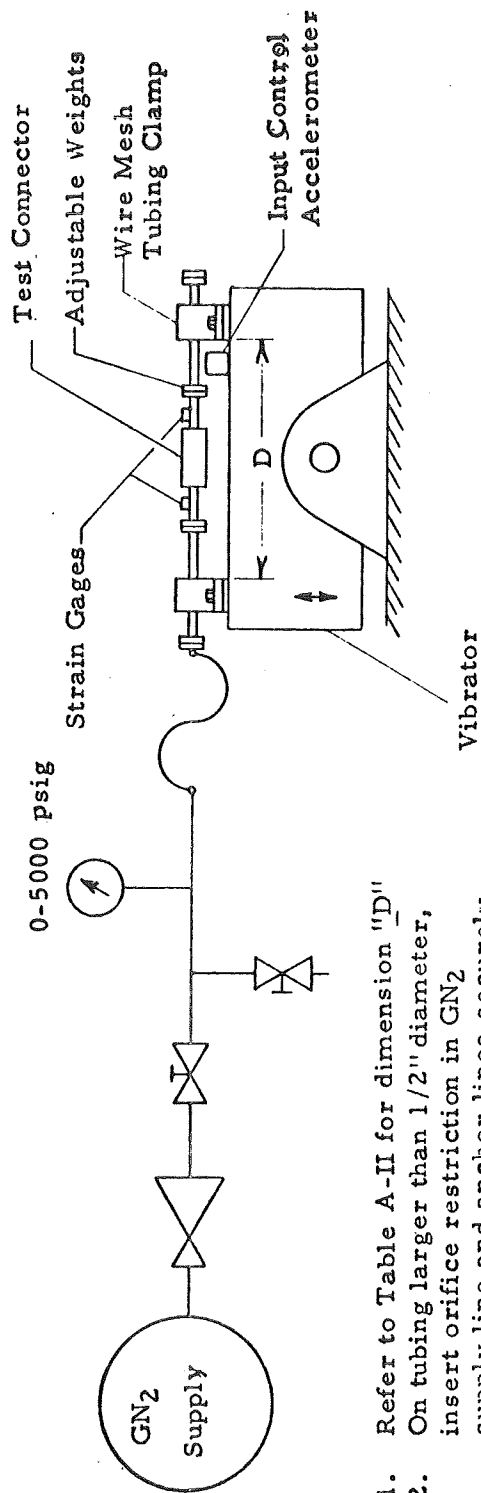
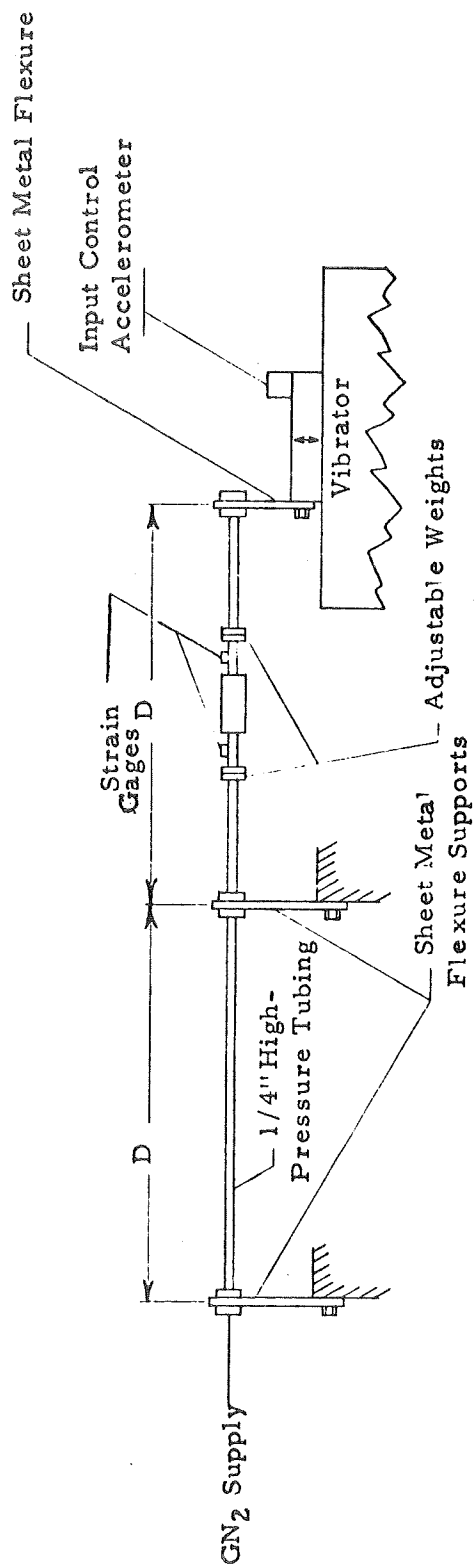


