ENGINEERING CALCULATIONS FOR THE SILCICON COOLING SYSTEM

D-ZERO ENGINEERING NOTE 3823.112-EN-549

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MANIFOLD FLOW MEASUREMENTS

RELIEF VALVES

SUMMARY:

The cooling system has several sections of pipe and tanks that can be isolated with valves. Trapped volume relief valves are located in each trapped volume and also on the tanks. The valve size is based on the fire condition as described in the API Recommended Practice for the design and installation of Pressure-Relieving Systems in Refineries. The tank sizes are less than 120 gallons and have pressures that are less than 300 psig, indicating code stamping is not necessary.

ANALYSIS:

Trapped volume relieves on the piping

According to API code, the heat absorbed by a vessel exposed to an open fire is evaluated by:

$Q=21{,}000\ F\ A^{.82}$ (Section 5, formula #9)

Q= Total heat absorption to the wetted surface BTU/hr
F= Environmental factor = 1 for a bare vessel with no insulation
A= Total wetted surface in square feet

To be conservative, all piping trapped volume relief valves were sized based on the largest ID pipe.

The heat absorbed into a 10 foot section of 1 ½" sch 5 pipe is
Q=74,000 BTU/hr.

The Latent Heat of Vaporization for water
H= 971 BTU/Lbm.

Dividing the heat absorbed by the Latent Heat of Vaporization of water,
Rate of Vaporization = Q/H= 75 lbm/hr.

The relief pressure for the piping trapped volumes was set at 100 psig. A maximum allowable pressure of 100 psig was chosen to protect any instrumentation and hose sections from damage. At 110 psig the saturated vapor density is 4.05 ft3/lbm. This assumes a maximum allowable over pressure of 110%.

Minimum allowable flow rate through the valve
Min flow rate = Rate of Vaporization/4.05 ft^3/Lbm = 5.1 cfm

The commercial relief valve selected was Nupro part number SS-4CA.

Relief on the Air Separator Tank System

The air separator tank system consists of a lower tank that is completely full and an upper overflow tank that never actually has liquid in it. The two tanks are connected through a ¾" sch 40 PVC pipe. There are no isolation valves between the two tanks, so the two tanks are considered part of the same system.

According to API code, the heat absorbed by a vessel exposed to an open fire is evaluated by :

Q=21,000 F A.82 (Section 5, formula #9)

Q = Total heat absorption to the wetted surface BTU/hr
F = Environmental factor = 1 for a bare vessel with no insulation
A = Total wetted surface in square feet

Only the air separator tank is full of liquid during normal operations. The tank size is 24 inches diameter and 60 inches tall

The heat absorbed into the air separator tank
Q=124,000 BTU/hr.

The upper dry tank does not have a wetted surface and is connected to the lower air separator tank through a ¾" sch 40 PVC pipe. Therefore, sizing the relief valve is based on the wetted surface area of the lower air separator tank only.

The Latent Heat of Vaporization for water
H= 971 BTU/Lbm.

Dividing the heat absorbed by the Latent Heat of Vaporization of water,
Rate of Vaporization = Q/H= 127 lbm/hr.

The relief pressure for the tank pressure was set at 15 psig. At 15 psig the saturated vapor density is 26.29 ft3/lbm. Since the relief pressure is low, the allowable overpressure is not considered here.

Minimum allowable flow rate through the valve
Min flow rate = Rate of Vaporization/26.29 ft^3/Lbm = 55.8 cfm

This flow rate is reduced to a factor of 0.3 since the tank is not likely to be engulfed in flames.

Min flow rate = 55.8 cfm *.3 = 16.4 cfm

The commercial relief valve selected was a Circle Seal 500 series, 4mp relief valve. This valve is capable of venting 20 scfm at 15 psig.

Relief on the Chiller Tank

According to API code, the heat absorbed by a vessel exposed to an open fire is evaluated by :

$$Q=21{,}000\ F\ A^{.82} \quad \text{(Section 5, formula \#9)}$$

Q=Total heat absorption to the wetted surface BTU/hr
F=Environmental factor = 1 for a bare vessel with no insulation
A=Total wetted surface in square feet

This tank is completely full of liquid during normal operations. The tank size is 12 inches diameter and 24 inches tall

The heat absorbed into the tank
Q=114,000 BTU/hr.

The Latent Heat of Vaporization for water
H= 971 BTU/Lbm.

Dividing the heat absorbed by the Latent Heat of Vaporization of water,
Rate of Vaporization = Q/H= 117 lbm/hr.

The relief pressure for the tank pressure was set at 70 psig. At 80 psig the saturated vapor density is 5.47 ft3/lbm. This assumes a maximum allowable over pressure of 110%.

Minimum allowable flow rate through the valve
Min flow rate = Rate of Vaporization/5.47 ft^3/Lbm = 10.7 cfm

The commercial relief valve selected was Circle Seal 500 series 2MP. This valve is capable of venting 25 cfm at 80 psig.

Relief on the Expansion Tank

The expansion tank on the platform is open to atmosphere at all times except when leak testing the system. When the system is Vacuum leak tested, there is a relief valve on the vacuum pump. When the system is pressure tested, there is a relief valve on the filling station. A relief valve is not required on this tank.

CONCLUSIONS:

Relief valves were selected based on API guidelines. The trapped volumes in the piping are relieved at 100 psig. The expansion tank on the platform does not require a relief valve since it is always exposed to atmosphere. The air separator tank and dry tank are vented through the same 15 psi relief valve on the air separator tank. The tank on the chiller is vented at 75 psi.

REFERENCES:

API Recommended Practice 520, Design and Installation of Pressure-Relieving Systems in Refineries.

COOLANT VOLUME CHANGES WITH TEMPERATURE

SUMMARY:

The cooling system has about 200 gallons of coolant. When the system cools down or warms up, it goes through a temperature change of about 55 F. The thermal expansion of the liquid becomes significant with these large volumes and temperature changes.

ANALYSIS:

Coolant Volume Change with Temperature

The coolant is a mix of 70% distilled water and 30% ethylene glycol. The average density of the coolant at 14 F is 1.051 gm/cc and at 68 F is 1.043 gm/cc. Calculating the change in volume for a system volume of 200 gallons:

Volume =
200 Gallons= 46200 in^3 =757082 cc

Density at 14 F
1.051 gm/cc

Mass of coolant at 14 F
=1.051 gm/cc* 757082 cc
= 795693 gm

Density at 68 F
1.043 gm/cc

Volume of coolant at 68 F
=795693 gm/1.043 gm/cc =762889 cc

Change in Volume
=762889 cc – 757082 cc
=5807 cc = 354 in^3 = 1.53 gallons

CONCLUSIONS:

When the system warms up or cools down with a temperature change of 54 F, a system volume change of 1.53 gallons should be expected.

REFERENCES:

Union Carbide Figure 5, Specific Gravities of Aqueous Ethylene Glycol Solutions.

NOMINAL OPERATING COOLANT LEVELS

SUMMARY:

The nominal operating coolant level depends on four conditions, if the chiller pump and vacuum pumps are OFF, if the Chiller pump is OFF and the Vacuum pump is ON, and if both the chiller pump and Vacuum pumps are ON and system volume changes due to coolant temperature changes.

ANALYSIS:

Fill level with the vacuum pumps OFF and chiller pumps OFF

When the system is filled with the chiller pumps and vacuum pumps OFF, the system level is set 10 inches below the center of the beampipe. This assumes the coolant is at room temperature and the expansion tank is open to atmosphere with a nitrogen purge above the liquid surface. Setting the coolant level to this elevation guarantees there will never be a positive head pressure on any of the silicon cooling channels.

Conditions:

- Coolant at room temperature ~68F
- Chiller pumps are OFF
- Vacuum pumps are OFF
- Expansion tank open to atmosphere

Fill level

Level in the expansion tank

10" below the beam pipe,

or ,

28.9 inches (1.044 psid water, 1.097 psid glycol mix) of coolant above the Tank's lower Differential Pressure port

Level in the clear PVC pipe above the Air Separator Tank

10" below beam pipe center

or,

15 feet ½ inch above the sidewalk floor.

or,

12 feet 11 ½ inches (5.6 psid water, 5.9 psid glycol mix) of coolant head on the Tank's lower differential pressure port

Fill level with the vacuum pump ON and the chiller pump OFF

The system levels change when the vacuum pump (MB-602, Senior Engineered Products) turns ON and the chiller pump remains OFF. The Vacuum pump maximum achievable pressure is 25" of mercury. This corresponds to 28.3 feet of water. When the vacuum pump is turned ON, the vacuum will lift liquid in the clear piping above the air separator tank approximately 27.5 feet. The liquid is pulled from the expansion tank reservoir. The volume in the clear PVC line reduces the expansion tank level. The clear PVC line is ¾" sch 40 pipe with an ID of 0.524". The ¾" pipe has a volume of 0.0112 gallons per foot. When the vacuum pump is turned ON the 28.3 feet of lift will pull 0.32 gallons of liquid out of the expansion tank. The expansion tank has a diameter of 16" which corresponds to a volume of 1 gallon per inch height of tank. The 0.32 gallons removed from the tank when the vacuum pump is turned ON lowers the liquid level in the tank by 0.32 inches.

Change in the expansion tank liquid level when the vacuum pump turns ON

Approximately 0.32 inches lower

New nominal level

28.6 inches above the DPT port

(1.033 psid water, 1.086 psid glycol mix)

Change in the Liquid level in clear piping above the air separator tank when the vacuum pump turns ON

Increase in level

28.3 feet (maximum)

New nominal level

27.5 feet above the beam pipe center (maximum)

19.15 psid water, 20.13 psid glycol mix at the DPT port

For reference, the differential pressure port on the Air separator tank is 13.8 feet below the beam pipe center.

Measurements of the vacuum pump indicate a maximum suction of –10.6 psig or a lift of approximately 24.5 feet. The new nominal level measured would be close to 16.5 psid mix at the DPT port

Fill level with the vacuum pumps ON and the Chiller pumps ON

After the system has been filled, and the vacuum pump turned ON, the coolant level changes again when the chiller pump is turned ON. The level in the clear PVC piping depends on the differential pressure between the air separator tank and the dry tank above the crane rail. The pressure in the air separator tank can be read using the pressure gauges in the piping between the tank and the chiller pump. The height of the liquid in the piping above the air separator tank can be calculated by taking the differential pressure between the return side of the chiller pump and the vacuum pump pressure.
At 11 gpm, the nominal system flow rate, a return suction pressure of 8 psia is expected. Assuming a vacuum pressure of 25 inches Hg, or 2.4 psia, a differential pressure of 5.6 psi, or 12.9 feet of water is expected. The expected liquid level in the clear piping above the air separator tank is about 13.5 feet above the sidewalk floor, or about 2.4 feet below the beam pipe centerline.

To determine the maximum system flow rate, the minimum liquid level above the air separator tank is considered. The air separator tank should be full at all times. The height of the tank above the sidewalk floor is about 84 inches. The DPT port is about 25 inches from the floor. This sets a differential pressure limit of 59 inches of coolant (2.3 psi) between the return side of the chiller pump and the vacuum pump pressure. This limit imposes a minimum chiller pump suction of 2.3 psid plus 2.4 psia vacuum or 4.7 psia.

Liquid level in the piping above the air separator tank

Assumes pump suction operating pressure range of 4.7 psia to 8 psia

Operating liquid level

7 feet to 13.5 feet above the sidewalk floor.

Minimum DPT reading on Air Separator Tank,

2.3 psid

To be conservative, the DPT low limit is set at 80" of water, 2.9 psid

Expected volume change when the coolant goes from warm to cold

The coolant system is started with the coolant at room temperature (68F). The normal operating temperature is 14F. The coolant volume decreases with temperature change, per above calculation, 1.53 gallons. The expansion tank is 16 inches in diameter and holds approximately 1 gallon of liquid per inch height. When the coolant is chilled to 14F, it is expected that the expansion tank level will decrease approximately 1.5 inches. Although the liquid height will change, the psid over the tank will not.

CONCLUSIONS:

The system level changes based on the stage of operation. When the system is first filled, the liquid level is filled to 10 inches below the beam pipe. When the vacuum pump is turned ON, the liquid is pulled up about 28 feet in the piping above the air separator tank. The liquid level decreases in the expansion tank by 1/3 of an inch. When the chiller pump is turned ON, the expansion tank liquid level should stay stable. The pump suction pressure reduces the liquid level above the air separator tank. The normal liquid level in the piping above the air separator tank operating limits are 7 to 13.5 feet above the sidewalk floor. This corresponds to a pump suction pressure of 4.7 psia to 8 psia depending on the system flow rate.

SYSTEM FLOW CURVES

SUMMARY:

Flow curves for the filters, manifolds, and chiller are given. Also, expected flow curves are given for different sections of piping. The system piping is described by dwg #386983 and #399294.

ANALYSIS:

System flow curves

Expect filter flow curve

The flow curve of two 9 ¾" pleated polyethylene filters in parallel were measured by Bruce Squires. He describes the flow curve as

Flow (gpm) = 7.9 sqrt(dP)

Where dP is the differential pressure in psi.

At 11 gpm the expected drop over the filters is 1.93 psid. If the pressure drop over the filters increases above 3 psid, the filters should be replaced

Expected silicon manifold flow curve

The silicon manifold flow curve is described in the Manifold Flow Measurement Section of the E-note. The curve that describes the expected flow curve through the silicon including the H-disk manifolds is

Psid=.0068 gpm^2 +.6377 gpm

Where gpm is the total system flow rate

At 11 gpm, the expected drop over the manifolds is 7.84 psid.

Expected chiller flow curve

Bruce Squires measured the chiller flow curve. It assumes the Goulds pump and piping chiller piping configuration at the time of the test. The flow curve can be described by:

Psid=0.0212 gpm^2 +0.193m

At 11 gpm, the expected drop over the chiller is 4.09 psid.

