#28

PRESSURE VESSEL ENGINEERING NOTE
PER MANDATORY STANDARD SD37

)

Prepared by: Dan Burke

Preparation date: 10 FB 1987

REVISED 7-1-87

1 Description and Identification

Fill in the label information below:

This vessel conforms to engineering standard SD37

Vessel Title: Liquid Argon Calorimeter (LAC)

Vessel Number: NB 4778 RD 2048

Vessel Drawing Number: CBI (Drawing is attached) CONTRACT 851553, DRAWINGS 1-33

Maximum Allowable Working Pressure (MAWP): BOTTOM VESSEL 16 PSIG; TOP VESSEL 16 PSIG

Working Temperature Range: BOTTOM -305 °F 100 °F; TOP -20 °F 650 °F

Contents: Liquid Argon

Designer/Manufacturer: /Chicago Bridge and Iron (CBI) Oak Brook, Il

Test Pressure (if tested at Fermi) Acceptance Date: ______

______ PSI, Hydraulic ______ Pneumatic ______

Accepted as conforming to standard by

V C Stanfield

of Division/Section: Research

NOTE: Any subsequent changes in contents, pressures, temperatures, valving, etc., which affect the safety of this vessel shall require another review and test.

Obtain from Division/Section Safety Officer

Actual signature required in this space

Reviewed by: SIGNED CONDITIONALLY. THE FLANGE HEATING SYSTEM MUST BE INSTALLED AS STATED IN MY MEMO OF JULY 28, 87 [signature] Date: JULY 31-8

Director's signature (or designee) if the vessel is for manned areas but doesn't conform to the requirements of the standard.

______ Date: ______

Lab Property Number(s): NOT AVAILABLE

Lab Location Code: MES MW A (obtain from Safety Officer)

Purpose of Vessel(s): Vessel is to be used by E-706 to contain detectors under the proper conditions for experimental physics

Vessel Capacity/Size: 18000 Gal LAr Diameter: 17 ft. Length: 28' Vert.

Normal Operating Pressure (OP) 2 PSIG

MAWP-OP = 14 PSI

Is the above enough to provide relief cracking pressure tolerance plus system uncertainty tolerance per M-9. yes

As an option, provide a photo of the entire vessel in the Appendix.

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6/86

List the numbers of all pertinent drawings and the location of the originals. (Append copies).

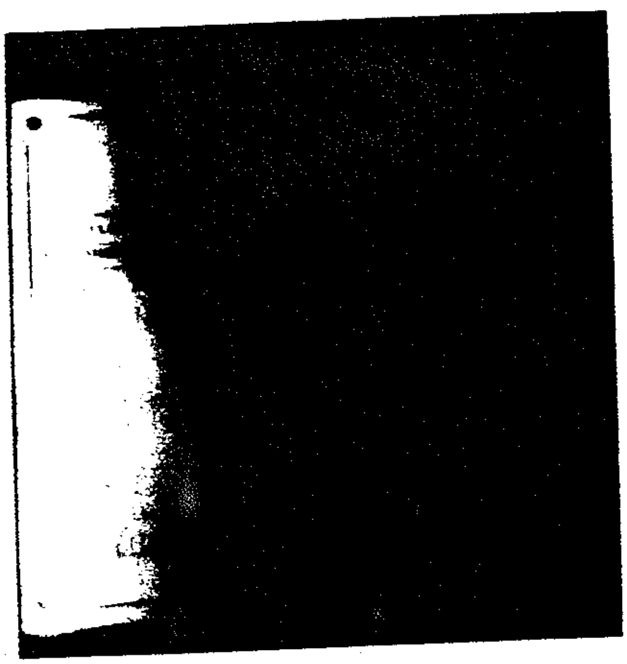
Drawing #	Location of Original
CBI DRAWING 1-33, CONTRACT	CBI, Oak Brook, IL
851553	
2220.1-ME-183293	WILSON HALL 11

2 Design Verification

Does the vessel(s) have a U stamp? Yes X No ______. If "Yes", fill out data below and skip page 3; if "No", fill out page 3 and skip this page.

Staple photo of U stamp plate below.

Copy "U" label details to the side if photo is not clear of if copies are unreadable.



Copy data here:

Horton Pressure Vessel
Duplicate name plate
CBI Contract No. 851553

U W RT2

NB 4778, MFR # C4773

Year Built 1985

17' x 28' LAr Vessel

MAWP 16 PSIG @ 100°F

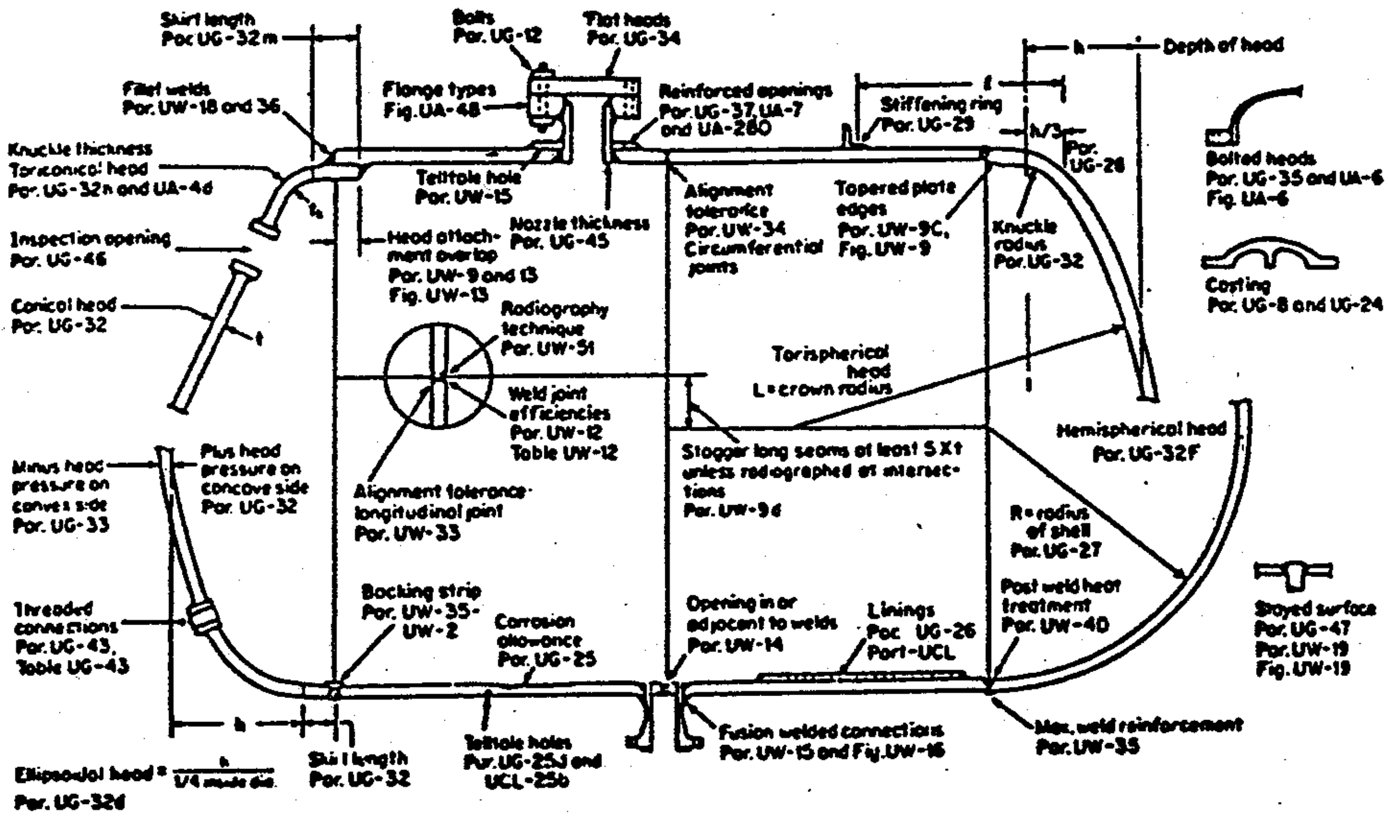
Min Allow -325 F

Max Design Temp Range

100/-305

Certified by CBI
Oak Brook, IL
5109A

On the sketch below, circle all applicable sections of the ASME code per Section VIII, Division I. List the results of all calculations. (Insert copies of calculations in the appendix).



Summary of ASME Code

Item	Reference ASME Code Section	CALCULATION RESULT (Required thickness or stress level vs. actual thickness or calculated stress level)
		vs.
		vs.
		vs.
		vs.
		vs.

If this vessel is exceptional or had exceptional parts, list their details under 5.6. Yes______ No___x___

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6/86

3 System Venting. Provide the system schematic in the Appendix, if the vessel safety is system sensitive.

Is it possible to isolate the relief valves by a valve from the vessel?

Yes______ No X

If "Yes", the system must conform to M-5. Provide an explanation on the appended schematic. (An isolatable vessel, not conforming to M-5 violates the Standard.)

Is the relief cracking pressure set at or below the M.A.W.P.?

Yes X No______ Actual setting 7 PSIG
(A no response violates the Standard.)

Is the pressure drop of the relief system at maximum anticipated flow such that vessel pressure never rises above the following? (UG 125)

Yes X No______ 110% of MAWP (one relief)
116% of MAWP (multiple reliefs)
→ 121% of MAWP (unexpected heat source)

Provide test or calculational proof in the Appendix.
(Non-conforming pressure rises violate the Standard.)

List of reliefs and settings:

Manufacturer	Relief	Setting	Flow Rate	Size
AGCO93T0608A	SV3003	7 PSIG	9069 scfm air	6 x 8
BS & B DSV	RD 3002	12.5 PSIG	8469 scfm air	6

Is the relief device an ASME stamped device? Yes X No ______

4 Operating Procedure

Is an operating procedure necessary for the safe operation of this vessel?

Yes X No______. If "Yes", please append.

5 Welding Information

Has the vessel been fabricated in a Fermilab shop? Yes______ No X

If "Yes", append a copy of the welding shop statement of welder qualification and a copy of the Welding Procedure Specification (WPS) used to weld this vessel.

6 Exceptional, Existing, Used, and Non-Manned Area Vessels

Is this vessel or any part thereof in the above categories? Yes______ No X

If "Yes", follow the Engineering Note requirements for documentation in free form below.

Fermilab

July 28, 1987

TO: Roman Dachniwskyj

FROM: Andrew Szymulanski A. Sz -

SUBJECT: Review of Pressure Vessel Engineering Note for Liquid Argon Calorimeter, NB-4778 (RD-2042)

Thank you for partial updating the Pressure Vessel Engineering Note for "LAC".

The problem, however, still exists with working temperature range for "top plate assembly".

The Engineering Note's description and identification label must include and distinguish temperature range for:

1. "Argon Dewar" (Material: 304 SS) - Temp Range: 100^{O}F to -305^{O}F

2. "Top Plate Assembly" (Material: SA516, GR70) - Working temperature range should be stated by the vessel fabricator.

The temperature of the carbon steel section of the vessel must be maintained at a level which will guarantee material strength which should match that used in vessel's engineering computations.

The "SA 516 Grade 70" has carbon content of 0.31%, which is high from brittle fracture standpoint. Once established, minimum allowable temperature, the range should be controlled by adequate heating system.

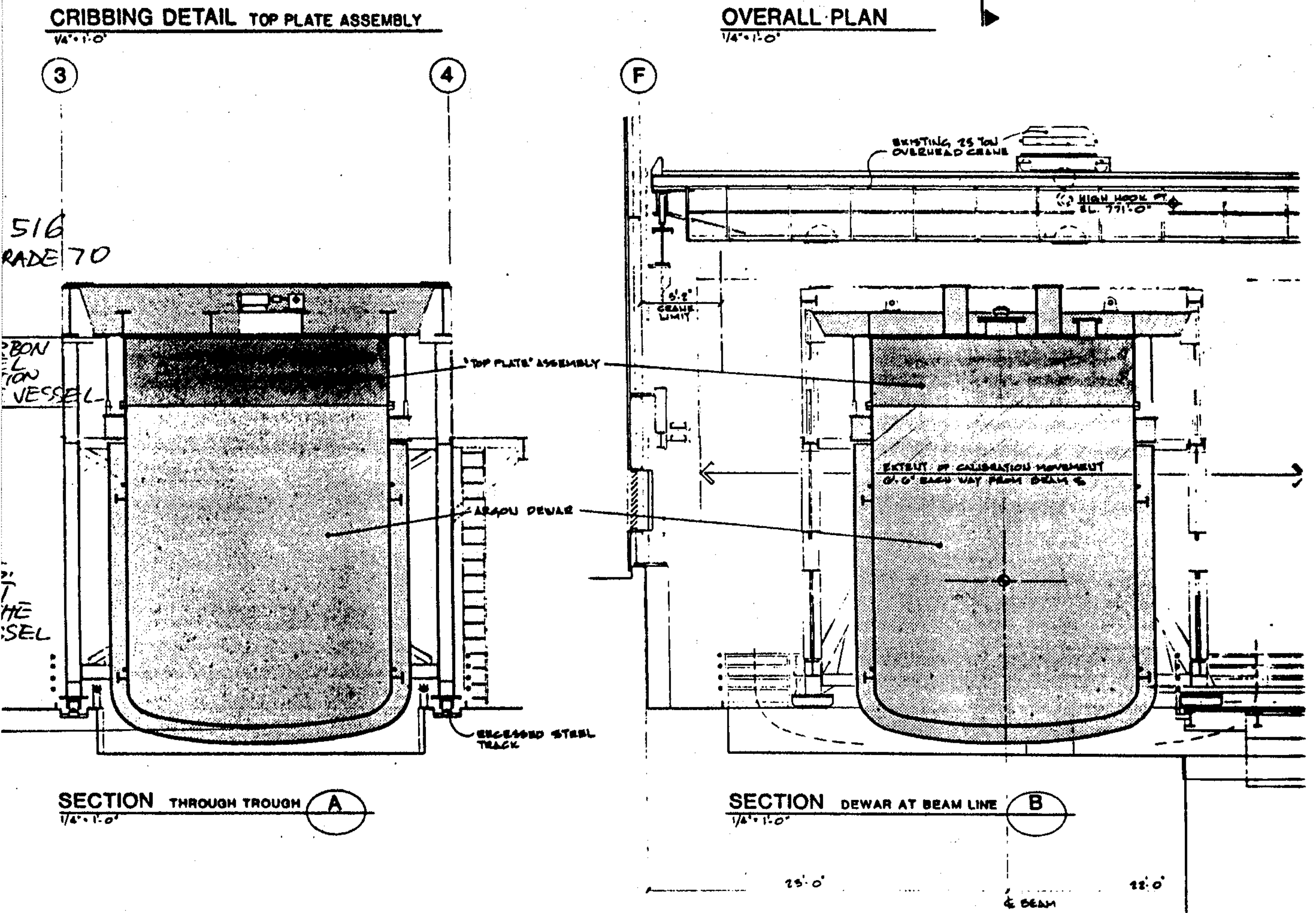
The system should be automatic and power supply must be from at least two independent sources.

Figure 4 in enclosed data (Metal's Handbook) shows correlation between carbon content and impact energy. For approximately 15 ft./lb, the corresponding temperature is approximately 23°F.

ASz:ed

Enclosure

Copy to:
J. F. Lindberg


CRIBBING DETAIL TOP PLATE ASSEMBLY
1/4" = 1'-0"
OVERALL PLAN
1/4" = 1'-0"
3
4
F
516
RADE 70
VESSEL
SEL
EXISTING 25 TON OVERHEAD CRANE
HIGH HOOK PT. EL. 771'-0"
5'-2"
CRANE LIMIT
'TOP PLATE' ASSEMBLY
ARGON DEWAR
EXTENT OF CALIBRATION MOVEMENT
RECESSED STEEL TRACK
SECTION THROUGH TROUGH
A
1/4" = 1'-0"
SECTION DEWAR AT BEAM LINE
B
1/4" = 1'-0"
25'-0"
22'-0"
℄ BEAM

SCHEMATIC 1

Cu:
0.02 min
Nb

(d) These grades may contain niobium, vanadium or nitrogen.

