D Zero Collider Detector

Cryopump Design
and
Operation

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Summary

The vacuum pumping of the CC Cryostat was anticipated to be dominated by a water vapor load. The Engineering Note 270, extrapolating from earlier experience, predicts the removal of water vapor will be the dominant pumping load and take ca. 45 days to remove at the pumping speed planned. Part of the planned pumping capability was a homemade, liquid nitrogen temperature, water vapor cryopump. This note describes the design, fabrication and performance experiences of the Cryopump described in the D0 assembly drawing 3740.514-ME-294693[1] .

General Design Considerations

Cryogenic pumping is the entrainment of gas molecules on a cooled surface by van der Waal's forces, i.e. gas adsorption, and the condensation and solid phase change from a gas to a solid on the cryopump surface. The latter best describes the pumping of water vapor by a one atmosphere equilibrium liquid nitrogen cooled (77.3K) bath, the case here. The vapor pressure of water at 77K is 10^{-19} Pa. Thus a cooled panel in a closed vessel reduces the pressure, i.e. pumps the gas at its surface, removing it from the free volume.

The free surface (unencumbered by barriers to gas flow) water vapor pumping speed at liquid nitrogen temperatures is 14.5 $l/(s)(cm^2)$. A uniformly cooled, flat plate, 77K, cryopump surface of 19,000 cm^2 (the surface area here) can pump saturated water vapor at 275,500 l/s. It should be clear that the space chamber technique of suspending the panels *inside* the chambers is very effective and results in the greatest possible

[1] A reduced drawing is attached in Appendix A-1

pumping. It should be equally clear that in our LAr cryostat application it is not sufficient to trap the water vapor temporarily, it needs to be *removed* from the system. That implies a connecting conductance, an isolation valve, and, as a practical LAr calorimeter design consideration, a pumping speed approximately equal to the conductance of the connection provided. In the CC cryopump the conductance was determined by the short, 4" connecting piping and serial 4" isolation gate valve. The conductance value for this arrangement is 1000 l/s at 100 microns, and scales linearly with pressure.

There are two reasons to be interested in large cryopump surface areas. The first is the pumping speed, and the second is the time between reactivation periods. If the pumped load is heavily water laden, a cryopump pumping speed matched to the available conductance will ice over very quickly and spend more time in reactivation (defrosting and drying) than pumping. The reactivation time should be designed as a small part, ca. 5%, or less, of the operate time. The operate time should, for practical reasons, be some multiple of 24 hours for the long haul pumping, i.e. other than the initial pump down.

Fabrication of the Cryopump

The design extends the surface of a 24" long, 4.125" diameter, copper tube, liquid nitrogen reservoir with three 24" by 26" by 1/16" copper sheets attached at the cylinder every 120 degrees. The sheets are then wrapped around the cylinder with interleaved spacers to make a three-in-hand spiral wrap (see A-3). Each sheet has 5 copper rod spacers. The first rod is welded at the cylinder for improved thermal conductivity, and then the sheet and the remaining rods are tack welded to the previous copper spiral-to-spiral spacer rods for dimensional stability. The net surface area provided by this arrangement is the 19,000 cm^2 previously mentioned. The liquid nitrogen cooled assembly is thermally isolated by a stainless steel extension tube from the supporting flange, and assembles into a 8" IPS vacuum jacket. The assembly is operated vertically, and gravity holds the pump assembly in place and makes the initial flange "O" ring seal to the vacuum jacket. This arrangement inherently relieves the vessel should the pressure overcome the gravity forces, at ca. 5 psig. The 8" jacket has a

4" IPS connection that serves as the inlet (see A-1).

Although the pump can be operated without a "forepump", the need to put the pump online after reactivation and speed the initial pump down justifies a vacuum connection. A 1" CVI pumpout was installed for those reasons, and serves as a convenient fabrication and installation PO as well. After a number of reactivations the fore pump was left in place, and pumped all through the normal reactivation period.