Expected System Flow Curve

With a bypass at the CC faces

For diagnostic purposes, the entire system can be operated without the silicon part of the system. Putting in a bypass hose across the hosebarbs on the CC faces does this. This bypass is used when coolant is not desired in the silicon. Table 1 lists items in the coolant path and the expected pressured drop at 11gpm flow rate. A flow rate of 11 gpm can be achieved by throttling the flow with a ball valve and monitoring the flow meters.

Table 1, list of items and their expected pressure drop at 11 gpm

ITEM	PSID AT 11 GPM
Chiller	4.69 psid
Filters	3 psid
23 elbows supply	1.1 psid
140 feet straight pipe, supply	8.88 psid
Hose Barbs, supply	0.7 psid
Expansion in and out of Tank	0.24 psid
Hose Barbs, Return	0.3 psid
136 feet straight pipe, return	3.48 psid
9 elbows, return	0.14 psid
Total	22.53 psid

If the chiller pump is started in this configuration with the throttle valves wide open, the system flow rates are different. To match the system curve with the March pump curve, the system flow rate would be about 17 gpm with a pressure drop of 82 feet over all of the components in Table 1. With the expansion tank open to atmosphere, the pressure at the pump suction is –5 psig. This indicates the pump would run normally without cavitating. This indicates the system could be operated with the throttle valves wide open.

With a bypass at the under the sidewalk piping

For diagnostic purposes, the system can be operated through the piping on the sidewalk with a bypass at the cryo corner. This bypass is used when coolant is not desired in the platform plumbing. Table 2 lists items in the coolant path and the expected pressured drop at 11gpm flow rate. A flow rate of 11 gpm can be achieved by throttling the flow with a ball valve and monitoring the flow meters.

Table 2, list of items and their pressure drop at 11 gpm

ITEM	PSID AT 11 GPM
Chiller	4.69 psid
Filters	3 psid
13 elbows supply	0.607 psid
1.05" ID, 73 feet straight pipe, supply	6.15 psid
Hose Barbs, supply	0.7 psid
Hose Barbs, Return	0.3 psid
0.92" ID, 73 feet straight pipe, return	2.02 psid
6 elbows, return	0.09 psid
Total	17.6 psid

If the chiller pump is started in this configuration with the throttle valves wide open, the system flow rates are different. To match the system curve with the March pump curve, the system flow rate would be about 22 gpm with a pressure drop of 82 feet over all of the components in Table 1. The pump suction would see half of the overall pressure drop or require 41 feet of suction. This indicates the pump would cavitate. Do not start or run the system in this configuration with the throttle valves wide open.

With the system in its normal operating mode.

For diagnostic purposes, the entire system can be operated without the silicon in the system. Placing a bypass hose across the hosebarbs on the CC faces does this. This bypass is used when coolant is not desired in the silicon. Table 2 lists items in the coolant path and the expected pressured drop at 11gpm flow rate. A flow rate of 11 gpm can be achieved by throttling the flow with a ball valve and monitoring the flow meters.

Table 3, list of items and their pressure drop at 11 gpm

ITEM	PSID AT 11 GPM
Chiller	4.69 psid
Filters	3 psid
23 elbows supply	1.1 psid
140 feet straight pipe, supply	8.88 psid
Hose Barbs, supply	0.7 psid
Expansion in and out of Tank	0.14 psid
Silicon detector	8-9 psid
Hose Barbs, Return	0.3 psid
136 feet straight pipe, return	3.48 psid
9 elbows, return	0.14 psid
Total	30.43 psid

If the chiller pump is started in this configuration with the throttle valves wide open, the system flow rates are different. To match the system curve with the March pump curve, the system flow rate would be about 12.5 gpm with a pressure drop of 82 feet over all of the components in Table 1. With the expansion tank open to atmosphere, the pressure at the pump suction is –10 psig. This indicates the pump would run normally without cavitating. However, at this higher flow rate, the liquid level in the air separator tank would be below the low limit. This indicates the system should not be operated with the throttle valves wide open.

Sample calculations of pressure drops in the piping.

A sample calculation of the pressure drop over a foot pipe, an elbow, and the inlet and outlet of a tank is given. The assumed conditions are a flow rate of 11 gpm, 30-70 mix of glycol, and the coolant at –10C.

Pressure drop in 1 foot of pipe

Row, Fluid Density = 1054 Kg/M^3
Flow = 12.5 gpm out of the pump = 0.00075 M^3/sec
Viscosity = 0.006 N*sec/M^2
v-Kinematic viscosity= 5.6926 e-6 M^2/sec
Pipe ID =1.185 for 1 inch sch 5 pipe
=0.03 Meter
Length of pipe L= 1 foot =0.3 meters

Crossectional area of pipe = PI*(ID/2)^2
= 3.141 *(1.185/2)^2
= 1.102 in^2 =
=0.00071 M^2

Linear flow velocity in pipe,V = Flow/area
= 0.00075/0.00071
=1.056 M/sec

R, Reynolds number
=4*Flow/(PI*Kinematic Viscosity*ID)
=4*0.00075/(3.141*5.6926e-6*0.03)
=5592 >2200 which indicates Turbulent flow

f, Friction factor
=0.316*R^-.25
=0.316*5592^-.25
=0.036

velocity head
=f(L/ID)*V^2/2
=0.036*(0.3/.03)*1.056^2/2
=0.20 M^2/sec^2

Multiplying by the fluid density to get pressure
=0.20 * 1054
= 210.8 N/m^2
= 0.03 psi drop per foot of pipe

Pressure drop over one long radius elbow

Row, Fluid Density = 1054 Kg/M^3
Flow = 12.5 gpm out of the pump = 0.00075 M^3/sec
Viscosity = 0.006 N*sec/M^2
v-Kinematic viscosity= 5.6926 e-6 M^2/sec
Elbow ID =1.185 for 1 inch sch 5 pipe
Friction term K for 1" elbow = 0.3

Crossectional area of elbow = PI*(ID/2)^2
= 3.141 *(1.185/2)^2
= 1.102 in^2 =
=0.00071 M^2

Linear flow velocity in elbow,V = Flow/area
= 0.00075/0.00071
=1.056 M/sec

Pressure drop across elbow
=Row*K*V^2/2
= 1054*0.3*1.056^2/2
= 176.3 N/M^2
= 0.025 psid per 1" long radius elbow

Pressure drop over the inlet and outlet of a tank

Row, Fluid Density = 1054 Kg/M^3
Flow = 12.5 gpm out of the pump = 0.00075 M^3/sec
Viscosity = 0.006 N*sec/M^2
v-Kinematic viscosity= 5.6926 e-6 M^2/sec
Elbow ID =1.185 for 1 inch sch 5 pipe
Friction term Ke for expansion into a tank = 1
Friction term Kc for contraction into the piping = 1 (most conservative value)

Pipe ID of the at the inlet/outlet of the tank = 1.185
Crossectional area of the piping going into and out of the tank = PI*(ID/2)^2
= 3.141 *(1.185/2)^2
= 1.102 in^2 =
=0.00071 M^2

Linear flow velocity in inlet/outlet of the tank ,V
= Flow/area
= 0.00075/0.00071
=1.056 M/sec

Pressure drop across tank

=Row*Ke*V^2/2+ Row*Kc*V^2/2,

=2*Row*K*V^2/2, assumes both inlet and outlet pipe sizes are 1" pipe

= 2* 1054*1*1.056^2/2

= 1175 N/M^2

= 0.17 psid per tank

CONCLUSIONS:

Flow curves were given for various components of the silicon cooling system. Sample calculations were given for some of the fittings in the system. Care should be given to understand the system flow curve to prevent pump cavitation and to maintain liquid level limits in the air separator tank.

HEAT LOSSES

SUMMARY:

The cooling system piping is insulated to prevent excessive heating to the coolant and to prevent the pipes from condensing moisture. Depending on the location of the pipe or tank, it is either insulated with foam or a vacuum jacket. In the case of vacuum jacketed lines, heat losses through the isolators and through the walls are calculated. Another source of heat to the system is the work the chiller pump does on the liquid.

ANALYSIS:

Expected coolant heating through Foamed lines

Some of the piping is insulated with a foam jacket. The heating into the coolant through the foam-insulated line is calculated. To give a conservative estimate of the heating, the largest diameter pipe is used in the calculation. The temperature of the foam exposed to the air surface is calculated by balancing the heat loss due to air convection with the conductive heat through the foam wall.

ID of the insulation
ID = 0.048 M
=1.9 inch
OD of the insulation
OD = 0.099 M
=3.9 inch
wall thickness of the insulation
L = 0.025 M
= 1.0 inch
Thermal conductivity of the typical insulation
K =0.05 W/MK
=0.029 Btu/hr-ft-F
Air thermal convection coefficient
H =2 W/M^2K, assumes air velocity over the insulation is low
Room Temperature
=68 F
=293 K
Liquid temperature
=14 F
=263K

ID surface area of insulation in one foot of pipe
IDa =0.0316 m^2
OD surface area of insulation in one foot of pipe
ODa =0.0681 m^2

Heat loss through the insulation
QK= K*IDa*(Tliquid-Twall)/L
QK= 0.05* 0.0316*(263-Twall)/0.025

Heat added by air convection
QH= H*ODa*(Troom-Twall)

QH=   2*0.0681*(293-Twall)

QH must equal QK for energy balancing. Twall the temperature of the insulation exposed to the air is calculated by setting QH=QK

Twall = 283K
=50.5F

The wall temperature is greater than the dew point, so its unlike condensation will occur on the foamed piping.

The heat added to the coolant per foot of pipe is calculating the QH or QK by substituting in the temperature for Twall

QH=   2*0.0681*(293-283)
QH=   1.4 watts per foot of insulated pipe.

There is approximately 70 feet of pipe. The total coolant heating on the sidewalk is estimated at 100 watts

Expected coolant heating due to the chiller pump

Due to inefficiencies in the pump, work is done on the coolant by the pump. Using the pump curve for the March pump TE-7.5K-MD, an efficiency of 20% in expected at 11 gpm. The pump HP required at 11 gpm is 1.15 HP. Heat input into the liquid is 0.92 HP or 686 watts. For reference, the theoretical power required to pump water to an 80 foot head is 226 watts.

Expected heat loss through the Air separator tank wall

The air separator tank is insulated with Armorflex foam. Heating due to air convection of the surface of the tank is calculating. The temperature of the foam exposed to the air surface is calculated by balancing the heat loss due to air convection with the conductive heat through the foam wall. The heat input into the tank is then calculated.

The wetted surface area of the tank is calculated assuming the tank is a cylinder with flat ends.

Tank Diameter
D   =24 inches
Liquid height in the tank
H   = 54 inches
Wetted surface area
Aw   =2*(D/2)^2*PI+D*PI*H
=2*(24/2)^2*3.141 + 24*3.141*54
= 4974 in^2
= 3.2 M^2
Wall thickness of the insulation
L   = 0.05 M
= 2.0 inch
Thermal conductivity of the Armorflex insulation
K   =0.039 W/MK
Air thermal convection coefficient
H   =2 W/M^2K, assumes air velocity over the insulation is low
Room Temperature
=68 F
=293 K
Liquid temperature
=14 F
=263K

Heat loss through the insulation

QK= K*Aw*(Tliquid-Twall)/L

QK= 0.039*3.2*(263-Twall)/0.025

Heat added by air convection

QH= H*Aw*(Troom-Twall)

QH= 2*3.2*(293-Twall)

QH must equal QK for energy balancing. Twall the temperature of the insulation exposed to the air is calculated by setting QH=QK

Twall = 285K

= 53 F

The wall temperature is greater than the dew point, so it is unlikely condensation will occur on the foamed tank.

The heat added to the coolant is calculating the QH or QK by substituting in the temperature for Twall

QH= 2*3.2*(293-285)

QH= 51.2 Watts.

Expected coolant heating through the Expansion tank wall

The air separator tank is insulated with Armorflex foam. Heating due to air convection of the surface of the tank is calculating. The temperature of the foam exposed to the air surface is calculated by balancing the heat loss due to air convection with the conductive heat through the foam wall.

The wetted surface area of the tank is calculated by assuming the tank is a cylinder with flat ends.

Tank Diameter

D =16 inches

Liquid height in the tank

H = 32 inches

Wetted surface area

Aw =(D/2)^2*PI+2*D*PI*H

=(16/2)^2*3.141 + 2*16*3.141*32

= 3416 in^2

= 2.2 M^2

Wall thickness of the insulation

L = 0.025 M

= 1.0 inch

Thermal conductivity of the Armorflex insulation

K =0.039 W/MK

Air thermal convection coefficient

H =2 W/M^2K, assumes air velocity over the insulation is low

Room Temperature

=68 F

=293 K

Liquid temperature

=14 F

=263K

Heat loss through the insulation

QK= K*Aw*(Tliquid-Twall)/L

QK= 0.039*2.2*(263-Twall)/0.025

Heat added by air convection

QH= H*Aw*(Troom-Twall)

QH= 2*2.2*(293-Twall)

QH must equal QK for energy balancing. Twall the temperature of the insulation exposed to the air is calculated by setting QH=QK

Twall = 286K

= 56 F

The wall temperature is greater than the dew point, so it is unlikely condensation will occur on the foamed tank.

The heat added to the coolant is calculating the QH or QK by substituting in the temperature for Twall

QH= 2*2.2*(293-286)

QH= 30.8 Watts.

CONCLUSIONS:

Expected heating to the system was calculated for heating through the tank walls, the foam insulated lines, and heating due to the chiller pump. The tanks add about 80 watts of heat, the insulated piping adds about 100 watts of heating, and the chiller pump adds the most heating at about 700 watts. The total heat input into the coolant with the silicon power OFF is expected to be less than 1000 watts.

HEAT REQUIRED TO WARMUP SILICON WITH THE CHILLER PUMP OFF

SUMMARY:

If for some reason the silicon detector needs to be warmed to above the dewpoint quickly, the dry gas purge could be used. A simple calculation is given to determine the minimum amount of dry air needed to warm the mass of the silicon detector. The calculation is based the energy balance between heat loss in a given amount of dry air and heat gained in the mass of the silicon detector. The H-disk, F-disk and Barrels are considered separately.

