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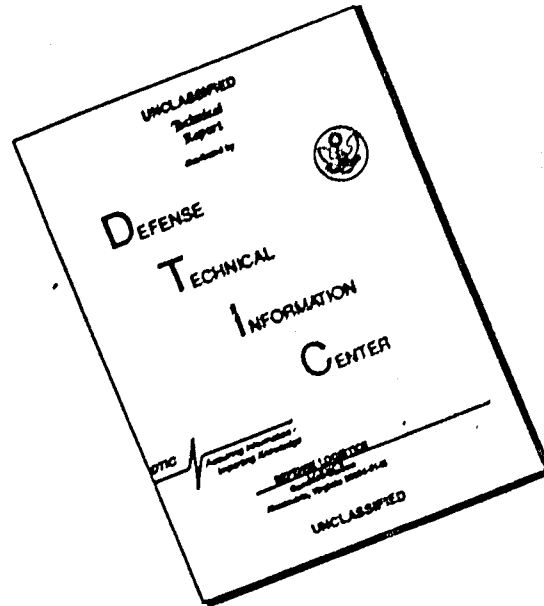
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ESTABLISHING PROVEN DESIGN CRITERIA  
FOR CRYOGENIC BOOST TANKS

QUARTERLY PROGRESS REPORT  
PERIOD ENDING 31 JULY 1961

J. G. Connelly  
B. R. Etheridge

BEEHCRAFT RESEARCH AND DEVELOPMENT, INC.  
BOULDER, COLORADO

BEEHCRAFT ENGINEERING REPORT NO. 13306

CONTRACT AF33(616)-5154  
SUPPLEMENT S3(59-207)  
PROJECT NO. 3084  
TASK NO. 30304

DECEMBER 1961

DGRPT  
AIR FORCE FLIGHT TEST CENTER  
AIR RESEARCH AND DEVELOPMENT COMMAND  
UNITED STATES AIR FORCE  
EDWARDS AIR FORCE BASE, CALIFORNIA

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## FOREWORD

This contract was initiated by the Propulsion Laboratory, Wright Air Developing Center, Wright-Patterson Air Force Base, Ohio, and for the past two years has been monitored by the Rocket Propulsion Laboratory of the Air Force Flight Test Center, Edwards Air Force Base, California. The work upon which this report is based is being accomplished by Beechcraft Research and Development, Inc., Boulder, Colorado, under Air Force contract AF33(616)-5154, Supplement S3(59-207). Mr. J. Branigan of the Rocket Propulsion Laboratory is the Air Force Project Engineer in charge of the work done under this contract.

This is the eighth quarterly progress report submitted per Item IV, Part I of the S3(59-207) Supplement to the contract. This report covers all work accomplished from 15 June 1960 to 31 July, 1961.

## ABSTRACT

Status of the analytical programs and progress of the flight simulation test program during the eighth reporting period of the contract are reported.

Status of the condensing film heat transfer research program is reported.

In the flight simulation test program, the progress on the 7,000 gallon test tank system design, system fabrication, pre-test program and thermal test facility is reported. A description of the fabrication progress of the titanium tank and insulation concepts and testing of the stainless steel test tank is presented.

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## INTRODUCTION

This is the eighth progress report on work being performed under contract AF33(616)-5154 Supplement S3(59-207) involving research and development of cryogenic propellant tanks for rocket vehicles. This program is a continuation of an investigation of propellant tank design problems begun by Beechcraft Research and Development, Inc., in July, 1957.

During the original study program, preliminary design criteria for the tank system of a series of chemical and nuclear rocket vehicles was evolved. It was determined during that program that further research and development work was needed in certain areas in order to firmly establish the desired tank design criteria. The thermal performance of a hydrogen fuel tank during powered flight was determined to be an important tank design parameter and that the relationship between thermal performance and tank design is quite complex.

The flight simulation test program now in progress is directed toward the solution of this basic heat transfer problem. A 7,000 gallon stainless steel tank has been constructed and another 7,000 gallon tank fabricated of titanium is presently being fabricated. These tanks will be tested under simulated powered flight conditions wherein simulated aerodynamic heating will be programmed through the tank walls while fuel is being drained from the tank.

This report covers an extended period of time due to the fact that funds were unavailable for a period of approximately four months. Therefore, Sections 1.0 and 2.0 of this report entail that work which was accomplished before the stoppage, and Section 4.0 the three months period after funding was made available.

## 1.0 ANALYTICAL AND BASIC RESEARCH PROGRAMS

### 1.1 Analytical Programs

During this period of time, no further analytical work was required to support the program. Some thermal data was reduced and preliminary analysis made and is reported in Section 2.0.

### 1.2 Condensation Film Heat Transfer Research Program

The study and test program was essentially completed before the nonoperating period. Certain data reduction and the final report remained to be completed. After the program was funded, the data was assembled and the final report released. The report was released as Volume II of AFFTC TR 60-43.

## 2.0 FLIGHT SIMULATION TEST PROGRAM

This section of the report will summarize the work accomplished during the period from June 15, 1960, through December 31, 1960, at which time the program was made inactive (see Section 4.0 for program continuation).

A description of the work progress will be made on the following subject topics:

- (a) 7,000 gallon titanium test tank system
- (b) 7,000 gallon stainless steel test tank system
- (c) Thermal test facility

As previously reported (paragraph 2.0, E.R. 8129), the stainless steel tank fabrication schedule was projected ahead of the titanium tank in order to have a test vehicle at the earliest date possible.

### 2.1 7,000 Gallon Titanium Test Tank System

The following subsections will be devoted to describing the work progress during the period stated above:

- (a) Additional design considerations
- (b) Structural analysis
- (c) Tank fabrication progress

#### 2.1.1 Additional Design Considerations

##### 2.1.1.1 Structural

No major structural design changes were made during this period. Some changes were made in fabrication tolerances to facilitate the completion of subassemblies. However, these changes did not affect the structural design or integrity of the parts.

##### 2.1.1.2 Thermal

The insulation concept originally scheduled for the titanium tank was transferred to the stainless steel tank due to the schedule change. The consideration of other insulation concepts for the titanium tank as reported in E.R. 8129 were continued. However, no decision was made during this period as to the insulating material to be used.

#### 2.1.2 Structural Analysis

All structural analysis work had been completed including the computer reruns necessary because of previous design changes. These reruns are described in paragraph 2.1.2, E.R. 8129.

### 2.1.3 Tank Fabrication Progress

The fabrication progress of the titanium tank is described in the following subsection (see Engineering Report 7602 for identification of sections and subassemblies).

#### 2.1.3.1 Cylindrical Section

The two cylindrical sections were completed except for the final closure weld. These parts were stored until the head assemblies were completed.

#### 2.1.3.2 Skirt Assemblies

The two skirt subassemblies were completed during the last half of June, 1960. They were stored with the cylindrical sections awaiting next assembly operation.

#### 2.1.3.3 Drain Assembly

The drain assembly is completed and ready for welding to the bottom cone section.

#### 2.1.3.4 90° Right Circular Cone

The cone section was completed and trimmed for welding to the lower hemisphere head section and drain assembly.

#### 2.1.3.5 Cylinder to Head Transition Splices

These bands had been machined to proper taper and skirt step cut and ready for next assembly operation.

#### 2.1.3.6 Hemispherical Heads

The head assemblies had been completed with the exception of welding in the reinforcing splice fittings. Some rework was necessary on the forward head due to cracks in the weld around the manhole cover. The repair of the cracks had been accomplished, and the heads ready for attaching to other subassemblies. It might be noted that some welds in the head had marginal areas as to porosity and thin-out. However, if good quality welds were achieved in the remainder of the assembly, the integrity of the final assembly would be sufficient for the testing purposes intended.

#### 2.1.3.7 Tank Assembly

Assembly of the tank subassemblies was begun the last of June. The joining of the 90° cone and hemispherical head section was attempted. However, the tooling proved to be inadequate to hold the material down properly while welding. It was necessary to do minor rework of the tooling in an effort to improve the hold-down features. The efforts to make the circumferential

welds joining the subassemblies together continued through July and most of August, 1960. However, the work was plagued with problems resulting from inadequate tooling. As a result, the circumferential welds were of a poor quality and not acceptable, particularly in view of the questionable areas in the heads already mentioned.

During September, 1960, all work on the titanium tank was stopped and the fabrication facilities were put on a stand-by basis with only normal maintenance to be performed.

## 2.2 7,000 Gallon Stainless Steel Tank System

The following subsections will be devoted to describing the work progress during the period stated above.

- (a) Additional design considerations
- (b) Tank fabrication progress

### 2.2.1 Additional Design Considerations

#### 2.2.1.1 Structural

The construction of the stainless steel tank using the same tooling was completed and no major design changes were made during this period.

#### 2.2.1.2 Thermal

The insulation encapsulation of the stainless steel tank became a major problem in itself. As originally contemplated, the Min-K insulation tiles were to be covered with a cylinder of Mylar, which would allow the insulation to be evacuated.

As conceived, the Mylar jacket was to be fabricated by a vendor into one large cylinder which could then be drawn over the tank and shrink fitted to the insulation. The best grades of Mylar are purported to be free of pin holes, thus allowing the use of the Mylar as one side of a vacuum shell. However, when Mylar is folded such that three loose folds extend from one point, a pin hole almost invariably results. This unique feature of Mylar resulted ultimately in the failure of the Min-K Mylar concept.

The Mylar sleeve could not be slipped over the tank without folding or wrinkling, so it was decided to sleeve the tank and then repair the three-corner leaks. Having accomplished this, the test tank was transported to the thermal test facility for heat shrinking of the Mylar.

Earlier testing on the vacuum bell check-out cylinder using a short cylinder of Mylar indicated that the Mylar was transparent to heat and would not shrink until it was made opaque to heat. Therefore, the

test samples were spray painted with a form of carbon black and the shrink test repeated. The Mylar shrank but without uniformity, causing wrinkles and puckers.

