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VACUUM JACKETED UMBILICAL LINES TECHNOLOGY ADVANCEMENT STUDY

BAYONET JOINT

AMETEK/Straza
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El Cajon, California 92021

CASE FILE COPY

November 28, 1969

Final Technical Report, Task VII
Contract Number NAS 10-6098

Prepared for
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
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16. Abstract

This report is a detailed study of the bayonet joints located in the cryogenic propellant lines and vent lines routed across the retractable service arms on the Launcher Umbilical Tower. These lines contain numerous bayonet joints to permit disassembly for repair and ease of installation. These joints have experienced damage during assembly due to misalignment and the heavy, cumbersome nature of the line to which they are attached. As a result of comprehensive evaluation and testing of the existing hardware, it was concluded that simplification of this hardware and improvement in joint assembly methods are necessary to reduce damage, reduce replacement rate, and still maintain the required level of insulation. Two new units, one 8-inch diameter and one 6-inch diameter vacuum jacketed bayonet joint test section, were developed during this study which successfully met all of the primary design goals.

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AMETEK/Straza
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Final Technical Report
for
Vacuum Jacketed Umbilical Lines
Technology Advancement Study
Task VII - Bayonet Joint
Contract Number NAS 10-6098
November 28, 1969

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ABSTRACT

In any missile launch complex similar to SATURN V, cryogenic propellant lines and vent lines are located on moveable service arms. These lines contain numerous joints to permit disassembly for repair and ease of installation. In order to meet vacuum insulation requirements for the propellant lines, a bayonet joint consisting of a double-walled, tapered-nose male plug and double-walled female receptacle is presently used. This joint, even though made of heavy gauge steel, is easily damaged during assembly due to misalignment and the heavy, cumbersome nature of the line to which it is attached. Simplification of this hardware and improvement in joint assembly methods are necessary to reduce damage, reduce replacement rate, and still maintain the required level of insulation.

The objective of this program was to develop, fabricate, test and evaluate an improved joint design. One basic concept for a jacketed single-plane-assembly cryogenic joint was developed during this study. It is essentially the same cone configuration used by AMETEK/Straza and others with a convection barrier that was developed and patented by Arthur D. Little, Inc., in 1968. The basic anticipated improvement over the patented unit is a new anti-convection block for use with liquid hydrogen. A cross-section of this joint is shown in Drawing 8-030928. The new unit uses the existing ring joint flange as well as inner and outer pipe diameter envelope currently used on the Launch Complex 39 propellant lines and is capable of replacing all existing LC 39 units.

All environmental testing of the bayonets was done when coupled with the vacuum jacketed rotary joint which was also developed during this same program. This program was divided into two phases. The first phase, covering a period of six months, consisted of completing the tasks in Par.7.1 shown in the table of contents. After receiving approval of the Phase II Proposal and Test Plan, the second phase was started. This covered a period of nine months and consisted of fabricating and testing one 8-inch diameter and one 6-inch diameter vacuum jacketed bayonet joint test section.

Conclusions

The two units developed under this contract successfully met all of the primary design goals which were as follows:

A. To confirm the low heat leak of the basic design single-plane-entry coupling as originally developed by Masoneilan. Heat leak values came out lower than calculated.

B. To extend the design concept for use in liquid hydrogen systems. This required development of a new anti-convection barrier which was pressure sealed against the highly conductive gaseous hydrogen to 300 psi.

C. To maintain interchangeability with the flanged bayonets presently in use on the existing Launch Complex 39 propellant transfer lines. All existing lines could be modified to accept this new joint without disturbing the present overall system heat leak.

D. To maintain structural integrity and a low heat leak on a joint which does not use the stiffener rings required on the Masoneilan units. This allows the designer to use a smaller radial clearance for any vacuum jacketed piping system.

Recommendations

Additional work should be done to complete the assembly techniques and heat leak tests on other types of anti-convection barriers for liquid hydrogen systems.

All heat leak tests on LH_2 systems should be run in liquid hydrogen in lieu of liquid nitrogen.

Conductivity tests should be run on the CTL Dixie insulator to further confirm the findings of this program and the Masoneilan Program. This would be a definite aid in future LO_2 system designs.

The liquid nose seal used at the inner pipe junction should be investigated from the standpoint of simplification. There are probably other less expensive seal configurations which would perform the same function.

If the bayonet presently in use on LC 39 continues to give assembly and handling problems, consideration should be given to retro-fitting to this new joint.

7.0 FINAL REPORT

7.1 PHASE I TECHNICAL REPORT

The following report presents the results of all the tasks required to accomplish the program objectives. These objectives are summarized as follows:

A. "On-site review and evaluation of present component operating and environmental conditions including: misalignment of male and female bayonet joints during installation; installation procedures; handling equipment and procedures; failure history and test data."

B. "Review all data and perform a design evaluation including: Improved seal design, sturdier structural qualities, lower heat leak rate joint. Determine pressure loading to accomplish structural analysis. Prepare drawings for new designs or modifications to existing bayonet joint designs."

C. "Coordinate with vendors to ascertain availability of hardware required to meet study needs. Determine if hardware exists that will meet low heat leak rate, required assembly/disassembly ease, ruggedness, positive sealing, simplicity of design and reliability."

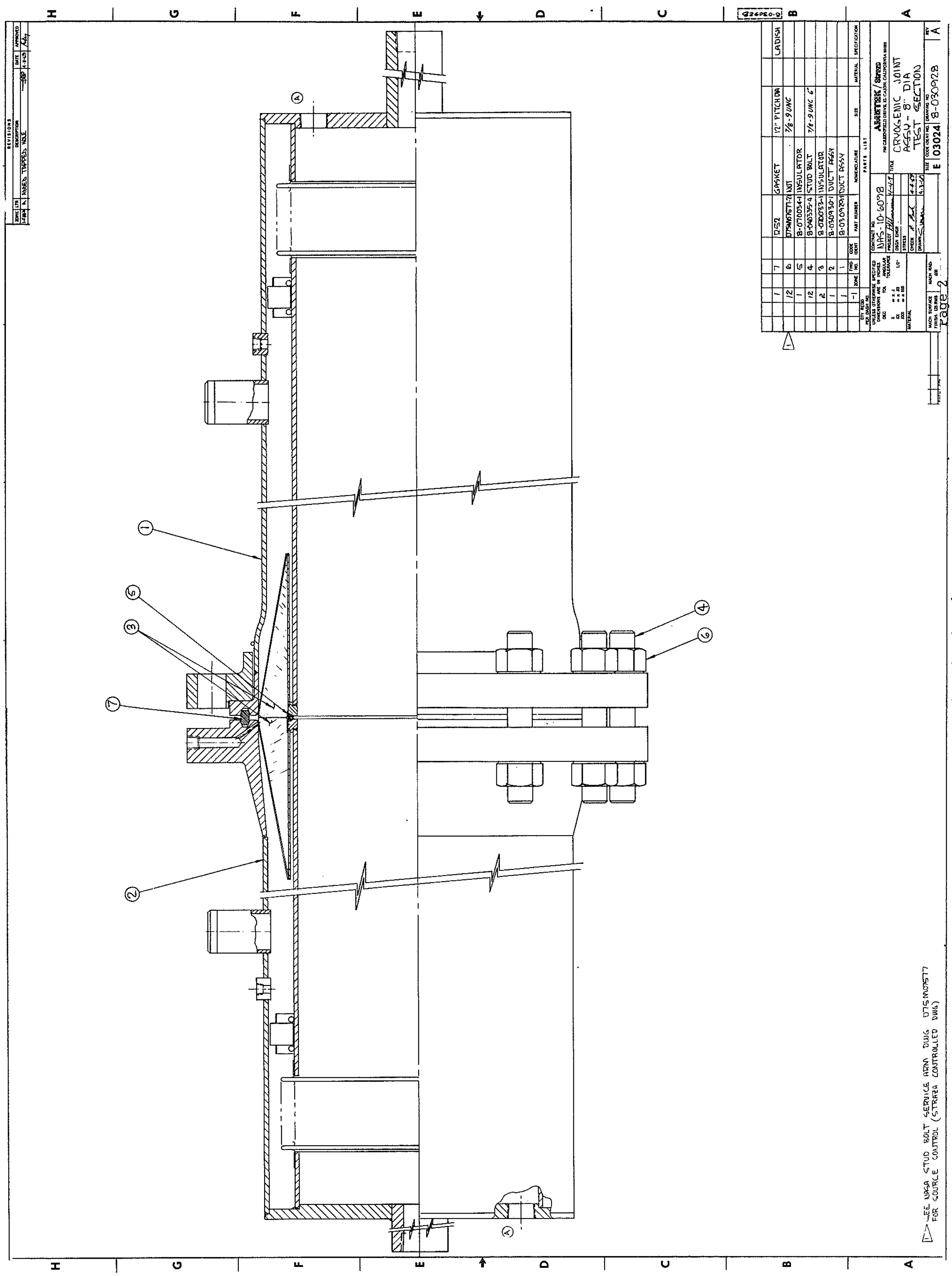
D. "Prepare a technical report of all Phase I findings including recommendations for new designs and/or modifications."

7.1.1 Hardware Evaluation

7.1.1.1 Functional Review

During the week of October 7, 1968, at Kennedy Space Center and Huntsville, the pertinent information gathered in reference to bayonets indicated that the existing bayonet performed satisfactorily except when used in conjunction with the Conoseal-type flange. Maintaining the seal in place during assembly was difficult and, in several instances, leaks were created due to improper seating of the seal during bayonet assembly.

We were advised that even though the existing bayonet performs well once installed, it is extremely difficult to slip together. This is, of course, due to the handling problems associated with these massive lines (8-inch Pipe x 10 feet long).



8-030928 Cryogenic Joint 8 Inch

The octagonal ring joint gasket used with the standard lap and weld neck flange was performing satisfactorily. The two leak checks made on this seal per Assembly Specification 75M10474 (one at assembly and one just prior to launch) indicated that this type joint has the structural integrity necessary to withstand operating loads.

7.1.1.2 Component Operating Requirements

There were no indications that the existing bayonet design did not meet the specification requirements in regard to heat leak or gas leak. Several incidents of leakage were reported, but in each case the fault was improper flange bolt load which precluded sealing by the octagonal ring. There was no data uncovered during Kennedy Space Center trips which established whether or not the existing units met the specification heat leak. It is known, however, that the heat leak is higher than originally established in the NASA specification to Brown Engineering. This is due to a heavier male bayonet outer tube wall requirement brought about as a result of an early bayonet failure caused by buckling under external proof pressure.

The design data used for the bayonet joint are the same as for the rotary joint and were taken from NASA Specification 75M09783, Revision D, and 75M06519, Revision E, as follows:

Vent Lines 75M09783

Material:	316L Exposed	
	321 Internal	
Temperature:	Ambient	+125°F
	Outer Duct	-250°F
	Inner Duct	-423°F
Pressure:	Operating	50 psig
	Proof	100 psig
	Burst	200 psig
Flow:	35,000 SCFM on 8-inch lines	
	75,000 SCFM on 12-inch lines	
Cycling:	10,000 pressure cycle 0 to 50 at -423°F	
Leak:	$<1 \times 10^{-6}$ ATM/cc/sec helium at 50 psig	

Propellant Lines 75M06519 (LH_2 and LO_2, 8 in. x 10 in. V.J.)

Pressure Cycles:	10,000 from 0 psi working pressure.
Pressure:	The most critical line pressure will be used to design this joint: 190 psi operating; 285 proof, 760 burst.
Flow Rate:	5,000 GPM LO_2 or 79,000 SCFM GO_2
Temperature:	+125°F ambient to -423 LH_2 internal
Heat Gain:	The existing system has heat gains ranging from 180 to 300 Btu/hr. The majority of this is due to bayonets. In order to optimize the envelope for the rotary and maintain common anti-convection blocks in the bayonet joints and rotaries, the higher heat leak value is being used.
Leakage:	The gas leakage through this joint will be the same as the existing system since the same ring joint flange is being used. The value to be used will be the same as required in NASA Test No. 26427 which is 1×10^{-4} atm /cc/sec at 50 psig helium pressure.
Vibration:	The vibration of loads will be selected from Procedure II of KSC-STD-164 and are equal to $\approx$20 g rms.

7.1.1.3 Evaluation of Equipment

This section is a review of the actual hardware to determine if problems with the unit are associated with the installation and/or removal of the component from the system.

The main problems associated with the existing design bayonet is the difficulty in sliding the male bayonet into the female.

Many units were damaged as can be seen from a review of the inspection reports written by Receiving Inspection. All the I.R.'s reflect damage done as a result of installation. A total of 33 I.R.'s were written against the lines in the existing system. They were all for the following reasons:

A. Scratches on I.D. of female bayonet;

B. Nicks or dents on female and male bayonet tubes;

C. Nose seal surface nicked and scratched.

Similar damage occurred on the vent lines. The vent line bayonet is basically a studier design than the propellant line bayonet and even they were susceptible to this damage.

The evaluation of the male/female bayonet joint as it is used in this system indicates that bayonet type joints should be limited to approximately 3-inch diameter V.J. Lines and smaller. The lines used in this system are basically too large, cumbersome and heavy to be fitted with the standard bayonet design. The design concepts used throughout this study will be other than the male/female type joint.

Due to the extreme weight of some of the lines, the standard ring joint flange and lap joint flange will be maintained. They also have sufficient flexibility for flange alignment during assembly.

The high g loads recorded during the first two launches would preclude going to anything lighter or weaker. The primary load carried by the joint will still be the internal proof pressure load since there is no accurate way to determine and apply the vibration g loads to the new design. The new design will, however, be tested as outlined in Section 7.2.1 to determine the operating g load effects on the units.

7.1.1.4 Review of Conditions and Failures

This section contains a review of all data delineating problems encountered during operational service and a review of all conditions to which the system is subjected.

There appears to be a few problems with the existing joints which are associated with actual operating service. As previously mentioned, the primary problem is one of handling and installation.

The main function of the joint is to maintain line vacuum integrity, gas tight external sealing capability, and low heat leak. There were no failures uncovered during this study that indicated the existing design did not meet specification except where improper seal assembly occurred on the Conoseal joints of Arm 6 propellant lines. It was pointed out by the personnel at Huntsville that the nose seal on all propellant lines had to be grooved to allow ambient test gas pressure to be ported to the primary ring joint seal. Without this groove the nose seal was tight enough to abort an ambient external leakage check prior to actual propellant loading.

The environmental conditions to which the new joint will be subjected, and must therefore be kept in mind during the design phase, are as follows:

A. Assembly ease

B. Handling abuse

C. G loads, vibrational

D. Heat due to blast

E. Noise — blast

F. Internal gas leakage

G. Heat leak

H. Flow loads

I. Pressure loads

J. Static seal limitations

7.1.1.5 Review of Test Data

A review of the past test data which assisted in establishing a preliminary reliability goal is presented here. The pertinent test data would be heat leak, gas leak and structural failures to compare with calculated data. These data were non-existent at the time of inquiry during the Kennedy Space Center trips.

All information available to use at this time indicates that had there been no Conoseal assembly problems, there would be zero failures.

This would necessitate a reliability goal of 26-0 (see Page 49) failure/26 = 100%. No other failures have been observed or recorded by AMETEK/Straza, Boeing, or Kennedy Space Center personnel which indicate a heat leak or flange failure. Since this is an unreasonable goal, a failure analysis based on the original joint design as shown in SK 4053-1 (Fig. 1) will be made.

The first assumption is to establish the quantity of units per launch tower. In the existing system, there are 26 bayonets per missile launcher (ML). Assume 3 ML's in service.

26 x 3 = 78 + 20% spares = 94 units manufactured for project.

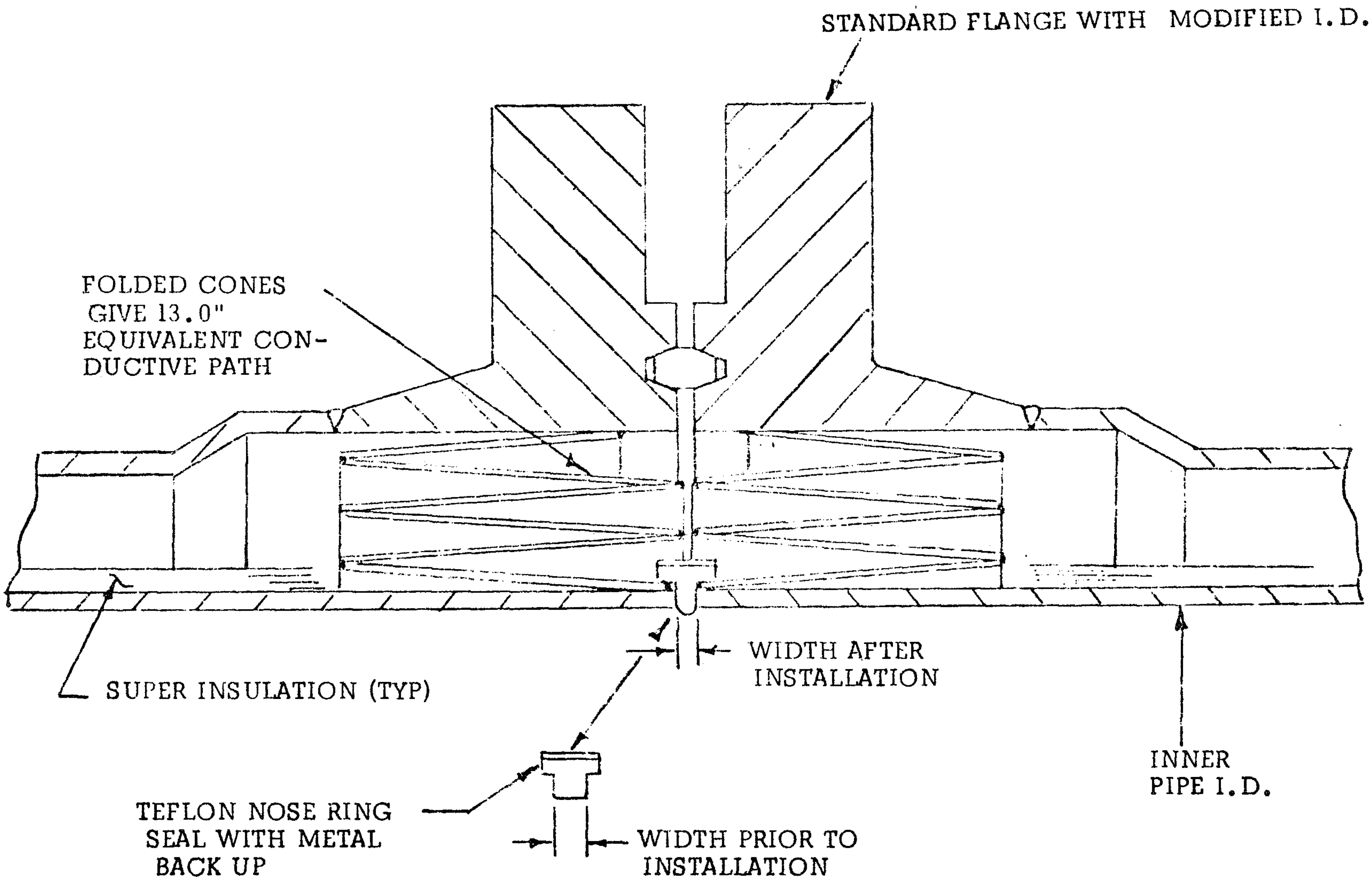


Figure 1 - SK 4053-1 Cryogenic Coupling

Failure Potential

A.	Primary nose seal damage at installation causing liquid short and excessive heat leak	1 Failure
B.	Weld crack on cone due to temperature shock causing vacuum loss in V. J.	1 Failure
C.	Failure of cone due to vibration causing vacuum loss in line	1 Failure
		3 Failures

Therefore,

$$\text{Preliminary Reliability Goal} = \frac{94-3}{94} = .9681$$

7.1.2 Product Review

7.1.2.1 State-of-the-Art Investigation

The most promising data uncovered during this phase of the study was the following report presented at the 1964 National Cryogenic Conference. The following report presents a detailed description of the development of the joint which will be used with a few modifications in this study. A copy of Figure 1, 2, 3 and 4 of the patent covering this joint is presented. Also included on pages 11 through 26 is the test report on this same joint made by the Annin Company (now Masoneilan International).

March 5, 1968 G. A. BLEYLE, JR., ET AL 3,371,946

CRYOGENIC COUPLING

Filed Nov. 2, 1965 2 Sheets-Sheet 1

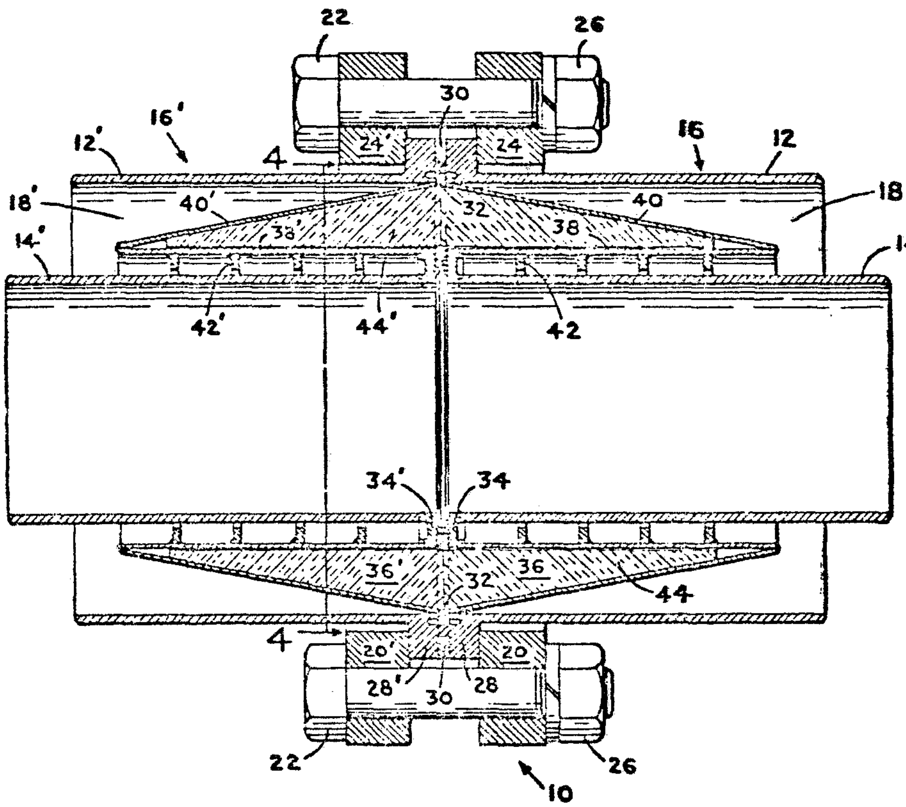


FIG. 1

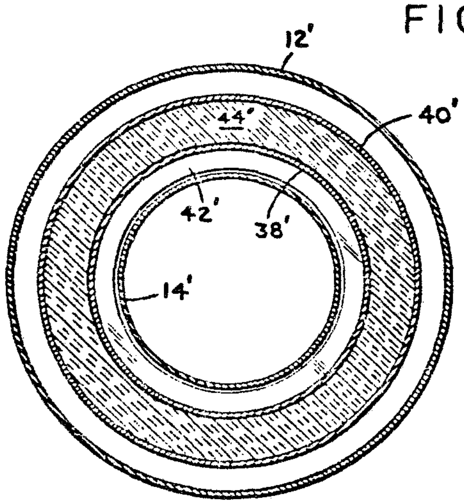


FIG. 4

GUSTAVE A. BLEYLE JR.
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BY Daniel H. Bobis
Atty

Patent 3,371,946, Figure 1 and 4

CRYOGENIC COUPLING

Filed Nov. 2, 1965 2 Sheets-Sheet 2

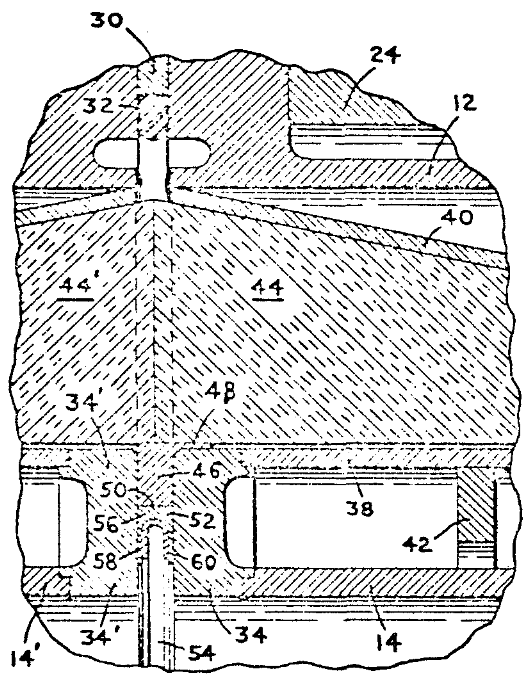

FIG. 2

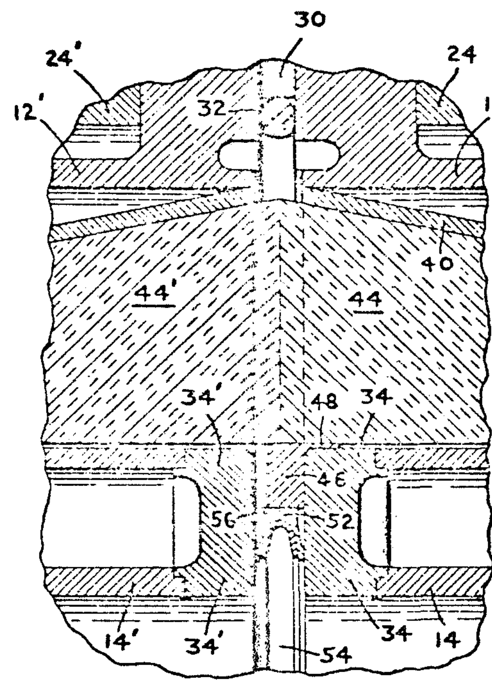

FIG. 3

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INVENTORS

BY David H. Bobis
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Patent 3,371,946, Figure 2 and 3

V-12

PROPELLANT LOADING SYSTEMS 906-30

A NEW VACUUM-INSULATED CRYOGENIC COUPLING

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&
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ABSTRACT

A new coupling method for vacuum-insulated cryogenic lines has been conceived, analyzed and tested in prototype and production configurations. The coupling provides a combination of low heat leak and single-plane assembly through the use of a novel double-seal and insulation space arrangement. The test program has shown the superiority of a pre-molded silicon-bonded fiberglass insulator in this service. A 4-inch prototype coupling using this material displayed a 69 Btu/hr heat leak in calorimetric tests. In its production configuration the coupling design emphasizes ruggedness, simplicity, ease of maintenance, small cool-down mass and reliability. The mating halves of the coupling are interchangeable; and the possibility of introducing particulate contamination to the piping system is minimized by a porous Teflon coating applied to the fiberglass insulator. Tabulated test results for a range of production model sizes are provided.

*Currently with Litton Systems, Inc.
Space Sciences Laboratories

A NEW VACUUM-INSULATED CRYOGENIC COUPLING

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INTRODUCTION

A program to develop an improved vacuum-insulated transfer line coupling was initiated to meet the increasing need for simplicity, low heat leak, small cool-down mass, reliability and ease of maintenance of cryogenic equipment. Although respectable levels of thermodynamic efficiency have been demonstrated by existing types of couplings, it was felt that a slight compromise in heat leak performance to permit an improvement in maintainability and reliability would be appropriate for a number of applications.

Three general types of couplings are currently available to join vacuum-insulated cryogenic lines and equipment. The re-entrant bayonet system, while efficient, rates low in maintainability because significant axial clearance is required for installation and because the male portion must be handled with care to prevent damage during assembly and disassembly. Welded joints offer relatively high thermal effectiveness at the expense of complex and generally irreversible assembly methods. Coupling systems which use inner line gasketed mechanical joints are easily disassembled, but impose a cool-down penalty, as the result of direct contact between the cryogen and a relatively heavy inner assembly. There is also the choice between accepting the hazard of a leak into the vacuum space or the heat leak involved in sealing the jackets to the inner line on each side of the coupling.

The coupling developed during this program provides single-plane assembly and disassembly of interchangeable mating halves, with an experimentally verified low heat leak.

* Currently with Litton Systems, Inc.
Space Sciences Laboratories

DESIGN CONSIDERATIONS

The following design goals were established at an early stage of the effort: (1) single-plane assembly, (2) identical coupling halves, (3) simple fool-proof installation, (4) minimum heat leak and cool-down losses. Figure 1 shows the general features of the coupling which evolved from this program.

An initial prototype configuration which closely resembled that shown in Figure 1 was designed, fabricated in a 2-inch size, and tested for thermal performance. These early tests established the feasibility and attractiveness of this coupling concept, while indicating those aspects of the design which required optimization. The steady-state thermal performance of this prototype was found to be strongly affected by the gas-space insulator material and its configuration; and, to a lesser extent, by the effectiveness of the inner lip-seal. Thus, the design resolved itself to material selection for the insulator and lip-seal, and optimization of the basic configuration.

A 4-inch prototype coupling and a calorimetric test fixture were designed and constructed to permit insulator and lip-seal performance evaluation in a device which closely approximated the final coupling configuration. The number of candidate insulator materials was restricted by the following requirements: (1) low thermal conductivity, (2) chemical insensitivity in 0_2 atmospheres, (3) freedom from tendency to shred or fragment and thereby introduce particulate contamination into the line or associated equipment. Tests were conducted with polyurethane, sintered Teflon (5-micron hole size), and silicon-bonded fiberglass. The fiberglass displayed a marked superiority to the other materials tested. Initially, stacked-disks of 0.080" thick fiberglass were used; but an appreciable improvement in thermal performance was observed with substitution of special fiberglass insulators molded to fit the coupling.

Table I summarizes the results obtained with the 4-inch prototype coupling, as well as the performance of a later, more refined, 4-inch test unit. The analytically predicted heat leak for the improved unit compared well with the observed performance of this improved coupling. A number of lip-seal configurations were tested during this program, and it was determined that the design of the lip-seal does not significantly

TABLE I

THERMAL PERFORMANCE OF PROTOTYPE 4-INCH CRYOGENIC COUPLING

TEST NO.	INSULATION MATERIAL	LINE ORIENTATION HORIZ/VERT	LINE PRESSURE (PSIG)	*CALCULATED HEAT LEAK (BTU/HR)	MEASURED HEAT LEAK (BTU/HR)
1-14	Fiberglass Stacked Disks	V	0	70.2	75
1-14A	Fiberglass Stacked Disks	H	0	70.2	79
1-14B	Fiberglass Stacked Disks	H	50	70.2	88
1-14C	Fiberglass Stacked Disks	V	135	70.2	110
COUPLING RE-DESIGNED FOR A 165 PSIA WORKING PRESSURE FOLLOWING MECHANICAL FAILURE OF PHASE I PROTOTYPE AT 125 PSIA					
II-3	Molded Fiberglass	V	0	64	64
II-4	Molded Fiberglass	V	100	64	69

* Based on insulator conductivity of 10^{-3} Btu-in/hr-in^2-°F.

affect the heat leak of the coupling as long as a resonable obstacle to fluid transfer into the insulation space is maintained. Accordingly, a commercially available spring-loaded Teflon face seal was selected for this function.

TEST PROGRAM

Initial tests of the 2-inch prototype coupling were conducted with liquid nitrogen at atmospheric pressure. The heat leak of the 2-inch coupling when installed in a vertical line was obtained by observation of the difference between the boil-off rate with the liquid level two feet above and two feet below the coupling. Although this technique gave satisfactory and reproducible results, it did not permit performance evaluation in a horizontal attitude. In addition, the time required to test larger couplings using this method would be excessive. For this reason, a more refined test method was employed for the 4-inch prototype test articles.

Figure 2 schematically depicts the calorimeter fixture used to measure the heat leak to the 4-inch prototype test coupling. By encasing the test article in 3/16-inch copper sheet and separate $1\frac{1}{2}$-inch copper rings butted against the coupling flanges, connecting copper bars between this assembly and external copper pads, and with a 4-inch thickness of styrofoam insulation over the entire assembly, a controlled isothermal environment could be maintained around the coupling by application of heat to the external pads using light-bulb heat sources. The experimental technique then consisted of measuring the temperature difference between the inner and outer end of each copper bar, with subsequent conversion of this temperature difference into an equivalent heat flow on the basis of the known characteristics of the copper bar. For each test, the thermal environment of the pipe and coupling was maintained within 2°F of ambient temperature, in which configuration the spurious heat leak through the styrofoam calculated to be less than 1% of the total measured heat input through the copper path. Manual temperature control of the test fixture through variac-regulation of the light-bulb heat sources proved satisfactory, and steady-state operation was achieved approximately one hour after start-up.

In addition to monitoring coupling heat leak, the effectiveness of the lip-seal was checked by observing the rate of pressure rise in the insulation space during pressurization of the inner line. During the prototype test series, it was noted that the lip-seal behavior did not materially affect the thermal performance of the coupling as long as an obstacle to gross flow between the inner line and insulation space was maintained.

As the result of an early test failure of a thin-walled cylinder during pressurization tests, the cylindrical coupling sections shown in Figure 1 were fabricated and exposed to destructive collapse-loading in a hydraulic chamber. With the information obtained from these tests, a modified prototype coupling was constructed with stiffening rings and a reinforced nose piece incorporated in the cylindrical section. This later configuration was successfully tested to twice the selected design working pressure of 165 psia.

DISCUSSION OF RESULTS

During this development, an analytical evaluation of the thermal performance of the coupling was completed. Figure 3 illustrates the calculated relationship between heat leak and several important coupling design parameters. At the beginning of the program, we believed that an insulation conductivity of 8×10^{-4} Btu-in/hr-in^2-°F could be attained. With this value and with, say, $K_1 = 1.0$, $K_2 = 0.14$ for a 4-inch coupling, the calculated C_c would be 56 Btu/hr to which radiation heat transfer would add approximately 3 Btu/hr. With stacked rings of fiberglass as an insulator, a heat leak of 81 Btu/hr was observed with the 4-inch test article. This heat leak corresponds to an apparent conductivity (K_2) of 1.6×10^{-3} Btu-in/hr-in^2-°F. With later substitution of a molded silicon-bonded fiberglass insulator, the experimental heat leak dropped to 64-69 Btu/hr. We feel that the 10^{-3} Btu-in/hr-in^2-°F apparent conductivity displayed by this specially prepared material resulted largely from the altered "lay" of the individual fibers comprising the material. In the stacked-disk array the generally radial orientation of the fibers provided more, and more direct, heat transfer paths than the wrapped fibers in the molded insulator.

On the basis of the results obtained with the prototype 4-inch coupling, the design of a production configuration was completed. Figure 4 illustrates the general features of the production units and presents the basic dimensions and anticipated performance for a range of production coupling sizes. The heat leak values quoted for these units are somewhat higher than were observed in prototype tests because a more rugged design has been adopted to withstand operating pressures to 250 psi. The design utilizes a commercially-available cold seal and a flat compression-type warm seal. The insulator is pre-molded in two pieces, each coated with a thin porous layer of Teflon to eliminate the possibility of fibrous contamination of the line during assembly or subsequent repair--early tests have substantiated the feasibility of this coating concept.

Three sizes of the production coupling, $1\frac{1}{2}$, 3 and 6-inch, have been fabricated and have been tested as shown in Figure 7. This method utilizes a housing of insulating material, split so it can be slipped over the pipe, which contains electric lamps for heat sources, and a stirring fan to provide uniform air temperatures. Thermometers are placed through the walls to indicate internal air temperatures. The method basis is that when there is no temperature difference between the interior of the box and the room ambient, the heat furnished by the lamps is equal to that abstracted by the coupling. The lamps are provided in units which can be switched in as needed, with a variable transformer voltage adjustment to provide fine adjustment. Power input was measured with a standard watt hour meter by timing one revolution of the meter disk.

The results of the tests are shown in Table II.

TABLE II

Size	Heat Loss, Btu/hr			
	Zero Pressure		150 Psi	
	Calculated	Measured	Calculated	Measured
1½	46.9	59.8	49.8	64.0
3	72.0	81.7	79.4	85.8
6	124	132.5	136.3	

CONCLUSIONS

An extensive test program has proven the feasibility of a novel coupling concept that provides a simple, rugged, relatively low heat loss joint for vacuum-insulated cryogenic lines. In its production version, the coupling is comprised of identical mating pieces which offer single-plane assembly or disassembly with a minimum number of loose pieces and reduces the possibility of contamination from the insulation. Analytical predictions of heat leak have been substantiated by evaluation tests on both prototype and production versions of the coupling. It is anticipated that this coupling concept will find application in systems requiring low heat loss joints that are readily separated for modification or maintenance.