ANALYSIS:

The amount of dry air required to heat an H-disk from –10 C to 5 C

Temperatures

Be temp	-10 C
Si temp	-10 C
Incoming air temp	20 C
Dewpoint	15 C

Heat Capacities

C-Be	1750 J/Kg.K
C-Si	712 J/Kg.K
Coolant	3683.7 J/Kg.K

Amount of material in the H-disk

M-Be	0.651 Kg
M-Si	0.250 Kg
M-coolant	0.040 Kg

The total mass of one H-disk is estimated at 0.941 Kg

Energy required to warm the material from –10 C to 5 C

Energy required Q, is the mass times the heat capacity times the temperature change

Q-Be	1140 J
Q-Si	178 J
Q-coolant	147 J
Total	1465 J

The amount of air required to balance the energy equation is

Air density	1.1614 Kg/M^3 at 1 atm
Heat Capacity	1007 J/Kg.K

Q=mCdt

M =Q/Cdt

=1465/1007*5

=0.29 Kg of air

= 0.82 m^3

=10ft^3 of dry air

To warm one H-disk from –10 C to 15 C requires about 10 ft^3 of dry air at 20 C. There are 2 H-disks per end or a total of 4 H-disks in the system. To warm all 4 H-disks would require about 40 ft^3 of dry air at room temperature.

The amount of dry air required to heat an F-disk from –10 C to 5 C

Temperatures

Be temp	-10 C
Si temp	-10 C
Incoming air temp	20 C
Dewpoint	15 C

Heat Capacities

C-Be	1750 J/Kg.K
C-Si	712 J/Kg.K
Coolant	3683.7 J/Kg.K

Amount of material in the F-disk

M-Be	0.0507 Kg
M-Si	0.144 Kg
M-coolant	0.0055 Kg

The total mass of one F-disk is estimated at 0.2 Kg

Energy required to warm the material from –10 C to 5 C

Energy required Q, is the mass times the heat capacity times the temperature change

Q-Be	2218 J
Q-Si	2563 J
Q-coolant	505 J
Total	4781 J

The amount of air required to balance the energy equation is

Air density	1.1614 Kg/M^3 at 1 atm
Heat Capacity	1007 J/Kg.K

Q=mCdt

M =Q/Cdt

=4781/1007*5

=0.95 Kg of air

= 0.82 m^3

=29 ft^3 of dry air

To warm one F-disk from –10 C to 15 C requires about 32 ft^3 of dry air at 20 C. There are 6 F-disks per half cylinder or a total of 12 F-disks in the system. To warm all 12 F-disks would require about 350 ft^3 of dry air.

The amount of dry air required to heat a Barrel from –10 C to 5 C

Temperatures

Be temp	-10 C
Si temp	-10 C
Incoming air temp	20 C
Dewpoint	15 C

Heat Capacities

C-Be	1750 J/Kg.K
C-Si	712 J/Kg.K
Coolant	3683.7 J/Kg.K

Amount of material in the Barrel

M-Be	0.28 Kg
M-Si	0.55 Kg
M-coolant	0.04 Kg

The total mass of one Barrel is estimated at 0.87Kg

Energy required to warm the material from –10 C to 5 C

Energy required Q, is the mass times the heat capacity times the temperature change

Q-Be	12250 J
Q-Si	9790 J
Q-coolant	3683 J
Total	22040 J

The amount of air required to balance the energy equation is

Air density	1.1614 Kg/M^3 at 1 atm
Heat Capacity	1007 J/Kg.K

Q=mCdt

M =Q/Cdt
=22040/1007*5
=4.38 Kg of air
=3.77 m^3
=134 ft^3 of dry air

To warm one barrel assembly from –10 C to 15 C requires about 134 ft^3 of dry air at 20 C. There are 3 F-disks per half cylinder or a total of 5 barrels in the system. To warm all 6 barrels would require a minimum of 800 ft^3 of dry air.

CONCLUSIONS:

A minimum of 1200 cubic feet of air at room temperature is required to warm up the silicon detector from –10 C to 5 C. The calculations are based on complete energy transfer from the air to the silicon detector.

MANIFOLD FLOW MEASUREMENTS

SUMMARY:

Manifolds were built to provide coolant to the central silicon detector. The device coolant paths require four manifolds; two supply manifolds and two return manifolds. The manifolds can be broken down into two sections, the silicon manifold, which services the central silicon trough, and the H-disk manifold, which services the H-disks. The central silicon manifolds are constructed of ½" schedule 80 pvc pipe. The H-disk manifolds are constructed of ½" sch 40 pipe. PVC nozzles were glued into the pipes to make connections to the silicon cooling rings. The manifolds were then flow tested on a test rig at the Photon Assembly Building. Orifices were placed into the nozzles as required to balance the flows between coolant paths.

COOLANT PATHS:

A schematic of the coolant paths is included as DWG # 900888. A supply and a return line is located at the 3 O'clock and 9 O'clock positions on the silicon support trough. Each supply line drains into both return lines.

MECHANICAL DRAWINGS:

Mechanical Drawings of the manifolds are included as DWG #'s 386679 through #386682. A rough mechanical schematic of how the manifold is connected to the device is included as DWG # 399235. The coupling hose used was Cilran ¼" and 3/16" tubing purchased from McMaster Carr. Formed elbows are used to couple to the barrel cooling rings and are included as DWG # 399105. Adjusting the flows to each device/cooling ring is done by placing an orifice in the return side nozzle on the manifold. Drawings for the different size orifices are DWG #'s 386990 and 386991.

DEVICE FLOW CURVES:

Device Flow curves were both measured using models and calculated. References for this information came from Bill Cooper. The flow curves that are attached have Pressure drop vs. Flow and Temperature vs. Flow. The device flow is based on where the Temperature and Pressure drops curves cross. The flow is then picked a little higher than this point to ensure a low device temperature.

TEST SETUP:

Cary Kendziora's group built the test setup at PAB. The setup included dummy devices that were precalibrated to the device flow curve. The F-disk dummies were a piece of flattened stainless tubing. Flattened dimensions were about 4" long by ½" wide by about .090" thick. The original stainless tubing wall thickness was 0.035". The simulated barrel devices were a piece of ¼" tubing wrapped in a circle of about 4" diameter. Total tubing length was about 24 inches. At the end of each piece of tubing was a [illegible] chamber. The chamber size was about 1" diameter and about 1.5" long. All components for each half cylinder were tested at the same time including the 2 return and the 2 supply manifolds. Pressure drops were then measured across each dummy device. The pressure drop across the device can then be cross checked to the flow going through the device using the device flow curves. Tubing length from the manifold to the dummy device was modeled from the actual half cylinder. The tubing used was ¼" servicing the silicon barrels and 3/16" servicing the f-disks. Both diameters were made of Cilran Tubing. The coolant path to the barrel devices included 2 PVC elbows.

RESULTS:

Results recorded are the pressure drop across the system and the pressure drops across each device. The flows can then be interpreted from this data. Table 1 gives results for the South half manifolds; Table 2 gives results for the North Half Manifolds. Table 3 gives results for the North Half Silicon Manifolds with the North H-disk Manifolds. Table 4 is the expected flows. The test rig was used first with the South half manifolds, so the Table does not include the system pressure drops. Also during the testing of the South half manifolds, the chiller pump failed and debris from the pump caused the device flow characteristics to change in the dummy F-disks. This was discovered during the testing and the F-disks were then cleaned and testing continued. Test conditions were 30% ethylene glycol 70% distilled water. Coolant temperature was 14 deg F. To ensure the system was cold, results were recorded after the manifolds had condensed moisture.

Table 1. South half manifold testing results.

DEVICE	Pressure Drop (No Orifice)	Pressure Drop/orifice Diam	Pressure Drop/orifice Diam	Pressure Drop/orifice Diam	Pressure Drop/orifice Diam	Pressure Drop/orifice Diam	Pressure Drop/orifice Diam
F-disk 6	7.0	6.2 /0.1	5.5/0.080	4.65/0.080	5.7/0.100	5.3/0.100	6.2/0.100
F-disk 5	7.15	6.55/0.1	5.55/0.080	4.6/0.080	5.9/0.100	5.5/0.100	6.3/0.100
F-disk 4	7.45	6.95/0.1	5.55/0.080	4.55/0.080	5.9/0.100	5.55/0.100	6.35/0.100
F-disk 3	6.95	6.4/0.125	5.35/0.080	4.3/0.080	6.1/0.100	5.6/0.100	6.5/0.100
Barrel 3-3	6.55	5.2/0.125	7.0/.125	5.65/.125	5.8/0.125	5.4/0.125	6.2/0.125
Barrel 3-9	6.55	5.2/0.125	7.0/.125	5.65/.125	5.8/0.125	5.4/0.125	6.3/0.125
F-disk 2	6.3	6.2	7.45	6.1	6.1	5.6	6.6
Barrel 2-3	5.75	5.6	7.4	5.85	6.0	5.5	6.5
Barrel 2-9	5.9	5.75	7.5	5.9	6.2	5.6	6.65
F-disk 3	6.35	6.25	7.65	6.2	6.2	5.7	6.7
Barrel 1-3	6.0	5.85	7.7	6.2	6.1	5.7	6.6
Barrel 1-9	5.55	5.65	7.7	6.15	6.0	5.7	6.7
System Drop Supply-Return	*A	*A	24.7 –13 psia	21.1-11.5 psia	21.7-12.3 psia	20.4-11.8 psia	23.0-12.8 psia
Notes	*B	*B	*C	*C	*C	*C	*C

Table 2. North half manifold testing results.

DEVICE	Pressure Drop (No Orifice)	Pressure Drop (No Orifice)	Pressure Drop (No Orifice)	Pressure Drop/orifice Diam	Pressure Drop/orifice Diam	Pressure Drop/orifice Diam
F-disk 6	6.8	6.2	5.4	4.75/0.10	5.3/0.10	6.4/0.10
F-disk 5	6.5	6.0	5.2	4.8/0.10	5.4/0.10	6.9/0.10
F-disk 4	6.8	6.2	5.4	4.7/0.10	5.3/0.10	6.6/0.10
F-disk 3	6.8	6.2	5.4	4.5/0.10	5.35/0.10	6.4/0.10
Barrel 3-3	6.8	6.0	5.3	4.5/0.125	5.15/0.125	6.5/0.125
Barrel 3-9	6.7	6.1	5.2	4.7/0.125	5.5/0.125	6.9/0.125
F-disk 2	5.4	5.0	4.4	4.65	5.3	6.65
Barrel 2-3	5.9	5.3	4.7	5.0	5.7	7.4
Barrel 2-9	6.0	5.4	4.7	5.5	5.8	7.5
F-disk 3	6.0	5.5	4.8	4.95	5.9	7.4
Barrel 1-3	5.9	5.4	4.6	5.1	5.8	7.4
Barrel 1-9	5.9	5.3	4.75	4.9	5.7	7.3
System Drop Supply-Return	23-13	21.4-13	19.6-12.4	19.4-12	21.4-12.5	25.2-14
Notes	*C	*C	*C	*C	*C	*C

Table 3. North half Silicon Manifold testing results including the North H-disk Manifolds.

DEVICE	Pressure Drop/orifice Diam	Pressure Drop/orifice Diam	Pressure Drop/orifice Diam	Pressure Drop/orifice Diam
H-disk 2	3.7	2.2/0.08	2.7/0.10	2.8/0.10
H-disk 1	3.4	2.0/0.08	2.7/0.10	2.7/0.10
F-disk 6	5.3/0.10	5.2/0.10	5.2/0.10	5.2/0.10
F-disk 5	5.0/0.10	5.2/0.10	5.4/0.10	5.4/0.10
F-disk 4	5.2/0.10	5.3/0.10	5.3/0.10	5.2/0.10
F-disk 3	5.1/0.10	5.5/0.10	5.1/0.10	5.05/0.10
Barrel 3-3	5.5/0.125	5.3/0.125	5.4/0.125	5.4/0.125
Barrel 3-9	4.9/0.125	5.0/0.125	5.1/0.125	5.0/0.125
F-disk 2	4.6	5.0	5.2	5.25
Barrel 2-3	5.3	6.3	5.5	5.5
Barrel 2-9	5.5	6.0	5.6	5.8
F-disk 3	5.5	6.4	5.65	5.7
Barrel 1-3	5.4	6.2	5.5	5.7
Barrel 1-9	5.3	6.2	5.6	5.7
System Drop Supply-Return	17-7.8	16.3-6.9	17.4-9.1	17-8.7
Notes	*D	*D	*D	*E

*A –System Pressure not available
*B- Pump Failure caused debris to alter F-disk flow curves
*C- Filter placed in system, F-disks cleaned
*D- H-disk nozzles did not have proper orientation
*E- H-disk manifolds were replaced and re-tested with correct nozzle orientation

Based on the measured pressure drops, expected device flows can be found from referring to the device flow curves that are attached to this document. Table 3 lists the expected flows for each device.

Table 4. Expected Device Flows, based on measured pressure drops

DEVICE	EXPECTED FLOW (LPM)	MEASURED PRESSURE DROP (PSID)	EXPECTED TEMP (C)
H-Disk 2	1.3	2.7	2.0
H-Disk 1	1.3	2.7	2.0
F-disk 6	1.3	5.3/0.10	4.5
F-disk 5	1.35	5.4/0.10	4.4
F-disk 4	1.3	5.3/0.10	4.3
F-disk 3	1.3	5.15/0.10	4.35
Barrel 3-3	1.8	5.35/0.125	7.3
Barrel 3-9	1.85	5.5/0.125	7.0
F-disk 2	1.3	5.3	4.3
Barrel 2-3	1.9	5.7	6.8
Barrel 2-9	1.95	5.8	6.9
F-disk 1	1.4	5.7	4.2
Barrel 1-3	1.95	5.8	6.9
Barrel 1-9	1.9	5.7	6.8
System totals	21.9 lpm /half	8.3	

The expected device temperature is taken off of the included plots. The temperature is the expected temperature of the Beryllium cooling ring with the heat load from the chips applied.

