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# LLO BEAM TUBE BAKEOUT READINESS REVIEW

*13 August 1999  
W. E. Althouse*



# LIGO REQUIREMENTS

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- LIGO Science Requirements Document
  - ›› sets the goal for residual gas pressure “...at a level or below an equivalent strain noise of  $2 \times 10^{-25} \text{ Hz}^{-1/2}$ ”

# DESIGN REQUIREMENTS

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- COMPONENTS TO BE BAKED
  - ›› All vacuum surfaces of the bake volume (i.e., tube wall material, expansion joints, pump ports, pump port hardware, 114/122cm gate valves, etc.)
- PARTIAL GAS PRESSURES DURING THE BAKEOUT
  - ›› Control by suitable choice of pumping speeds and control of temperature rate-of-rise
  - ›› Maintain the RGA in its linear range
  - ›› Water vapor pressure shall be  $P(\text{H}_2\text{O}) < 2 \times 10^{-8}$  torr @ 150°C at the end of the bake
  - ›› Sum of partial pressures for AMUs 41, 43, 55 and 57 shall be  $P(41,43,55,57) < 2 \times 10^{-9}$  torr @ 150°C at the end of the bake

# DESIGN REQUIREMENTS (CON'T)

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- **BAKE TEMPERATURE**
  - ›› Minimum temperature at any surface shall be  $> 130^{\circ}\text{C}$
  - ›› Maximum temperature of the beam tube wall shall be  $< 170^{\circ}\text{C}$
  - ›› Maximum temperature of the beam tube bellows shall be  $< 400^{\circ}\text{C}$
  - ›› Maximum temperature at any point on the 114/122 cm gate or gate valve shall not exceed  $170^{\circ}\text{C}$
- **MAXIMUM DIFFERENCE IN TUBE WALL TEMPERATURES - mechanical overstress**
  - ›› axial - the average temp of the beam tube wall of a section between fixed supports shall not differ from the average temp of any other section by more than  $40^{\circ}\text{C}$
  - ›› transverse horizontal - the average temp of any right half of a section between guided supports shall not differ from the average temp of the left half by more than  $5^{\circ}\text{C}$
  - ›› transverse vertical - the average temp of any top half of a section between guided supports shall not differ from the average temp of the bottom half by more than  $30^{\circ}\text{C}$

# DESIGN REQUIREMENTS (CON'T)

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- **BAKE DURATION**

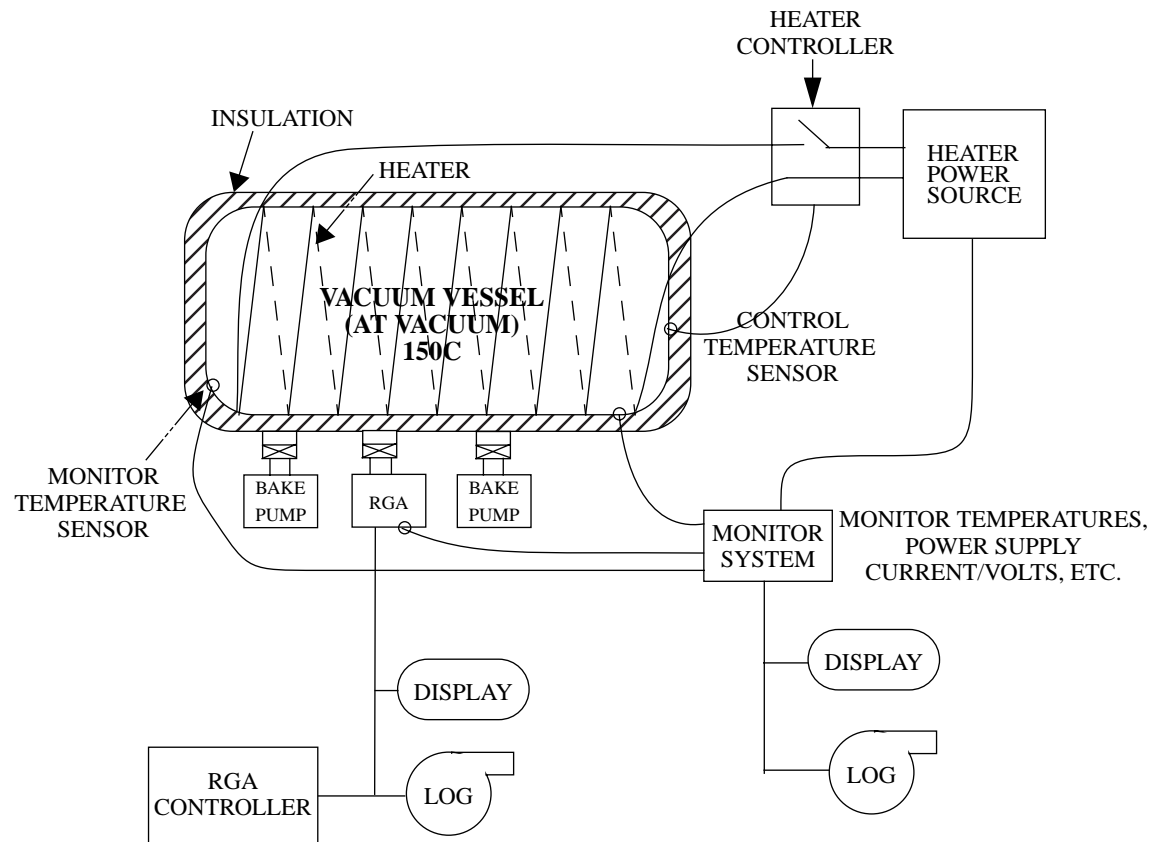
- ›› **The coldest spot of the module under bake shall be maintained  $T > 130^{\circ}\text{C}$  for the earlier of either:**
  - an elapsed time of 30 days, or
  - a water outgassing rate  $J(\text{H}_2\text{O}) < 1 \times 10^{-11}$  torr l/s  $\text{cm}^2$  at  $150^{\circ}\text{C}$
- ›› **If the temp of any tube wall monitoring sensor falls below the minimum bake temperature, the bake time shall be extended as needed to ensure minimum time requirement is met**