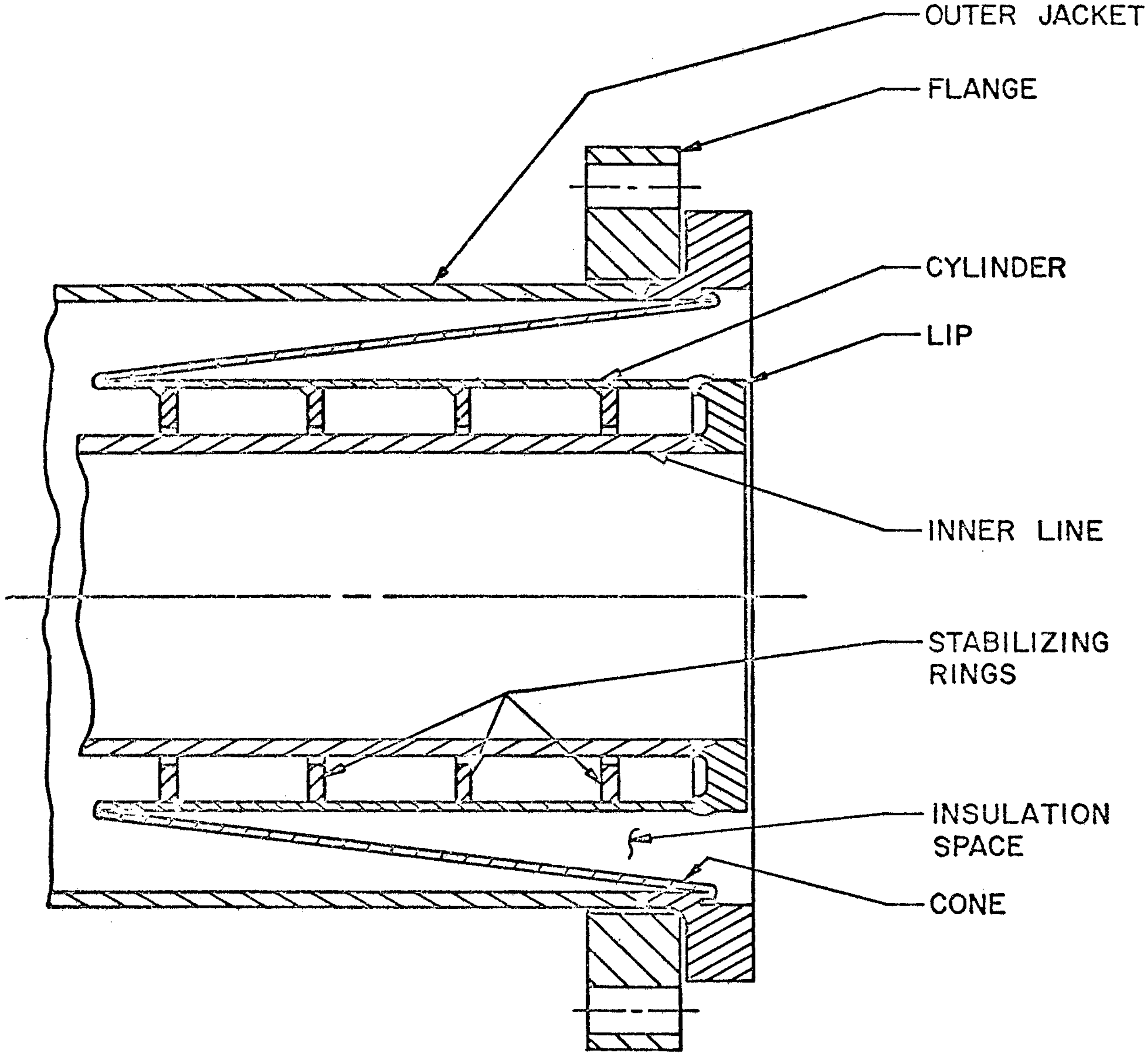
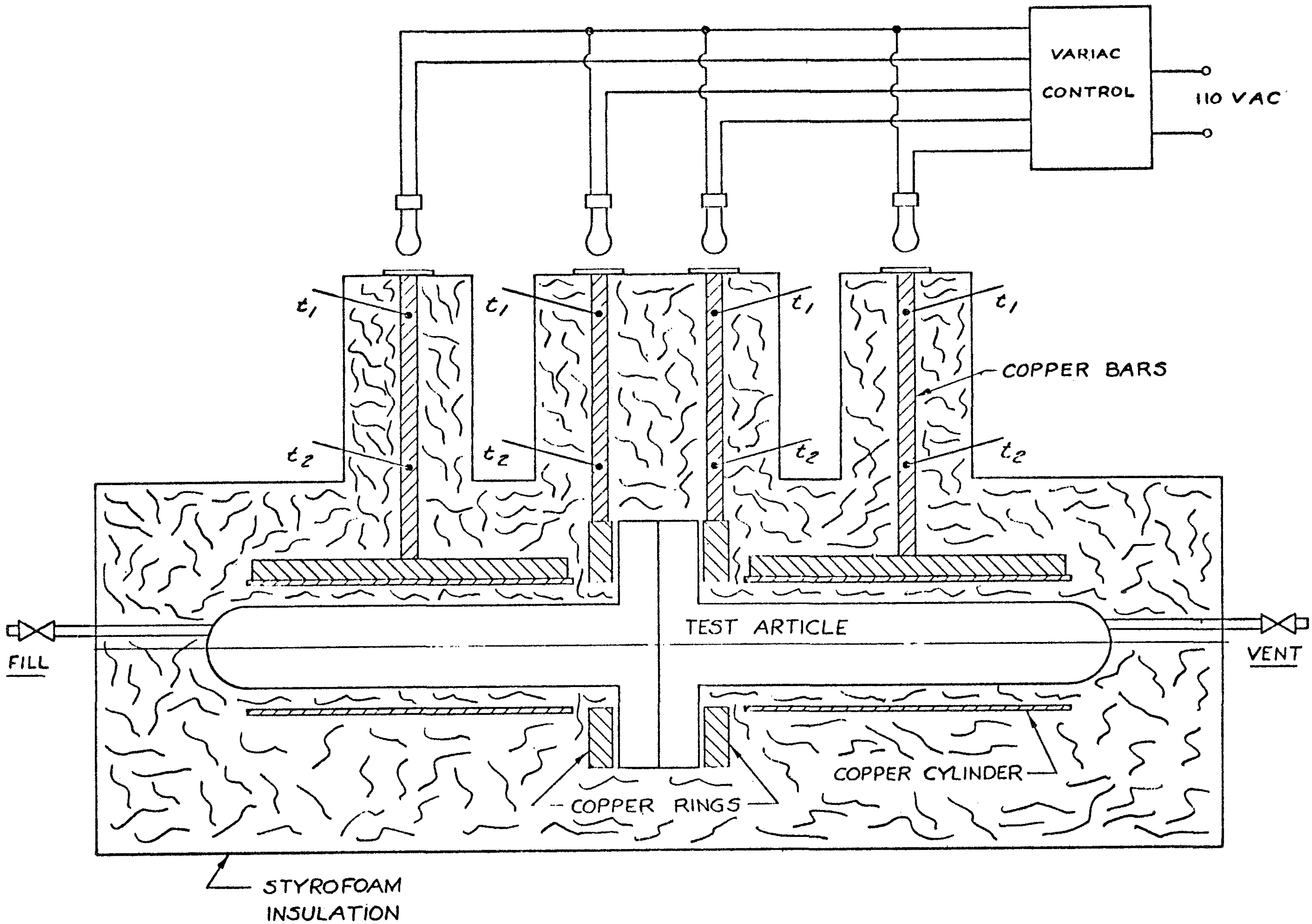


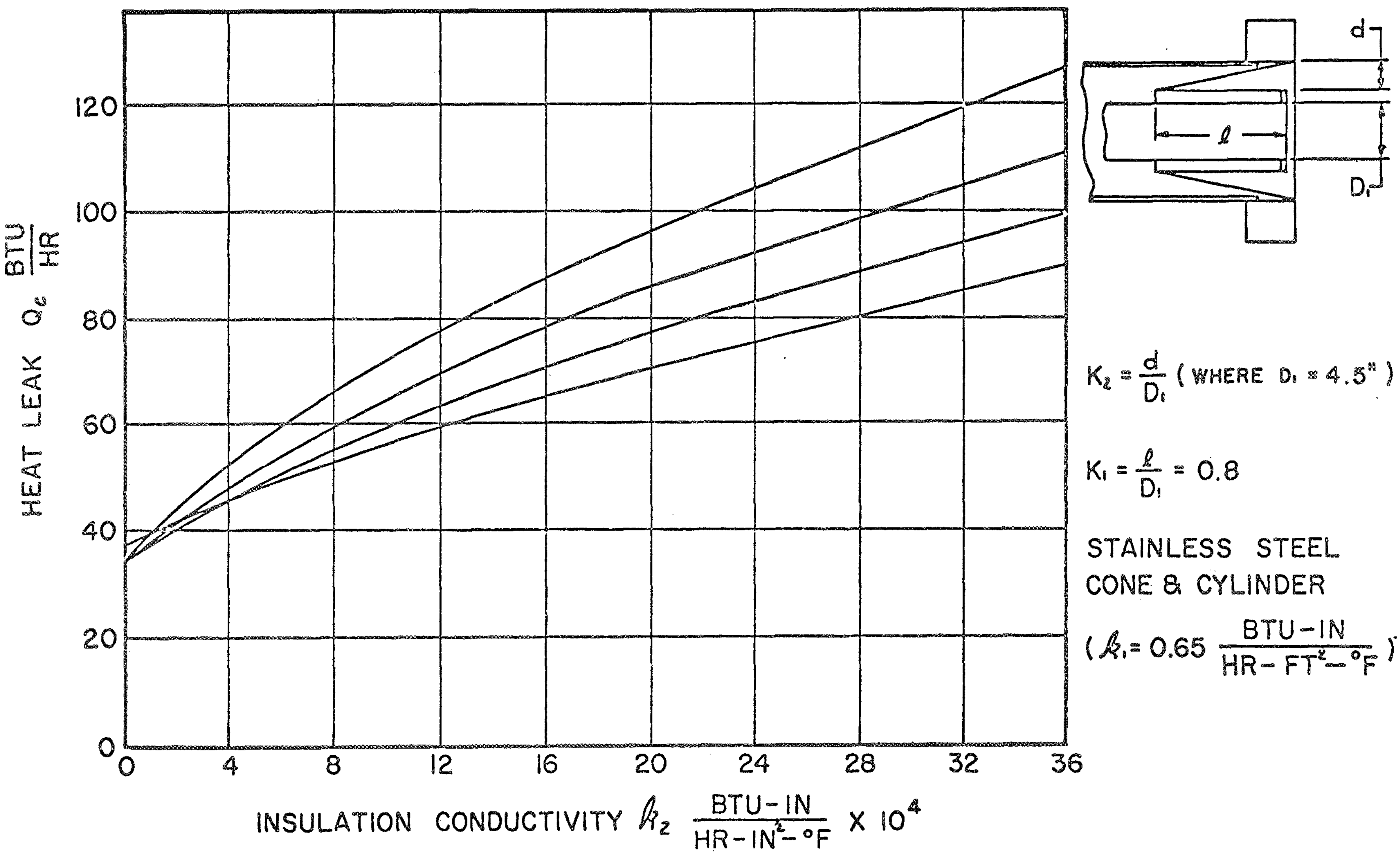
FIGURE 1
PROTOTYPE COUPLING
GENERAL CONFIGURATION

Annin Cryogenic Coupling, Figure 1



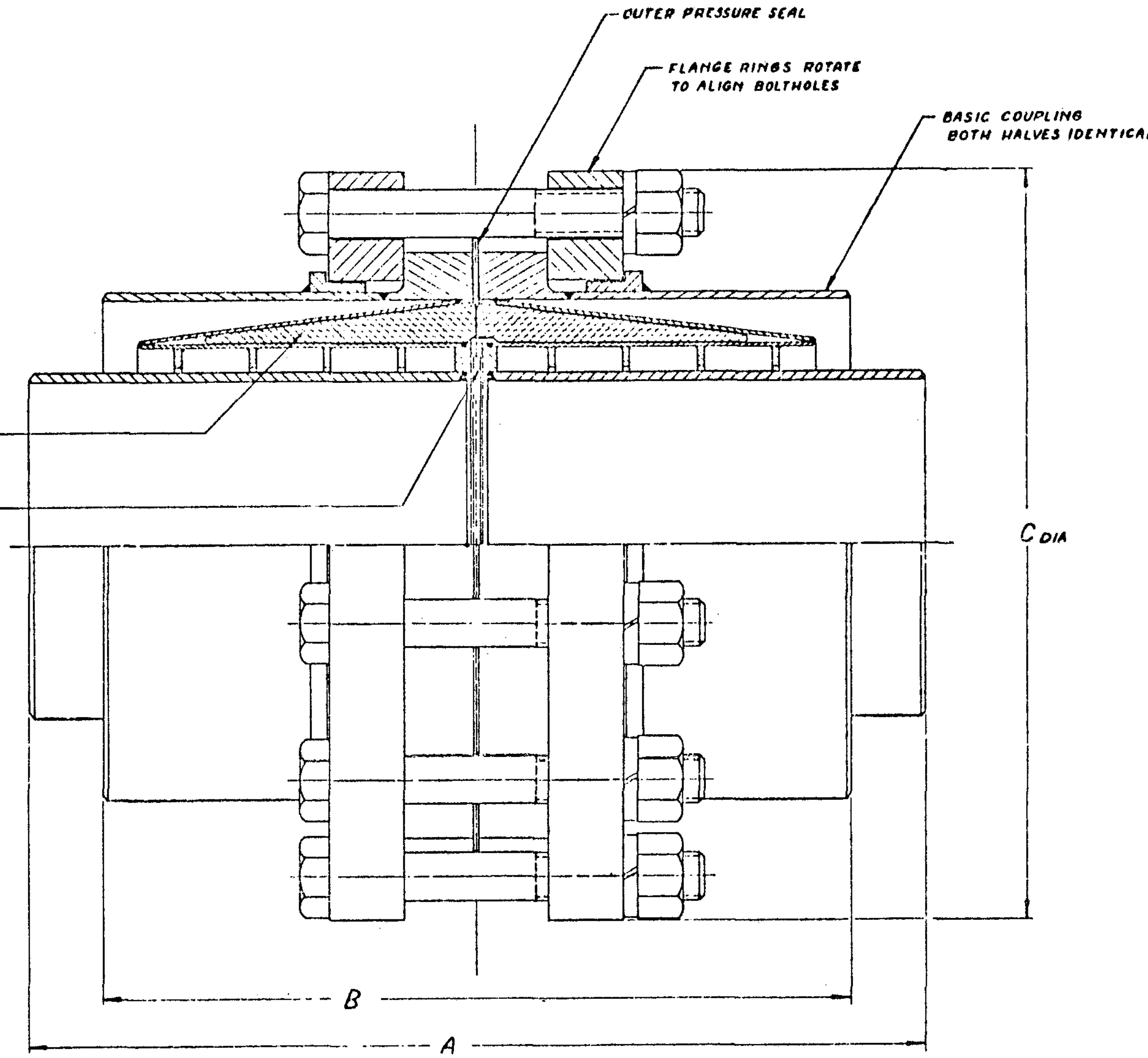
4 INCH PROTOTYPE CALORIMETER
TEST APPARATUS

Annin Cryogenic Coupling, Figure 2



CONDUCTIVE & CONVECTIVE HEAT LEAK FOR
A NOMINAL 4 — INCH COUPLING

Annin Cryogenic Coupling, Figure 3

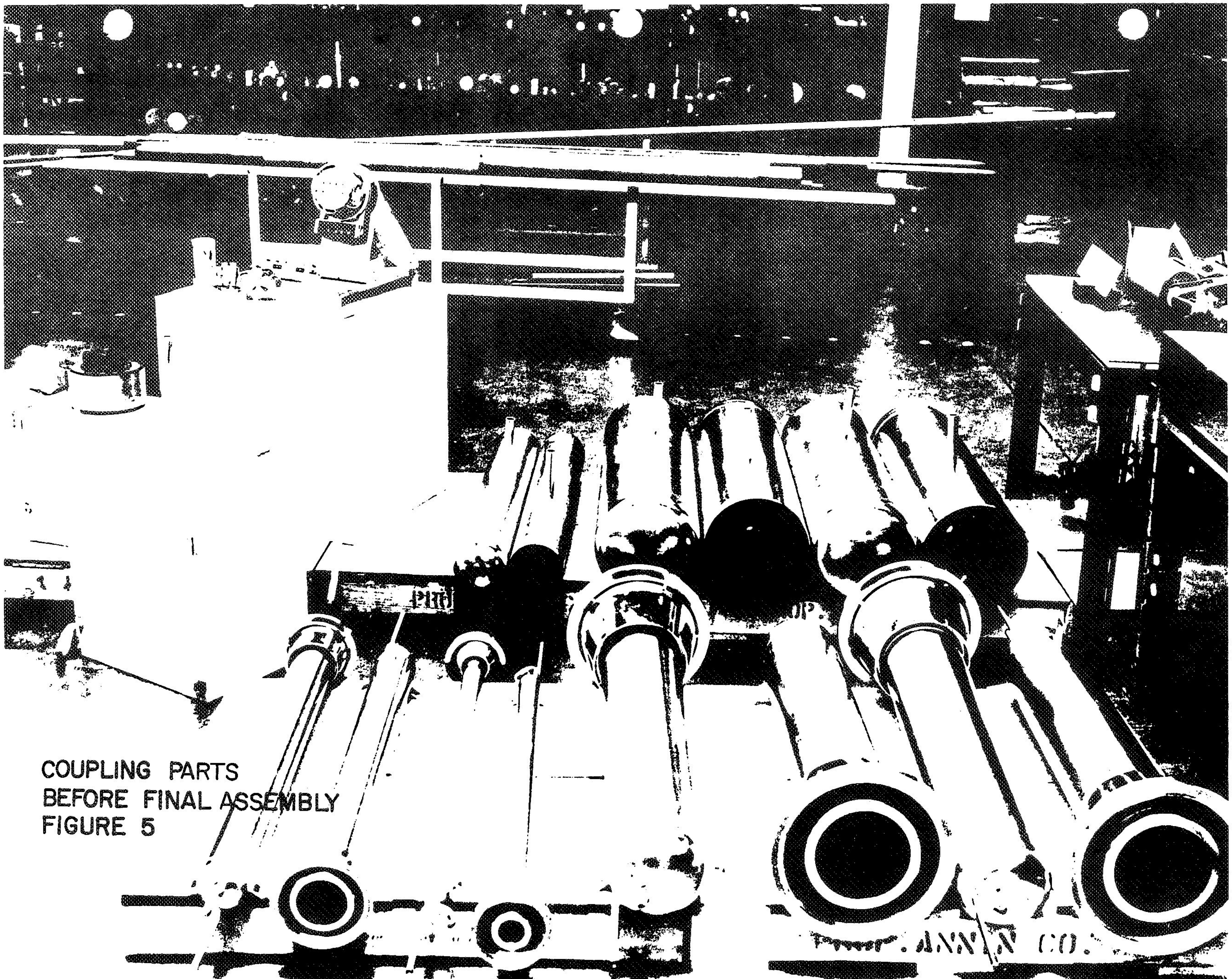


NOM LINE SIZE SCHED 10	NOM JACKET SIZE SCHED 5	EST'D WEIGHT (LBS)	HEAT INFLUX*	A	B	C	
1	3	12	37	5.0	3.5	7.0	
1 1/2	4	19	47	6.5	5.0	8.3	
2	4	20	48	7.5	6.0	8.3	
3	6	32	72	9.5	8.0	9.5	
4	6	50	97	12.0	10.0	10.5	
6	10	125	125	16.0	14.5	15.0	
8	12	165	180	20.0	18.5	17.0	

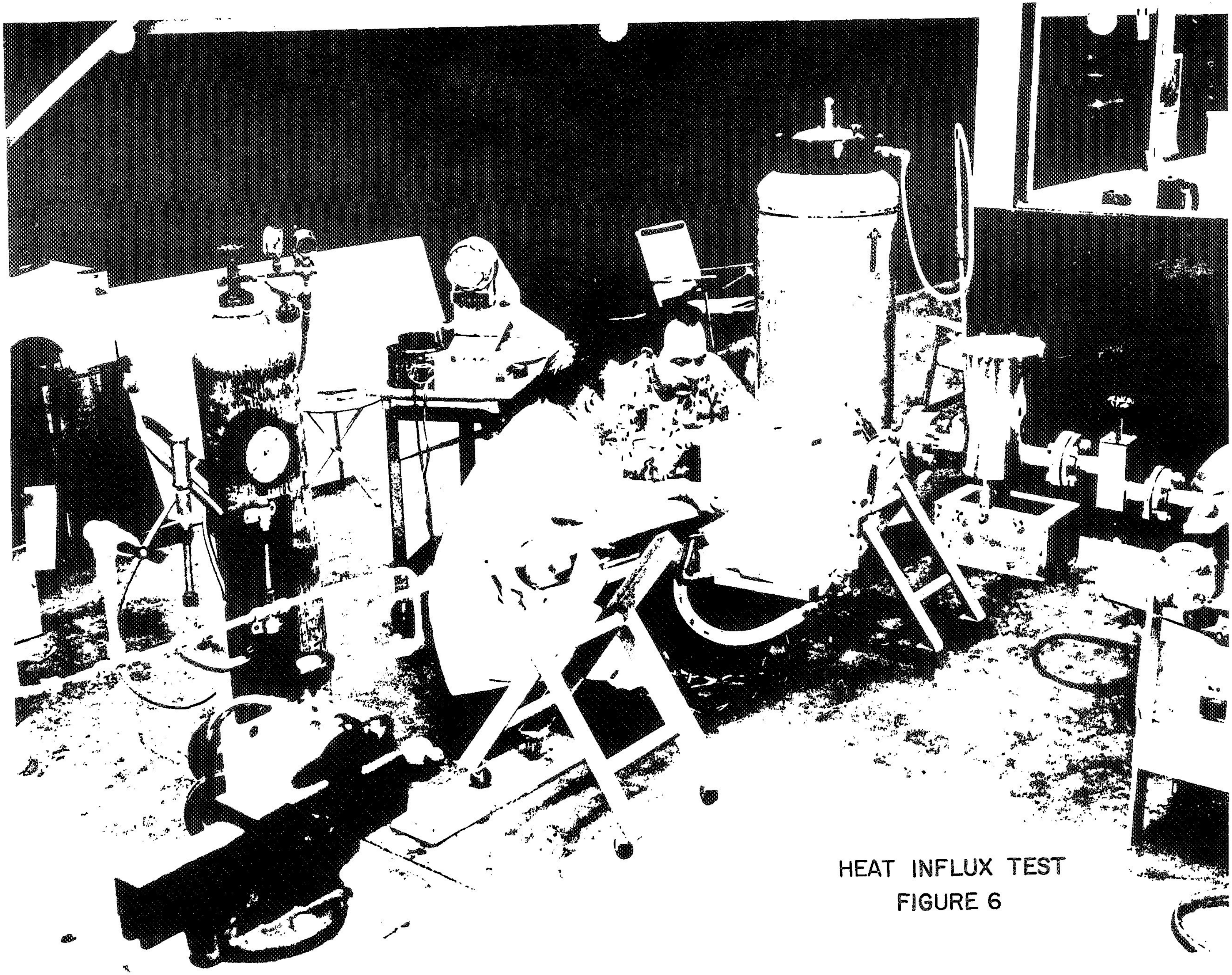
*BTU/HR INFLUX AT LN_2 TEMPERATURE AND ATM PRESSURE

COUPLING ASSEMBLY

Annin Cryogenic Coupling, Figure 4

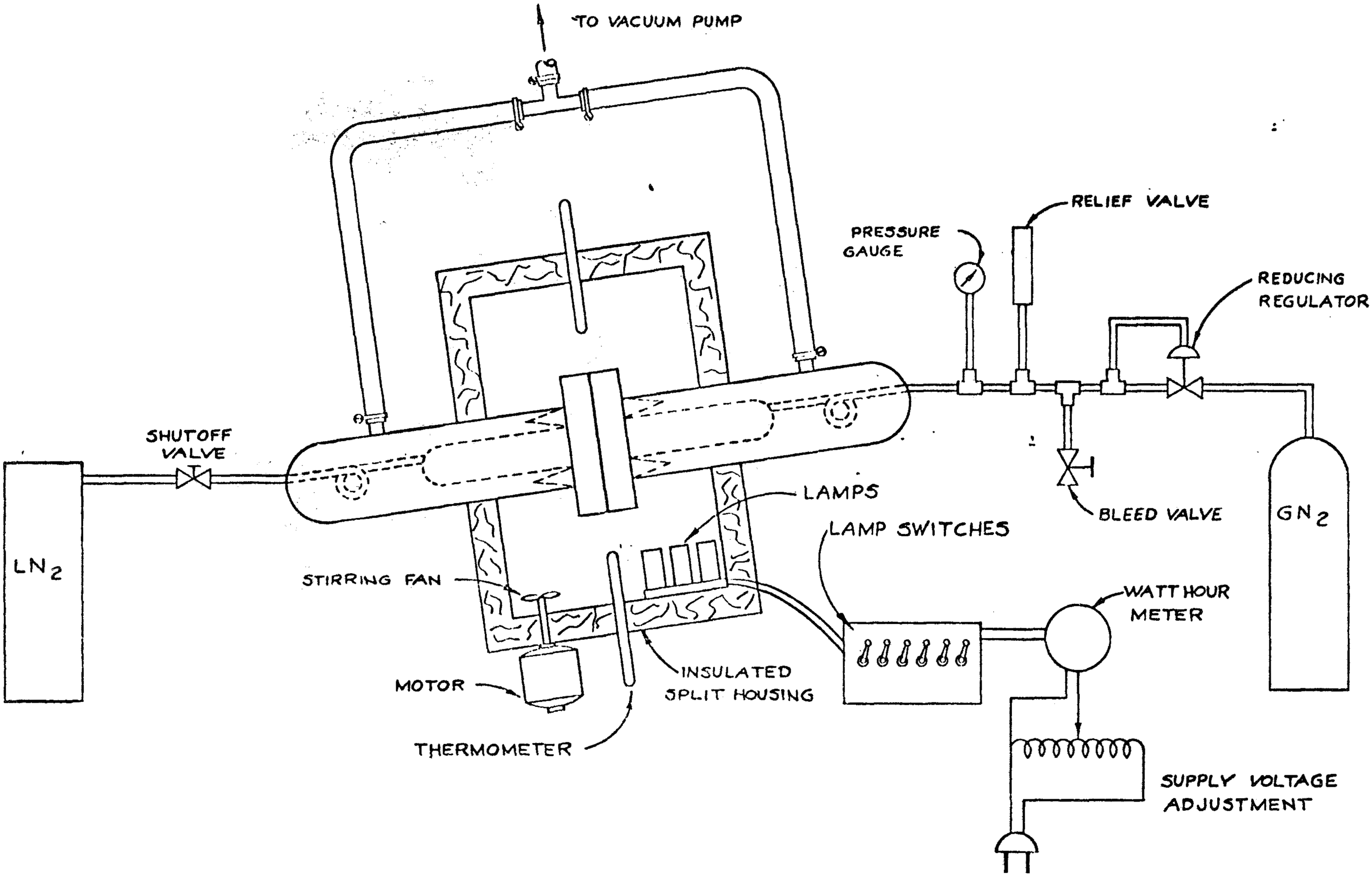


Annin Cryogenic Coupling, Figure 5



HEAT INFLUX TEST
FIGURE 6

Amin Cryogenic Coupling, Figure 6



FINAL HEAT INFLOW
TEST METHOD
Annin Cryogenic Coupling, Figure 7

7.1.2.2 Hardware Investigation

The availability of new hardware which could fill the requirements for this study was very limited. A letter of inquiry was sent to each of the following vendors as listed under bayonet suppliers in Cryogenic Engineering News. The VSMF was consulted along with checks against IDEP, DDC, and PRINCE data files.

Airco Cryogenics
American Cryogenics, Inc.
Andonian Associates, Inc.
Beech Aircraft Corporation
Cleveland Tool and Die
*Consolidated Precision Corp.
*Cryogenic Associates, Inc.
*Cryogenic Engineering Co.
CVI
DK Aero Company, Cobra Plant
Flexible Metal Hose
*The Heckerman Corporation
Kentube Company
Minnesota Valley Engineering, Inc.
Spembly Technical Products
*Uni-Flex Cryogenics
*Vacuum Barrier Corporation

Only those vendors with the asterisk before their names responded to the inquiry. In every case there were no new innovations. All existing bayonets are the typical male/female concentric tube type units used primarily on a laboratory basis or small diameter, four inch O.D., line sizes.

An unsuccessful attempt was made to acquire more detailed design data from Masoneilan (Annin) who manufactured the A. D. Little unit. This information was to be used to confirm the analytical design approach for the new modified unit. A comparison between the analytical and the empirical results was to be made for the Masoneilan unit. The comparison would then have been applied to the new unit to verify the analysis. Since this information is unavailable, an analytical confirmation of the heat leaks shown on the previous Figure 1 Table cannot be presented.

7.1.3 Design Phase

7.1.3.1 Design Evaluation

Several design configurations were developed early in the program as shown in SK4053-1 (Figure 1) and SK4053-2 (Figure 2). The radially stacked cone concept used here is a carry-over from standard industry practice in manufacturing vacuum jacketed lines. It gives the desired long metal conductive heat path while, at the same time, maintaining a single plane assembly. As can be seen in these sketches, an attempt was made to maintain a minimum gas space between cones to decrease the convection heat losses. The calculations presented in the Appendix indicate that convection is not a problem, therefore, it was not included in the total heat leaks for this type joint. It was later discovered, after reviewing the Annin design, that convection must be completely blocked. For this reason and the additional complexity of the multiple welded cones, this design was given up in favor of the Annin type joint.

The design criteria used for the joint is as follows:

A. Leakage

1×10^{-4} atm cc/sec as measured in accordance with NASA TCPV-26427 Line Leak Check Procedure.

B. Temperature

$+125^{\circ}F$ to $-423^{\circ}F$ internal, $1400^{\circ}F$ for 10 seconds external.

C. Pressure

190 psi operating, 285 proof and 760 burst.

D. Size

Six inch and eight inch inside diameter as required to fit rotary joints.

E. Heat Leak

300 Btu/Hr. maximum.

F. Vibration

20 grms.

The original Figure 1 and Figure 2 designs compare favorably on a heat leak basis with the existing 8" and 10" propellant line bayonet as shown on SK 4053-3 (Figure 3). The calculated heat leak of the former is 150 Btu/hr as compared with 238 Btu/hr for the existing LC39 bayonet. These heat losses are based on liquid oxygen system temperatures of $-297^{\circ}F$ on the cold side and $+100^{\circ}F$ on the hot side.

The design of the Final unit to be tested in Phase II of this program is shown in Drawing 8-030928 and 8-030929.

This design will be used to test several types of anti-convection blocks. Since Masoneilan did not attempt to develop an LH_2 system block, considerable effort will be expended on this program to optimize a design capable of minimizing the heat leak for this highly conductive gas. The problem is to obtain a material that can withstand the collapse proof pressure when encased in a gas tight closure and, at the same time, have a low conductivity and cryopump capability.

The materials being considered for the anti-convection barrier and analyzed in this report are as follows:

LO_2 System (Breathing Type)	LH_2 System (Sealed Type)
1. CTL-Dixie Silicone-bonded fiberglass	1. Teflon foam filled honeycomb

