SSCL-N-707

ARGON CALORIMETER

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SUMMARY

This paper describes the liquid argon portion of the EMPACT calorimeter. This description would apply to any large argon calorimeter but this paper is specific to EMPACT. The plant will be described as well as the cooling system for the calorimeter itself. Figure 1 shows a possible layout. The following cryogenic system is an extrapolation of the SLAC detectors: MARK II, SLD, and also the D0 of Fermi Lab.

* Operated by Universities Research Association, Inc., for the U.S. Department of Energy under Contract No. DE-AC02-89ER40486.

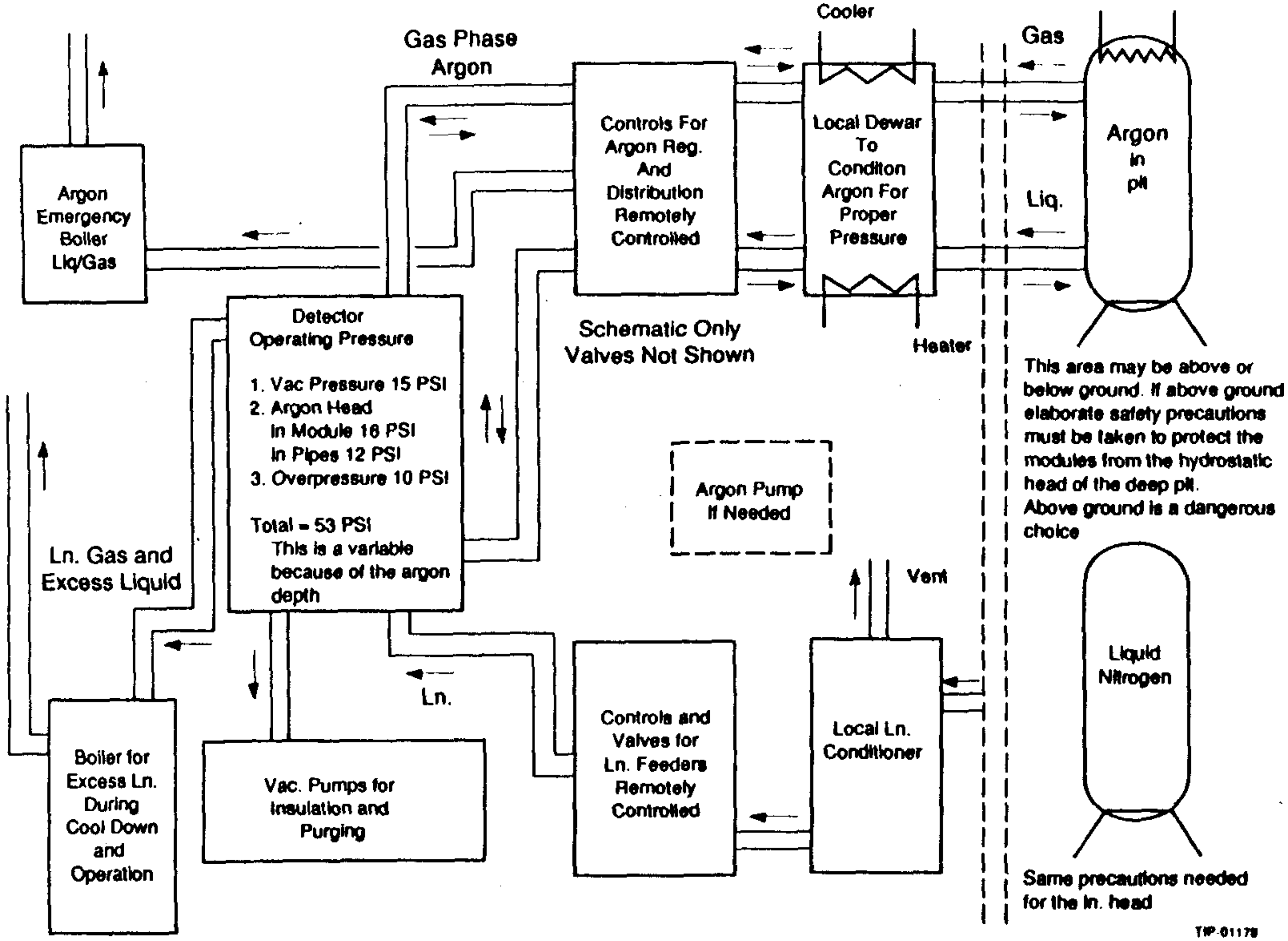

Figure 1. Calorimeter System Block Diagram

MAIN SYSTEMS

The local (at level) argon storage has the capacity to hold a full argon charge for the barrel module, plus the two endcaps, and 20 or 30% excess.

Remote liquid nitrogen storage. This dewar farm will have the capacity to store 30 or more hours of liquid peak nitrogen, which is being used at the cool down use rate. During cool down, the flow rate will be in excess of 2000 liters of liquid-per-hour. The average flow rate for the barrel module could be 500–700 liters of liquid per hour for a 45-day cool down.

Detector. Refers to the detector itself, including endcaps, with a liquid nitrogen use rate of 1300 liters per hour if the amplifiers are placed in the argon liquid (assuming 50 kW of heat from the amplifiers and another 10 kW for assorted heat loads).

Vacuum pumps. Vacuum pumps will be used for insulation of the argon modules.

Local (at level) liquid nitrogen conditioner provides liquid at a vapor pressure of approximately 30 psig. Liquid nitrogen valves and their automatic controls maintain the argon module temperature and pressure.

Local argon reference pressure dewar. The "over pressure" in the modules is maintained by a small volume (1000 liters) dewar so that a reasonably fast response can answer a request for a module pressure change.

Control system for argon "over pressure" regulation and filling and dumping of the modules.

Boiler. A boiler provides vaporization of excess liquid nitrogen blow through in the cooling system for all argon containers. The vent line to the surface must remain free of liquid that would produce back pressure on the liquid nitrogen coolant in the various heat exchangers. A boiler to vaporize argon in the event a liquid dump should be required in case of an emergency. Loss of insulating vacuum would be one example.

Instrument and valve controller air (filtered, etc.) with back-up.