Performance

The pump was assembled to the cryostat at 4" port installed for the purpose in a signal box closure plate (see A-4). Although the cryopump assembly was originally planned to cantilever from the short 4" stub, the final decision provided a supporting gusset for the ca. 200 lb. load.

The performance of the cryopump was disappointing at first. Outgassing loads early in the pump down with large noncondensible components are not greatly aided by, especially a dead-ended (no forepumping) cryopump. As soon as the background gas load subsides, the water vapor dominates the load and significant cryopumping begins.

The liquid nitrogen in the pump was maintained with an automatic fill system. A resistor level gage sensor controls a liquid nitrogen source solenoid to fill the volume below a given level, and close at a level a few inches higher. The fill scheme worked unerringly throughout, but the cold vapor generated and the liquid droplets impinging on the flange surface with each fill cooled the upper flange after a while. The cooling caused an "O" ring failure on two occasions. After the second such failure that problem was successfully addressed by a modification to lower fill level and the application of a layer of foam insulation on the cryopump top flange.

A concern that the radiation load on the outer ends of the copper spiral sheets might warm them enough to seriously reduce their pumping capacity led to the addition of a radiation shield. A cylinder of stainless steel sheet with a closed top was fabricated to fit between the outermost cryopump fins and the vacuum shell (see A-1, radiation shield). Three pins welded to the radiation shield closure plate support it above the LN_2 vessel closure plate, but keep them thermally uncoupled. A hole was provided to accommodate the LN_2 vessel support tube. No measurement was made to determine the improvement provided by the shield.

The cryopump pumped at a rate estimated, by the measurement of accumulated water, to be five times the rate of all the other four LN_2 trapped pumps together.

Recommendations for Improvement

Although the cryopump was a practical success, it is clear that certain of the design decisions would be made differently given this operating experience.

1. Provide a larger (6"?) pumping port. That should increase the pumping speed by (6/4)**4.8.

2. Increase the size of the fore pump connection to 4" and pipe accordingly. That should aid in turn around and contribute to the overall system pumping speed.