Conclusions:

The north silicon manifolds and H-disk manifolds were tested at PAB. Coolant flowed through the manifolds and pressure drops were recorded. Based on the attached flow tables, the pressure drops can be correlated to flows and cooling ring temperatures. The expected flow at a pressure drop of 8.3 psid across the manifolds is 21.9 lpm (system flow of 11.6 gpm).

SECTION 5—RELIEF REQUIREMENTS FOR VESSEL EXPOSURE TO OPEN FIRES

5.1 Average Heat Absorption Rates

An attempt was made to determine an adequate relieving capacity to prevent the development of excessive pressure in pressure vessels exposed to fire. Tests were studied which provided means to measure the total heat absorbed by a vessel (1) by computing the heat required to bring the liquid content to the boiling range and (2) by measuring the amount of liquid content evaporated in a given time. Data from a considerable number of such tests and a discussion of the conditions under which they were run are presented in Appendix A.

5.2 Formulas for Amount of Heat Absorbed

The amount of heat absorbed by a vessel exposed to an open fire is markedly affected by the size and character of the installation and by the environment. The test data and some of the formulas that have been used to estimate the heat input are discussed in Appendix A. These conditions are evaluated by the following equivalent formulas, in which the effect of size on the heat input is shown by A; the vessel wetted area; the exponent of A; and a factor F which is the effect of other conditions:

$$q = 21{,}000\, FA^{-0.18} \qquad (8)$$
$$Q = 21{,}000\, FA^{0.82} \qquad (9)$$

Where:

q = average unit heat absorption, in British thermal units per hour per square foot of wetted surface.

Q = total heat absorption (input) to the wetted surface, in British thermal units per hour.

A = total wetted surface, in square feet.[4] (The expression $A^{-0.18}$, or $\frac{1}{A^{0.18}}$, is the area-exposure factor or ratio. This ratio recognizes the fact that large vessels are less likely to be completely exposed to the flame of an open fire than are small vessels.)

F = environment factor, values of which are shown in Table 3 for various types of installation.

[4] It is recommended that the total wetted surface (A in the foregoing formulas) is at least that wetted surface included within a height of 25 feet above grade or—in the case of spheres and spheroids—at least the elevation of the maximum horizontal diameter or a height of 25 feet, whichever is greater. The term "grade" usually refers to ground grade, but may be at any level at which a sizable fire could be sustained.

The aforementioned formulas, upon application of the value of factor (F = 1.0) for a bare vessel, become:

$$q = 21{,}000\, A^{-0.18} \qquad (10)$$
$$Q = 21{,}000\, A^{0.82} \qquad (11)$$

These are the basic formulas for the usual installation of a bare vessel in a refinery with good drainage (see Paragraph 6.3.4) and available fire-fighting equipment. These formulas are plotted in Figure 9. Curves for q and Q, respectively, for various values of factor F are presented in Figures 10 and 11.

5.3 Surface Area Exposed to Fire

The surface area wetted by its internal liquid contents is effective in generating vapor when it is exposed to fire. The liquid contents under variable level conditions should ordinarily be taken at the average inventory, namely:

1. *Liquid-Full Vessels* (such as treaters) operate liquid full. Therefore, the wetted surface would be the total vessel surface within the height assumed to be affected by a fire as recommended in the footnote to Paragraph 5.2.

TABLE 3—Environment Factor

Type of Installation	Factor F[a]
1. Bare vessel	1.0
2. Insulated vessels[b] (These arbitrary insulation conductance values are shown as examples and are in British thermal units per hour per square foot per degree Fahrenheit):	
a. 4.0	0.3
b. 2.0	0.15
c. 1.0	0.075
3. Water-application facilities, on bare vessel[c]	1.0
4. Depressurizing and emptying facilities[d]	1.00
5. Underground storage	0.0
6. Earth-covered storage above grade	0.03

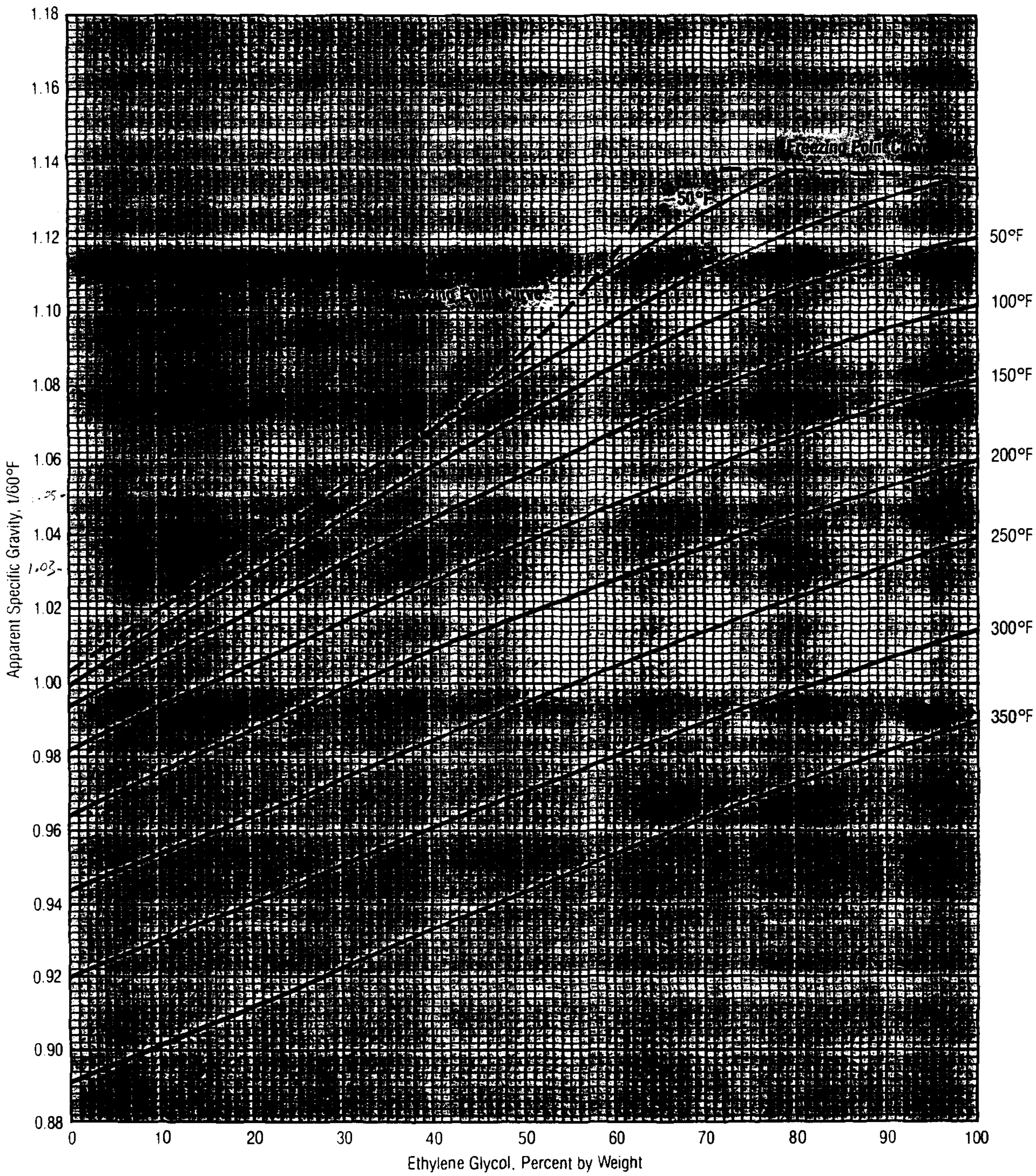
[a] These are suggested values for the conditions assumed in Paragraph 5.2. When these conditions do not exist, engineering judgment should be exercised either in selecting a higher factor or in providing means of protecting vessels from fire exposure as suggested in Paragraph 6.1.

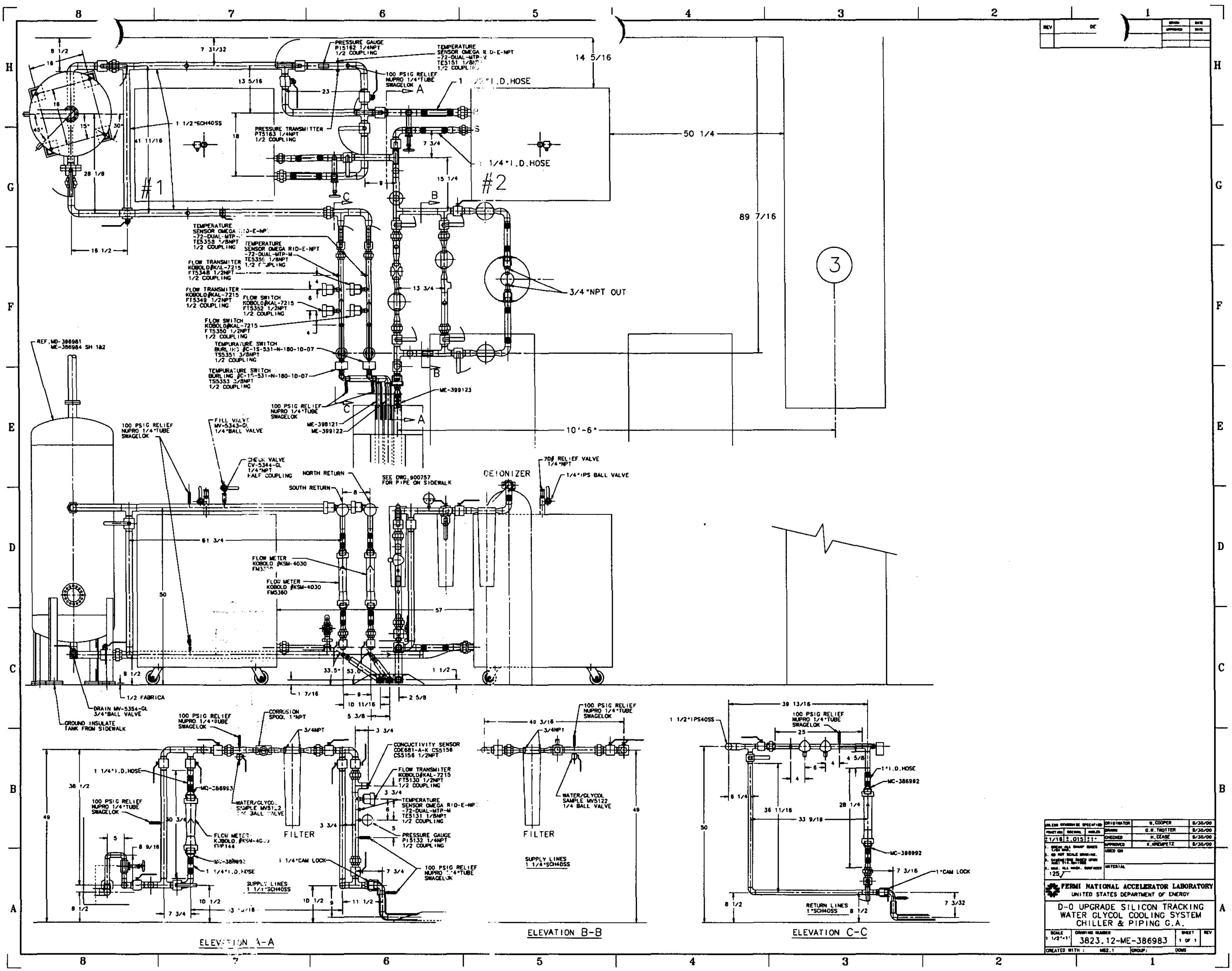
[b] Insulation shall resist dislodgement by fire hose streams. For the examples a temperature difference of 1,600 degrees Fahrenheit was used. In practice it is recommended that insulation be selected to provide a temperature difference of at least 1,000 degrees Fahrenheit and that the thermal conductivity be based on a temperature that is at least the mean temperature.

[c] See Paragraph 6.3.3 for recommendations regarding water application.

[d] Depressurizing will provide a lower factor if done promptly but no credit is to be taken when safety valves are being size for fire exposure.

Figure 5 • Specific Gravities of Aqueous Ethylene Glycol Solutions





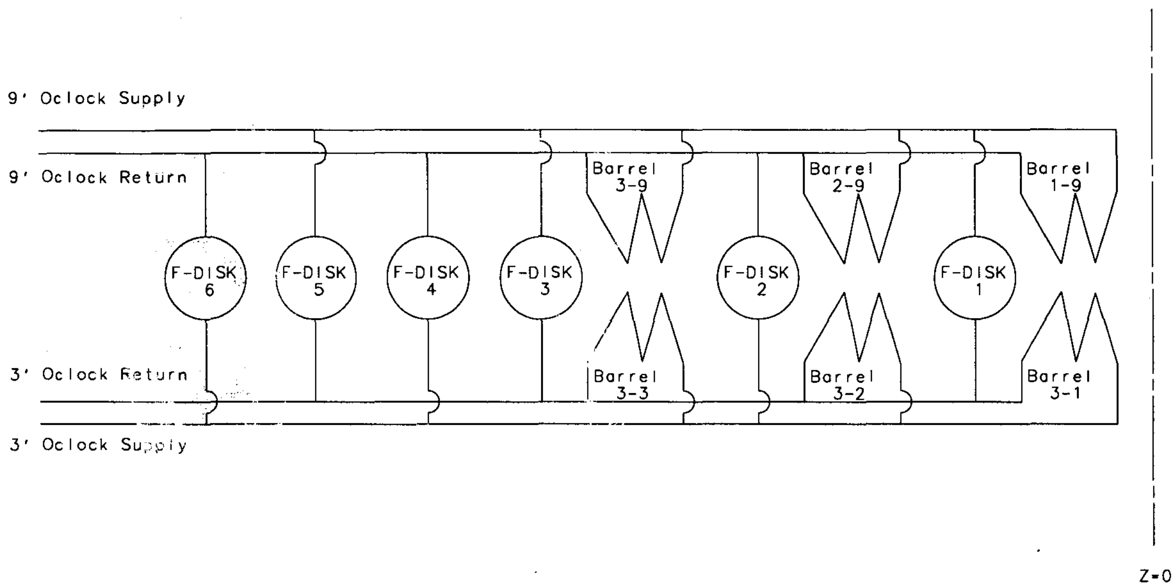
UNLESS OTHERWISE SPECIFIED	ORIGINATOR	W.COOPER	8/30/00
FRACTION ±1/16 / DECIMAL ±.015 / ANGLES ±1°	DRAWN	G.R.TROTTER	8/30/00
	CHECKED	H.CEASE	8/30/00
	APPROVED	K.KREMPETZ	8/30/00

FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

D-0 UPGRADE SILICON TRACKING
WATER GLYCOL COOLING SYSTEM
CHILLER & PIPING G.A.