FIG. A-6 TEST SETUP FOR 500°F TEMPERATURE SOAK TEST



- NOTES:
1. Refer to Table A-II for dimension "D"
  2. On tubing larger than 1/2" diameter, insert orifice restriction in GN<sub>2</sub> supply line and anchor lines securely to prevent whipping in the event of failure.

FIG. A-7 TEST SETUP FOR VIBRATION AT ROOM TEMPERATURE

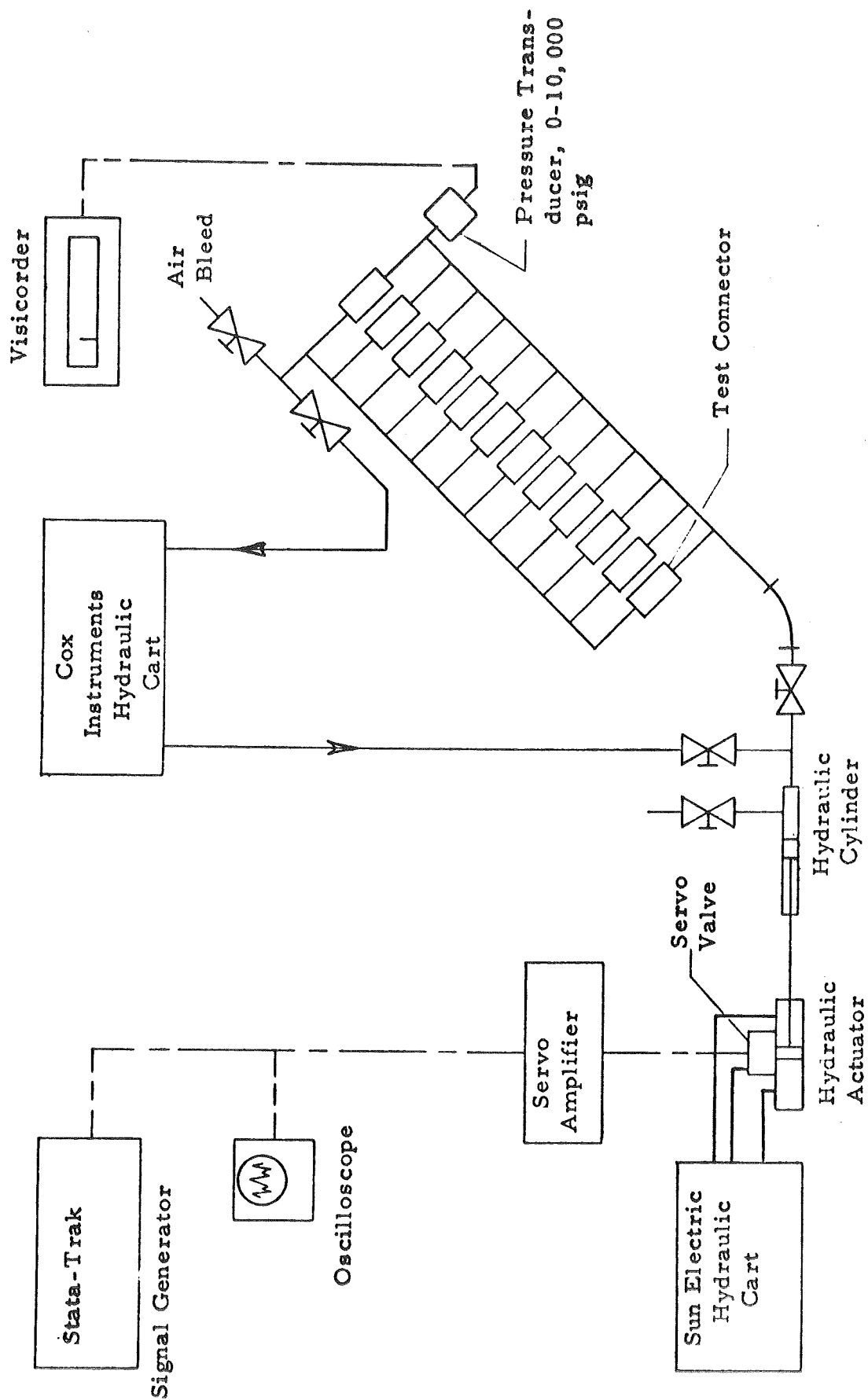