It was then decided that a full-scale attempt should be made and suspend a weighted ring from the bottom of the Mylar cylinder while being shrunk in the vacuum bell. Figure 1 shows the tank covered with Mylar being lowered into the vacuum bell. Figure 2 shows the Mylar-covered tank prior to heating. Figures 3 and 4 show the result of the shrink attempt. Note that some areas show circumferential shrinkage with gathers of material due to lack of longitudinal shrinkage. Also, in other areas, no shrinkage occurred. It appeared that certain areas were heated and other areas witnessed no heat at all. It has been subsequently determined that the heater control thermocouples attached to the Mylar were not sensing the actual temperature of the Mylar nor were they acting uniformly over the length of the tank wall.

Due to schedule considerations, every effort was directed toward using the insulation concept if possible even though the cover had not shrunk uniformly. However, due to the difficulty in obtaining a vacuum in the insulation space as well as increased temperature requirements due to LOX-Rp and LOX-LH<sub>2</sub> trajectories which would melt the Mylar, it was decided that a new cover should be put on the insulation.

The new covering consisted of wrapping the tank insulation with 1 mil aluminum foil, and then a final wrap of three layers of glass cloth. The foil and glass cloth were wrapped in a spiral fashion. As the foil was wrapped, it was bonded to the Min-K insulation and to itself with General Electric RTV-11 silicone rubber (room temperature vulcanizing). After the foil was installed, the tank was then wrapped with three layers of glass cloth, each layer being impregnated with the RTV-11 silicone rubber. Figure 5 shows a cross section of the tank with the new cover installed. Thermocouples were installed on the aluminum foil prior to being wrapped with the glass cloth. The thermocouples would provide external tank wall temperatures during thermal runs. Although this type of material would result in a heavier cover, the advantages to be gained were worth the extra weight. These advantages were as follows:

- (1) More durable outer cover
- (2) High temperature allowable (700°F)
- (3) Reliable thermocoupling

#### 2.2.2 Tank Fabrication Progress

Design of the insulation encapsulating cover was completed the last of June, 1960, and released for installation. Satisfactory progress was made and the sidewall was completed the middle of July. Figures 6 through 9 show the steps in applying the aluminum foil, thermocouples, and glass cloth. The end insulation had suffered damage during the

FIGURE 1  
PHOTOGRAPH OF MYLAR-COVERED TANK  
BEING LOWERED INTO VACUUM BELL

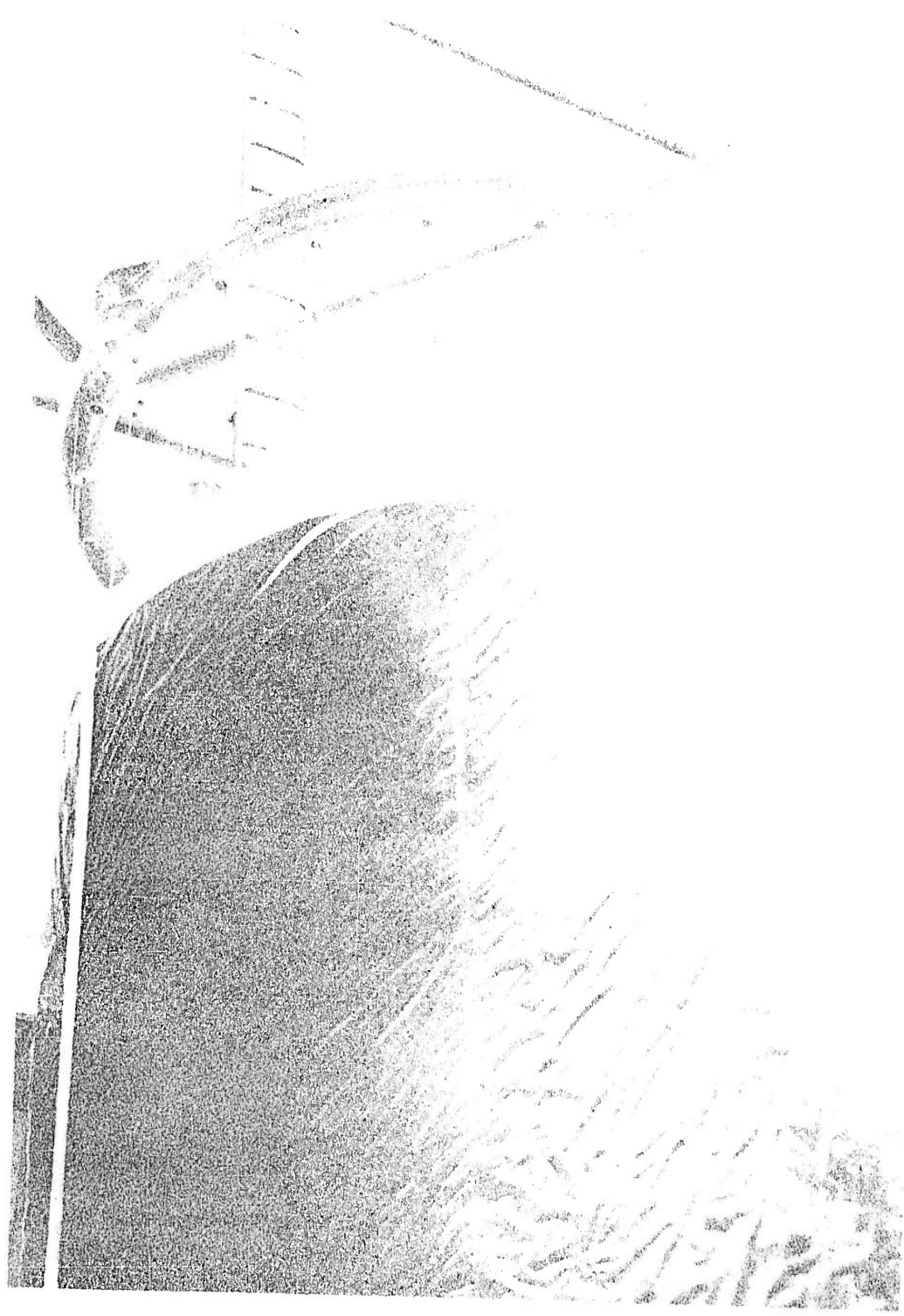
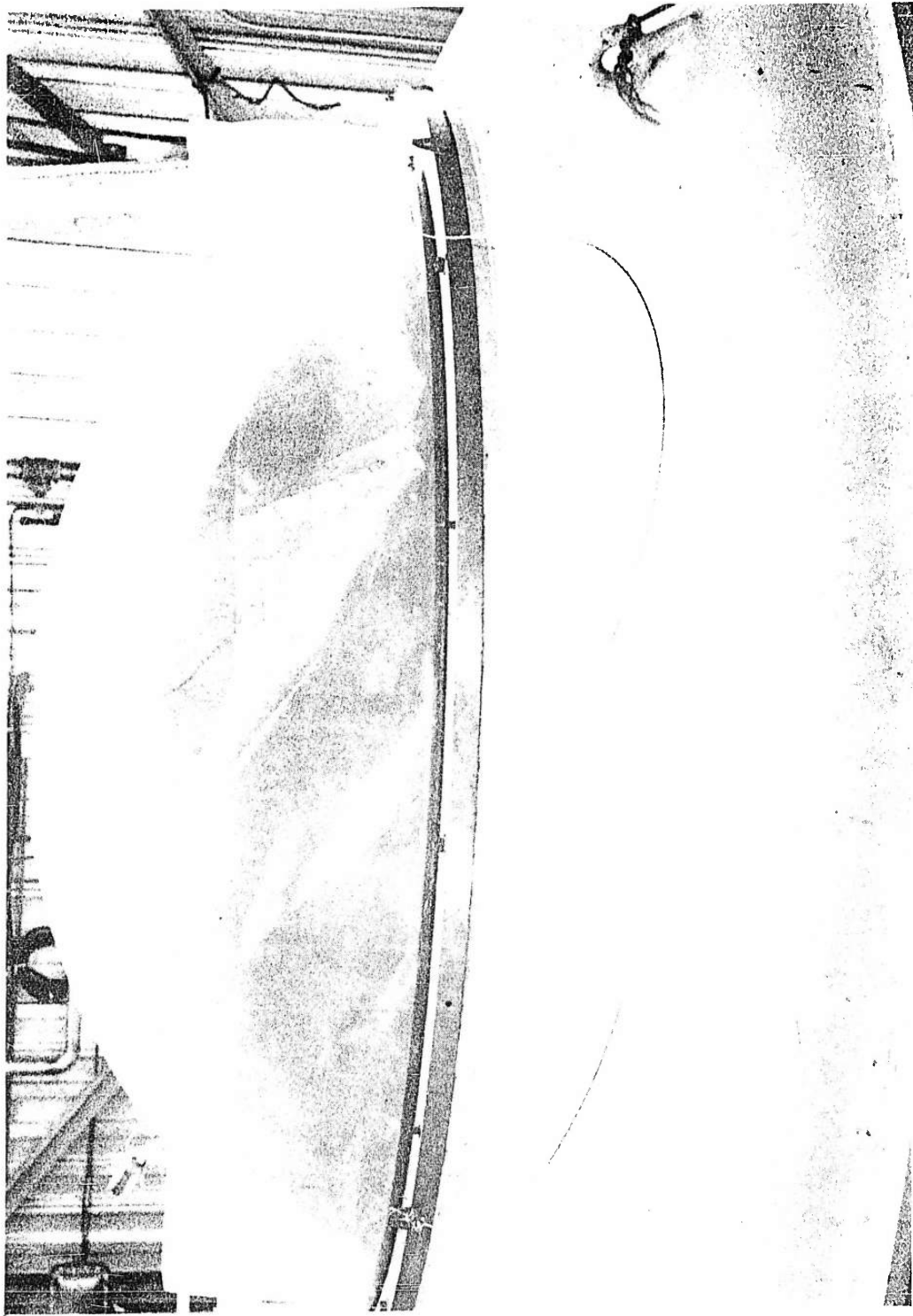