Table 29 Composition ranges and limits for carbon steel pressure-vessel plate (ASTM specifications)

Specification	Type or grade	UNS designation	Heat composition ranges and limits, % C max	Mn	P max	S max	Si
A285	Grade A	K01700	0.17	...	0.035	0.045	...
	Grade B	K02200	0.22	0.90 max	0.035	0.045	...
	Grade C	K02801	0.28	0.90 max	0.035	0.045	...
A288	...	K02803	0.30	0.90-1.50	0.035	0.040	0.15-0.30
A442	Grade 55	K02202	0.24	0.60-1.10	0.04	0.05	0.15-0.30
	Grade 60	K02402	0.27	0.60-1.10	0.04	0.05	0.15-0.30
A455	Type I	K03300	0.33	0.85-1.20	0.040	0.060	0.10 max
	Type II	K02802	0.28	0.85-1.20	0.040	0.050	0.15-0.30
A515	Grade 55	K02001	0.28	0.90 max	0.035	0.040	0.15-0.30
	Grade 60	K02401	0.31	0.90 max	0.035	0.040	0.15-0.30
A515	Grade 65	K02800	0.33	0.90 max	0.035	0.040	0.15-0.30
	Grade 70	K03101	0.35	0.90 max	0.035	0.040	0.15-0.30
A516	Grade 55	K01800	0.26	0.60-1.20	0.035	0.04	0.15-0.30
	Grade 60	K02100	0.27	0.60-1.20	0.035	0.04	0.15-0.30
	Grade 65	K02403	0.29	0.85-1.20	0.035	0.04	0.15-0.30
	Grade 70	K02700	0.31	0.85-1.20	0.035	0.04	0.15-0.30
A537	...	K02400	0.24	0.70-1.60	0.035	0.040	0.15-0.30
A612(a)	...	K02900	0.27	1.00-1.50	0.035	0.040	0.15-0.30
A662	Grade A	K01701	0.17	0.90-1.35	0.035	0.040	0.15-0.30
	Grade B	K02203	0.19	0.85-1.50	0.035	0.040	0.15-0.30
A724(a)	Grade A	...	0.18	1.00-1.60	0.035	0.040	0.55 max

(a) Residual alloying elements restricted as follows: 0.35 max Cu; 0.25 max Ni; 0.25 max Cr; 0.08 max Mo; 0.08 max V.

Notch Toughness of Steels

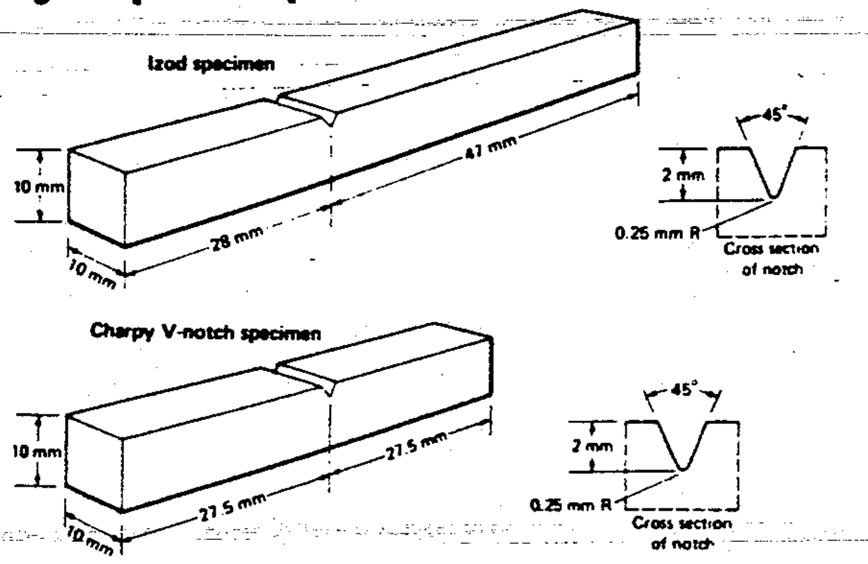
By G. J. Roe
and the ASM Committee on
Plain Carbon and Alloy Steels

TOUGHNESS is the ability of a metal to absorb energy and deform plastically before fracturing; the amount of energy absorbed during deformation and fracture is a measure of the toughness of the metal. By contrast, the amount of deformation that occurs prior to fracture is a measure of the metal's ductility, and the force necessary to cause fracture is a measure of its strength. For an application in which a metal object must withstand some specified load, the strength of the metal is the controlling property. Ductility may be the governing property if the metal must be formed to a specified shape. But if the metal must be able to absorb a certain quantity of mechanical energy without fracturing, its toughness is the limiting property.

Systematic investigations into the failures of various types of steel structures, such as bridges, storage tanks, pressure vessels and gas pipe lines, have firmly established notch toughness as an important parameter for selecting the material to be used in any structure that might be subjected to impulsive loading at low temperatures. Perhaps the most thorough such investigation was that into the brittle fractures encountered in welded transport ships during and immediately following World War II. There were several factors that were common to the brittle fractures that occurred in these ships: the fractures originated at a stress raiser, such as a design feature or fabrication defect; the fractures occurred at low ambient temperatures, typically about 4 °C (40 °F); the fractures were characteristically brittle in appearance, even though the failed plates possessed adequate ductility in room temperature tension tests. The investigation also revealed that the notch toughness (measured by Charpy V-notch testing) was substantially lower at failure temperatures and below that at room temperatures. Selection of steels with sufficient notch toughness at anticipated service temperatures and designing the ships to minimize the severity of any stress raisers virtually eliminated these ship disasters.

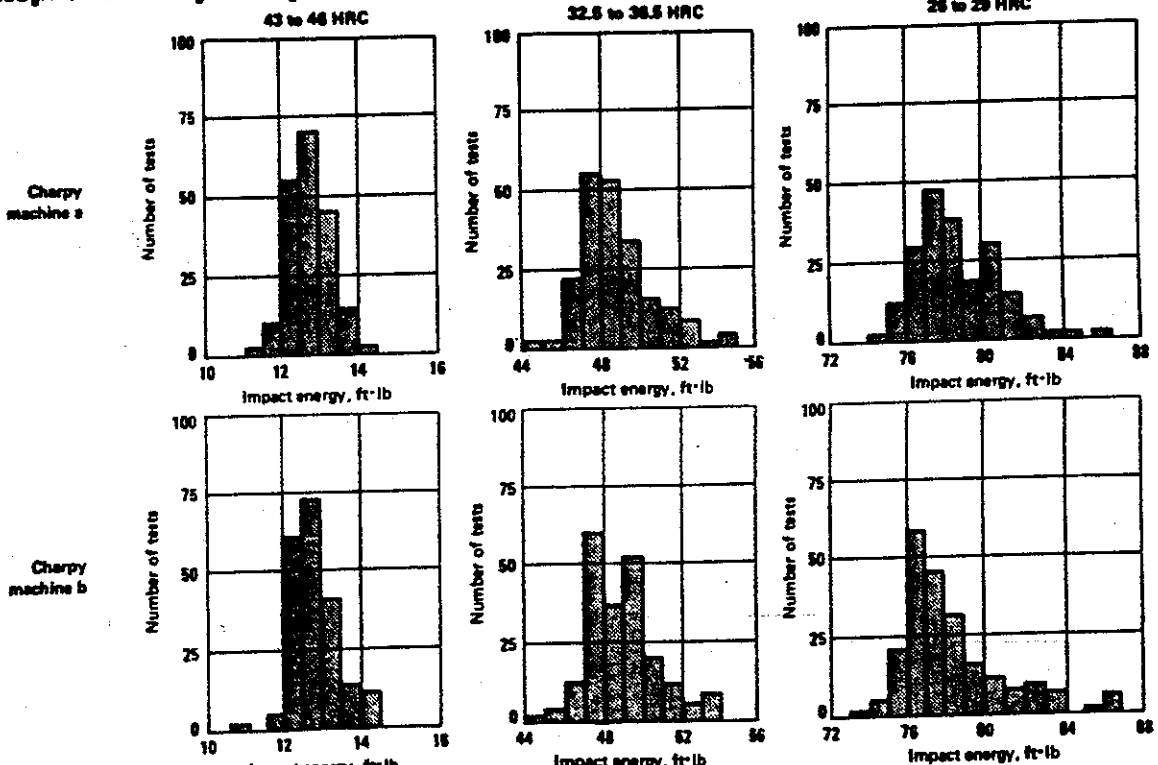
Notch toughness usually is evaluated by testing specimens of prescribed size and shape at a known temperature in a single-blow pendulum-type impact machine. Two commonly used method[s] impact testing are the Charpy and I[zod] tests, which are discussed in detail[...] ASTM Standard E23. Notched sp[eci]mens, such as those illustrated in Fig[...] usually are used to evaluate the tou[gh]ness of most metals. Although so[me]what redundant, the term notch tou[gh]ness is very descriptive of the result[s] these tests and it reduces the likelih[ood] of data being misinterpreted. [...] notched test specimens usually are u[sed] to evaluate the toughness of less duc[tile] metals, such as gray cast irons. Seve[ral] other types of toughness tests, less co[m]monly used than the Charpy and I[zod] tests, are described in Metals Ha[...]

Fig. 1 Impact test specimens



Izod and Charpy V-notch test specimens used for evaluation of notch toughness (ASTM E23)

Fig. 2 Reproducibility of impact testing



Charpy test averages	43 to 46 HRC		32.5 to 36.5 HRC		26 to 29 HRC	
Machine A	12.7 ft·lb	17.2 J	48.6 ft·lb	65.9 J	78.4 ft·lb	106.3 J
Machine B	12.8 ft·lb	17.1 J	49.1 ft·lb	66.6 J	77.9 ft·lb	105.6 J

Comparison of test results from two Charpy impact machines manufactured by two companies. 1200 specimens were made from a single heat of aircraft-quality 4340 steel. Specimens were hardened and tempered to three hardness levels: 43 to 46 HRC, 32.5 to 36.5 HRC and 26 to 29 HRC. 200 specimens at each of the three hardness levels were tested at 21 °C (70 °F) on each of the impact machines. (Ref 1)

book, 8th Edition, Volume 10, pages 37-40.

Fracture toughness, a material property related to notch toughness, describes the resistance of a metal to the propagation of an existing crack. The value usually reported is the stress intensity necessary at the tip of a crack for that crack to propagate. Although there is often an empirical correlation between notch toughness and fracture toughness, the two types of tests and the resulting data are different, and must not be confused.

Notch toughness values derived from test results cannot be used directly in engineering design calculations. The values become significant for design only when correlated with a particular type of structure in a particular kind of service, or when these values are used to compare different materials.

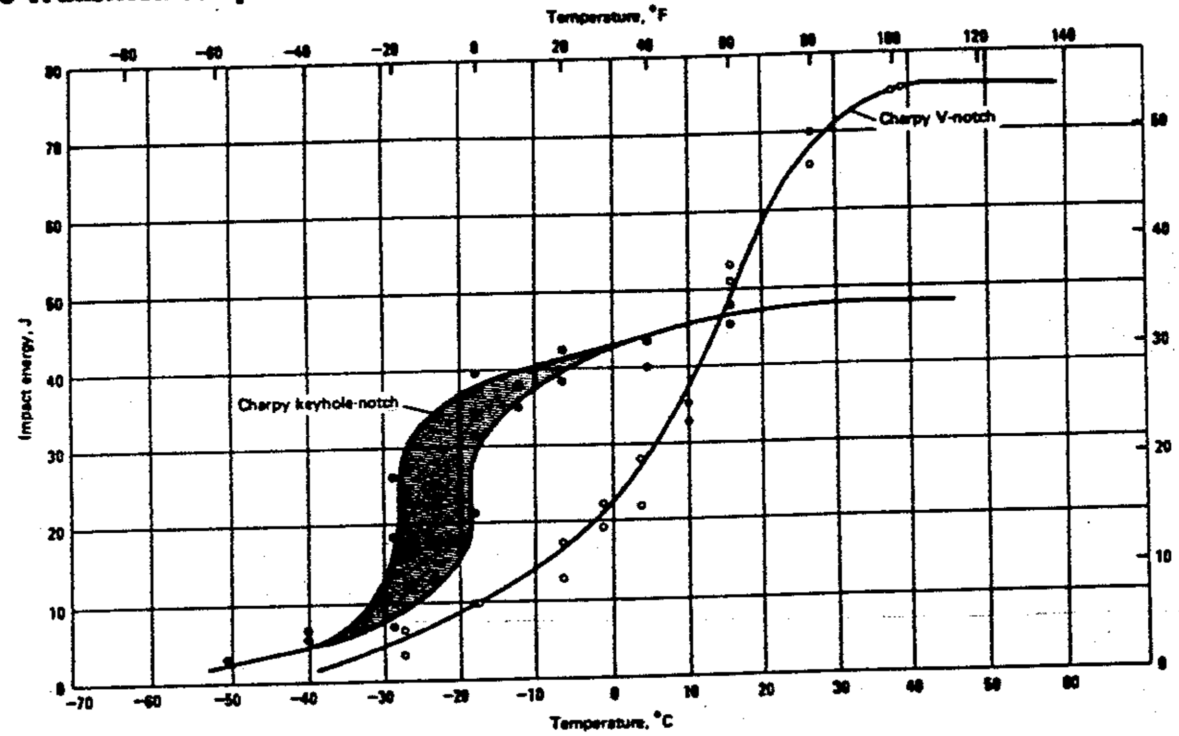
Notch toughness of a metal is influenced by chemical composition and many physical factors. For steels, carbon content, alloying elements, gas content and impurities are chemical factors that affect this property. The physical factors include microstructure, grain size, section size, hot and cold working temperature, method of fabrication and specimen orientation in relation to working direction. Surface conditions, such as carburization and decarburization, are important, also.

Reproducibility of Test Results. The Army Materials and Mechanics Research Center (formerly Watertown Arsenal Laboratory) conducted a closely controlled experiment that established the Charpy V-notch impact test as both reliable and reproducible. A total of 1200 specimens from a single heat of aircraft-quality 4340 steel were divided into three groups and heat treated to three different ranges of hardness: 43 to 46, 32.5 to 36.5 and 26 to 29 HRC. Two hundred specimens at each hardness level were impact tested in each of two Charpy machines manufactured by two companies; the average impact-energy values and distribution of results are shown in Fig. 2.

The test program just described clearly demonstrated the narrow spread of results that can be obtained under carefully controlled testing conditions. However, the experience of other laboratories indicates that even when preparation and testing of impact specimens are closely controlled, a considerable spread of test results can still occur. When the effects of these variables are added to the inherent scatter that occurs among different heats of steel, the distribution of test results is broadened appreciably. Thus, judging notch toughness on the basis of one or two tests for a specific set of conditions is unwise without voluminous data on prior production heats of the material.

Some specifications designate that a specific number of specimens be tested at a particular temperature or over a particular range of temperatures. In

Fig. 3 Transition temperature behavior of low-carbon steel



Charpy V-notch and Charpy keyhole-notch impact energy for semikilled low carbon steel (0.18C, 0.54 Mn, 0.07Si) tested over the ductile-to-brittle transition temperature range.

other instances, the number of specimens with minimum or average values, or both, is negotiated. The accuracy and usefulness of results vary directly with the number of specimens tested.

Ductile-to-Brittle Fracture Transition

Plain carbon and low-alloy steels, like many metals with body-centered-cubic lattice structures, are susceptible to a lowering of absorbed impact energy with decreasing temperature, either in service or during testing. This change is accompanied by a transition from a fibrous to a crystalline-appearing fracture surface. A somewhat arbitrarily defined temperature in the transition range is called the ductile-to-brittle fracture transition temperature, or T_c. Because there are several ways of defining T_c, the criterion used to establish the value should be stated whenever a value of T_c is given. Because brittleness is seldom desirable, it usually is necessary to prevent brittle behavior under impact loading by keeping T_c below the expected service temperature.

Charpy notched-bar impact tests are especially effective in determining T_c for plain carbon and low-alloy steels. Figure 3 shows that, in a plot of energy absorbed during fracture versus testing temperature, there is a sharp drop in absorbed energy as the testing temperature decreases. This drop is called the energy transition. The value of T_c associated with energy transition is called the energy transition temperature. As shown in Fig. 3, in this series of tests on low-carbon steel plate the drop in energy for the Charpy keyhole specimens was steeper and more sharply defined than for the Charpy V-notch specimens; thus, the value of T_c for keyhole specimens was more precise. However, the value of T_c for keyhole specimens was lower than the temperatures at which brittle fractures occurred in service and lower than T_c for V-notch specimens. On the other hand, T_c for V-notch specimens correlated well with the temperatures at which service failures occurred in components made of this steel.