FIG. A-8 IMPULSE TEST SETUP

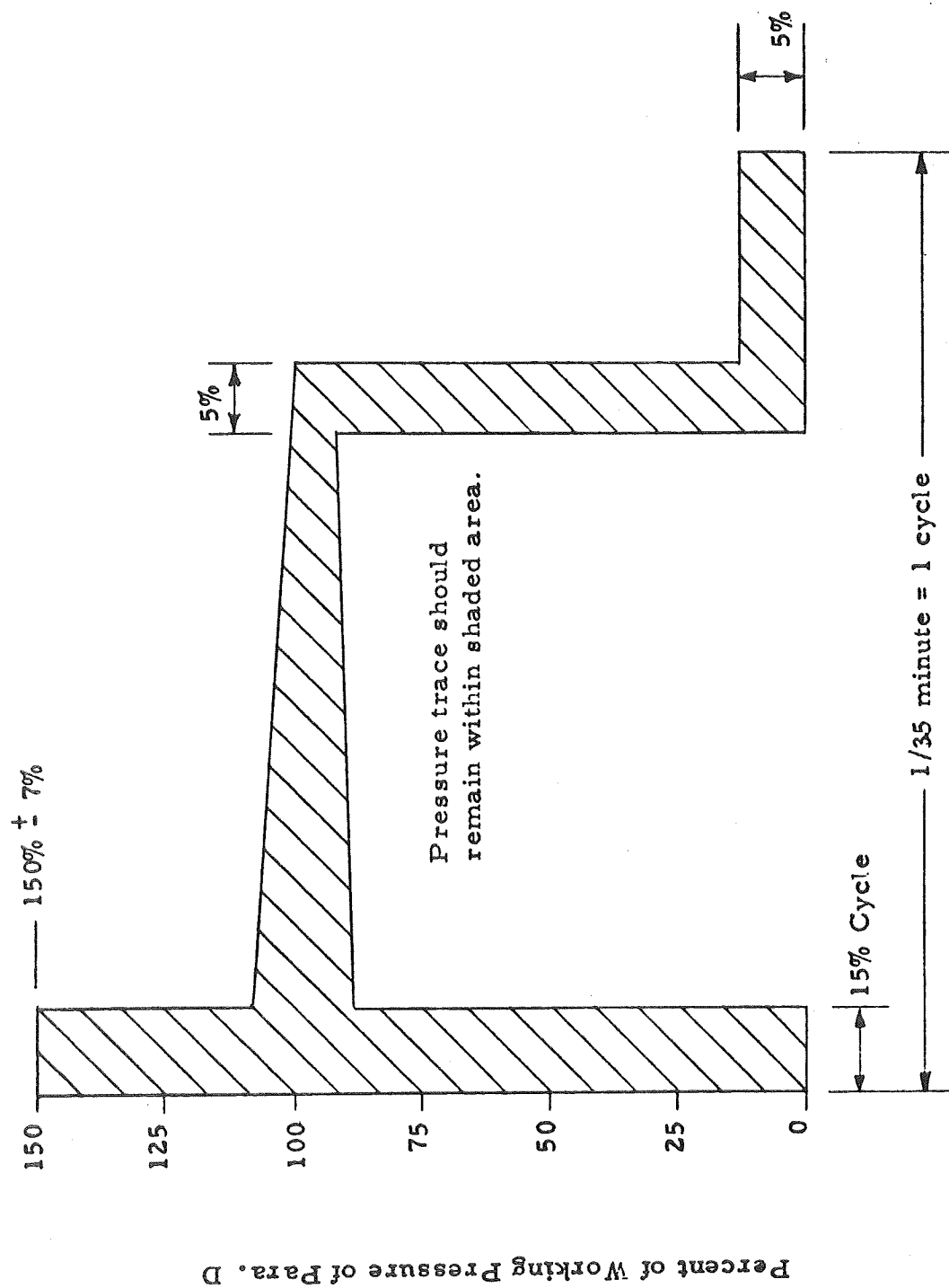


FIG. A-9 IMPULSE WAVE SHAPE