SCALE 1 1/2"=1' | DRAWING NUMBER 3823.12-ME-386983 | SHEET 1 OF 1 | REV

CREATED WITH : MS2.1 | GROUP: DOMS



REV.	DESCRIPTION	DWN / APPROVED	DATE

ITEM NO.	PART NO.	DESCRIPTION OR SIZE	QTY. REQ.

PARTS LIST

UNLESS OTHERWISE SPECIFIED					
.XX	.XXX	ANGLES	ORIGINATOR	Bill Cooper	10/00
±	±	±	DRAWN	Herman Cease	10/13/00
			CHECKED		
			APPROVED		

1. BREAK ALL SHARP EDGES .015 MAX.
2. DO NOT SCALE DRWG.
3. DIMENSIONING IN ACCORD WITH ANSI Y14.5M-1982 STD'S.
4. ALL DIMENSIONS ARE IN INCHES.

√ MAX. ALL MACHINED SURFACES

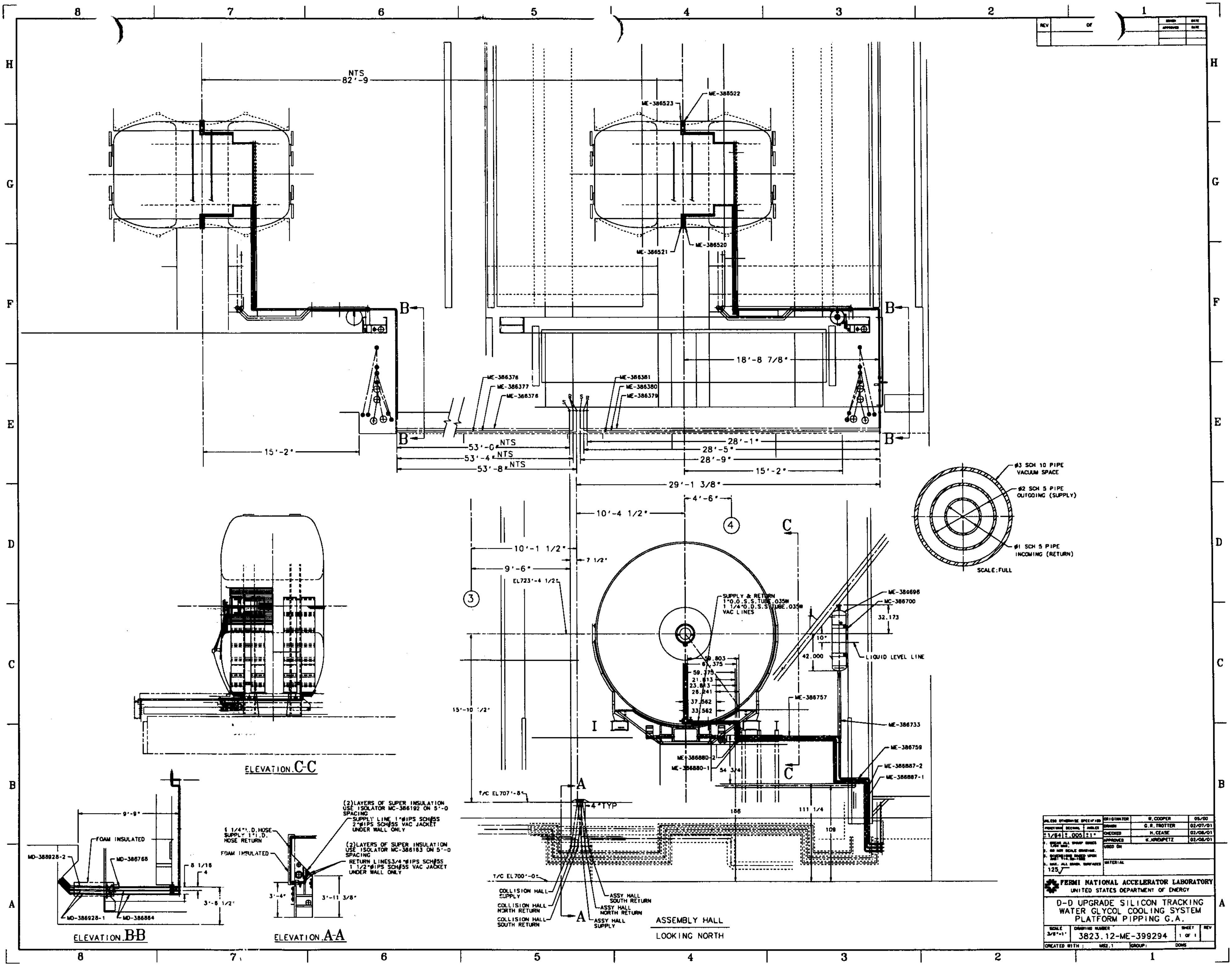
USED ON

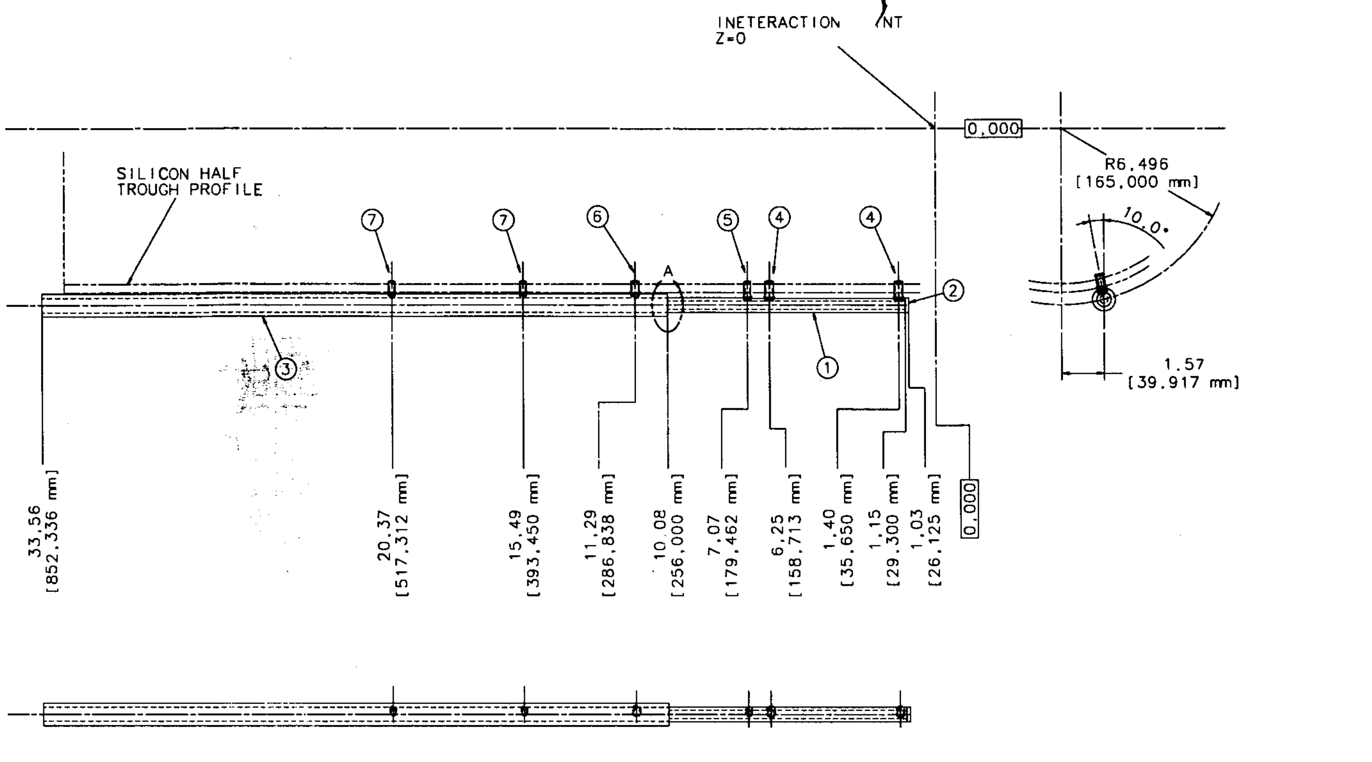
MATERIAL

FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

PPD/MECHANICAL SUPPORT
D-ZERO SILICON
HALF MANIFOLD SCHEMATIC

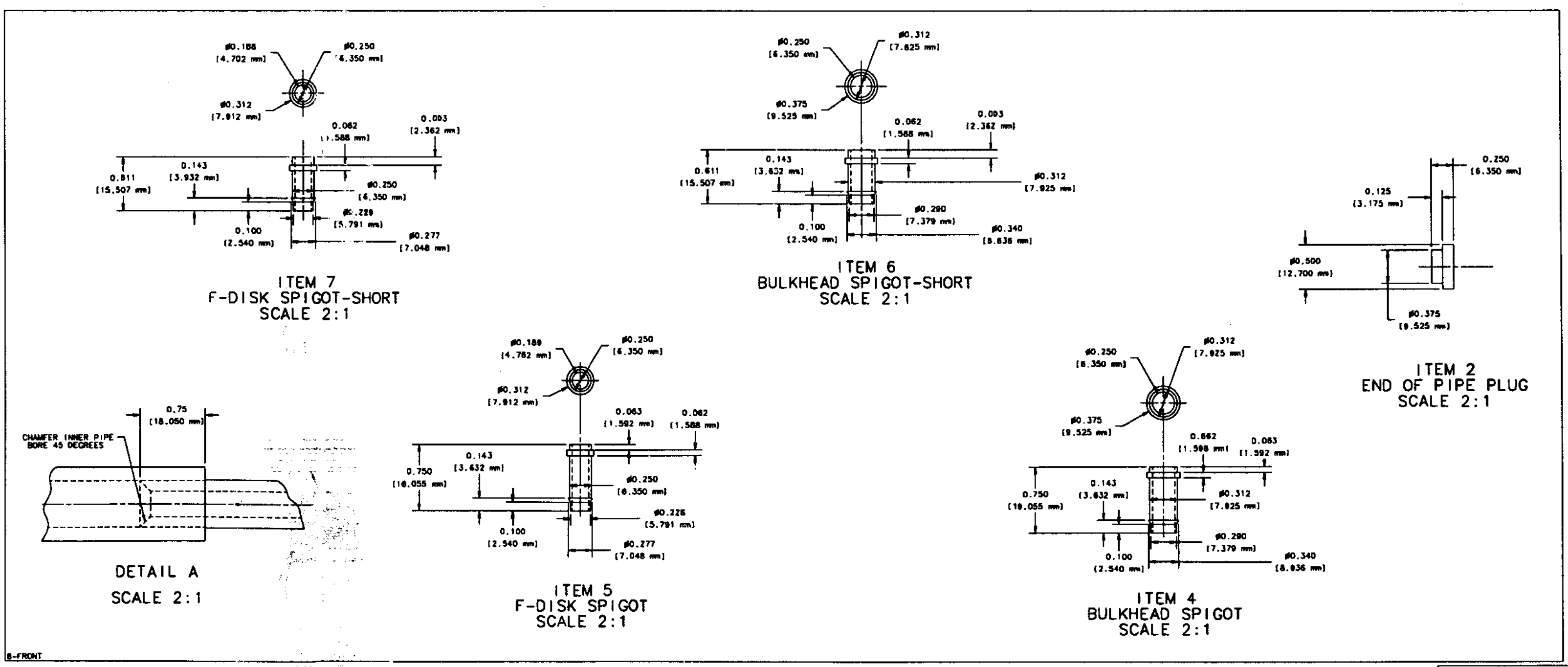
SCALE	DRAWING NUMBER	SHEET NO.	REV.
	3823.112-MC-900888	1 OF 1	


