Vacuum Equipment Specification Review

J. Worden

Aug 31/94

LIGO-G940005-00-V

Outline

- Performance
- Machine safety and controls
- Interfaces
- Failure modes

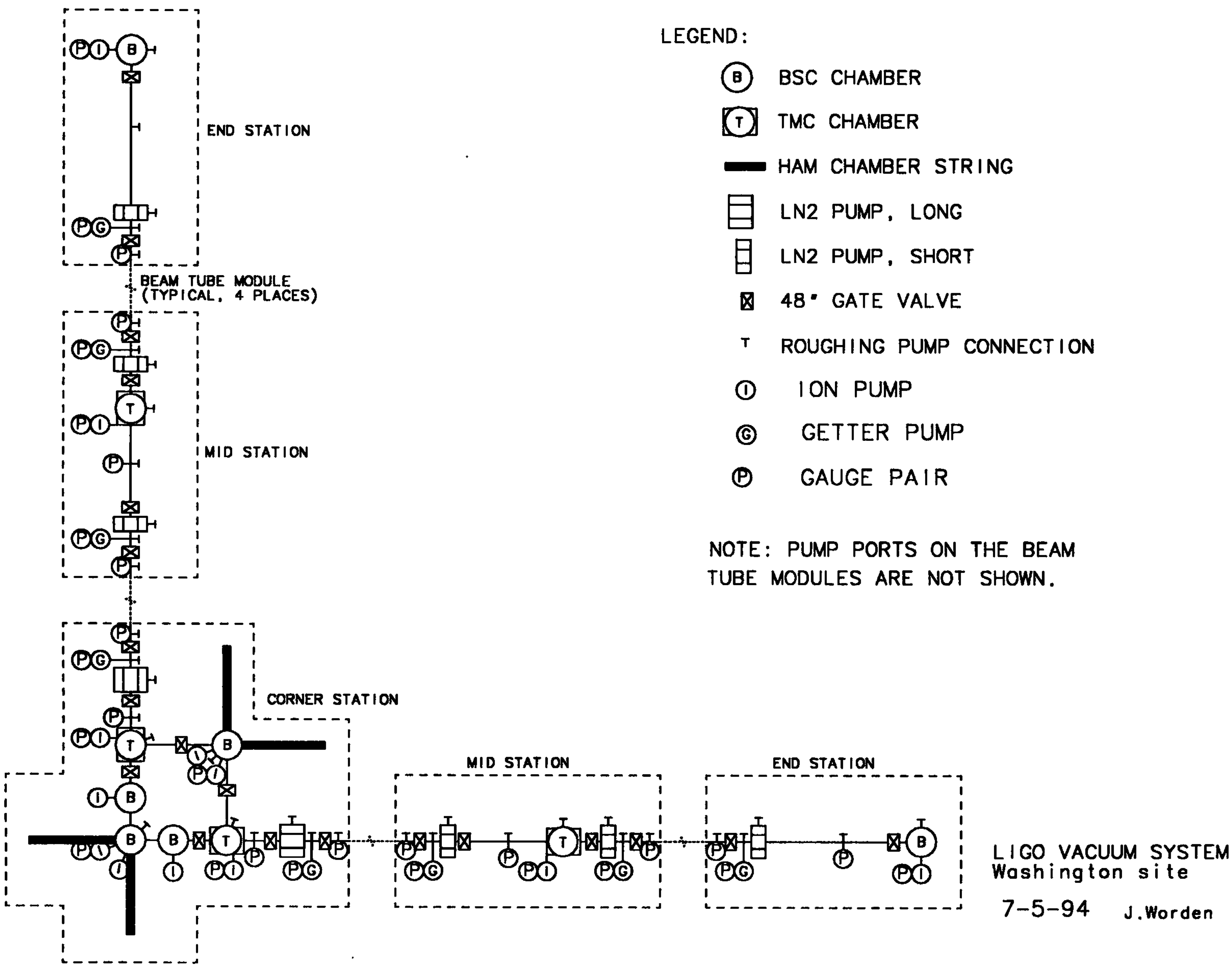

END STATION
BEAM TUBE MODULE
(TYPICAL, 4 PLACES)
MID STATION
CORNER STATION
MID STATION
END STATION
LEGEND:
BSC CHAMBER
TMC CHAMBER
HAM CHAMBER STRING
LN2 PUMP, LONG
LN2 PUMP, SHORT
48" GATE VALVE
ROUGHING PUMP CONNECTION
ION PUMP
GETTER PUMP
GAUGE PAIR
NOTE: PUMP PORTS ON THE BEAM TUBE MODULES ARE NOT SHOWN.
LIGO VACUUM SYSTEM
Washington site
7-5-94 J.Worden

Figure 2.

Performance

The vacuum equipment must provide

- a "UHV" quality environment with respect to cleanliness
- a rigid, quiet structure
- minimum gas load due to air leaks
- reasonable pump down times
- sufficient pumping to handle the IF gas loads
- isolation of the beam tube from the IF gas loads
- robust, fail-safe controls

Cleanliness

Cleanliness will be obtained and maintained by:

- selection of materials — SS, Cu, Al, ceramics, viton, hard coating “lubricants”
- welding procedures to avoid virtual leaks and contaminant traps
- cleaning, handling and bakeout procedures
- selection of pumps-all “dry”
- operational procedures

Vent/Purge System

To aid in cleanliness and pump down

- dry clean air-class 100 with dew point of −70C
- 100 cfm provides < 8 feet per minute flows but vents largest section in 70 minutes.

Low vibration

The Vacuum Equipment must include

- a rigid mechanical structure with well placed and designed expansion joints and supports
- "quiet" valve mechanisms
- "quiet" pumps

Gas load due to air leaks

Air leaks will be controlled by:

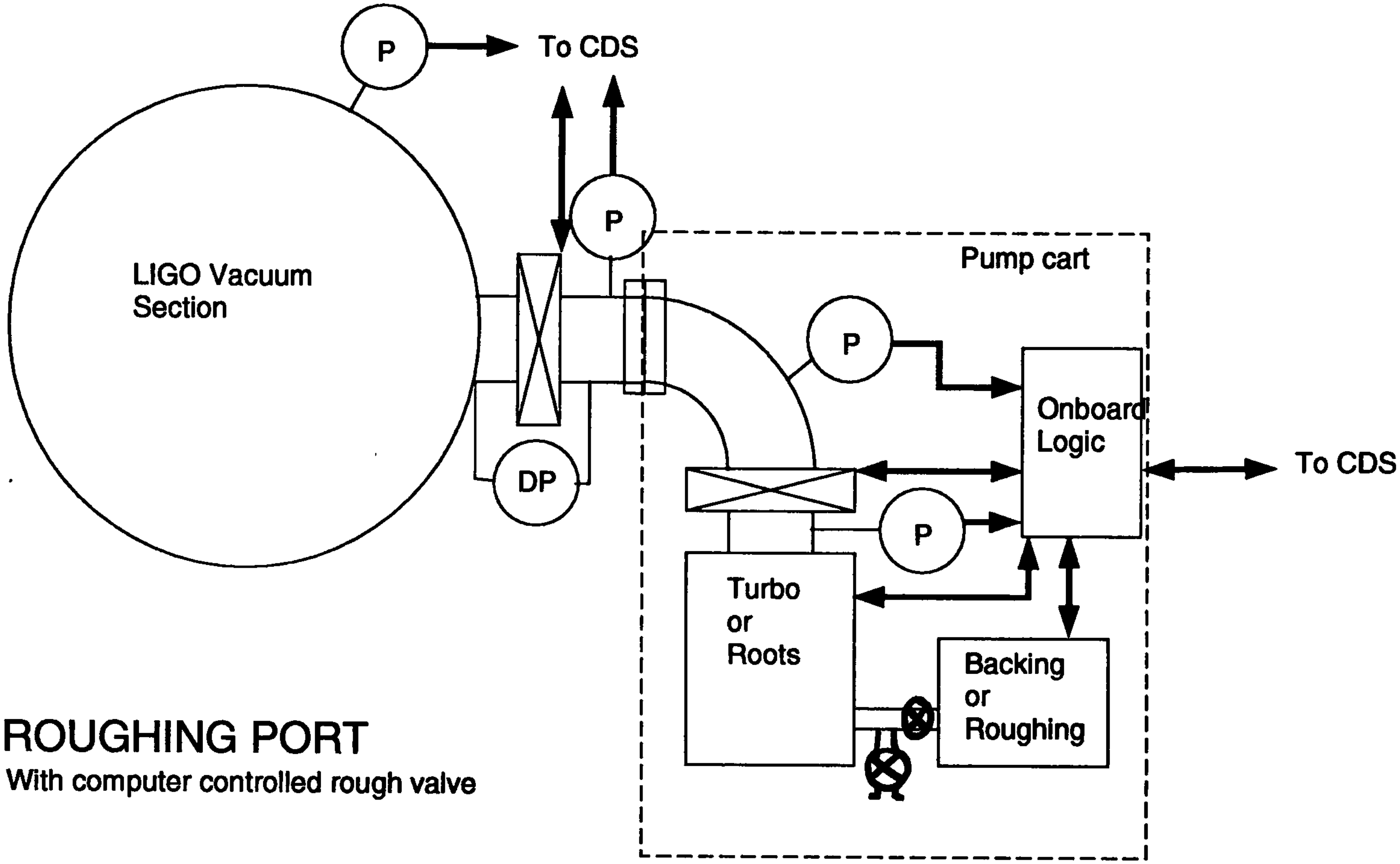
- leak testing of components to 10^{-9} tl/s
- leak testing of vacuum sections to 10^{-8} tl/s

A single 10^{-8}tl/s leak would contribute $< 10^{-11}$ torr to the total pressure of a vacuum section

Roughing Strategy

Portable roughing system

- 2 types of pump cart-Roots pump, Turbo pump-both backed by “dry pumps”
- each cart is self contained/protected
- Roughing valves may be manual or electro-pneumatic-if computer controlled requires extra sensors for redundant interlocks-if manual requires procedural controls, lockout devices.