Various Systems In More Detail

The Local Argon Storage

These dewars are placed at the detector level to reduce the large liquid head (over 120 psig) that would be produced by full vertical lines from the surface to the bottom. The detector is designed to operate with about 30 psig and would be destroyed if accidentally (valve failure) exposed to such a high pressure. The result could be catastrophic in terms of financial loss and loss of human lives.

Each dewar will have a condensing coil in the gas phase capable of condensing a few hundred liters per hour of argon at a vapor pressure of one or two psig and a heater to raise the argon temperature if needed. Transfer to and from the local storage dewar from the modules will be done by using pressure differences between the dewar and the modules to force liquid to transfer. Some liquid will be vaporized but not all of it. Care must be taken in the elevation of the piping to be sure large pressures in the modules will not be required to force the liquid over needlessly high transfer line elevations.

The present design for EMPACT requires about 200,000 liters of local argon storage.

The nitrogen control system for the argon dewars consists of the following:

1. A liquid N2 supply valve to the top condenser and an exhaust valve which controls the temperature of the nitrogen in the condenser. All are remotely controlled and adjusted.

   The inlet valves (supply) should be 1" vacuum insulated, proportional control cryo valves with remote controllers.

   The outlet valves (exhaust) should be 1-1/2" vacuum insulated, proportional control cryo valves with remote controllers.

2. The nitrogen transfer lines from the dewars to the argon tanks at the lower level.

If the nitrogen dewars are placed on the surface, one large 2" transfer line can be used to carry liquid to the lower level. The one line could supply all of the nitrogen needed including that for cooling the modules themselves. Redundant valving would be necessary at the top and bottom of this line as well as local pressure conditioning dewars for the distribution system below. The vertical depth of more than 150 feet causes liquid nitrogen to be at 70 or 80 psig at the bottom and the cooling loops in the modules will run in the pressure range of 30 to 40 psig.

Major components:

A. Liquid nitrogen dewars at the top (60,000 liters).

B. Valves at the top with remote and local control.

C. 2" or bigger transfer line from the top to the bottom.

D. Valves at the bottom to control the local conditioning dewar.

E. 2" cryo inlet valve and controller.

F. 2" cryo gas outlet valve to control temperature and pressure of the liquid in the conditioner.

G. 2" cryo liquid outlet valve and controller, supply to various cooling loops.

H. Local 1000 liter conditioning dewar for the module cooling loops.

The module temperature control system. The argon modules are both cooled and refrigerated by cooling loops which are attached to the various outer surfaces of the liquid argon container. The barrel module, for example, has (see Figure 2) four cooling loops on the outer cylindrical wall and two loops on the inner cylindrical wall. Others probably will be put on the barrel ends.

The feed lines for each loop will originate in the LN control rack, placed as close as possible to the detector, and the exhaust lines will go to a similar rack on the other end of the detector.

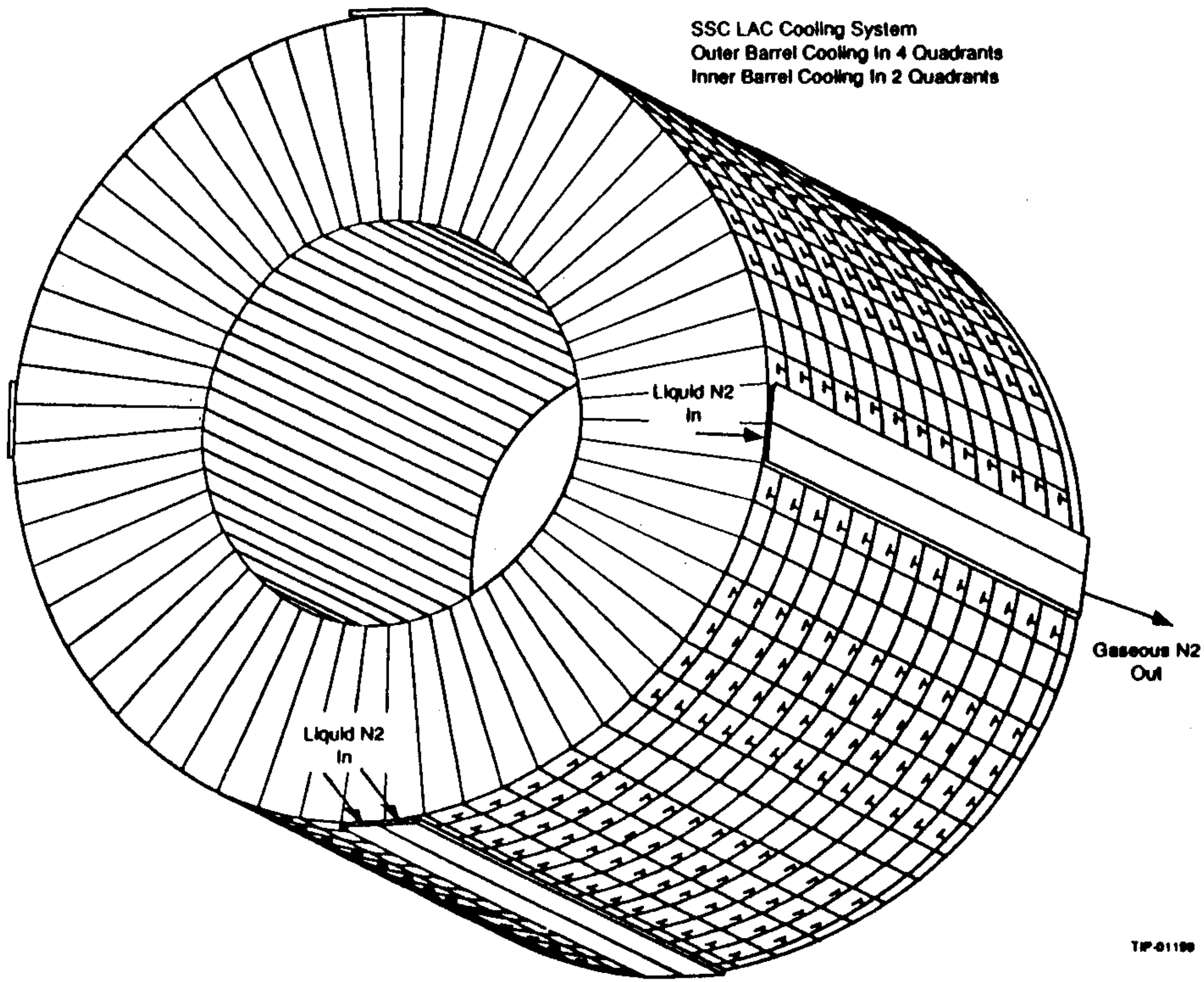

Figure 2. Barrel Module Example

The supply system will consist of:

A. Supply valves (Barrel module only)

6- 1-1/2" vacuum insulated proportional control valves

B. 6 controllers

C. 6 vacuum insulated transfer lines 30–50 feet long

The exhaust system will consist of:

A. Exhaust valves (Barrel module only)

6- 2 or 2-1/2" vacuum insulated proportional control valves

B. 6 controllers

C. 6 2 to 3" vacuum insulated exhaust lines to the collector line

D. 1 insulated collector line 50 to 100 feet

These valves are all sized for the flow rates during cool down and must be capable of handling and controlling flow rates as much as 10 times smaller during some phases of operation.

The endcaps have had very little attention given to the cryo system but the following assumptions will be made:

A. 4 cooling loops for each endcap.
B. 1" supply lines and 1-1/2" exhaust lines.
C. 1 collector line to the LN boiler, can be common with the barrel collector line.

Each endcap will have:

A. 4 cryo inlet valves 1".
B. 4 vacuum insulated supply lines 50–100 ft.
C. 4 exhaust valves 1-1/2".
D. 4 vacuum insulated exhaust lines 1-1/2" 50–100 ft.
E. 8 valve controllers.

The Local Argon Conditioner

The 1000 liter dewar used for pressure reference for the modules has a condenser in the gas phase to maintain the pressure at a preset value and a heater to speed the response time. It can move argon to the modules in either liquid or gas form. It can pass argon gas directly back to the storage dewars when additional condensing capacity is needed.

The condenser temperature is controlled by a liquid nitrogen supply valve and an exhaust valve whose function is to control the vapor pressure of the nitrogen in the loops. Feedback is taken to the control system from the pressure references in the gas phase of the modules. If all three modules can be run at the same overpressure the system is relatively simple. If three reference dewars are required, it is much more expensive. Assume a single reference dewar.

The components are:

A. 1" cryo inlet valve for the LN loop
B. 1-1/2" cryo outlet valve for the LN loop
C. 2 controllers
D. Dewar, 1000 liter, with internal condenser and heater
E. Cryo liquid argon supply valve from main supply dewars
F. Cryo gas argon valve from main supply dewars

<u>Controls for argon to the modules from the argon pressure reference dewar.</u>

This system, shown for the barrel modules only, controls the gas and liquid phase argon to the three modules.

Valves, all cryo-vac insulated:

A. 3 – 2" cryo valves, supply to the modules.
B. 3 – 3" cryo valves, gas phase to the modules.

Other system components:

6 controllers.
Transfer lines to the modules.

3-liquid phase 2" lines 50–100 ft long.
3-gas phase 3" lines 50–100 ft long.

If it is necessary to operate a module and dump a second module, additional bypass transfer lines and valves may be needed.

Argon Emergency Dump

In the event that it becomes necessary to vent argon from the module system because of vacuum loss or some other emergency, liquid argon must be prevented from accumulating in the vertical vent line. The line is about 175 feet high and if filled to a point high enough to back-pressure the argon to 70 psig, the test pressure would be exceeded, and possibly would damage the modules.

Needed:

A. 3" transfer line to the boiler from the argon control rack 150 ft
B. 3 – 2" open-close valves for cryo service, one for each module
C. 1 vent line to the surface 8–10" line 175 ft, not insulated
D. Boiler and 150 kW heater

Nitrogen Boiler

A small amount of liquid nitrogen is blown on through the loops and could possibly fill the vent line with liquid nitrogen. The density is such that a column of liquid 10 feet deep would place a back pressure of about four psi on the cooling system. This would raise the boiling temperature of the nitrogen about two degrees and thus reduce its cooling potential. In order to prevent this from happening, an automatic heater is installed in a boiler module and level detectors are used to turn heaters on when needed to boil off the excess liquid.

In normal cooling, if all of liquid is vaporized, the use rate of liquid will be about 1200 liters an hour. Unfortunately, only one half of the cold available (the heat of vaporization part) is used and the other one half of the cold will pass on up the vent and be exhausted as a cold plume of gas. The vent line would get cold and freeze. The vent line should probably be insulated. The alternative is to have a warm-up heater in the stack that runs 60 or 70 kW of heat continuously.

Insulated transfer lines from the modules to the boiler includes:

A. 4" ID 150 ft
B. Boiler with 3 level heaters
C. 250 feet of insulated line (6") to the surface

Neither of these lines need, from the cryogenic standpoint, to be high quality transfer lines, but they will produce a lot of ice and dripping water if they are not good enough.

<u>Main Vacuum Pumps</u>

Two systems are needed, each with a specific purpose and different requirements on its performance.

1. The main insulating vacuums for the three modules is relatively simple and can consist of several (for redundancy) roughing and backing pumps. Their purpose is to rough the insulating region down to 20 or so microns and then be switched over to provide backing for several (redundancy) turbo molecular pumps in parallel on each module. The main purpose of this system is to produce a vacuum of well below 1 micron in the insulating space. Super insulation will be used to reduce the radiation heat load. Some care should be taken with procedures to eliminate oil backstreaming during the roughing stage.

2. The pump and purge system to be used on the modules themselves has much more rigorous requirements on its performance. It needs to be large enough to pump the systems to about 500 to 1000 microns in a few hours and yet clean enough to keep any contaminants, oil, etc., from backstreaming into the modules. The argon is easily contaminated and less than 1 ppm of most electronegative materials will make it unusable. So far there is no way to purify it economically.