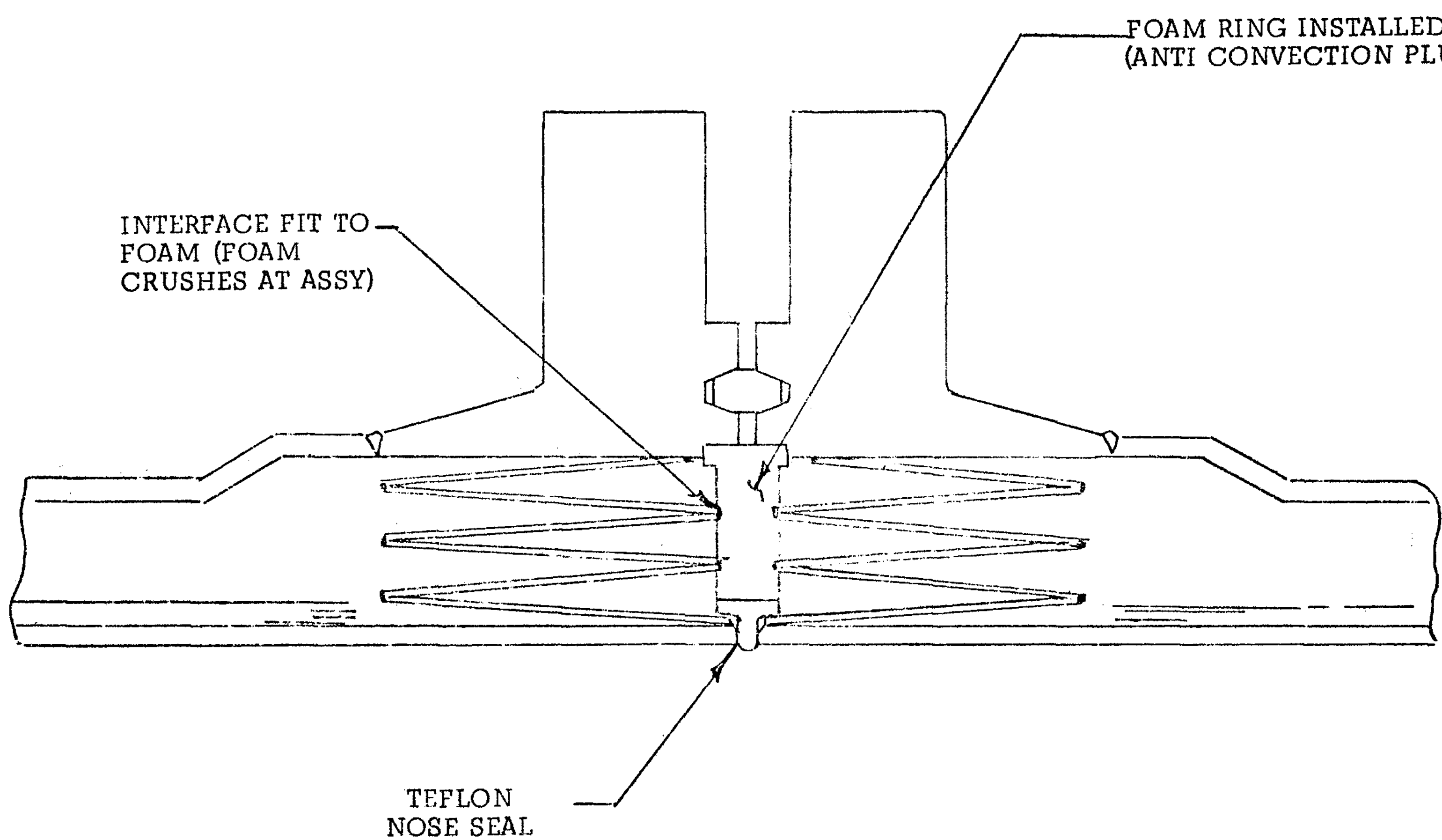


Figure 2 - SK 4053-2 Cryogenic Coupling

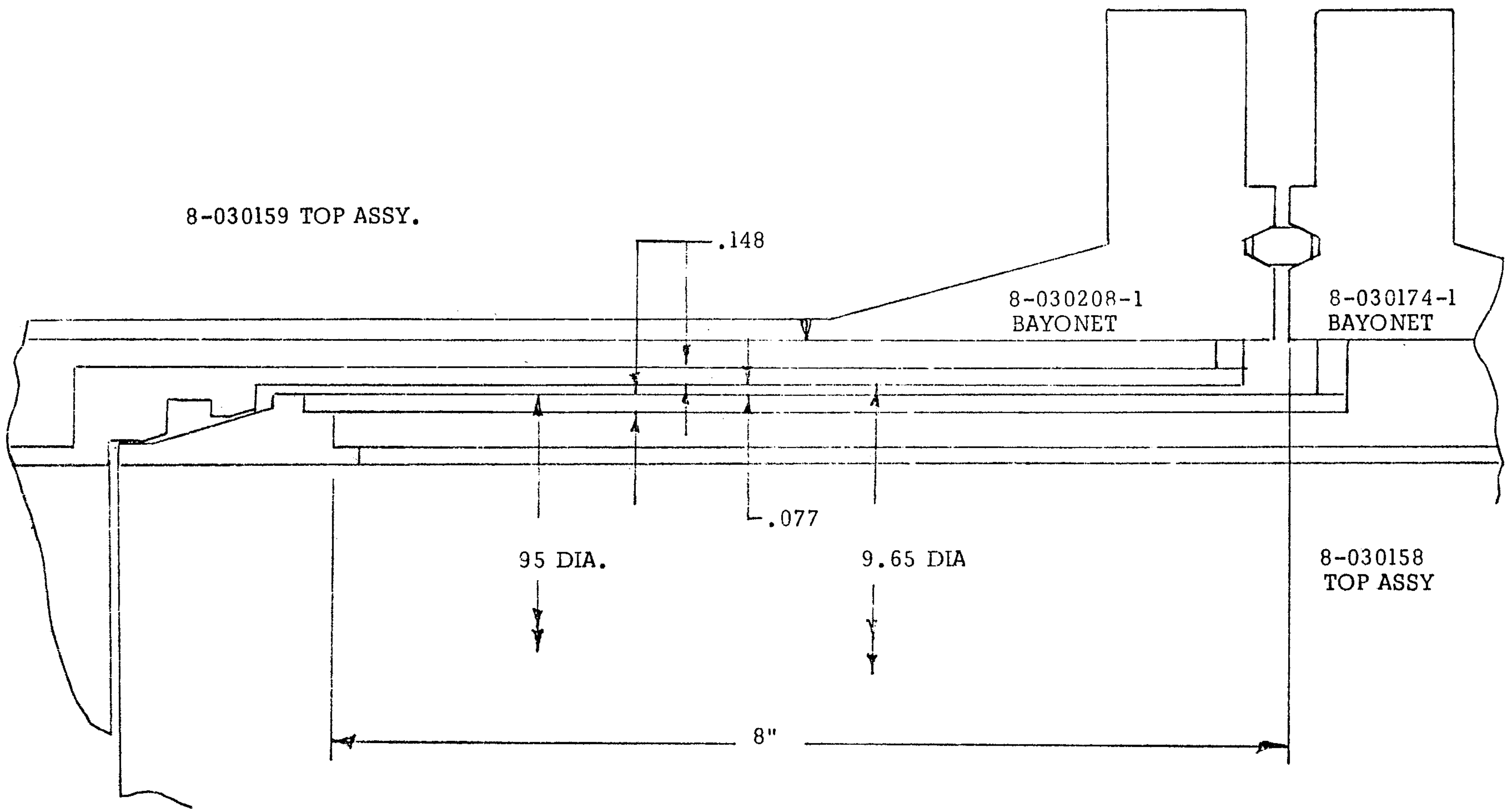
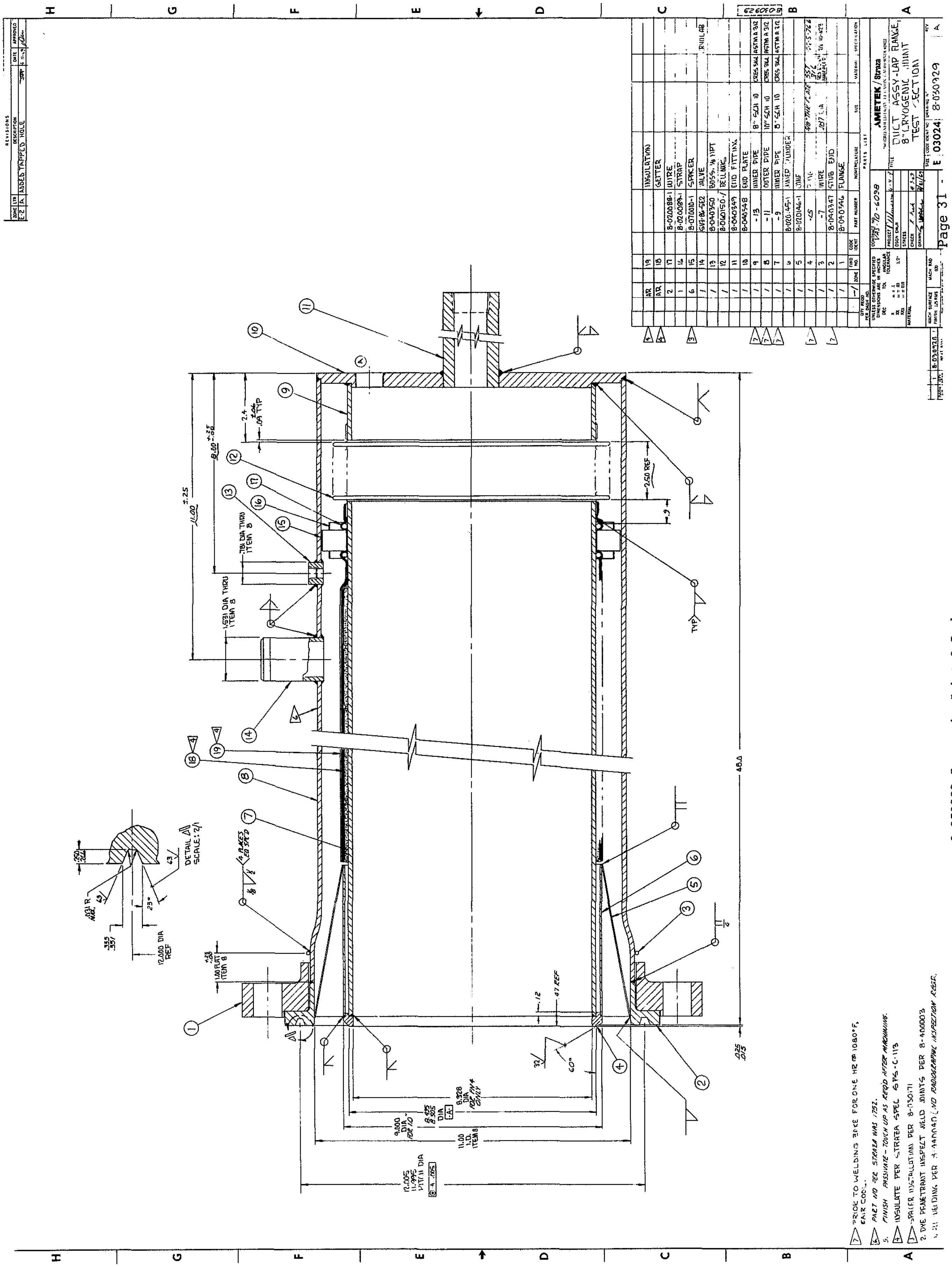


Figure 3 - SK 4053-3 Cryogenic Coupling

SK 4053-3



8-030929 Cryogenic Joint 8 Inch

LO_2 System
(Breathing Type)

1. (Continued)
(Used on Annin Unit for A.D. Little Company)
(Dwg. 8-070033)

2. Thermic, Inc.

Open cell foamed teflon

LH_2 System
(Sealed Type)

1. (Continued)
(Dwg. 8-100100)

2. Closed cell polyurethane foam.

3. Union Carbide

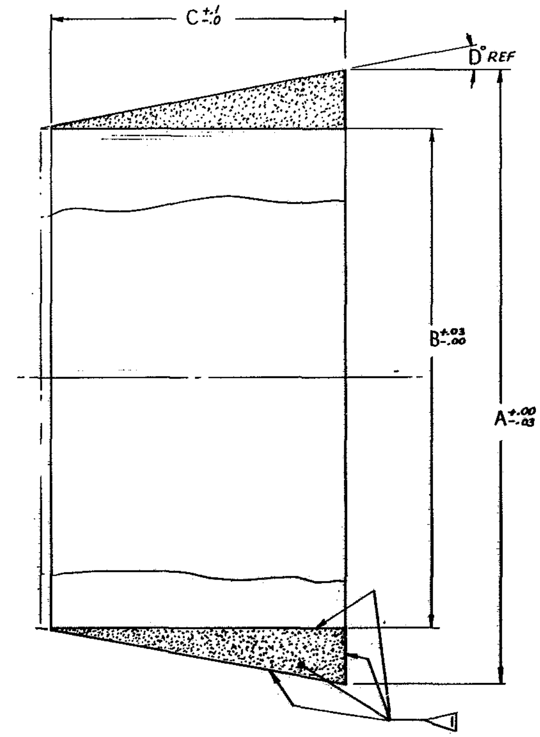
Open cell polyurethane foam.

7.1.3.2 Analysis

The analysis for these cryogenic joint configurations is broken down into two parts. The first part covers the liquid oxygen unit with its breathing type anti-convection block. The second part covers the liquid hydrogen units with its sealed anti-convection block. The LO_2 system insulators are summarized in Table I and the LH_2 in Table II.

A. Liquid Oxygen Unit

The new design, based on modifying the A. D. Little design so as not to use the reinforcing rings on the inner cylinder, is shown in Figure 4. This eight inch size joint uses a weld neck and a lap joint flange to be representative of a typical installation. The lap joint has been slightly modified to allow for as thick a convection barrier as possible. The sizing of the cylinder and cone are based on a proof pressure of 285 psi.



DASH NO	A DIA	B DIA	C LENGTH	D ANGLE
-1	11.00	9.00	5.3	10°25'
-2				

5. THERMAL CONDUCTIVITY THRU WALL TO BE APPROX .001 BTU-IN/HR IN² °F.
4. UNIT MUST BE OXYGEN-COMPATIBLE.
3. ITENTIFY WITH AMETEK/STRAZA PART NO.
2. AVAILABLE FROM: CTL DIXIE CORP., P.O. BOX 15188, CINCINNATI, OHIO, 45215.
1. MATERIAL: SILICON-RESIN-BONDED CIRCUMFERENTIALLY-ORIENTED GLASS FIBRE INSULATION CORE, @DENSITY ≤ 8.0 LBS/CU.FT.; COVERED WITH A GREEN-COLORED POROUS TEFLON FILM .002/.001 THICK.

NOTES

SPECIFICATION CONTROL DRAWING

DASH NO.	QTY REQD	NEXT ASSY
-1	2	8-100098
-1	1	8-100089

CONTRACT NO. NAS-10-6098

STRAZA INDUSTRIES, 790 GREENFIELD DR., EL CAJON, CALIFORNIA 92021

TITLE: INSULATOR, ANTI-CONVECTION, OUTSIDE TAPER

SIZE D | CODE IDENT NO. 03024 | DRAWING NO. 8-070033

4057

8-070033 Insulator Fiberglass

Page 33

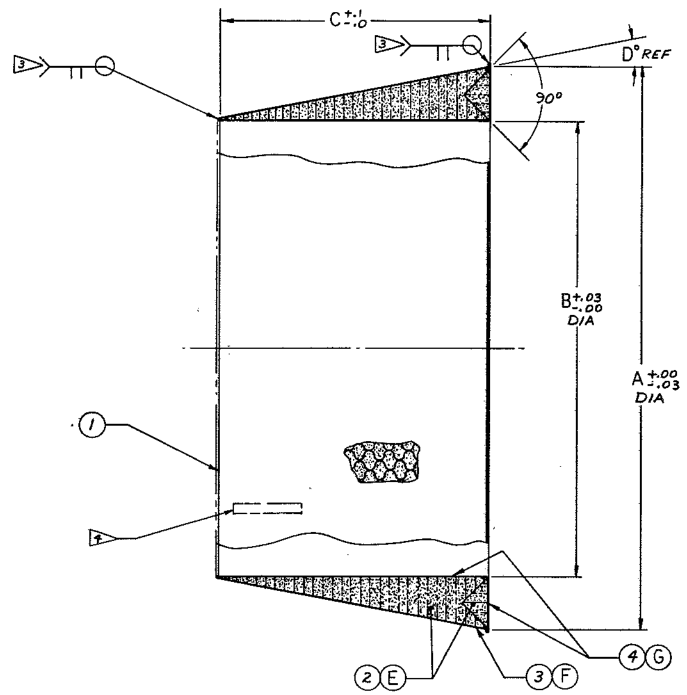


TABLE I

DASH NO.	A DIA	B DIA	C LENGTH	D ANGLE	E CORE	F COVER	G LINER
-1	11.00	9.00	5.3	10°25'	8-070036-1	8-020148-1	8-020149-1

NOTES:

1. MATERIAL: SINE-HONEYCOMB PHENOLIC, FILLED WITH FOAMED TEFLON ® DENSITY OF 6 LBS./CU.FT. (REF).
2. MATERIAL: SST FOIL, .002 THK, TYPE 321 PER MIL-S-6721 (REF).
3. WELDS TO BE PER STRAZA 8-440040; HELIUM GAS TIGHT.
4. IDENTIFY WITH AMETEK/STRAZA PART NO. & DASH NO. PER WAS-1752.

PARTS LIST

QTY REQD PER DASH NO. -1	ZONE	FIND NO.	CODE IDENT	PART NUMBER	NOMENCLATURE	SIZE	MATERIAL	SPECIFICATION
1		4		G	LINER	(PER TABLE I)	2	
1		3		F	COVER	(PER TABLE I)	2	
1		2		E	CORE	(PER TABLE I)	1	
X		1			ASSEMBLY			

DASH NO.	QTY. REQD	NEXT ASSY
-1	2	8-030928
-1	1	8-100089

APPLICATION

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
DEC TOL: X = ±.1, XX = ±.03, XXX = ±.010; ANGULAR TOLERANCE 1/2°

MATERIAL

MACH SURFACE FINISH: 125 RMS — MACH RAD: .030

DO NOT SCALE PRINT

PARTS TO BE FREE OF BURRS & SHARP EDGES

CONTRACT NO. NAS-10-6098
PROJECT Hillsmann 4-30-69
DSGN ENGR
STRESS
CHECK
DRAWN H. Hiller 4-30-69

4057

STRAZA INDUSTRIES, 790 GREENFIELD DR., EL CAJON, CALIFORNIA 92021

TITLE: INSULATOR, JACKETED, ANTI-CONVECTION, OUTSIDE TAPER

SIZE D | CODE IDENT NO. 03024 | DRAWING NO. 8-100100 | REV

SCALE — | WEIGHT | SHEET 1 OF 1

8-100100

8-100100 Insulator Honeycomb

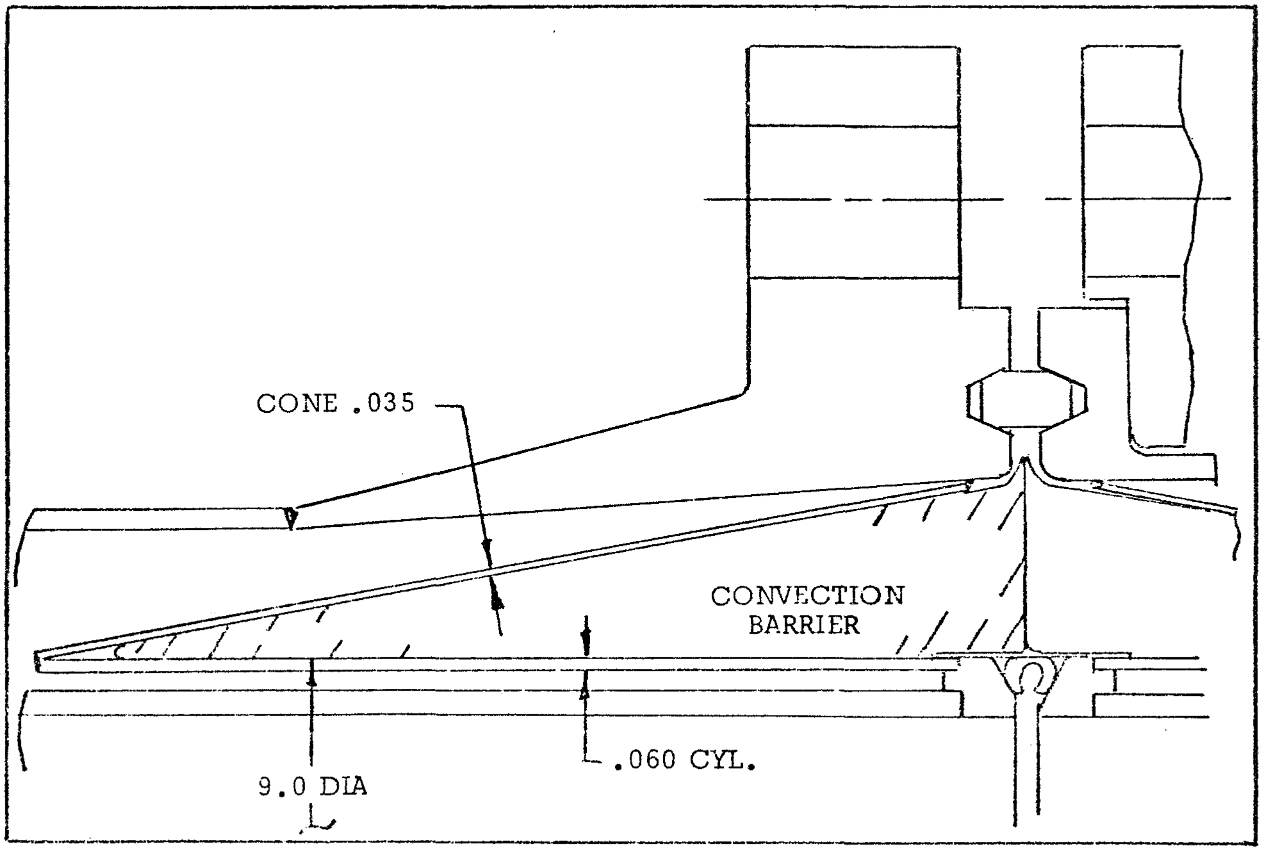


Figure 4 - Insulator Cone Detail

TABLE I

Insulator No.	Line Size	1-side convection barrier	1 side Cone .035"th	1 side Cyl. .060"th	Total For LO_2 One Side	Two Sides 1 ATM	Two Sides 10 ATM
1	8"	95.5	23.0*	39.0*	157.5	315	337
	6"	75.8*	19.0*	24.5*	119.3	238.6	260.1
2	8"	73.5	23.0	39.0	125.5	251.0	274.0
	6"	58.4	19.0	24.5	101.9	203.8	223.0

*Same as for Rotary Joint - WO 4057

Original Brown Engineering design heat leak

8" LO_2 Bayonet = 238 btu/hr @ 1 ATM
= 260 btu/hr @ 10 ATM

Insulator No. 1 (LO_2) (CTL-DIXIE)

This heat leak calculation will be based on using the A.D. Little convection barrier material where k = 0.012 Btu/hr-ft^2 — °F/ft. This is slightly worse than GO_2 (0.01) at mean temperature of -100°F. The material used by CTL-DIXIE in this barrier is discussed in detail in the Patent No. 3,371,946, Paragraph 7.1.2.1.

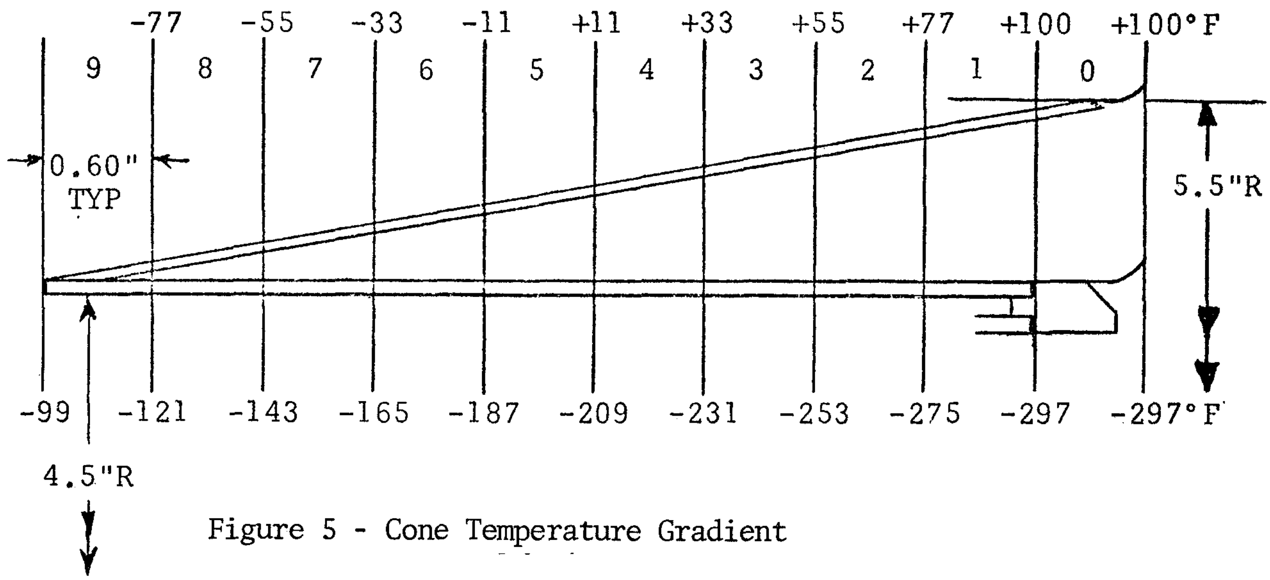


Figure 5 - Cone Temperature Gradient

8-Inch Joint Heat Leak for Convection Barrier

Assume flange temperature = 100°F at cone and flange junction. Figure 5 establishes the temperature gradients across the insulator for use in calculating the heat loss through the convection barrier. The heat loss through each of the sections 0 through 9 are totaled in Table II.

From the equation

$$\Sigma Q = k\Sigma \frac{A}{L} \Delta T,$$

the following table is made to establish the heat leak through the convection barrier.

TABLE II

Section	A Area Sq. Ft.	L Length Ft.	T Temp °F	Mean Heat Leak $Q = 0.012 \frac{A}{L} \Delta T$
0	.076	.083	397	4.36
1	.128	.075	397	8.12
2	.127	.065	352	8.25
3	.125	.056	308	8.25
4	.122	.056	264	8.40
5	.121	.037	220	8.63
6	.120	.029	176	8.72
7	.119	.019	132	9.80
8	.118	.008	88	15.50
9	.117	.004	44	15.50
				95.53

Insulator No. 2 (LO_2) (Foamed Teflon)

The heat loss calculations for the open cell foamed teflon are identical to those for the first insulator. The only difference is the thermal conductivity. The density ratio between the Thermic material and the CTL material is

$$\frac{0.008}{0.012}$$

or approximately a 30% decrease in heat loss for the foamed teflon. These heat loss values are tabulated in Table I.

B. Liquid Hydrogen Unit

Based on the information available today from References 1, 2, 3, 4, 5, and 6, several methods can be used to design a convection barrier block for use in the liquid hydrogen system. This block is different from that in the LO_2 system since it cannot be allowed to breathe the gaseous hydrogen due to its high thermal conductivity (about 7.5 X GO_2).

The material used must therefore be sealed against the 285 psi line proof pressure. Several materials are available, such as 10 lbs/cu. ft. rigid polyurethane foams and foam reinforced honeycomb.

Very little information is available on the conductivity of these materials designed to withstand the 285 psi pressure. Most work up to date has been for 20 to 40 psi systems similar to Centaur and Saturn V tank insulations.

Figures 6 and 7 are presented as two methods which can be used as convection barriers in the hydrogen line. The method shown in Figure 6 which uses the honeycomb/open cell foam teflon encased in a sealed 0.002 inch thick stainless shell, would be the more expensive approach but would give the lowest heat leak. The open cell teflon prevents convection losses within the cell while still allowing the cell cavities to cryopump. The cryopumped CO_2 charged cavity would have a negligible conductivity factor.

With this design, the shell could be evacuated to a high vacuum prior to sealing of the stainless covering. This would further improve the joint heat leak.

The method shown in Figure 7 which uses a closed cell rigid polyurethane foam capable of withstanding the 285 psi proof pressure will only partially cryopump due to the temperature gradient across the foam. Therefore, the high k factor of the foam would be reduced only by approximately 1/3 of its initial k factor of 0.30. This material does not lend itself to evacuation due to the heavier cell wall structure and the large size molecules of the freon foaming agent.

Insulator No. 1 (LH_2) (Foamed Teflon Filled Honeycomb)

The teflon foam filled honeycomb will be analyzed first. It will be assumed that the open-celled structure will be charged with CO_2 at 1 atmosphere prior to sealing of the outer jacket. A gettering material will be placed adjacent to the cold wall as shown in Figures 6 and 7 prior to seal-up. The thermal conductivity of this structure is as follows:

$$\overline{K}_{eff} = \overline{K}_{comb} + \overline{K}_{foam} + \overline{K}_{CO_2}$$

where

$$\overline{K}_{comb} = \frac{\text{density comb}}{\text{density resin}} \times \overline{K}_{resin}$$

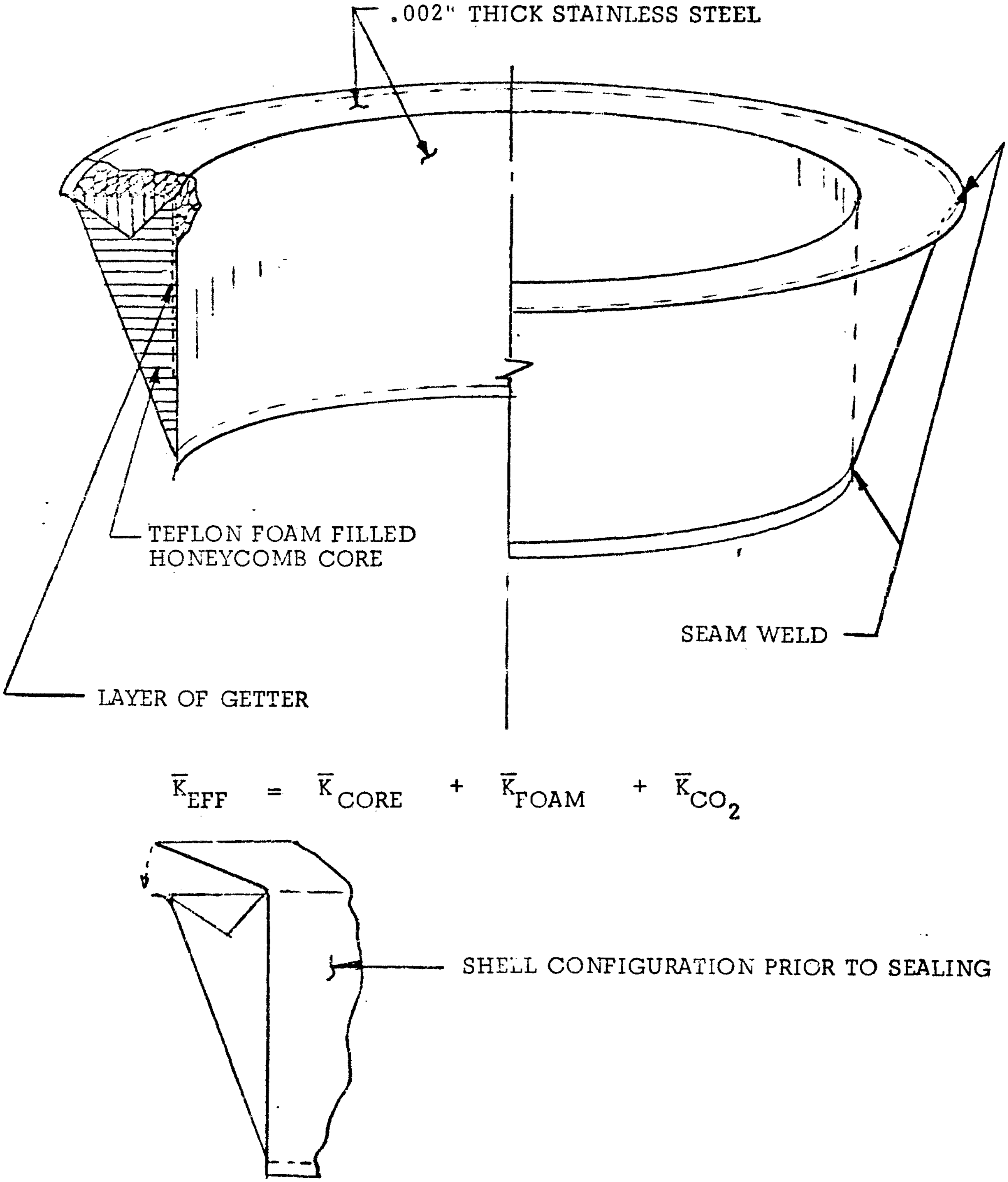
Honeycomb is Hexcel HRP 3/16-GF11-4.0
P = 4.0 lbs/cu. ft.
Compressive strength = 370 to 460 psi unbonded to shell.

This honeycomb is a flex-core glass reinforced plastic which allows one to bend it around the cylinder. This puts all cores in a radial direction for optimum load carry capacity and minimum heat leak.

Resin Density = 115 lbs/cu.ft.

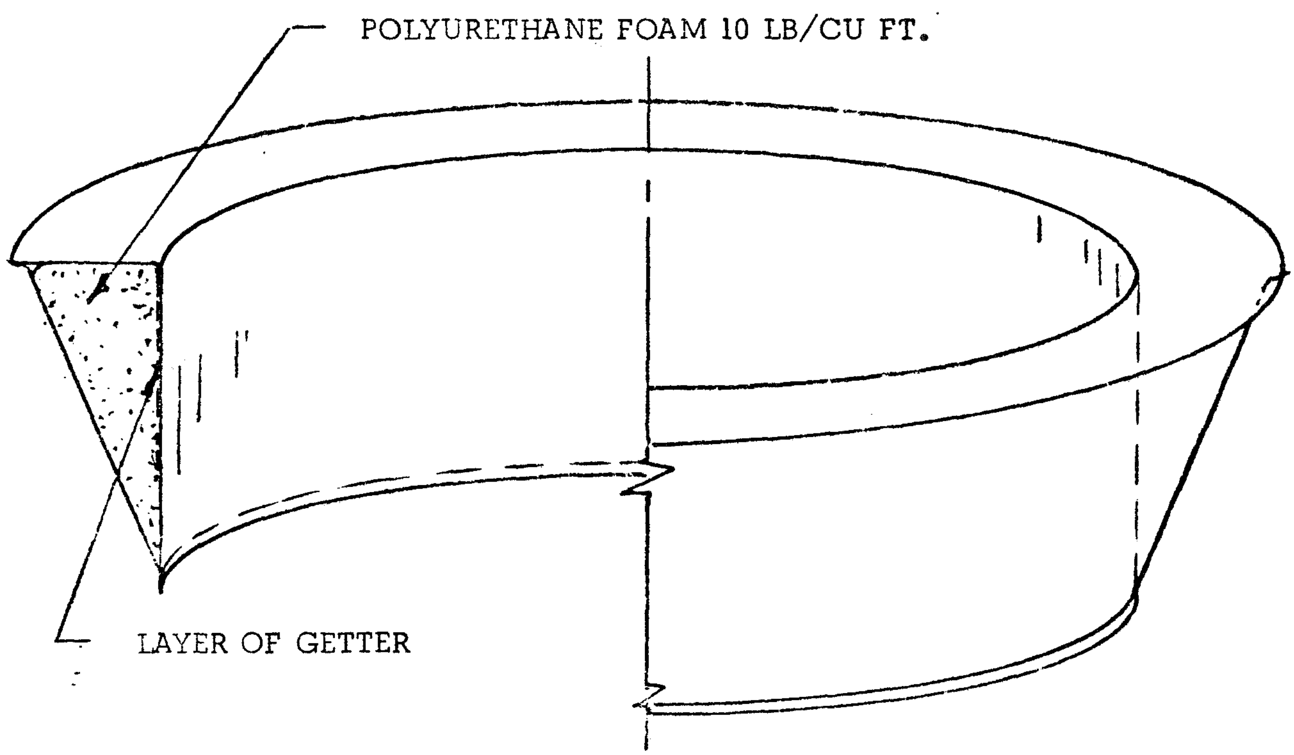
(references 6 and 8)

(Continued on Page 42)



$$\overline{K}_{EFF} = \overline{K}_{CORE} + \overline{K}_{FOAM} + \overline{K}_{CO_2}$$

Figure 6 - LH_2 Insulator #1



SHELL CONSTRUCTION SAME AS
FIGURE 6

$$\overline{K}_{EFF} = \overline{K}_{FOAM} + \overline{K}_{GAS}$$

Figure 7 - LH_2 Insulator #2 and #3

Thermal Conductivity (K) resin = 3.2 (Fig. 8)

$$\therefore \ \overline{K}_{core} = \frac{4}{115} \times 3.2 = 0.112 \text{ btu-in/hr ft}^2 \ ^oF$$

and:

$$\overline{K}_{foam} = \frac{\text{density foam}}{\text{density teflon}} \times \overline{K}_{teflon}$$

Density foam = 5.0 #/cu ft (From Thermic, Inc.)

Density teflon = 134 #/cu ft (ref. 7)

K_{teflon} = 1.7 btu-in/hr ft^2 ^{o}F (ref. 7)

$$\therefore \ \overline{K}_{foam} = \frac{5}{134} \times 1.7 = 0.064 \text{ btu-in/hr ft}^2 \ ^oF$$

and:

$\overline{K}_{CO_2}$ = 0 since it can cryopump out through the open cell foam.

$$\overline{K}_{eff} = 0.112 + 0.064 + 0 = 0.176 \ \frac{\text{btu-in}}{\text{hr-ft}^2 \ ^oF}$$

$$= \frac{.176}{12} = 0.0147 \ \frac{\text{btu-ft}}{\text{hr-ft}^2 \ ^oF}$$

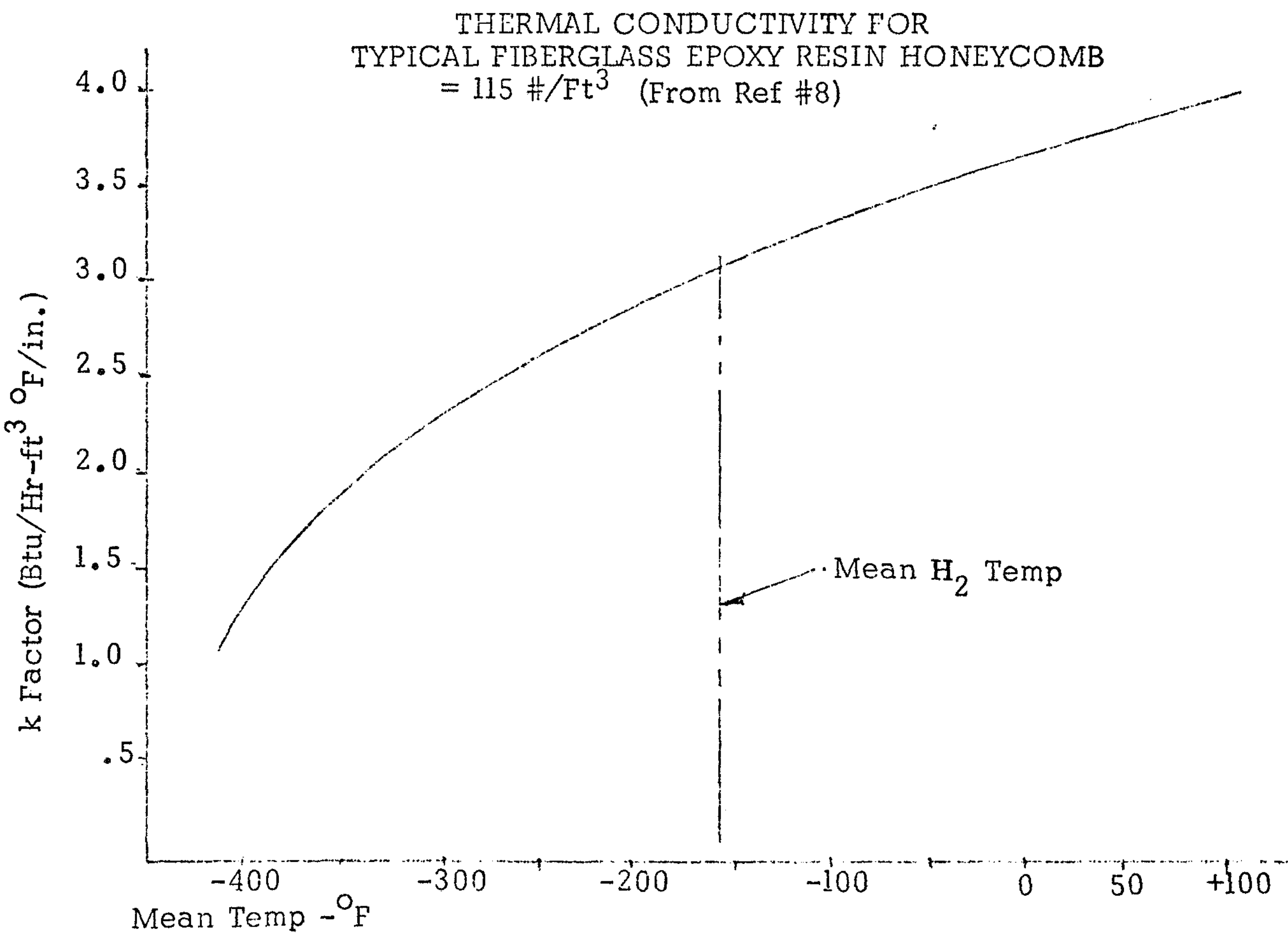
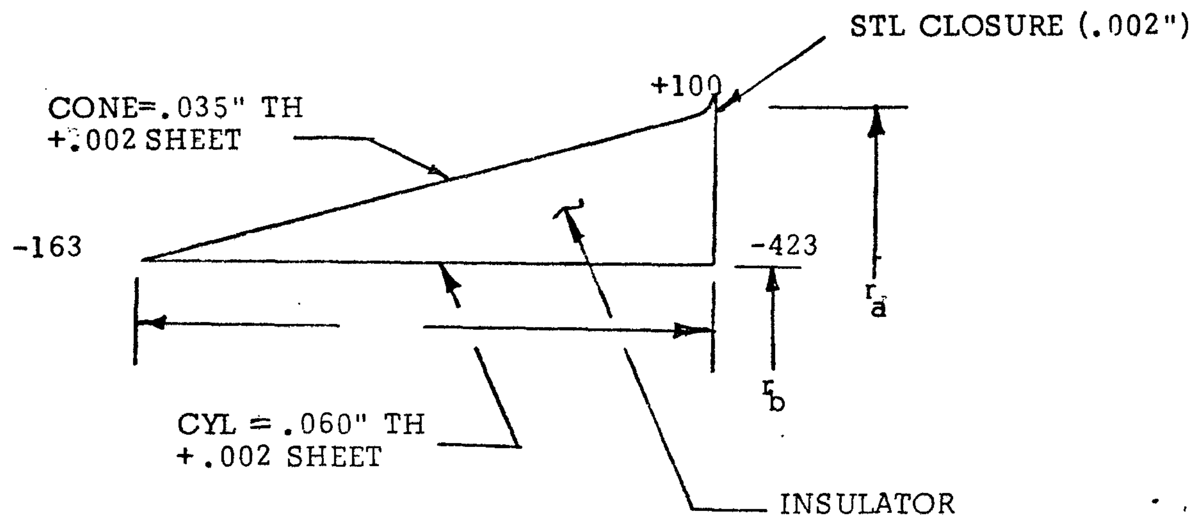


Figure 8 - Honeycomb Conductivity

The total heat leak for the Honeycomb design is as follows:

$$q_{TOT} = q_{CONE} + q_{CYL} + q_{INSUL} + q_{STL}$$

WHERE:



CONE:

$r_a = 5.5"$; $r_b = 4.5"$; $L = 5.3"$

$$q = 2\pi \times 7.0 \times \frac{.037}{12} \left[1 + \left(\frac{5.5 - 4.5}{5.5}\right)^2\right]^{1/2} \left(\frac{5.5 + 4.5}{11}\right) \left[-163-(+100)\right]$$

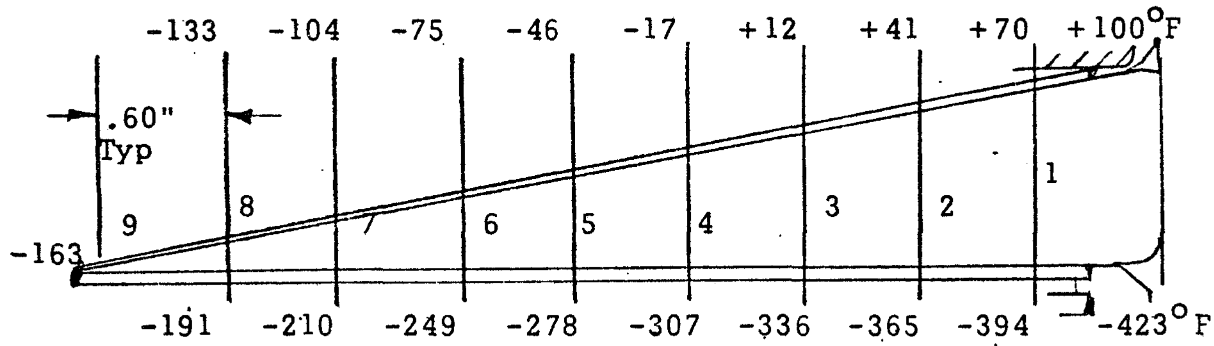
$$= 32.8 \text{ Btu/Hr}$$

(Ref: Appendix 7.5.4.)