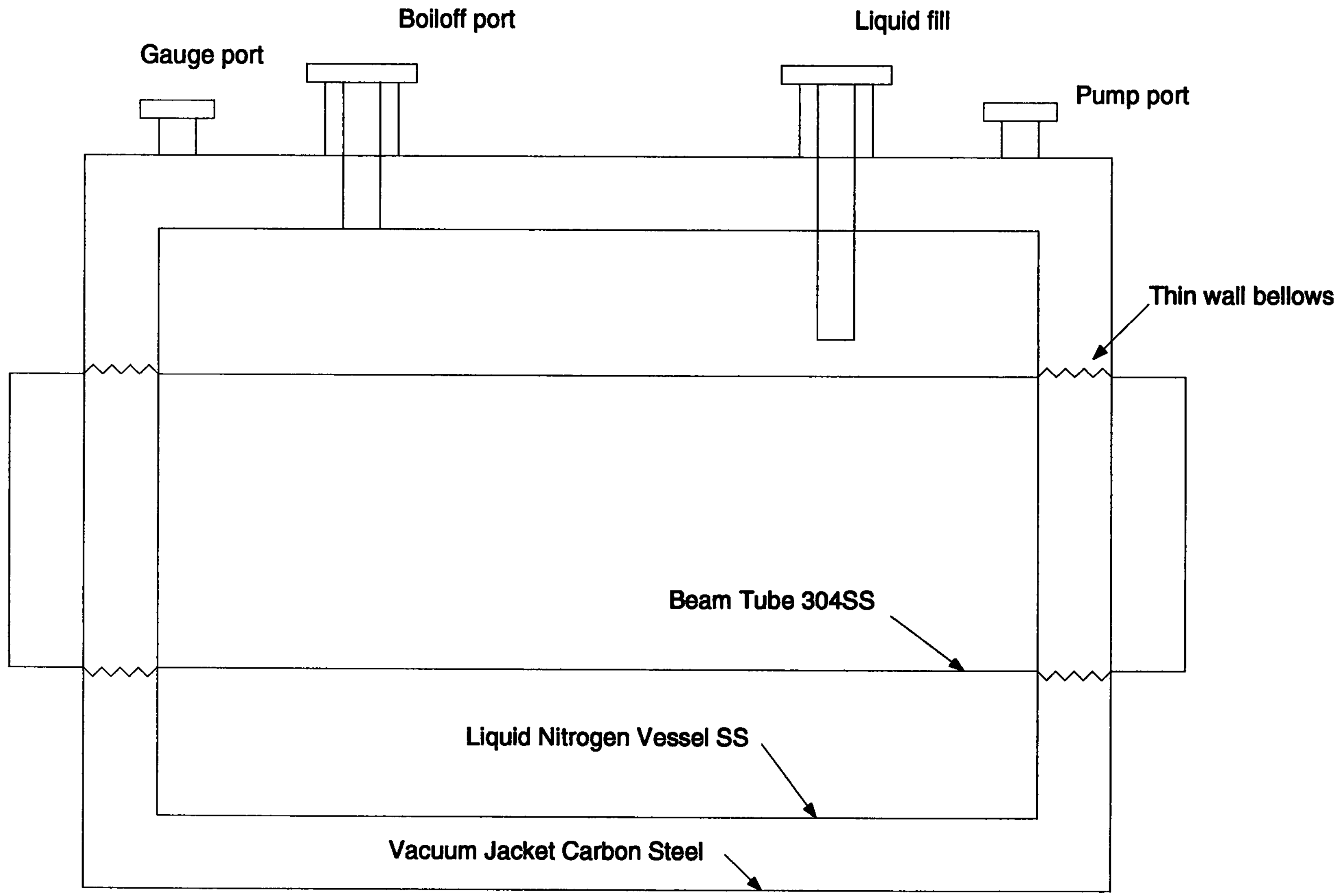
ROUGHING PORT

With computer controlled rough valve

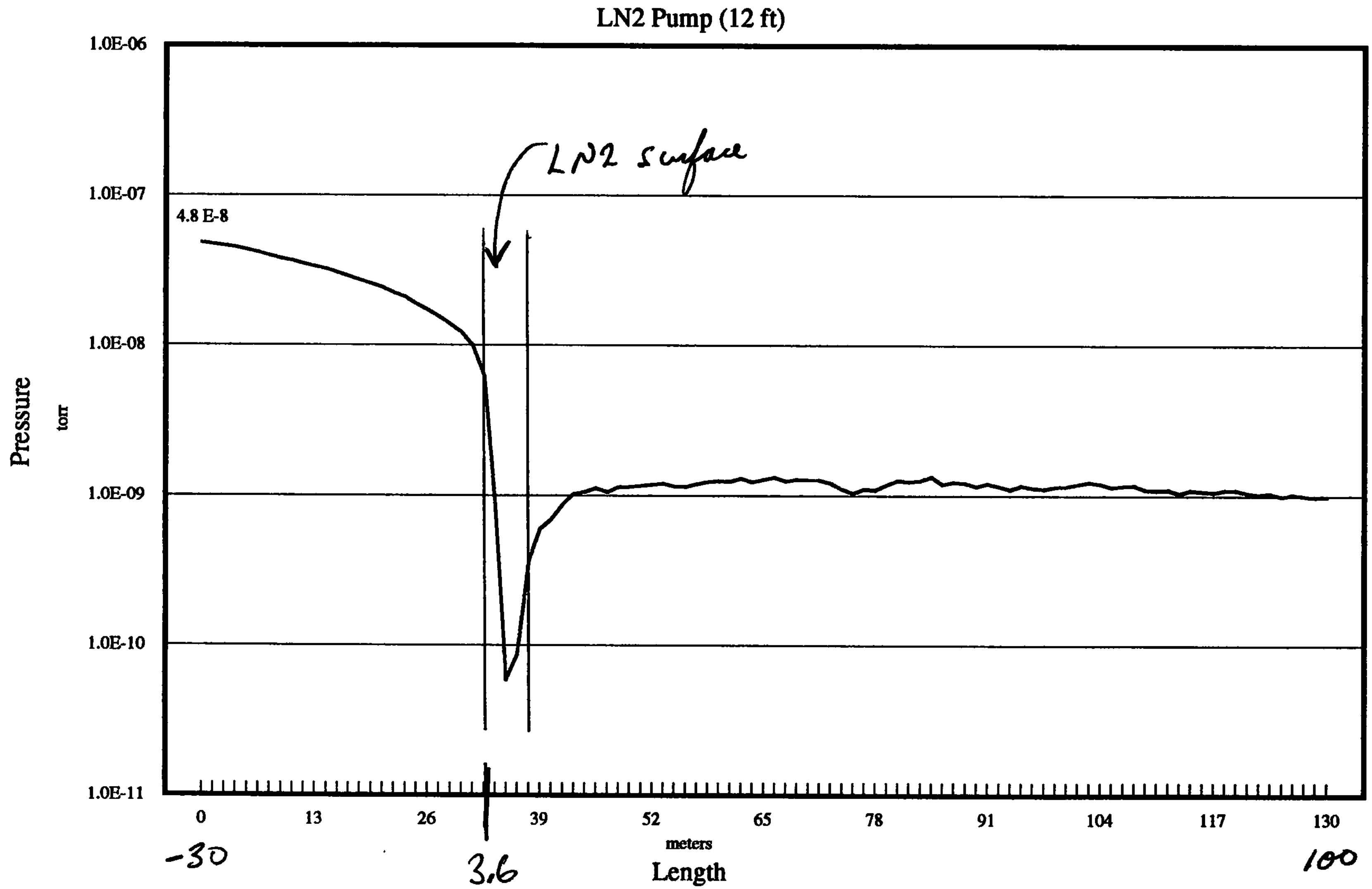
"Quiet" Pumps

- 3 types of pumps-Ion pumps, LN2 Pumps, and getter pumps
- Ion pumps are near the chambers and pump hydrogen as well as other gases. Need "noble gas" pumps as these will be the only pumps for inert gases. Ion pumps also provide additional pressure information.
- LN2 Pumps provide water vapour pumping and help isolate beam tube vacuum from chamber vacuum.
- Getter pumps-provide Hydrogen pumping in the beam tube.

LIQUID NITROGEN PUMPS (LN2 TRAP)

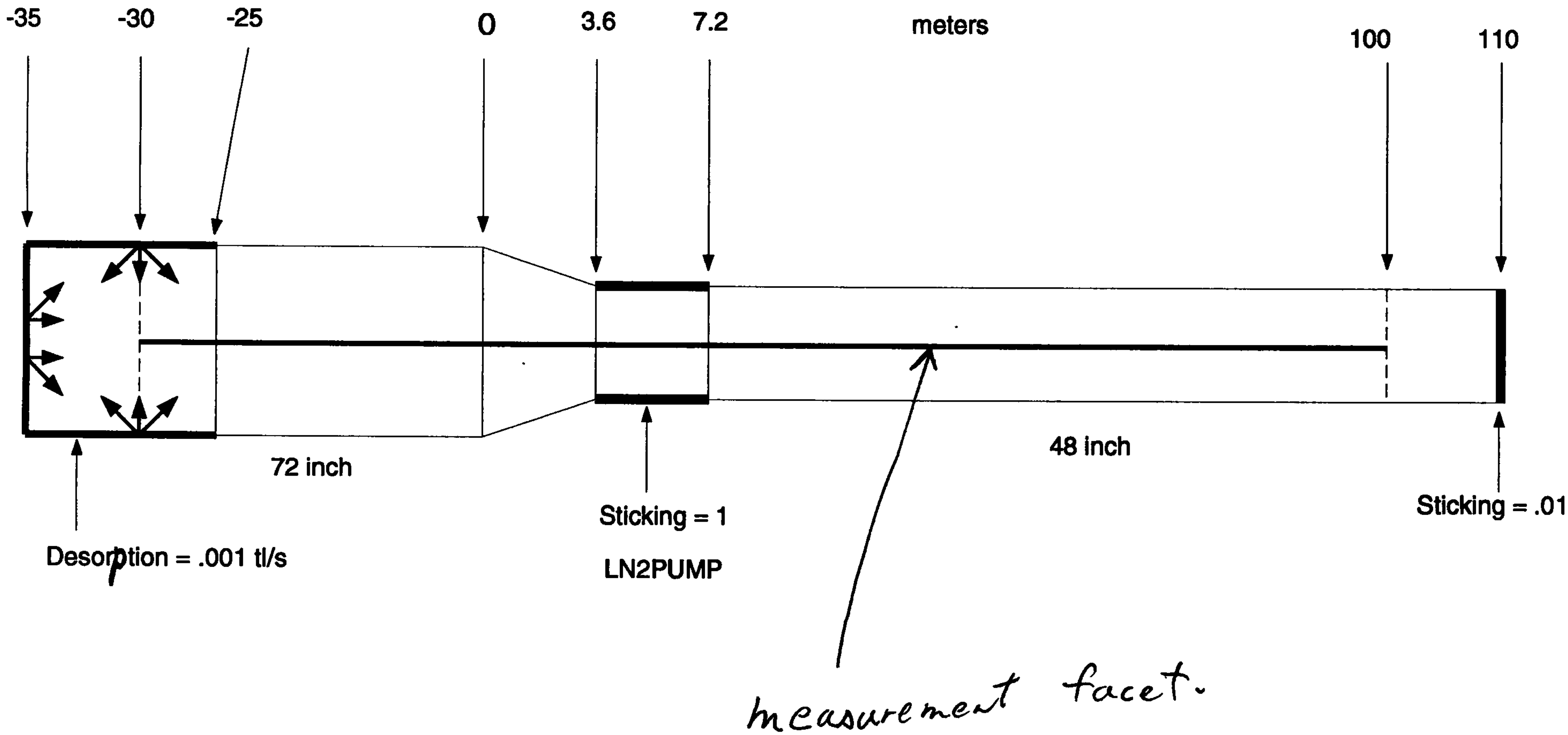


Pressure Distribution



Pump is from 33.6 to 37.2 m
Q(gas load) is .001 tl/s

Corner Station LN2 PUMP and beam manifold



Pre-conditions to Pumping Performance Tests

Both the pump down time and ultimate pressure will be improved by making use of the bake system and the dry air system. The prior conditioning outlined below will simulate actual maintenance operations:

- Bakeout at 150C for 24–48 hours or longer.
- Vent to dry clean air with −70C dewpoint.
- Purge with −70C dewpoint air at 100 CFM for 24 hours.
- Begin pumping tests.

Pump Down Times

The goal is to:

- limit time with roots system to <4 hours with IF components installed
- switch to turbo system after 4 hours
- be able to switch to ion pumps in <24 hours

Pump Down Times

Continued:

assume that the worst case is section 1 (3 BSCs, 9 HAMs-4.2E6 cm^2 and 195 m^3) Using a Leybold blower system WSU2001 with a DK200 backing pump we get to 0.1 torr in approx. 4 hours.