# DESIGN REQUIREMENTS (CON'T)

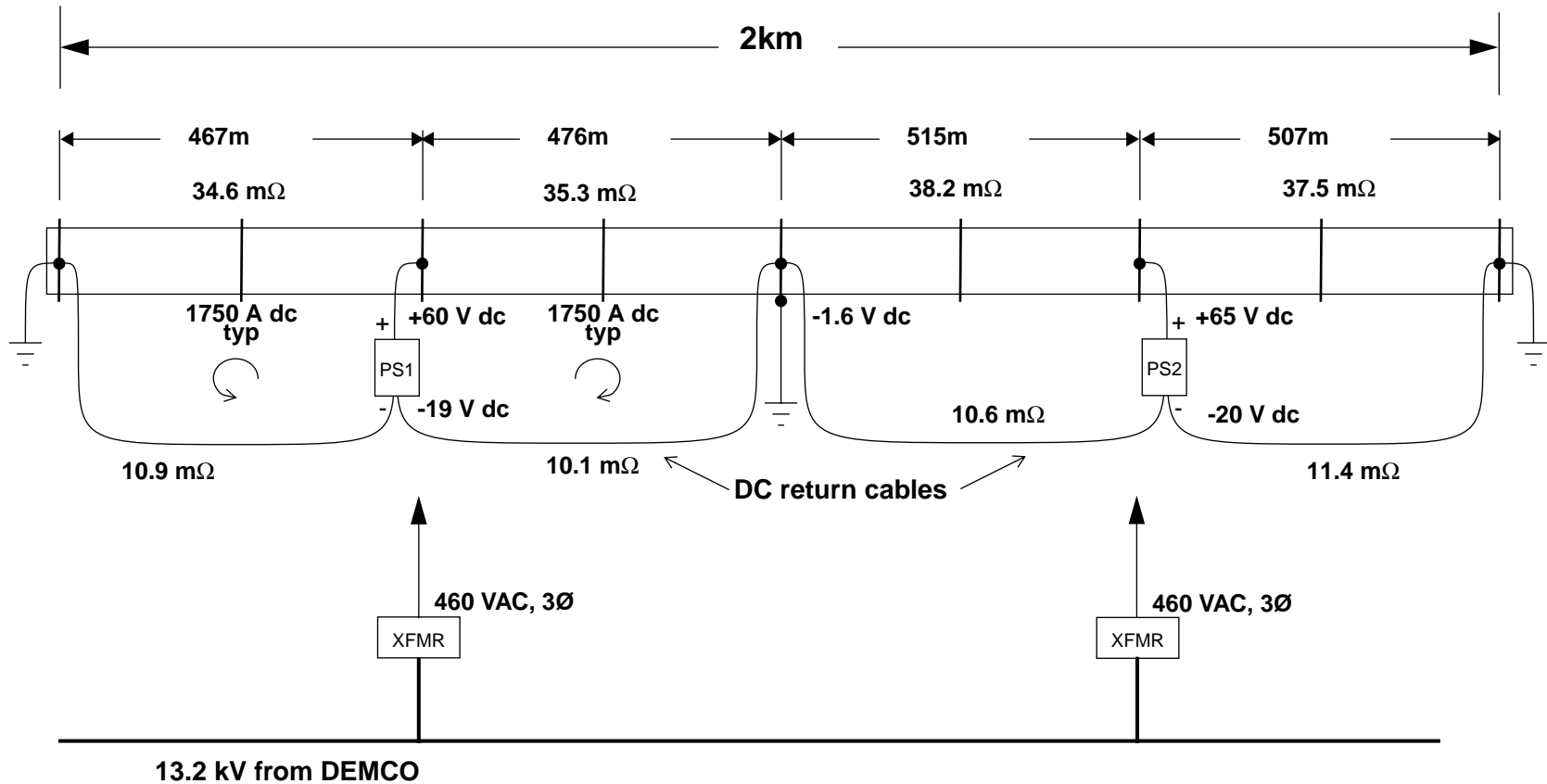
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- DATA ACQUISITION, DISPLAY, MONITORING & RECORDING
  - ›› Wall temperatures at representative positions (including anticipated hot or cold spots)
  - ›› Temperature interfaces at the end gate valves, supports and pump port hardware
  - ›› Temperatures at the 114/122 cm gate valves and terminations
  - ›› At least one RGA to measure partial pressures through AMU 100 (bakeout and post-bake)
  - ›› DC power supply currents and voltages
  - ›› Operating status of equipment (i.e., vacuum pumps)[state vector]
  - ›› Other engineering data (e.g., ambient environment conditions)