CYLINDER: FROM $q = k \times A/L \times \Delta T$

$$q = \frac{7.0 \times \pi \times 9 \times .062}{144} \times \frac{12}{5.3} \left[-163 - (-423)\right] = 50 \text{ Btu/Hr}$$

INSULATOR #1 (Honeycomb + Foam Teflon + Cryopumped CO_2)



Section	-A- Area Ft^2	-L- Length Ft	-ΔT- Temp °F	Mean Heat Leak $q = .0147\frac{A}{L}\Delta T$
1	.128	.075	523	13.0
2	.127	.065	464	13.3
3	.125	.056	406	13.3
4	.122	.046	348	13.7
5	.121	.037	290	13.8
6	.120	.029	232	14.1
7	.119	.019	174	19.2
8	.118	.008	106	22.8
9	.117	.004	58	25.0
			TOTAL	148.2

See Table III for total heat leak of joint using Insulator #1.

Insulator No. 2 (LH_2) (Closed Cell Polyurethane Foam)

The thermal conductivity of the polyurethane structure as estimated by Upjohn, CPR Division of the Upjohn Company, is shown in Figure 9. This extrapolates to a k factor of 0.30 at the mean temperature of -166°F. With the partial cryopumping of the foaming agent, this will drop to possibly 0.25 Btu-in/hr ft^2 °F $\left(0.021 \dfrac{\text{Btu-ft}}{\text{hr ft}^2\ {}^\circ\text{F}}\right)$

The calculated k using the previous method and as outlined in Reference 6 is as follows:

$$\overline{K}_{eff} = \overline{K}_{foam} + \overline{K}_{gas}$$

where:

$$\overline{K}_{foam} = \frac{\text{Density foam}}{\text{Density resin}} \times \text{K resin}$$

$$= \frac{10}{70} \times 0.917 \quad \text{(Reference 6)}$$

$$= 0.13 \text{ Btu-in/hr ft}^2\ {}^\circ\text{F} = 0.011 \text{ Btu-ft/hr Ft}^2\ {}^\circ\text{F}$$

Since this value is approximately equal to a density of 2 #/ft^3 foam as shown in Figure 9, the higher value of 0.021 will be used.

The heat loss for this value is therefore:

$$148.2 \times \frac{.021}{.0147} = 212.0 \text{ Btu/hr}$$

See Table III for the total heat leak of joint using Insulator No. 2.

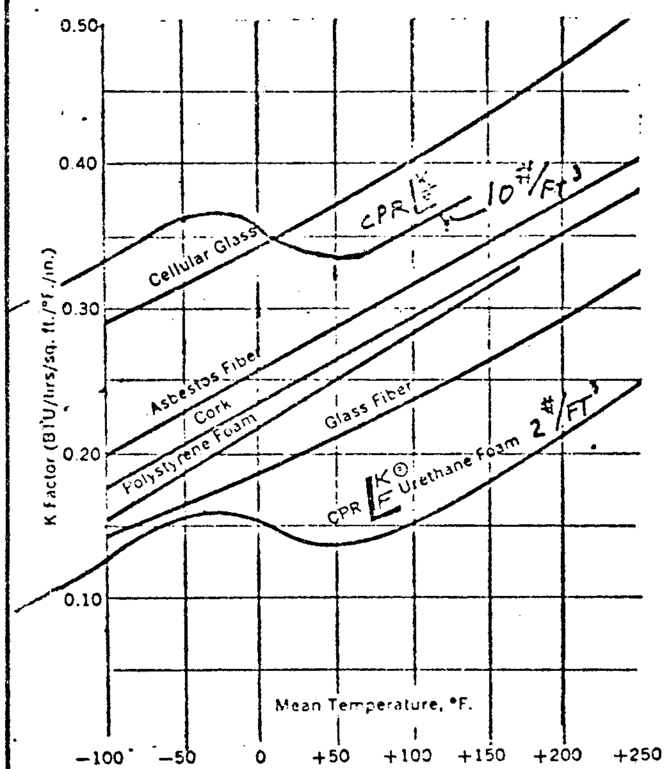
Insulator No. 3 (LH_2) (Open Cell Polyurethane Foam)

A new method, little known in the industry, was recently uncovered for manufacturing open cell polyurethane foam (see Reference 9). This material, developed by Union Carbide, fits this application very nicely since it allows the entire block cavity to cryopump. The open cell polyurethane has a total heat leak less than Insulator No. 2 and will carry a higher compressive load than the same density closed cell foam. The load carrying capability increases between 20% and 100%.

UPJOHN

Low K Factor means Insulation Efficiency with Great Savings in Space Weight and Cost

The lower the "K" value the better the insulation properties, and CPR rigid urethane foam has the lowest K-factor of all commercial insulation materials. The insulating effectiveness of CPR urethane is the result of circumjacent, fluorocarbon-filled, closed micro cells. This make-up gives it not only low thermal conductivity, but also an extremely low moisture-vapor permeability and a high resistance to water absorption. Added to this is a symmetrically formed cell structure which provides a high degree of strength along all axes. The resulting dimensional stability prevents costly heat gains or losses caused by shrinkage or buckling, and assures a lasting uniform performance without sagging, packing, or crumbling. This unique cell structure also accounts for CPR urethane's high strength and low density (nominal 2.0 lbs. per cubic foot). This lightness combined with the fact that less than half the thickness is usually needed for equal insulation value, means a saving in space and fewer supports. CPR urethane is an insulating material that becomes a permanent installation as it has excellent heat and chemical resistance, as well as resistance to rot; and since it has no food value, it does not attract fungi, termites, rodents, or insects. Being odorless, it is ideal for use in food processing and storage plants. CPR urethane is easy and economical to install. Its solvent resistance allows a wide choice of adhesives, and it can be cut to any size or shape with ordinary hand tools.



	K Factor @ 75°F.	Weight Equivalent	Thickness Equivalent
Cellular Glass (9.0 pcf)	0.39	12.6	2.8
Polystyrene Foam (2.0 pcf)	0.26	1.9	1.9
Glass Fiber (3.6 pcf)	0.23	2.9	1.6
CPR Urethane Foam (2.0 pcf)	0.14	1.0	1.0
Cork (6.5 pcf)	0.27	6.2	1.9
Asbestos Fiber (16.0 pcf)	0.30	17.6	2.2

Figure 9 - Urethane Foam Conductivity

This material must be foamed in large buns from which the cone is cut. This allows the cells to open. A No. 422 aluminum powder is added to the basic polyurethane mix to create the open cell configuration. By varying the foaming agent (UCON 11), the desired density is established. The formulation for this rigid open cell foam is as follows for a 10 #/cu. ft. density:

Component	Parts by Weight
NiAX POLYOL T-221	100.0
UCON 11	15.0
L-5320	4.0
TMBDA	0.6
Aluminum No. 422	1.0
NiAX AFPI	103.0
Stannous Octoate	0.2

If we assume the worst case of 20%, then 8 #/cu. ft. foam could be considered. By extrapolating from Figure 9, the k factor for this material would be approximately:

$$0.25 \frac{\text{Btu-in}}{\text{hr-ft}^2\,{}^\circ\text{F}}$$

and should cryopump to about one half this value per Reference 4.

This would give a k factor of:

$$.13 \frac{\text{Btu-in}}{\text{hr-ft}^2\,{}^\circ\text{F}} \quad (.011 \frac{\text{Btu-ft}}{\text{hr-ft}^2\,{}^\circ\text{F}})$$

This material will have a total heat leak of:

$$Q = 148.2 \times \frac{.011}{.0147} = 101.2$$

The following table summarizes the total heat leak for the three insulators when encased in the 0.002 inch thick stainless steel closure:

Where:

$$q = \frac{7.0 \times \pi \times 10.0 \times .002}{144} \times \frac{12}{1} + 100 - (-423)$$

$$= 19.1 \text{ Btu/hr}$$

TABLE III

Insulator No.	Line Size	Insul 1 Side	Cone 1 Side	Closure 1 Side	Cyl .060 1 Side	Total Heat Leak for LH_2 System in Btu/hr: One Side	Two Sides: 1 ATM	Two Sides: 10 ATM
1	8"	148.2	32.8	19.1	50.0	250.0	500	504
2	8"	212.0	32.8	19.1	50.0	317.0	634	639
3	8"	101.2	32.8	19.1	50.0	202.0	404	407

Original Brown Engineering Unit SK 4053-3 (Figure 3)

q = 329 Btu/hr at 1 ATM

q = 330 Btu/hr at 10 ATM

In order to prevent interchanging the LOX system insulation barriers with those in the hydrogen system during installation, a color code should be used. The existing porous teflon covering used in the A.D. Little block will be colored green. The hydrogen system will be red.

7.1.3.3 Conclusion

As can be seen from the tabulated heat leaks for the LO_2 joint, this design concept will give heat loss values very close to the 300 btu/hr established early in the program as a design goal.

The higher heat leak values for the liquid hydrogen system are to be expected due to the lower mean temperature. It also becomes obvious that a sealed convection barrier must be used in this system due to the high conductivity of the gaseous hydrogen.

Due to the original nature of the hydrogen system convection barrier, it was decided to file a patent application for this design concept. The methods presented appear to be as unique as the barrier patented by Annin.

7.1.4 Reliability Program

The reliability numbers established for this unit are summarized below:

A.	Preliminary Reliability Goal (See Page 8)	R = .9681
B.	Existing Hardware Reliability	R = .9231
C.	State-of-the-Art Reliability	R = .9231

It was determined that no difference existed between the hardware at Kennedy Space Center (existing hardware) and that presently available (state-of-the-art). Therefore, of necessity, the reliability figures are identical.

D.	Final Reliability Goal (From Paragraph 7.1.4.1)	R = .9787

In order to establish the reliability numbers for the bayonet, a unit quantity had to be assumed. This was done by totaling the individual lines in the existing system hardware, assuming this total to be representative of new systems quantities.

Arm 1 Propellant	3
Arm 4 Propellant LO_2	4
Arm 4 Propellant LH_2	3
Arm 5 Vent	5
Arm 6 Propellant	6
Arm 7 Vent	5
	26

Based on failures reported (2) on the Conoseal joint, the existing hardware reliability is:

$$R = \frac{26-2}{26} = \frac{24}{26} = .9231$$

7.1.4.1 Final Reliability Goal

The basis for the Final Reliability Goal is the configuration shown in Drawing 8-030928.

The assumed environmental and procedural problems, as indicated in the review of conditions and failures, were as follows:

A. Assembly ease
B. Handling abuse
C. G loads - vibration
D. Heat due to blast
E. Noise - blast

F. Internal gas leakage
G. Heat leak
H. Flow loads
I. Pressure loads
J. Static seal limitations

The preliminary reliability goal in Section 7.1.5 anticipated resolution of all the above potential failure modes except:

A. Nose seal damage at assembly
B. Weld crack at chill-down
C. Vibration

Based on present configuration and assuming successful testing phase, the failure potential of weld crack at chill-down and failure due to vibration should be eliminated. Probability of damage at assembly or during installation, although reduced, has not been eliminated and is the most likely failure mode. In addition, the possibility of failure due to the combination of environmental stresses still exist (vibration, flow loads, pressure loads, noise-blast and heat).

Therefore, the final reliability is:

$$R = \frac{94-2}{94} = \frac{92}{94}$$

$$R = .9787$$

7.1.5 <u>Quality Assurance Program</u>

Even though this hardware is being developed on purely a research and development basis, full Quality Control will be maintained. All drawings are being made and released as required by MIL Specifications. Each part will be fully planned and all parts will be completely traceable. All manufactured parts and assemblies will be 100% inspected by the Straza Quality Control group. All discrepancies will be reviewed by Quality Control, Quality Assurance, and the Design Engineering groups.

During the testing phase, all tests will be witnessed by Straza Quality Control Inspectors and NASA personnel will be notified within five days of the test.

7.1.6 BAYONET JOINT - PHASE II TECHNICAL PROPOSAL

During the first phase of this program, the A.D. Little patented cryogenic coupling was uncovered. The design which we are proposing for this study is based on this concept (shown in Fig. I of Patent 3,371,946). The modification will be as follows:

A. Reduce I.D./O.D. ratio.

B. Modify nose seal.

C. Possible change in anti-conductive block material.

D. Reduce cone length to simplify unit and make it compatible with the rotary joint envelope while still maintaining heat leak equal to the existing bayonet design.

Drawing 8-030928 shows this modified joint in detail.

The design phase has been brought to a sufficient point of completion to warrant parts procurement for Phase II testing.

The heat leak analysis as tabulated in Table I & III of the Phase I Technical Report shows very favorable comparisons of the new design joint as opposed to the original Brown Engineering design bayonet. The new joint consists of the following three basic parts:

A. Single structural cone/cylinder where L = IR. This cone and cylinder are designed to take the 285 PSI proof pressure without the use of reinforcing rings. The cone is fabricated from Armco 21-6-9 stainless steel which has a F_{ty} = 58 ksi. The higher strength is required since the cone is designed for high strain. The cylinder is 316 stainless steel since its mode of failure is a function of its modulus E.

B. Anti-convection block. Three different types of material will be tested in this assembly to determine effect on heat leak. These materials will be foamed teflon; open cell polyurethane foam and the CTL Dixie Fiber glass block.

C. Nose seal to prevent liquid short to cone cavity. This seal will be LN_2 chilled and shrunk into a thin aluminum band. This assembly is slipped in along with the foam block at line installation.

7.1.6.1 Test Plan

One 6 inch joint and one 8 inch joint will be fabricated and tested. These joints will be configured as shown in Drawing 8-030928. A short convoluted section will be used as shown for thermal compensation of the inner to outer line. One end will be constructed to facilitate bearing assembly for use in the rotary joint testing. The majority of the bayonet test will be performed with the rotary attached. This is described in the Rotary Joint Report, Sub-task IV, NASA Contract NAS 10-6098, Vacuum Jacketed Umbilical Lines Technology Advancement Study.

The following functional test will be accomplished on each bayonet joint assembly prior to the final environmental tests covered in the rotary joint report.

A. Leakage: 1×10^{-4} atm cc/sec maximum as measured in accordance with NASA Test #TCP V-26427 line leak check procedure.

B. Pressure: 190 psig operating, 285 psig proof.

C. Heat Leak: 300 Btu/hr maximum with line filled with LN_2.

7.1.6.2 Procurement Plan

Since these joints will be manufactured entirely by AMETEK/Straza, only the following materials will be procured outside:

	Item	Size	Quantity
1.	Weld neck flange	8"	2
2.	Weld neck flange	6"	2
3.	Foamed Teflon Anti-Convection Block	8"	2
4.	CTL Dixie Anti-Convection Block	8" 6"	4 4

The above quantities will provide one complete flanged joint for the 6 inch size and one for the 8 inch size.

The foamed teflon blocks will be the only long lead time items. The flanges will be ordered out of 316 stainless steel in lieu of 316L, since the L material is a long lead item and is not necessarily warranted for this type of program.

7.2 PHASE II PROGRAM

The second phase of this program covering a period of nine months required the completion of the following tasks:

A. Hardware and test fixture fabrication.

B. Preparation of test procedures and procurement specifications.

C. Preparation of the test report and the final program technical report.

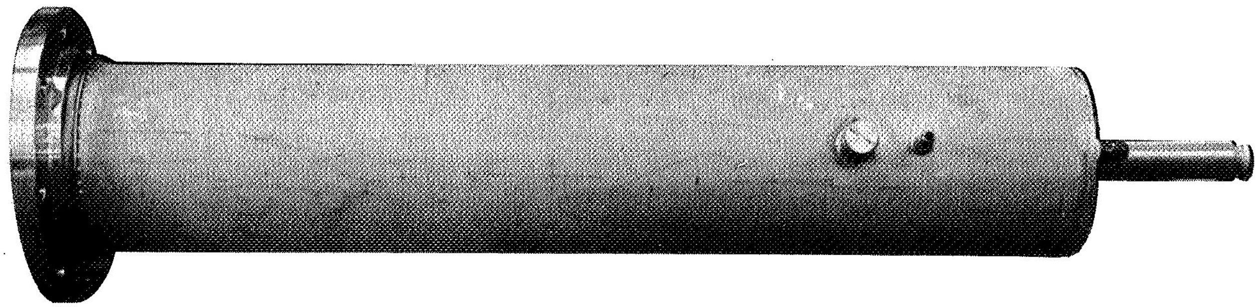
Fabrication of each test section as shown in Drawing 8-030929 was accomplished with few problems. Preliminary vacuum leakage check of one unit required re-welding of Item 4 to Item 5 due to cracks uncovered during the machining of the 9 inch diameter. Subsequent leakage checks showed this unit to be leak tight. Photographs of the 6 inch and 8 inch units are included.

On the following pages are shown the LO_2 insulator blocks procured by the specification control Drawing 8-070033 from the CTL Dixie Corporation. Considerable effort was required by CTL to re-establish the bake-out procedure used during the development of the Masoneilan coupling. This process is critical to the liquid oxygen compatibility of the material. Samples of this material were sent to MSFC, Huntsville, for LO_2 compatibility testing. Results of the tests confirmed the Masoneilan data, that the material was suitable for this application.

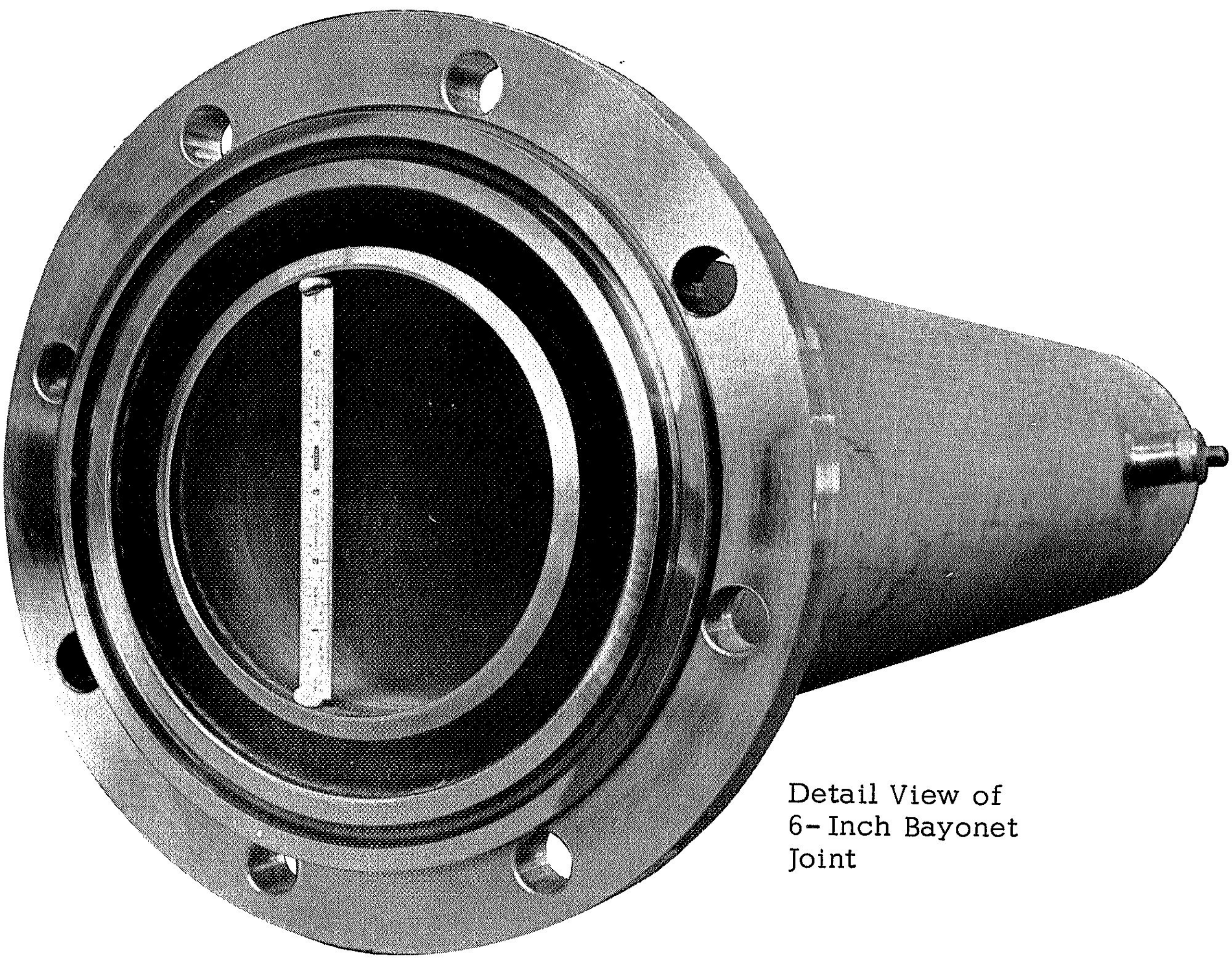
The second insulator block developed for LO_2 service was manufactured by Thermic Incorporated. This insulator was made of foamed teflon and purchased on a best effort basis since no previous attempt had been made to fabricate it into the cylindrical shape. The protective teflon film covering it had to be removed to facilitate installation. A photograph of this insulator is included.

A sample of the foamed teflon was subjected to a thermal conductivity test at Convair. The results of these tests indicated that this material would have a heat leak approximately twice that of the CTL material. A copy of this report No. ZZL-69-027, MA-572-1-681 is included in the Appendix.

Of the three insulators discussed in the Phase I Report for the LH_2 system, only the third one was carried through to completion. Due to a lack of time and funds, the foamed filled honeycomb insulator was carried only as far as fabricating the core. A photograph of this core is included. Had this unit been completed, it would look essentially as shown in Drawing 8-100100.