Suggested Alternate Test Setup with test specimen mounted as in Figure A-7

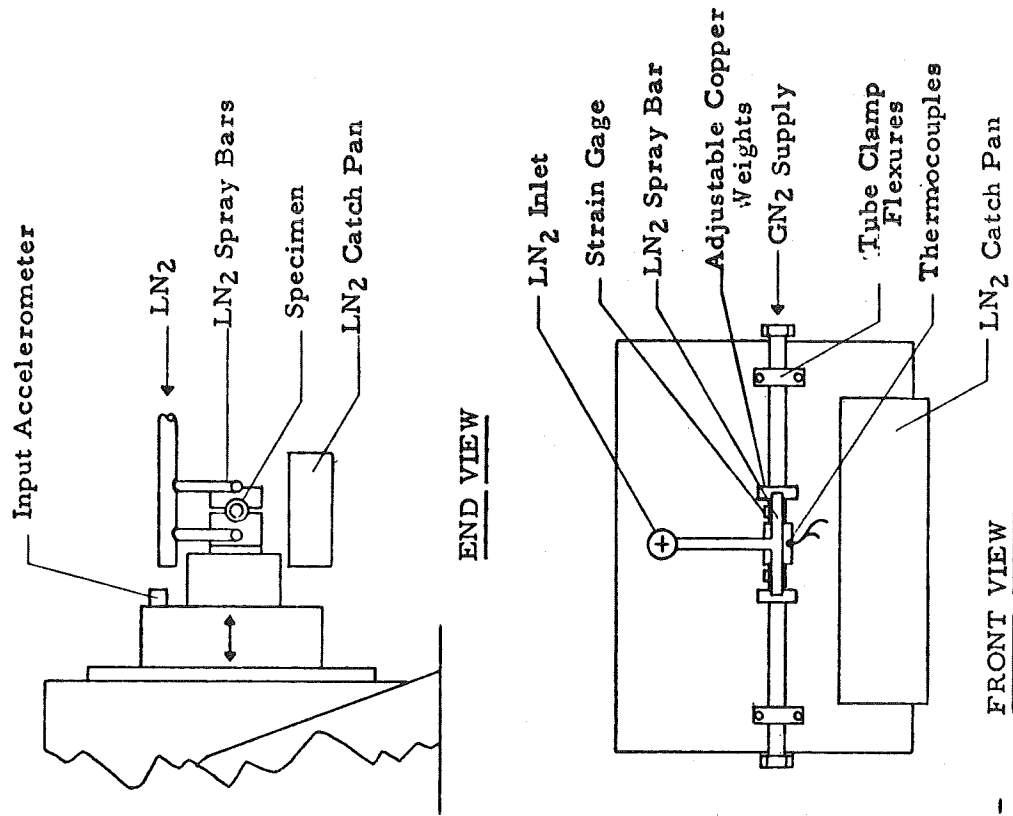