# EQUIPMENT CONFIGURATION DURING BAKEOUT



# BEAM TUBE BAKEOUT ELECTRICAL HEATING POWER

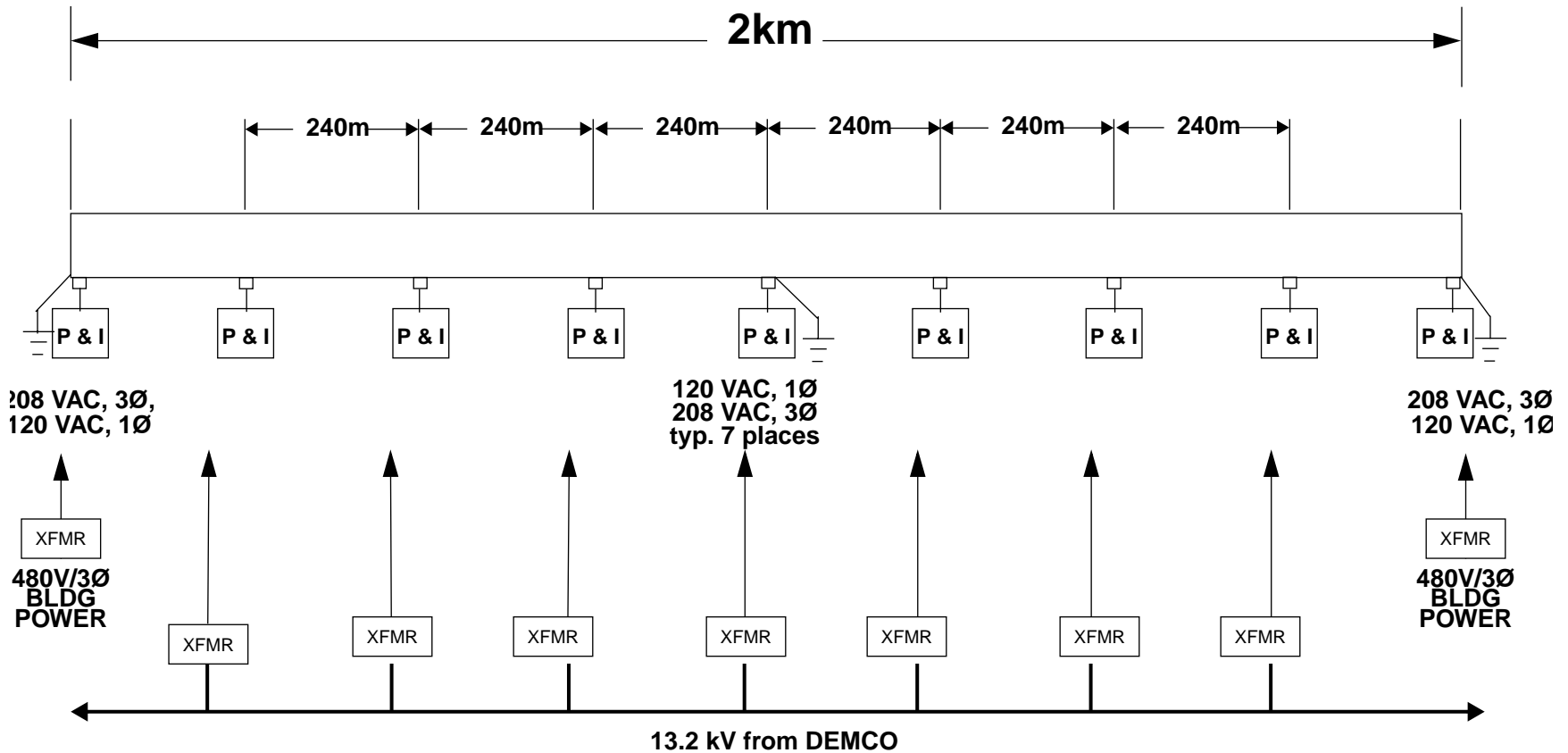


Legend: XFMR Power Transformer PS Low voltage, high current DC power supply





# ELECTRICAL POWER FOR HEATER JACKETS, PUMPS AND INSTRUMENTATION

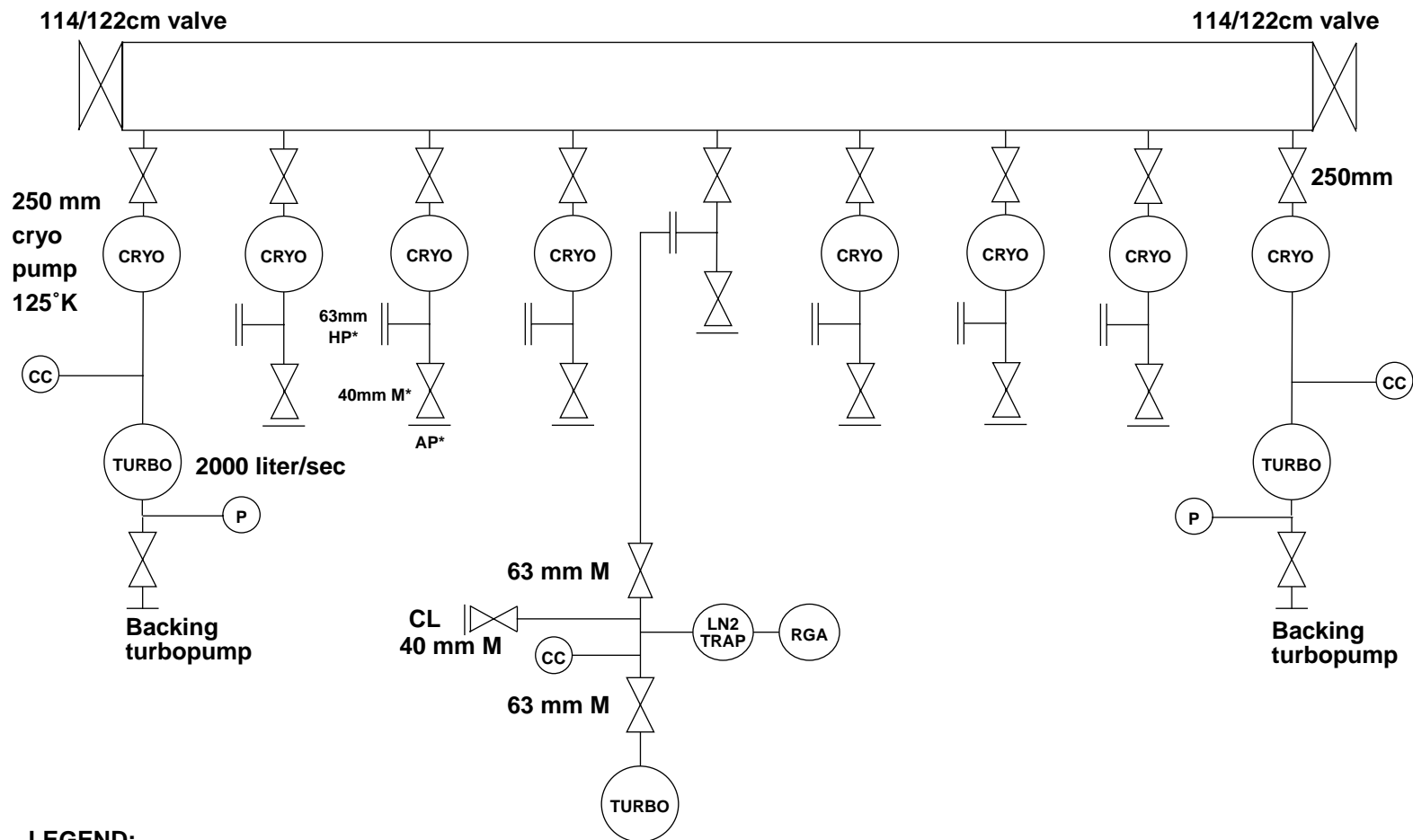