3. Incorporate an improved radiation shield.

4. The height could be decreased, the ice never formed above the ca. middle of the pump vertically.

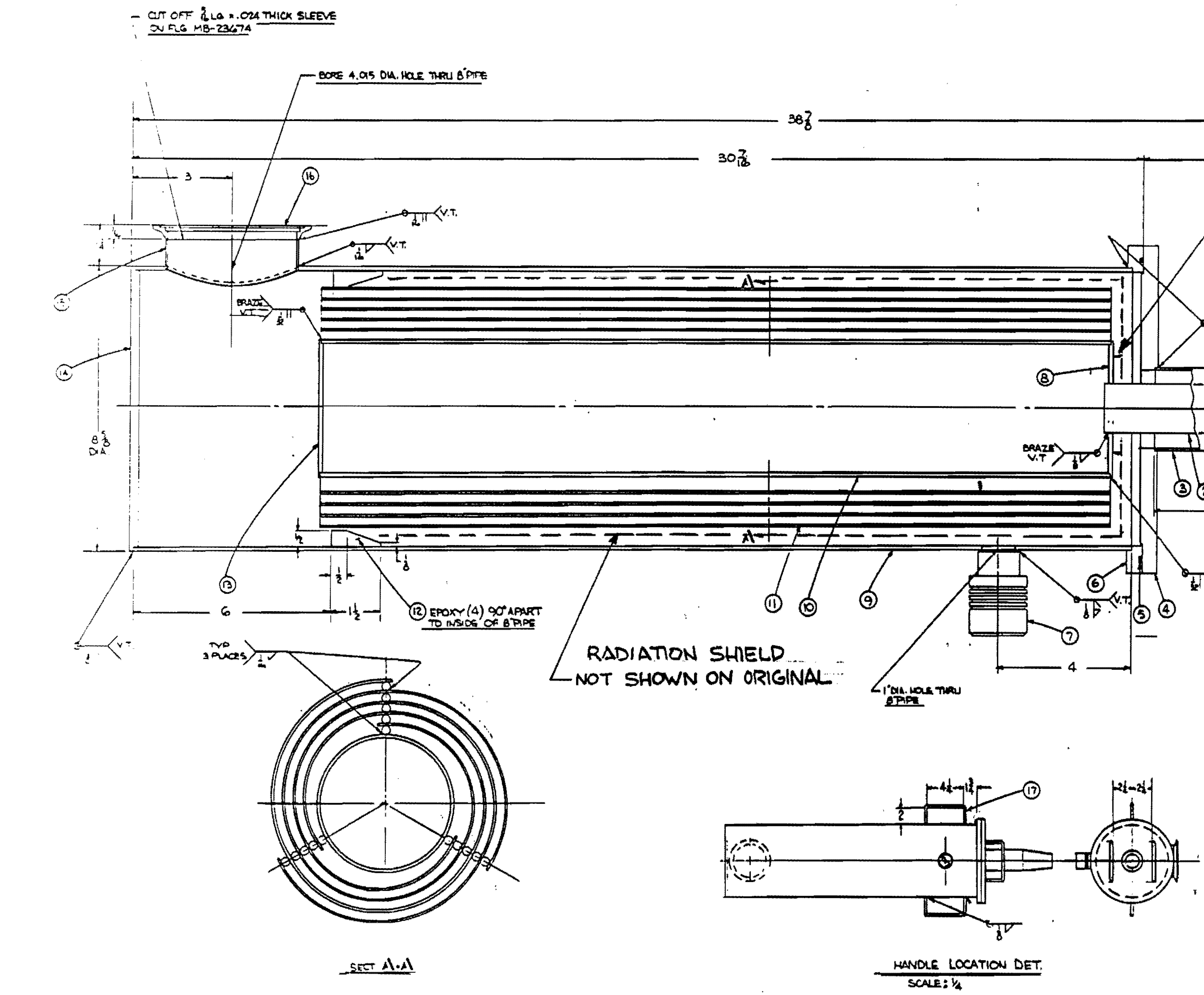
5. Incorporate a top flange LN_2 spill shield.

6. Consider a geometry change that would open the fin to fin gap by 50% or so. Ice froming at the bottom blocked flow to the upper reaches.

7. Consider multiple devices to increase the pumping speed.

Appendices

A-1	Assembly dwg.
A-2	Lifting provisions
A-3	Fin detail closeup
A-4	Modified side plate



17		$\frac{1}{4}$ Ø x $\frac{3}{4}$ LG 304 SS ROD	4
16	MB-234674	VACUUM BELLOWS FLG	1
15		4 O.D. x .065 W 304 SS TUBE x [illegible]	1
14	MC-294696	VACUUM SHELL BOTTOM FLG	1
13	MC-294695	LN_2 RESERVOIR BOTTOM FLG	1
12		[illegible] THK x $\frac{1}{2}$ x $1\frac{1}{2}$ G-10	4
11	MD-294699	COLLECTOR R	3
10		$4\frac{1}{2}$ OD x .095 W x [illegible] TUBE	1
9		8 IPS SCH 5 x 30 1/16 304 SS	1
8	MC-294694	LN_2 RESERVOIR TOP FLG.	1
7		[illegible] CVI PART NO. V-1096	1
6	MC-294697	VACUUM SHELL TOP FLG	1
5		[illegible] x 9 I.D. VITON O RING	1
4	MC-294698	LN_2 RESERVOIR TOP FLG VACUUM	1
3		$2\frac{1}{2}$ OD x .035 W [illegible] x [illegible]	1
2		$1\frac{1}{2}$ O.D. x .035 W [illegible] x [illegible]	1
1	MAKE FROM	[illegible]	1