PLATE 1  
PHOTOGRAPH OF NYLAR-COVERED TANK PRIOR TO HEATING



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FIGURE 3  
PHOTOGRAPH OF WRINKLING EFFECT ON MYLAR COVER AFTER HEATING

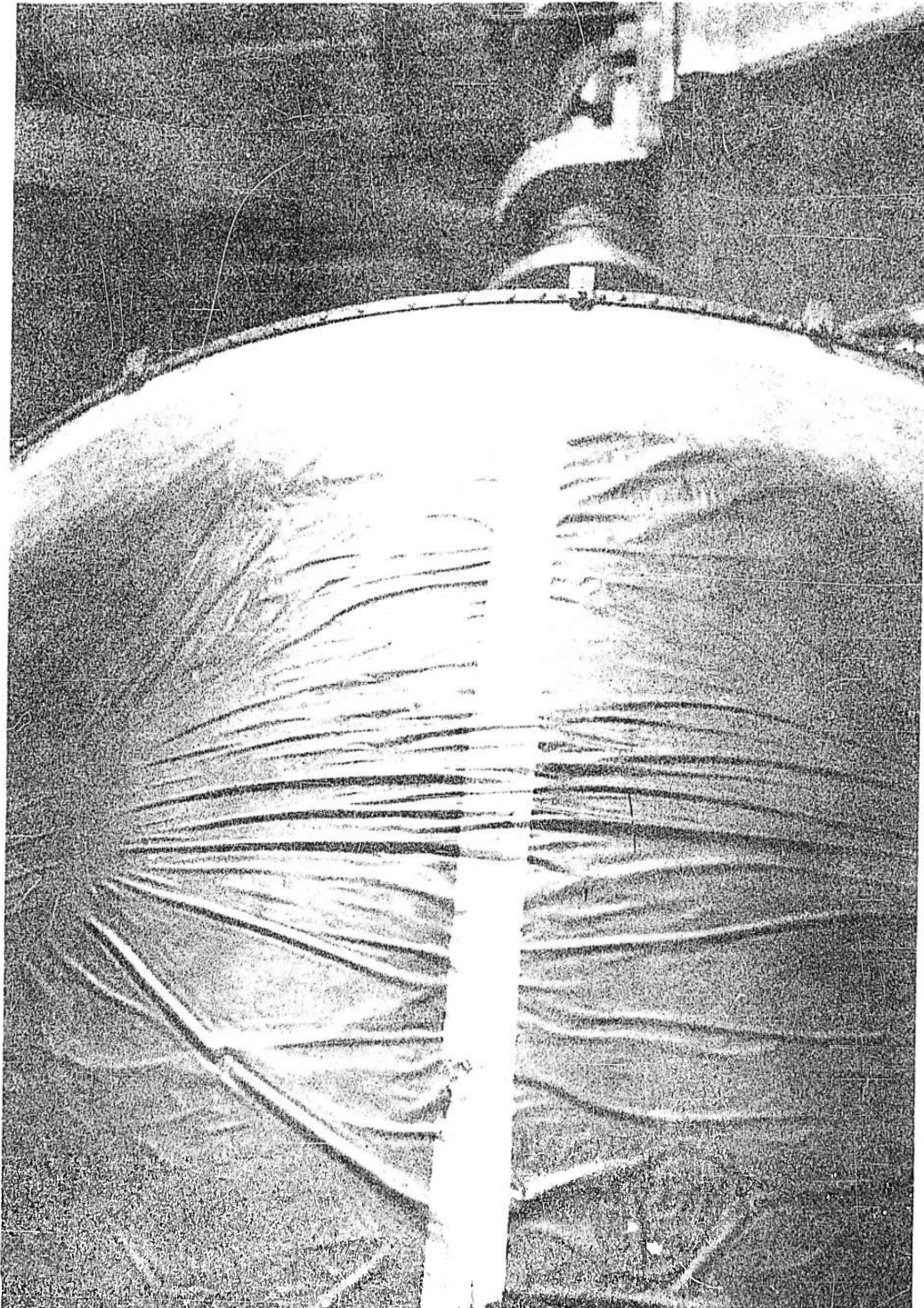


FIGURE 4  
PHOTOGRAPH OF WRINKLING EFFECT OF MYLAR COVER AFTER HEATING

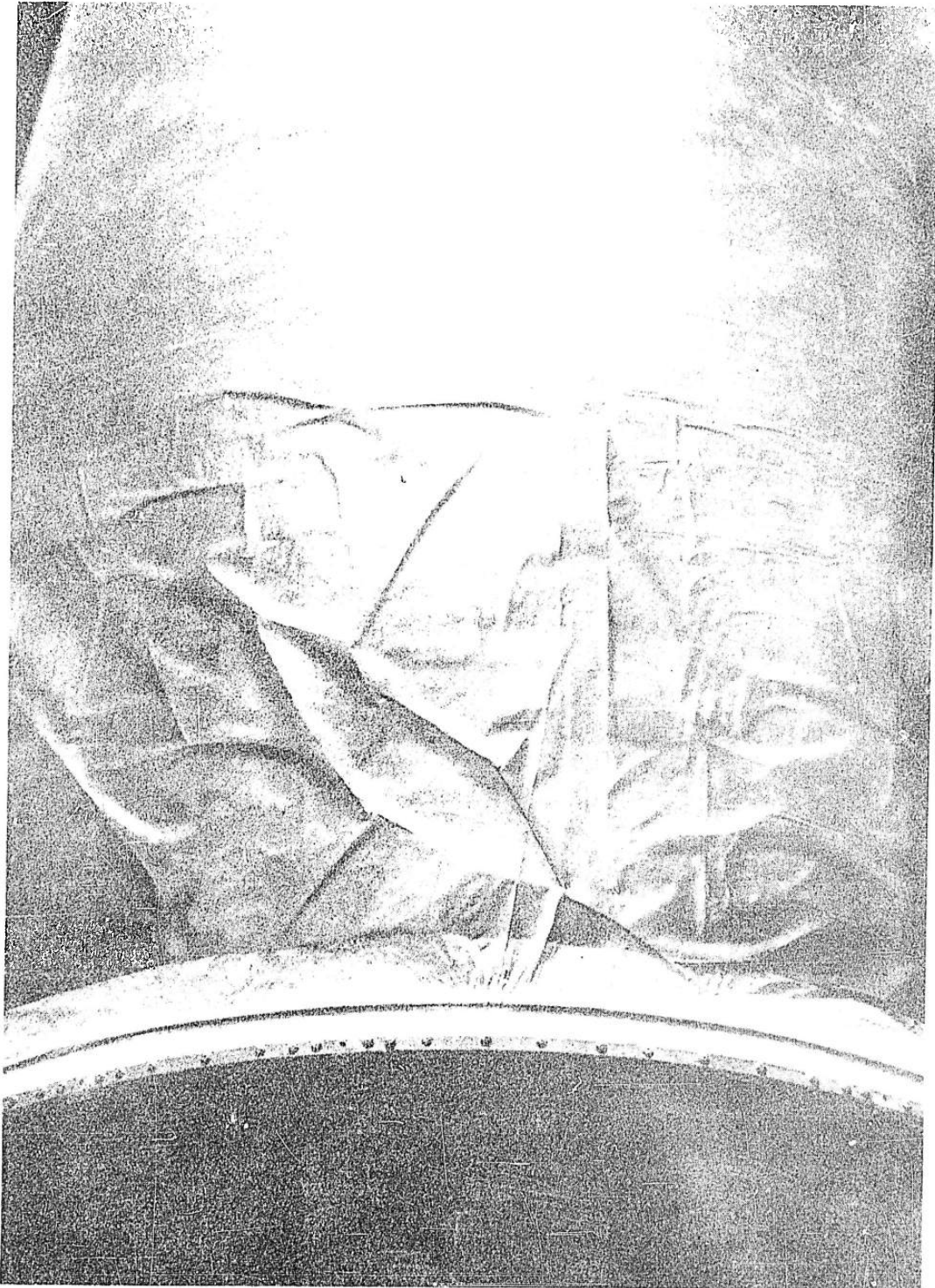


FIGURE 5  
INSULATION CONCEPT  
7,000 GALLON STAINLESS STEEL TEST TANK

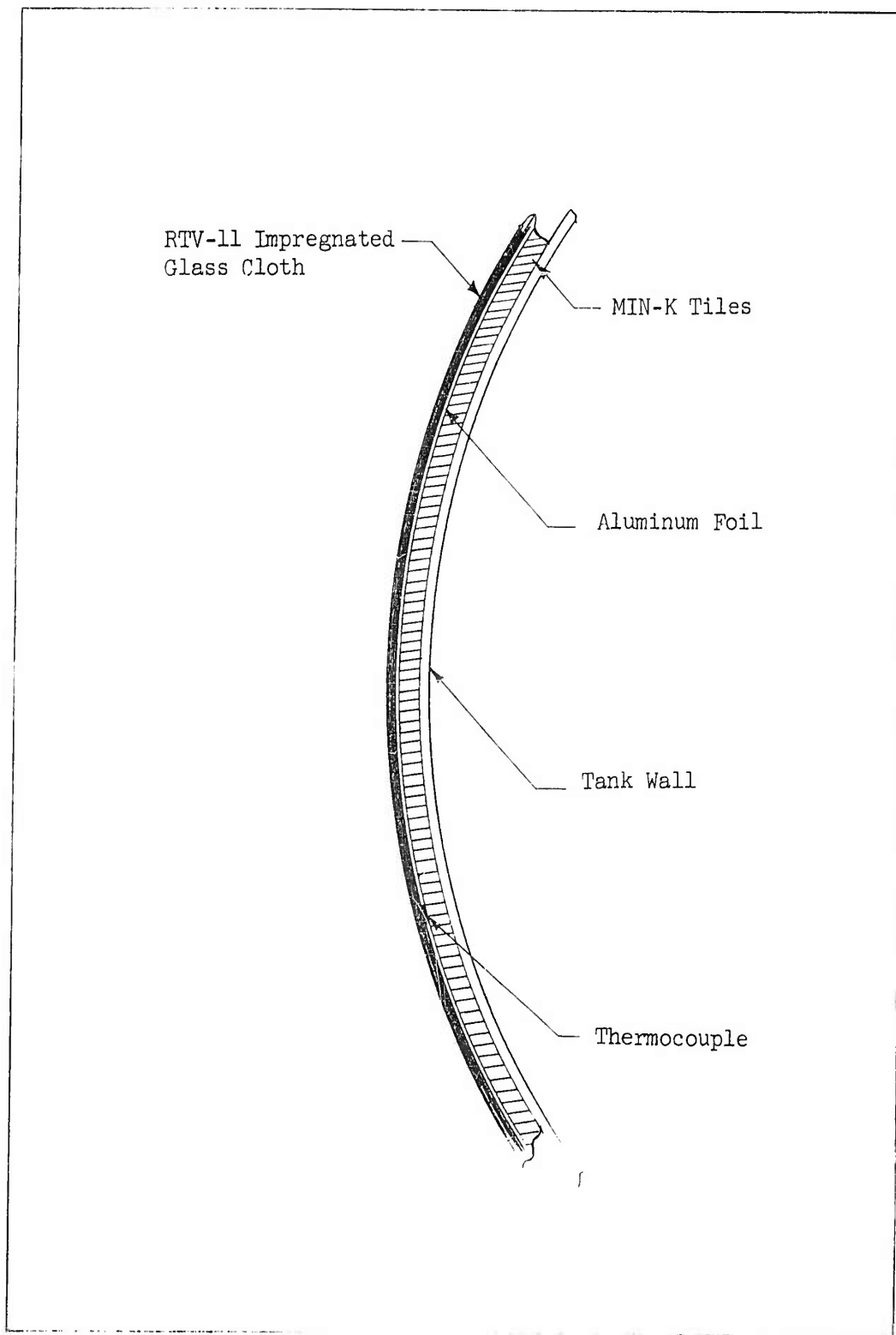


FIGURE 6  
PHOTOGRAPH OF ALUMINUM FOIL BEING APPLIED TO SIDEWALL

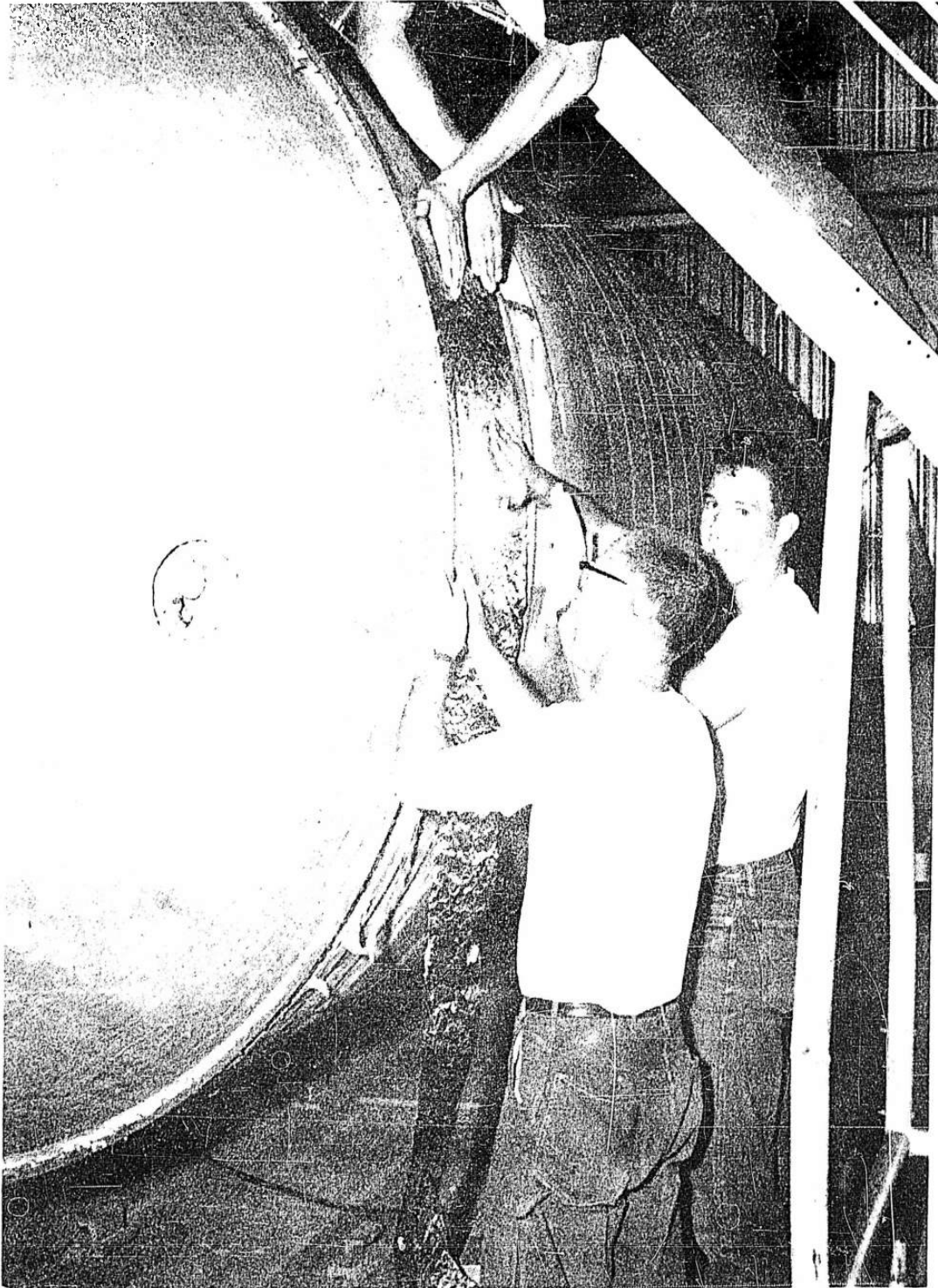


FIGURE 2  
PHOTOGRAPH OF FINISHED ALUMINUM FOIL COVERING



PHOTOGRAPH OF INSTALLATION OF AIRWAY SYSTEM IN TUNNEL



FIGURE 9  
PHOTOGRAPH OF INSTALLING FIBER GLASS CLOTH  
IMPREGNATED WITH RTV-11



efforts to heat shrink the Mylar cover. Consequently, the damaged foam in the transition space between the skirts and heads had to be removed and repoured. Resealing of the end insulation was then necessary to hold a vacuum.

This work was accomplished during July, 1960. The insulation was then subject to leak checks in preparation of moving the tank to the heat tower facility, which was accomplished the first week of August, 1960.

### 2.3 Thermal Test Facility

The following subsections will describe the progress during this period in testing the stainless steel test tank.