THE BARREL VACUUM INSULATING SYSTEM

Barrel volume = 400 cubic feet/about 12,000 liters

Requires:

A. 2 – 400 liters/second turbo pumps as close as possible (15 ft)
B. 2 – 8" vacuum lines 15 ft long
C. 4 – 8" vacuum gate valves
D. 2 – 100 CFM mechanical pumps
E. 85 ft. of 8" line from the turbos to the mechanical pumps
F. 2 – 8" vacuum gate valves

Operation Description

The mechanical pumps would, if both were on, pump the volume to one-half pressure every two minutes and would be used to take the tank down to about 30 microns. At 30 microns, the turbo pumps would be started because they are many times faster than a mechanical pump. When the tank is evacuated enough that one turbo with two mechanical pumps reaches a backing pressure of about 40 microns, both turbos should be opened and the pump down should be continued. Turbo pumps do not like to pump against a backing pressure over 100 microns, so care has to be taken to prevent this from happening.

The lines and pumps are sized to pump down in a reasonably short time and more importantly, to maintain a usable vacuum in case a small leak develops in the module system. If a leak develops in the vacuum system, speed is the limiting factor in how good a vacuum can be maintained. A vacuum of two microns or better should be maintained.

THE BARREL ARGON PUMP AND PURGE SYSTEM

Purity of the argon and no backstreaming of oil is the problem in this system. Several 100 CFM high quality mechanical pumps with in-line filtration to reduce oil backstreaming and particulate back flow will suffice.

The procedures must be carefully written to reduce the chance of accidental opening of a valve or shutting down a pump in such a way that air can rush back into the modules.

Requires:

A. 2 – 100 CFM mechanical pumps
B. Multiple filters
C. 6 – 3" vacuum valves
D. 3 – 1" purge gas valves
E. 4" vacuum line to each module. These lines go to the gas phase.
F. Switch gear for the pump motors and valve controllers.

Additional Notes

Transfer Lines

Transfer lines vary in cost with their complexity and whether the cost includes valves and gages. The following numbers are best guesses for the cost/foot of various simple lines:

A. 1" double wall vacuum insulated = \$70/foot
B. 2" double wall vacuum insulated = \$110/foot
C. 3" double wall vacuum insulated = \$150/foot
D. 4" double wall vacuum insulated = \$200/foot

Cryogenic Valves (Cryo)

Cryo valves also vary greatly and the following numbers will be used but should be checked. All valves have operators and positioners, but not controllers:

A. 1" cryo valve	\$2500
B. 2" cryo valve	\$3500
C. 3" cryo valve	\$5000
D. 4" vacuum valves	\$1600
E. 8" vacuum valves	\$2700
F. 1" vacuum valve remote	\$370

Valve Controllers

One controller	$1500

Pumps

From Leybold 1989 catalog:

A. 100 CFM mechanical pump	$8300
B. 359 liter/sec. turbo pump	$9400

Back Stream Filter

None found

Dewars

1000 liter dewars should cost about $50,000 with condensers, etc.

Preliminary Component List and Costs

<u>Local Argon Storage LN Systems</u>

A. 3 dewars 15 ft OD by 32 ft tall with condensing coil inside	1M$
Process engineering est. each (this seems much too high)	$360,000
B. LN control valves for condensers in storage dewars	
1. 3 – 1" supply cryo valves with positioners	$7,500
2. 3 – 1-1/2" exhaust cryo valve with positioners	$9,000
3. 6 controllers	$9,000
C. Transfer lines to lower level from surface LN source 2" ID vacuum insulated 250 feet	$27,500
D. Transfer lines from LN conditioner to dewars 3 – 1" ID vacuum insulated 100 feet	$21,000
E. 3 – 1-1/2" ID vacuum insulated exhaust lines from dewar condenser	$27,000
F. 6 controllers for D and E	$9,000

LN Source System at Surface

A. 60,000 liters, at least, of LN storage (dewar)	\$200,000
B. Filling station	\$30,000
C. 4 – 2" valves, manual cryo or remote open/close	\$14,000
D. Transfer lines to dewars, 100' of 2" ID vac insulated	\$11,000
E. 2 or 3-2" ID redundant cryo open/close valves to feed line (2") below in the experiment area	\$10,500

LN Conditioning Systems to Reduce the 175 foot Head Pressure from 70 to 30 or 40 psig

A. Dewar about 1000 liter	\$50,000
B. 2" cryo valve with positioner for proportional control	\$3,500
C. Controller for the valve	\$1,500
D. LN depth gage for 1000 liter dewar and transmitter	\$5,000
E. 1" cryo valve to control pressure in gas phase of the 1000 liter dewar to about 30 psig	\$2,500
F. Controller for the valve	\$1,500
G. 1000 L dewar outlet 2" cryo valve, open/close	\$3,500
H. Vent system to surface to remove gas produced in the 1000 liter dewar. 200 ft of 3" diameter insulated to prevent ice formation.	\$30,000

NOTE: THIS VENT MIGHT BE PIPED OVER TO THE MAIN NITROGEN VENT WHICH HAS AN AUTOMATIC HEATER SYSTEM.

The Argon Dewar Fill and Distribution System

A. Filling station on the surface, monitors, valve controllers, etc.	$30,000
B. Depth gage feed back from each argon dewar	$10,000
C. 2" cryo open/close valves on surface to 2" fill line going below	$3,000
D. 2" transfer line 250 ft long from the fill station to the distribution manifold on the argon dewar supplies	$27,500
E. 3 – 2" open/close valves. 1 to each dewar fill line. Remotely switched at fill station. Auto monitor of dewar pressure and depth to override valves in emergency.	$10,500
F. 2" transfer lines to each dewar from the 2" vertical fill line. 100 ft each	$33,000

The Argon Dewar to Argon Conditioner System

A. 3 – 2" cryo valves, open/close, one at each dewar liquid outlet	$10,500
B. Transfer lines from the valves in item A. to the main 2" line over to the argon conditioner. 3 – 2" ID 50 ft long	$16,500
C. 2" liquid line from the valves in item B. to the argon conditioner on the detector above the top of the argon module liquid level	$16,500
D. 3 - 3" cryo valves, open/close to return gaseous argon to the top of the 3 argon storage dewars	$15,000
E. Transfer line from the valves in item D. to the 3" ID collector line from the valves to the argon conditioner 3–50 ft long	$22,500
F. 3" ID transfer line from the lines in E. to the gas phase of the argon conditioner, 150 ft long	$22,500