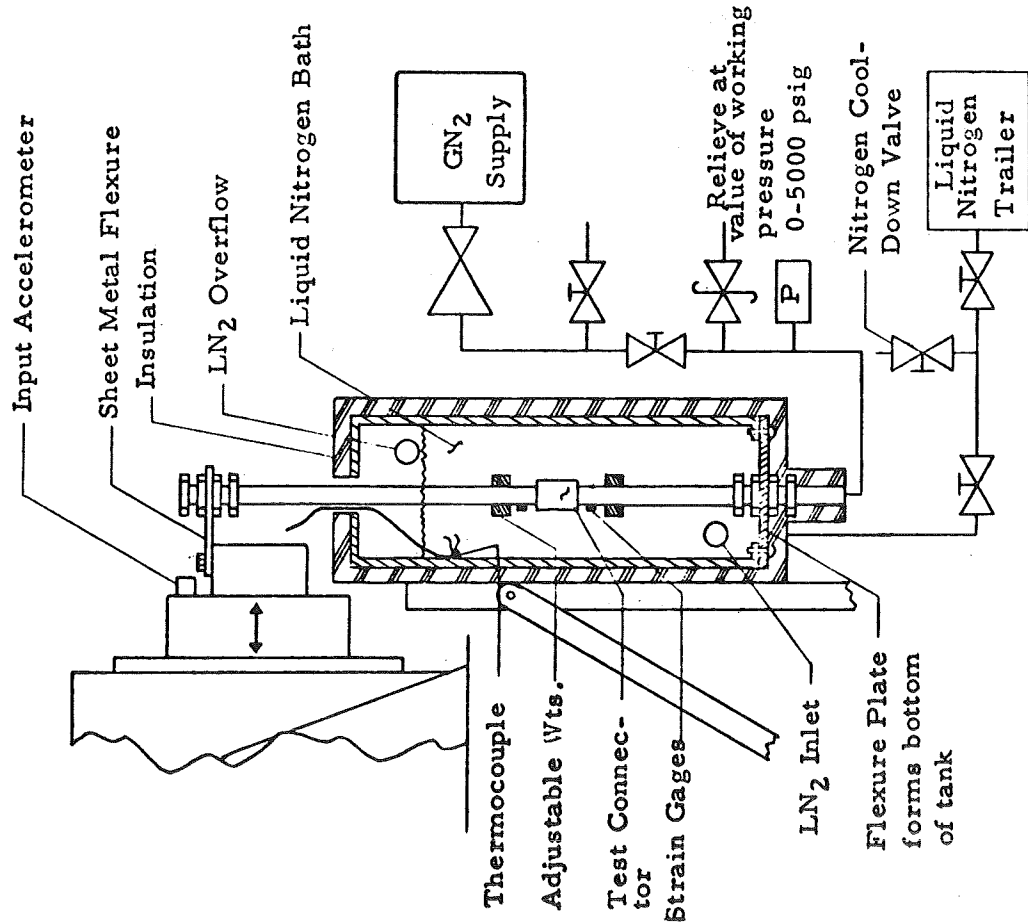
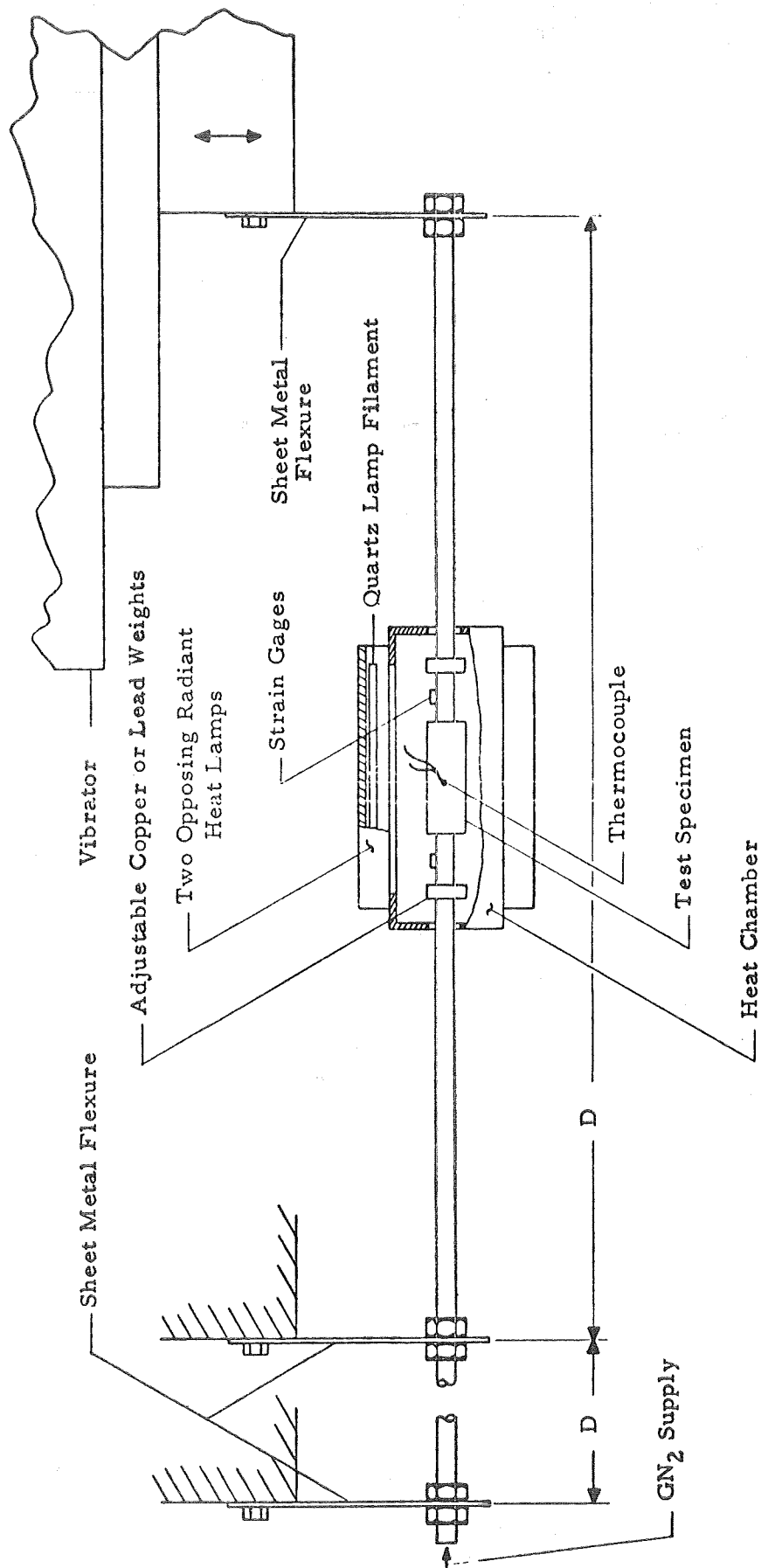
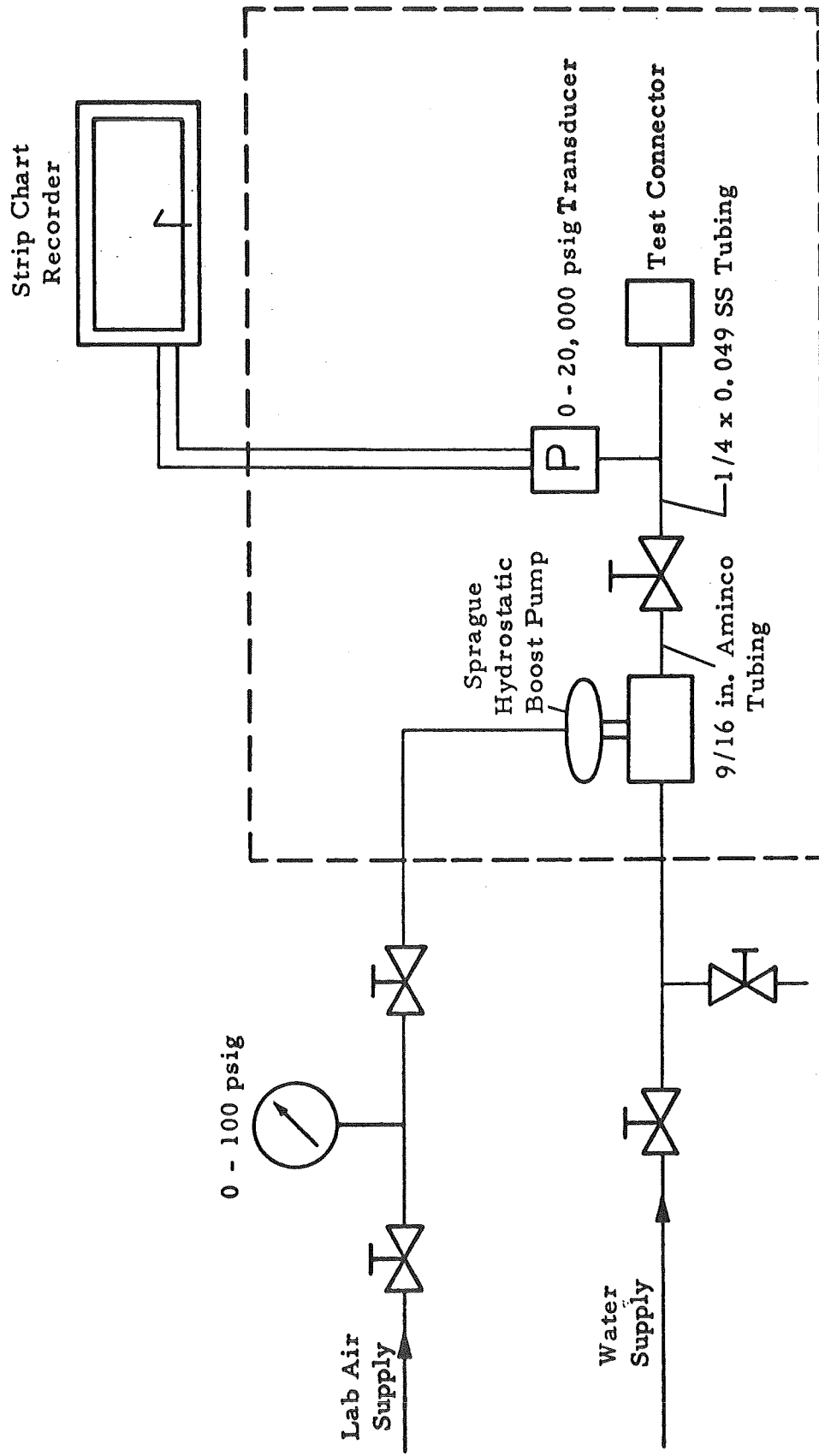