#### 2.3.1 Instrumentation and Data Acquisition

During the second week of August, 1960, heat tower personnel completed coordinating the tank instrumentation and plumbing with that of the heat tower facility. The completed hook-up consisted of the following:

- (1) Installation of NPSH ring and connecting tank drain to facility plumbing for fill and drain operations.
- (2) Connecting tank vent assembly to facility vent plumbing.
- (3) Installation of internal umbrella assembly containing temperature sensors for recording liquid and vapor temperatures of various stations across the tank from top to bottom.
- (4) Installation of rakes to tank wall at two elevations to measure liquid temperature at tank wall and at small increments out from the tank wall. (Tank wall surface temperature sensors, both internal and external, were installed prior to placing the tank in the heat tower facility.)

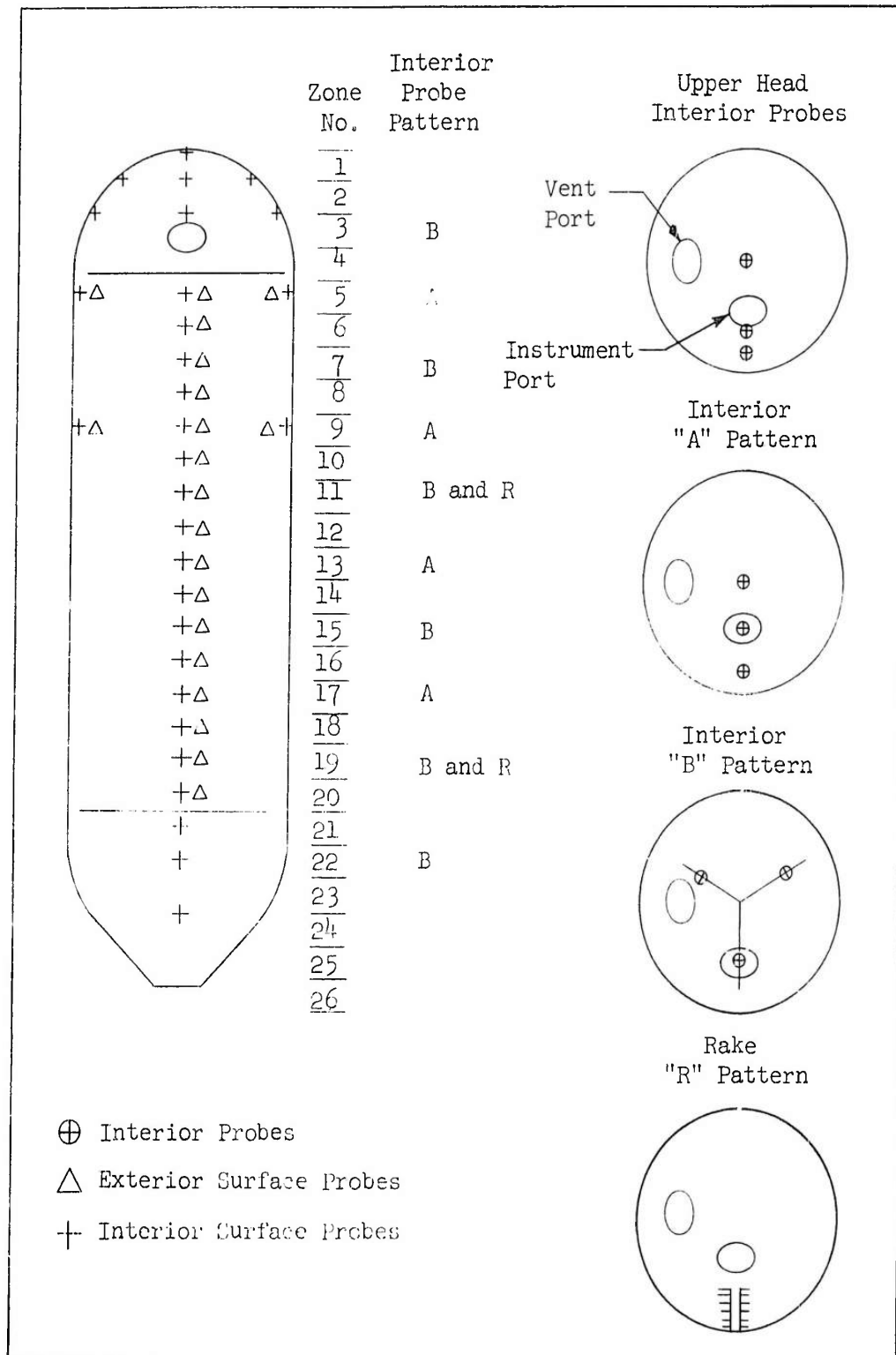
The distribution and location of the internal and external temperature probes are shown in Figure 10. To provide orientation of these probes, the tank was divided into 26 twelve-inch vertical zones. Zone No. 1 was located at the top of the tank and the remaining zones numbered consecutively to the bottom of the tank. The centerline of the instrumentation port was used for angular orientation.