The Argon Conditioner System

A. A 1000 liter dewar with a liquid nitrogen refrigerated condenser in the top and a 10 kW heater to speed the response time of a temperature change — $50,000

B. Liquid nitrogen cooling system for the argon conditioner

1. 1" cryo valve proportional control for the liquid IN circuit — $2,500
2. 1-1/2" cryo valve proportional controller for the gas OUT circuit — $3,000
3. 2 controllers for these valves — $3,000
4. 10 kW heater control to raise the dewar pressure quickly — $2,000

C. Argon transfer lines from the conditioner to the control valve racks

1. 2" liquid supply line, 30 ft long — $3,300
2. 3" gas return line, 30 ft long — $4,500

D. The argon control valve rack. This has the following.

Valves for controlling liquid from the argon conditioner to the modules.

Valves to control the argon gas returning from the modules gas phase to the argon conditioner.

Valves to vent one or all modules to the argon boiler in emergency.

1. 3 – 2" liquid argon control cryo valves — $10,500
2. 3 – 3" gaseous argon control cryo valves — $15,000
3. 3 – 3" cryo valves to vent argon to the boiler — $15,000
4. 3 – Controllers for the module gas phase valves in case partial closing is needed to reduce pressure oscillations in the gas phase — $4,500
5. 2 switch control systems for the vent valves — $—

The Module Cooling System

A. The main barrel has six cooling loops (8 if the ends are cooled). Each loop has a liquid nitrogen IN control valve and a gaseous nitrogen OUT control valve. The LN comes from the liquid nitrogen conditioner.

1. LN supply valves	
6 – 1-1/2" cryo valves	$18,000
2. LN exhaust valves	
6 – 2" cryo valves	$21,000
3. 12 controllers	$18,000
4. Transfer lines	
6 – 1-1/2" transfer lines, 30 feet long	$18,000
6 – 2" exhaust lines, 30 feet long	$19,800

B. The 2 endcaps, each with 4 loops. The nitrogen comes from the LN conditioner.

1. *The inlet valves. 8 – 1" cryo valves*	*$20,000*
2. The exhaust valves. 8 - 1-1/2" cryo valves	$24,000
3. 16 controllers	$24,000

The Argon Boiler for Excess Argon During Emergencies

1. The collector transfer line that takes argon from the 3 modules if needed.	
3" vacuum insulated line, 100 ft long	$15,000
2. The boiler and heaters, with controls	$50,000
3. The vent line to the surface 175 to 200 ft of 6" line, no insulation	$—

The Boiler for Excess LN in the Cooling System

1. The collector transfer line that takes outflow from all of the exhaust valves and moves it to the boiler.	
4" vacuum insulated line, 100 ft long	$20,000
2. The boiler with three stage heater and controllers	$50,000
3. The partially insulated line to the surface, 6" line 180 ft long	$—

The Argon Supply Storage Dewars

200,000 liters needed probably $250,000 each for three dewars	$750,000

Work Breakdown Sheet

5.4.3	Cryogenics
5.4.3.2	Calorimetry
5.4.3.2.1	Liquid argon system
5.4.3.2.1.1	Storage dewars
5.4.3.2.1.1.1	Ground level storage dewars
	1 or 2 60,000 liter, with condenser
	distribution system
	vertical transfer line to lower region
	jacket pump out and monitor
	relief valves
	valves and controllers
	monitors for liquid levels
	various pressure gages
	purity tester for new argon shipments
	brackets, panels supports
	labor, installation, overhead
5.4.3.2.1.1.2	Pit level argon
	2 to 3 60,000 liter, with condensers and heaters
	valves and controllers
	transfer lines
	depth gages
	remote control system
	distribution from topside to local dewars
	heater controllers
	monitors for liquid levels
	brackets, panels supports
	labor, installation, overhead
5.4.3.2.1.2	Pit level argon conditioner
	1000 liter with condenser and heater
	heater controller
	monitor for depth and pressure
	liquid argon inlet valve
	gaseous argon return valve to storage
	liquid argon valve to module control rack
	liquid nitrogen loop inlet valve
	gaseous nitrogen outlet valve from loop
	loop pressure gages
	controllers for all valves
	remote monitoring and control

brackets, panels supports
labor, installation, overhead

5.4.3.2.1.3 Control rack for argon to modules
3 liquid phase cryo valves
3 gas phase cryo valves
3 gas vent valves to dump boiler
remote monitoring and control
3 transfer lines to liquid phase
3 transfer lines to gas phase
transfer line to boiler for excess argon
labor, installation, overhead

5.4.3.2.1.4 Argon modules
6 to 8 cooling loops on the barrel module
4 loops on each endcap
many vapor pressure bulbs
many thermocouples
pressure gages and transmitters
depth gages for module liquid levels
heaters for module warm-up
remote controls and indicators
labor, installation, overhead

5.4.3.2.1.5 Argon boiler for excess liquid
boiler with several hundred liters volume
3 stage heater
controls for it
partially insulated vent line to surface
depth gage for heater control
pressure gage to detect liquid in vent line
labor, installation, overhead

5.4.3.2.2 Liquid nitrogen system

5.4.3.2.2.1 Liquid nitrogen storage dewars
1 or 2 60,000 liter dewars on surface
filling station for trucks
control rack for distribution to lower region
transfer line to pit
depth gages
valves
remote controls
evaporator coils to produce gaseous nitrogen
mechanical pumps to pump transfer line vacuums

labor, installation, overhead

5.4.3.2.2.2 Liquid nitrogen in pit

local batch fill dewar, 10,000 liter

distribution transfer lines to

argon conditioner

LN control rack

depth gages

valves and manifolds

controls, local and remote

safety shut offs to stop over fill from above

vent to surface to exhaust gaseous N2

relief valves on all transfer lines

labor, installation, overhead

5.4.3.2.2.3 LN control rack on supply side

transfer lines to 3 modules

transfer lines to argon conditioner

liquid supply valves to lines

controls

monitors

labor, installation, overhead

5.4.3.2.2.4 Gas nitrogen control rack on exhaust side

valves to N2 vent from the following

3 modules

argon conditioner

transfer collector line to N2 boiler

gages

relief valves

monitor and control system

labor, installation, overhead

5.4.3.2.2.5 LN boiler for excess LN

boiler with several hundred liters volume

3 stage heater

controls for it

partially insulated vent line to surface

depth gage for heater control

pressure gage to detect liquid in vent line

labor, installation, overhead

5.4.3.2.3 Cryogenic vacuum system

5.4.3.2.3.1 Argon pump and purge system

mechanical vacuum pumps

valves
filters
gages
controls
vent to surface
pipes to modules
helium back fill system for module cool down
labor, installation, overhead