NTS
82'-9
ME-386523
ME-386522
ME-386521
ME-386520
B
18'-8 7/8"
ME-386376
ME-386377
ME-386378
ME-386381
ME-386380
ME-386379
15'-2"
53'-0" NTS
53'-4" NTS
53'-8" NTS
28'-1"
28'-5"
28'-9"
15'-2"
29'-1 3/8"
4'-6"
10'-4 1/2"
10'-1 1/2"
7 1/2"
9'-6"
EL723'-4 1/2"
#3 SCH 10 PIPE VACUUM SPACE
#2 SCH 5 PIPE OUTGOING (SUPPLY)
#1 SCH 5 PIPE INCOMING (RETURN)
SCALE:FULL
SUPPLY & RETURN
1"O.D.S.S.TUBE.035W
1 1/4"O.D.S.S.TUBE.035W
VAC LINES
ME-386696
MC-386700
32.173
10"
42.000
LIQUID LEVEL LINE
ME-386757
ME-386733
ME-386759
ME-386887-2
ME-386887-1
ME-386880-2
ME-386880-1
54 3/4
15'-10 1/2"
T/C EL707'-8"
4" TYP
186
111 1/4
109
T/C EL700'-0"
COLLISION HALL SUPPLY
COLLISION HALL NORTH RETURN
COLLISION HALL SOUTH RETURN
ASSY HALL SOUTH RETURN
ASSY HALL NORTH RETURN
ASSY HALL SUPPLY
ASSEMBLY HALL
LOOKING NORTH
ELEVATION C-C
9'-9"
FOAM INSULATED
MD-386928-2
MD-386768
8 1/16
4
3'-8 1/2"
MD-386928-1
MD-386884
ELEVATION B-B
(2)LAYERS OF SUPER INSULATION USE ISOLATOR MC-386192 ON 5'-0 SPACING
SUPPLY LINE 1"#IPS SCH#5S 2"#IPS SCH#5S VAC JACKET UNDER WALL ONLY
(2)LAYERS OF SUPER INSULATION USE ISOLATOR MC-386183 ON 5'-0 SPACING
RETURN LINES3/4"#IPS SCH#5S 1 1/2"#IPS SCH#5S VAC JACKET UNDER WALL ONLY
1 1/4"I.D.HOSE SUPPLY 1"I.D. HOSE RETURN
FOAM INSULATED
3'-4"
3'-11 3/8"
ELEVATION A-A
UNLESS OTHERWISE SPECIFIED
±1/64 ±.005 ±1°
125
ORIGINATOR W.COOPER 05/00
DRAWN G.R.TROTTER 02/07/01
CHECKED H.CEASE 02/08/01
APPROVED K.KREMPETZ 02/08/01
USED ON
MATERIAL
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY
D-D UPGRADE SILICON TRACKING
WATER GLYCOL COOLING SYSTEM
PLATFORM PIPPING G.A.
SCALE 3/8"=1'
DRAWING NUMBER 3823.12-ME-399294
SHEET 1 OF 1
REV
CREATED WITH : MS2.1
GROUP: DOMS



NOTES:

1. USE PRIMER AND MEDIUM DUTY PVC PLASTIC PIPE CEMENT TO BOND PIECE PARTS INTO AN ASSEMBLY.
2. ALL ADHESIVE BONDS TO BE VACUUM LEAK TIGHT.
3. LEAK TEST: NO LEAK SHALL BE DETECTABLE ON THE MOST SENSITIVE SCALE OF A HELIUM LEAK DETECTOR WITH A MINIMUM SENSITIVITY OF 1 x 10^{-9} ATM.CC/SEC.



ITEM	PART NO.	DESCRIPTION OR SIZE	QTY.
9		MEDIUM DUTY PVC PIPE CEMENT-CLEAR	AS REQ'D.
8		PRIMER-SURF. PREP. FOR PVC PIPE CEMENT	AS REQ'D.
7		3/16" ID BARBED SPIGOT	2
6		1/4" ID BARBED SPIGOT	1
5		3/16" ID BARBED SPIGOT	1
4		1/4" ID BARBED SPIGOT	2
3		1/2" Sch. 80 PIPE	AS REQ'D.
2		END OF PIPE PLUG	1
1		1/4" sch 80 PIPE	AS REQ'D.

PARTS LIST

ORIGINATOR	W. COOPER	6/05/00
DRAWN	HERMAN CEASE	10/11/00
CHECKED	HERMAN CEASE	12/13/00
APPROVED	K. KREMPETZ	12/13/00

UNLESS OTHERWISE SPECIFIED: .XX ±.02, .XXX ±.005, DEG ±1/2°

USED ON 3823.112-ME-399235-01

MATERIAL PVC

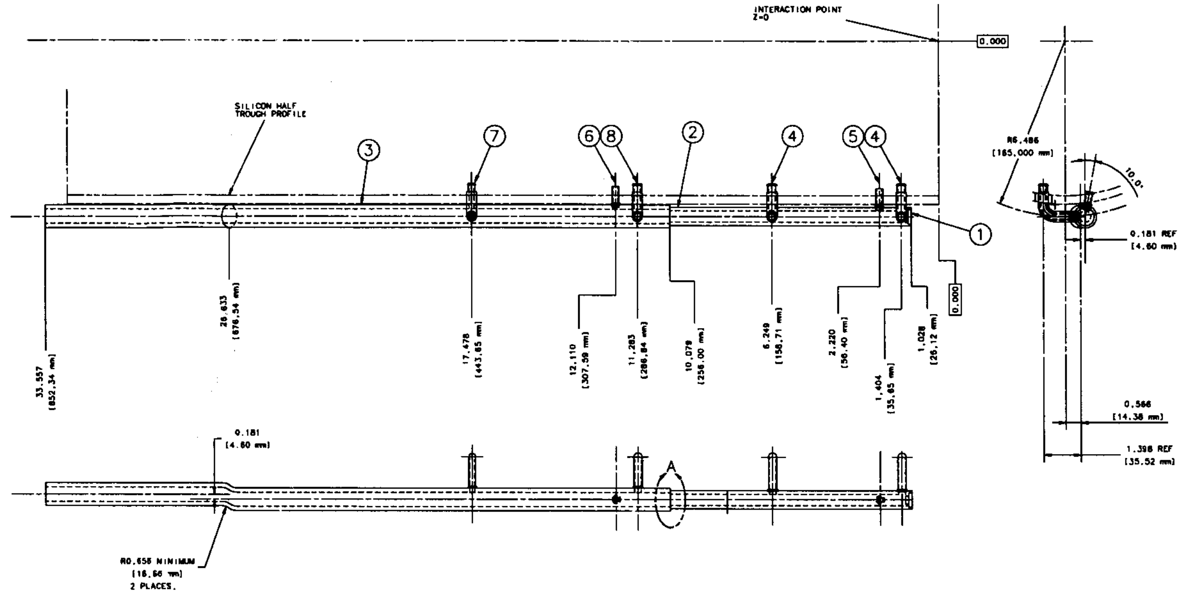
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

D-Ø UPGRADE SILICON TRACKING
SILICON HALF TROUGH MANIFOLD
3 O'CLOCK SUPPLY

SCALE 0.6 : 1 — DRAWING NUMBER 3823.112-ME-386679

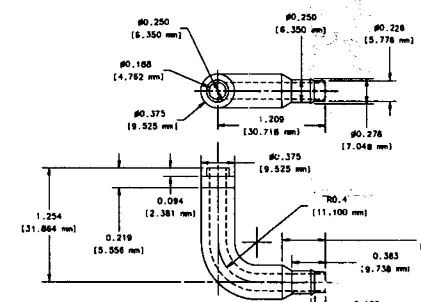
CREATED WITH I-DEAS_VI — USER NAME:

Plotted by cease on 03-Jun-2001 , File: 38667901__.pff

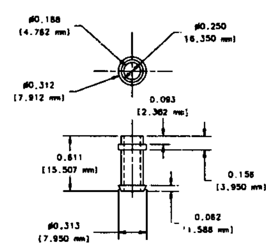


NOTES:

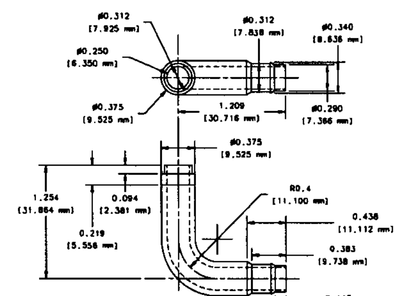
1. USE PRIMER AND MEDIUM DUTY PVC PLASTIC PIPE CEMENT TO BOND PIECE PARTS INTO AN ASSEMBLY.
2. ALL ADHESIVE BONDS TO BE VACUUM LEAK TIGHT.
3. LEAK TEST: NO LEAK SHALL BE DETECTABLE ON THE MOST SENSITIVE SCALE OF A HELIUM LEAK DETECTOR WITH A MINIMUM SENSITIVITY OF 1 x 10⁻⁹ ATM.CC/SEC.



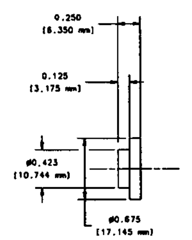
ITEM 7
F-DISK SPIGOT SHORT
SCALE 2:1



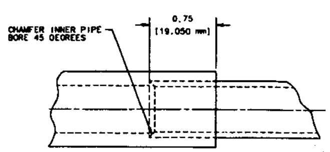
ITEM 6
H-DISK/F-DISK SPIGOT
SCALE 2:1



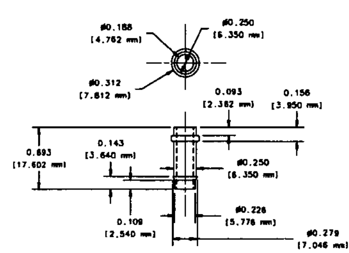
ITEM 8
BULKHEAD SPIGOT SHORT
SCALE 2:1



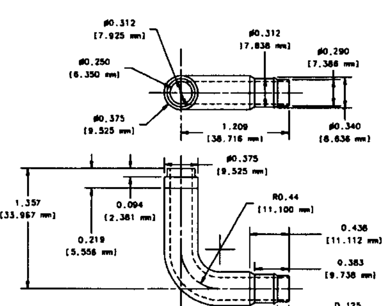
ITEM 1
END OF PIPE PLUG
SCALE 2:1



DETAIL A
SCALE 2:1



ITEM 5
F-DISK SPIGOT LONG
SCALE 2:1



ITEM 4
BULKHEAD SPIGOT LONG
SCALE 2:1

ITEM	PART NO.	DESCRIPTION OR SIZE	QTY.
10		MEDIUM DUTY PVC PIPE CEMENT-CLEAR	AS REQ'D.
9		PRIMER-SURF. PREP. FOR PVC PIPE CEMENT	AS REQ'D.
8		1/4" ID BARBED SPIGOT-SHORT	1
7		3/16" ID BARBED SPIGOT-SHORT	1
6		3/16" ID BARBED SPIGOT	1
5		3/16" ID SPIGOT-LONG	1
4		1/4" ID BARBED SPIGOT LONG	2
3		1/2" Sch. 80 PIPE	AS REQ'D.
2		3/8" sch 80 PIPE	AS REQ'D.
1		END OF PIPE PLUG	1

PARTS LIST

ORIGINATOR	W.COOPER	6/05/00
DRAWN	HERMAN CEASE	10/11/00
CHECKED	HERMAN CEASE	12/13/00
APPROVED	K. KREMPETZ	12/13/00

.XX ±.02 | .XXX ±.005 | DEG ±.01

USED ON 3823.112-ME-399235-01

MATERIAL PVC

FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

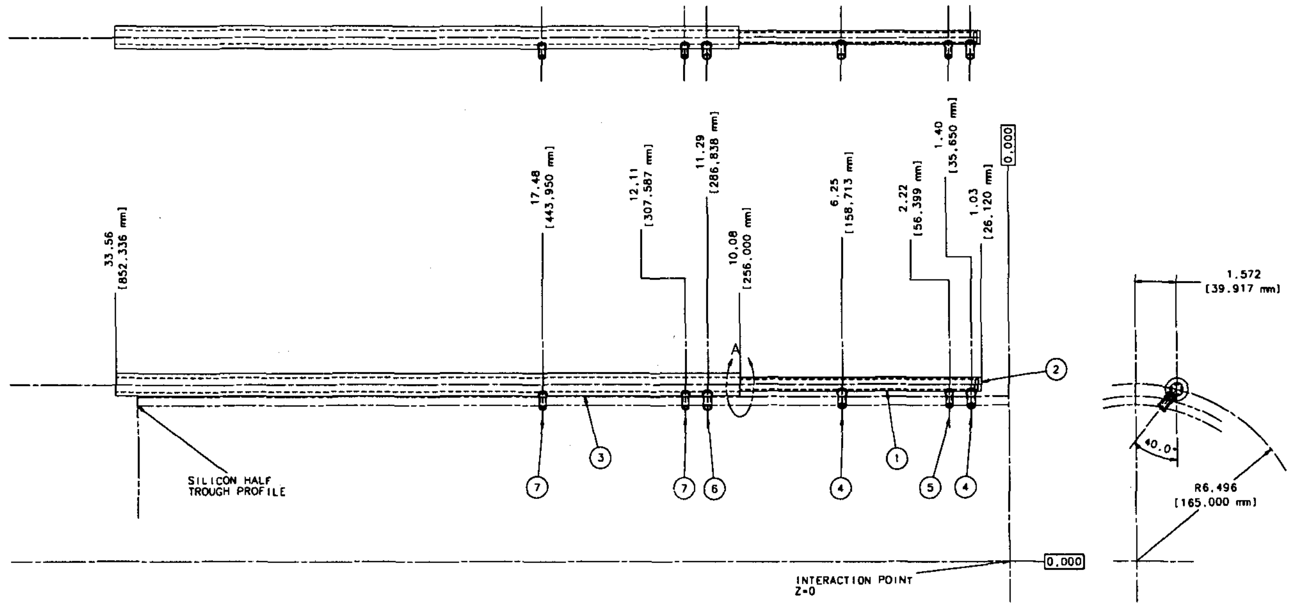
D-Ø UPGRADE SILICON TRACKING
SILICON HALF TROUGH MANIFOLD
3 O'CLOCK RETURN

SCALE 0.6 : 1 | DRAWING NUMBER 3823.112-ME-366680 | REV.