From this point the outgassing dominates: Assume outgas rates of 1E-11 Hydrogen and 4E-9/hours H20 (both tl/s cm^2)

At some pressure < 0.1 torr switch to Turbo pump system. At 10 hours outgas load = 4.1E-10 x 4.2E6 = .002 tl/s. With 1000 l/s net pump speed we get 2E-6 torr at which point the ion pumps should start. If the outgassing is 10 times worse then 24 hours gets us to 7E-6. We can double up on the turbos to get 3.5E-6. Therefore, without using the LN2 Pumps we can switch to ion pumps by 24 hours.

Ultimate Pressure (100 hours)

This test will demonstrate:

- the ion pump and LN2 pump performance
- the excess pumping capacity available for the IF gas loads
- overall system cleanliness and leak-tightness

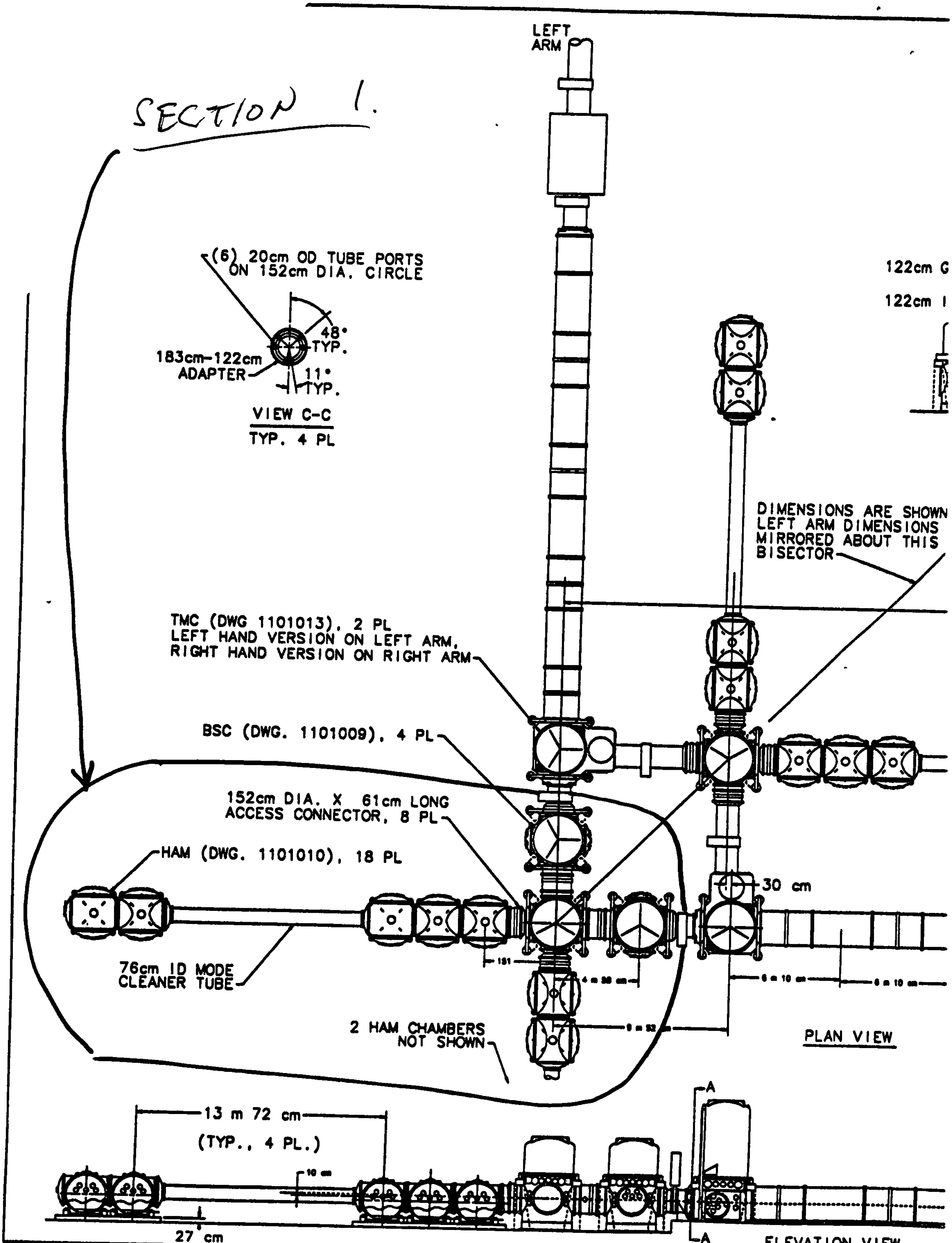
Ultimate Pressure

Continued:

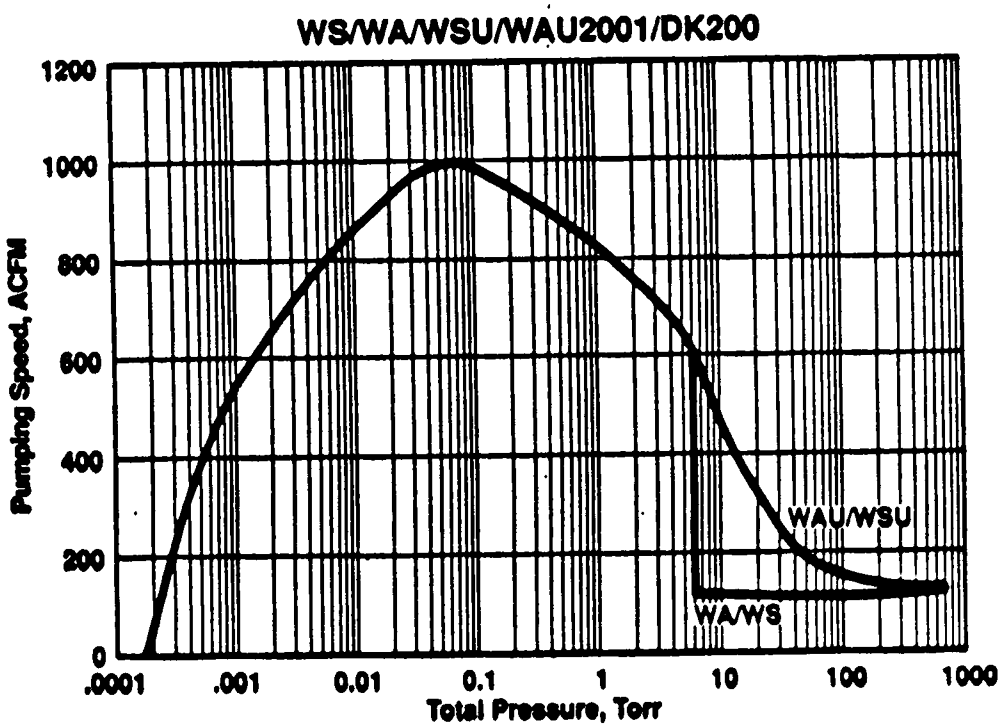
assume that the worst case is section 1 (3 BSCs, 9 HAMs-4.2E6 cm^2 and 195 m^3)

Present are 4 ion pumps for a net pumping speed of 7200l/s for hydrogen. The LN2 pumps provide > 40,000 l/s for H20