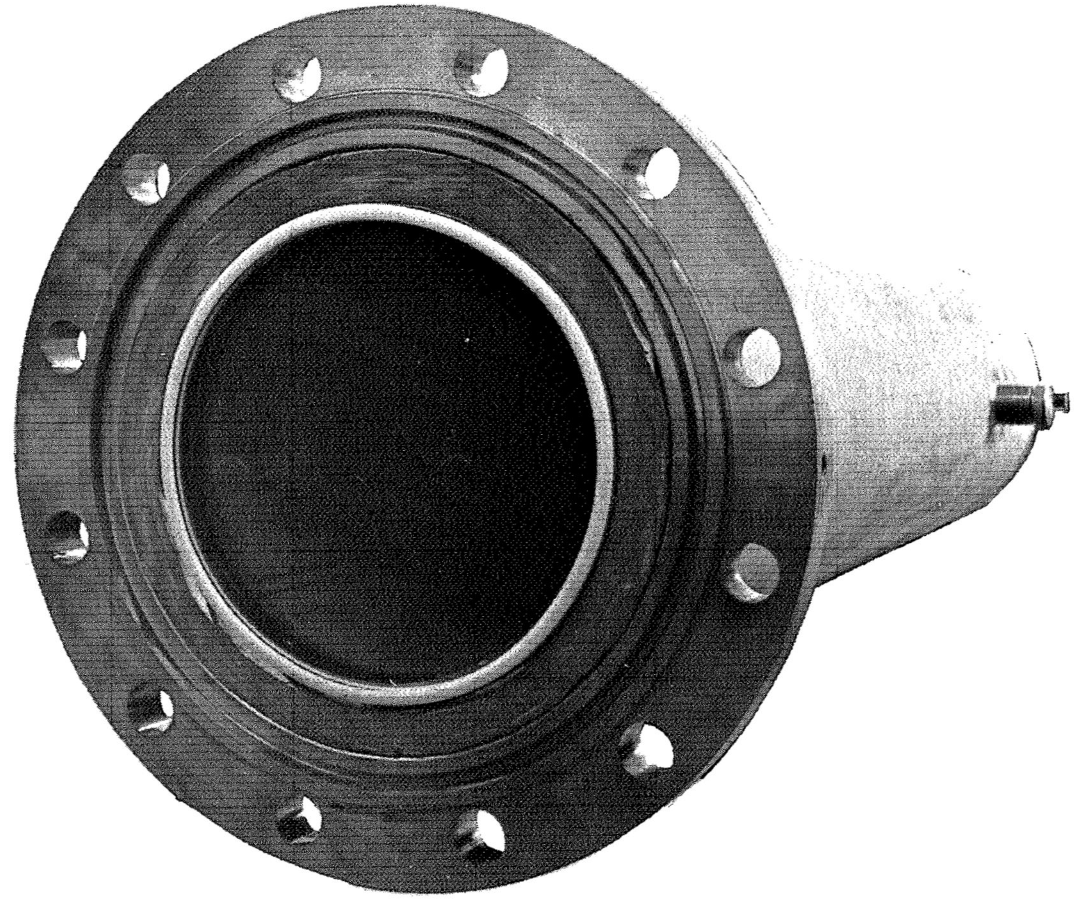


Over-all View

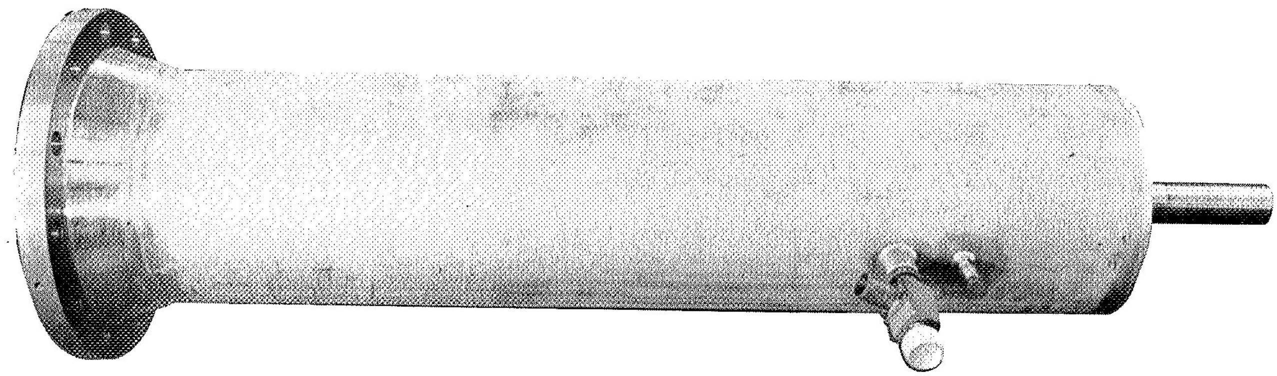


Detail View of
6- Inch Bayonet
Joint

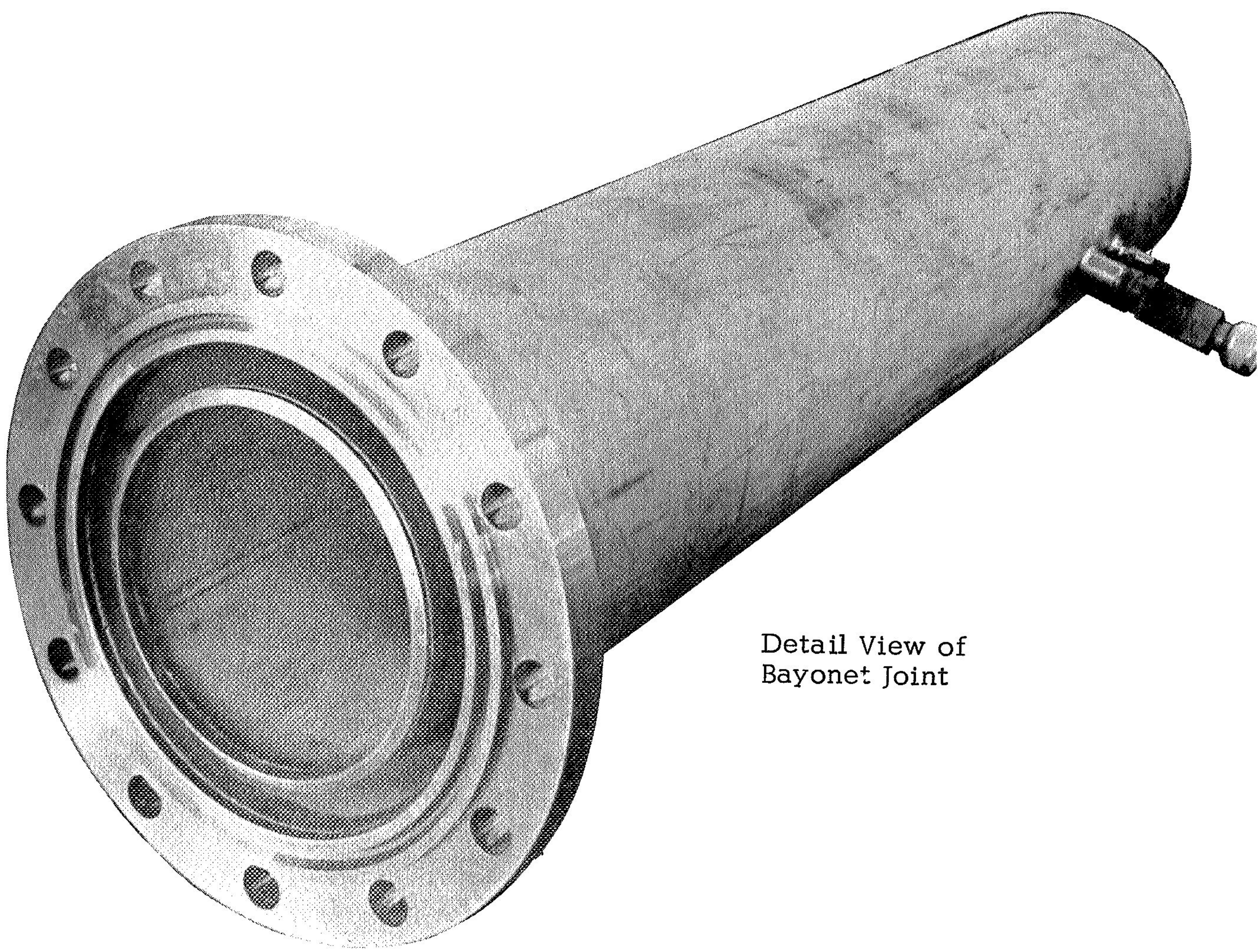
6-Inch Cryogenic Coupling Half



8 Inch Cryogenic Coupling Half

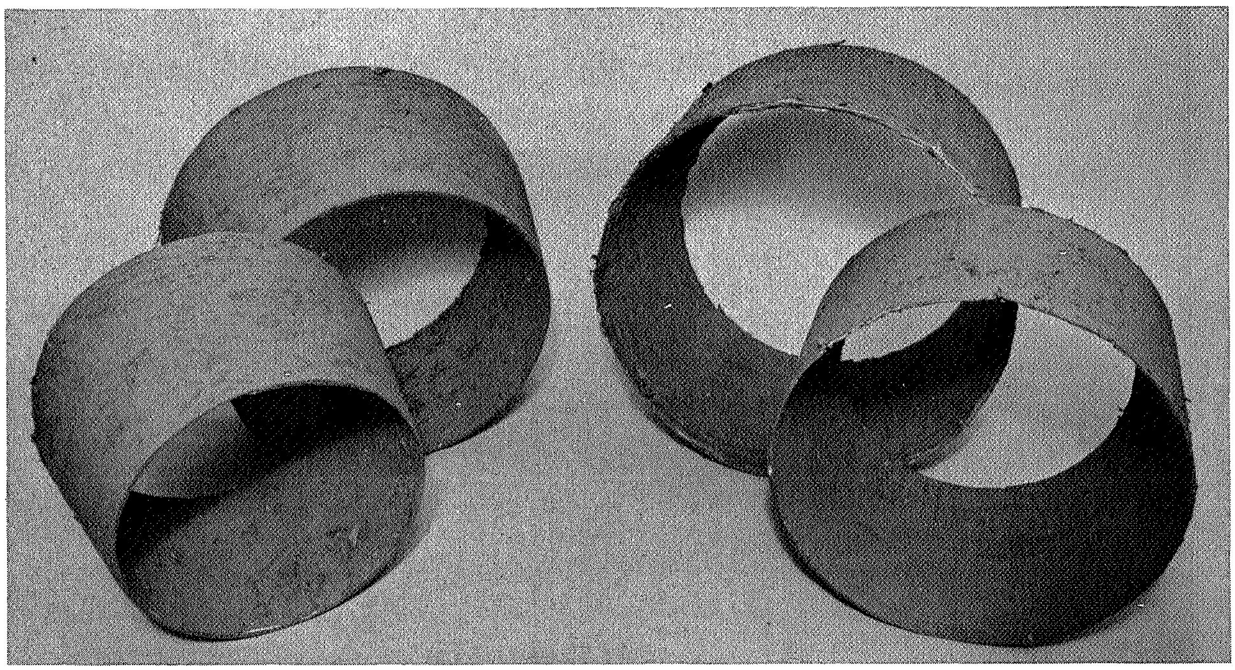


Over-all View

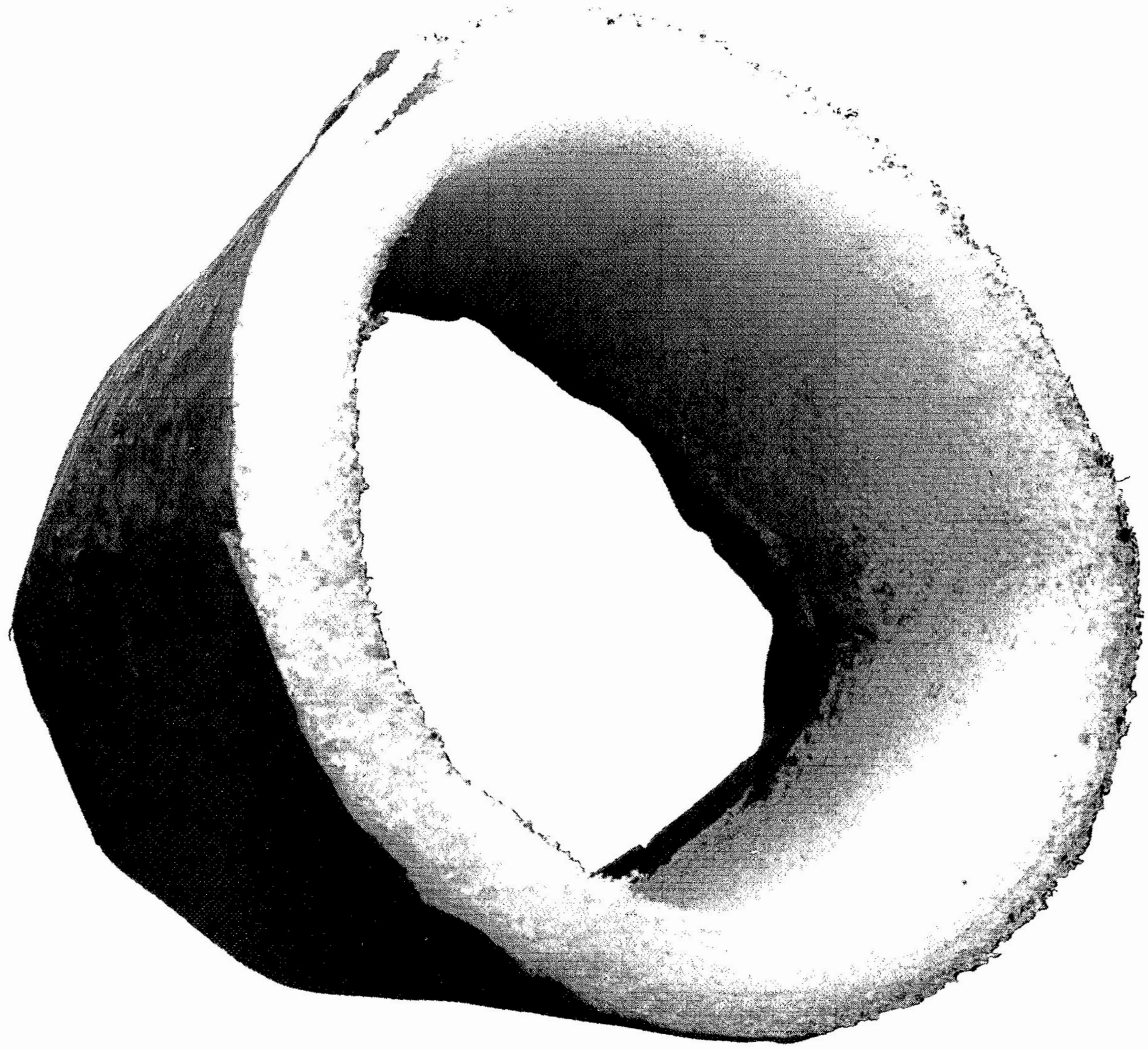


Detail View of
Bayonet Joint

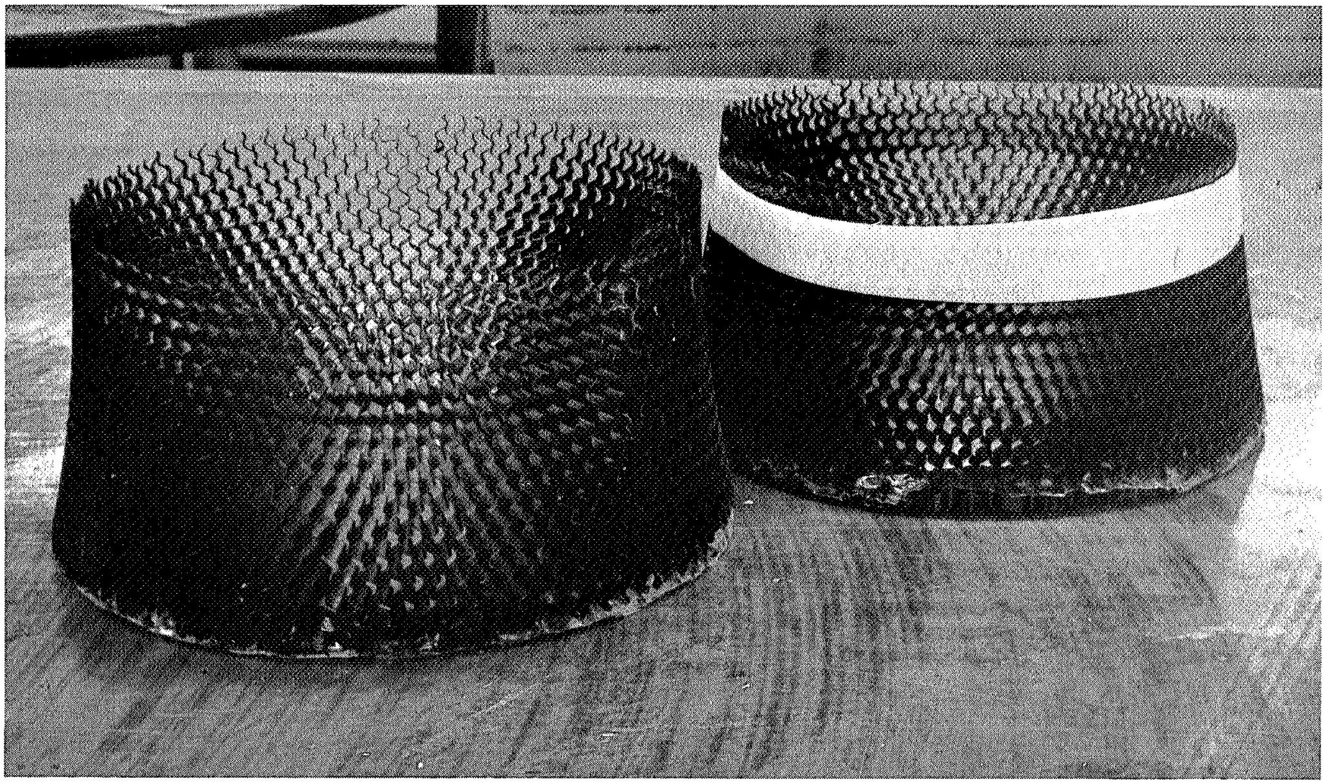
8 Inch Cryogenic Coupling Half

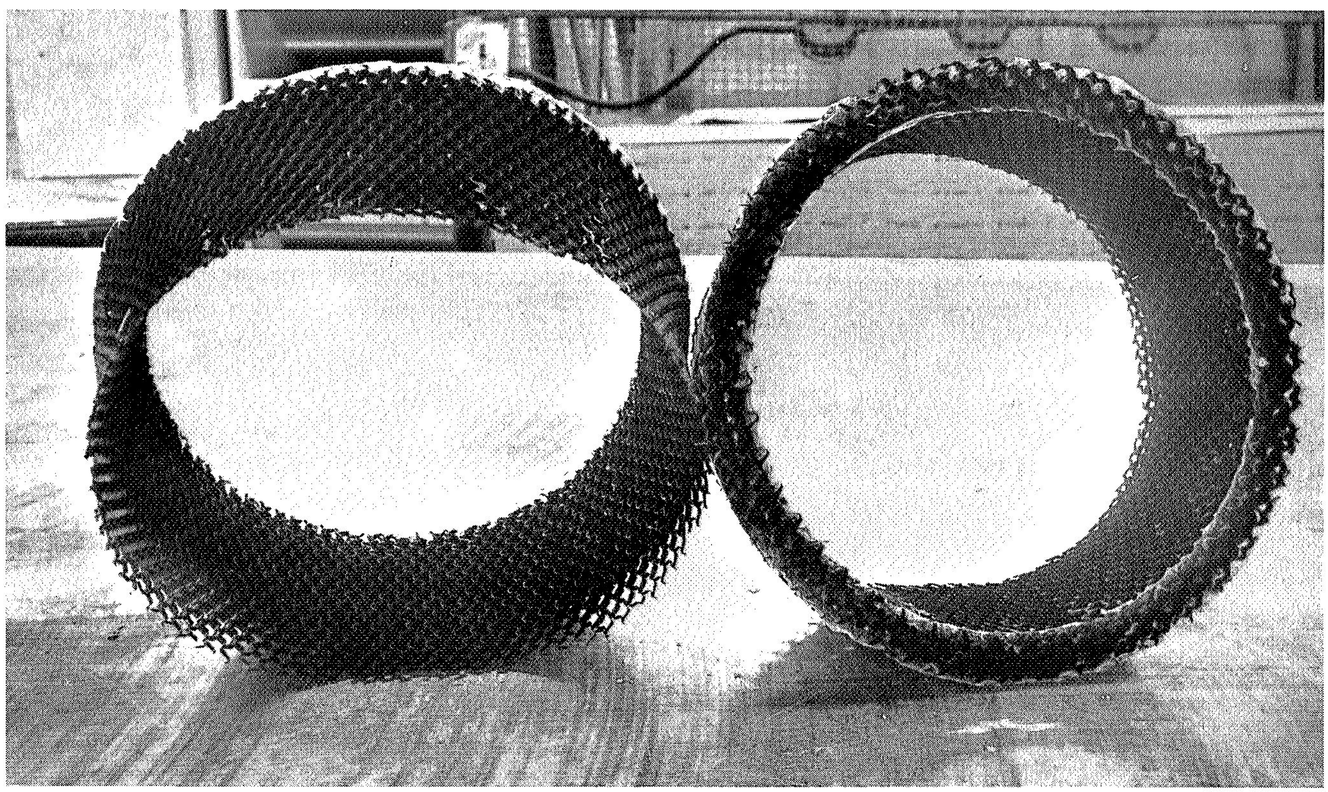


CTL Dixie LO_2 Insulator

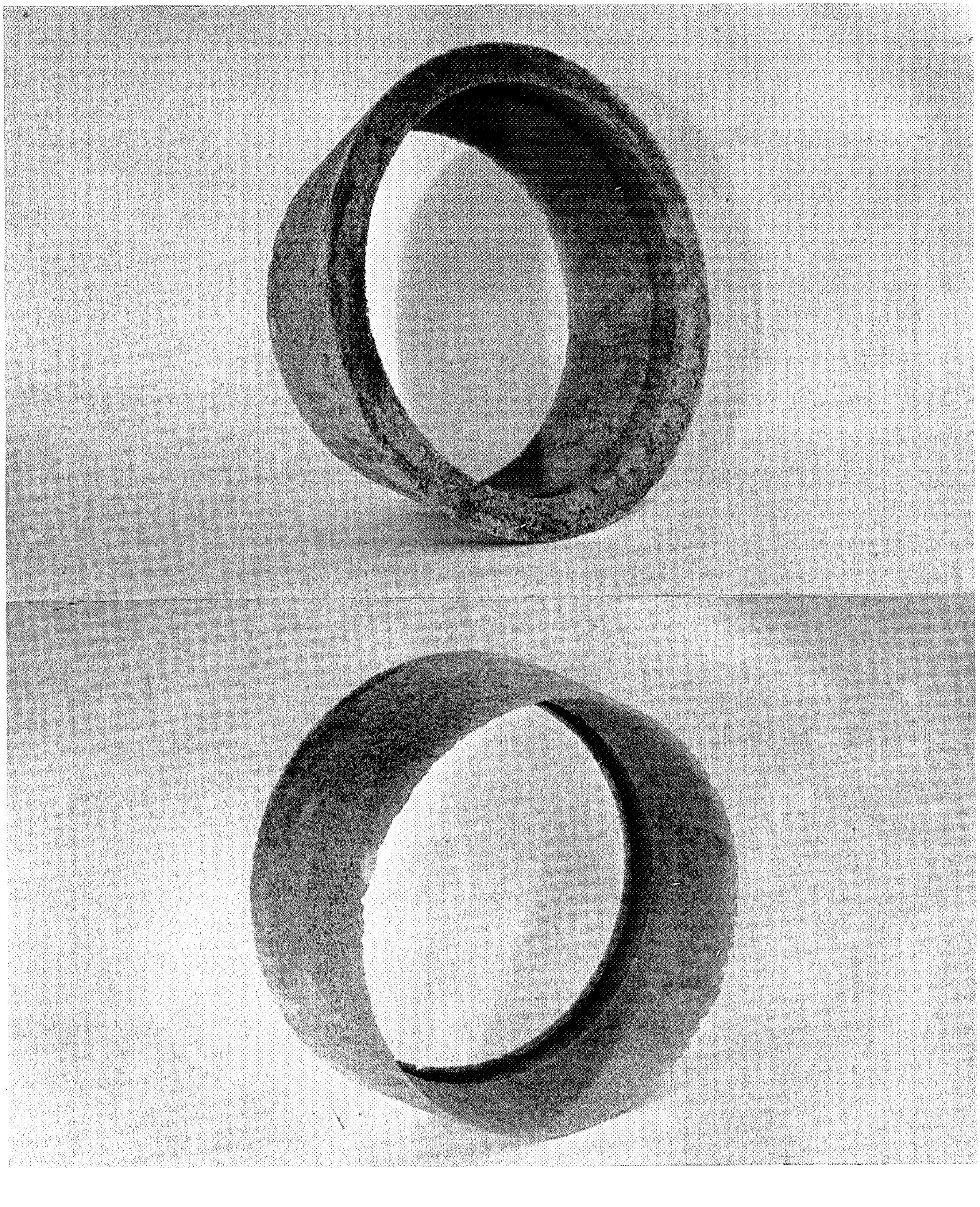


Thermic Disc, LO_2 Insulator





AMETEK/Straza Honeycomb Insulator



AMETEK/Straza Open-cell Polyurethane Insulator

LH_2 Foil Covered Insulator

LH_2 System Anticonvection Barrier Cone After Heat Leak And Operating Pressure Test

LH_2 Foil Covered Insulator

LH_2 System Anti-Convection Barrier Cone After 285 psi Proof Pressure

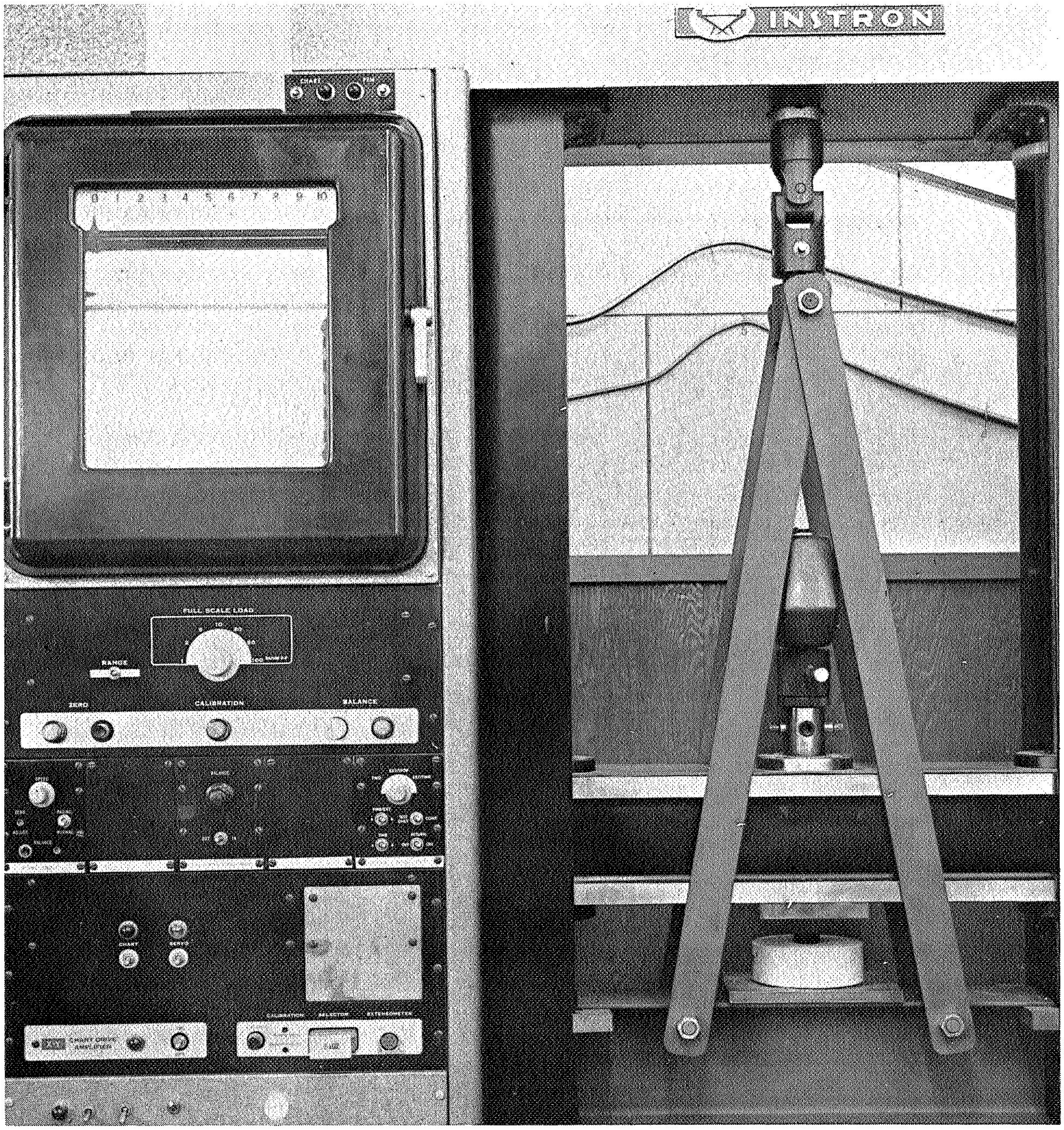
Since it was desirable to have complete cryopumping of this insulator, only the open cell polyurethane was investigated. Photographs of the foam core and the foil covered units are included. The first photograph of the foil covered insulator shows the effects of a leaking cover creating the bulged effect. This unit opened a weld seam during proof pressure. The second photograph shows the good unit with no leakage after proof pressure.

In order to ensure a high level of cryopumping in the foam cavity, a gettering material of charcoal was placed at the cold wall. These getter packs can be seen in the photograph of the good insulator where the foil cover was depressed around each pack. The recess in the foam, for placing the packs, can be seen in the photograph of the uncovered foam insulator.

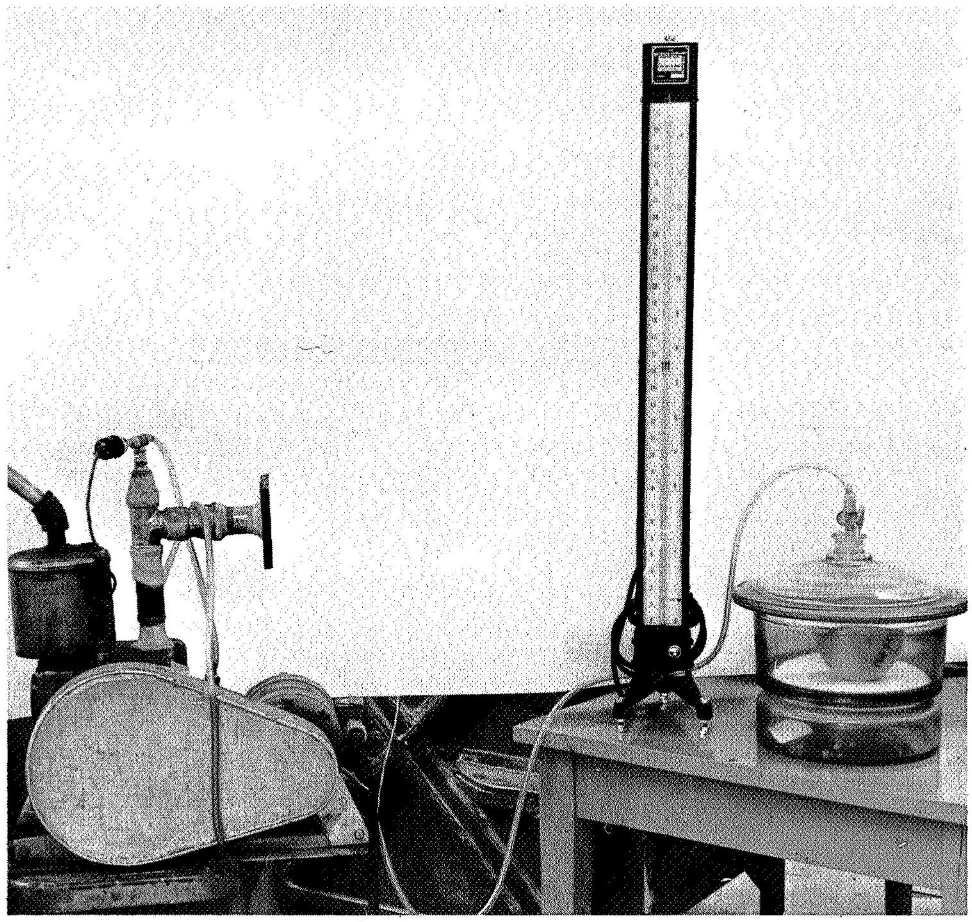
Considerable effort went into developing the open-celled polyurethane foam. After investigating approximately 40 different mixes, a mixture was developed which gave the desired properties. These are, an 8 to 10 lb/cu.ft density with open-cell rigid foam capable of withstanding 285 to 325 lbs. per sq. in. compressive load.

The following series of photographs show the equipment used to determine the compressive load capability of the foam, the foam evacuation equipment used to assist in opening the cells and several samples of test specimens.

It is expected that some cells are broken by the force created by the pressure differential between the forming gas and external low pressure (vacuum). Foam evaluation No. 1 was created by using the ingredients discussed in the LeRC Report (Ref. 9) on the fabrication of open-cell foam. The low crushing strength of 36 psi was far below the 300 psi desired. Foam evaluation No. 2 was made with an adjustment in the UCON 11 (Freon) foam blowing agent from 15 grams down to 13 grams. The strength improved and for an unknown reason, the density dropped but the resultant product was not usable. Foam evaluation No. 3 made further adjustment in the freon, but strength was still only 1/5 the desired value. By cutting back the L5320 to 1 gram, foam evaluation No. 4 approached the desired strength, but with an inadequate degree of open cells. Foam evaluations No. 4 through No. 12 and No. 20 are further attempts to develop the desired open-celled foam with a 300 psi minimum. All these attempts met with failure due to insufficient open cell indications. Most tests yielded samples of inadequate strength as well. The final process, No. 40, was discovered by AMETEK/Straza's Materials and Processes Manager, Mr. L. Russell, who had been supporting this project on a consulting basis. The combination of materials form a foam of the desired strength that is truly open-celled.



Compression Apparatus Used During Foam Evaluation
Compressing Test Apparatus



Vacuum Pump Apparatus

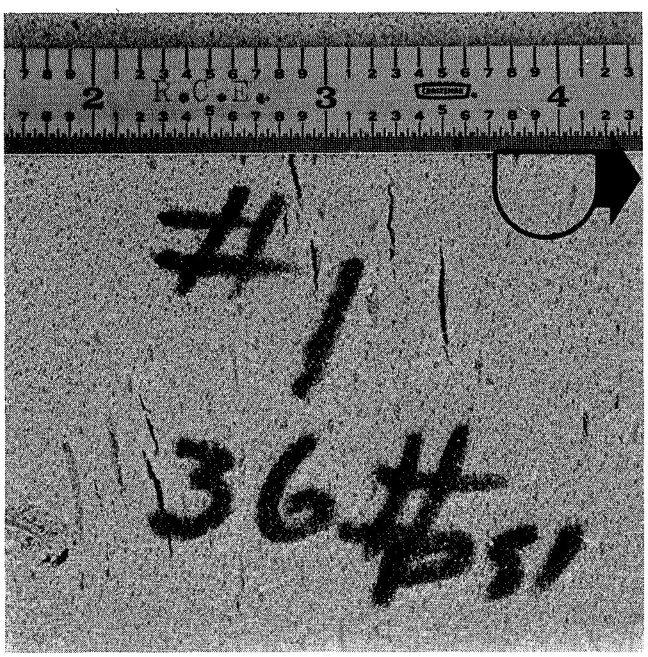
KSC STUDY

FOAM EVALUATION NO. 1

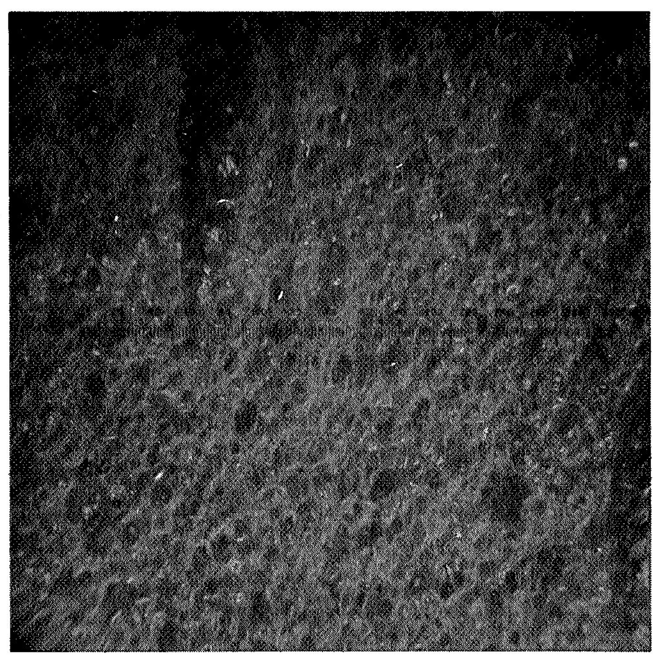
CONSTITUENTS		PROCESS	
Material	Weight (gms)	Cure Time (hrs)	4
T-221	100.0	Foamed in Vacuum:	
L 5320	4.0	No	x
TMBDA	0.6	Yes (in. Hg)	
AL #422	1.0	RESULTS	
STAN. OCT	0.4	Density (lb/ft^3)	4.08
UCON 11	15.0	Compressive Strength (psi)	36
NI AX AFPI	103.0		

PHOTOGRAPHS OF SAMPLE

General View



10X Magnification



Foam Evaluation No. 1

KSC STUDY

FOAM EVALUATION NO. 2

CONSTITUENTS

Material	Weight (gms)
T-221	100.0
L 5320	3.0
TMBDA	0.6
AL #422	1.0
STAN. OCT	0.4
UCON 11	13.0
NI AX AFPI	103.0

PROCESS

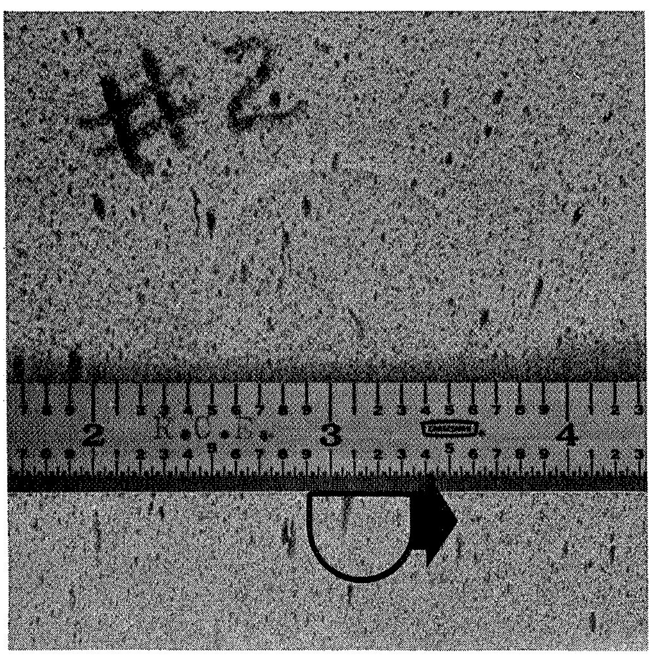
Cure Time (hrs)	4
Foamed in Vacuum:	
No	x
Yes (in. Hg)	

RESULTS

Density (lb/ft^3)	3.9
Compressive Strength (psi)	56

PHOTOGRAPHS OF SAMPLE

General View



10X Magnification

Foam Evaluation No. 2

KSC STUDY

FOAM EVALUATION NO. 3

CONSTITUENTS

Material	Weight (gms)
T-221	100.0
L 5320	2.0
TMBDA	0.6
AL #422	1.0
STAN. OCT	0.4
UCON 11	10.0
NI AX AFPI	103.0

PROCESS

Cure Time (hrs)	4
Foamed in Vacuum:	
No	x
Yes (in. Hg)	

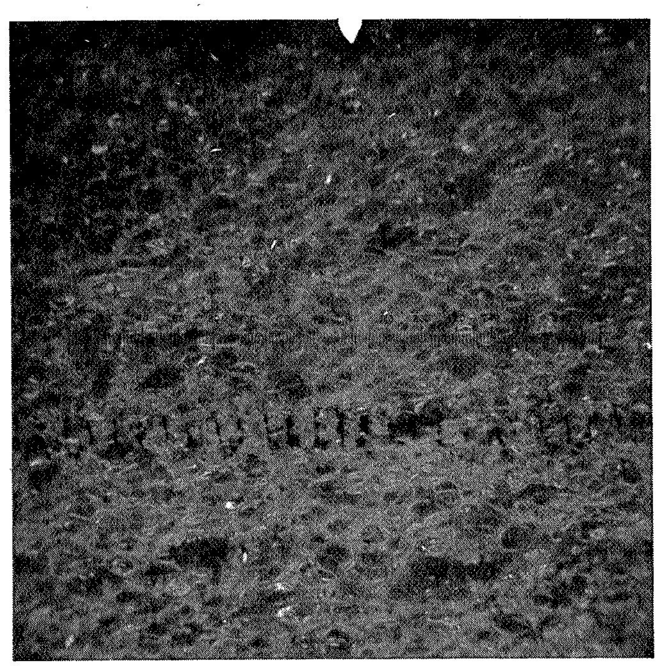
RESULTS

Density (lb/ft^3)	3.65
Compressive Strength (psi)	60

PHOTOGRAPHS OF SAMPLE

General View

10X Magnification



Foam Evaluation No. 3

KSC STUDY

FOAM EVALUATION NO. 4

CONSTITUENTS

Material	Weight (gms)
T-221	100.0
L 5320	1.0
TMBDA	0.6
AL #422	1.0
STAN. OCT	0.4
UCON 11	10.0
NI AX AFPI	103.0

PROCESS

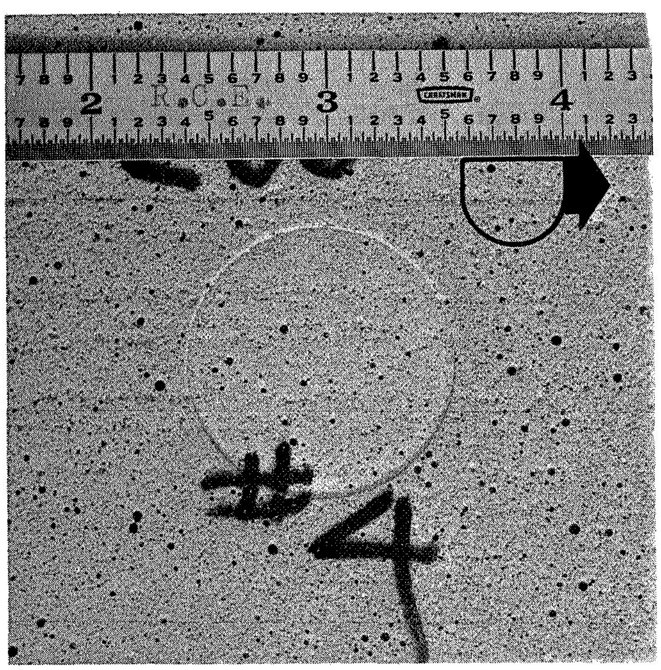
Cure Time (hrs)	4
Foamed in Vacuum:	
No	x
Yes (in. Hg)	

RESULTS

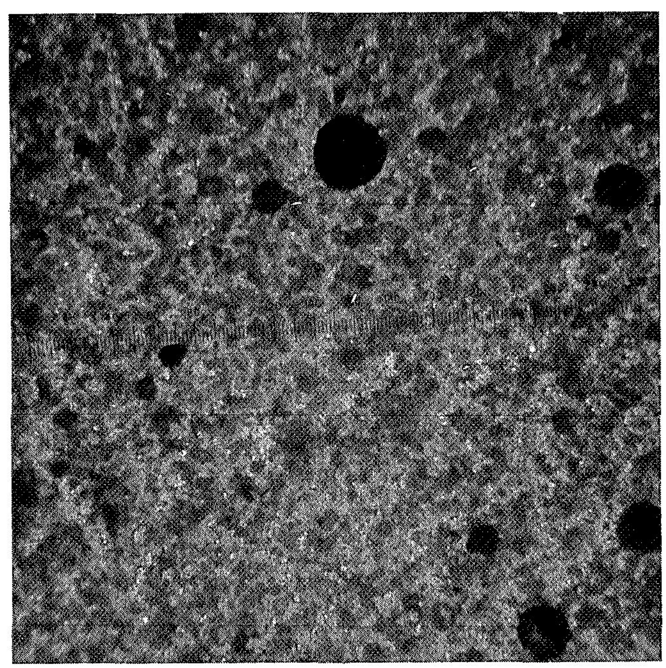
Density (lb/ft^3)	8.4
Compressive Strength (psi)	280

PHOTOGRAPHS OF SAMPLE

General View



10X Magnification



Foam Evaluation No. 4

KSC STUDY

FOAM EVALUATION NO. 5

CONSTITUENTS

Material	Weight (gms)
T-221	100.0
L 5320	0.5
TMBDA	0.6
AL #422	1.0
STAN. OCT	0.4
UCON 11	10.0
NI AX AFPI	103.0

PROCESS

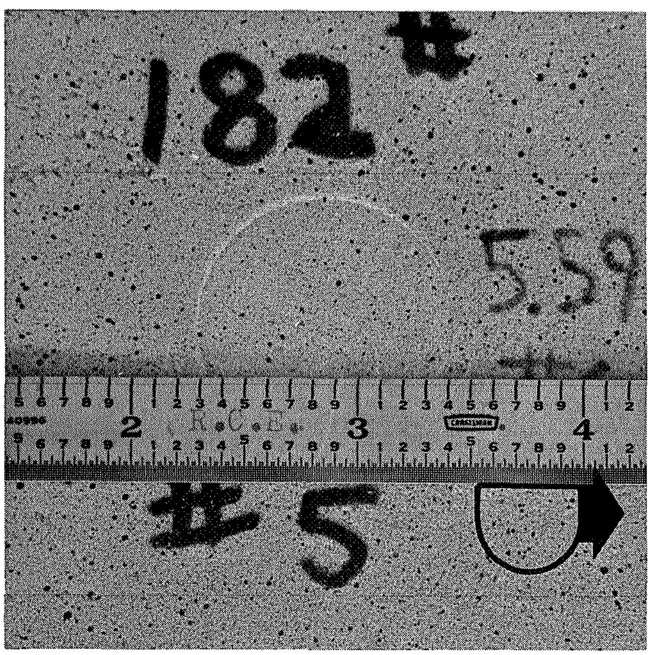
Cure Time (hrs)	4
Foamed in Vacuum:	
No	x
Yes (in. Hg)	

RESULTS

Density (lb/ft^3)	5.59
Compressive Strength (psi)	182

PHOTOGRAPHS OF SAMPLE

General View



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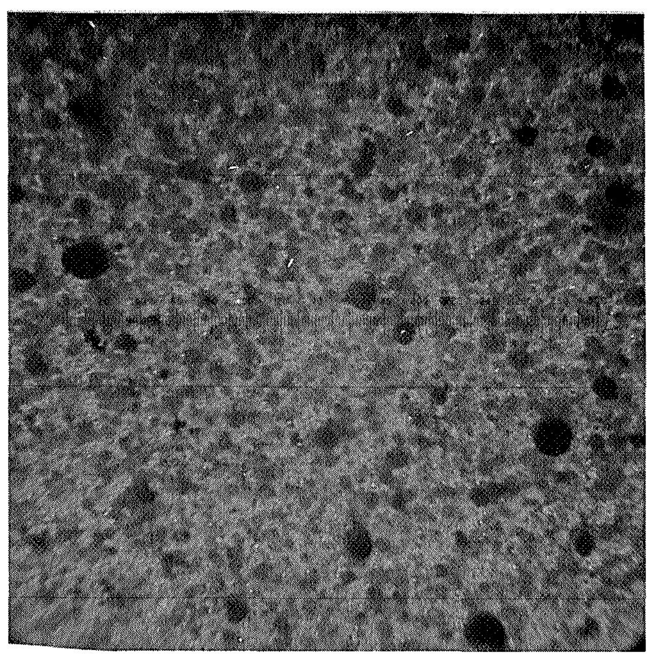