CREATED WITH I-DEAS_VI | USER NAME:

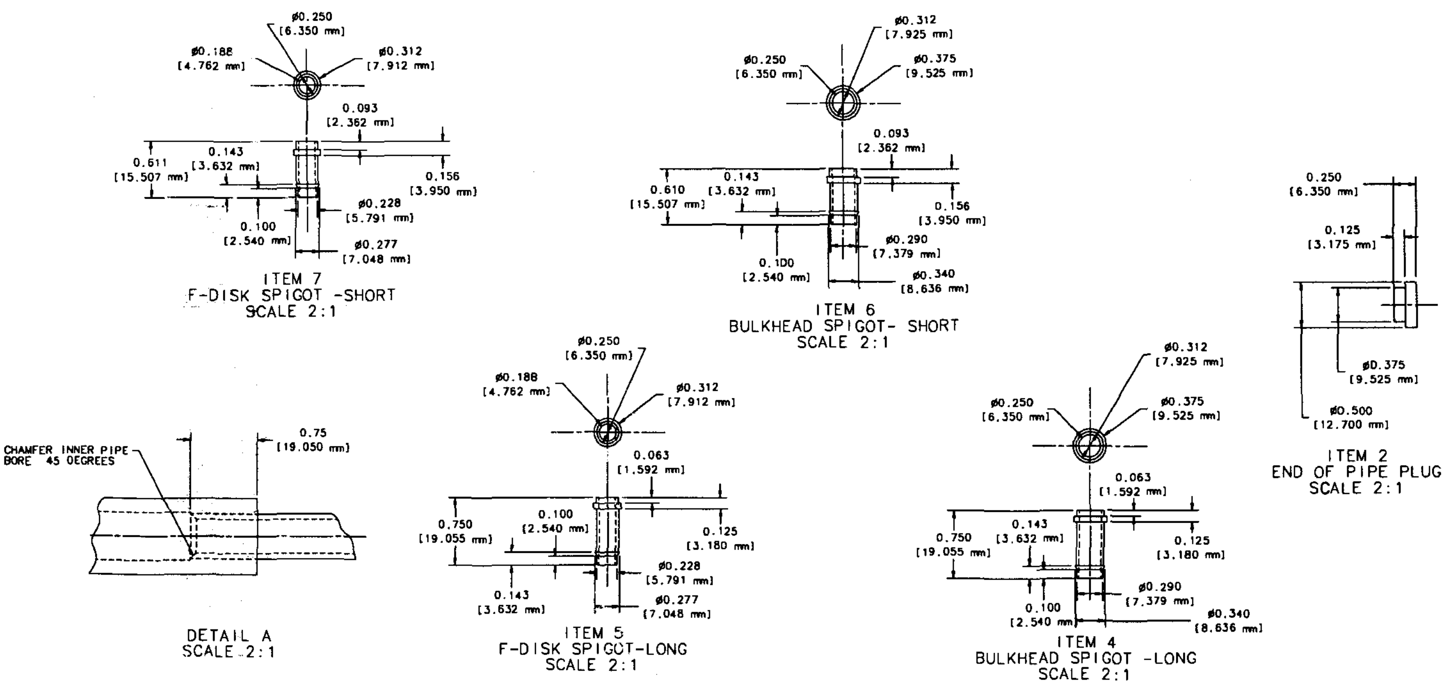
CADFILE:

Plotted by cease on 03-Jan-2001 , File: 38668001__.pff



NOTES:

1. USE PRIMER AND MEDIUM DUTY PVC PLASTIC PIPE CEMENT TO BOND PIECE PARTS INTO AN ASSEMBLY.
2. ALL ADHESIVE BONDS TO BE VACUUM LEAK TIGHT.
3. LEAK TEST: NO LEAK SHALL BE DETECTABLE ON THE MOST SENSITIVE SCALE OF A HELIUM LEAK DETECTOR WITH A MINIMUM SENSITIVITY OF 1 x 10^{-8} ATM.CC/SEC.



ITEM	DESCRIPTION OR SIZE	QTY.
9	MEDIUM DUTY PVC PIPE CEMENT-CLEAR	AS REQ'D.
8	PRIMER-SURF. PREP. FOR PVC PIPE CEMENT	AS REQ'D.
7	3/16" ID BARBED SPIGOT-SHORT	2
6	1/4" ID BARBED SPIGOT-SHORT	1
5	3/16" ID BARBED SPIGOT	1
4	1/4" ID BARBED SPIGOT	2
3	1/2" Sch. 80 PIPE	AS REQ'D.
2	END OF PIPE PLUG	1
1	1/4" Sch 80 PIPE	AS REQ'D.

PARTS LIST

ORIGINATOR	W. COOPER	6/05/00
DRAWN	HERMAN CEASE	10/11/00
CHECKED	HERMAN CEASE	12/13/00
APPROVED	K. KREMPETZ	12/13/00

.XX ±.02 | .XXX ±.005 | DEG ±1/2°

USED ON 3823.112-ME-399235-01

MATERIAL PVC

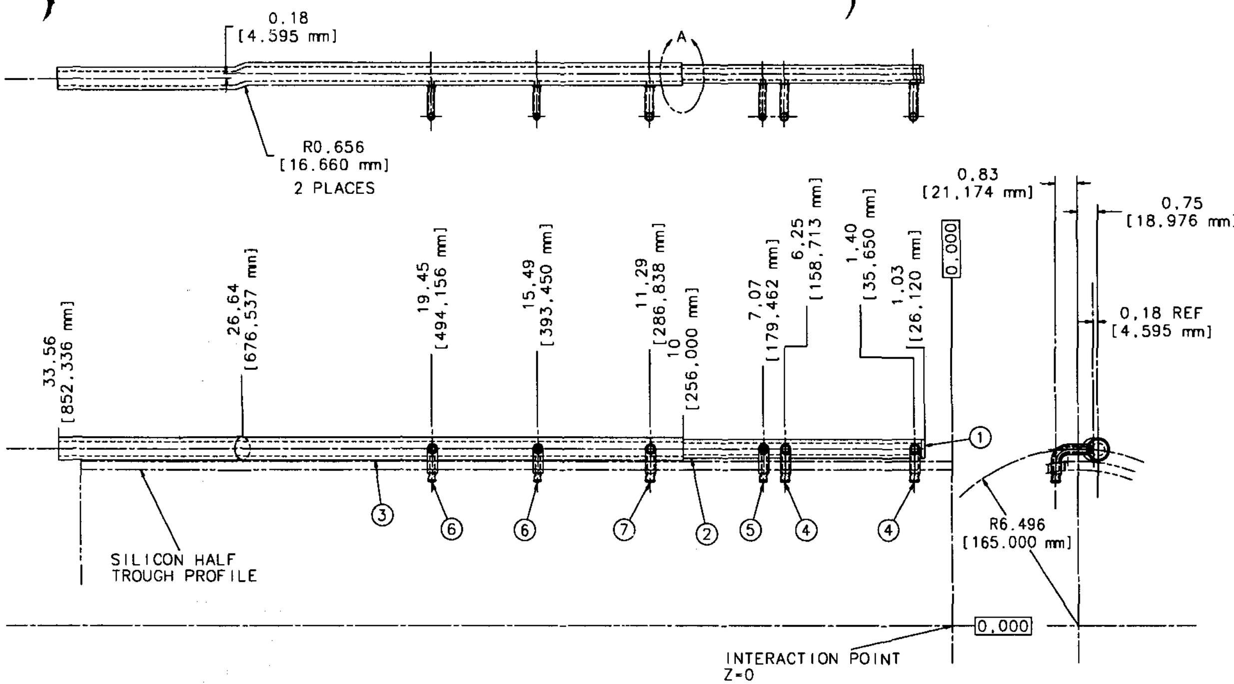
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

D-Ø UPGRADE SILICON TRACKING
SILICON HALF TROUGH MANIFOLD
9 O'CLOCK SUPPLY

SCALE 0.6 : 1 — DRAWING NUMBER 3823.112-ME-386681

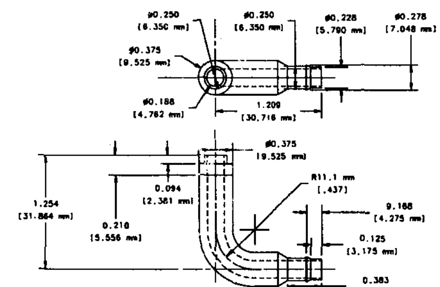
CREATED WITH I-DEAS_VI

Plotted by cease on 03-Jan-2001 , File: 38668101__.pff

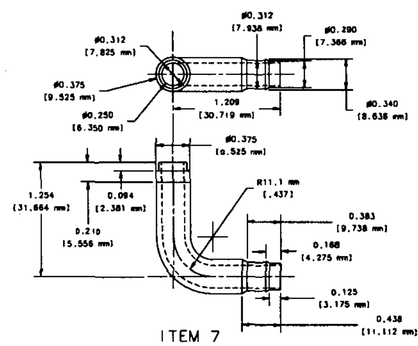


NOTES:

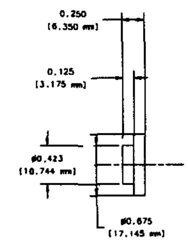
1. USE PRIMER AND MEDIUM DUTY PVC PLASTIC PIPE CEMENT TO BOND PIECE PARTS INTO AN ASSEMBLY.
2. ALL ADHESIVE BONDS TO BE VACUUM LEAK TIGHT.
3. LEAK TEST: NO LEAK SHALL BE DETECTABLE ON THE MOST SENSITIVE SCALE OF A HELIUM LEAK DETECTOR WITH A MINIMUM SENSITIVITY OF 1 x 10^{-8} ATM.CC/SEC.



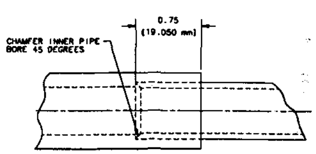
ITEM 6
F-OISK SPIGOT SHORT
SCALE 2:1



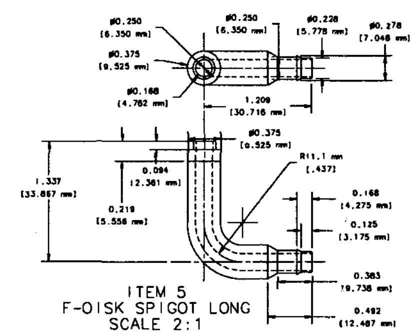
ITEM 7
BULKHEAD SPIGOT SHORT
SCALE 2:1



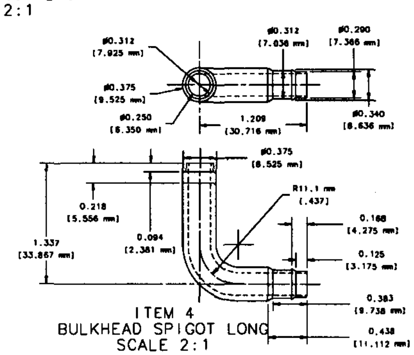
ITEM 1
END OF PIPE PLUG
SCALE 2:1



DETAIL A
SCALE 2:1



ITEM 5
F-OISK SPIGOT LONG
SCALE 2:1



ITEM 4
BULKHEAD SPIGOT LONG
SCALE 2:1

ITEM	PART NO.	DESCRIPTION OR SIZE	QTY.
9		MEDIUM DUTY PVC PIPE CEMENT-CLEAR	AS REQ'D.
8		PRIMER-SURF. PREP. FOR PVC PIPE CEMENT	AS REQ'D.
7		1/4" ID 3/8" OD BARBED SPIGOT-SHORT	1
6		3/16" ID 3/8" OD BARBED SPIGOT-SHORT	2
5		3/16 ID 3/8" OD BARBED SPIGOT-LONG	1
4		1/4" ID 3/8" OD BARBED SPIGOT LONG	2
3		1/2" Sch. 80 PIPE	AS REQ'D.
2		3/8" sch 80 PIPE	AS REQ'D.
1		END OF PIPE PLUG	1

PARTS LIST

ORIGINATOR	W.COOPER	6/05/00
DRAWN	HERMAN CEASE	10/11/00
CHECKED	HERMAN CEASE	12/13/00
APPROVED	E. KREMPETZ	12/13/00

.XX ±.02 | .XXX ±.005 | DEG ±1/2°

USED ON 3823.112-ME-386235-01

MATERIAL PVC

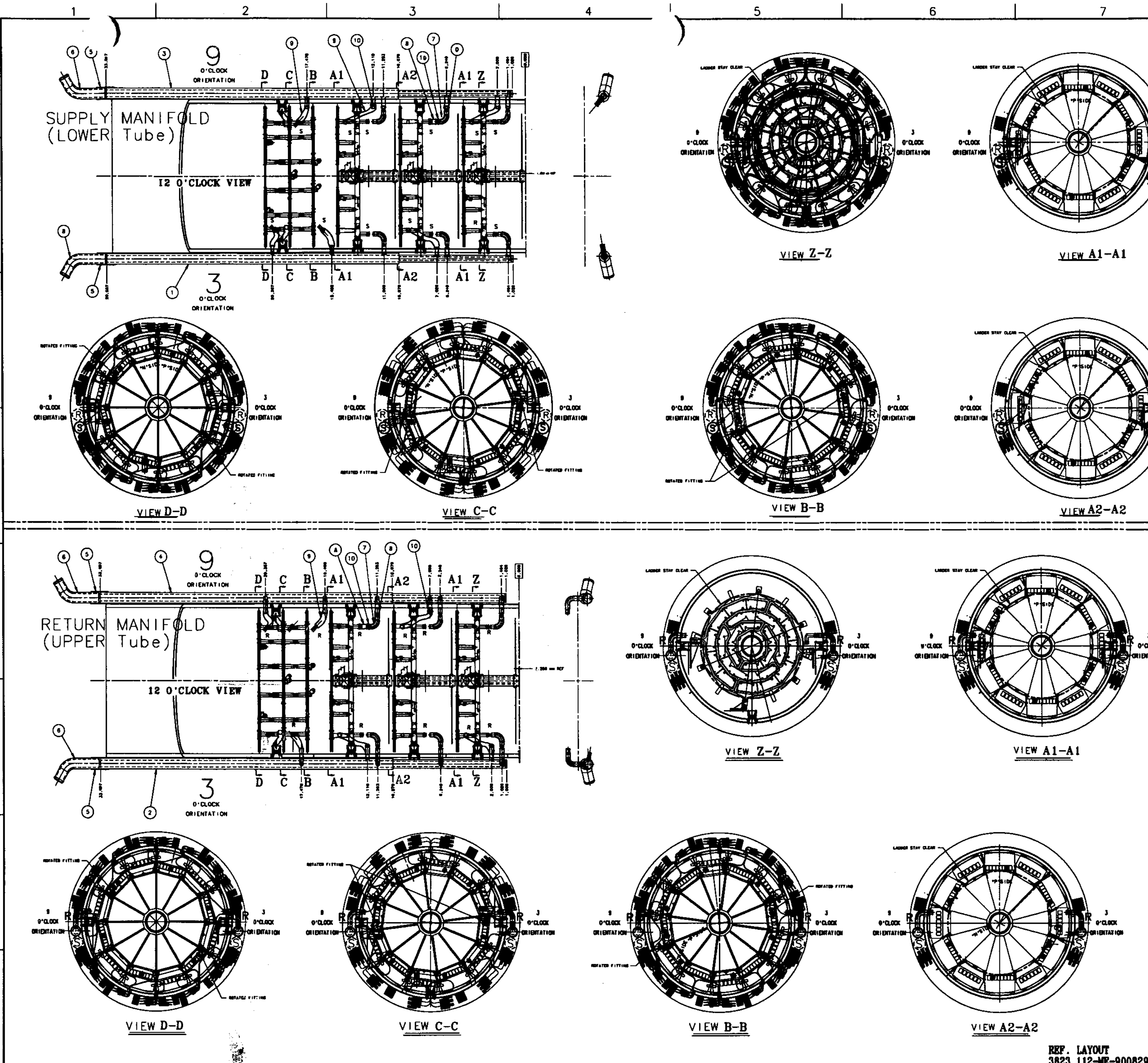
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