During the third week of August, 1960, preliminary liquid nitrogen fills were made to check for leaks in the plumbing and to check out the instrumentation and data acquisition systems. Minor difficulties were experienced during these runs and the remainder of August was spent in correcting and adjusting the systems. By September 1, 1960, the tank and facility were ready for liquid hydrogen testing.

#### 2.3.2 Testing

During September, 1960, two limited quantity LH<sub>2</sub> fill tests were accomplished. On September 6, 1960, the tank was filled with 1,100 gallons of LH<sub>2</sub> and

FIGURE 10  
TEMPERATURE PROBE DISTRIBUTION  
7,000 GALLON TEST TANK



drained. The purpose of these two runs was to check out the tank drain assembly. Both runs were successful with no difficulties experienced.

Four days after the above runs were made, the test tank was found to be in a collapsed condition. Investigations were started to determine the reason for the collapse. The following conclusions were drawn after careful study.

1. The tank did not collapse or suffer any damage during the LH<sub>2</sub> run of September 9, 1960

2. The most likely reason for the tank collapsing was being tightly closed off overnight. The ambient temperature that particular night experienced a considerable drop, sufficient to have caused enough negative pressure to collapse the tank.

Steps were taken immediately to insure that a collapse for the reason set forth would not happen again.

This difficulty delayed the start of the thermal test runs. The tank was pressurized and most of the cans in the tank popped out to the extent that the tank itself was considered usable. Repairs had to be made to internal instrumentation and some heat lamps in the vacuum bell had to be replaced.

On September 30, a leak developed in the outer shell of storage dewar No. 1 with resulting loss of hydrogen. The vessel was repaired and on October 1, 1960, the tank and facility were again ready to start thermal test runs.

The first LH<sub>2</sub> fill test was attempted on October 6, 1960. When the tank level indicated 750 gallons had been transferred, a leak developed in the drain assembly and resulted in a fire. However, prompt action by heat tower personnel using hand extinguishers held damage to a minimum. Examination of the drain assembly indicated the leak to be between the NPSH ring and the tank drain ring. The following steps were followed in attempting to solve this problem.

- (1) A new "O" ring was installed and tested, but did not stop the leak.
- (2) An "O" ring was silver plated to make it oversize and then installed and tested. Leakage was still detected under test.
- (3) It was decided to insure no further leakage by welding the NPSH ring and drain transition assembly into one integral part. This was done and leak checked with no leakage being detected.

The slight damage to the insulation and plumbing as a result of the fire was quickly repaired and the tank was ready for preliminary LH<sub>2</sub> tests by

October 17, 1960. Limited maintenance, calibration, and testing was to be carried on to the point where funds expired.

On October 27, 1960, a limited liquid hydrogen run, utilizing 1,720 gallons of LH<sub>2</sub> was made to check the welded drain assembly. No leakage occurred, but during the warm-up period after the tank was emptied the cone insulation was damaged due to air pumping. After tank warm-up, the insulation was repaired. During the next fill, the insulation was to be continuously evacuated to protect the insulation from damage.

Several LH<sub>2</sub> test runs were made on November 9, 1960, to check out the drain assembly, NPSH assembly, vortexing, quality meter and tank insulation. The amount of fluid used in these runs was 3,300 gallons of LH<sub>2</sub>. Two problem areas developed during these runs. The NPSH assembly was found to have a leak inside the tank where the torus ring connects. Since this assembly was now welded into the tank and could not be removed, no repairs could be made. Therefore, on any subsequent test runs, NPSH data could not be taken.

It was also discovered that the vent gas flowmeter froze up at -320°F. The meter was removed from system, repaired, and replaced.

Two other series of test runs were made in November, 1960, for purposes of checking out the system prior to a fill test with heat being applied to the exterior. These test runs were as follows:

- (1) On November 16, 1960, six flow control tests were conducted, utilizing from 4,250 to 5,150 gallons of LH<sub>2</sub> in each run.
- (2) On November 22, 1960, six more flow control tests were run. During these runs, the tank pressurization system was used for the first time with good results. These runs utilized from 3,000 to 6,000 gallons of LH<sub>2</sub> in each run.

At the completion of these test runs, the facility was ready for a fill test with heat to be added to the full tank.

On December 14, 1960, five programmed flow control tests were conducted without any difficulty. After these tests were completed, a 4-level heat rate thermal test was performed on the stainless steel experimental test tank. A description of the tests and the results is as follows.

A pertinent tank description is that of a 7,000 gallon capacity, liquid hydrogen fill, 1/8" Min-K insulated, stainless steel, pressure stiffened tank. The pressurization was provided by hydrogen gas boil-off maintained at 10 psig.

After filling, the outer surface of the tank was exposed to ambient conditions for a period of ten minutes. The resulting equilibrium

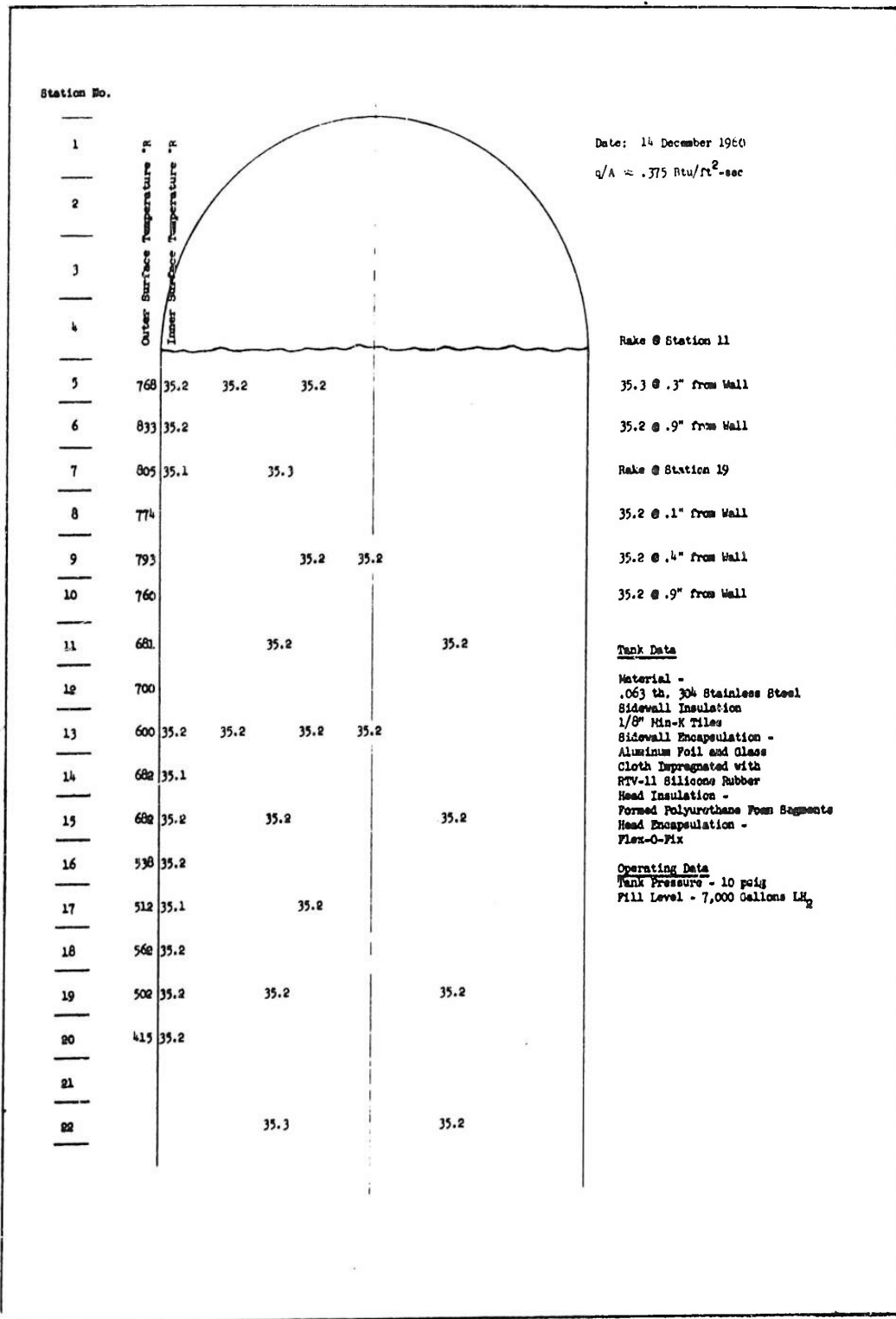
temperature of the outer surface was  $380^{\circ}\text{R}$ , which was in good agreement with that of the theoretical analysis for  $1/8$ " evacuated Min-K 504.