5.4.3.2.3.2 Main insulating vacuum system
turbo molecular pumps
valves
monitor and control
remote system
nitrogen back fill
labor, installation, overhead

5.4.3.2.4 Control room/area, remote
dedicated computer
general control system
data logging
monitoring of all functions
control of appropriate functions
labor, installation, overhead

5.4.3.2.5 Emergency dump system for major argon dumps
controversial (effectiveness)
subterranean insulated catch basins
limit maximum dump by anti siphon piping
exclude personnel when argon present
gas tight seals from hall to tunnels
breather units worn at all times
guide paths to nearest safe compartment
  heavy fog forms on spill, no visibility!
argon leak detectors
loud alarms on leak
many thermally insulated, air supplied
  safe compartments close to work

Figures 3 to 6 are provided without explanation as examples of distribution systems for the detectors considered. They are of a size similar to that given in the text.

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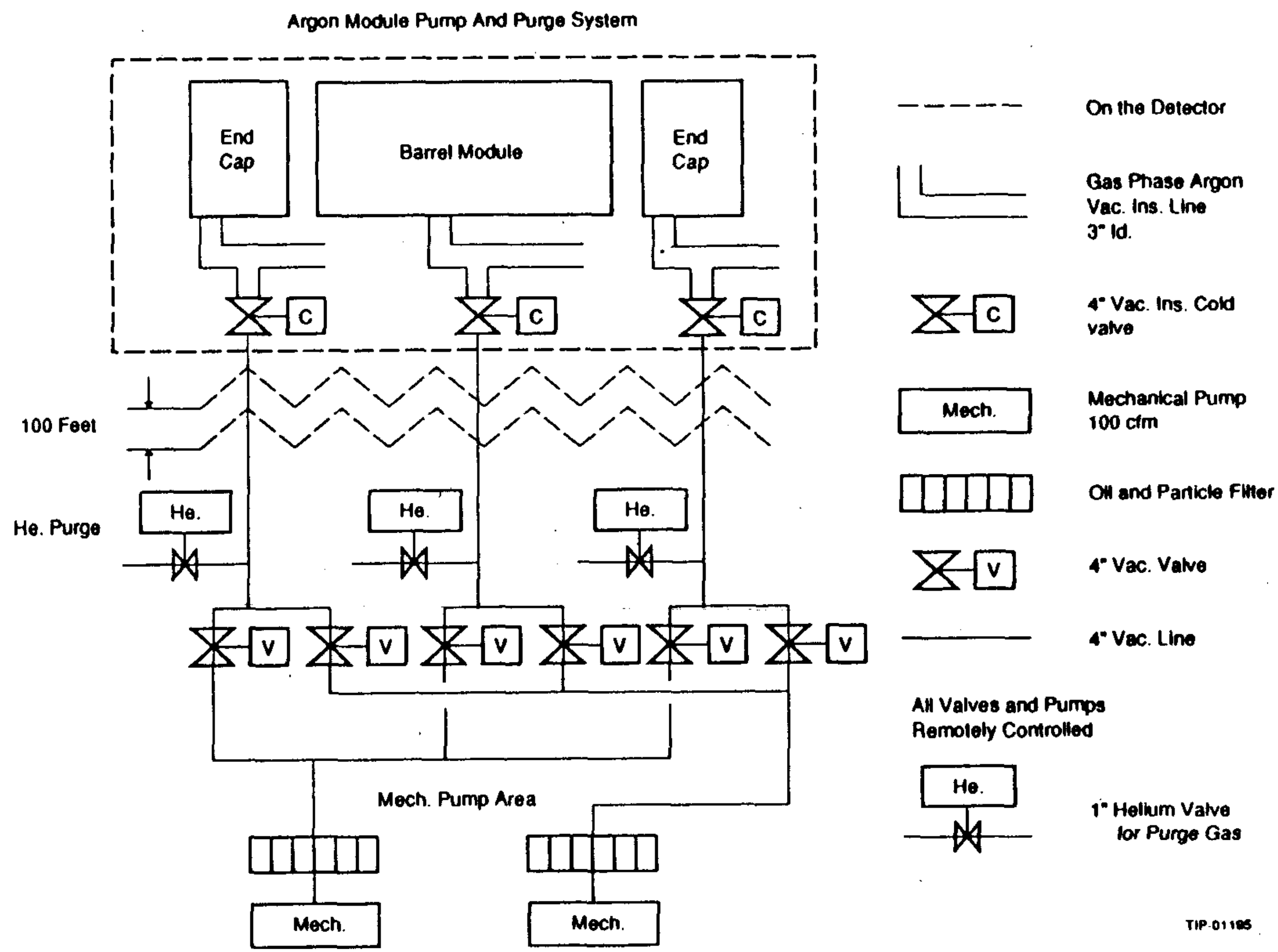