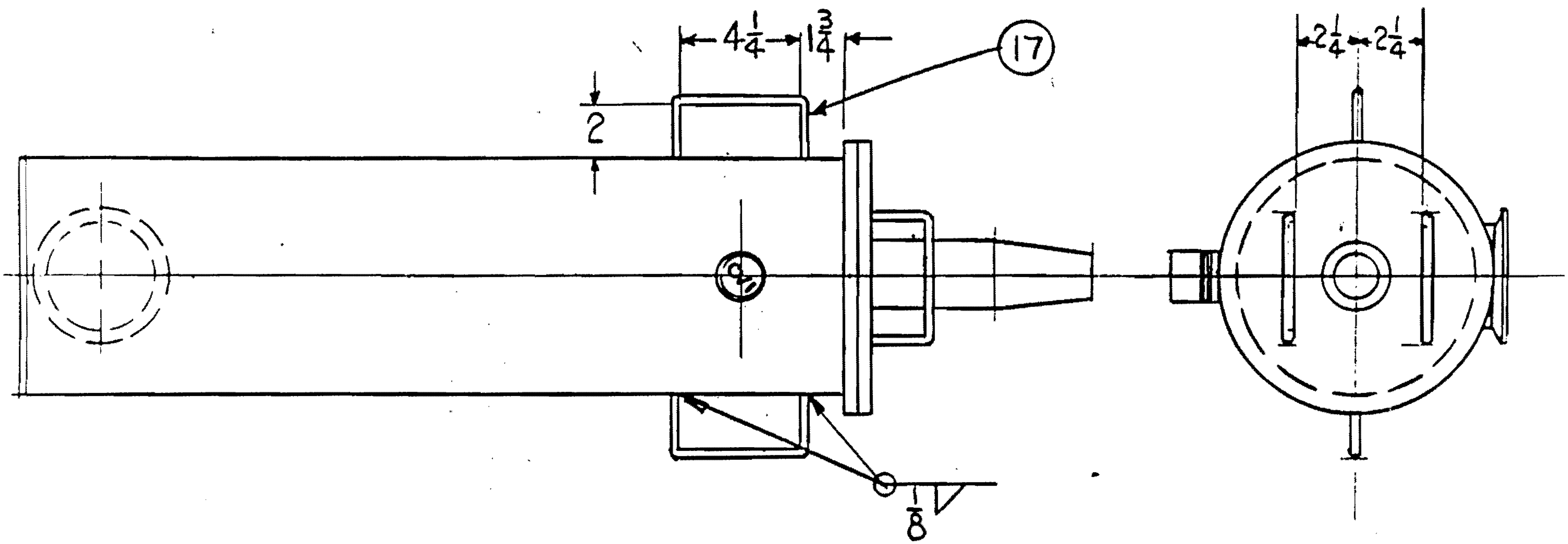
PARTS LIST

MATERIAL: LISTED ABOVE

FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

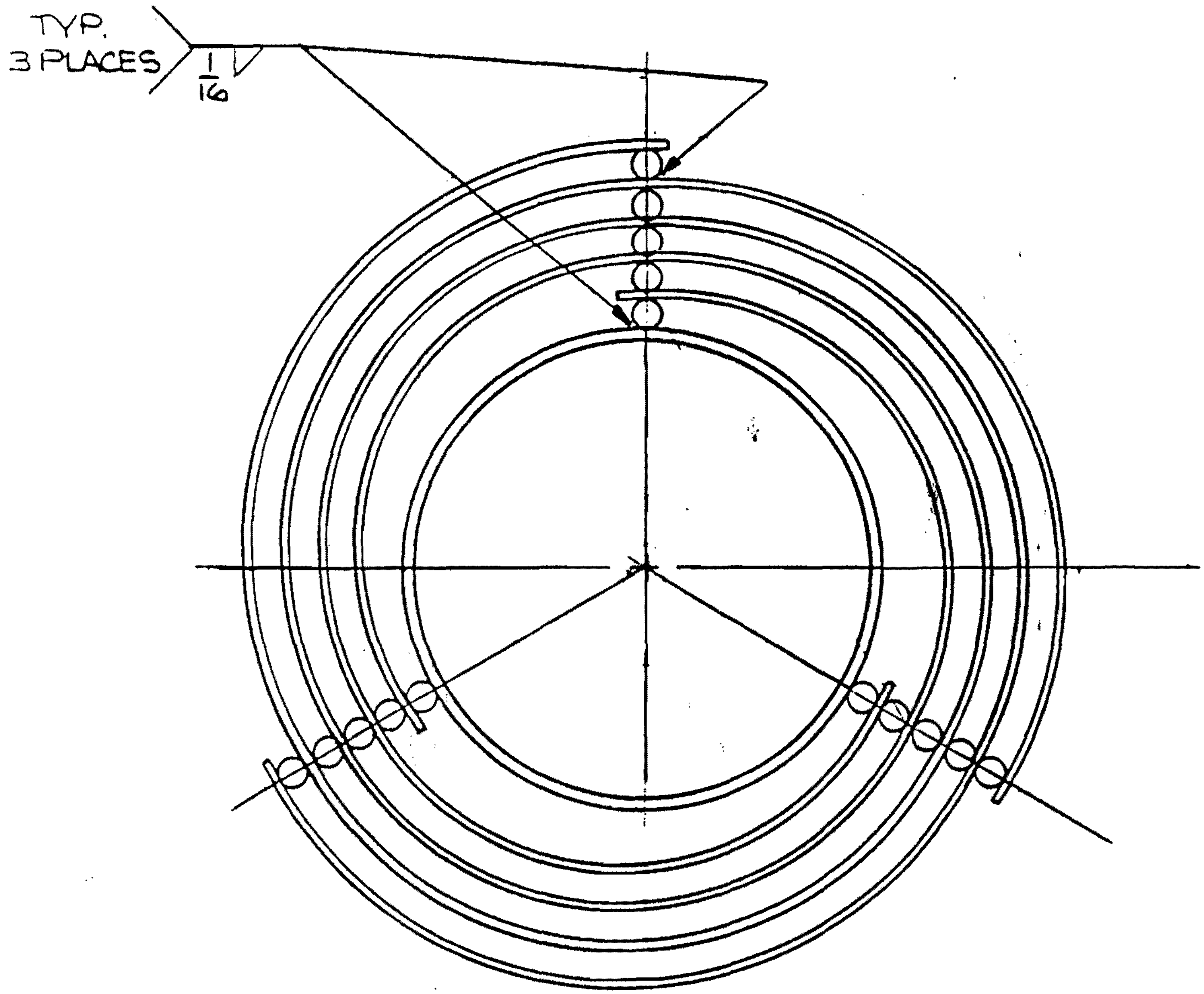
D-Ø DETECTOR
LN_2 CRYO-PUMP
ASSEMBLY

FULL | 3740.514-ME-294693



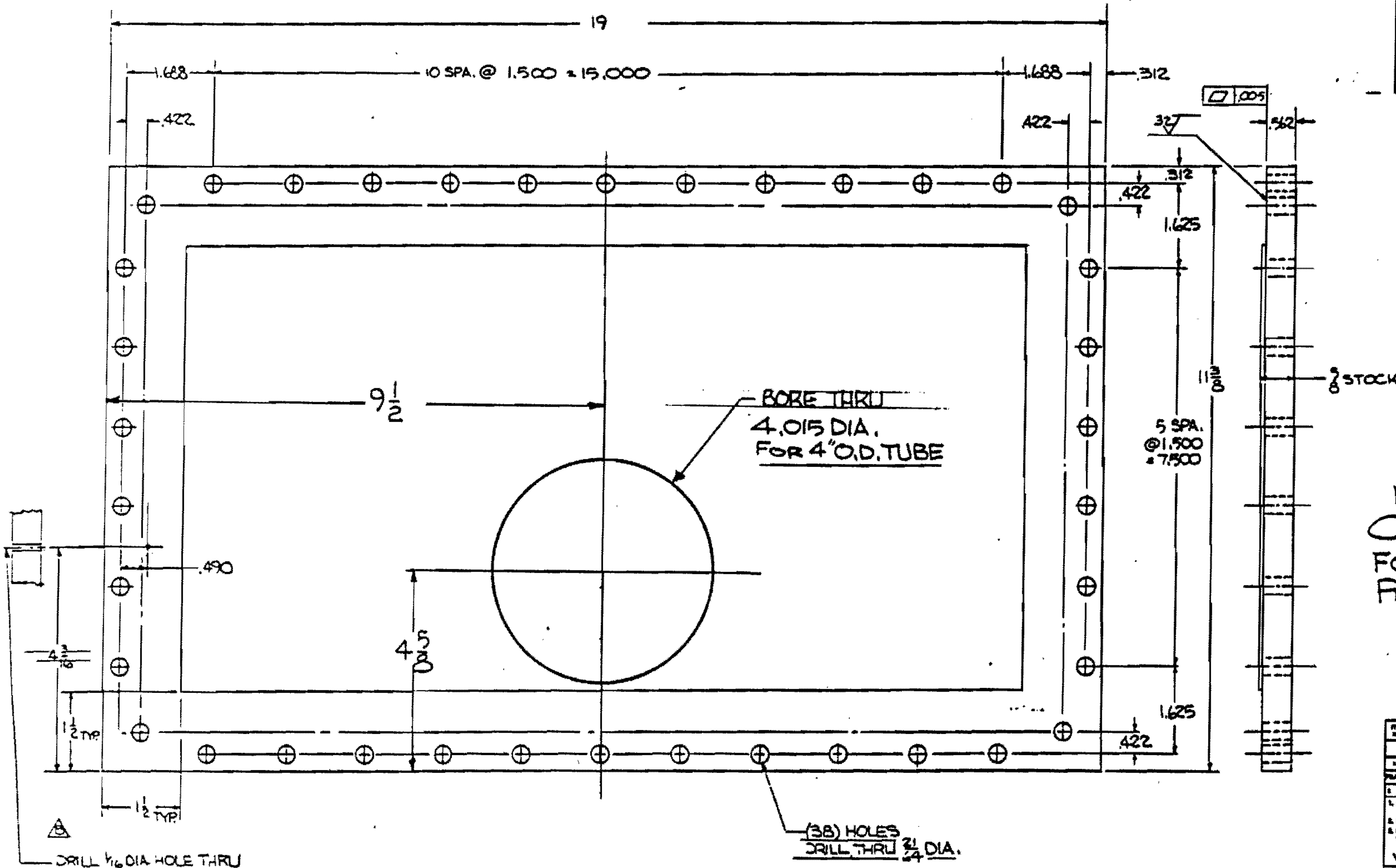
HANDLE LOCATION DET.

SCALE: 1/4



SECT. A-A

REV.	DESCRIPTION	DRAWN / APPD	DATE
A	CHG. FINISHED SURFACE TO 1½ BOARDER ONLY	TROTTER	12-9-86
B	ADDED TEST HOLE	TROTTER	11-13-89



5-8-90
MODIFY ONE
COVER PL AS SHOW
FOR CC VACUUM
PUMP DOWN

ITEM NO.	PART NO.	DESCRIPTION OR SIZE	QTY. REQ.
PARTS LIST			
ORIGINATOR	V. CHRISTENSON	—	
DRAWN	G.R. TROTTER	12-2-85	
CHECKED	KAS	8/30/87	
APPROVED	[signature]	9/21/87	
USED ON	ME-224540	(2)	
MATERIAL	304 STAINLESS STEEL 3/4 THICK		

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D-Ø DETECTOR
END CAP CALORIMETER SIGNAL BOARD
FEED THRU BOX SIDE PLATE

SCALE	FILMED	DRAWING NUMBER	REV.
FULL		3740-223-MD-223637	B

M/P