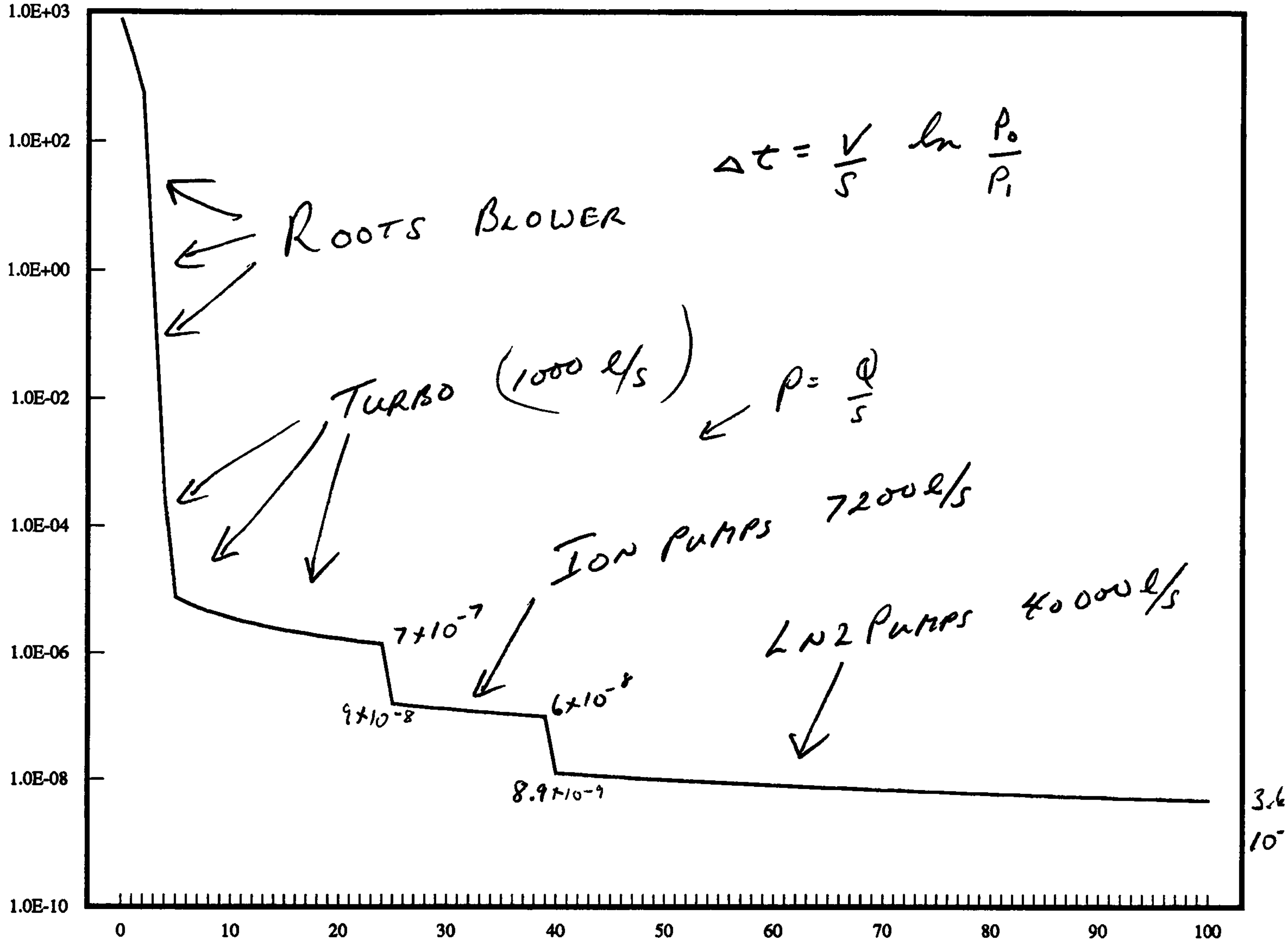
With outgas rates of 1E-11 Hydrogen and 4E-9/hours H20 (both tl/s cm^2):P_{H2} = 5.8 E-9 torr and P_{H20} = 3.6E-9 torr . Therefore the total pressure after 100 hours should be ~1E-8 torr.


SECTION 1.
LEFT ARM
(6) 20cm OD TUBE PORTS ON 152cm DIA. CIRCLE
48° TYP.
183cm-122cm ADAPTER
11° TYP.
VIEW C-C
TYP. 4 PL
122cm G
122cm I
DIMENSIONS ARE SHOWN
LEFT ARM DIMENSIONS MIRRORED ABOUT THIS BISECTOR
TMC (DWG 1101013), 2 PL
LEFT HAND VERSION ON LEFT ARM,
RIGHT HAND VERSION ON RIGHT ARM
BSC (DWG. 1101009), 4 PL
152cm DIA. X 61cm LONG ACCESS CONNECTOR, 8 PL
HAM (DWG. 1101010), 18 PL
30 cm
76cm ID MODE CLEANER TUBE
2 HAM CHAMBERS NOT SHOWN
PLAN VIEW
13 m 72 cm
(TYP., 4 PL.)
27 cm
A
A
ELEVATION VIEW
Figure 4.

ROOTS PUMP CART



SECTION 1 EMPTY



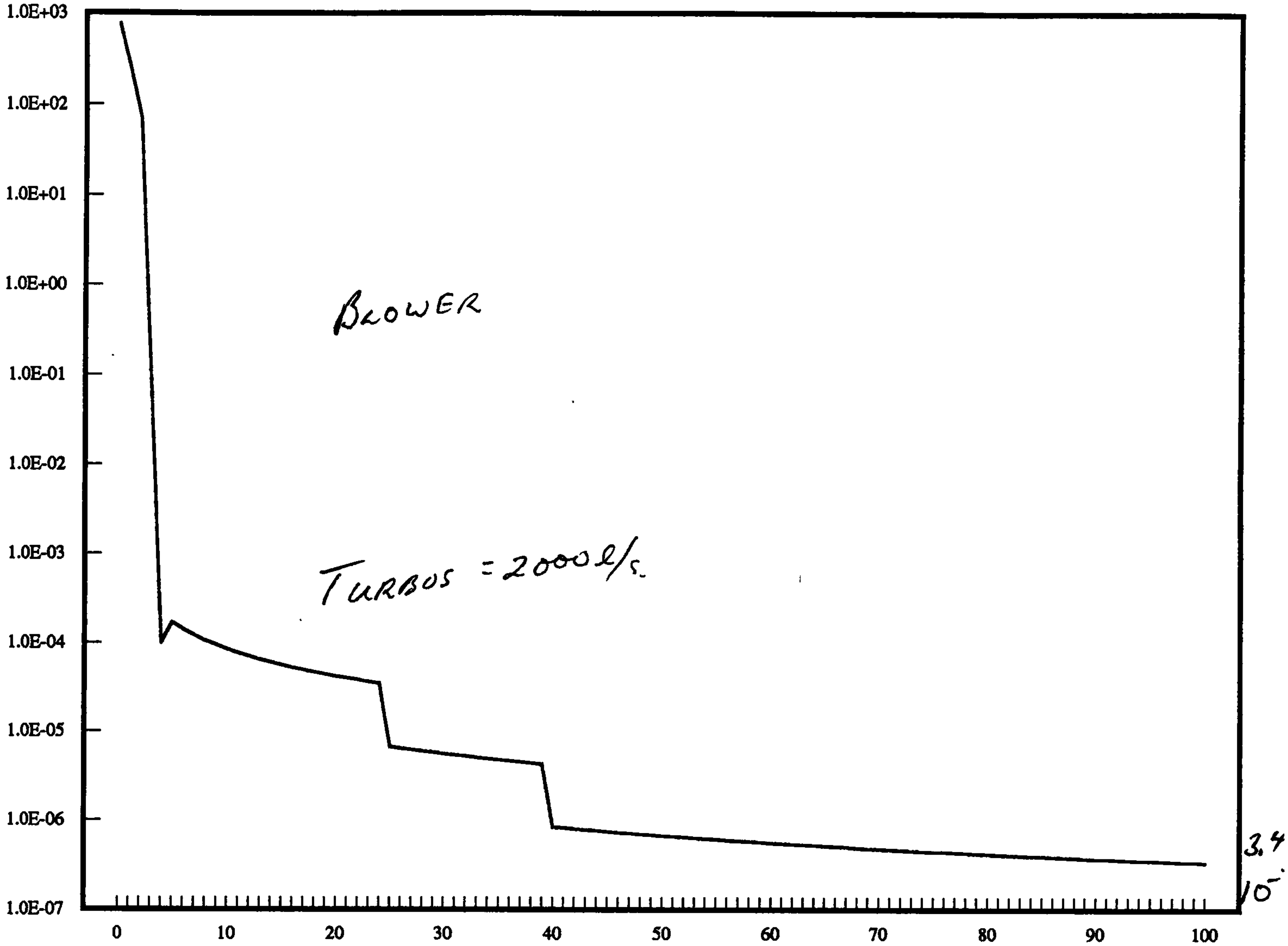
$$J_{H_2O} = \frac{4\times10^{-9}}{t_{hr}} \ t\,l/s\,cm^2 \qquad Q_{H_2O} = 1.7\times10^{-4} \ t\,l/s$$