The wide range of temperature over which V-notch energy transition occurs (see Fig. 3) emphasizes the importance of the criterion for defining T_c. One criterion is the average-energy criterion (the temperature corresponding to the median between the maximum energy, or upper-shelf energy, and the minimum energy, or lower-shelf energy). In many instances, the temperature at which the transition curve crosses an arbitrary value of absorbed energy (such as 20 or 40 J, or 15 or 30 ft·lb) is chosen. An alternative criterion is the average-temperature criterion (the median temperature of the transition range).

Transition temperature also can be defined by observing the change in fracture appearance from fibrous to crystalline as the test temperature is reduced. The fracture appearance changes because above T_c fracture occurs predominantly by microvoid coalescence whereas below T_c fracture occurs predominantly by cleavage. Some specifications (particularly those of ASTM) define the temperature at which specimens fracture 50% in shear and 50% in cleavage as the transition temperature; this value of T_c is usually referred to as the 50% FATT. Other specifications use 100% shear as the criterion, which defines the 100% fracture appearance transition temperature (100% FATT). Still other specifications, such as those for ship plate, require a minimum impact energy at a given testing tempera-

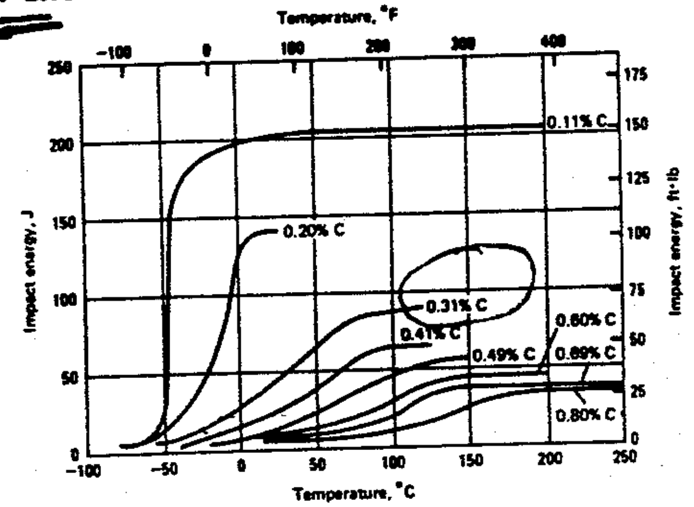
FROM FIG. 4 FOR 0.31% C. − 5°C (23°F) → IMPACT ENERGY ~ 15 Ft lbs

ture—20 J at 5 °C (15 ft·lb at 40 °C), for example. These methods of determining transition temperature, plus several other methods, are described in detail on pages 45 to 47 in Volume 10 of the 8th Edition of Metals Handbook.

Selection of the method most appropriate for a given application is difficult and requires and understanding of both toughness testing and service behavior. Often, additional tests are needed to establish a correlation between the transition temperature determined using a certain method and service behavior of a specific structure made of the same material. The method in which the impact energy at a given temperature must exceed a specific value is one method requiring such a correlation.

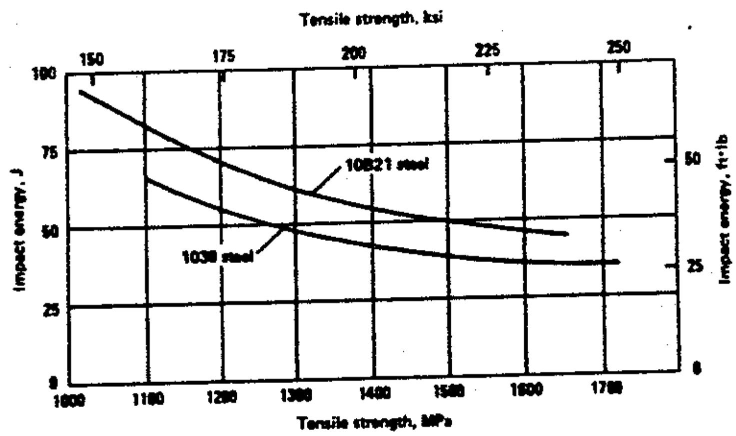
Despite the importance of notch toughness, other mechanical requirements must be considered and often some compromise must be made in selection. For example, notch toughness usually decreases as carbon content, strength and hardness are increased. Hard surfaces required for wear resistance also have an adverse effect on notch toughness.

Fig. 4 Effect of carbon content on notch toughness



Variation in Charpy V-notch impact energy with temperature for normalized plain carbon steels of various carbon contents. (Ref 3)

Fig. 5 Effect of boron content on notch toughness



Variation of room-temperature Charpy V-notch impact energy with tensile strength for 10B21 and 1038 steels with tempered martensite structures.

Effects of Composition

The composition of a steel, as well as its microstructure and processing history, significantly affects both *Tc* and the energy absorbed during fracture at any particular temperature. The effects of the various alloying elements and those of microstructural and processing variables are intimately interrelated; in practice, it is difficult to change one variable without affecting another. Contributions to notch toughness that have been attributed to individual alloying elements are as follows:

Carbon increases transition temperature and decreases upper-shelf fracture energy. These effects, measured by Charpy V-notch impact tests, are shown in Fig. 4. Carbon is one of the more potent alloying elements in its effect on notch toughness. Consequently, for maximum toughness, the carbon content should be kept as low as possible, consistent with strength requirements.

Boron. A practical way of attaining toughness without reducing strength is to use a boron-containing grade of steel with a lower carbon content. As shown in Fig. 5, 10B21 steel has greater toughness than 1038 steel at all strength levels. However, the benefit of boron is applicable only to quenched-and-tempered steels; boron reduces the toughness of as-rolled, as-annealed and as-normalized steels.

Manganese can substantially reduce the transition temperature of low-carbon steels, as shown in Fig. 6. In higher carbon steels, manganese may be less beneficial. As illustrated in Fig. 7, increasing the manganese content of a normalized medium-carbon steel lowered *Tc* probably because the additional manganese reduced pearlite plate spacing. In a hardened and tempered steel manganese can have the opposite effect, as illustrated in Fig. 8. Manganese can make the steel susceptible to temper embrittlement and it may cause the formation of brittle upper bainite (rather than fine pearlite) during normalizing.

Sulfur. The effect of sulfur on notch toughness of steels is directly related to deoxidation practice. For rimmed, semi-killed and Si-killed steels, sulfur in amounts up to about 0.04% has a negligible effect on notch toughness. However, for Si-Al-killed steels, a reduction in sulfur content can substantially increase upper shelf energy, as shown in Fig. 9. This improvement in energy absorption results from reduction of the number of sulfide stringers in the steel.

FORM U MANUFACTURER'S DATA REPORT FOR PRESSURE VESSELS

(Alternative Form for Single Chamber, Completely Shop Fabricated Vessels Only)

As Required by the Provisions of the ASME Code Rules, Section VIII, Division 1

1. Manufactured and certified by: Weldon, Inc., 51 Terminal Ave., Clark, New Jersey 07066 (Name and address of manufacturer)

2. Manufactured for: Cryofab, Inc., P.O. Box 485, Kenilworth, N.J. 07033 (Name and address of purchaser)

3. Location of installation: University of Rochester, Rochester, N.Y. (Name and address)

4. Type: Vert. Tank (Horiz. or vert., tank) — 3381-1&2 (Mfg's serial No.) — --- (CRN) — 7414-E/7483-E (Drawing No.) — 3770/3771 (Nat'l Bd. No.) — 1985 (Year built)

5. The chemical and physical properties of all parts meet the requirements of material specifications of the ASME BOILER AND PRESSURE VESSEL CODE. The design, construction, and workmanship conform to ASME Rules, Section VIII, Division 1 1983 (Year) to 12/31/84 (Addenda (Date)) -------- (Code Case Nos.) -------- (Special Service per UG-120(d))

6. Shell: SA-312-304 (Mat'l (Spec. No., Grade)) .180" (Nom. Thk. (in.)) 0 (Corr. Allow. (in.)) 1'-0-3/8" (Diam. I.D. (ft & in.)) 3'-3" (Length overall (ft & in.))

7. Seams: Butt- Dbl.Weld (Long. Welded, Dbl., Sngl., Lap, Butt) None (R.T. (Spot or Full)) 70 (Eff. (%)) None (H.T. Temp. °F) (Time hrs.) None (Girth Welded, Dbl., Sngl., Lap, Butt) (R.T. (Spot, Partial, or Full)) 1 (No. of courses)

8. Heads: (a) Mat'l SA-240-304 (Spec. No., Grade) (b) Mat'l SA-240-304 (Spec. No., Grade)

	Location (Top, Bottom, Ends)	Minimum Thickness	Corrosion Allowance	Crown Radius	Knuckle Radius	Elliptical Ratio	Conical Apex Angle	Hemispherical Radius	Flat Diameter	Side to Pressure (Convex or Concave)
(a)	Top	5/8"	0	Flat					12-3/4"	Flat
(b)	Bottom	5/8"	0	Flat					12-3/4"	Flat

If removable, bolts used (describe other fastenings): Singl. Fillet Weld (Mat'l, Spec. No., Gr., Size, No.)

9. MAWP 50/FV psi at max. temp. 100 °F

Min. temp. (when less than -20°F) -325 °F. Hydro. test pressure 75

10. Nozzles, inspection and safety valve openings:

Purpose (Inlet, Outlet, Drain)	No.	Diam. or Size	Type	Mat'l	Nom. Thk.	Reinforcement Mat'l	How Attached	Location
In & Out	2	1/2"	ButtWeld	SA-312-304	.109"	None	Welded	Head
In & Out	2	1"	ButtWeld	SA-213-304L	.120"	None	Welded	Head
In & Out	2	3/16"	ButtWeld	SA-249-304	.049	SA-240-304	Welded	Head
SAFETY VALVES BY OTHERS.								

11. Supports: Skirt No (Yes or no) Lugs (No.) Legs (No.) Other None (Describe) Attached (Where and how)

12. Remarks: Manufacturer's Partial Data Reports properly identified and signed by Commissioned Inspectors have been furnished for the following items of the report: None (Name of part, item number, Mfg's name and identifying stamp)

(2) Vessels are Argon Recondensers for non-lethal servcie.
Customer P.O. No. 9089.

CERTIFICATE OF SHOP COMPLIANCE

We certify that the statements made in this report are correct and that all details of design, material, construction, and workmanship of this vessel conform to the ASME Code for Pressure Vessels, Section VIII, Division 1. "U" Certificate of Authorization No. 11,621 expires Aug.10, 1987

Date 6/7/85 Co. name Weldon, Inc. (Manufacturer) Signed [signature]

CERTIFICATE OF SHOP INSPECTION

Vessel constructed by Weldon, Inc. at 51 Terminal Ave., Clark, New Jersey

I, the undersigned, holding a valid commission issued by the National Board of Boiler and Pressure Vessel Inspectors and/or the State or Province of New Jersey and employed by N.J. Dept. of Labor of Trenton have inspected the component described in this Manufacturer's Data Report on 6/7, 19 85, and state that, to the best of my knowledge and belief, the Manufacturer has constructed this pressure vessel in accordance with ASME Code, Section VIII, Division 1. By signing this certificate neither the Inspector nor his employer makes any warranty, expressed or implied, concerning the pressure vessel described in this Manufacturer's Data Report. Furthermore, neither the Inspector nor his employer shall be liable in any manner for any personal injury or property damage or a loss of any kind arising from or connected with this inspection.

Date 6-7-85 Signed [signature] Commissions NB7135-NJS21

ROCHESTER PARTICLE PHYSICS

MADE: RTC . . . 85 F.03
CHKD: TCP 11 Jul 85

FORM U-1 MANUFACTURER'S DATA REPORT FOR PRESSURE VESSELS

As Required by the Provisions of the ASME Code Rules, Section VIII, Division 1

Con:. 851553

1. Manufactured and certified by Chicago Bridge & Iron Co. St. Geo. Rd. & IL Rt. 50 Kankakee, IL (Name and address of manufacturer)

2. Manufactured for University of Rochester River Campus Station Rochester, NY (Name and address of purchaser)

3. Location of installation Fermi National Accelerator Lab Batavia, IL (Name and address)

4. Type Vert. (Horiz. or vert., tank) C4773 (Mfg's serial No.) --- (CRN) 1 Rev. 1 (Drawing) 4778 (Nat'l Bd. No.) 1985 (Year built)

5. The chemical and physical properties of all parts meet the requirements of material specifications of the ASME Boiler and Pressure Vessel Code. The design, construction, and workmanship conform to ASME Rules, Section VIII, Division 1 1983 (Year) --- (Special service per UG-120(d))

Summer 84 (Addenda (date)) --- (Code Case No.)

Items 6-11 incl. to be completed for single wall vessels, jackets of jacketed vessels, or shells of heat exchangers

6. Shell: SA240 TP 304 (Matl (Spec. No., Grade)) 9/16 (Nom. Thk. (in.)) --- (Corr. Allow. (in.)) 17'-0 (Diam. I.D. (ft & in.)) 28'-0 (Length (overall) (ft & in.))

Spot (R.T. (Spot or Full)) 85 (Eff. (%)) --- (H.T. Temp. (°F))

7. Seams: Welded DBL. (Long. (Dbl., Sngl.)) Welded DBL. (Girth (Dbl., Sngl.)) Spot (R.T. (Spot, Partial or Full)) 2 (No. of Courses)

--- (Time)

8. Heads: (a) Matl. SA 240 TP 304 (Spec. No., Grade) (b) Matl. SA516-70 (Spec. No., Grade)

Location (Top, Bottom, Ends)	Minimum Thickness	Corrosion Allowance	Crown Radius	Knuckle Radius	Elliptical Ratio	Conical Apex Angle	Hemispherical Radius	Flat Diameter	Side to Pressure (Convex or Concave)
Bottom	5/8	---	---	---	6:1	---	---	---	Concave
(b) Top	1 1/8	---	---	---	---	---	---	208	---

2a If removable, bolts used (describe other fastenings) 104 - 1 1/4" 40 Stud Bolts SA193-B7 (Matl. Spec. No. Gr. Size No.)

Proof Test _____ If bolted, describe or sketch.

9. Type of Jacket --- If bar, give dimensions

10. Jacket Closure (Describe as ogee & weld, bar, etc.) -325 °F

11. MAWP 16 psi at max. temp. 100 °F. Min. temp. (when less than -20° F)

Hydro. XXXXXXX test press. 24 psi.

Items 12 and 13 to be completed for tube sections

12. Tubesheets: --- (Stationary Matl (Spec. No., Gr.)) (Diam. (in.) (Subject to pressure)) (Nom. Thk. (in.)) (Corr. Allow. (in.)) (Attach. (Welded, Bolted))

(Floating Matl (Spec. No., Gr.)) (Diam. (in.)) (Nom. Thk. (in.)) (Corr. Allow. (in.)) (Attach.)

13. Tubes: --- (Matl (Spec. No., Gr.)) (O.D. (in.)) (Nom. Thk. (in. or Gauge)) (Number) (Type (Straight or "U"))

Items 14-17 incl. to be completed for inner chambers of jacketed vessels or channels of heat exchangers

14. Shell: --- (Matl (Spec. No., Grade)) (Nom. Thk. (in.)) (Corr. Allow. (in.)) (Diam. I.D. (ft & in.)) (Length (overall) (ft & in.))

(R.T. (Spot or Full)) (Eff. (%)) (H.T. Temp. (°F))

15. Seams: --- (Long. (Dbl., Sngl.)) (R.T. (Spot, Partial or Full)) (No. of Courses)

(Time) (Girth (Dbl., Sngl.))

16. Heads: (a) Matl. --- (Spec. No., Grade) (b) Matl. (Spec. No., Grade)

Location (Top, Bottom, Ends)	Minimum Thickness	Corrosion Allowance	Crown Radius	Knuckle Radius	Elliptical Ratio	Conical Apex Angle	Hemispherical Radius	Flat Diameter	Side to Pressure (Convex or Concave)
(a)									
(b)									

If removable, bolts used (describe other fastenings) (Matl. Spec. No. Gr. Size No.) °F.