Three constant rate radiant heating intensities were imposed upon the tank. These rates were approximately .125, .250, and .375 Btu/ft<sup>2</sup>-sec. The rates were only approximate, since a considerable amount of uncontrolled convective heat transfer resulted from exposure to a nitrogen gas environment during heating. As a result, the outer surface temperature varied considerably with tank height during the heating tests. The first two levels of intensity were maintained for a period of five minutes or more; the latter level was maintained for approximately one minute. Figure 11 shows the temperature distribution throughout the tank during heating at the approximate level of .375 Btu/ft<sup>2</sup>-sec. The outer surface temperature varied from  $415^{\circ}\text{R}$  at the lower end of the cylindrical section to  $833^{\circ}\text{R}$  near the upper end of the cylindrical section. The inner surface temperature remained at  $35.2^{\circ}\text{R} \pm .1^{\circ}\text{R}$ , the same as the temperature throughout the liquid. Temperatures of the liquid were taken at various distances from the tank wall ranging from .1 inch to 4 feet. Liquid temperatures were also taken at various heights in the tank. No temperature change occurred at any point in the liquid during these tests. It is interesting to note that the bulk temperature of the liquid in the tank after 20 minutes at 10 psig,  $35.2^{\circ}\text{R}$ , was the same as the equilibrium temperature of the hydrogen at 0 psig prior to leaving the storage dewar.

The above test data is presented for reference only and is not to be used as a criteria for calculations or design. This is due to the response time of internal temperature probes not being fast enough to record the actual changes of temperature versus time. Therefore, there is an inherent time error that cannot be compensated for in this series of tests. This problem must be investigated further to determine a method of accurate measurement of rapid temperature changes at  $\text{LH}_2$  temperatures.

At the completion of these tests all testing activity was suspended. Partial Company funding was necessary to complete the thermal tests described above. Only normal maintenance of the facility was to be performed starting January, 1961.

FIGURE 11  
TEMPERATURE DISTRIBUTION  
STAINLESS STEEL TANK THERMAL TEST



### 3.0 NONOPERATING PERIOD

During the time that funding was not available, all operations ceased. Tooling was stored and the thermal test facility closed. All design and test personnel were given other responsibilities.

In the nonoperating period, the data acquisition system was for all intents and purposes redesigned and rebuilt by instrumentation personnel. This effort was on a spare time Company-sponsored basis.

Continued effort on the part of Air Force personnel resulted in refunding the program such that the titanium tank could be fabricated and thermal testing continued.

Prior to the time that funding was made available, a program for completion of the contract was developed.

The program as developed included completion of the titanium tank, repair, and insulation of the stainless steel test tank, thermal testing of the stainless steel and titanium test tanks.

#### 4.0 SIMULATED FLIGHT TEST PROGRAM

This section of the report will describe the work accomplished from May 8, 1961, to July 31, 1961.

A description of the work progress will be made on the following subject topics:

- (a) 7,000 gallon titanium test tank system
- (b) 7,000 gallon stainless steel test tank system
- (c) Thermal facility

#### 4.1 7,000-Gallon Titanium Test Tank System

The following subsections will be devoted to describing the work progress during the period stated above:

- (a) Additional design considerations
- (b) Structural analysis
- (c) Tank fabrication progress

##### 4.1.1 Additional Design Considerations

##### 4.1.1.1 Structural

During this period the upper and lower hemispherical heads were redesigned in an effort to solve the problems as set forth in previous reports in making the circumferential welds joining the subassemblies and also improve the quality of welds joining the head segments. A major change in fabrication of the head segments has been incorporated in the design. This change calls for hot stretch forming of the head segments from .032 titanium material followed by chemical milling to remove the excess material down to .018 where the thicker section is not desirable. The advantages of this process are as follows:

1. Provide weld lands around the perimeter of each segment .032 thick by .75 wide. This thicker weld section will greatly improve hold-down characteristics and provide a greater heat sink for the actual welding. The use of more heat in the welding process will eliminate, for the most part, the problem of porosity encountered previously.
2. The reinforcing splice bands that were previously welded into the heads will be eliminated. The reinforcement now will be an integral part of segment material, thus eliminating two welds and the corresponding fit-up and trim operations.
3. Provide thicker weld lands for attaching the manhole ring, and instrumentation port rings. This will essentially eliminate the problem of the skin wrinkling in the weld area as was experienced before.

Figure 12 shows the new concept as it will appear at final assembly. Although a small amount of additional weight will be added by this approach, the advantages gained in the fabrication process should more than offset the penalty in weight for the particular application. It is believed that the original concept would be feasible for a flight article with adequate tooling.

#### 4.1.1.2 Thermal

The insulation concept to be used on the titanium test tank will be the same as the installation now on the stainless steel test tank. This concept is described in detail in paragraph 4.2.1.2.

#### 4.1.2 Structural Analysis

All structural analysis has been completed on the titanium test tank and reported in previous reports. It is believed that the new design considerations for the end closures will not affect the structural integrity of the tank. Therefore, no further analysis will be made.

#### 4.1.3 Tank Fabrication Progress

The following subsections will be devoted to describing the progress made on the titanium test tank during the period stated above.

##### 4.1.3.1 Engineering

During this period, engineering drawings covering the new design of the hemispherical heads were released for fabrication. All other drawings were brought up to date, incorporating all changes made previously, and re-released to activate the fabrication program. This work has all been accomplished and fabrication has begun.

##### 4.1.3.2 Cylinder Sections

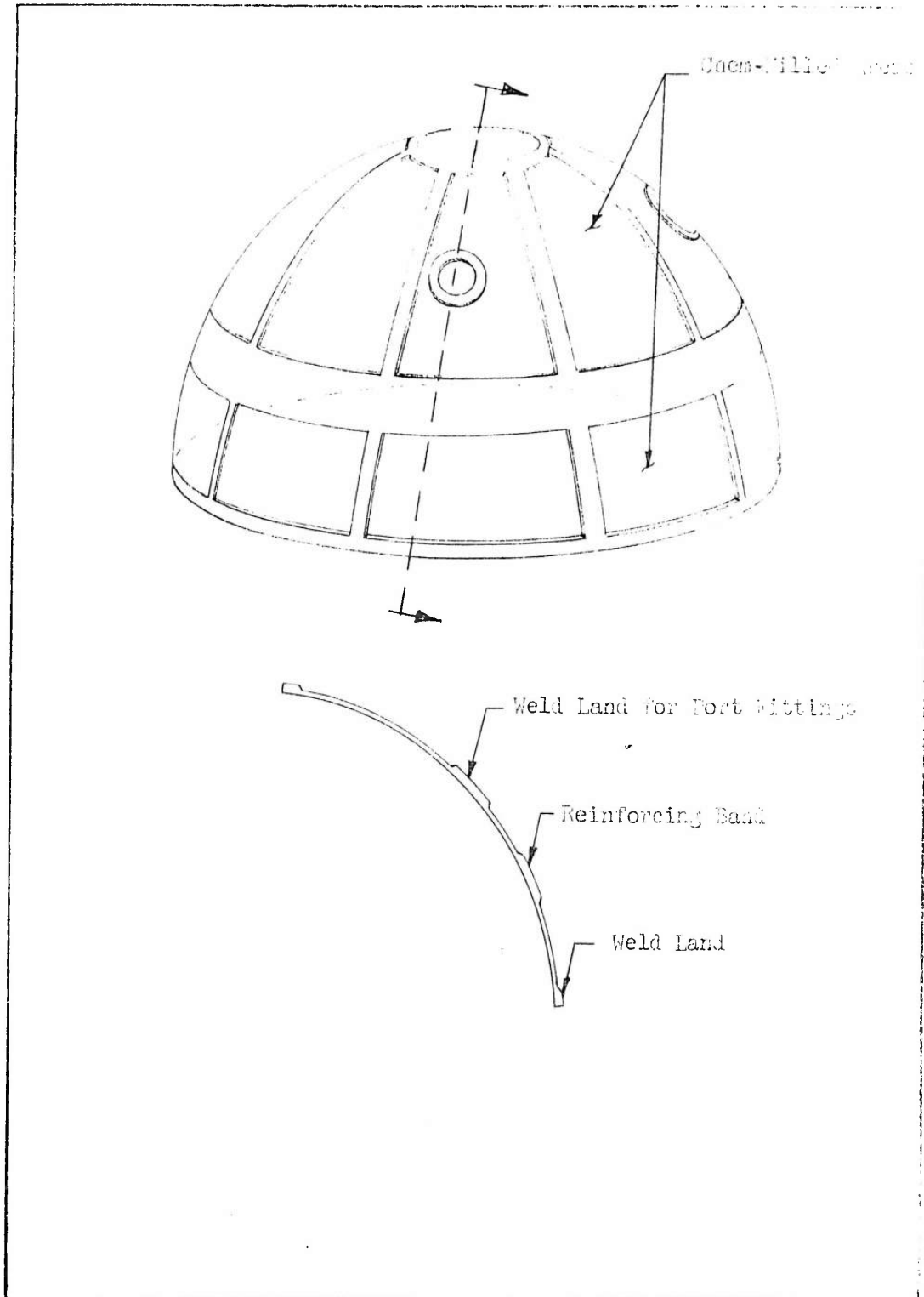
The cylinder sections are complete except for final trim and closure weld and are still in storage. These sections are in good condition and are ready for final assembly.