$$J_{H_2} = 1\times10^{-11}$$

$$P_{H_2O} = 3.6\times10^{-9}$$

$$P_{H_2} = 5\times10^{-9} \ t.$$

SECTION 1 with IF



$$J_{H_2O} = \frac{4\times10^{-7}}{t_{hr}} \quad tl/s\,cm^2 \qquad \Phi_{H_2O} = 1.7\times10^{-2}\, tl/s$$

$$P_{H_2O} = 3.4\times10^{-7}\ t.$$

"Large valves"

48 inch and 60 inch

- 48 inch valves allow isolation of beam tube and regeneration of LN2 Pumps.
- 48 inch valves and 60 inch "air lock" allow maintenance and access to chambers without venting all optics.
- Require independant interlocks and mechanical lock-out to ensure safe operation.

Controls

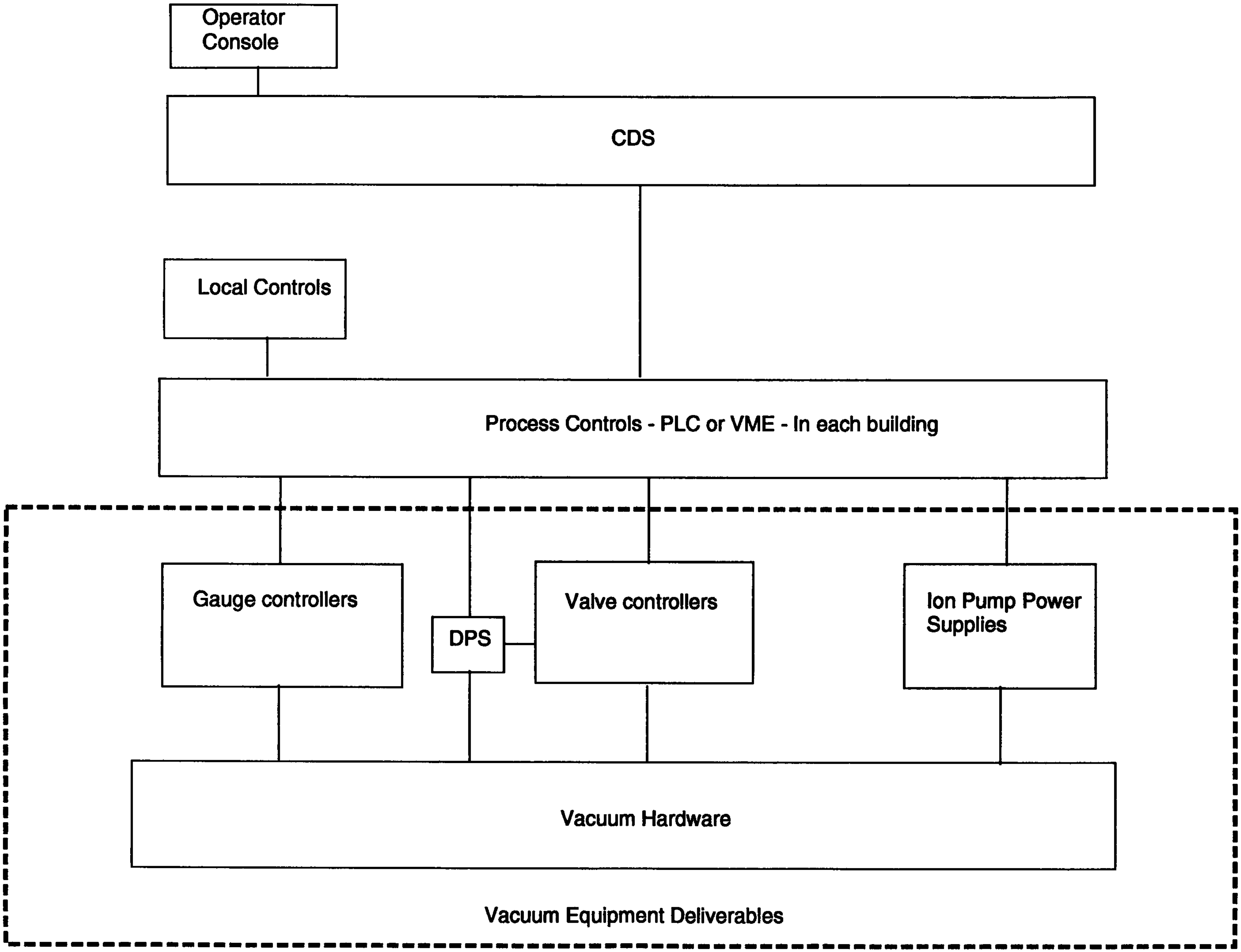
Monitoring and interlocking

- "Absolute" gauges for venting and rough down.
- Pirani type gauges to enable ion pumps, cold cathode ion gauges.
- Cold cathode gauges to monitor trends, provide interlocks for large gate valves.
- Differential pressure switches for independant interlocks for large valves.
- Ion pump current/pressure used to monitor trends, provide interlocks for large gate valves.
- LN2 Pump temperature sensors and liquid level sensors. May need a device to monitor "ice" thickness.