FIG. A-10 TEST SETUP FOR VIBRATION TEST AT LN<sub>2</sub> TEMPERATURE



NOTES: See Notes on Figure A.7

FIG. A-11 TEST SETUP FOR VIBRATION TEST AT +500°F TEMPERATURE



Note: Anchor pump and high pressure tubing to prevent whipping in case of failure.

FIG. A-12 BURST TEST SETUP

#### LIST OF REFERENCES

1. Standard, MSFC-STD-362, Amendment 1, March 5, 1965,  
"Qualification Testing, Separable Tube Connectors."
2. Memorandum, R-P&VE-SVR-66-60, November 15, 1966, "Brazed  
and Welded Connectors Test Program. R-ME-MW Induction  
Brazing Manual."
3. Brochure, R-ME-MW, "Tube Welding and Brazing."

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1. Memorandum, R-P&VE-PE-64-M-113, April 10, 1964, "Qualification Test Program for Brazed and Welded Connectors."
2. Memorandum, R-MW-118-64, May 13, 1964, "Transmittal of Sample Brazed and Welded Tube Joints for Qualification Testing."
3. Memorandum, R-P&VE-PMC-64-M-158, June 9, 1964, "Evaluation Program for Brazed and Welded Tube Connectors."
4. Memorandum, R-P&VE-PE-64-M-434, November 16, 1964, "Minutes of the Meeting Concerning the Selection of Tubing for Brazed and Welded Fittings."
5. Memorandum, R-P&VE-SSE-64-83, November 27, 1964, "Stress Check of AISI 321 Steel Tubing."
6. Memorandum, R-P&VE-PE-64-M-482, December 31, 1964, "Tube Wall Thickness for Brazing Evaluation."
7. Memorandum, R-ME-MW, March 12, 1965, "Tubing Required for Tube Brazing Evaluation."
8. Memorandum, R-ME-MW, June 23, 1965, "Transmission of Brazed and Welded 321 S.S. Tube Specimens."
9. Memorandum, R-P&VE-PE-65-M-311, September 8, 1965, "Qualification Test Program for Brazed and Welded Connectors."
10. Memorandum, R-P&VE-MMM-66-33, April 22, 1966, "Evaluation of B&W Tube Assemblies Fabricated from Welded and Drawn Type 321 S.S. Tubing."
11. Memorandum, BECO-67-24, February 6, 1967, "Investigation of B&W Tube Connectors."
12. Memorandum, R-P&VE-MMA-67-8, March 6, 1967, "Metallographic Examination of Brazed and Welded S.S. Tubing from 180 Day Corrosion Study."
13. Memorandum, R-P&VE-MMA-67-49, August 11, 1967, "Report on Brazed and Welded Tube Connector Test Program."

14. Memorandum, R-P&VE-MWM, August 17, 1967, "Qualification Testing of Brazed and Welded Connections."
15. Memorandum, R-P&VE-67-385, September 7, 1967, "Minutes of a Meeting Held on August 31, 1967, on Brazed and Welded Tube Connectors."
16. Memorandum, R-P&VE-PE-67-466, October 12, 1967, "Minutes of a Meeting Held October 9, 1967, Concerning the Brazed and Welded Tube Connector Program."
17. Memorandum, R-P&VE-PE-67-491, November 3, 1967, "Minutes of a Meeting with Aeroquip Corp. on October 10, 1967, Concerning the Brazed and Welded Fitting Program."
18. Aeroquip Letter, November 13, 1967, "Braze Weight and Fitting Wall Thickness."
19. Memorandum, R-P&VE-PE-67-548, December 19, 1967, "Stress Level Changes in the Brazed and Welded Tube Connector Program."
20. Memorandum, R-P&VE-MMS-67-84, December 26, 1967, "Analysis of Connectors from Brazed and Welded Tube Connector Test Program."
21. Memorandum, R-P&VE-SVE-67-213, January 12, 1968, "321 S.S. Tube Connector Evaluation."
22. Memorandum, BECO-68-15, April 3, 1968, "Investigation of Brazed and Welded Tube Connections, Interim Report on 1/4 in. Size Specimens."
23. Memorandum, BECO-68-30, August 26, 1968, "Investigation of Brazed and Welded Tube Connections, Interim Report on 3/4 in. Specimens."
24. Memorandum, R-P&VE-PE-68-313, October 22, 1968, "Investigation of Brazed and Welded Tube Connections, Interim Report on 1 1/2 in. Connections."