Foam Evaluation No. 5

KSC STUDY

FOAM EVALUATION NO. 6

CONSTITUENTS

Material	Weight (gms)
T-221	200
L 5320	
TMBDA	1
AL #422	
STAN. OCT	
UCON 11	
NI AX AFPI	206

PROCESS

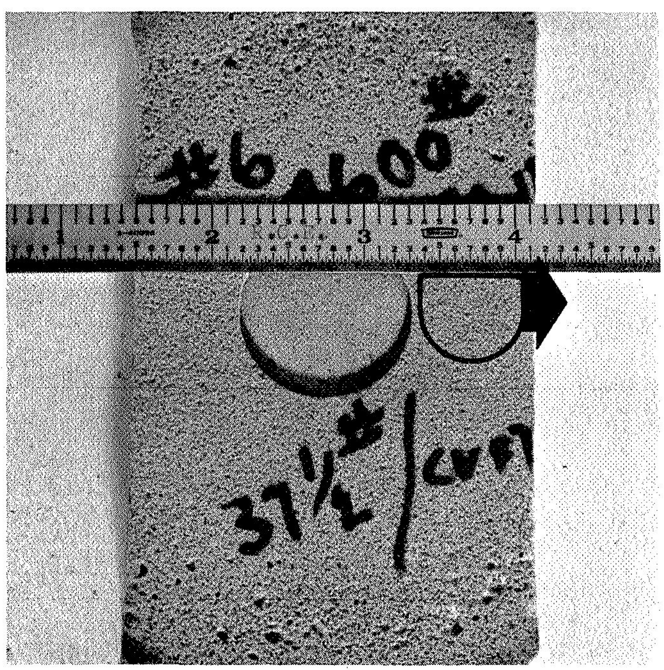
Cure Time (hrs)	0.75
Foamed in Vacuum:	
No	
Yes (in. Hg)	14

RESULTS

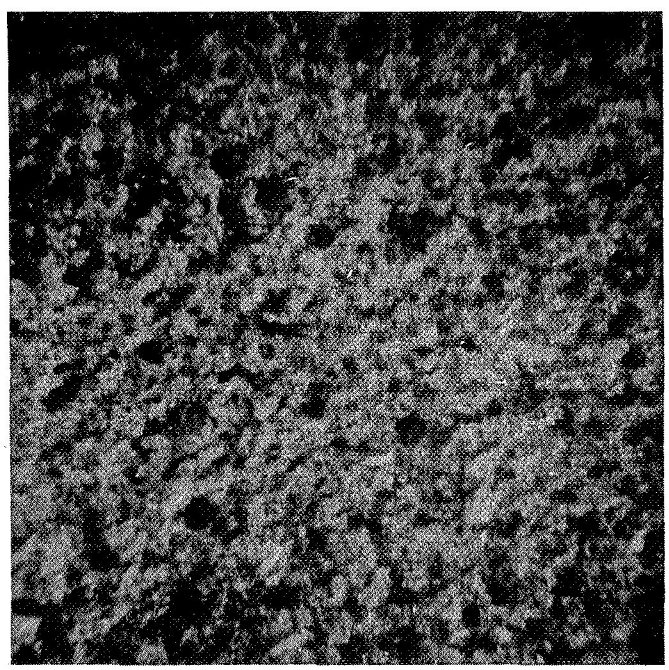
Density (lb/ft^3)	37.5
Compressive Strength (psi)	4600

PHOTOGRAPHS OF SAMPLE

General View



10X Magnification



Foam Evaluation No. 6

KSC STUDY

FOAM EVALUATION NO. 7

CONSTITUENTS

Material	Weight (gms)
T-221	200
L 5320	
TMBDA	
AL #422	
STAN. OCT	
UCON 11	
NI AX AFPI	206

PROCESS

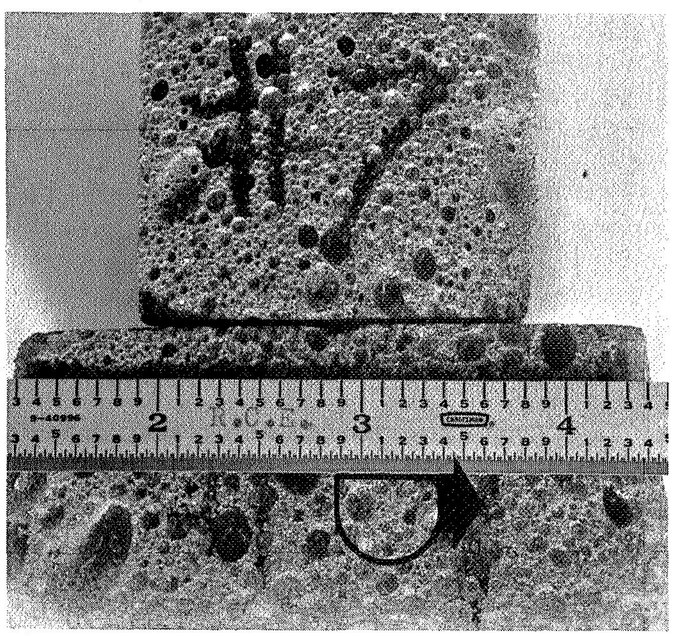
Cure Time (hrs)	4
Foamed in Vacuum:	
No	
Yes (in. Hg)	28

RESULTS

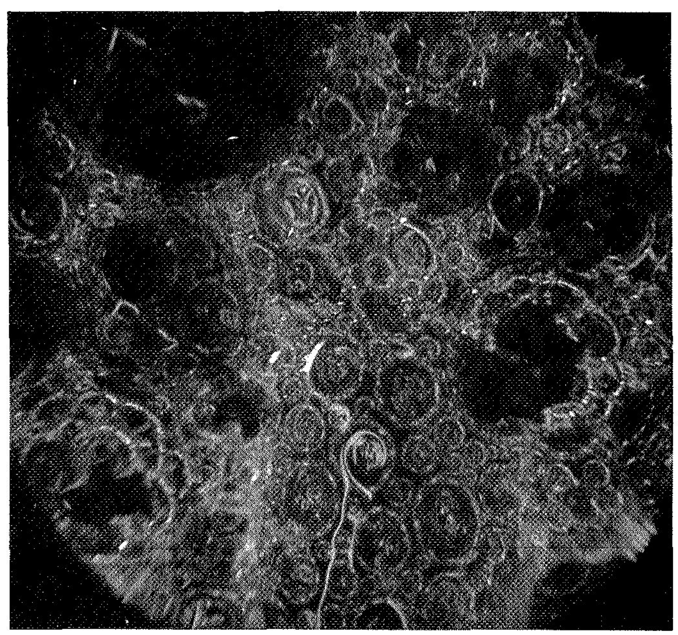
Density (lb/ft^3)	7.1
Compressive Strength (psi)	505

PHOTOGRAPHS OF SAMPLE

General View



10X Magnification



Foam Evaluation No. 7

KSC STUDY

FOAM EVALUATION NO. 8

CONSTITUENTS

Material	Weight (gms)
T-221	200
L 5320	
TMBDA	
AL #422	
STAN. OCT	
UCON 11	
NI AX AFPI	206

PROCESS

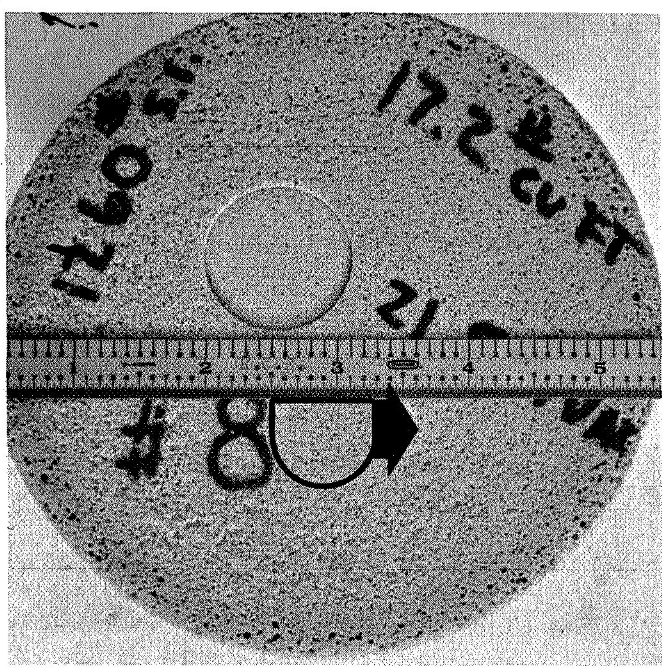
Cure Time (hrs)	4
Foamed in Vacuum:	
No	
Yes (in. Hg)	21.5

RESULTS

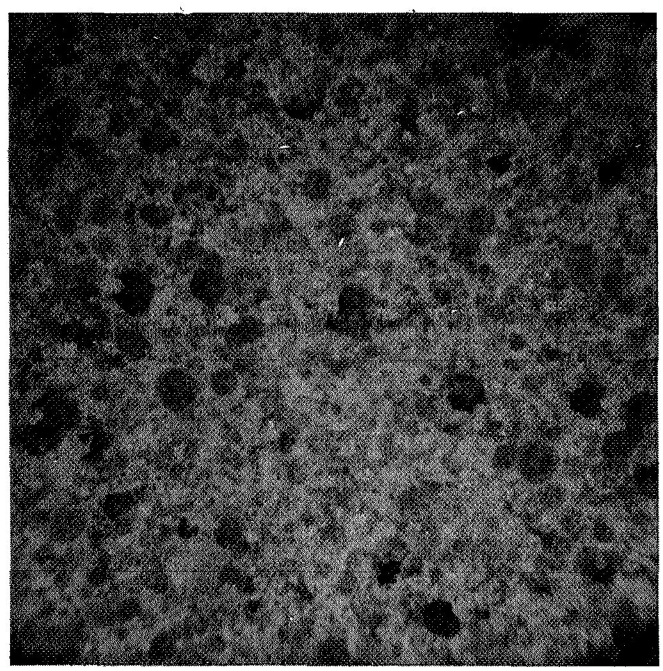
Density (lb/ft^3)	17.2
Compressive Strength (psi)	1260

PHOTOGRAPHS OF SAMPLE

General View



10X Magnification



Foam Evaluation No. 8

KSC STUDY

FOAM EVALUATION NO. 9

CONSTITUENTS

Material	Weight (gms)
T-221	200
L 5320	
TMBDA	
AL #422	
STAN. OCT	
UCON 11	
NI AX AFPI	206

PROCESS

Cure Time (hrs) 4

Foamed in Vacuum:

No

Yes (in. Hg) 28

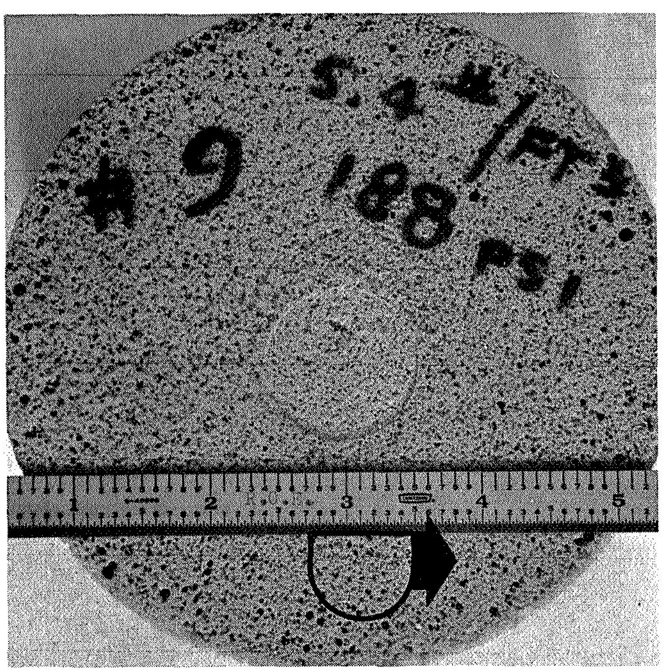
RESULTS

Density (lb/ft^3) 5.4

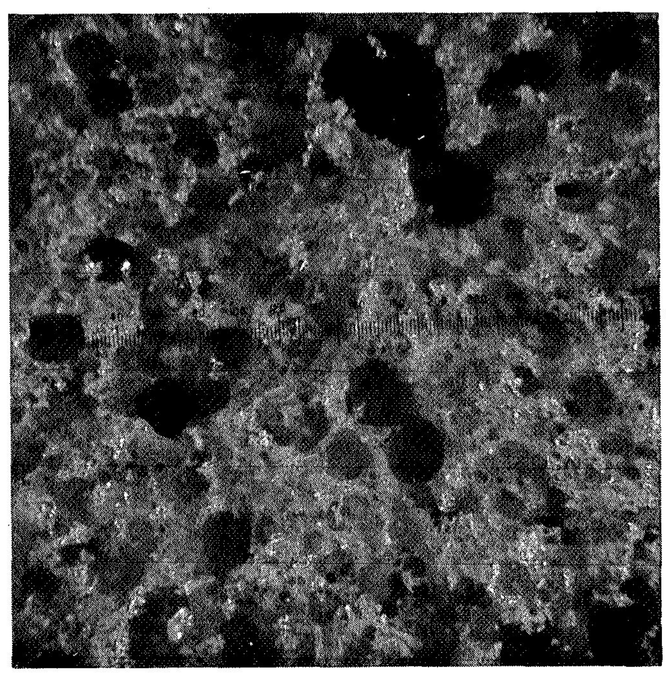
Compressive Strength (psi) 188

PHOTOGRAPHS OF SAMPLE

General View



10X Magnification



KSC STUDY

FOAM EVALUATION NO. 10

CONSTITUENTS

Material	Weight (gms)
T-221	100
L 5320	
TMBDA	
AL #422	
STAN. OCT	
UCON 11	
NI AX AFPI	103

PROCESS

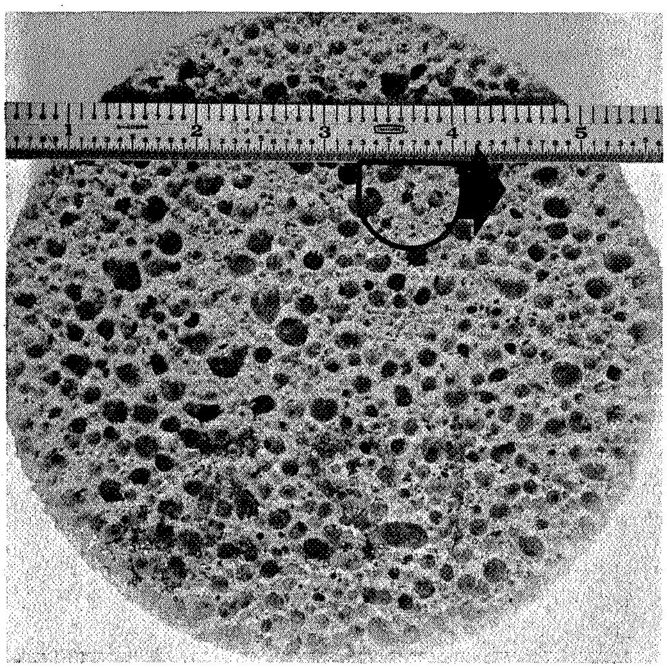
Cure Time (hrs)	0.75
Foamed in Vacuum:	
No	
Yes (in. Hg)	27

RESULTS

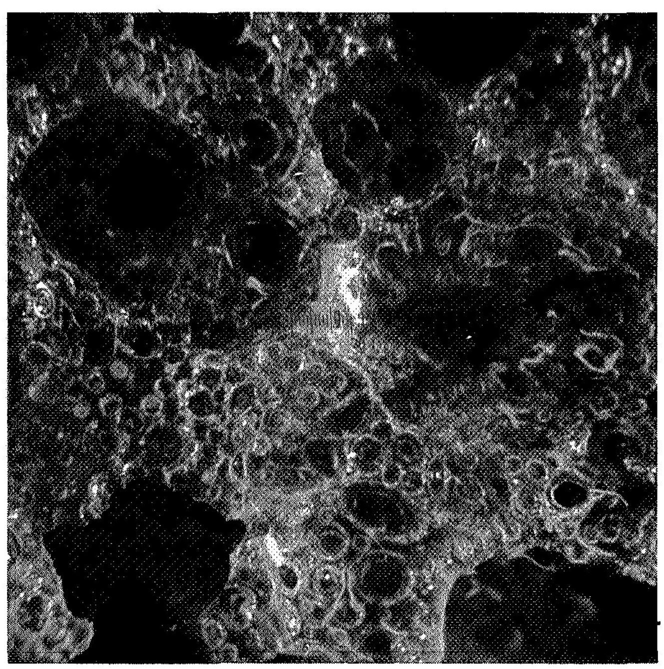
Density (lb/ft^3)	8.26
Compressive Strength (psi)	152

PHOTOGRAPHS OF SAMPLE

General View



10X Magnification



Foam Evaluation No. 10

KSC STUDY

FOAM EVALUATION NO. 11

CONSTITUENTS

Material	Weight (gms)
T-221	100.0
L 5320	1.0
TMBDA	0.6
AL #422	1.5
STAN. OCT	0.2
UCON 11	10.0
NI AX AFPI	103.0

PROCESS

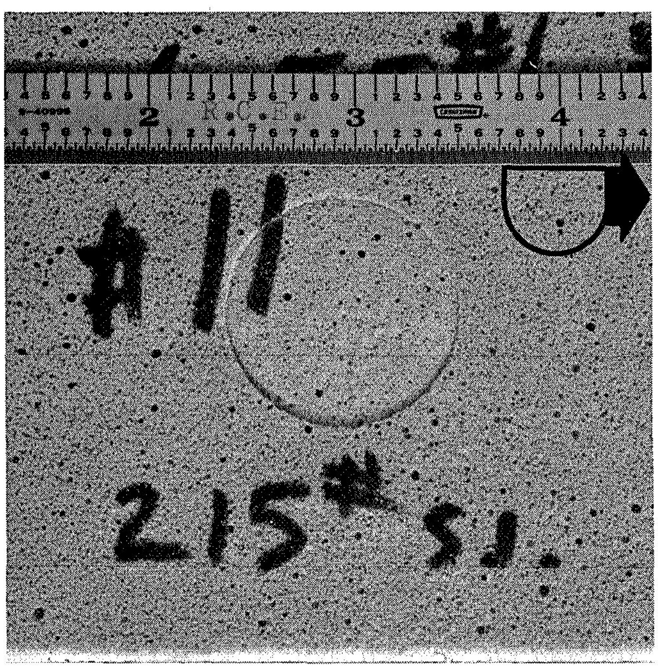
Cure Time (hrs)	4
Foamed in Vacuum:	
No	x
Yes (in. Hg)	

RESULTS

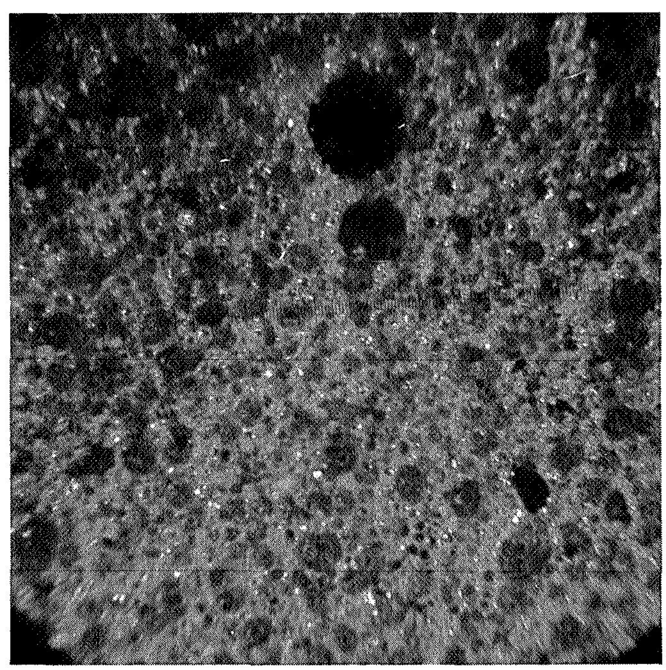
Density (lb/ft^3)	6.55
Compressive Strength (psi)	205

PHOTOGRAPHS OF SAMPLE

General View



10X Magnification



Foam Evaluation No. 11

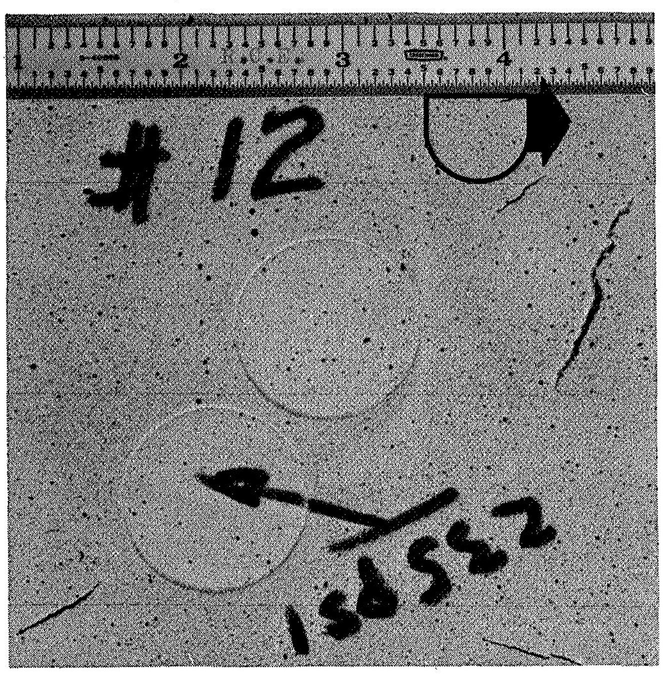
KSC STUDY

FOAM EVALUATION NO. 12

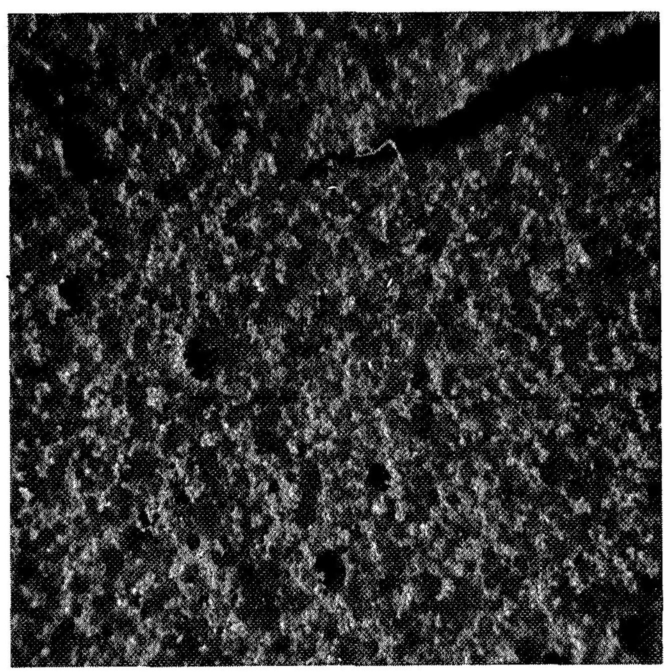
CONSTITUENTS		PROCESS	
Material	Weight (gms)	Cure Time (hrs)	4
T-221	100.0	Foamed in Vacuum:	
L 5320	1.5	No	x
TMBDA	0.6	Yes (in. Hg)	
AL #422	1.0	RESULTS	
STAN. OCT	0.2	Density (lb/ft^3)	7.6
UCON 11	13.0		
NI AX AFPI	103.0	Compressive Strength (psi)	235

PHOTOGRAPHS OF SAMPLE

General View



10X Magnification



Foam Evaluation No. 12

KSC STUDY

FOAM EVALUATION NO. 20

CONSTITUENTS

Material	Weight (gms)
T-221	100.00
L 5320	1.25
TMBDA	------
AL #422	2.00
STAN. OCT	0.20
UCON 11	9.00
NI AX AFPI	103.00

PROCESS

Cure Time (hrs)	4
Foamed in Vacuum:	
No	x
Yes (in. Hg)	

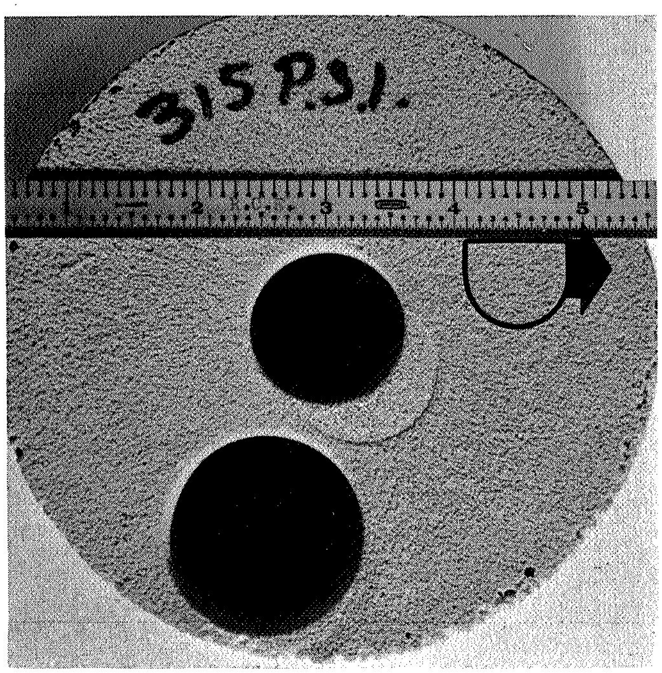
RESULTS

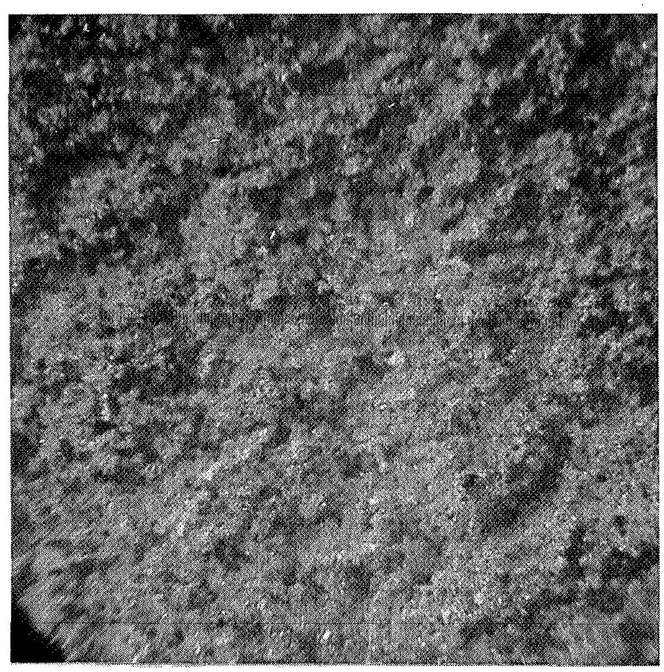
Density (lb/ft^3)	10.3
Compressive Strength (psi)	315

PHOTOGRAPHS OF SAMPLE

General View

10X Magnification





Foam Evaluation No. 20

KSC STUDY

FOAM EVALUATION NO. 40

CONSTITUENTS

Material	Weight (gms)
T-221	47.38
TMBDA	0.21
STAN. OCT	0.09
NI AX AFPI	51.20
*MIXTURE	0.60

*MIXTURE consists of 40% H_2O, 40% MEK, 20% ETH. AL.

PROCESS

Premix TMBDA & STAN. OCT with T-221.

Premix *Mixture with NI AX AFPI.

Material placed in vacuum chamber after it has "set hard" and while still hot.

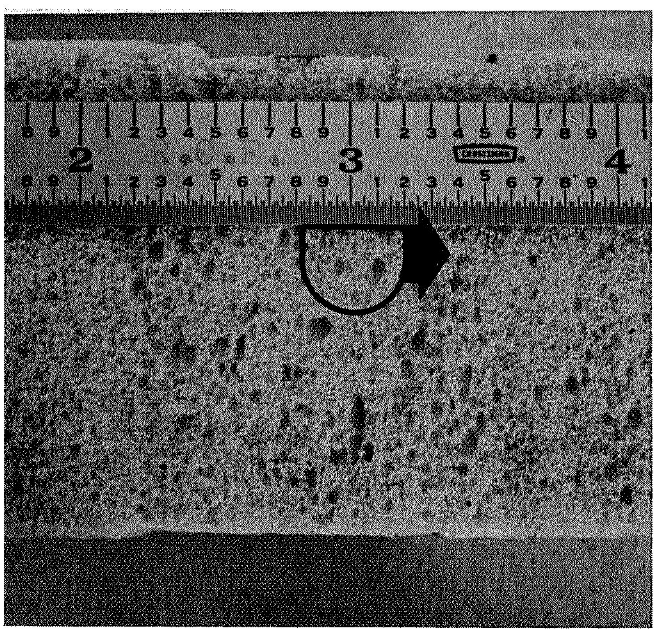
Cured 30 minutes in vacuum of 200 microns.

RESULTS

Density (lb/ft^3)	8.3
Compressive Strength (psi)	295 - 325

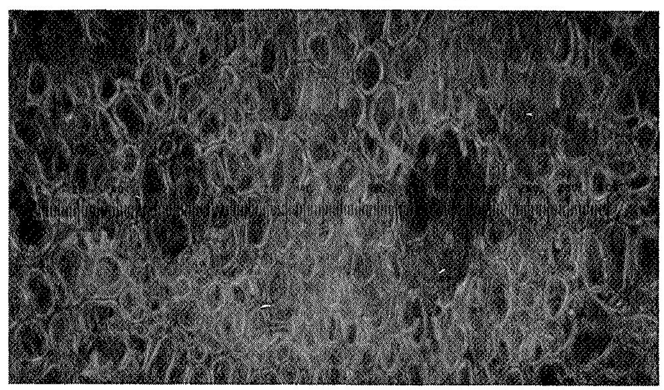
PHOTOGRAPHS OF SAMPLE

General View

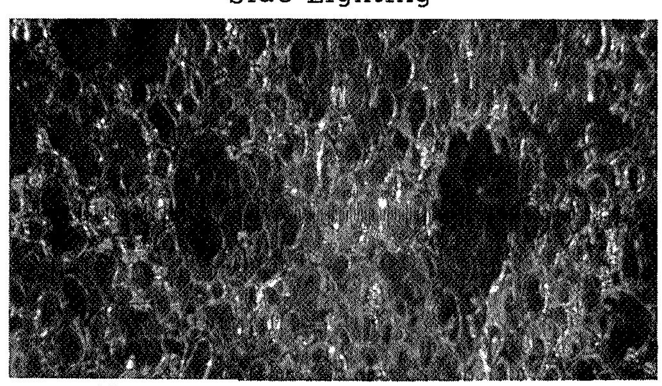


10X Magnification

Diffused Lighting



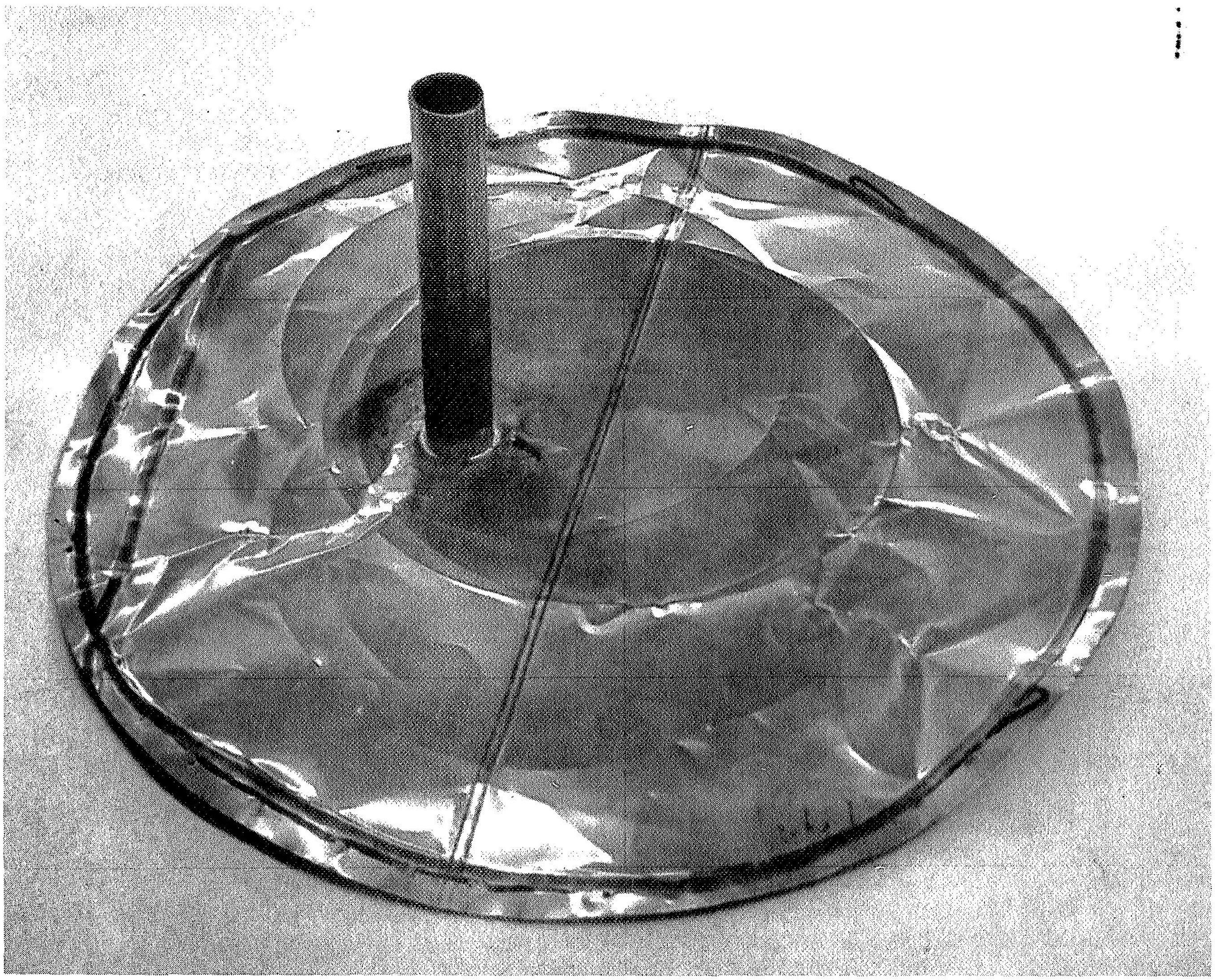
Side Lighting



Foam Evaluation No. 40

The final task required to complete the development of the LH_2 system insulator was the 0.002 inch thick stainless steel foil cover. In order to determine the leak tightness of the cover, a sample was constructed as shown in the accompanying photograph (Page 81). This unit was evacuated through the stand pipe and mass spectrometer leak checked. The results proved the manufacturability of this design to be compatible with present seam welding methods.

The aluminum band restrained Tek-Seal used for the liquid nose seal, performed satisfactorily. Only one modification was required as a result of the original pressure checks. During this test the seal was sufficiently gas tight to prevent pressurization into the insulator cavity. Since this seal is meant to act only as a liquid seal, similar to the existing bayonet nose seal, four (4) 0.032 inch diameter holes were drilled around the outside. Pressurization of this cavity is checked by placing a gage in the flange port shown on Item #2 of drawing 8-030928. In order to check for adequate flow through the four small holes, the gage was monitored during rapid line pressurization to insure that the cavity pressure was always equal to the line pressure.



LH_2 System Insulator for Test Specimen

LH_2 System 0.002 In. Thick Stainless Steel Foil
Weld Test Specimen

7.2.1 Test Report

The primary task of the second phase of this program was to complete testing on each of the bayonet test sections and their associated LO_2 and LH_2 system insulators. This report is presented on the following pages.

7.2.1.1 Introduction

The results of the Design Verification Tests performed on two (2) bayonet joints developed under Task VII of the "Vacuum Jacketed Umbilical Lines Technology Advancement Program" are presented herein.

This coupling method provides a single-plane assembly, low heat leak joint compatible with both liquid oxygen and liquid hydrogen vacuum jacketed piping systems. Both the 6 inch and 8 inch size couplings tested displayed heat leaks well within the design goal for LO_2 and LH_2 systems.

The following tests were conducted in the order shown:

A. Functional

Leakage
Pressure
Heat Leak

B. Sand and Dust

C. Salt Fog

D. Vibration

7.2.1.2 Scope

This report presents tests that were performed to determine the ability of the coupling to satisfy functional and environmental requirements established during the first phase of this program. The procedure followed in conducting the tests, and the data obtained from them, are presented. Two (2) units were tested.