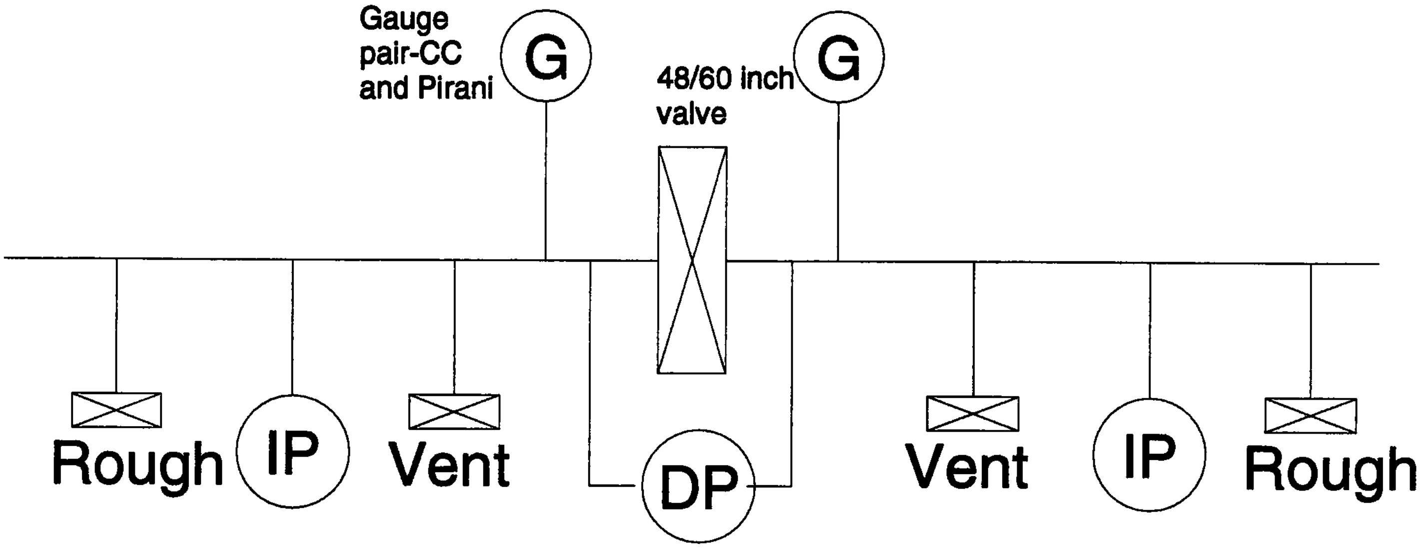
Controls

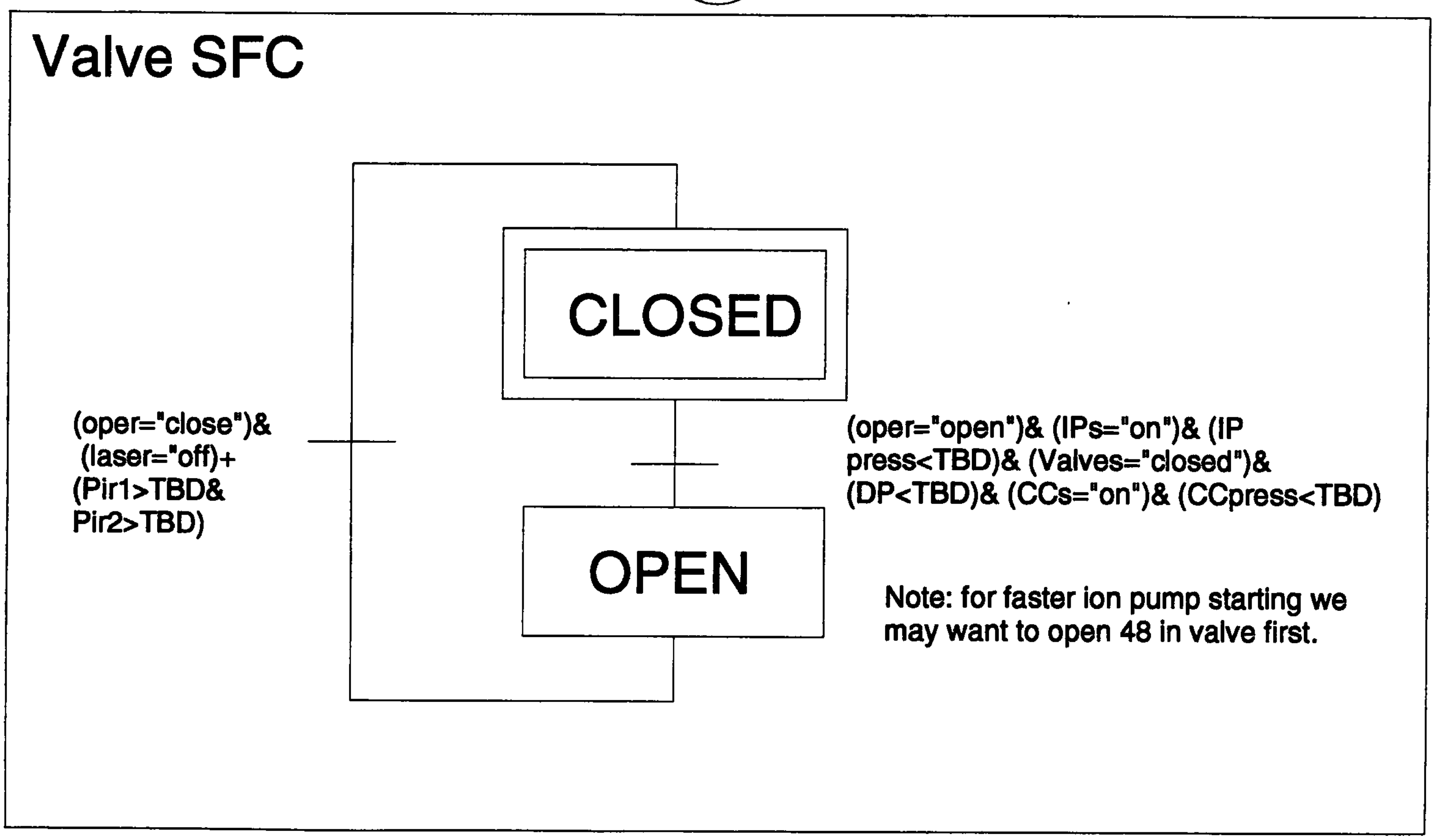
Process controls and user interface

- Dedicated process controls for year round, 24 hours per day operation and protection.
- "Local" control for operation and maintenance from any location.
- Central control for control room operation, data logging, interface to networks.