°F. Min. temp. (when less than -20° F)

17. MAWP --- psi at max. temp. _____ psi.

345 E. 47th St., New York, N.Y. 10017

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Form U-1 (Back)

18. Nozzles, Inspection and Safety Valve Openings.

Purpose (Inlet, Outlet, Drain, etc.)	No.	Diam. or Size	Type	Matl.	Nom. Thk.	Reinforcement Matl.	How Attached	Location
Rupture Disc	1	6	Flg	SA312 TP 304	.322	SA516-70	Welded	Top
N2 Recond.	2	14	Stub	SA312 TP 304	.375	SA516-70	Welded	Top
N2 Vent & Fill	2	1 & 3/4	Stub	SA312 TP 304	.154	---	Welded	Top
Pump Out	1	3	Flg	SA312 TP 304	.216	---	Welded	Top
Feed Thru	7,1	10 & 3	Flg	SA106-B	.365,.216	SA516-70	Welded	Top
Hutch Mtg	30	8	Flg	SA106-B	.322	---	Welded	Shell
Liquid Fill	1	3	Stub	SA312 TP 304	.300	---	Welded	Shell
Press Relief	1	6	Flg	SA312 TP 304	.322	SA516-70	Welded	Top
Access Port	1	24	Flg	SA106-B	.375	SA516-70	Welded	Top

19. Supports: Skirt No (Yes or No) Lugs 4 (No.) Legs --- (No.) Other --- (Describe) Attached --- (Where and how)

20. Remarks: Manufacturer's Partial Data Reports properly identified and signed by Commissioned Inspectors have been furnished for the following items of the report: (2) N2 Recondensers, Item 10, Weldon Inc. 3381-1 & 2

(Name of part, item number, mfg's name and identifying stamp)

CERTIFICATE OF SHOP COMPLIANCE

We certify that the statements made in this report are correct and that all details of design, material, construction, and workmanship of this vessel conform to the ASME Code for Pressure Vessels, Section VIII, Division 1.

"U" Certificate of Authorization No. 35 expires 4-30, 19 87

Date 10/4/85 Co. name Chicago Bridge & Iron Co. (Manufacturer) Signed ________ (Representative)

CERTIFICATE OF SHOP INSPECTION

Vessel constructed by Chicago Bridge & Iron Co. at Kankakee Shop

I, the undersigned, holding a valid commission issued by the National Board of Boiler and Pressure Vessel Inspectors and/or the State or Province of Illinois and employed by HSBI & I Co. of ________ have inspected the pressure vessel described in this Manufacturer's Data Report on Oct. 4, 19 85, and state that, to the best of my knowledge and belief, the Manufacturer has constructed this pressure vessel in accordance with ASME Code, Section VIII, Division 1. By signing this certificate neither the Inspector nor his employer makes any warranty, expressed or implied, concerning the pressure vessel described in this Manufacturer's Data Report. Furthermore, neither the Inspector nor his employer shall be liable in any manner for any personal injury or property damage or a loss of any kind arising from or connected with this inspection.

Date 10/4/85 Signed [signature] Jr. (Authorized Inspector) Commissions N.B. 9857 IL. 1302 (Nat'l Board, State, Province and No.)

CERTIFICATE OF FIELD ASSEMBLY COMPLIANCE

We certify that the field assembly construction of all parts of this vessel conforms with the requirements of Section VIII, Division 1 of the ASME Boiler and Pressure Vessel Code.

"U" Certificate of Authorization No. 35 expires 4-30, 19 87

Date 11-6-85 Co. name CHICAGO BRIDGE & IRON Co. (Assembler that certified and constructed field assembly) Signed [signature] (Representative)

CERTIFICATE OF FIELD ASSEMBLY INSPECTION

I, the undersigned, holding a valid commission issued by the National Board of Boiler and Pressure Vessel Inspectors and/or the State or Province of ILLINOIS and employed by H.S.B.I. & I. Co. of HARTFORD CT. have compared the statements in this Manufacturer's Data Report with the described pressure vessel and state that parts referred to as data items ________, not included in the certificate of shop inspection, have been inspected by me and that, to the best of my knowledge and belief, the Manufacturer has constructed and assembled this pressure vessel in accordance with ASME Code, Section VIII, Division 1. The described vessel was inspected and subjected to a hydrostatic test of 33 psi. By signing this certificate neither the Inspector nor his employer makes any warranty, expressed or implied, concerning the pressure vessel described in this Manufacturer's Data Report. Furthermore, neither the Inspector nor his employer shall be liable in any manner for any personal injury or property damage or a loss of any kind arising from or connected with this inspection.

Date 11-5-85 Signed [signature] JR. (Authorized Inspector) Commissions N.B. 9857 IL. 1302 (Nat'l Board (incl. endorsements), State, Prov., and No.)

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LAC VESSEL ENGINEERING NOTE

TABLE OF CONTENTS

BACKGROUND

This vessel is an ASME certified vessel to operate between 1 psig and 4 psig. The MAWP is 16 psig.

The vessel, which contains detectors of considerable volume and mass, is located inside the MW Building. Pressure is controlled by LN_2 coils located within the ullage space (Please refer to the attached CBI drawing). These LN_2 coils are dubbed "Operating Pot" and "Cooldown Pot" and are an integral part of the vessel. Separate 14.1 notes for these "pots" will be written to ensure adequate design with respect to the Liquid Argon Calorimeter (LAC).

The relief system is composed of a single relief valve and burst disk which are plumbed to a common 14 IPS discharge header. This vent piping is arranged such that no discharge can hit people, equipment, or the vessel. In addition, the piping is installed in such a way that the cooling effect of the contents does not influence performance of the relief devices. Singe the vent piping discharges outside the building, precautions are taken to insure that no obstructions may develop which could reduce the capacity of the relief system.

Specifications for the relief devices are as follows, from the tags:

Relief Valve (AGCO) SV 3003

Anderson - Greenwood	
Part No:	93T0608A
Size:	6"
Serial No:	85/06244
Set Pressure:	7 PSIG
Capacity:	5933 scfm, air

Burst Disk RD 3002

BS&B Rupture Disk	
Capacity:	9371 scfm, air
Size:	6"
Material:	AL, TFE, 316, AL
Lot No:	85001807-2
Rupture Pressure:	12.5 PSIG @ 72°F

A complete system schematic, Research Division Drawing **"E-706 Flow Sheet"**, 2220.1- ME-183293, Revision 11, is attached for reference.

VESSEL PHYSICAL DATA

Vertical Cylinder vessel: 17' diameter x 28' tall

Total volume of LAr: 18000 gallons

Total external surface area
for CGA computations: 1641 ft^2

Working pressure range: 1 psig to 4 psig

MAWP: 16 Psig

The insulation system is shown in the attached description. Note that GN_2 shielding is used.

For relief computations the following equation will be used:

$$F \times MAWP + 14.7 = P \text{ absolute}$$

$$F = \text{CGA Factor } (1.21, 1.16, \text{etc.})$$

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SUBJECT: LAC Vessel Flange Temperature

BY: R.I. Dachniwskyj

DATE: 7/20/87

There are four possible scenarios that could cause the flange temperature to drop below -20 F, they are as follows:

1.) Cryogen spillage on or near the critically stressed points of the carbon steel vessel part

2.) Substantial Argon gas leakage through the flanges located on the top or side of the vessel.

3.) An uncharacteristically low room temperature perhaps resulting from a power outage during the winter.

4.) Overfilling of the LAC vesse with liquid Argon

Appendix A contains a note titled "LAC Vessel Flange Temperature" which shows that it is highly improbable to spill cryogens on critically stressed points of the carbon steel vessel and as long as the ambient temperature around the flange is kept above 40 F it will not be possible for the flange to reach -20 F.

To protect the flange from cold temperatures due to excessive Argon gas leakage and overfilling of the LAC vessel, there are thermocouples placed around the outside of dewar flange at six equally spaced locations (60 degrees apart). There are also two platinum resistors, one which is 85 inches above beam center which warns the operator of a high liquid Argon level and another resistor at 88 inches above beam center, which automatically closes PV300 and PV101 and trips off the pump when liquid Argon reaches it. Appendix B contains the procedures which will be followed if there is excessive gas leaking past the flange and/or if LAC vessel continues to fill beyond the 88 inch mark above beam center line.

The flanged area is completely enclosed by the Faraday room, therefore it is only necessary to keep the Faraday room above 40 F to prevent the flange from going below -20 F. Electic base board heating units will be installed, to assure that the Faraday room never goes below 40 F. In case of an electrical outage a permanent generator will be provided to power the base board units. Appendix B contains the procedure that will be followed if the Faraday room temperature starts to fall below 40 F.

APPENDIX A

March 7, 1986

TO: F. Lobkowicz, E706

FROM: K. Dixon

SUBJECT: LAC Vessel Flange Temperature

Without adequate protection measures, there is a possibility that the upper shell of the LAC vessel will experience a temperature which could cause structural damage perhaps leading to a catastrophic failure. This scenario could evolve most probably from:

1. Cryogen spillage on or near the critically stressed points of the carbon steel vessel part.

2. Substantial argon gas leakage through flanges located on the top or side of the vessel.

3. An uncharacteristically low room temperature perhaps resulting from a power outage during the winter. (Remember the Space Shuttle!)

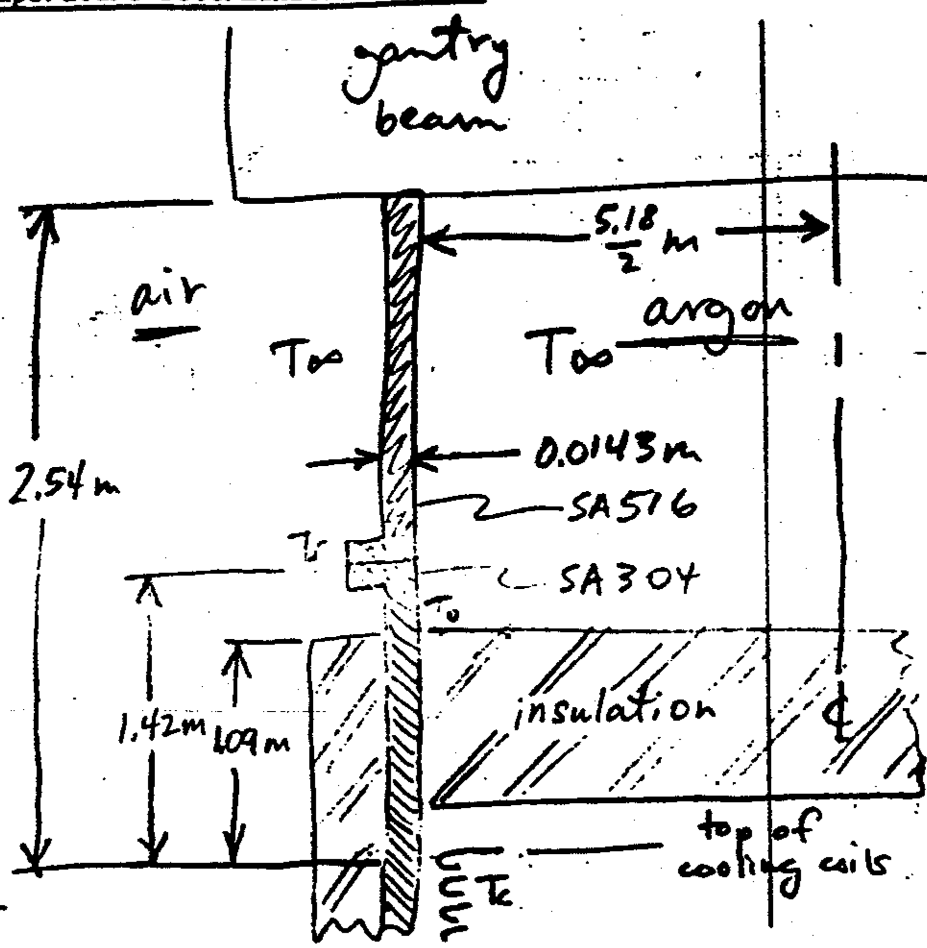
The first scenario is highly improbable due to transfer line locations, failure rates, and proposed safety measures. Although the second scenario could be more probable, it will not be discussed in this letter.

Regarding item #3, it appears that if the temperature in the MW Detector Hall dropped below +27°F for a period of time, with enough frost buildup it is possible for the flange to reach a critical -20°F. Since this is a highly stressed area, it will be susceptible to structural failure.

Therefore, I recommend some means to ensure that the air temperature around the uninsulated top portion remains above +40°F or that flange heaters of sufficient power be employed. If a decision is made to maintain a warm air temperature, one must be careful to include the uninsulated portion below the flange as well as above it.

KD/tg
cc: R.P. Smith

Flange Temperature Determination on LAC



k_{SA304} = 15.0 W/m·K @ 300 K

= 12.1 W/m·K @ 170 K

k_{SA516} = 53 W/m·K

$P = 2 \pi d$

= 32.5 m

$A = \pi d t$

= 0.233 m^2

$$q_{\substack{cond\\cold}} = q_{\substack{cond\\warm}} + q_{conv}$$

$$q_{\substack{cond\\cold}} = \frac{\bar{k}A\,(T_o - T_c)}{\Delta x}$$

For top uninsulated parts, assume an infinitely long fin of SA 304 material with a base temperature, T_o, equal to the wall temperature just above the insulation. To find T_o, we will assume the following heat balance

$$q_{\substack{cond\\warm}} + q_{conv} = \sqrt{hPkA}\quad (T_\infty - T_o)$$

Ref. Karlekav & Desmond, Engr. Heat Transfer, West Publishing Company, 1977, p. 471.

$$\therefore \frac{k_c A}{\Delta x}(T_o - T_c) = \sqrt{hPkA}\,(T_\infty - T_o)$$

$$T_o = \frac{k_c A/\Delta x\ T_c + \sqrt{hPk_w A}\ T_\infty}{k_c A/\Delta x + \sqrt{hPk_w A}}$$

$$h_{avg} = \frac{Nu_{avg}\,k_{fluid}}{L}$$

$$Nu_{ag} = C(R_a)^n \quad R_a = G_r\,P_r$$

.·. use 2.3 W/m^2k for h

$$\frac{k_c A}{\Delta x} = \frac{12.1\ (0.233)}{1.09} = 2.59\ W/K$$

$$\sqrt{hPK_w A} = [2.3(32.5)(15.0)(0.233)]^{1/2} = 1.1\ W/K$$

$$T_o = \frac{2.59\ (87\ k) + 16.1\ (300\ k)}{2.59 + 16.1}$$

$$T_o = 270\ k$$

$$\frac{T_f - T_\infty}{T_o - T_\infty} = e^{-mx}$$ Ref: Karlekav & Desmond, p. 468

$$T_f = e^{-mx}\ (T_o - T_\infty) + T_\infty$$

$$m = \frac{hP}{kA} = \frac{2.3\ (32.5)}{15\ (0.233)}^{1/2} = 4.62$$

$$x = 1.42 - 1.09 = 0.33\ m$$

$$T_f = e^{-(4.62)(0.33)}\ (259 - 300) + 300$$

$T_f = 291$ K flange temperature w/no frost

$$q = \frac{12.1\ (0.233)\ (270 - 87)}{1.09}$$

q = 473 watts to cold

Minimum allowable flange temperature is -20^oF or 244 K. For simplicity we will find what T_∞ must be for $T_o = 244$ K. By using previous methods and units: k_c = 14 T_{fin} = 261, h_{air} = 1.86, h_{argon} = 1.48, and h_{avg} = 1.67