## Legends:

□ Pump Port

▣ P & I Pumps & Instrumentation

# SCHEMATIC OF PUMPS AND RGA DURING BAKEOUT



**LEGEND:**

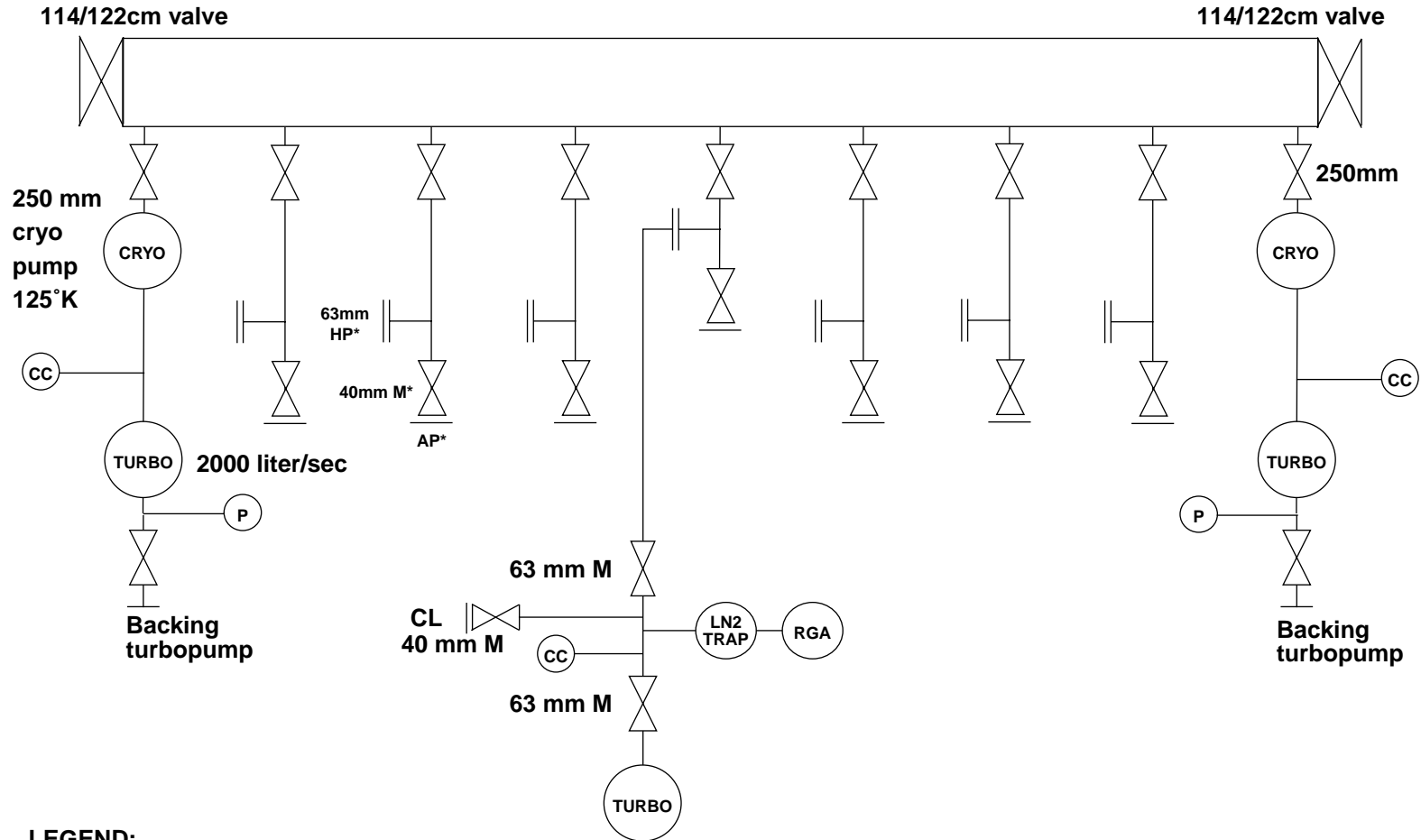
- AP Port for auxiliary pump
- CC Cold Cathode gauge
- CL Port for calibration leaks
- HP Port for RGA head installation