Figure 3. Argon Module Pump and Purge System

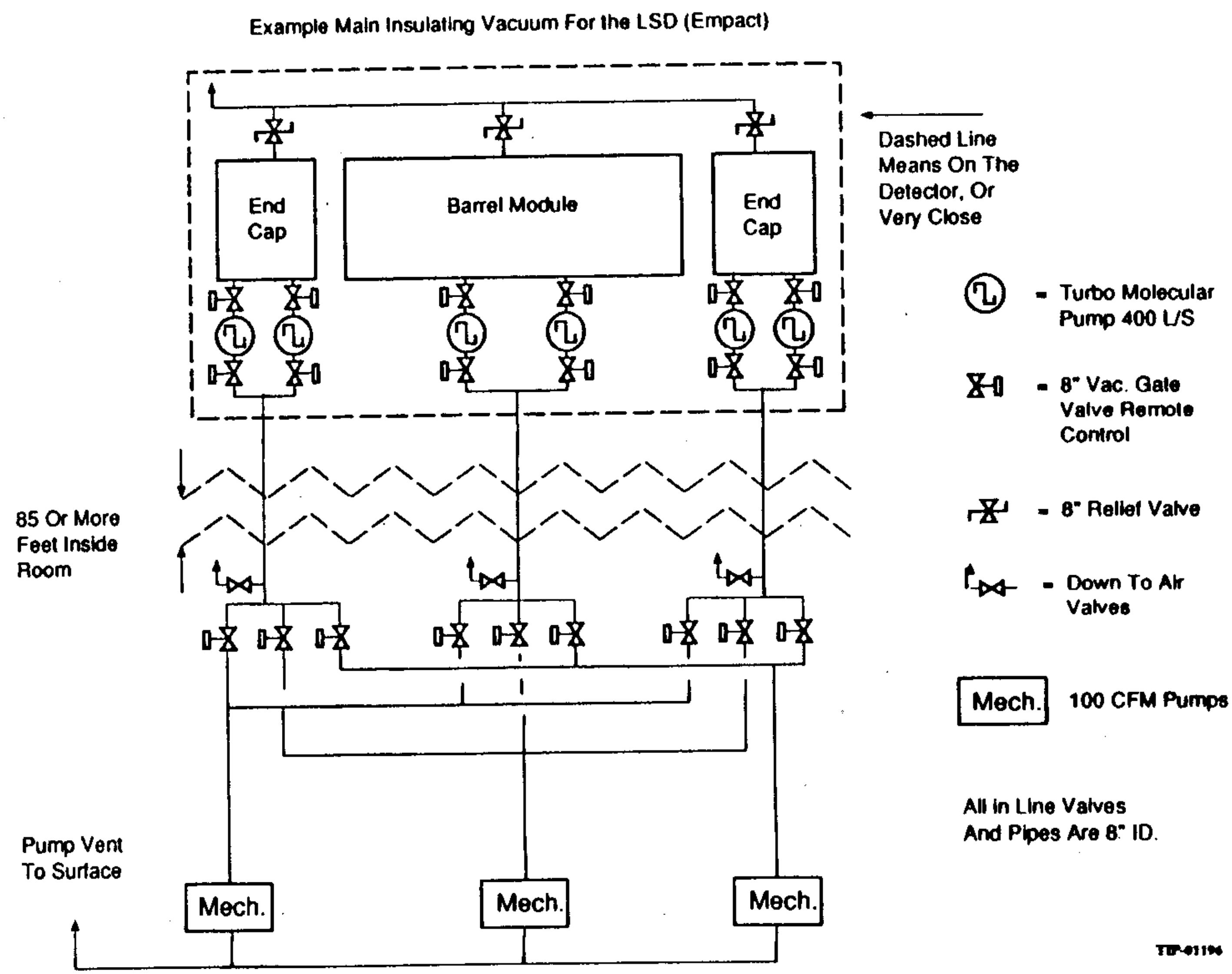

Figure 4. Example Main Insulating Vacuum for the LSD (EMPACT)

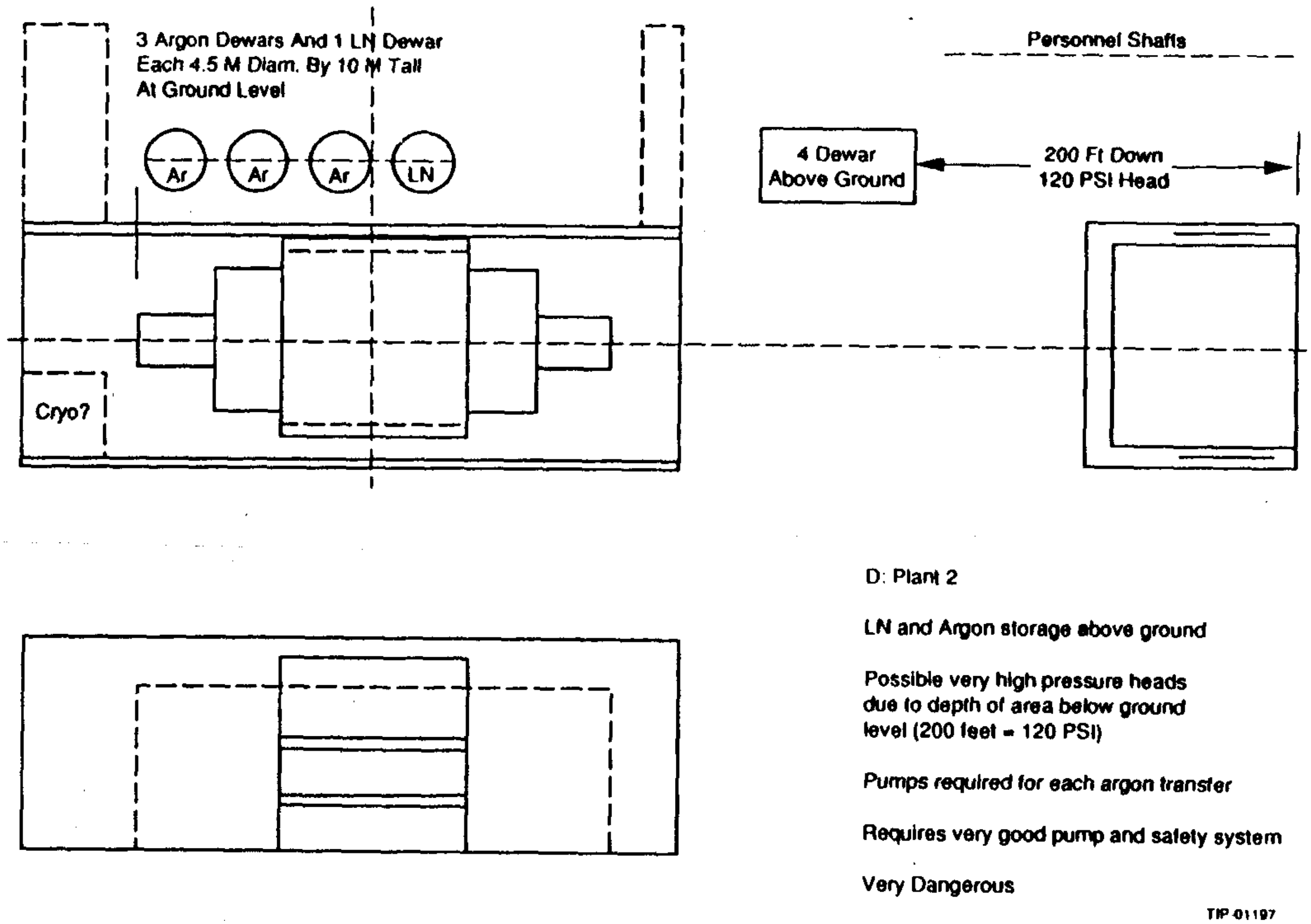
3 Argon Dewars And 1 LN Dewar
Each 4.5 M Diam. By 10 M Tall
At Ground Level
Ar
Ar
Ar
LN
Cryo?
Personnel Shafts
4 Dewar
Above Ground
200 Ft Down
120 PSI Head
D: Plant 2
LN and Argon storage above ground
Possible very high pressure heads
due to depth of area below ground
level (200 feet = 120 PSI)
Pumps required for each argon transfer
Requires very good pump and safety system
Very Dangerous
TIP-01197