then

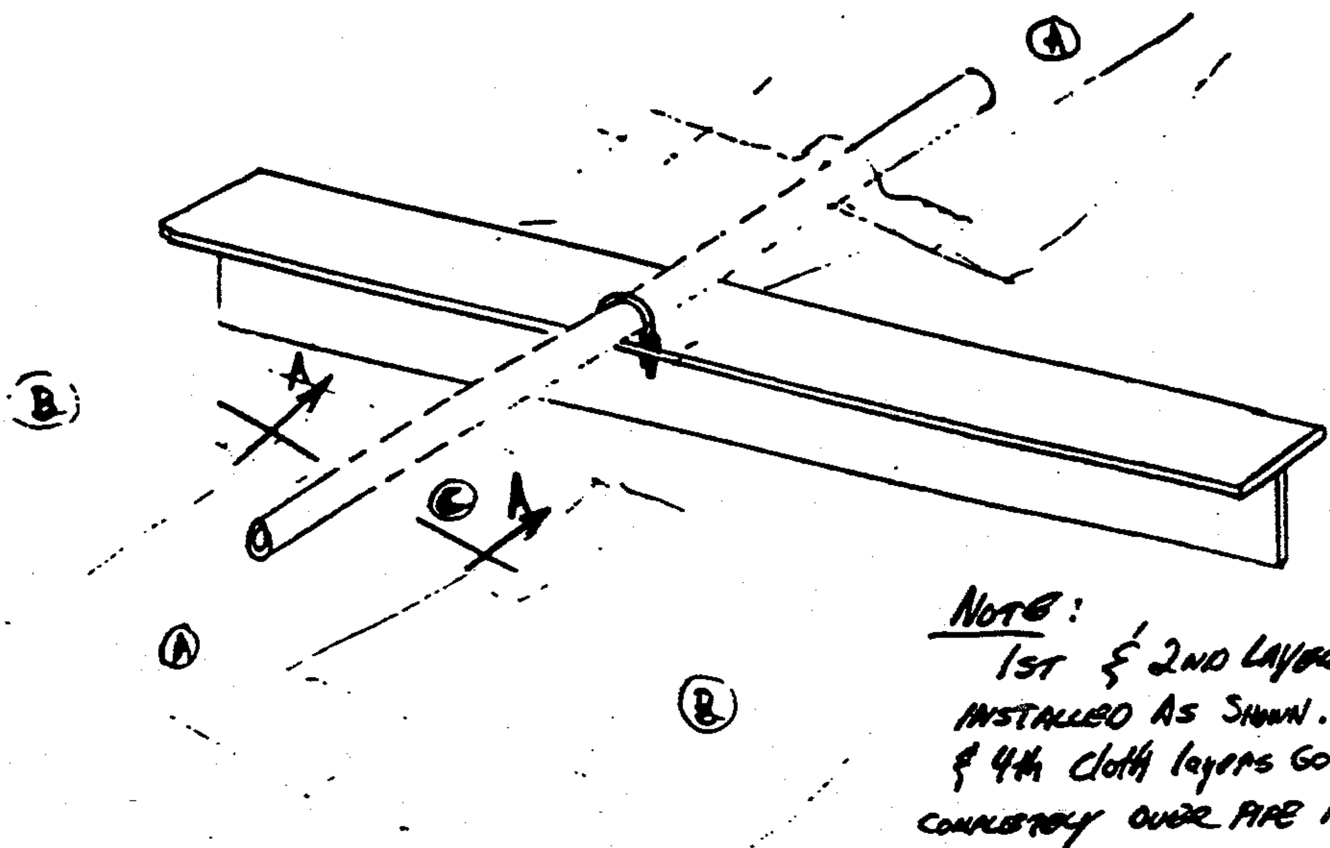
$$T_o = \frac{2.24\ (87) + 13.3(T_\infty)}{2.24 + 13.3}$$

$$T_o = 12.5 + 0.856\ T_\infty$$

$$T_\infty = \frac{T_o - 12.5}{0.871}$$

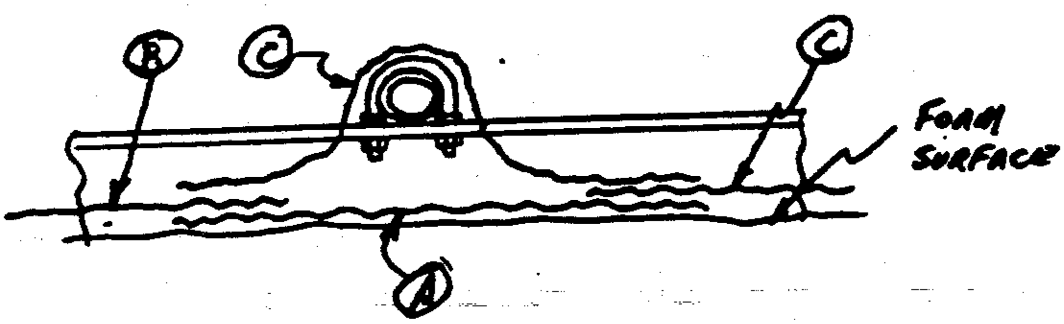
$$= \frac{244 - 12.5}{0.856}$$

$= 270$ K or $27^{o}F$



NOTE:
1st & 2nd Layers installed as shown. 3rd & 4th cloth layers go completely over pipe and stiffener, no special detail

CLOTH LAYOUT

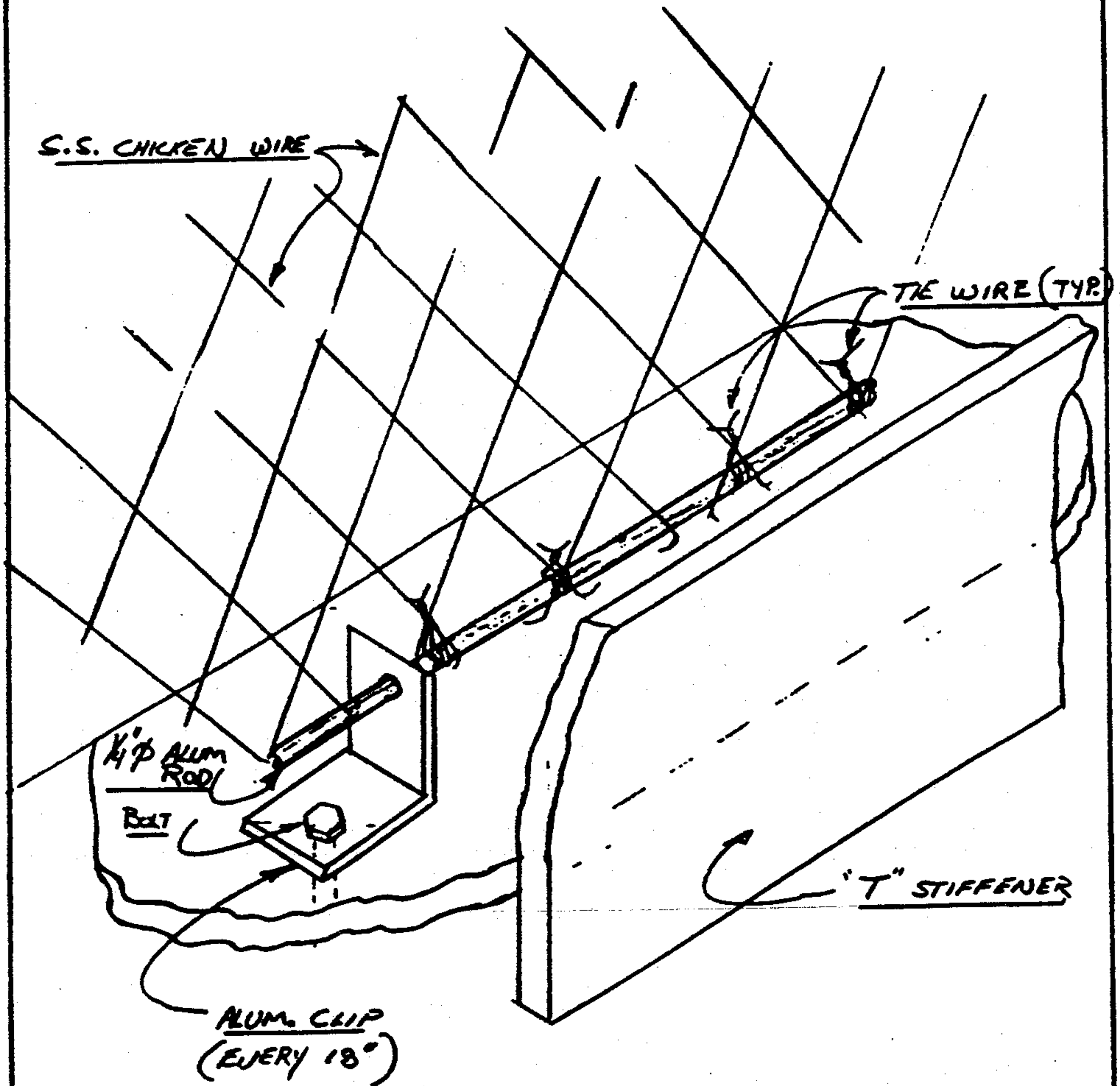


SECT A-A

REINFORCEMENT DETAILS AT PURGE PIPE

(FOAM NOT SHOWN)

SUBJECT	OFFICE	REVISION		REFERENCE NO.
LIQUID ARGON DEWAR INSUL. DETAILS	CBI OB ENG			851553
	MADE BY: MPD / CHKD BY:	MADE BY	CHKD BY	SHT 3 OF ___
	DATE / DATE	DATE	DATE	



SUBJECT	OFFICE	REVISION		REFERENCE NO.
LIQUID ARGON DEWAR INSULATION DETAILS	CBI [illegible]			85 [illegible]
	MADE BY: RS / CHKD BY:	MADE BY	CHKD BY	SHT 4 OF __

APPENDIX 8: PROCEDURES TO PREVENT OVERCOOLING OF LAC VESSEL UPPER FLANGE

D. Overcooling of LAC Vessel Upper Portion

There is a reasonable possibility of structural failure of the LAC vessel should the upper portion become exposed to -20°F or less. Therefore, it is imperative to take immediate action at the first sign of overcooling. The following identifies the possible scenarios, their symptoms, and emergency actions to be taken.

1. LAC Overfill

The LAC can be overfilled by allowing PV-300 to stay open too long and failure of the interlocks or by having PV-306 allowing flow to the LAC where it is slowly condensed. High liquid level will be indicated by LI-317 (alarm sounds for 29 level lights in Counting Room. 30 lights should close PV-300) and LI-310 (closure of PV-300 should occur at 197.5 inches argon).

If an overfilled condition exists, LI-317 higher than 29 level lights, then the following steps should be taken.

a. Close PV-300 or PV-101 if fill/dump line jumper is installed. Other liquid line manual valves could be closed as well.
b. Close PV-306 and MV-1031.
c. If the fill/dump line jumper is installed and pumped and purged to argon, then lower the argon level by sending argon back to the storage dewar by using the procedures outlined in Section IV, Part A.
d. If the flange temperatures are below -20°F on IBM channels 60 to 66, immediately depressurize the LAC through PV-309. Call pager 867 and request emergency assistance. If the pressure is above 1/2 psig after 5 minutes, vent the main relief valve, SV-3003 by opening its test connection.
e. Drain liquid from the LAC to the ground outdoors as follows:
    1. Connect filljumpers LAr 9393 and LAr 9394.
    2. Close MV-2001, MV-2002, MV-2003 at the argon filter. Close MV-1002A and 1028 at the dewar.
    3. Depressurize and remove jumper LAr 9293 at the filter.
    4. Open MV-2003, MV-2007, Pv-300 and MV-3001.
    5. Rope off the parking lot between MV & MW.
    6. When the flange temperature begins to rise, close MV-3001.

2. Leakage of Upper Vessel Flanges

Conditions indicative of flange leakage are: an uncharacteristically low LAC pressure, reduction of nitrogen flow to the cooling pots, unusual amounts of condensation or frost on the LAC surface, low internal ambient space temperatures (tcs 78-88) or mating flange temperatures (tcs 71-76), and/or low O_2 levels as measured by the ODH monitors.

If a leaking flange(s) is suspected, one should take the following steps.

a. Reduce the LAC pressure to 1 psig by decreasing the set pressure on CS-303 and/or CS-302.
b. Check the ODH monitors in the Faraday Room and those on the top of the LAC.
c. If the O_2 level is acceptable, then use O_2 monitors, air packs, and someone as a spotter before entering slowly. Proceed to step g.

d. If the O_2 level is unacceptable, DO NOT ATTEMPT TO ENTER! Only qualified personnel having the proper equipment and supervised by the Fire Department may enter an oxygen deficient area.

e. If no such personnel are immediately available and the flange temperatures are above or leveling off above -20°F, then proper help can be waited for. Otherwise decrease the LAC pressure to 0 psig and proceed to drain the LAC by using steps c through f of the immediate proceeding procedure.

f. When qualified personnel, equipment, and the Fire Department are available, enter the Faraday Room or the top of the LAC.

g. Suspect flanges can be found by listening for leakage, sighting cold areas around the seal area, or by using an O_2 monitor.

h. Tighten or repair as required. Do not exceed the maximum torque values.

i. If the leak can not be stopped and it creates an ODH problem or is contaminating the argon and rendering it useless, then the LAC will have to be emptied in accordance with steps c through f, of the previous procedure.

j. If the leak has been stopped, then set CS-303 and/or CS-302 back to the normal operating pressure.

3. Low Faraday Room Temperature

If the temperature in the Faraday Room dropped much below 32°F for a period of time to create enough frost buildup on the vessel surface, it is possible for the mating flange to reach a condition of structural instability.

During the winter months when heat is lost to the Faraday Room (loss of power to the electronics and building heaters) one should do the following.

a. An alarm will sound in the counting room when the room temperature falls below +40°F. If this occurs, put the portable electric heaters in the Faraday Room.. If power has failed.. get an emergency generator from the Cryo Dept.

b. Closely monitor the LAC mating flange temperatures on IBM channels 60-66. If they approach -20°F., see "LAC Overfill", Section VI.D.1.

Fermilab

RD/Safety Group - MS #219
Wilson Hall 11th Floor - Ext. 3511

July 20, 1987

TO: Reviewer of LAC Vessel Engineering Analysis

FROM: R. Scherr/S. Stoy - E-706 Cryo Safety Review Panel R. Scherr S. Stoy

SUBJECT: LAC Venting Capacity

The E-706 Cryo Safety Review Panel has reviewed the calculation by R.Dachniwskyj for the venting flow capacities through the relief devices installed on the LAC vessel.

The panel will accept a reduction in venting flow capacities of 73% of the CGA requirement providing that two smoke detectors hooked to FIRUS are installed around the outside of the LAC vessel near the flange.

Although the vessel insulation was not conclusively proven to not propagate flame, it has been demonstrated that the flame retardant coating would delay sufficient heat transfer to deteriorate the foam insulation for several minutes. The installation of the smoke detectors would sound an early warning of smoke or fire in the area of the LAC and summon the emergency fire crews who are able to respond in less than 3 minutes to investigate the cause of the smoke and extinguish the fire.

cc W.Cooper
S.Stoy
R.Schmitt
R.Dachniwskyj
T.Murphy

TO: BILL COOPER (E706 CRYOSAFETY CHAIRPERSON)

From: ROMAN I. DACHNIWSKYJ

DATE: 7/6/87

Subject: MAXIMUM VENTING RATE, DURING STEADY STATE CONDITIONS. FOR THE E706 LIQUID ARGON CALORIMETER (LAC)

INTRODUCTION: COMPARISON of the AVAILable flow rate from the ANDERSON-GREENWOOD 6" x 8" 93T PILOT OPERATED RELIEF VALVE AND the 6" BS AN B Rupture disk AS RESTRICTED by the exsisting inlet AND exit vent line piping to that required by the compressed GAS ASSOCIATION (CGA) phamphlet S1.3 - 1980 edition paragraph 5.3.3 using NO REDUCTION FACTOR during steady STATE CONDITIONS.

ASSUMPTIONS:

1) STEADY STATE. (NO ~~cooldown~~ transients considered)
2) heat flux into the flowing media has an Negligible EFFECT ON THE PRESSURE DROP.
3) ~~the~~ flow is ~~taken~~ to be incompressible, Mach Number < 0.33.
4) flow properties to be determined ~~AS AN AVERAGE VALUE through~~ a ~~particular length~~ of the VENT SYSTEM
5) MAXIMUM ALLOWABLE WORKING PRESSURE (MAWP) EQUALS 16 PSIG FOR THE LAC VESSEL.
6) MAWP OVERPRESSURE due to A fire CONDITION EQUALS (MAWP)(1.21) + 14.7 = 34.1 PSIA.
7) FLOW through both RELIEF DEVICES. IS SUBSONIC.

REQUIRED FLOW RATE per CGA phamphlet S1.3-1980 EDITION paragraph 5.3.3.

$$Q_A = G_u A^{0.82}$$

Q_A = FLOW capacity in cubic feet per MINUTE OF FREE AIR

G_u = GAS Factor For UNINSULATED CONTAINERS

A = TOTAL OUTSIDE SURFACE AREA OF the CONTAINER IN SQUARE FEET.

$$G_u = \frac{633,000}{LC}\sqrt{\frac{ZT}{M}}$$

Z = (1.0) Compressibility Factor at Flowing CONDITION

T = (173.2 °R) TEMPERATURE of lading at Flowing PRESSURE.