- M Metal sealed valve
- P Pirani gauge

\* Type H Pump Port Hardware furnished by CBI



# POST-BAKE TEST CONFIGURATION



## LEGEND:





AP Port for auxiliary pump  
 CC Cold Cathode gauge  
 CL Port for calibration leaks  
 HP Port for RGA head installation

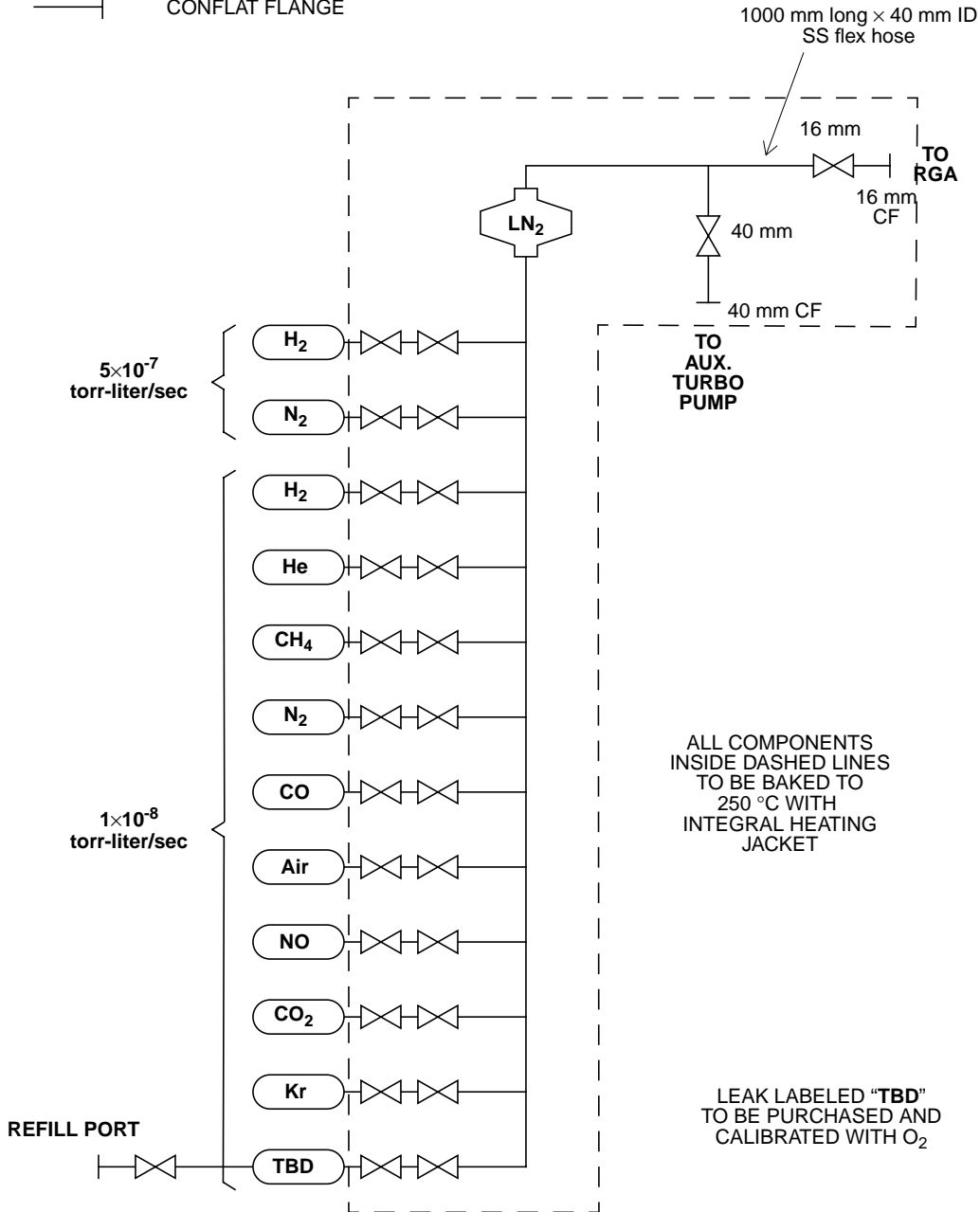
M Metal sealed valve  
 P Pirani gauge

\* Type H Pump Port Hardware furnished by CBI

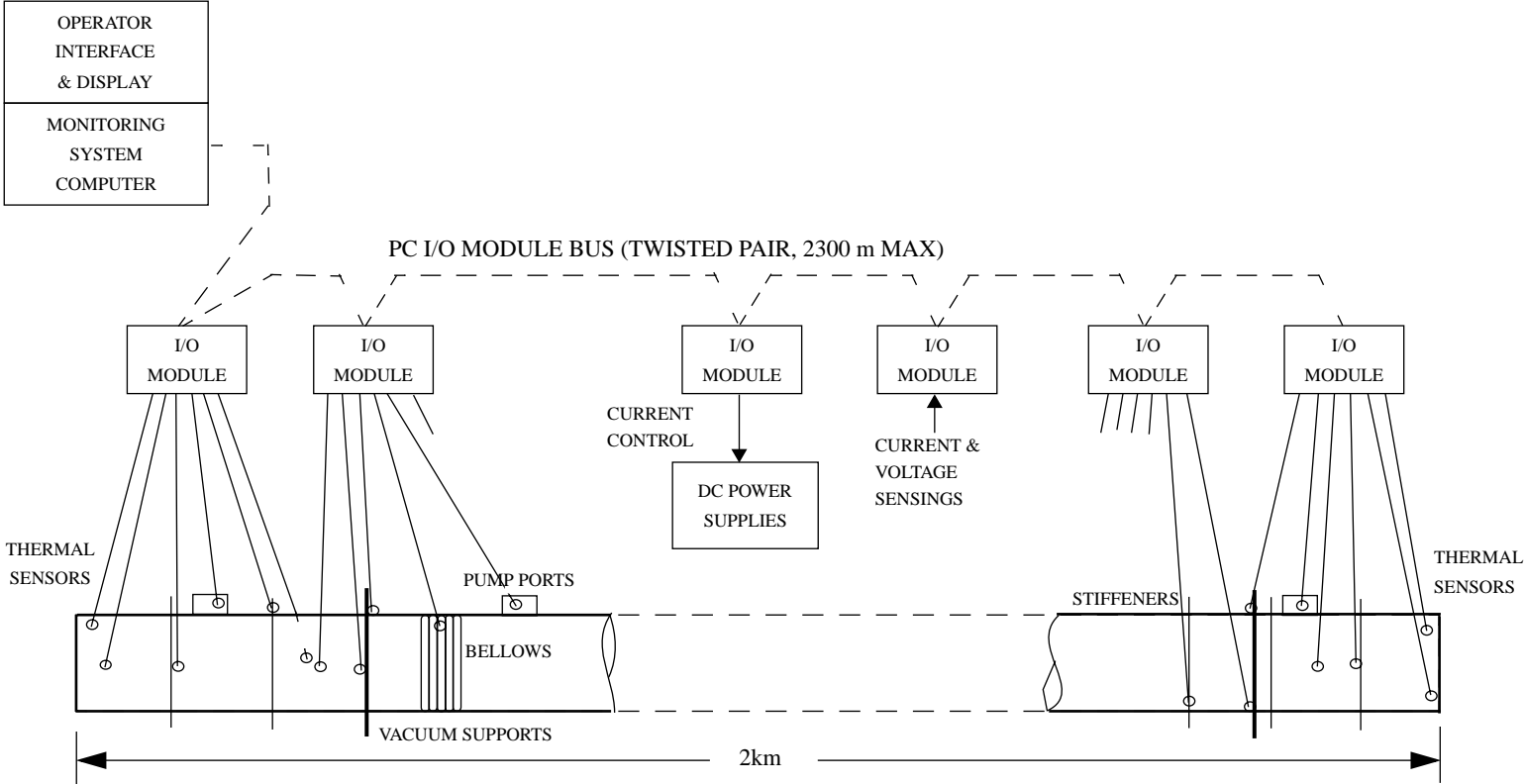
# CALIBRATION ASSEMBLY

**LEGEND:**

-  ALL METAL UHV VALVE
-  CALIBRATED GAS LEAK
-  LIQUID NITROGEN TRAP
-  CONFLAT FLANGE



# MONITORING SYSTEM



# MONITORING SYSTEM CHANNELS

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- Temperature channels:
  - ›› 28 channels “prime” tube wall temperatures - 7 locations, 4 clock angles
  - ›› 119 channels at each end (1<sup>st</sup> 60 m) of beam tube -- gate valve, pump port, anchor, fixed supports, bellows, guided supports, tube wall
  - ›› 10 channels at each pump port -- 4 around tube wall (3, 6, 9, 12 o'clock) and 6 at port hardware
  - ›› 26 temperature channels monitoring ambient air (inside BTE) and equipment
- Power supply electrical (16 channels DC + 18 channels AC)
- Vacuum gauges (4 channels)
- Equipment status [state vector]
- Weather station (wind, RH, etc.)
  
- OUTPUTS (2 channels): PS1 and PS2 current settings

# BAKEOUT STATES

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1. Pre-bake - DC power not connected to tube
2. Pre-bake - DC power connected to tube
3. Bake
  - 3a. Equipment end-to-end checkout
  - 3b. Ramp up temperature
  - 3c. Hold temperature
  - 3d. Ramp down temperature
4. Post-bake - DC power disconnected
  - 4a. Temperature stabilization - cryopumped
  - 4b. Pumped at ends only, bake RGA (250 °C) and ports xx2, 3, 4, 6, 7, 8 (150 °C)
  - 4c. Pumped at ends only, post-bake RGA measurements
5. After post-bake measurements completed, sealed off by 44" valves