7.2.1.3 Item Description

These units consisted of two (2) 4 foot long vacuum jacketed pipe sections constructed as shown on Drawing 8-030928 and 8-030929.

The main difference between this joint and the unit developed by Masoneilan (see Phase I Technical Report) is the shorter cone assembly. This simplified the design in that the stiffening rings were not required on the inner steel cylinder of the anti-convection barrier cavity. It also provided a larger radial gap in the existing envelope to minimize conduction heat losses through the insulator. This design uses a cone length to inside pipe diameters ratio of 0.6 as compared to the Masoneilan units of 1.0.

Two new insulators were developed by AMETEK/Straza and tested along with the original fiberglass unit used by Masoneilan and manufactured by CTL Dixie Corporation of Cincinnati, Ohio. For liquid oxygen systems, the two insulators are:

A. Silicone-bonded fiberglass developed and manufactured by CTL Dixie.

B. Open cell foamed teflon developed and manufactured by Thermic, Incorporated, Los Angeles, California.

For the liquid hydrogen system one new concept was tested. This consisted of vacuum-sealing open celled polyurethane foam in a stainless steel foil covering to minimize heat losses created by the highly conductive hydrogen gas in the insulator cavity.

7.2.1.4 Applicable Documents

The following documents form a part of this test report to the extent specified herein.

AMETEK/Straza Vacuum Jacketed Umbilical Lines Technology Advancement Program - Final Report Task VII, Bayonet Joint - Contract No. NAS-10-6098.

AMETEK/Straza Design Verification Test Procedure, Bayonet Joint No. 8-480089, dated 5/13/69

KSC-STD-164D Environmental Test Methods for Ground Support Equipment Installations at Cape Kennedy

NASA Test No. TCP-V-26427 Line Leak Test Procedure.

AMETEK/Straza Design Verification Test Procedure, Rotary Joint No. 8-480086, dated 5/13/69.

7.2.1.5 Test Performed

Unless otherwise specified herein, all general requirements of KSC-STD-164D apply to tests described in this document. In all instances in which KSC-STD-164D is in conflict with this document, statements herein shall take precedence. At the conclusion of each environmental test, the test item shall be visually inspected for signs of damage and deterioration.

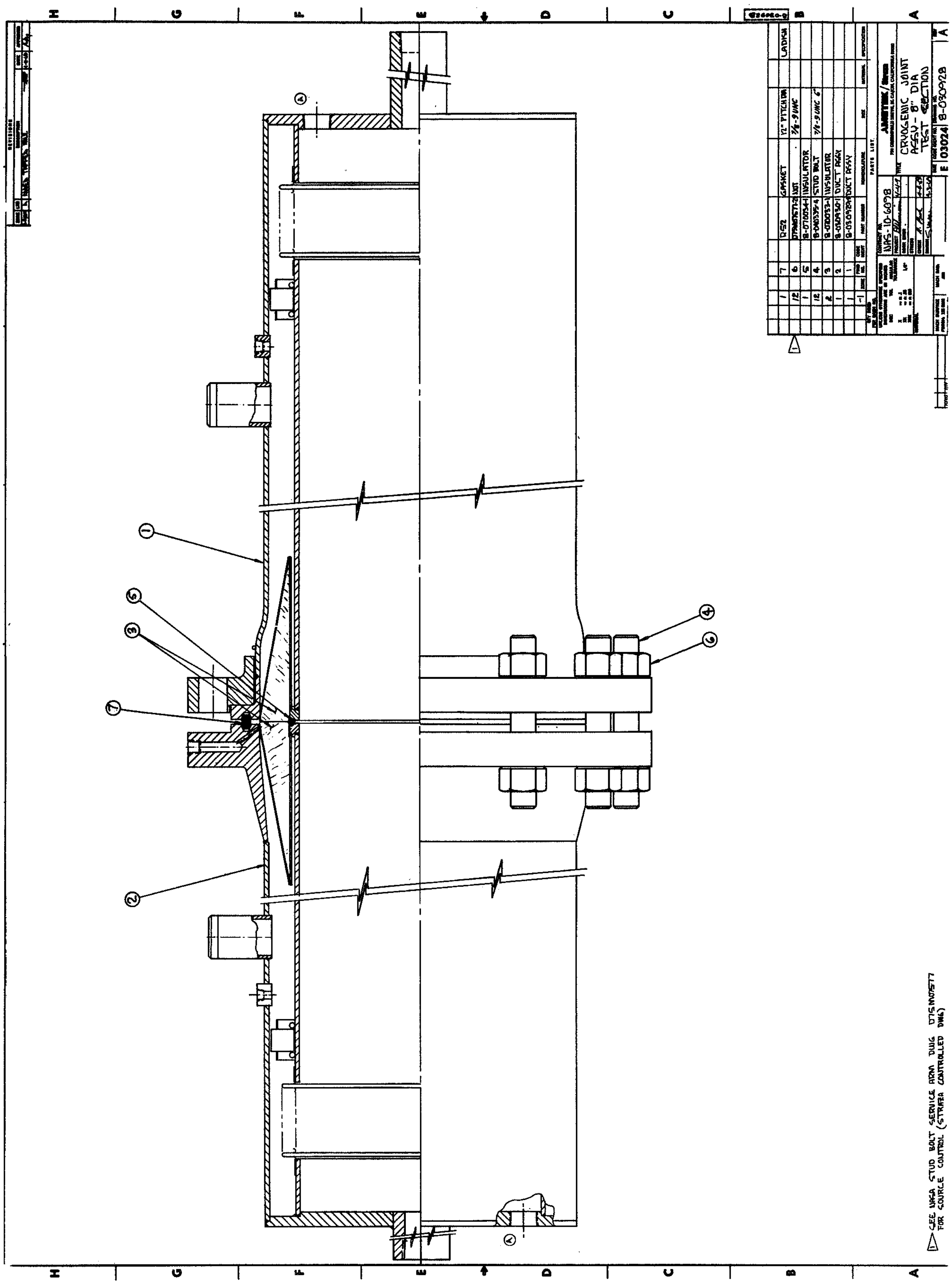
Unless otherwise specified, the test item shall be installed in the test facility in a manner that will simulate service usage. All test items will be subjected to all tests described in this document unless otherwise specified.

7.2.1.5.1 Functional Test

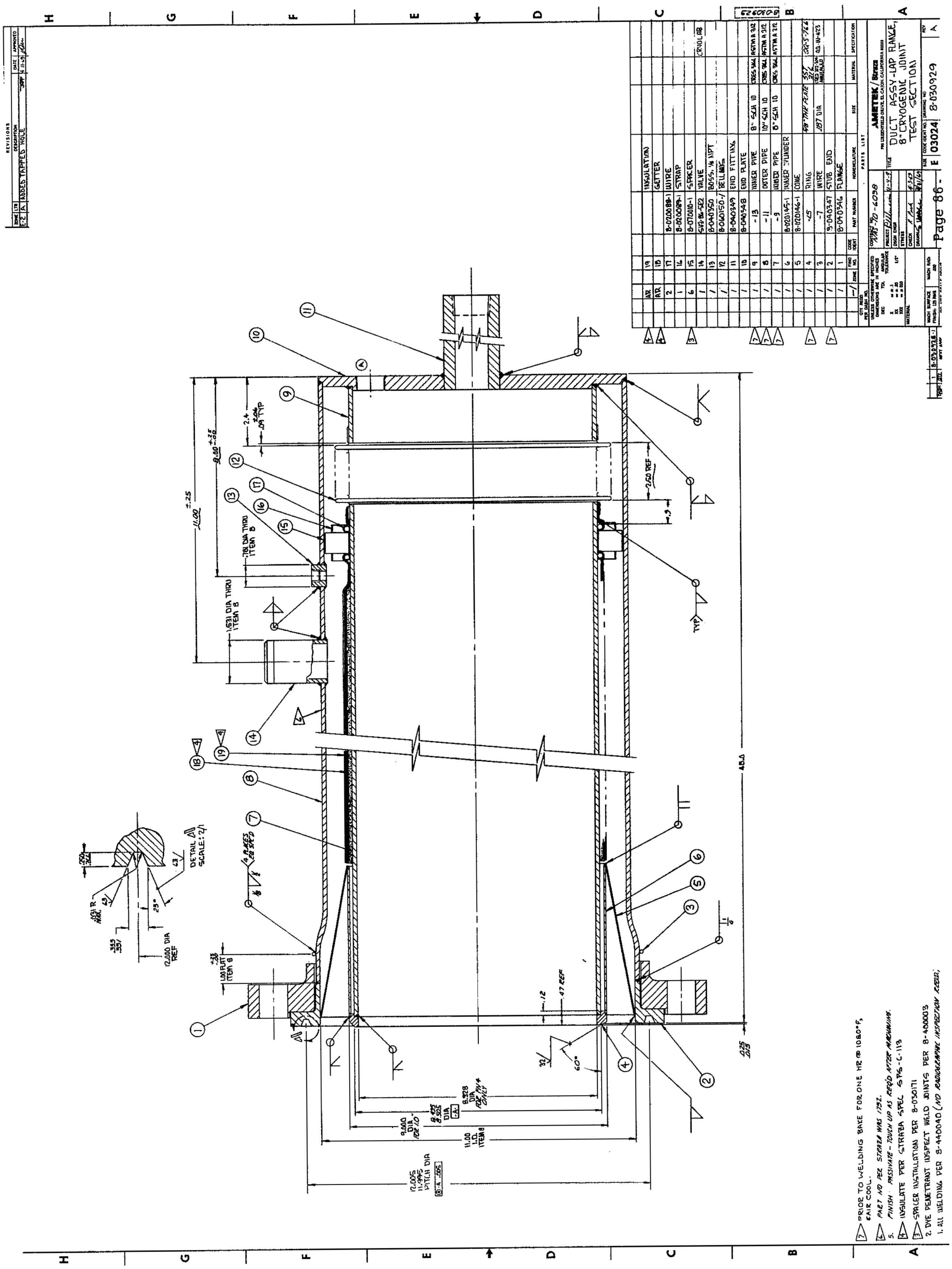
Test Requirements

The test requirements specified that prior to environmental testing, each test item to be subjected to the following tests:

Leakage	Using a helium mass spectrometer leak test a pin hole in the tape covered flange, the leak rate shall not exceed 1 X 10^{-4} atm cc/sec.
Pressure - Operating	The test item shall not deform when subjected to 190 psig internal pressure for five minutes.
Pressure - Proof	The test item shall not deform when subjected to 285 psig internal pressure for five minutes.
Heat Leak	The 8 inch test item shall meet the design heat leak goal of 300 Btu/hr for LO_2 systems. The heat leak for the 6 inch LO_2 system and the 8 inch LH_2 system shall be recorded for comparison with the calculated data.



8-030928 Cryogenic Joint Assembly, 8 Inch Test Section



8-030929 Cryogenic Joint, 8 Inch Test System

Test Procedure

The following tests were performed on each test item.

Leakage — The leakage test was conducted in accordance with NASA Test No. TCP-V-26427, Leak Line Test Procedure. The test item was installed in the test setup as shown in Figure 1.

The test item was pressurized to 50 +0/-10 psig with helium gas. All flanges were taped and punctured with a pin hole at the top of the flange. The time between the taping operation and the leak test was kept to a minimum to prevent a collection of helium under the taped area.

Using a helium mass spectrometer leak test at the pin hole and at all studs at each flange, the leak rate was recorded.

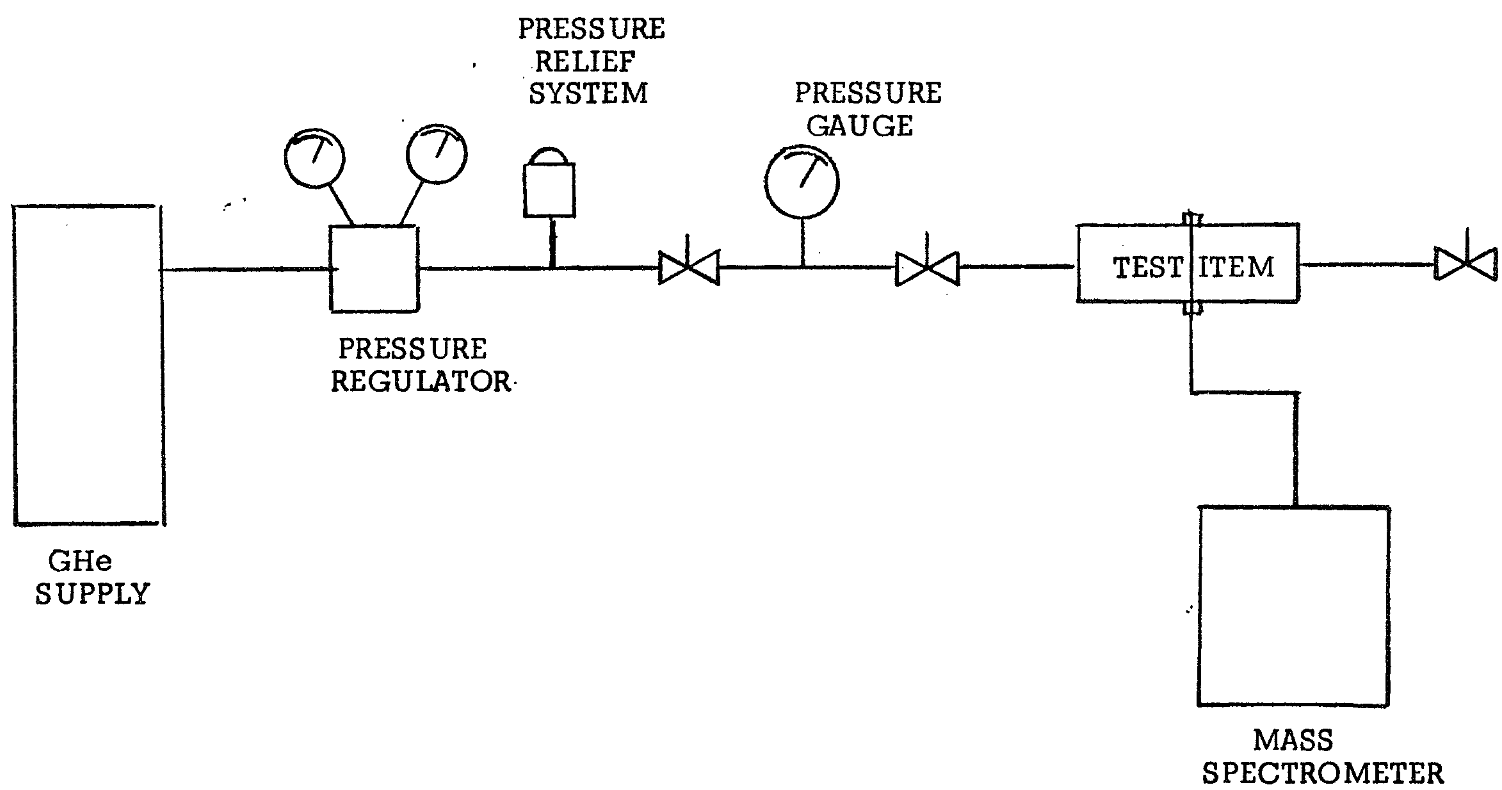
The tape was removed from all flanges and all bosses, studs and fittings were leak tested with soap solution.

Pressure - Operating — The test item was installed in the test setup as shown in Figure 2. The test item was pressurized at 190 +0/-10 psig with nitrogen gas and that pressure maintained for five minutes. After five minutes, the pressure was reduced to 0 psig. The test item was visually inspected for deformation or other defects as a result of the test.

Pressure - Proof — The test item was installed in the test setup as shown in Figure 2. The test item was pressurized to 285 +0/-20 psig with nitrogen gas and that pressure maintained for five minutes. After five minutes, the pressure was reduced to 0 psig. The test item was visually inspected for deformation or other defects as a result of the test. Particular attention was given to the cylinder/cone area after removal and inspection of the anti-convection blocks.

Heat Leak — The test item was installed in a test setup as shown in Figure 3. The test item was filled with LN_2 until it was stabilized. The heat leak was determined by LN_2 boil-off over a four-hour period. A totalizing flow meter was used to determine the GN_2 loss.

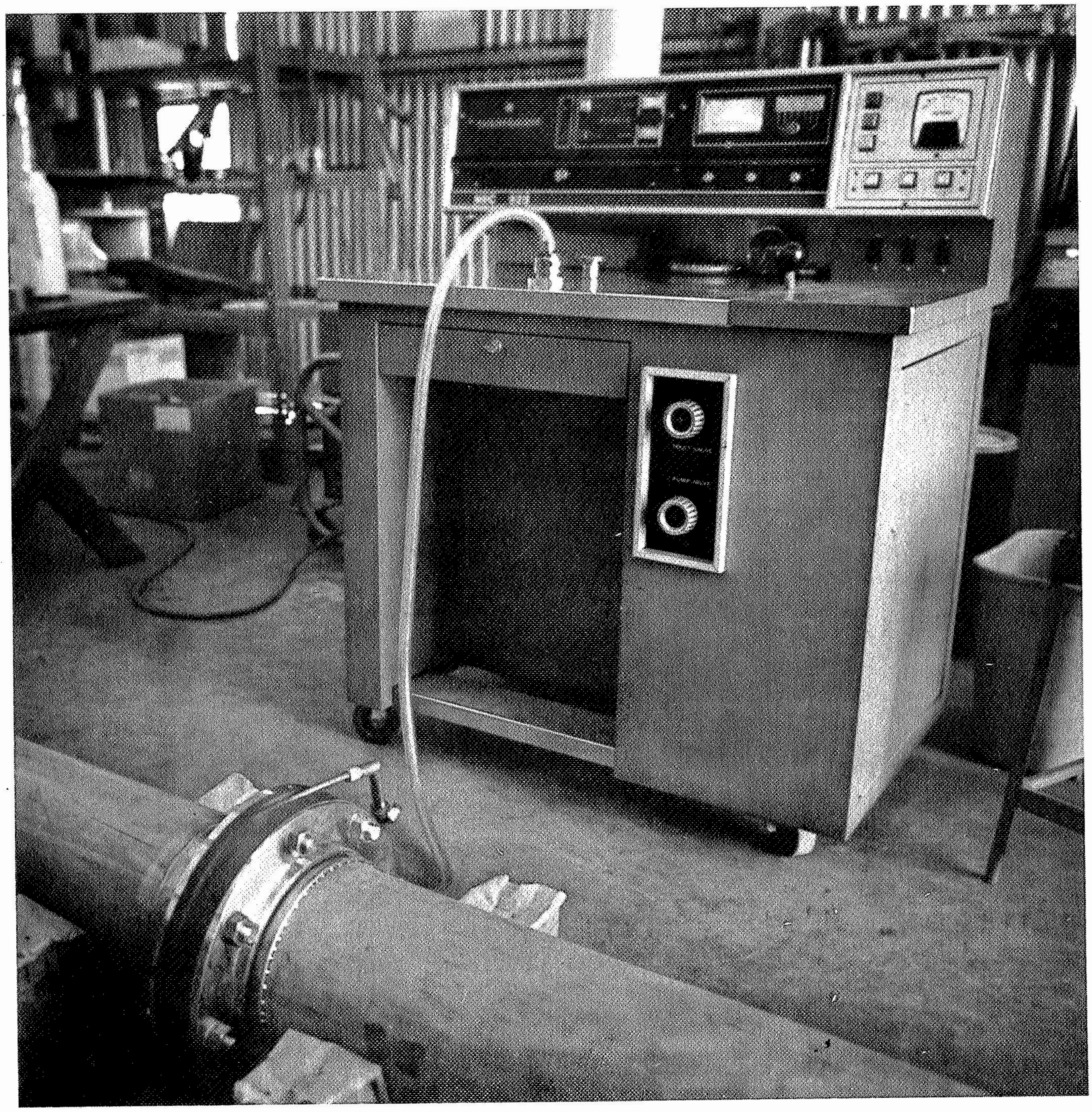
A potentiometer was used to determine GN_2 temperature. One hour after the test item had stabilized, and each hour thereafter for the duration of the test, the GN_2 loss, GN_2 temperature and barometric pressure were recorded. The gas loss was corrected to standard pressure and temperature. Applicable conversion calculations were made to determine the heat leak in terms of Btu/hr for LO_2 temperatures.



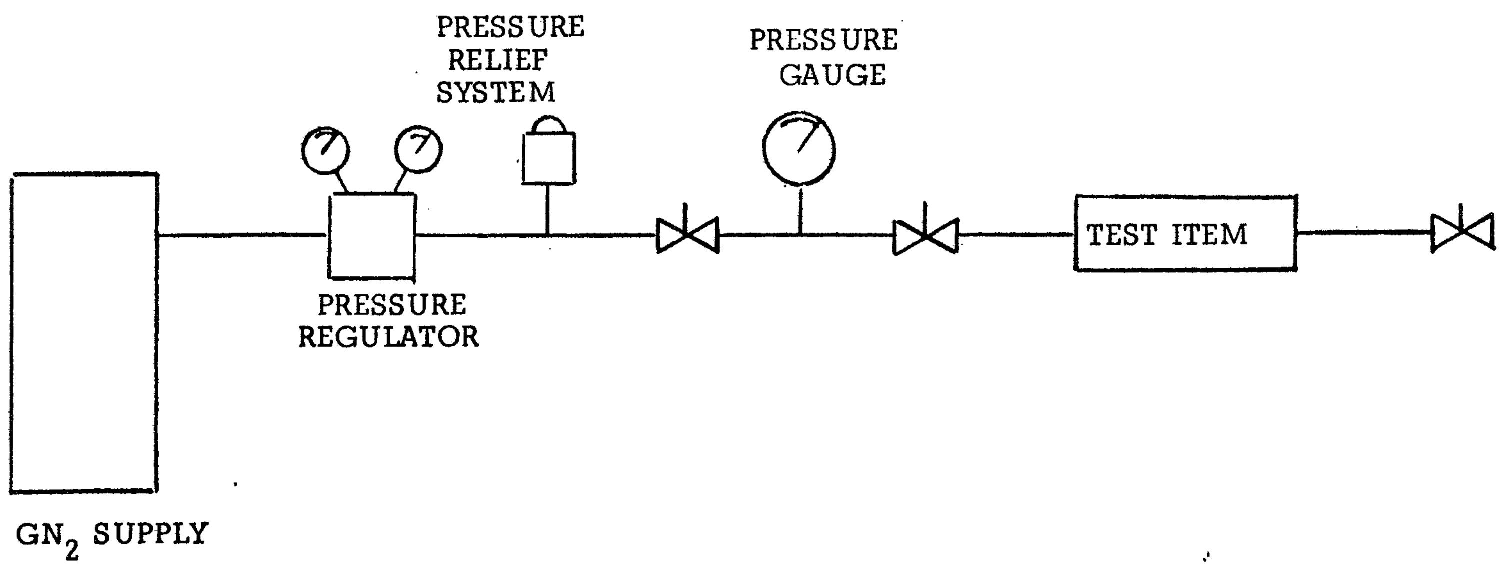
BAYONET JOINT LEAK TEST SET-UP

TEST REPORT

Test Report, Figure 1 Leak Test

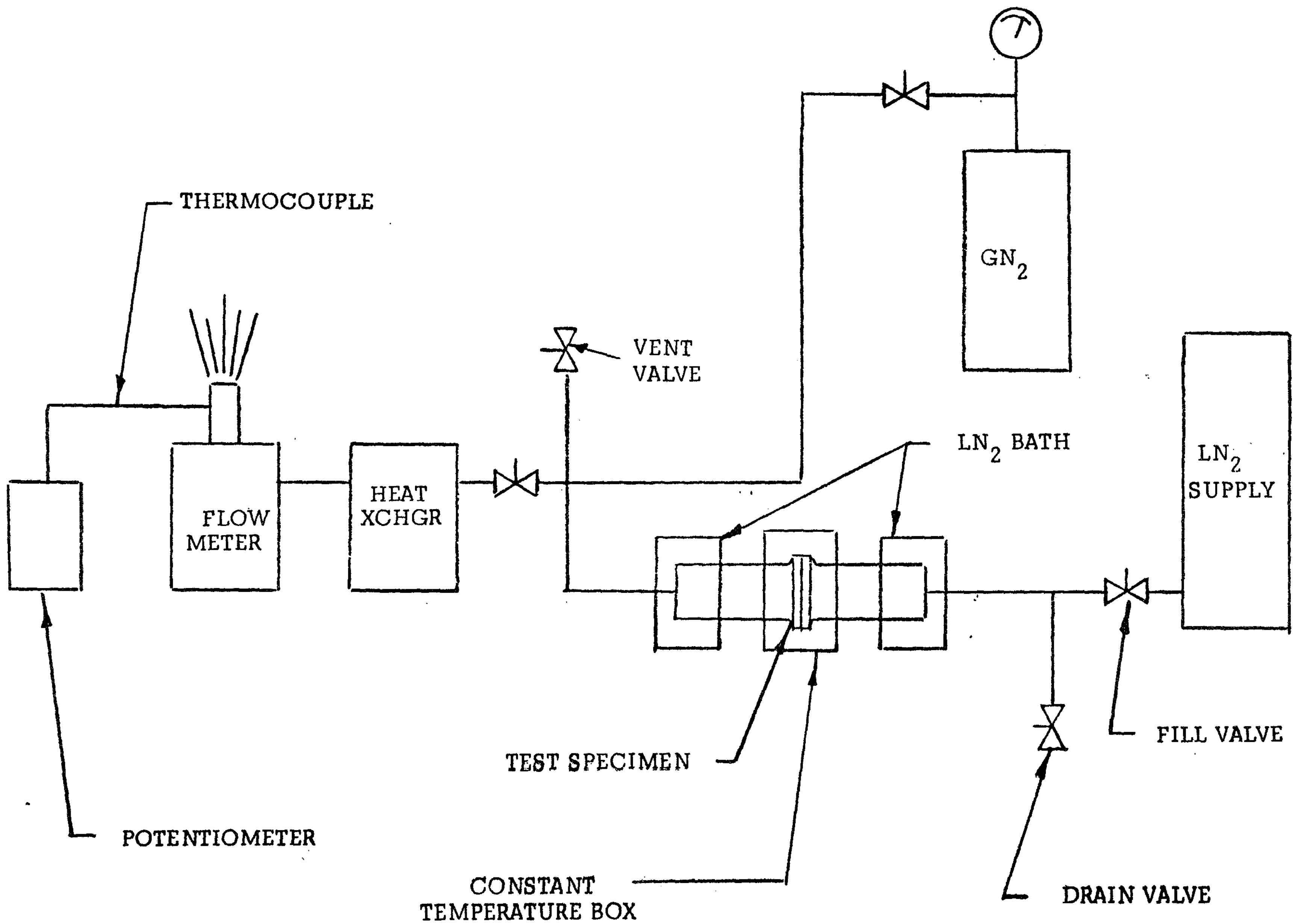


6 Inch Bayonet Joint Flange Leak Test



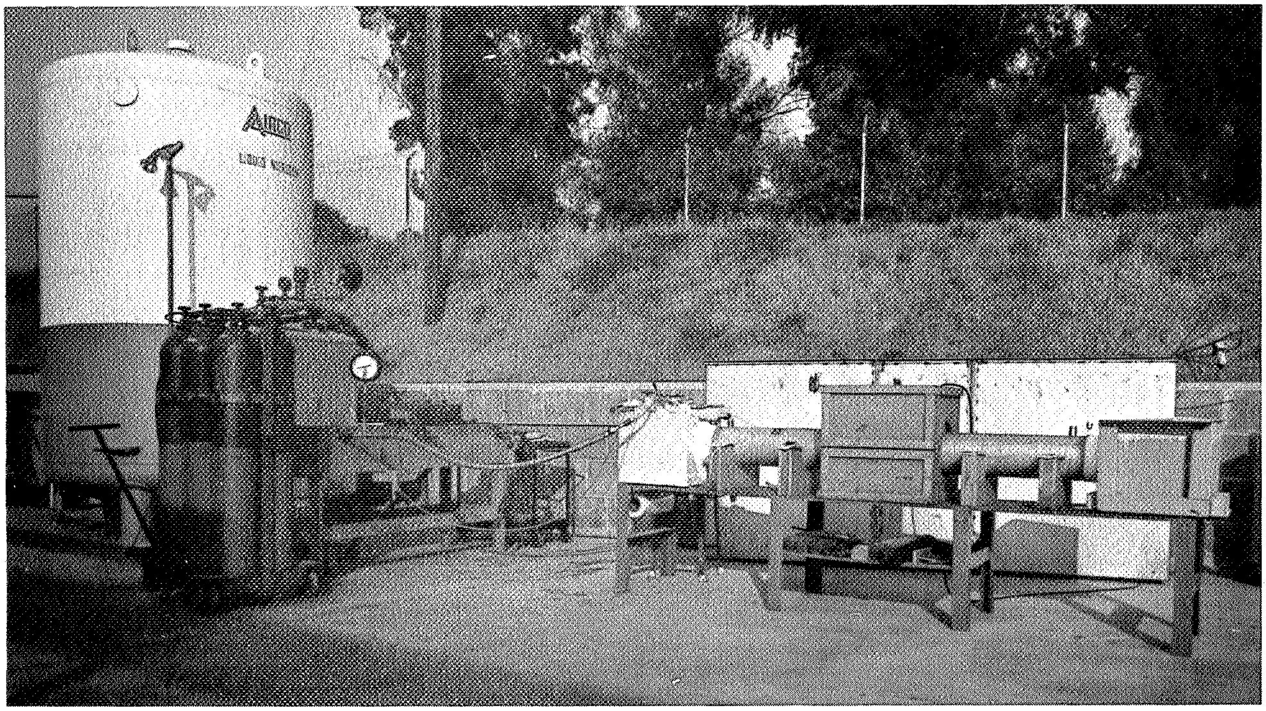
PRESSURE TEST SET-UP

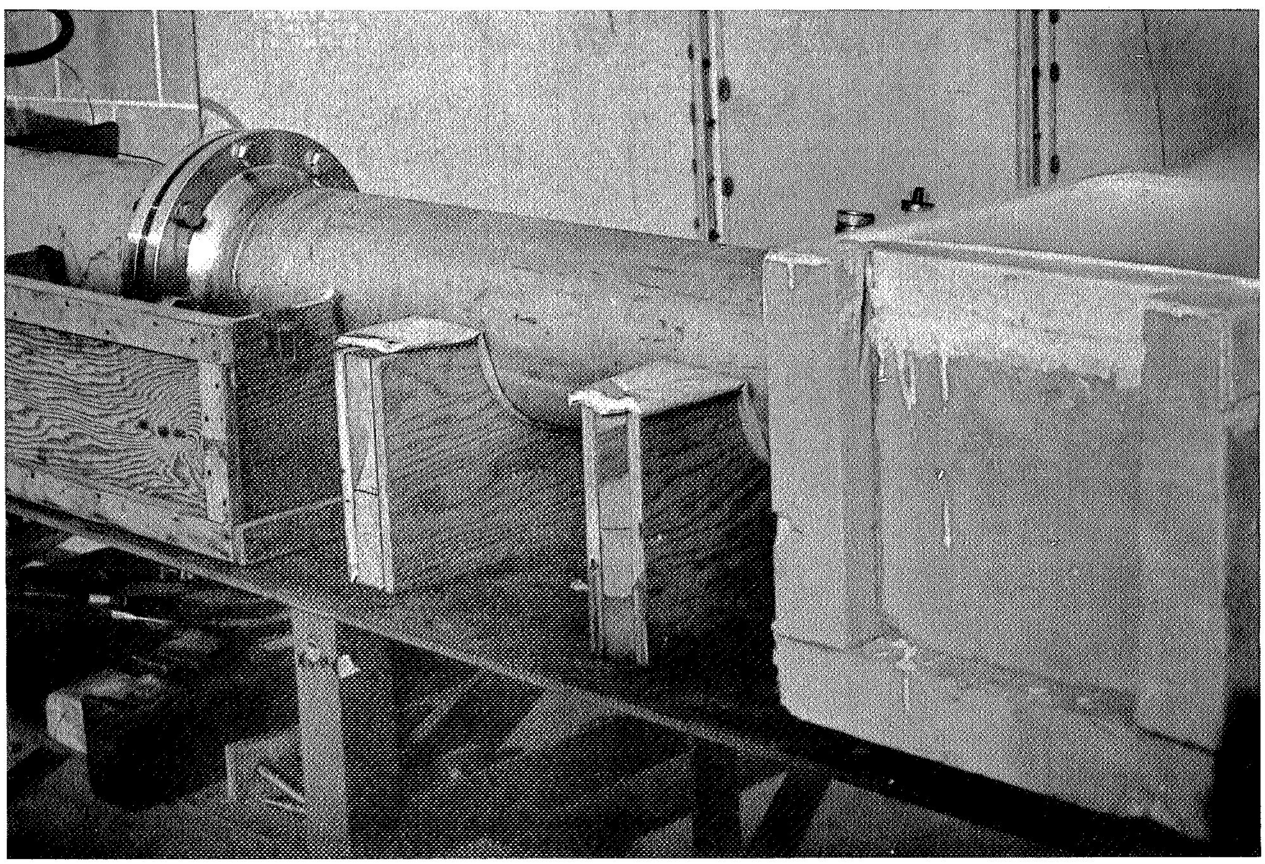
TEST REPORT
Test Report - Figure 2 - Pressure Test



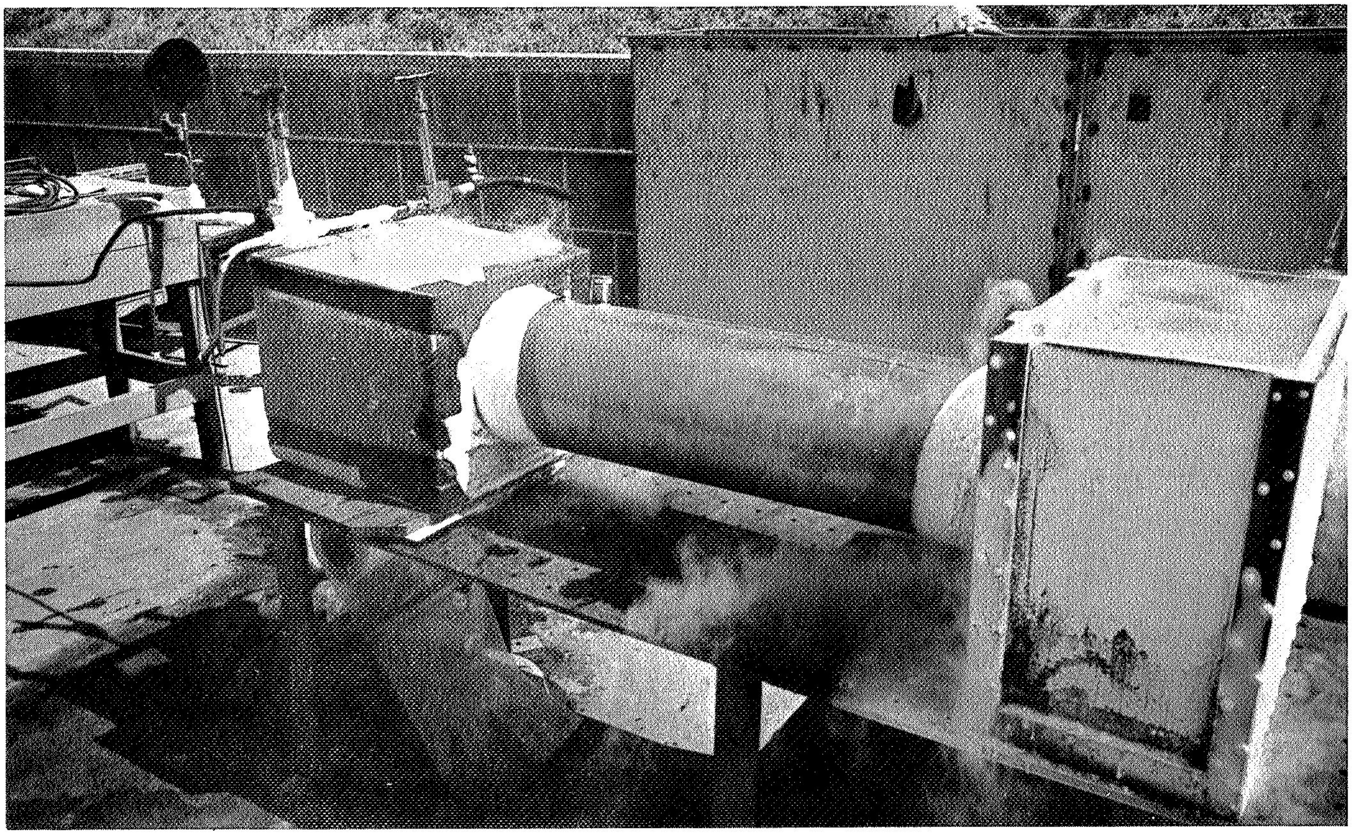
HEAT LEAK TEST SET-UP BAYONET JOINT

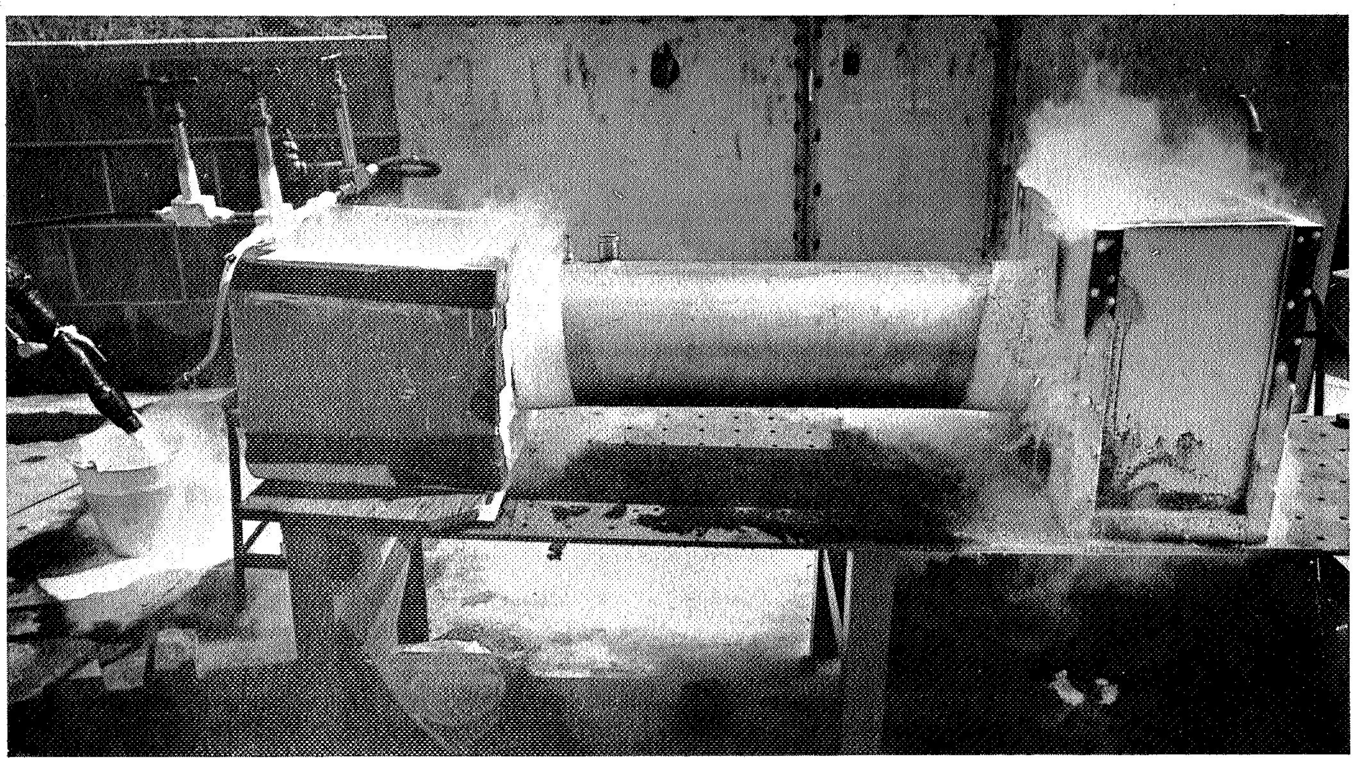
TEST REPORT
Test Report - Figure 3 - Heat Leak Test





Heat Leak Test Set-up 8 Inch Unit





Tare Heat Leak Test 8 Inch Unit

Test Results

Leakage — The internal pressure of the test item during the leak test was recorded. The leak rate of the flange and the flange studs, as determined by the mass spectrometer, were recorded. There was no detectable leakage at the flange joint. The leak test setup with the test item in the test position was photographed.