Figure 5.

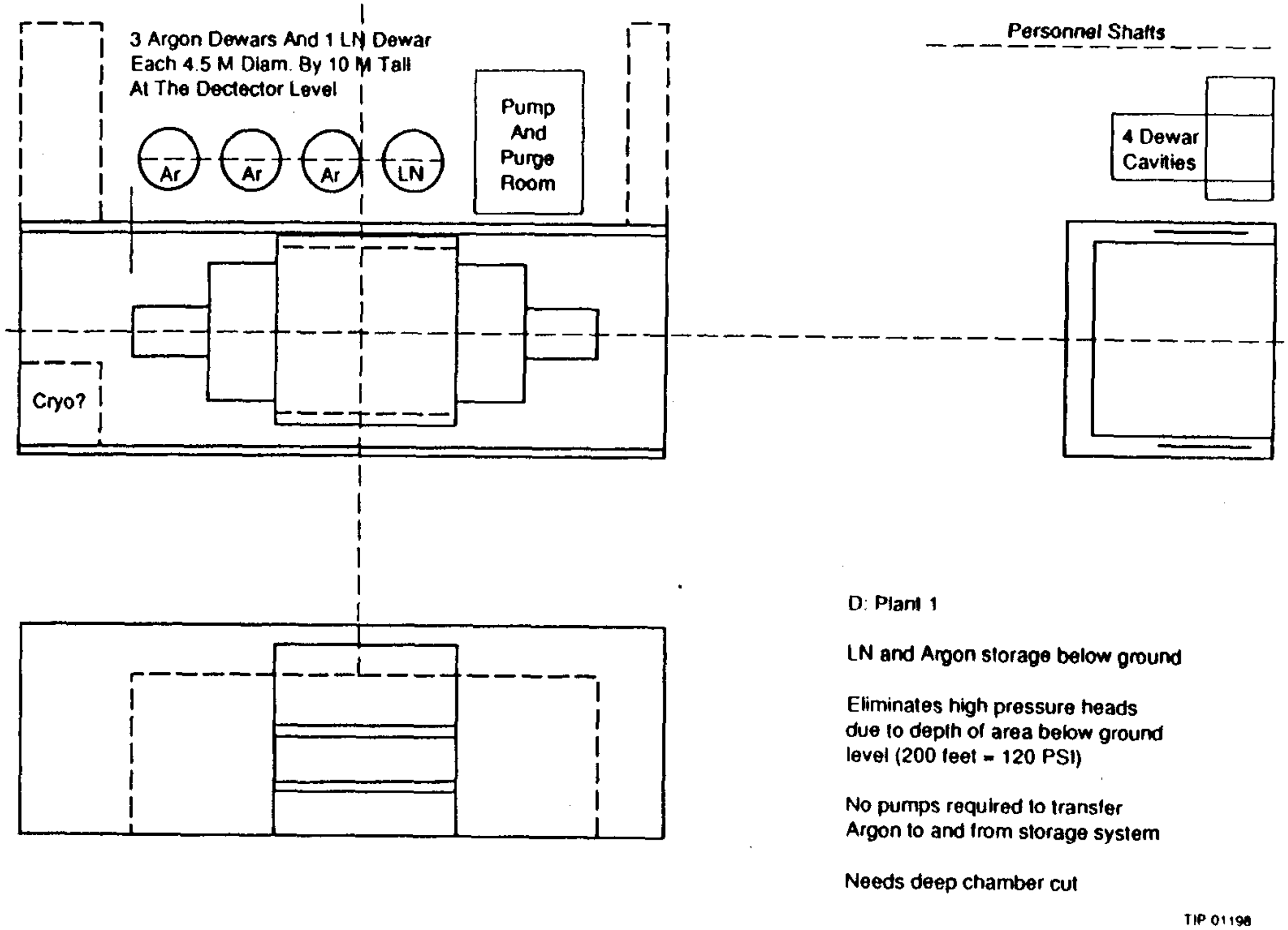
3 Argon Dewars And 1 LN Dewar
Each 4.5 M Diam. By 10 M Tall
At The Dectector Level
Ar
Ar
Ar
LN
Pump
And
Purge
Room
Cryo?
Personnel Shafts
4 Dewar
Cavities
D: Plant 1
LN and Argon storage below ground
Eliminates high pressure heads
due to depth of area below ground
level (200 feet = 120 PSI)
No pumps required to transfer
Argon to and from storage system
Needs deep chamber cut
TIP 01198

Figure 6.