##### 4.1.3.3 Hemispherical Heads

Sufficient material was received during this period to fabricate both heads. Some difficulty was encountered initially in forming the head skins. One head skin parted during the stretch operation and was not salvable. Two other skins also parted but in such a manner that they can be salvaged. Two extra sheets of material were ordered so sufficient material would be on hand in case further difficulties were encountered in forming.

During the last two weeks of July, 1961, welding of the head skins into pairs was commenced. By the end of July eight skins of the lower head were

FIGURE 12  
SKETCH OF NEW HEAD CONCEPT



welded into pairs of four. The weld X-ray examinations showed good quality and the welding in general has been excellent. The ninth skin is being refabricated because of wrinkles which appeared in the skin. The skin is scheduled for completion in August, 1961, at which time the lower head will be completed.

Sufficient skins have now been fabricated and received for the upper head. Prior to welding the skins into pairs, the instrumentation and vent port rings will be welded into the individual segments. This work will be performed early in August, 1961.

#### 4.1.3.2 Skirts

Both skirt assemblies were completed prior to reactivation of the program. These assemblies were inspected as to their condition and found to be ready for use and are now stored for final assembly.

#### 4.1.3.3 90° Right Circular Cone

The 90° cone was completed previously and has been in storage. It is ready for final trim and attachment to lower head section.

#### 4.1.3.4 Hemisphere-to-Cylinder Splice Fittings

Both of these fittings are completed. However, they will need to be re-trimmed to match the new design of the heads. This will be performed after the heads are completed and final assembly is begun.

#### 4.1.3.5 Miscellaneous Parts

The drain assembly has been attached to the 90° cone assembly. The drain adapter is complete and ready for bolting in place at final assembly. The manhole ring, instrumentation ring, and vent rings have been removed from the old head and retrimmed for installation in the new head. A new manhole cover plate is being fabricated by the chemical milling process to eliminate the need of welding the flange and cover skin. This welding of the thin circular cover skin to the attaching flange was extremely difficult and resulted in a poor quality weld. Now the cover plate is being fabricated to contour from a single piece of material.

### 4.2 7,000-Gallon Stainless Steel Test Tank

The following subsections will be devoted to the work progress during the period stated above:

- (a) Additional design considerations
- (b) Tank fabrication progress

#### 4.2.1 Additional Design Consideration

##### 4.2.1.1 Structural

No design changes were made during this period. The tank was completed in 1960 and has been subjected to tests described in previous sections. However, since a new insulation concept is being considered, the tank will be subjected to further inspection because of its being collapsed previously.

##### 4.2.1.2 Thermal

A new insulation concept was designed during this period. Engineering drawings have been completed and released and orders placed for the necessary material.

This new concept will be as follows.

- (1) The tank to be wrapped in a spiral fashion with one (1) mil thick fiberglass cloth 36 inches wide. Sufficient wraps will be accomplished until an insulation thickness of .10 inches is built up
- (2) The insulation will then be encapsulated in an aluminum foil cover. The aluminum foil will also be wrapped in a spiral fashion for three (3) layers. Each layer of foil will be bonded to the previous layer with General Electric RTV-11 silicone room temperature curing rubber. Prior to wrapping, the foil will be primed with General Electric SS4004 primer for good bonding characteristics. The last wrap will be primed on one side only, so that the finished exterior will be a bright aluminum color. Figure 13 shows a cross section of the insulation and aluminum foil cover when installed.
- (3) The heads will be insulated with contoured fiberglass segments. The segments will be attached to the heads with Stabond 511 adhesive. After installing the segments, the insulation will be encapsulated with aluminum foil. The aluminum foil is to be applied in great circle strips 12 inches wide with each layer bonded to the previous layer with General Electric RTV-11 Silicone rubber. The foil will also be bonded to the skirt angle rings to seal the entire head area. Figure 14 shows a cross section of the head insulation and aluminum foil cover.

#### 4.2.2 Tank Fabrication Progress

The following subsections will describe the work progress of reconditioning the tank and installation of the new insulating concept.

FIGURE 13  
CROSS SECTION OF SIDEWALL INSULATION AND COVER

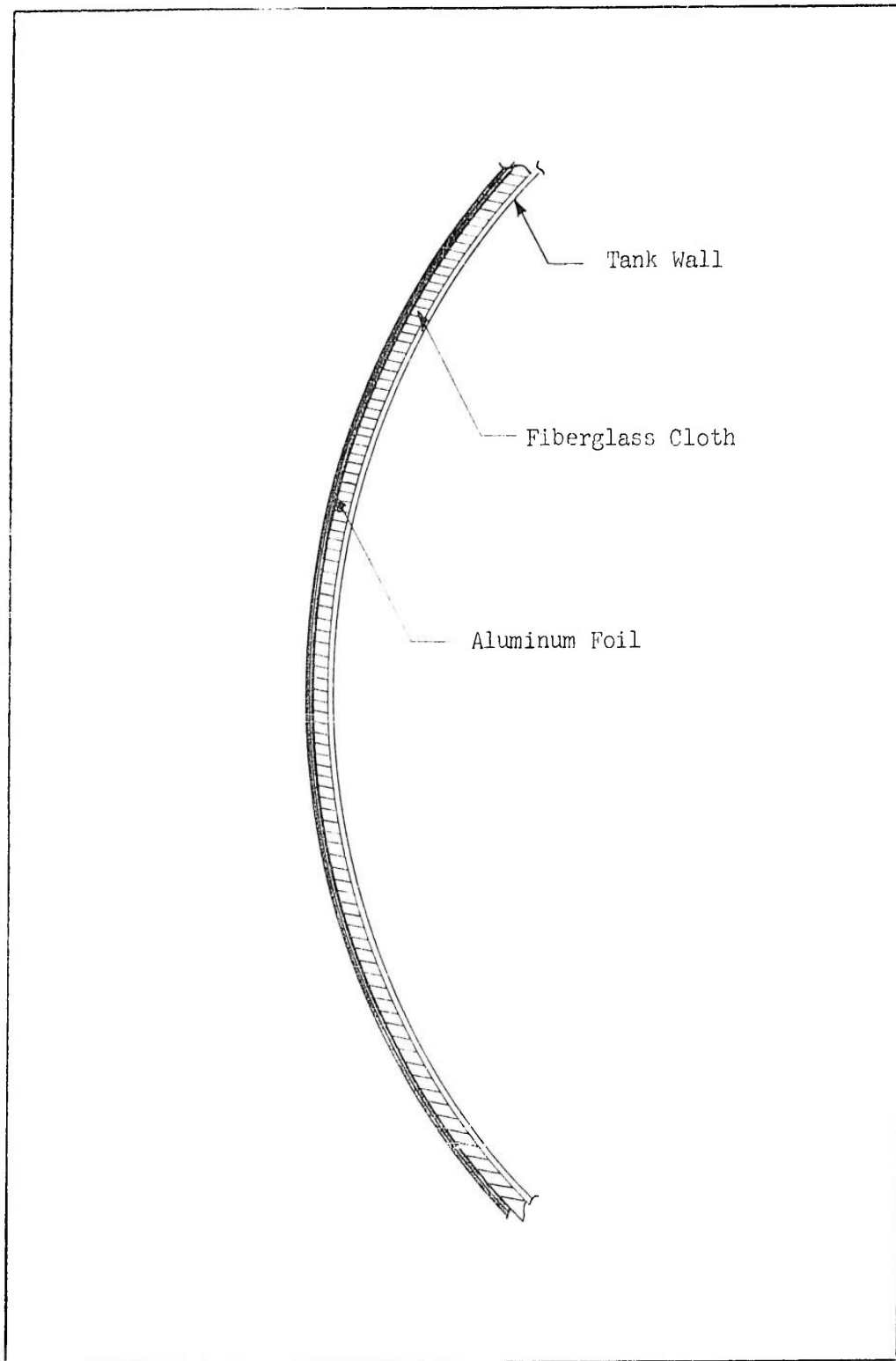
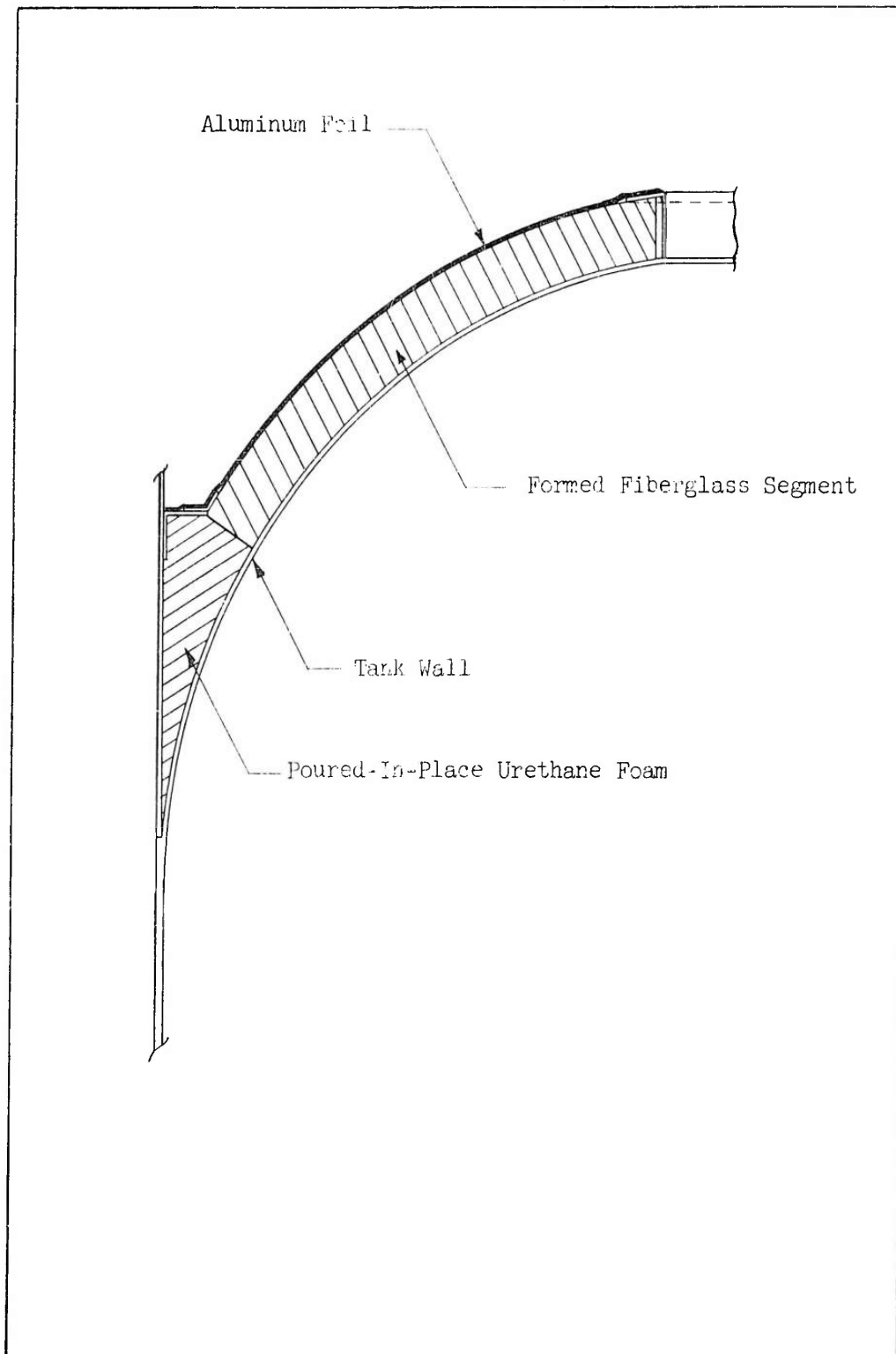