# EQUIPMENT CHECKOUT PROCEDURE

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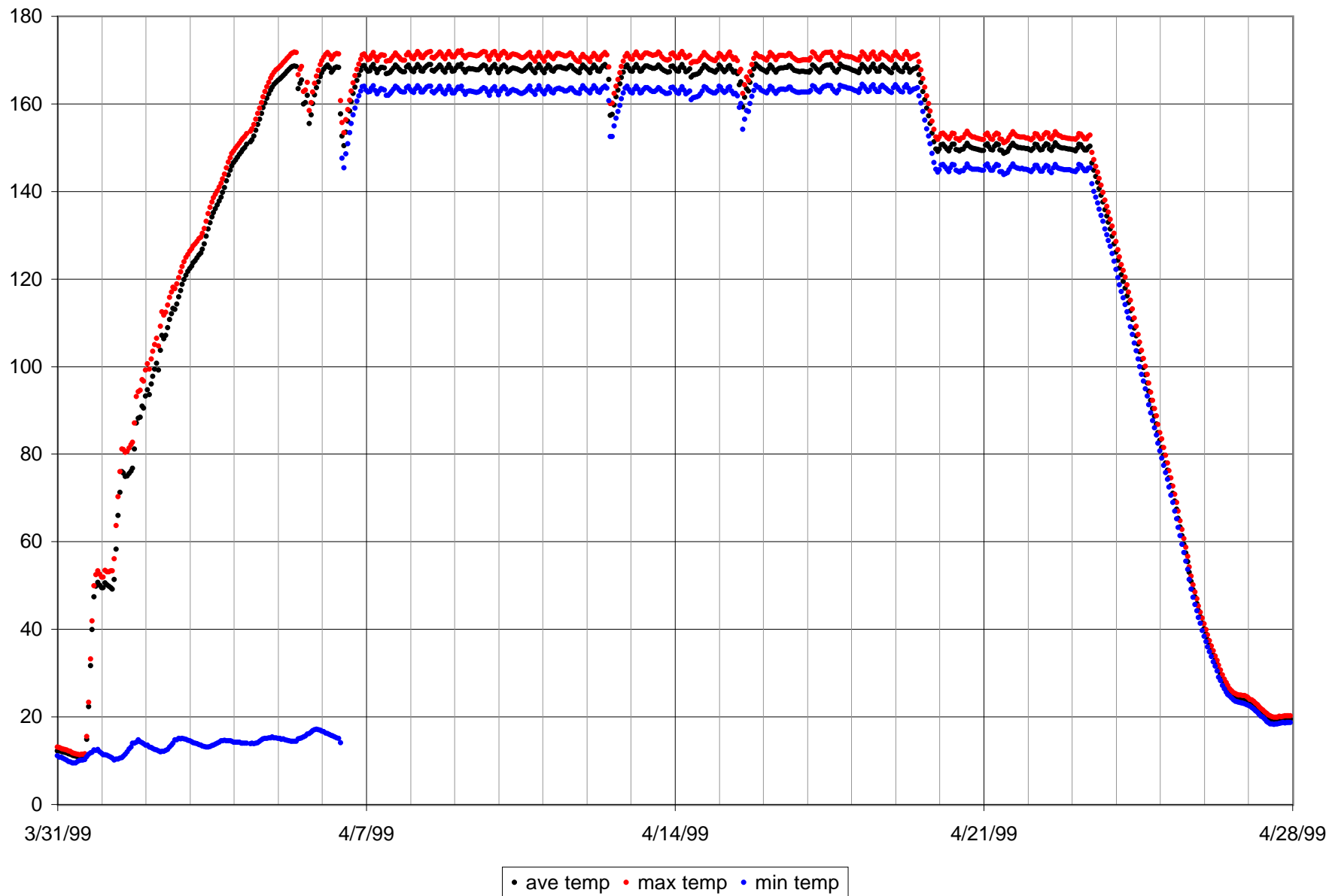
- Routine pre-bake end-to-end system checkout
  - ›› Equipment configuration checklist
  - ›› Data channel checklist
  - ›› Power supply coolant leak test
  - ›› Power supply functional check
  - ›› Manual valve status
  - ›› Main turbopump run status
  - ›› Cryopump turn-on and cold-head temperature check
  - ›› RGA, Calibration Assembly operational status
  - ›› DC supply functional check and transfer function calibration
  - ›› Heater jacket controller temperature and ramp-rate limits; heater jacket responses
  - ›› System safety, security check