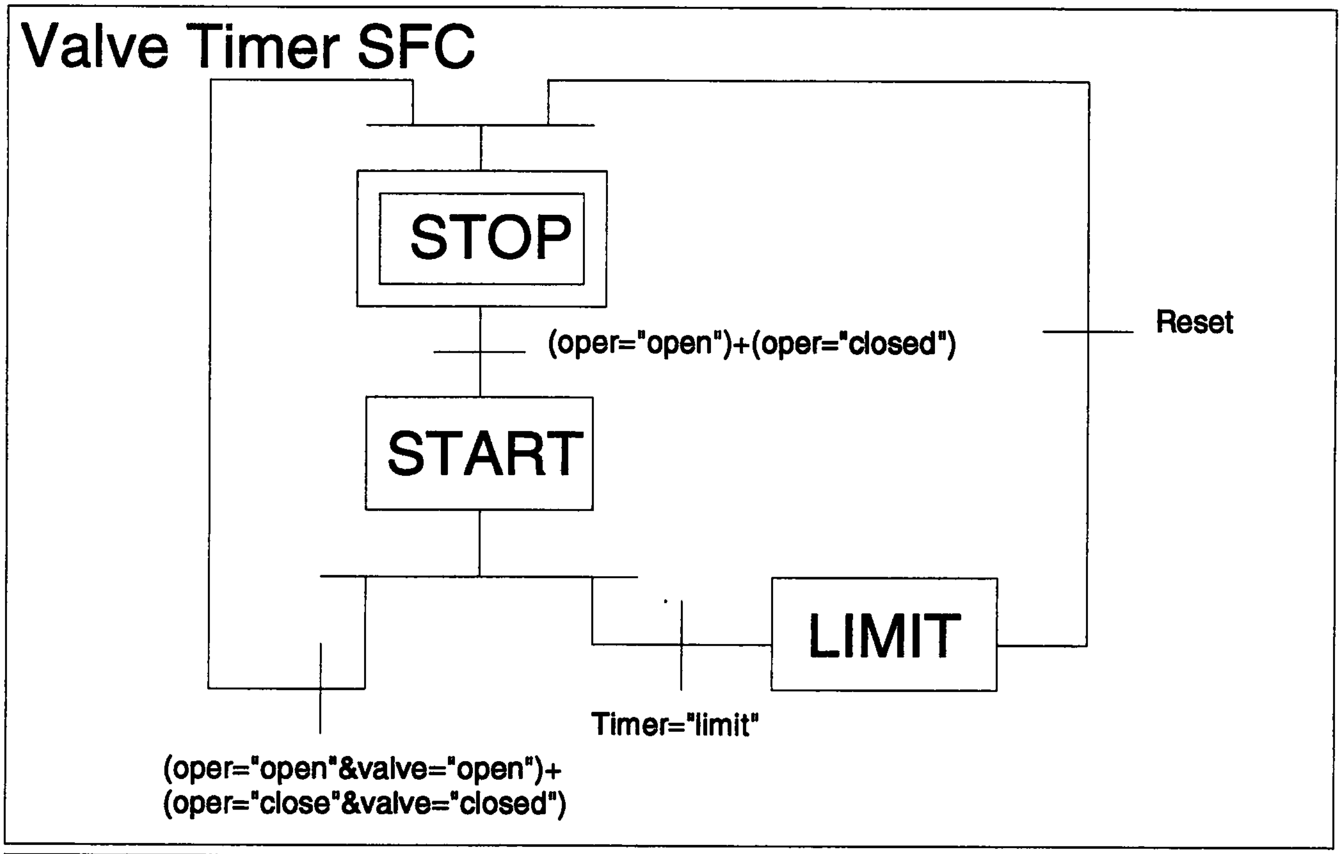

Operator Console
CDS
Local Controls
Process Controls - PLC or VME - In each building
Gauge controllers
DPS
Valve controllers
Ion Pump Power Supplies
Vacuum Hardware
Vacuum Equipment Deliverables

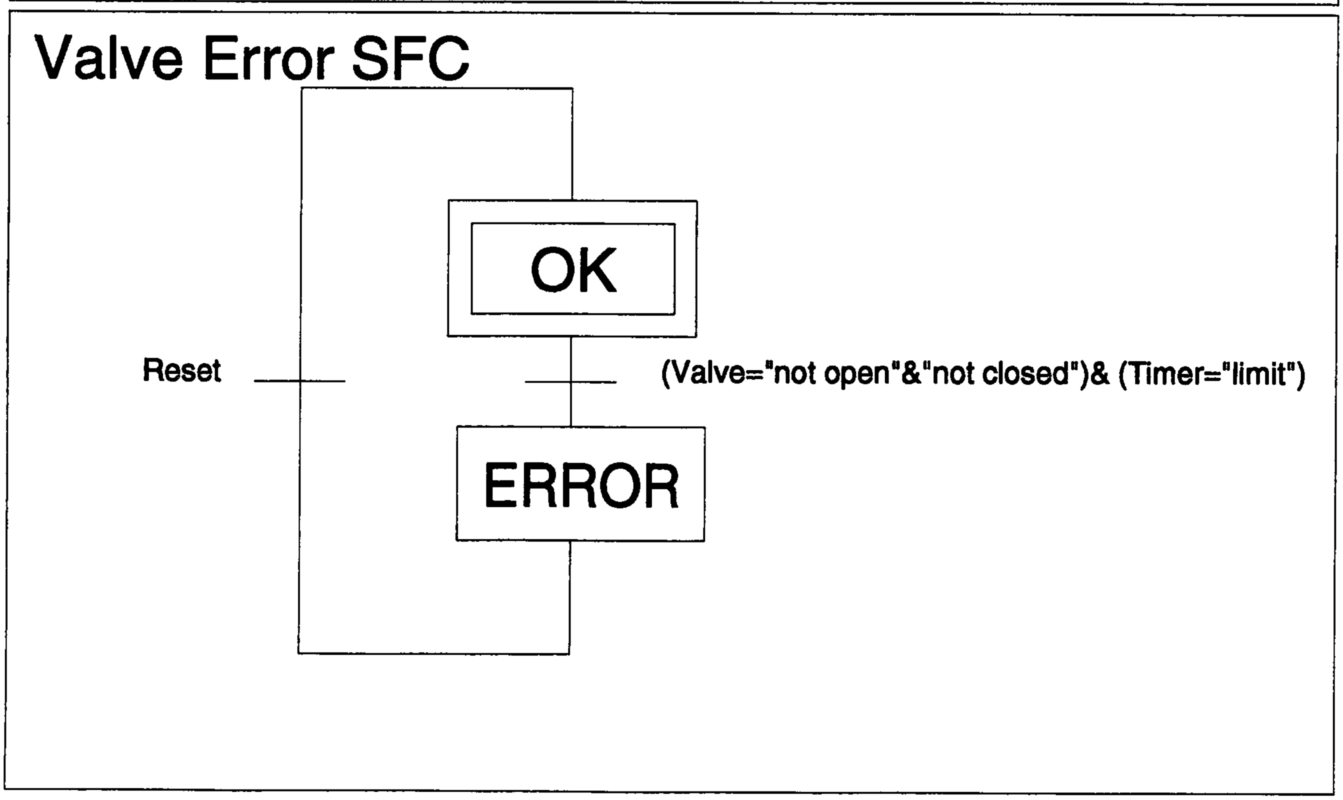
SAMPLE GATE VALVE LOGIC





SAMPLE GATE VALVE LOGIC cont'd





Interface Control

- Vacuum Equipment to Support Beam assembly-Supplied by Caltech/MIT
- Vacuum Equipment to Beam Tube-Supplied by Caltech/MIT
- Vacuum Equipment to building and utilities-supplied by VE contractor?
- Vacuum Equipment to process controls-Supplied by VE contractor.

Failure modes

Minor faults

- Pressure sensor failure-may cause 10inch valve closure, ion pump shutdown, ion gauge or RGA shutdown, rough pump shutdown. May require temporary modification of control logic to continue ops.
- Small valve failure-use alternate port, temporary modification to control logic to continue ops.
- Ion pump failure-substitute power supply, remove shorted pump from circuit, temporary modification to control logic to continue ops.
- mechanical pump failure-may cause 10inch valve closure. Use alternate pump.

Failure modes

Serious faults

- Contamination of vacuum system-may require extensive disassembly and cleaning. Use oil-free mechanical pumps, robust control system, monitor and control vent/purge gas quality, limit power input to any bake circuit, screen all materials and components before installation, no lubricants allowed even outside vacuum.
- 48/60 inch valve failure-use proven design, ensure proper mounting, use redundant seals, use robust controls to minimize unnecessary cycles, provide backup for bellows feedthrough.
- Structural failure of vacuum envelope or supports-perform redundant analysis of stresses at design. Design to ASME pressure vessel code. Procedures required to control, monitor and test support system. Load measurement devices on cranes. Skilled personnel to operate lifting equipment. Minimize size of optical ports.

Interface Control (more)

There are 4 major system to system interfaces which need to be clearly defined and controlled.

The first is the interface between the Vacuum chambers and the IF components. This interface is mainly defined by specifying the position, size, tolerances, etc. of the four flanges which the optics supports beams connect to via the isolation bellows. "Stay clear" regions also need to be defined. All three chamber designs must have this interface defined. These details should be supplied by the Caltech/MIT Interferometer group.

The second major interface is between the VE and the Beam Tube. Since it is likely that the beam tube will be installed first then the VE vendor must obtain the details of this connection from Caltech/MIT Facilities group.

The third interface is between the VE and the Civil construction. The VE will require certain utilities, mounting arrangements, overhead access, etc. The ideal case would have the VE contractor provide these requirements to the Civil construction A&E firm (via Caltech/MIT). However, due to schedule constraints, Caltech/MIT may have to make some educated guesses and supply details to both firms.

The fourth interface is that between the VE electronics and the LIGO Control and Data Systems. The VE vendor must supply signal, cable, and connector details to Caltech/MIT. However, we will supply the VE vendor with a list of acceptable signals and connector types.