FIGURE 14  
CROSS SECTION OF HEAD INSULATION  
AND ALUMINUM FOIL COVER



#### 4.2.2.1 Reconditioning

During this period the stainless steel tank was removed from the thermal facility and returned to the shop. The following steps were taken to recondition the tank in preparation for installing new insulation.

- (1) Strip all old insulation from tank except foam in annulus between skirt and head.
- (2) Repair any "cans" or dents remaining in tank cylinder when the tank was collapsed previously.
- (3) X-ray examination of all weld seams in damaged areas.
- (4) Repair NPSH ring and reinstall.
- (5) Leak check entire tank assembly.

All of this work was performed satisfactorily during June 1961 and the tank was judged to be in good condition for further test uses.

#### 4.2.2.2 Insulation

The insulation of the sidewall proceeded without difficulty during July 1961. By the end of this period the sidewall insulation was completed and initial pumpdown was started. This initial pumpdown indicates that the aluminum foil cover will hold a reasonable vacuum. Further testing in this area will be done.

Figures 15 and 16 show the method of applying the fiberglass cloth and aluminum foil cover.

The head insulation segments were delayed at the manufacturer. The date of delivery is now to be in August. Therefore, the insulation of the heads will not be completed until the latter part of August, 1961.

### 4.3 Thermal Facility

Reactivation of the thermal test facility was started at the commencement of the contract. The following subsections will be devoted to a description of the work progress during this period:

- (a) Mechanical
- (b) Instrumentation and Electrical

#### 4.3.1 Mechanical

During this period, all flow systems have been checked for deterioration and operation. All necessary repairs and maintenance have been performed and the systems are ready for final check with liquid nitrogen when the test tank is installed.

Some difficulty was experienced in evacuating the vacuum bell. The inflatable seals in use proved to be too soft and failed when a partial

FIGURE 15  
PHOTOGRAPH OF APPLYING FIBER GLASS CLOTH INSULATION

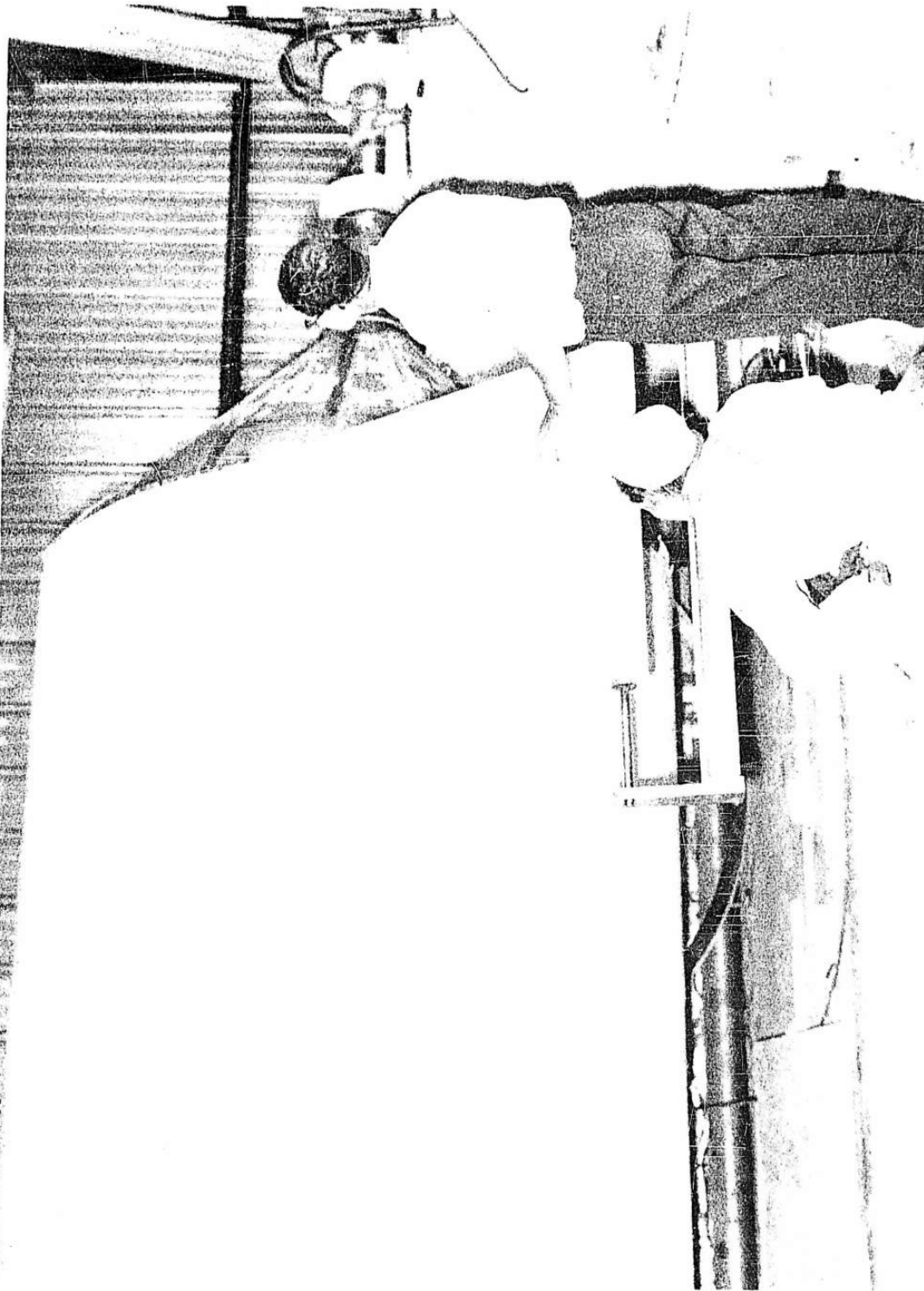


FIGURE 16  
PHOTOGRAPH OF APPLYING ALUMINUM FOIL COVER



vacuum was achieved. New seals of harder material were obtained and installed. These seals proved to be adequate in maintaining a vacuum using a stainless steel test cylinder to seal against. Final testing will be done when the test tank is installed.

#### 4.3.2 Instrumentation and Electrical

A program of complete renovation of the instrumentation and acquisition systems was started. This program was delayed shortly after it was begun due to lightning damage to the power transformers. Repair of these transformers delayed reactivation for a period of six weeks. The transformers were reinstalled in July, 1961, and rapid progress was made in checking out the instrumentation. This work will continue until the test tank is installed.

Two major problems exist in the data acquisition systems. These are as follows:

1. During previous test runs, a temperature sensing device would occasionally develop an open circuit which would cause the data acquisition amplifier to "see" an excessively high voltage, thus overdriving the amplifier to the point where no data could be recorded for that point or any of the remaining points on the commutator since the amplifier could not recover fast enough.

2. Accurate sensing of the surface temperature of a tank wall. This includes the proper sensing device and method of attachment.

The solution to problem No. 1 was believed to be in the amplifier. If the present amplifier were replaced with one with a more rapid recovery, then the problem would be eliminated. A new amplifier specifically designed for rapid recovery was obtained and installed and the results are very satisfactory.

The solution to problem No. 2 is not so simple. The accurate sensing of surface temperatures is a problem throughout the industry. The following approach will be undertaken to establish criteria for sensing surface temperatures.

- a. A team of Beech personnel is to make a survey of the industry to gather information concerning the work done in this area. This will include visits to various plants and interviews with those persons interested in this area.

- b. Set up a series of tests in a calorimeter to be designed and built for this purpose. These tests to evaluate various sensing devices, bonding agencies, and technique of attachment.

At the conclusion of this investigation, a report will be made of the results and the best method found will be used to sense the surface temperature of the tank wall. This work is proceeding and the results will be reported in the next quarterly report.

ENGINEERING REPORT REFERENCES

- E.R. 7602 FTRDI MR60-1, Establishing Proven Design Criteria for Cryogenic Boost Tanks, Quarterly Progress Report, Beechcraft Research and Development, Inc., March, 1960 (SECRET)
- E.R. 8129 FTRDI MR60-2, Establishing Proven Design Criteria for Cryogenic Boost Tanks, Quarterly Progress Report, Beechcraft Research and Development, Inc., June, 1960 (SECRET)

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