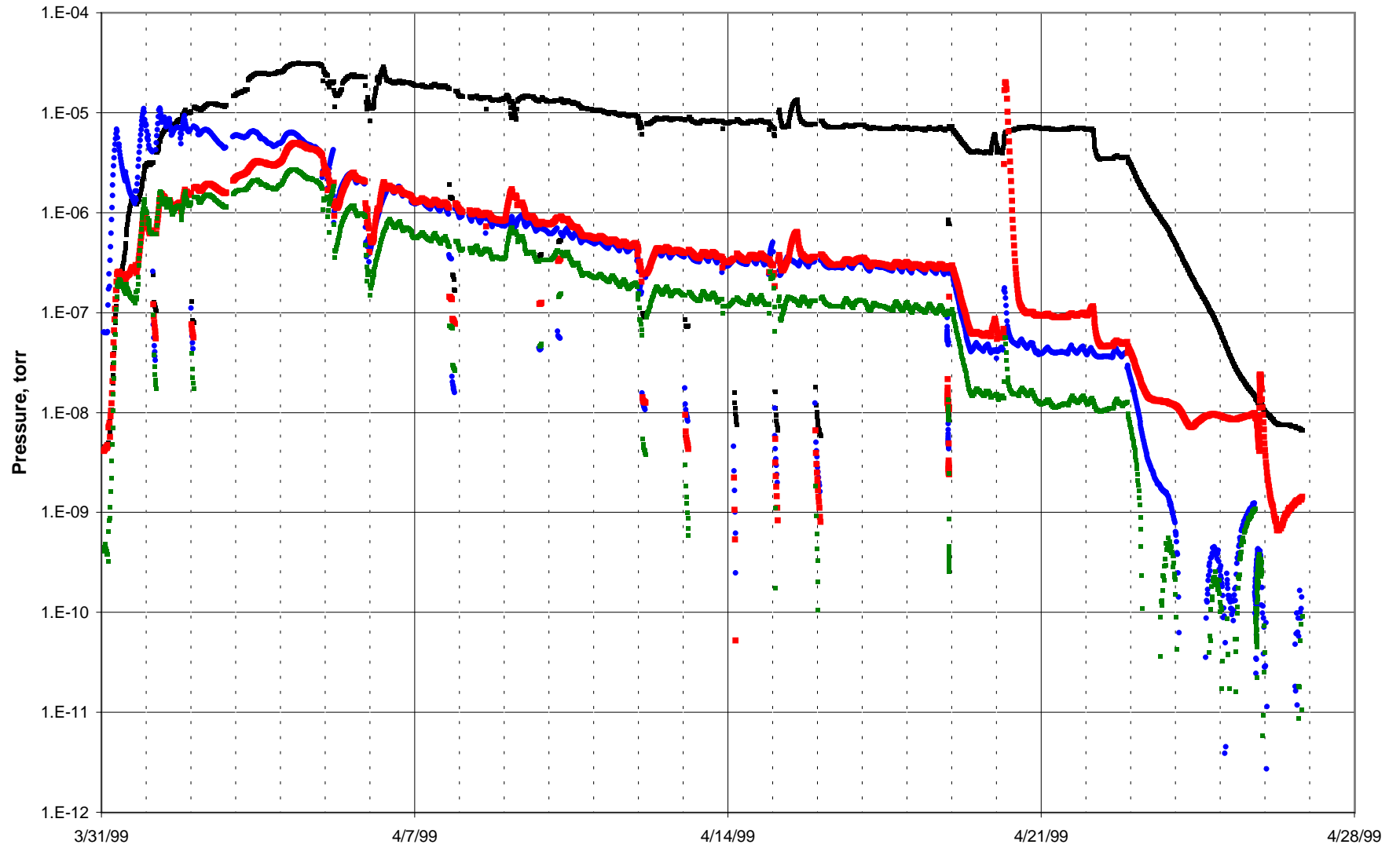
# BAKEOUT PROCEDURE

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- Requires that Equipment Checkout Procedures be completed
  - ›› Initiates data acquisition
  - ›› Initializes turbopump and cryopump operation
  - ›› Sets cryopump heating at ports Y22, Y23, Y24, Y26, Y27, Y28 to 150 °C
- Ramp temperature up to 150 °C at 2 °C per hr or  $P < 10^{-5}$  torr
  - ›› Requires changing setpoint on each of 44 heater jacket controllers - 25 C steps each 12 hrs
- Continue ramping tube wall temperature to 168 °C ( $P < 10^{-5}$  torr)
- Hold temp at 168 °C until  $P < 2 \times 10^{-8}$  torr (at 150 °C)
- Ramp temperature down at 2 °C per hr
  - ›› At T=50 C shutdown DC power ( $\tau = 9$  hr)
- Move to post-bake state



HX2 RGA PRESSURE, AMU 2 (blk), AMU 18 (blu), AMU 28 (red), AMU 44 (green)



# BEAM TUBE ENCLOSURE ENTRY PROCEDURE

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- Special bakeout-specific lock tumblers installed at doors
- Part A - for use near grounded ends and port xx5 of beam tube module
  - ›› Operator issues BLUE key and logs entry and exit
  - ›› User returns key to operator after work is completed
- Part B - for use at all other doors
  - ›› Operator sets DC power supply voltage to zero
  - ›› Operator issues GREEN key and logs entry
  - ›› User locks out power supply nearest work point
  - ›› After work is performed, user unlocks and turns on power supply, then returns key to Operator
  - ›› Operator restores power supply operation and logs exit and key return
  - ›› 2-way radio contact maintained throughout operation
  - ›› 2 people required for work away from lighted door areas

# POWER SUPPLY EMERGENCY SHUTDOWN

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- Bakeout Operator sets power supply control to zero
- If that is imprudent or doesn't work, push EMERGENCY STOP buttons on each DC power supply (mounted outside for ready access)

# OTHER BAKEOUT SAFETY MEASURES

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- Lighting in work areas
- Flashing beacons at access doors during operation
- Flashing beacons at emergency exits inside beam tube enclosure
- Signs on all access doors and electrified equipment
  - ››NO ENTRY - EMERGENCY EXIT ONLY on all single doors except at ends
  - ››DANGER - HOT on all double doors and at ends
  - ››DANGER - ELECTRICAL HAZARD - AUTHORIZED PERSONNEL ONLY on double doors at ports 2, 3, 4, 6, 7, and 8
  - ››DANGER - HIGH VOLTAGE on cryopump stands at ports 2, 3, 4, 6, 7, and 8
- CO2 fire extinguishers at each pump port (including ends)
- Ethylene glycol (PS coolant) storage, handling and spill cleanup equipment

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*Note 1, Bill Althouse, 08/11/99 09:59:23 AM*  
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*Note 2, Bill Althouse, 08/11/99 09:59:36 AM*  
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*Note 3, Bill Althouse, 08/11/99 09:57:39 AM*  
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*Note 4, Bill Althouse, 08/11/99 09:58:13 AM*  
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