Operating Pressure — The operating pressure and duration of the test was recorded. There was no deformation or defects as a result of the test.

Proof Pressure — The proof pressure and duration of the test were recorded. There was no deformation or defects as a result of the test.

Heat Leak — In order to compare the actual heat leak with the calculated heat leak, the recorded values were corrected as follows:

For the LO_2 System:

[Test item ambient temperature (+100° F) - liquid oxygen temperature (-297)] ÷ [Average test item temperature as measured on top and on bottom - liquid nitrogen temperature (-320)] x heat leak.

Example (for 6-inch unit)

$$\frac{100 - (-297)}{93 - (-320)} \times 174.3 = \frac{397}{413} \times 174.3 = 168 \text{ Btu/hr}$$

$$\text{Tare leak} = \frac{397}{413} \times 24.6 = 23.7 \text{ Btu/hr}$$

$$\text{Total joint heat leak} = 168 - 23.7 = 144.3 \text{ Btu/hr}$$

A separate heat leak test was run on the 6-inch unit with the CTL insulators removed. This was done to determine the convection losses and full effect of the insulator. The results gave a heat leak of 262 Btu/hr as compared with the original test of 174.3 Btu/hr.

Correcting this new value for unit temperature and LO_2 service gave

$$\frac{100 - (-297)}{92 - (-320)} \times 262 = 252 \text{ Btu/hr}$$

$$\text{Total heat leak} = 252 - 23.7 = 228.3 \text{ Btu/hr}$$

The convection heat leak through the gas space =

$$228.3 - 144 = 84.3 \text{ Btu/hr}$$

For the LH_2 system this test was performed only on the 8-inch joint using only one type insulator. The results are as follows:

Heat leak corrected for test item ambient x heat leak - tare heat leak:

$$0.0761 \text{ lb/min} \times 85.7 \text{ Btu/lb} \times 60 \text{ min/hr} = 392 \text{ Btu/hr}$$

Tare heat leak for 8-inch unit

$$88 \text{ Btu/hr} \times \frac{100 - (-297)}{100 - (-320)} = 88 \times 0.946 = 83 \text{ Btu/hr}$$

$$392 \times \frac{100 - (-297)}{77 - (-320)} = 392 \times 1 = 392 \text{ Btu/hr}$$

Total heat leak

$$392 - 83 = 309 \text{ Btu/hr}$$

Correcting for thermal conductivity was accomplished as follows:

[K, T - Thermal Conductivity x Temperature Difference for LH_2] ÷

[KT for LO_2] x Heat Leak

For LH_2 system, total heat leak =

$$\frac{30.4}{27.3} \times 309 = 344 \text{ Btu/hr}$$

There was no accurate way to determine the level of CO_2 cryopumping within the foil enclosure. This value must be considered conservative since LH_2 will cryopump to very high level as compared to the LN_2 used in this test.

TEST DATA

The data sheets for the 6-inch and 8-inch bayonets are presented on the following pages.

The following Table I summarizes the corrected measured heat leak values and compares them with the calculated data.

Insulator	Line Size (In.)	LO_2 System		LH_2 System	
		Calculated	Actual	Calculated	Actual
CTL Dixie	6	238	144	---	---
CTL Dixie	8	315	227	---	---
Foam Teflon	6	204	---	---	---
Foam Teflon	8	251	283	---	---
Original Design	8	238	---	329	---
Open Cell Foam Polyurethane	8	---	---	404	344

As can be seen, the LO_2 system insulators met the 300 Btu/hr design goal with only the foamed teflon having a higher measured heat leak than the calculated value.

DESIGN VERIFICATION TEST

TEST DATA SHEET

Type of Test: Leakage — Date of Test: 16 October 1969

Part Name: Bayonet Joint - 6 Inch — Part #: 8-030936

Test Procedure: 8-480089 (Para 5.2.2.1) — Part S/N: N/A

Test Pressure: 50 psig

Test Media: Helium

Duration of Test: N/A

Remarks

No detectable leakage at Flange Joint. The two test items were joined for this test.

Test Technician: /s/ L. Mc Knight

Test Engineer: /s/ R. C. Mursinna

DESIGN VERIFICATION TEST

TEST DATA SHEET

Type of Test: Leakage — Date of Test: 15 September 1969

Part Name: Bayonet Joint - 8 Inch — Part #: 8-030928

Test Procedure: 8-480089 (Para 5.2.2.1) — Part S/N: N/A

Test Pressure: 50 psig

Test Media: Helium

Duration of Test: N/A

Remarks

No detectable leakage at Flange Joint. The two test items were joined for this test.

Test Technician: /s/ C. Geller

Test Engineer: /s/ R. C. Mursinna

DESIGN VERIFICATION TEST

TEST DATA SHEET

Type of Test: Operating Pressure

Date of Test: 23 October 1969

Part Name: Bayonet Joint - 6 Inch

Part #: 8-030936

Test Procedure: 8-480089 (Para 5.2.2.2)

Part S/N: --

Test Pressure: 190 psig

Test Media: GN_2

Duration of Test: 5 minutes

Remarks

No visible damage or deformation. The two test items were joined for this test.

Test Technician: /s/ L. Mc Knight

Test Engineer: /s/ R. C. Mursinna

DESIGN VERIFICATION TEST

TEST DATA SHEET

Type of Test Operating Pressure Date of Test 15 September 1969

Part Name Bayonet Joint - 8 Inch Part # 8-030928

Test Procedure 8-480089 (Para 5.2.2.2) Part S/N --

Test Pressure 190 psig

Test Media GN_2

Duration of Test 5 minutes

Remarks

No visible damage or deformation. The two test items were joined for this test.

Test Technician /s/ C. Geller

Test Engineer /s/ R. C. Mursinna

DESIGN VERIFICATION TEST

TEST DATA SHEET

Type of Test: Proof Pressure

Date of Test: 23 October 1969

Part Name: Bayonet Joint - 6 Inch

Part #: 8-030936

Test Procedure: 8-480089 (Para 5.2.2.2)

Part S/N: --

Test Pressure: 285 psig

Test Media: GN_2

Duration of Test: 5 minutes

Remarks

No visible damage or deformation. The two test items were joined for this test.

Test Technician: /s/ L. Mc Knight

Test Engineer: /s/ R. C. Mursinna

DESIGN VERIFICATION TEST

TEST DATA SHEET

Type of Test: Proof Pressure — Date of Test: 15 September 1969

Part Name: Bayonet Joint - 8 Inch — Part #: 8-030928

Test Procedure: 8-480089 (Para 5.2.2.2) — Part S/N: --

Test Pressure: 285 psig

Test Media: GN_2

Duration of Test: 5 minutes

Remarks

No visible damage or deformation.

The two test items were joined for this test.

Test Technician: /s/ C. Geller

Test Engineer: /s/ R. C. Mursinna

DESIGN VERIFICATION TEST

TEST DATA SHEET

Type of Test: Heat Leak | Date of Test: 27 October 1969

Part Name: Bayonet - 6" Unit | Part Number: 8-030936

Test Procedure: 8-440089 (Para 5.2.2.3) | Part Serial Number:

B.O. = Boil off rate

Time	GN_2 Loss	GN_2 Temp	Barometric Pressure	Remarks
11:00	.44 Cu Ft / Min	71°F $\bar{V}$ = 13.835 B.O.= .0314#/min	29.87	Unit Temp Top 71°F Unit Temp Bottom 73°F Box Avg. Temp. 72°F
12:00	.43 Cu Ft / Min	80°F $\bar{V}$ = 14.073 B.O. = .0327#/min	29.87	Unit Temp. Top 90°F Unit Temp. Bottom 79°F Box Avg. Temp. 85°F
1:00	.40 Cu Ft / Min	82°F $\bar{V}$ = 14.110 B.O. = .0353 #/min	29.87	Unit Temp Top 94°F Unit Temp Bottom 82°F Box Avg Temp 86°F
2:00	.40 Cu Ft / Min	80°F $\bar{V}$ = 14.073 B.O.= .0352#/min	29.87	Unit Temp Top 96°F Unit Temp Bottom 98°F Box Avg Temp 85°F
3:00	.40 Cu Ft / Min	80°F $\bar{V}$ = 14.073 B.O. = .0352 #/Min	29.87	Unit Temp Top 100°F Unit Temp Bottom 89°F Box Avg Temp 90°F

Average B.O. = .0339

Total H.L. = .0339 X 84.7 X 60 = 174.3 Btu/Hr

Test Technician /s/ C. Geller | Test Engineer /s/ R. C. Mursinna

DESIGN VERIFICATION TEST

TEST DATA SHEET

Type of Test: Heat Leak - Tare | Date of Test: 30 October 1969

Part Name: Bayonet 6" (1/2 Unit) | Part Number: 8-030936

Test Procedure: 8-440089, Para 5.2.2.3 | Part Serial Number: --

Time	GN_2 Loss	GN_2 Temp	Barometric Pressure	Remarks
10:00	.09	98°F	29.93	
11:00	.07	97°F	29.90	
12:00	.07	101	29.83	
		$\overline{V} = 14.65\ Ft^3/\#$		
1:00	.07	101	29.75	
		$\overline{V} = 14.65$		
2:00	.07	101	29.75	
		$\overline{V} = 14.65$		

Average Boil Off - .00477 #/Min

Total H. L. - .00477 X 85.7 X 60 = 24.6 Btu/Hr

Test Technician: /s/ L. Mc Knight | Test Engineer: /s/ R. C. Mursinna

DESIGN VERIFICATION TEST

TEST DATA SHEET

Type of Test Heat Leak

Date of Test 19 September 1969

Part Name Bayonet with CTL Dixie Insulator , 8inch

Part Number 8-030928

Test Procedure 8-44089, Para 5.2.2.3

Part Serial Number --

Time	GN_2 Loss	GN_2 Temp	Barometric Pressure	Remarks
11:00	.83 CuFt/Min	64°F $\overline{V}$ = 13.655 cu ft/#	29.86	Unit Temp Top = 85°F Unit Temp Bottom 65°F
		B.O.= .0608#/min		Box Avg Temp 66°F
12:00	.84 CuFt/Min	73°F $\overline{V}$ = 13.885	29.86	Unit Temp Top 89°F Unit Temp Bottom 69°F
		B.O. = .0605		Box Avg Temp 72°F
1:00	.86 CuFt/Min	79°F $\overline{V}$ = 14.055	29.86	Unit Temp Top 92°F Unit Temp Bottom 72°F
		B.O. = .0612		Box Avg Temp 83°F
2:00	.88 Cu Ft/Min	80°F $\overline{V}$ = 14.073	29.85	Unit Temp Top 98°F Unit Temp Bottom 77°F
		B.O. = .0625		Box Avg Temp 82°F
3:00	.85 Cu Ft/Min	78°F $\overline{V}$ = 14.021	29.82	Unit Temp Top 101°F Unit Temp Bottom 80°F
		B.O. = .0606		Box Avg Temp 82°F

Average B.O. = .0611 #/min

Total Heat Leak = .0611 X 85.7 X 60 = 314 Btu/Hr

Test Technician /s/ L. Mc Knight

Test Engineer /s/ R. C. Mursinna

DESIGN VERIFICATION TEST

TEST DATA SHEET

Type of Test: Heat Leak - LH_2 Cones

Date of Test: 22 September 1969

Part Name: Bayonet - 8 Inch

Part Number: 8-030928

Test Procedure: 8-440089, Para 5.2.2.3

Part Serial Number: --

Time	GN_2 Loss	GN_2 Temp	Barometric Pressure	Remarks
10:00	1.05 Cu Ft/min	67°F $\overline{V}$ = 13.732	29.95	Unit Temp Top 86°F Unit Temp Bottom 65°F
		B.O.= .0766#/min		Box Avg Temp 67°F
11:00	1.04 Cu Ft/Min	74°F $\overline{V}$ = 13.916	29.91	Unit Temp Top 89°F Unit Temp Bottom 62°F
		B.O.= .0748#/min		Box Avg Temp 76°F
12:00	1.05 Cu Ft/min	65°F $\overline{V}$ = 13.675	29.91	Unit Temp Top 94°F Unit Temp Bottom 66°F
		B.O.= .077#/min		
1:00	1.06 Cu Ft/min	75°F $\overline{V}$ = 13.935	29.91	Unit Temp Top 94°F Unit Temp Bottom 66°F
		B.O.= .076#/min		
	Average Boiloff =	.0761		
	Pressurize line with GN_2 to 70 psig. Let line stabilize			
2:00*	.38 CFM	93°F	29.90	Unit Temp Top 97°F Unit Temp Bottom 53°F
				Box Avg Temp 75°F
3:00	1.50 Cu Ft/Min	55°F $\overline{V}$ = 13.415		Unit Temp Top 96°F Unit Temp Bottom 58°F
				Box Avg Temp 82°F
3:30*	1.18 Cu Ft/Min	70°F $\overline{V}$ = 13.811	29.90	Unit Temp Top 96°F Unit Temp Bottom 58°F
		B.O.= .0855#/min		Box Avg Temp 82°F

*This reading is N/G due to lack of accurate pressure stabilization during leakage measurement.

**Reading taken after pressurization of line to 190 psig. (One of 2 cones had leak after this test accounting for higher boil off.)

Test Technician /s/ L. Mc Knight Test Engineer /s/ R.C. Mursinna

DESIGN VERIFICATION TEST

TEST DATA SHEET

Type of Test: Heat Leak (LO_2 Foam Teflon) Date of Test: 23 September 1969

Part Name: Bayonet - 8 Inch Part Number: 8-030928

Test Procedure: 8-440089, Para 5.2.2.3 Part Serial Number: ---

Time	GN_2 Loss	GN_2 Temp	Barometric Pressure	Remarks
2:00	1.11 Cu Ft/min	76°F	29.92	Unit Temp Top 112°F Unit Temp Bottom 84°F
		$\overline{V}$ = 13.968 cu ft B.O. = .0795 #/min		Box Avg Temp 87°F
3:00	1.04 Cu Ft/min	75°F	29.88	Unit Temp Top 111°F
		$\overline{V}$ = 13.935 B.O.= .0748 #/min		Unit Temp Bottom 81°F Box Avg Temp 87°F
3:50	1.05 Cu Ft/min	74°F	29.88	Unit Temp Top 110°F
		$\overline{V}$ = 13.916 B.O.= .0757 #/min		Unit Temp Bottom 81°F Box Avg Temp 86°F

Average Boil Off .0752 #/min

.0752 X 85.7 X 60 = 385 Btu/hr

Test Technician: /s/ L. Mc Knight Test Engineer: /s/ R. C. Mursinna

<u>DESIGN VERIFICATION TEST</u>

<u>TEST DATA SHEET</u>

Type of Test Heat Leak - Tare

Date of Test 25 September 1969

Part Name Bayonet 8inch (1/2 Unit)

Part Number 8-030929

Test Procedure 8-440089, Para 5.2.2.3

Part Serial Number ---

Time	GN_2 Loss	GN_2 Temp	Barometric Pressure	Remarks
12:50	.25 Cu Ft/min	96°F	29.80	Tube Temp 100°F
		$\overline{V}$ = 14.410 cu ft/min B.O. = .0173 #/min		
2:00	.25 Cu Ft/min	98°F	29.78	
		$\overline{V}$ = 14.500		
3:00	.25 Cu Ft/min	98°F	29.75	
		$\overline{V}$ = 14.500		

Average B.O. = .0172 #/min
Total Tare Heat Leak = .0172 X 85.7 X 60 = 88 Btu/Hr

Test Technician /s/ L. Mc Knight

Test Engineer /s/ R. C. Mursinna

7.2.1.5.2 Sand and Dust Test

Test Requirements

The Sand and Dust Test was conducted as the first of the environmental tests. The test plan stated that the test item be connected to and tested in conjunction with the rotary joint (Reference Paragraph 7.1.6.1). Due to an overrun in funds caused by unanticipated testing required on the 8 inch rotary, the 6 inch bayonet test item was not subjected to the environmental tests.

Test Procedure

The test was conducted in accordance with Section 16 of KSC-STD-164D. The test item was placed in the test chamber in accordance with Paragraph 4.4.1 of KSC-STD-164D. The test item was exposed to a sand and dust environmental test for two (2) hours at $77 \pm 2^{\circ}F$ with a sand to air ratio of 0.1 to 0.25 grams per cu. ft. and with an air velocity of from 100 to 500 ft/min.

The temperature was then raised to $160 \pm 2^{\circ}F$ under the same test conditions for two (2) hours. At the conclusion of the Sand and Dust Test, the test item was returned to room ambient conditions.

The test chamber ambient temperature was continuously recorded. The sand to air ratio was measured at the beginning and conclusion of the test and every two (2) hours during the test. The test item was photographed at the conclusion of the test. A rotary joint functional test was performed as specified in Paragraph 5.3 of 8-480086 at the conclusion of this test. This test consisted of a pressure, leakage and torque measurement.

Test Results

The 8 inch bayonet suffered no deterioration or malfunction as a result of the Sand and Dust Tests.

Test Data

All data sheets and photographs are included in the Rotary Joint Design Verification Test Reports, Task IV.

7.2.1.5.3 Salt Fog

Test Requirements

The Salt Fog Test was the second of the environmental tests on the bayonet joint test item. The unit had to be tested while connected to the rotary joint of Task IV.

Test Procedure

The test was conducted in accordance with Section 17 of KSC-STD-164D.

Prior to installation in the test chamber, the test item was visually inspected for corrosion, dirt and oily films. Location and extent of corrosion was recorded. Dirt and oily films were removed. The test item was installed in the test chamber in accordance with Paragraph 4.4.1 of KSC-STD-164D. After 240 ±2 hours of exposure in salt fog of 5% salt and 95% water at 95 +2/-4°F, the test item was allowed to stand until thoroughly dry.

The test item was photographed at the conclusion of the Salt Fog Test while still in the test position.

A rotary joint functional test was performed as specified in Paragraph 5.3 of 8-480086 at the conclusion of this test.

Test Results

There was no evidence of excessive corrosion on the 8-inch bayonet test item after completing this Salt Fog Test.

Test Data

All test data sheets and photographs are included in the rotary joint test report Task IV.

7.2.1.5.4 Vibration Test

Test Requirements

The vibration (third environmental test) also had to be performed on the bayonet test item while connected to the rotary joint of Task IV. Due to a weight limitation on the shaker, only one-half of the bayonet joint was subjected to this test. Due to a lack of time in the overall program schedule, only the sinusoidal excitation was performed.

Test Procedure

The test item was installed in the test fixture as shown in the Task IV Test Report.

The test item was subjected to vibration tests in accordance with KSC-STD-164D, Paragraph 9.2, Procedure II, Paragraphs 9.3.1 and 9.3.4 except that the test levels were as specified in this document.

The entire sequence of vibration tests were accomplished three times (once in each of the principal axes) and all testing was completed in one axis before changing axis. The test sequence in each axis was: (1) resonant frequency search and (2) sinusoidal sweep.

Throughout the vibration test program, the test item was functionally monitored for possible failure detection. Prior to testing in each axis, the test item was functionally tested per Paragraph 5.3 of 8-480086.

Resonant Frequency Search

The test item was installed in accordance with Paragraph 4.4.1 of KSC-STD-164D. The fixture/test item assembly was exposed to sinusoidal vibration at an acceleration level of 1 g. The frequency range of 5 to 3000 cps was traversed logarithmically in directions of both increasing and decreasing for a period not to exceed 15 minutes per axis. The test item was functionally tested at the conclusion of the test per Paragraph 5.3 of 8-480086.

Sinusoidal Sweep

The fixture/test item assembly was exposed to sinusoidal sweep vibration at an acceleration as specified in Figure 7 for panel support structure. The frequency range of 10 to 2000 cps was traversed logarithmically in directions of both increasing and decreasing frequency for a test period of 20 minutes (10 minutes increasing and 10 minutes decreasing). The test item was functionally tested at the conclusion of the test per Paragraph 5.3 of 8-480086.

Test Results

The fixture/test item resonant frequencies were recorded. Critical frequencies of the test item were recorded. Critical frequencies were those frequencies at which functional degradation or excessive noise occurred. Actual test times were recorded. The vibration test setup was photographed. The test data from all functional tests were recorded as specified in Paragraph 5.3.3 of 8-480086. There were no failures of the 8-inch bayonet following vibration that could be detected from performing the functional test specified.

Test Data

All data sheets and photographs are included in the rotary joint test report, Task IV.

7.2.1.5.5 Burst Test

In order to prevent any damage to the test item which would preclude any future work with the bayonet or bayonet/rotary assembly, the Burst Test was not performed. The original requirements were to pressurize the test item to 760 psig for five minutes.

7.3 DESIGN SPECIFICATIONS

Contract NAS 10-6098 required the preparation of a procurement specification for the bayonet joint. This document titled "Coupling, Cryogenic-Vacuum Jacketed Cryogenic Transfer and Storage Systems" was assigned the number 79K00061 by KSC. The document was prepared on "B" size KSC format.

7.4 CONCLUSIONS

As can be seen in the results of the heat leak test, this design met the original 300 Btu design goals for LO_2 system. One heat leak data point has also been established for an LH_2 joint heat leak which will aid in future research.

The development of the high compressive strength open-celled polyurethane foam for the LH_2 system insulator proved very satisfactory as a support for the steel foil cover. The foil cover fabrication and insulator leakage test also proved that this insulator was a practical design.

The proof pressure tests proved the practicality of the non-ring reinforced cylinder/cone assembly while still maintaining heat leak values equal to the present coaxial bayonet design.

The re-use of the liquid nose seal proved satisfactory as long as it was used in the same joint each time. As pointed out in the Masoneilan report, this joint lends itself very nicely to those applications requiring a low heat leak and easy separation.

7.5 RECOMMENDATIONS

Due to the rather large difference between the calculated heat leak and the measured heat leaks using the CTL Dixie insulator, separate conductivity tests should be done on this material. This would allow for a more accurate analytical determination of the total heat leak for this type joint.

The tests on the LH_2 system insulators should be repeated using liquid hydrogen in lieu of LN_2. This design requires very high order of cryopumping to eliminate gas conduction. Since no attempt was made to use pure CO_2 back fill gas in the insulator, it is felt that the measured heat leaks still represents a considerable amount of gas conduction. It was mainly the gas convection that was reduced in cryopumping CO_2 with LN_2.

It was decided, prior to the tare heat leak test, that the majority of the heat gain was through the fill and vent piping connected to the test section and, therefore, only that portion of the assembly was tested. Any future testing should also include the other half to pick up its radiation heat gain in the total tare leakage. For purposes of this test program, it was felt that this error was small and could be ignored.

As a result of the test program, it was found that the Tek-Seal used as the liquid nose seal was re-usable on any one particular joint. The seal should not be transferred to and used on any other similar joint due to the tolerance variation between joints. The pre-crush of this seal can allow it to pass excessive amounts of liquid into the insulator cavity if cavity tolerances from one joint to another vary excessively. It is also recommended that the aluminum retaining band over the Tek-Seal be notched and bent slightly inward. This provides for a better grip of the seal since it is difficult to make a shrink fit between the seal and ring. It also aids in the assembly of the seal to the bayonet, by allowing the ring to feed under the insulator without damaging the insulator material.

In order to confirm the findings of this report with regard to ease of handling and installation of this type of joint, a typical pipe section at one of the KSC installations should be modified to include this design.

This joint should also be specified on all new installations requiring large vacuum jacketed lines. This is particularly true on the single-plane-entry joints required on the large cross-country assemblies. It provides a much simpler field joint.

7.6 APPENDIX

THE THERMAL CONDUCTIVITY OF "TECSULATE PF" TEFLON FEP FOAM IN NITROGEN

ZZL-69-027
MP-572-1-681

August 1969

Prepared by: E. L. Salter
E. L. Salter

Approved by: James F. Haskins
James F. Haskins
Chief of Materials Research

The thermal conductivity, K, of "TECSULATE PF" Teflon FEP foam has been determined for mean panel temperatures from -223 to 67°F in an atmosphere of gaseous nitrogen maintained at 14.7 psia (Ref. Ametek-Straza P.O. #74066).

A guarded hot-plate apparatus, developed at General Dynamics Convair by James F. Haskins, and described in ASTM Special Technical Publication No. 411, was used for the test.

Four 7" squares of the foam material, in 1/4" nominal thickness, were used to make two 1/2" thick test samples. The samples were placed in a stainless steel pillow cover, as shown in Figure 1.

Test results are presented in Table 1 and Figure 2. Test specimens were manufactured by Thermech Engineering Corp. of Anaheim, California.

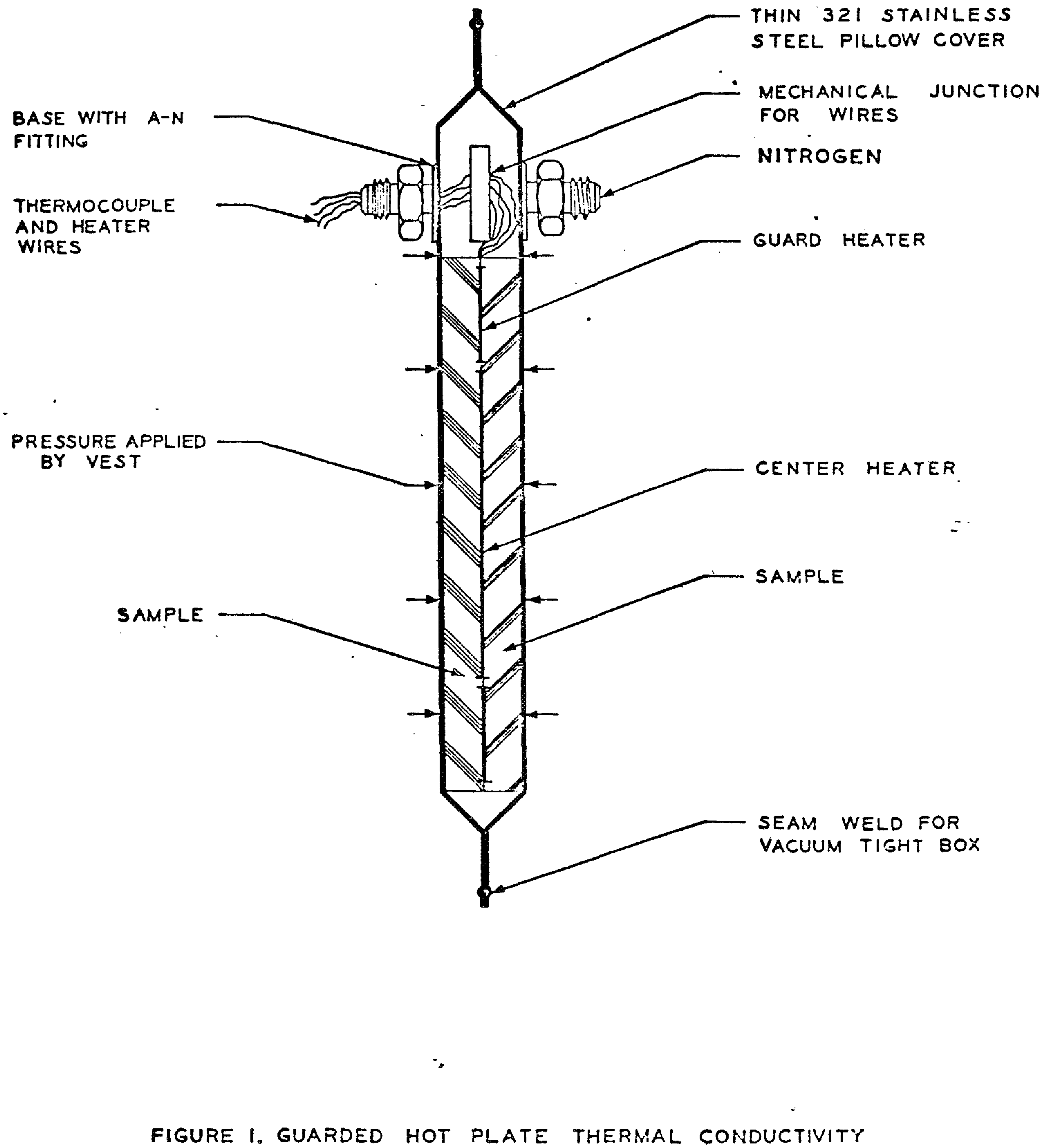


FIGURE I. GUARDED HOT PLATE THERMAL CONDUCTIVITY
APPARATUS SAMPLE CONTAINER

TABLE 1. TEST RESULTS - THERMAL CONDUCTIVITY OF 'TECSULATE PF' TEFLON FEP FOAM

14.7 PSIA GN_2 ATMOSPHERE

Hot Face Temp.(°F)	Cold Face Temp.(°F)	T (°F)	Mean Temp.(°F)	Q(BTU/Hr.-Ft.^{2})	K(BTU-In./Hr.-Ft.^{2}-°F)
-93.3	-309.1	215.8	-222.5	36.7	.170
-54.9	-301.7	246.8	-179.0	50.8	.206
6.4	-296.1	302.5	-145.0	67.5	.223
-77.0	-106.0	29.0	-92.0	7.4	.254
24.3	-100.8	125.1	-38.4	36.8	.294
51.0	32.5	18.5	41.8	6.2	.334
98.8	34.8	63.0	67.0	22.0	.349

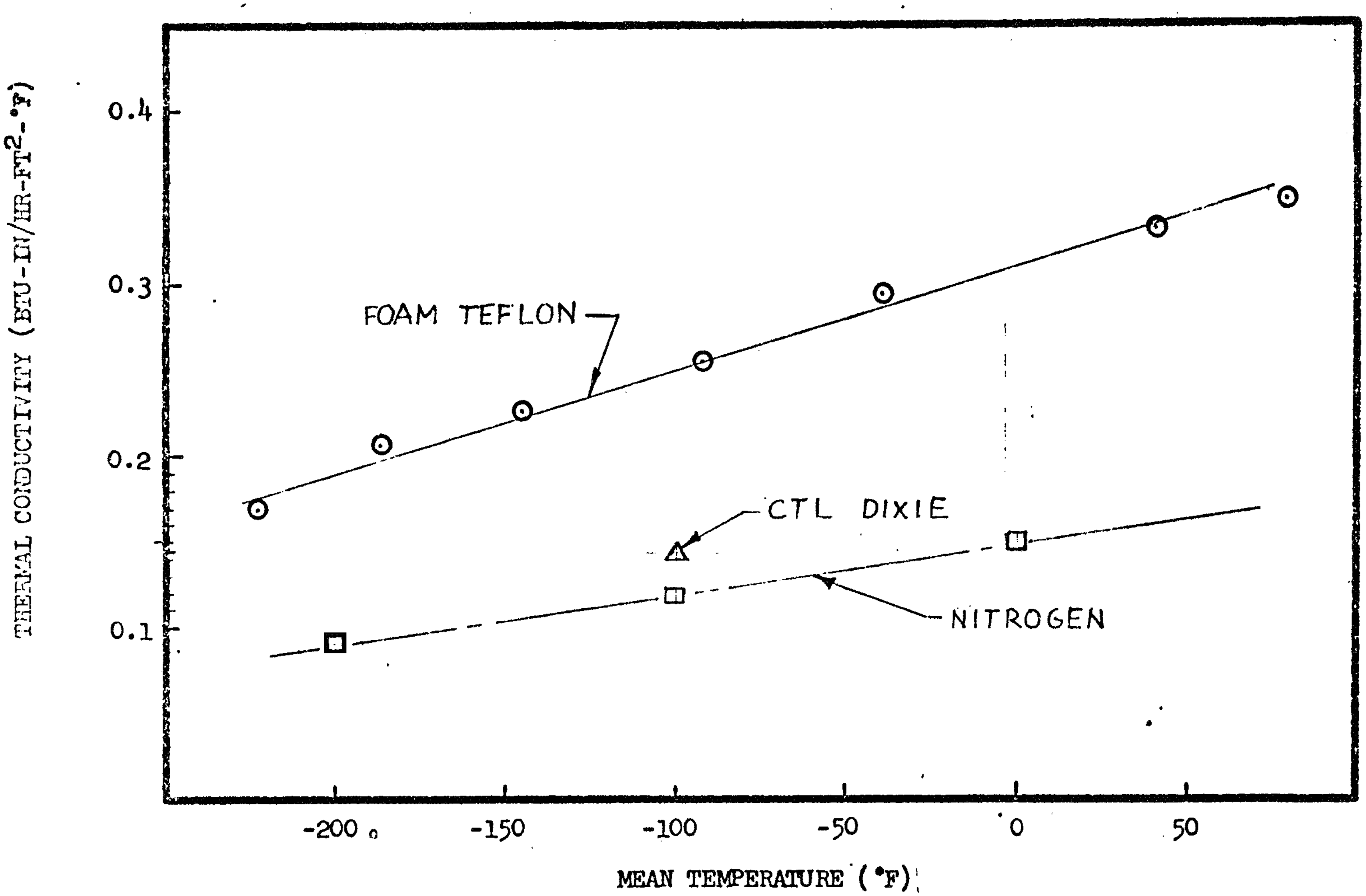


FIGURE 2. THERMAL CONDUCTIVITY OF "TECSULATE PF" TEFLON FEP FOAM - LOT NO. W21193.

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