D-Ø UPGRADE SILICON TRACKING
SILICON HALF TROUGH MANIFOLD
9 O'CLOCK RETURN

SCALE 0.6 : 1 — DRAWING NUMBER 3823.112-ME-386682

CREATED WITH I-DEAS_VI | USER NAME:

Plotted by cease on 03-Jan-2001 , File: 38668201__.pff



PRELIMINARY
--NOT CHECKED--
J. KOWALSKI
MON. 19 FEB. 2001

ITEM NO.	PART NO.	DESCRIPTION OR SIZE	QTY. REQ.
10	COMMERCIAL	WIRE-TWIST SEAL, 0.03 ∅ SOFT BRASS	AS REQ'D.
9	COMMERCIAL	3/16" I. DIA. PLASTIC TUBING-0.06 WALL THKNS. "CILRAN"(RANDOLPH-AUSTIN)	AS REQ'D.
0	COMMERCIAL	1/4" I. DIA. PLASTIC TUBING-0.06 WALL THKNS. "CILRAN"(RANDOLPH-AUSTIN)	AS REQ'D.
7	MC-399105	ELBOW-90°	12
6	MC-399104	ELBOW-120°	4
5	MC-399103	COUPLING	4
4	ME-386602	MANIFOLD-COOLING RTN. 9 O'CLK.	1
3	ME-386681	MANIFOLD-COOLING SUP. 9 O'CLK.	1
2	ME-386680	MANIFOLD-COOLING RTN. 3 O'CLK.	1
1	ME-386679	MANIFOLD-COOLING SUP. 3 O'CLK.	1

PARTS LIST

ORIGINATOR	W. COOPER	5/00
DRAWN	H. CEASE	5/11/00
CHECKED	H. CEASE	12/13/00
APPROVED	K. KREMPETZ	12/13/00

UNLESS OTHERWISE SPECIFIED

1. BREAK ALL SHARP EDGES .015 MAX.
2. DO NOT SCALE DWG.
3. DIMENSIONING IN ACCORD WITH ANSI Y14.5M-1982 STD'S.
4. ALL DIMENSIONS ARE IN INCHES.

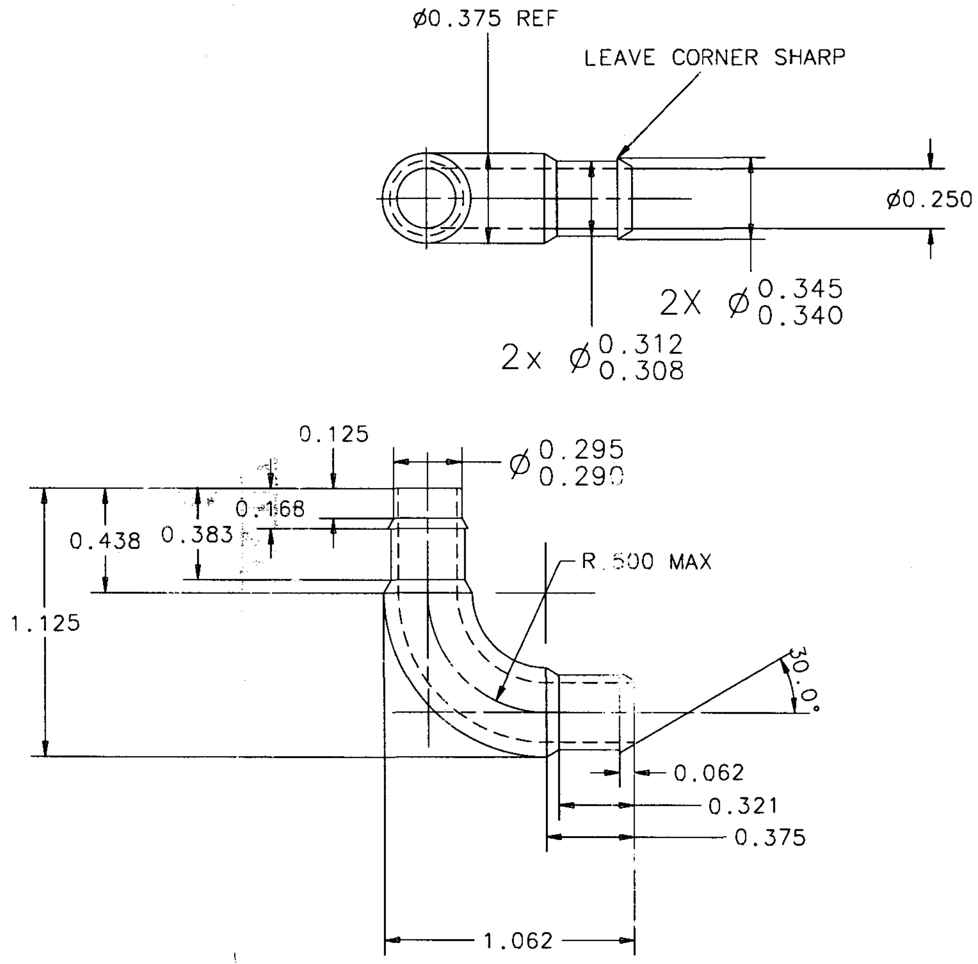
USED ON

MATERIAL

FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

D0 DETECTOR UPGRADE
SILICON DETECTOR COOLING
F. DISKS-3 BARREL ASSEMBLY

SCALE	DRAWING NUMBER	SHEET NO.	REV.
0.4 : 1	3823.112-ME-399235-01	1 OF 1	



REV.	DESCRIPTION	DRAWN / APPROVED	DATE / DATE

ITEM NO.	PART NO.	DESCRIPTION OR SIZE	QTY. REQ.

PARTS LIST

UNLESS OTHERWISE SPECIFIED				
.XX	.XXX	ANGLES	ORIGINATOR	BILL COOPER 8/00
±	±.010	±.1	DRAWN	HERMAN CEASE 8/31/00
			CHECKED	HERMAN CEASE 10/12/00
			APPROVED	KURT KREMPETZ 10/12/00

1. BREAK ALL SHARP EDGES .015 MAX.
2. DO NOT SCALE DRWG.
3. DIMENSIONING IN ACCORD WITH ANSI Y14.5M-1982 STD'S.
4. ALL DIMENSIONS ARE IN INCHES.

√ MAX. ALL MACHINED SURFACES

USED ON

MATERIAL: PVC

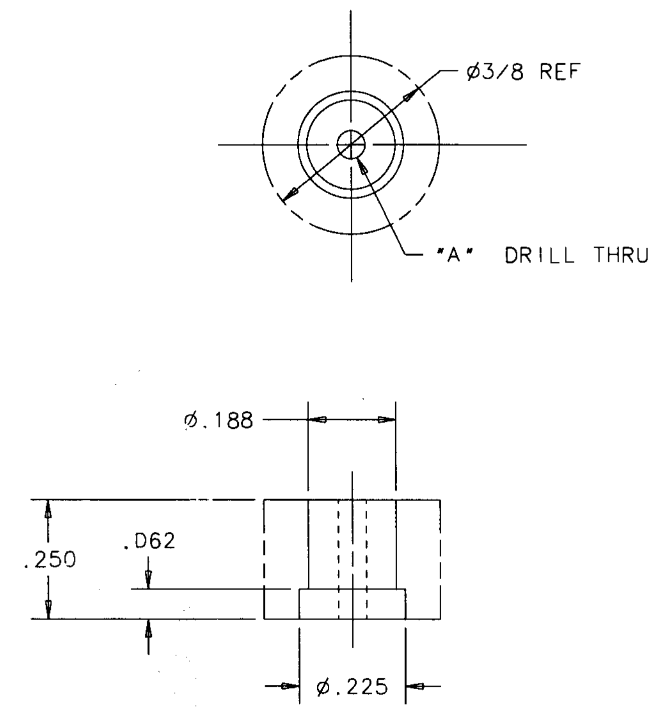
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

PPD/MECHANICAL SUPPORT

SCALE	DRAWING NUMBER	SHEET NO.	REV.
2X	3823.112-MB-399105	1 OF 1	

Plotted by ceose on 16-Oct-2000 File: 39910501__.pff

REV.	DESCRIPTION	DRAWN / APPROVED	DATE / DATE



-4	1/8 (.125)
-3	#38 (.1015)
-2	#46 (.081)
-1	#53 (.0595)
SUFFIX NO.	"A"

ITEM NO.	PART NO.	DESCRIPTION OR SIZE	QTY. REQ.

PARTS LIST

UNLESS OTHERWISE SPECIFIED					
.XX	.XXX	ANGLES			
± ---	± .005	± 1°			

ORIGINATOR	H. CEASE	10/00
DRAWN	D. FRIEND	10/16/00
CHECKED	H. CEASE	10/16/00
APPROVED	K. KREMPETZ	10/16/00

1. BREAK ALL SHARP EDGES .015 MAX.
2. DO NOT SCALE DRWG.
3. DIMENSIONING IN ACCORD WITH ANSI Y14.5M-1982 STD'S.
4. ALL DIMENSIONS ARE IN INCHES.

125 √ MAX. ALL MACHINED SURFACES

USED ON
ME-386679, ME-386680
ME-386681, ME-386682

MATERIAL
ROD, ⌀3/8", DARK GRAY PVC
MCMASTER-CARR #8745K42

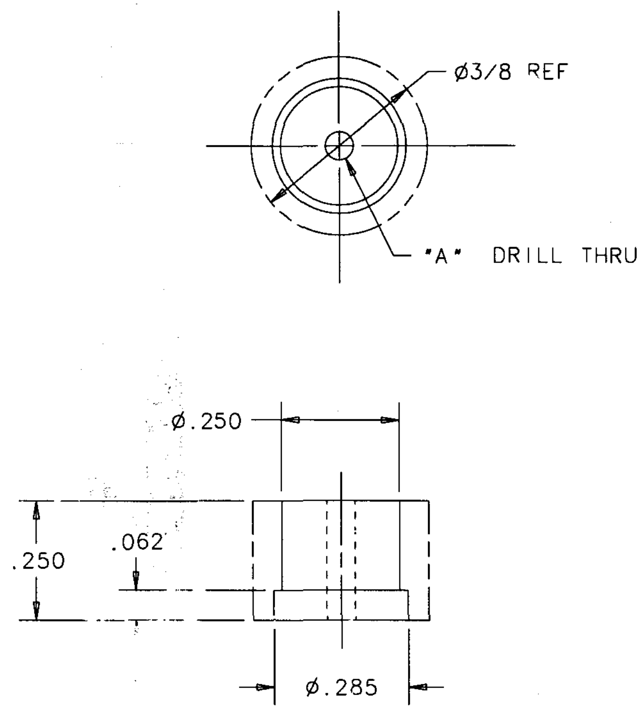
FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

D0 DETECTOR UPGRADE
SILICON TRACKER; GLYCOL MANIFOLD
HOSE ADAPTER; 3/16" NOMINAL

SCALE	DRAWING NUMBER	SHEET NO.	REV.
4X	3823.112-MB-386990	1 OF 1	

Plotted by cease on 07-Feb-2001 , File: 38699001__.pff

REV.	DESCRIPTION	DRAWN / APPROVED	DATE / DATE



-4	1/8 (.125)
-3	#38 (.1015)
-2	#46 (.081)
-1	#53 (.0595)
SUFFIX NO.	"A"

ITEM NO.	PART NO.	DESCRIPTION OR SIZE	QTY. REQ.

PARTS LIST

UNLESS OTHERWISE SPECIFIED

.XX	.XXX	ANGLES
± ---	± .005	± 1°

1. BREAK ALL SHARP EDGES .015 MAX.
2. DO NOT SCALE DRWG.
3. DIMENSIONING IN ACCORD WITH ANSI Y14.5M-1982 STD'S.
4. ALL DIMENSIONS ARE IN INCHES.

125 √ MAX. ALL MACHINED SURFACES

ORIGINATOR	H. CEASE	10/00
DRAWN	O. FRIEND	10/16/00
CHECKED	H. CEASE	10/16/00
APPROVED	K. KREMPETZ	10/16/00

USED ON
ME-386679, ME-386680
ME-386681, ME-386682

MATERIAL
ROD, Ø3/8", DARK GRAY PVC
MCMASTER-CARR #8745K42

FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

DO DETECTOR UPGRADE
SILICON TRACKER; GLYCOL MANIFOLD
HOSE ADAPTER; 1/4" NOMINAL

SCALE	DRAWING NUMBER	SHEET NO.	REV.
4X	3823.112-MB-386991	1 OF 1	

Plotted by cease on 07-Feb-2001 , File: 38699101__.pff