M = (40) MOLECULAR weight of ARGON

C = (377) CONSTANT FOR gas RELATED to RATIO OF SPECIFIC HEATS

L = (66.27 BTU/LB) Latent heat At flowing CONDITIONS

∴ G_u = 52.73

A = Area of cylinder below the flange

+ Area of the ASME dished and flanged head

+ Area of the cylinder above the flange

+ Area of the top head (flat circular disk)

$$= \frac{\pi(204)(221)}{144} + 282 + \frac{(\pi)(204)(17)}{144} + \frac{\pi(204)^2}{(4)(144)}$$

$$= 1738 \text{ FT}^2$$

$$\therefore Q_A = 52.73 \cdot (1738)^{0.82}$$

$$= 23,928 \text{ SCFM.}$$

DETERMINING FLOW (PRESSURE DROPS) through the VENT PIPE SYSTEM

TABLE 1

TABLE of VENT PIPING RESISTANCE COEFFICIENTS.

ITEM	D (IN)	L (IN)	f_T	K
INLET PIPING PRESSURE DROP				
ENTRANCE				0.78
6 inch sch 40 straight pipe	6.065	126	0.015	0.31
TOTAL				1.09
RUPTURE DISK VENT LINE COMPONENTS FROM the DISK to the 14 inch sch 10 VENT PIPE				
6 inch sch 5 PIPE	6.407	22	0.015	0.05
6" to 8" EXPANDER	6.407 8.407			0.20
TOTAL				0.25
90° 8 inch elbow r/d = 1.43	8.407		0.014	3.15 f_T 0.63
8 inch sch 10 PIPE	8.407	77	0.014	0.13
8 inch bellows	8.407	13x4 52	0.014	0.09
8 inch TEE branch FLOW	8.407		0.014	60 f_T 0.84
TOTAL				1.69
ANDERSON GREENWOOD RELIEF VALVE VENT LINE COMPONENTS FROM the VALVE TO THE 14 inch sch 10 VENT PIPE				
8 inch 90° ELBOW r/d = 1.43	8.407		0.014	0.21
8 inch sch 10 PIPE	8.407	62	0.014	0.10
8 inch bellows	8.407	13x4 52	0.014	0.09
8 inch tee through RUN	8.407		0.014	20 f_T 0.28
TOTAL				0.68
14 inch sch 10 VENT LINE COMPONENTS				

TOTAL				0.4
14 inch sch10 pipe	13.5	239	0.013	0.23
14 inch bellows		21 x 4 84	0.013	0.09
14 inch 90° elbow r/d = 1.56	13.5		0.018	14. ft 0.18
EXIT LOSS				1.0
TOTAL				1.50

APPENDIX A INCLUDES the following drawings which give the dimensions, sizes and types of components used to construct the E706 LAC VENT LINE And produce Table 1:

2753.700-ME-193629
2753.700-ME-193497
2753.700-ME-193627

EQUATIONS USED TO DETERMINE PRESSURE DROP (FLOW)

For PIPE

$$\Delta P = \frac{\rho K v^2}{144\, 2g}$$

From CRANE Technical paper 410 pg 1-6

g = gravitation constant 32.2 FT/sec²

ρ = density [Lb/FT³]

K = RESISTANCE COEFFICIENT

v = Velocity of the flowing MEDIA [FT/sec]

Δp = pressure drop [psi]

For ANDERSON - GREENWOOD Relief VALVE (subsonic flow)

From AGCO catalog

$$P_1 = \frac{429 \cdot W \sqrt{TZ}}{[illegible] \cdot K_d \cdot A \cdot F' \cdot \sqrt{M}}$$

P_1 = inlet pressure to the RELIEF VALVE [psia]

W = Flow through the Relief valve [Lb/sec]

T = Temperature of Flowing MEDIA [°R]

Z = (1) compressibility Factor (Z = 1)

K_d = (0.989) Actual ~~[illegible]~~ MEASURED NOZZEL COEFFICIENT

A = (19.56 in²) REQUIRED ORIFICE AREA

F' = Factor based upon the ratio of specific heats and pressure drop across valve nozzle. Fig 3 From AGCO catalog 1900 Revised March 1982.

M = (40) molecular weight of ARGON

For BSAN B 6 inch RUPTURE DISK
(subsonic flow)

$$P_o = \frac{W}{K C_1 a} \cdot \sqrt{\frac{T + 460}{M}}$$

P_o = Relieving pressure [PSIA]

W = Flow through the rupture disk [Lb/sec]

K = (0.62) ASME REQUIRES A COEFFICIENT of 0.62 For rupture disks As SOLE RELIEVING DEVICES

a = (28.3 IN^2) REQUIRED FLOW AREA

T = temperature of flowing MEDIA [°R]

M = (40) molecular weight of argon

$$\therefore P_o = \frac{W \sqrt{T}}{C_1} \cdot (0.0090)$$

Above Formula TAKEN FROM Fike METAL Products CORPORATION CATALOG ON Rupture DISKS, Explosion VENTS AND other PRESSURE RELIEF DEVICES pg. 10.

...M	P_{INLET} [psia]	P_{OUTLET}	P_{AVG} [psia]	ρ_{avg} lb/ft³	μ_{avg} centipoise	$\dot{m}$ lb/sec	Re	Area ft²	Velocity ft/sec
...ET RUPTURE DISK	34.1	32.25	33.15	0.759	8×10^{-3}	23	1.08×10^{7}	0.20	152
...ET RELIEF VALVE	34.1	31.85	32.98	0.748	8×10^{-3}	24	1.12×10^{7}	0.20	160
...TURE DISK 6 inch	34.1 − 13.204 19.06	18.45	18.76	0.420	8×10^{-3}	23	1.02×10^{7}	0.22	249
...TURE DISK 8 inch	19.06 − 0.7 18.36	17.0	17.68	0.389	8×10^{-3}	23	7.77×10^{6}	0.39	152
...IEF VALVE ...inch	34.1 − 2.26 − 14 17.84	17.13	17.49	0.389	8×10^{-3}	24	8.11×10^{6}	0.39	158
...ch vent LINE ...inch	17.13 ; 16.73 16.93	15.32	16.13	0.359	8×10^{-3}	47	1.59×10^{7}	0.39	336
...nch vent line ...4 inch	16.93 − 1.74 15.19	14.7	14.95	0.325	8×10^{-3}	47	9.89×10^{6}	1.00	145
...IEF VALVE ...ssure drop	31.[illegible]	18.85				24.4			
...PTURE DISK ...ssure drop	32.06	19.87				22.9			

TABLE 2 - Pressure drops and mass flows through the various sections of the vent line system.

ΔP PSIA	MACH NO.	
2.04	0.26	
2.26	0.27	
0.70	0.42	
1.63	0.26	
0.71	0.27	
1.74	0.57	
1.10	0.25	

DETERMINING MASS FLOW THROUGH the RELIEF DEVICE

BSAN B 6 INCH RUPTURE disk

$$W = \frac{P_0 C_1}{\sqrt{T}(0.0090)}$$

T = 173.2 °R

P_0 = 34.1 - 2.04 = 32.06 psia (inlet pressure)

↑ inlet piping pressure drop From Table 2

P_e = 14.7 + 1.10 + 1.74 + 1.63 + 0.70 = 19.87 (psia) exit pressure

Back pressure due to exit vent piping on the Rupture disk From TABLE 2

P_1 = 32.06 - 19.87 + 14.7 = 26.89 psia

P_e/P_0 = 19.87/32.06 = 0.620 ∴ C_1 = 0.1007

∴ W_{RD} = 22.9 LB/sec

Anderson Greenwood RELIEF VALVE.

$$W = \frac{P_1 \cdot F'}{\sqrt{T} \cdot (0.04218)}$$

T = 173.2 °R

P_1 = 34.1 - 2.26 = 31.84 psia (inlet pressure)

↑ inlet piping pressure drop From Table 2

P_2 = 14.7 + 1.10 + 1.74 + 0.71 = 18.25 psia (exit pressure)

Back pressure due to exit vent piping on the RELIEF VALVE From Table 2

∴ P_2/P_1 = 18.25 / ... = 0.573

$\therefore \frac{P_2'}{P_1} = 0.776$ FROM Fig 2 pg 21 FROM ASCO CATALOG 1900

$\therefore F' = 0.425$

$\therefore \dot{W}_{RV} = 24.4$ Lb/s

DETERMINING the INFLUENCE of heat transfer to the PRESSURE DROP IN the EXIT VENT line PIPING.

TOTAL mass flow = 47 Lb/sec

STEADY STATE HEAT TRANSFER TO THE VENT PIPING FROM BARRON; CRYOGENIC SYSTEMS pg 504, FOR AN UNINSULATED LIQUID OXYGEN LINE = 168.5 $\frac{W}{FT^2}$

Area of the exit vent piping = 147 FT^2

TOTAL HEAT LOAD INTO the exiting ARGON gas = (147)(168.5)

= 24,770 W

changed IN ENTHALPY = $\frac{24,770}{21.3 \times 10^3}$

= 1.16 J/g

At P= 1atm-abs this would cause the gas stream to rise ~ 2 °K

DETERMINING the Free AIR capacity of the Relief devices.

For the ANDERSON GREENWOOD RELIEF VALVE

Inlet pressure = 31.84 psiA

exit pressure = 18.25 psiA

$$\frac{P_{CF}}{P_1} = \left(\frac{2}{K+1}\right)^{\frac{K}{K-1}} \qquad K_{AIR} = 1.4$$

$$\therefore \frac{P_{CF}}{P_1} = 0.528$$

$$P_{EX}/P_{IN} = \frac{18.25}{31.84} = 0.573$$ ∴ Flow is subsonic.

$$V = \frac{A \cdot 4645 \cdot K_d \cdot P_{IN} \cdot F'}{\sqrt{MTZ}}$$

$A = 19.56\ \text{IN}^2$

$K_d = 0.939$

$P_{IN} = 31.84$ psiA

$F' = 0.410$

$M = 29$

$T = 520\ °R$

$Z = 1.0$

$\therefore V = 9,069$ SCFM of AIR.

FOR BRAND B 6 INCH RUPTURE DISK

$$Q_s = \frac{a\,(22{,}772)\,K \cdot C_1 \cdot P_1}{\sqrt{T \cdot M}}$$

P_o = 32.06 PSIA
P_c = 19.87

P_c / P_o = 0.620 ∴ C_1 = 0.0968

M = 29
T = 520.0 °R
K = 0.62
a = 28.3 IN^2
P_1 = 26.89 PSIA

∴ Q_s = 8,469 SCFM of AIR

TOTAL AVAILABLE FLOW = 17,538

$$\frac{\text{TOTAL AVAILABLE FLOW}}{\text{TOTAL REQUIRED FLOW}} = \frac{17{,}538}{23{,}928} \approx \boxed{0.73}$$

CONCLUSION: The calculated capacity of the venting system is only 73 % of that REQUIRED by the compressed gas ASSOCIATION, using the assumptions given in this paper, for a bare uninsulated vessel exposed to A fire. The CGA code allows for the Reduction of the Required flow by a 0.3 factor if the vessel is sutiably isolated from possible envelopment in a fire. It is felt that the LAC vessel is sutiably ISOLATED from possible envelopment in fire because there are no large amounts (sources) of flamable MATERIAL STORED NEAR OR AROUND the LAC and that all the flammable MATERIALS that are part of the PERMANENT INSTALLATION have been coated by a flame retardent. Therefore the 73 % capacity is more then adequate to insure safe operation of the LAC vessel.

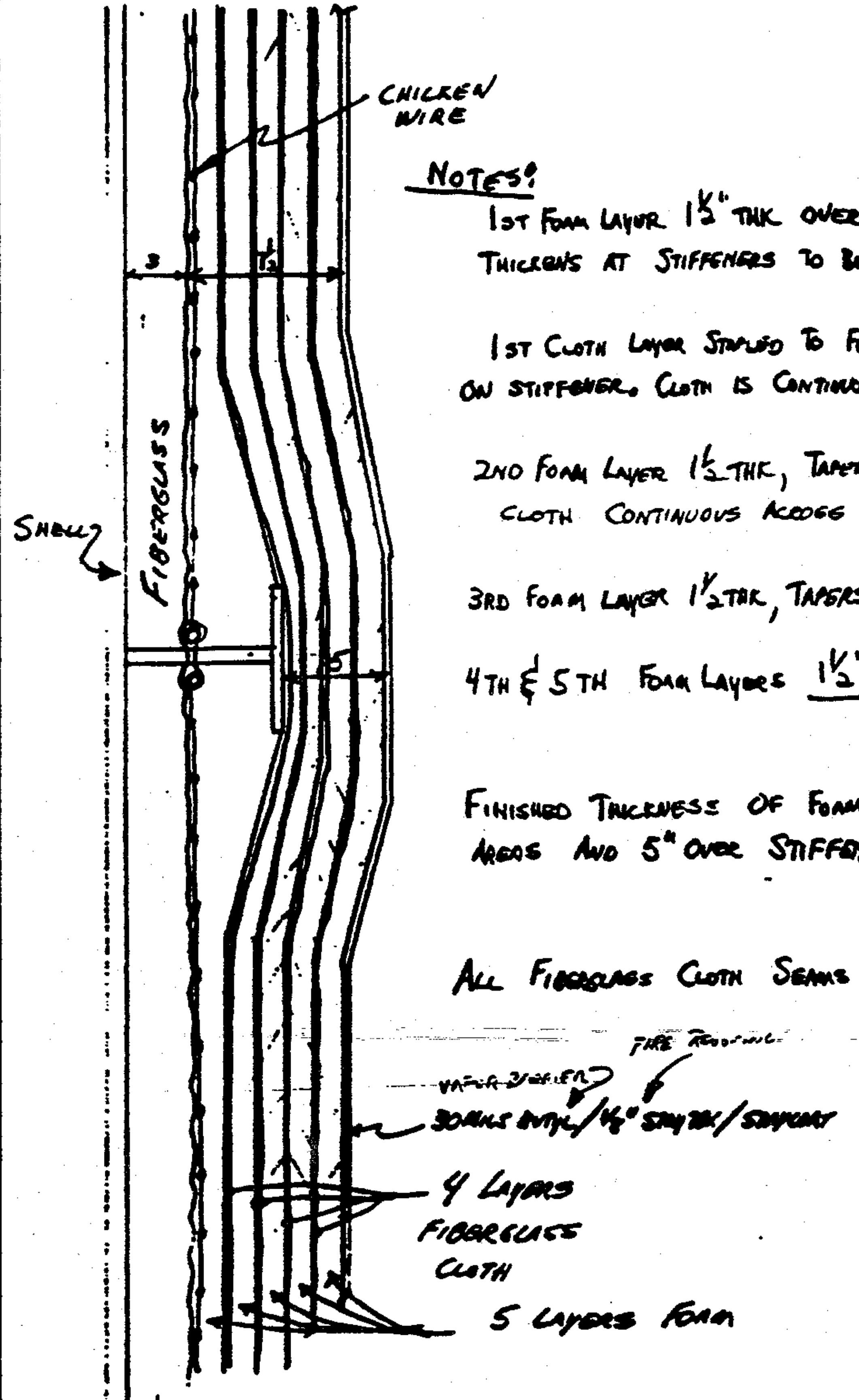
Fermilab

SUBJECT: LAC Outer Insulation

BY: R.I. Dachniwskyj

DATE: 7/20/87

The following paper, reference number 851553 from Chicago Bridge and Iron gives a detailed description of the insulation system which was installed on the liquid Argon calorimeter vessel to prevent the excessive boil off of the liquid Argon.



NOTES:

1ST FOAM LAYER 1 1/2" THK OVER FIBERGLASS, AND THICKENS AT STIFFENERS TO BE FLUSH WITH FLANGE

1ST CLOTH LAYER STAPLED TO FOAM AND LAYS DIRECTLY ON STIFFENER. CLOTH IS CONTINUOUS ACROSS STIFFENER

2ND FOAM LAYER 1 1/2 THK, TAPERS TO 1" OVER STIFF. CLOTH CONTINUOUS ACROSS STIFF., ALL LAYERS

3RD FOAM LAYER 1 1/2 THK, TAPERS TO 1" OVER STIFF

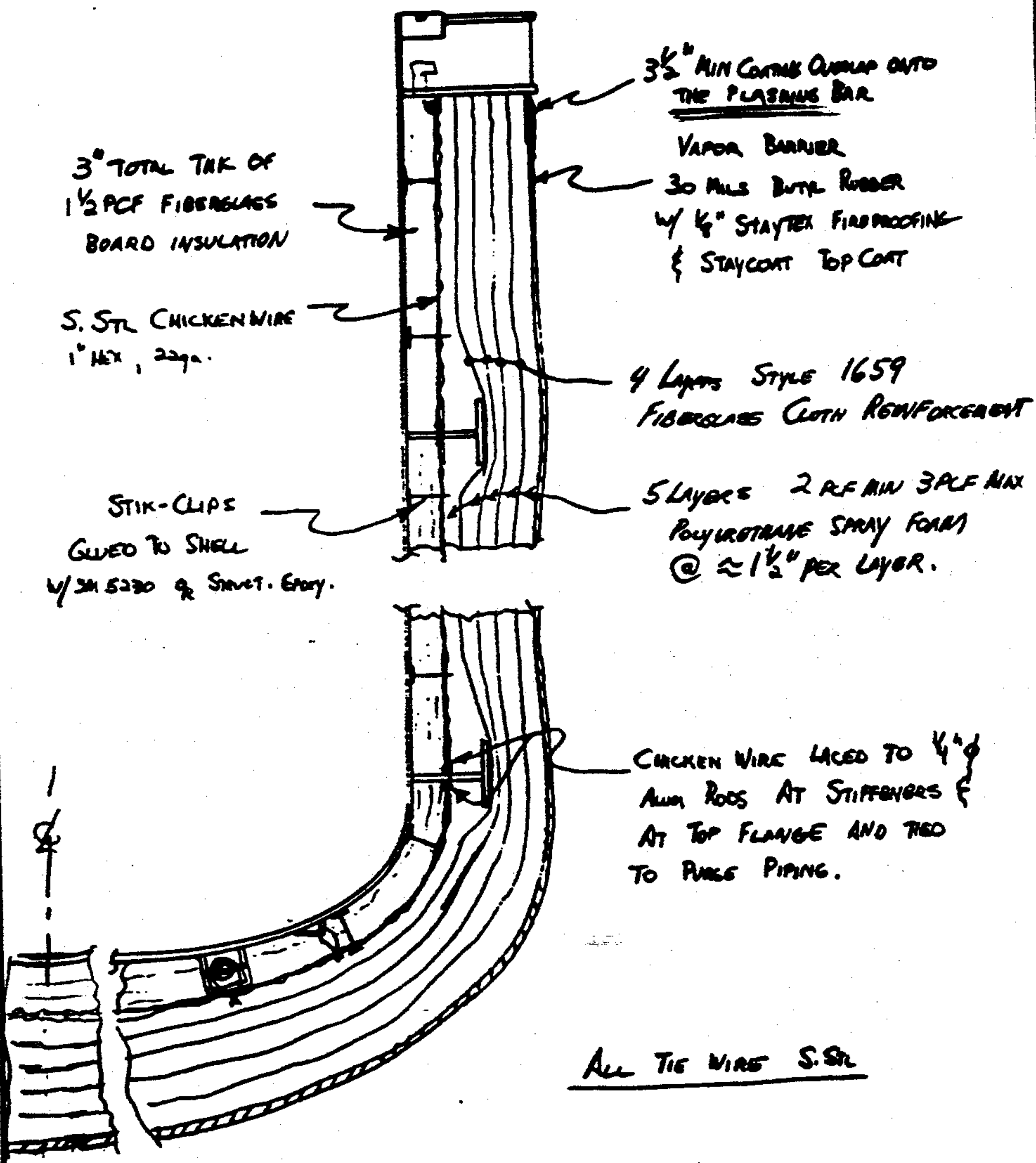
4TH & 5TH FOAM LAYERS 1 1/2" THICK OVER ALL

FINISHED THICKNESS OF FOAM IS 7 1/2" IN OPEN AREAS AND 5" OVER STIFFENER.

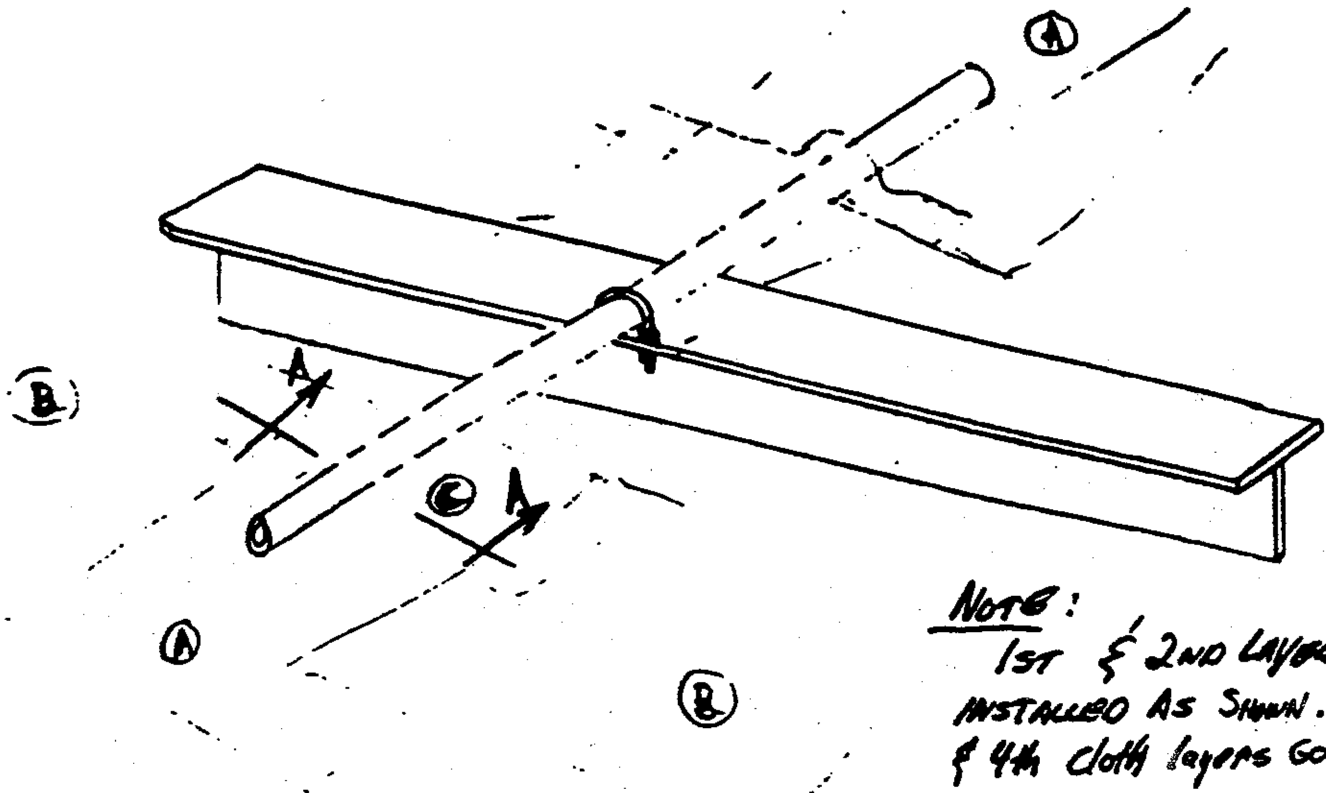
ALL FIBERGLASS CLOTH SEAMS OVERLAPPED 4" MIN.

TYPICAL DETAIL AT STIFF

SUBJECT	OFFICE	REVISION	REFERENCE NO.
LIQUID ARGON DEWAR INSUL. DETAILS	CBI CB ENG		851553
	MADE BY: NPD / CHKD BY:	MADE BY: / CHKD BY:	SHT 1 OF ___

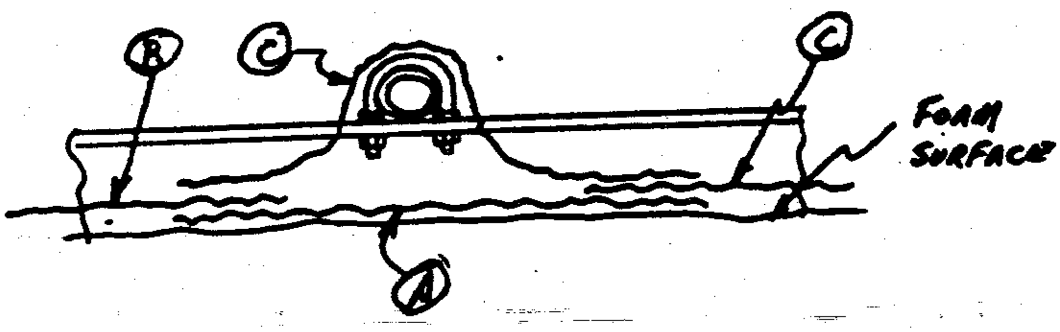


SUBJECT	OFFICE	REVISION		REFERENCE NO.
Liquid Argon Dewar Insulation Details	CBI OB ENG			851553
	MADE BY	CHKD BY	MADE BY	CHKD BY
	MPO			SHT 2 OF __
	DATE	DATE	DATE	DATE



CLOTH LAYOUT

NOTE:
1ST & 2ND LAYERS INSTALLED AS SHOWN. 3rd & 4th cloth layers GO COMPLETELY OVER PIPE AND STIFFENER, NO SPECIAL DETAIL

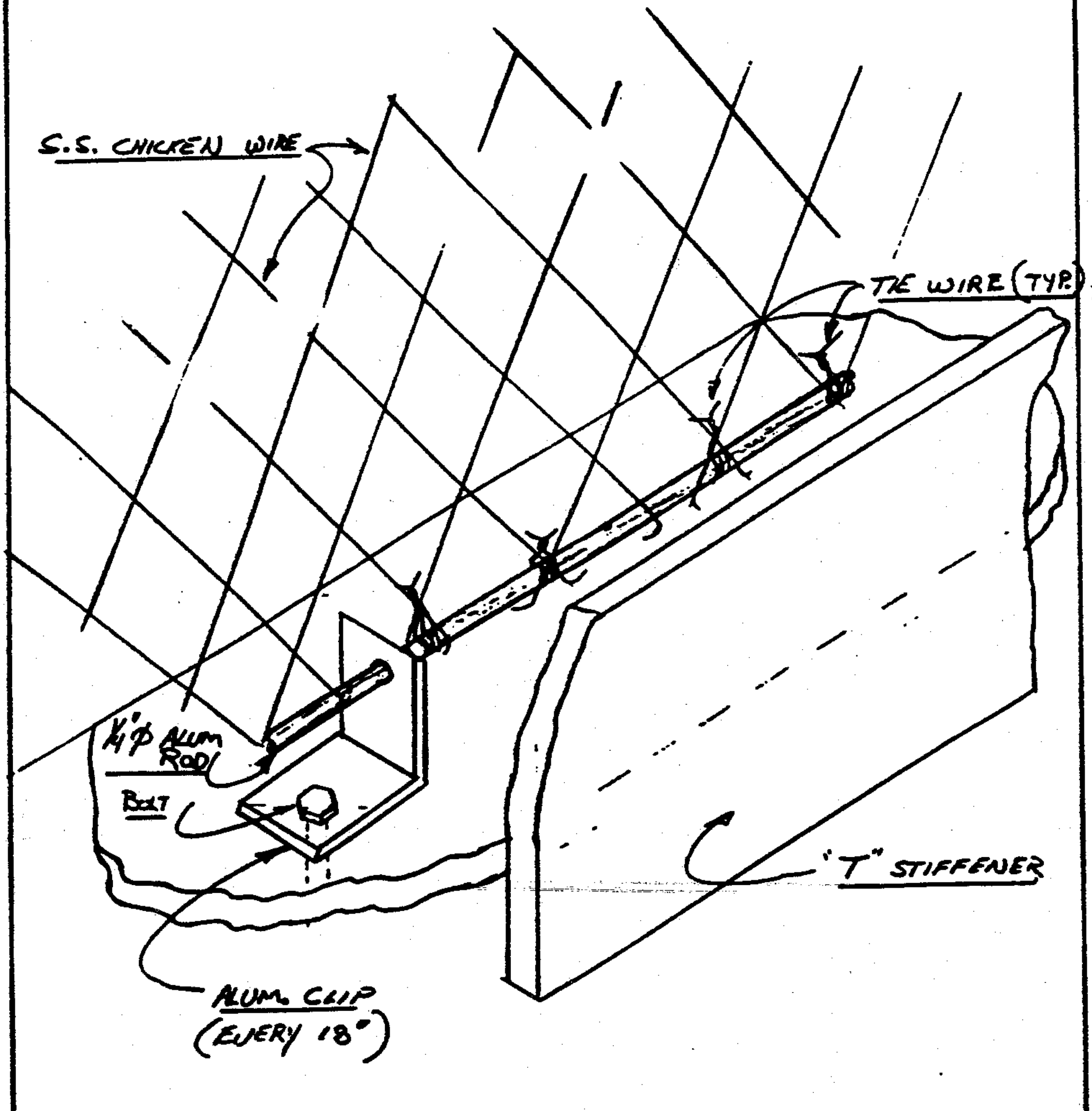


SECT A-A

REINFORCEMENT DETAILS AT PURGE PIPE

(FOAM NOT SHOWN)

SUBJECT	OFFICE	REVISION		REFERENCE NO.
LIQUID ARGON DEWAR INSUL. DETAILS	CBI OB Bldg			851553
	MADE BY MPD / CHKD BY	MADE BY	CHKD BY	SHT. 3 OF ___
	DATE / DATE	DATE	DATE	



SUBJECT	OFFICE	REVISION		REFERENCE NO.
LIQUID ARGON DEWAR INSULATION DETAILS	CBI NOVE NEW			85155-3
	MADE BY: RS	CHKD BY	MADE BY / CHKD BY	SHT 4 OF —

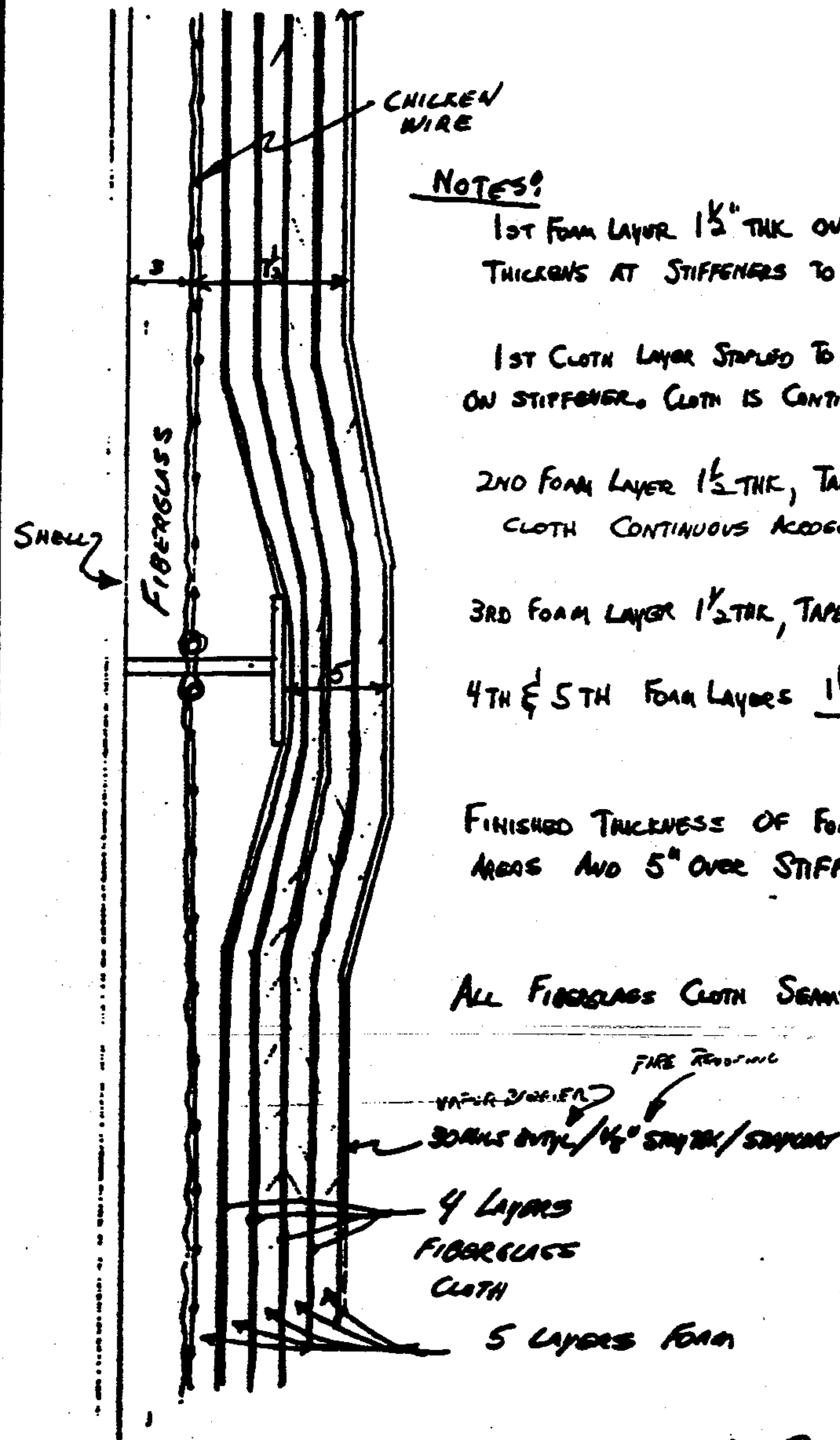
Fermilab

SUBJECT: LAC Outer Insulation

BY: R.I. Dachniwskyj

DATE: 7/20/87

The following paper, reference number 851553 from Chicago Bridge and Iron gives a detailed description of the insulation system which was installed on the liquid Argon calorimeter vessel to prevent the excessive boil off of the liquid Argon.



NOTES:

1ST FOAM LAYER 1½" THK OVER FIBERGLASS, AND THICKENS AT STIFFENERS TO BE FLUSH WITH FLANGE

1ST CLOTH LAYER STAPLED TO FOAM AND LAYS DIRECTLY ON STIFFENER. CLOTH IS CONTINUOUS ACROSS STIFFENER

2ND FOAM LAYER 1½ THK, TAPERS TO 1" OVER STIFF. CLOTH CONTINUOUS ACROSS STIFF., ALL LAYERS

3RD FOAM LAYER 1½ THK, TAPERS TO 1" OVER STIFF

4TH & 5TH FOAM LAYERS 1½" THICK OVER ALL

FINISHED THICKNESS OF FOAM IS 7½" IN OPEN AREAS AND 5" OVER STIFFENER.

ALL FIBERGLASS CLOTH SEAMS OVERLAPPED 4" MIN.

TYPICAL DETAIL AT STIFF.

SUBJECT: LIQUID ARGON DEWAR INSUL. DETAILS

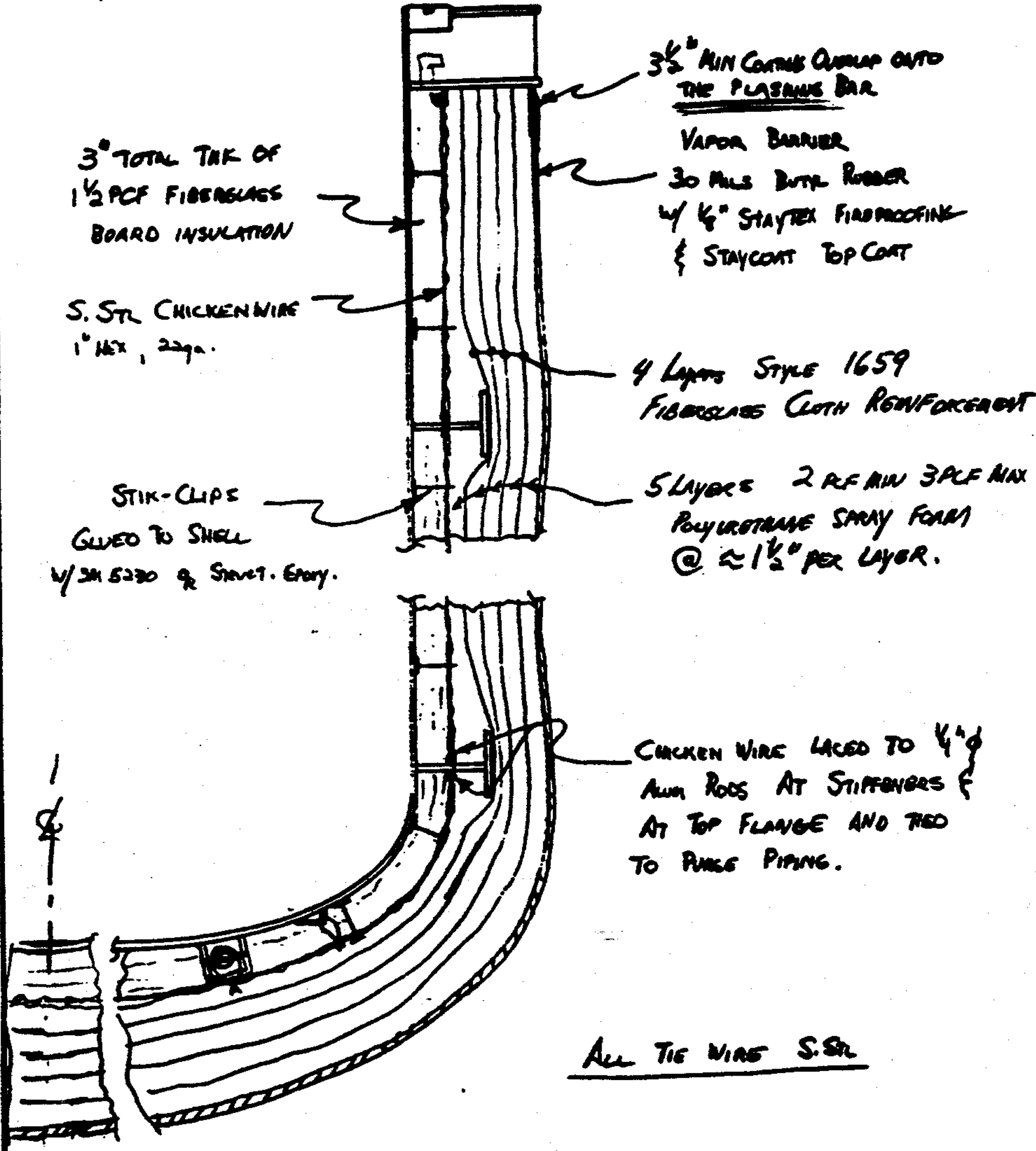
CBI OFFICE: OB ENG.

REVISION

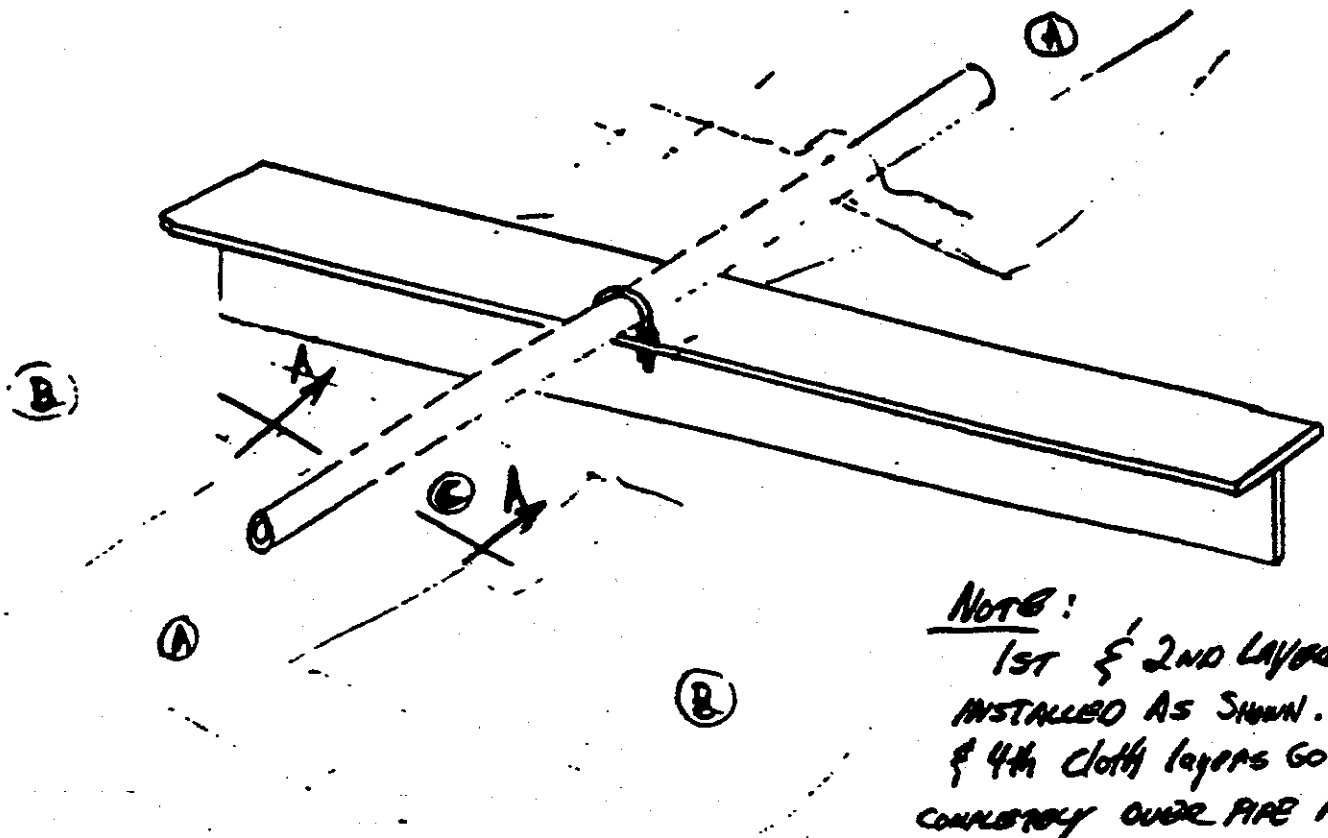
REFERENCE NO. 851553

MADE BY: NRD | CHKD BY | MADE BY | CHKD BY

SHT. 2 OF

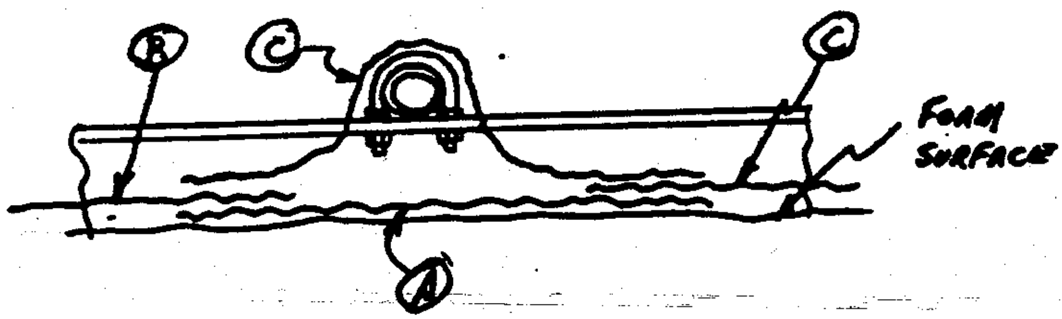


SUBJECT	OFFICE	REVISION		REFERENCE NO.
LIQUID ARGON DEWAR INSULATION DETAILS	CBI OB ENG			851553
	MADE BY: MPO / CHKD BY	MADE BY	CHKD BY	SHT 2 OF __
	DATE / DATE	DATE	DATE	



CLOTH LAYOUT

NOTE:
1ST & 2ND LAYERS INSTALLED AS SHOWN. 3rd & 4th cloth layers GO COMPLETELY OVER PIPE AND STIFFENER, NO SPECIAL DETAIL

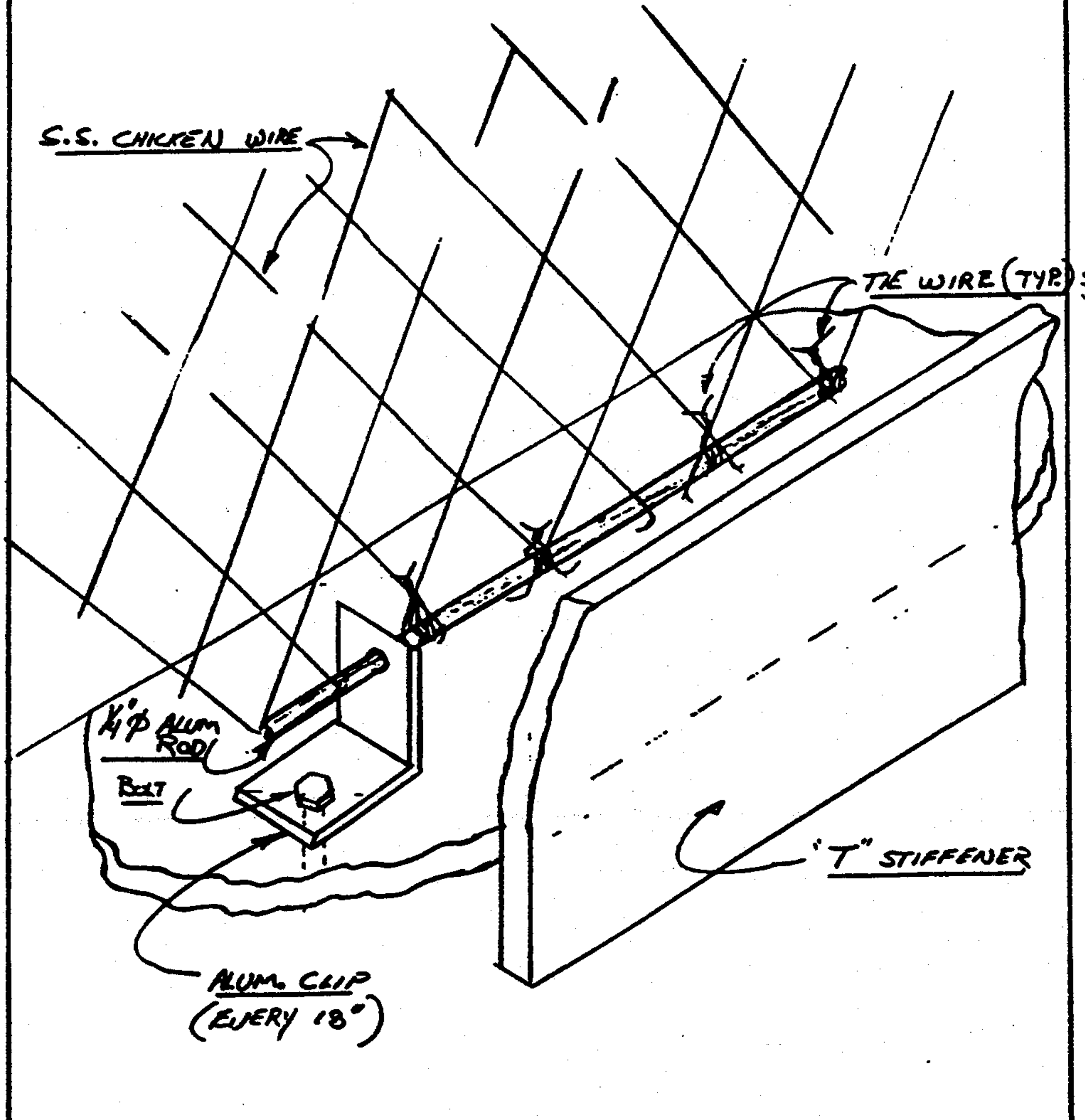


SECT A-A

REINFORCEMENT DETAILS AT PURGE PIPE

(FOAM NOT SHOWN)

SUBJECT	OFFICE		REVISION		REFERENCE NO.
LIQUID ARGON DEWAR INSUL. DETAILS	CBI OB ENG				851553
	MADE BY	CHKD BY	MADE BY	CHKD BY	SHT 3 OF __
	MPD				
	DATE	DATE	DATE	DATE	



SUBJECT	OFFICE	REVISION	REFERENCE NO.
LIQUID ARGON DEWAR INSULATION DETAILS	CBI NOVE IBEX		85155?
	MADE BY: RS / CHKD BY:	MADE BY: / CHKD BY:	SHT 4 OF __