BEAM TUBE BAKEOUT READINESS REVIEW

25 June 1998

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LIGO REQUIREMENTS

- LIGO Science Requirements Document
  - **sets the goal for residual gas pressure "....at a level or below an equivalent strain noise of 2×10^{-25} $Hz^{-1/2}$"**

DESIGN REQUIREMENTS

- 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 $P(H_2O) < 2\times10^{-8}$ torr @ 150˚C at the end of the bake**
  - **Sum of partial pressures for AMUs 41, 43, 55 and 57 shall be $P(41,43,55,57) < 2\times10^{-9}$ torr @ 150˚C at the end of the bake**

DESIGN REQUIREMENTS (CON'T)

- BAKE TEMPERATURE
  - **Minimum temperature at any surface shall be > 130˚C**
  - **Maximum temperature of the beam tube wall shall be < 170˚C**
  - **Maximum temperature of the beam tube bellows shall be < 400˚C**
  - **Maximum temperature at any point on the 114/122 cm gate or gate valve shall not exceed 170˚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˚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˚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˚C**

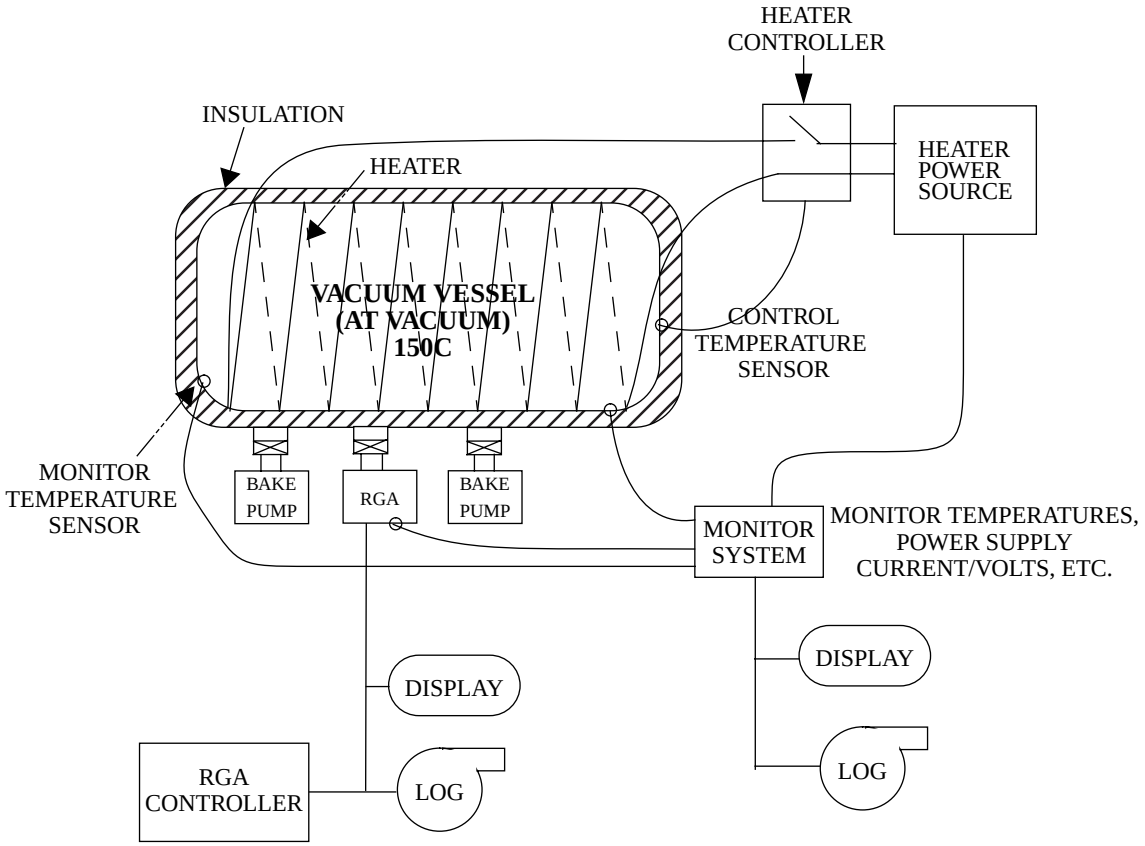
DESIGN REQUIREMENTS (CON'T)

- BAKE DURATION
  - **The coldest spot of the module under bake shall be maintained T > 130˚C for the earlier of either:**
    - an elapsed time of 30 days, or
    - a water outgassing rate $J(H_2O) < 1 \times 10^{-11}$ torr l/s cm^2 at 150˚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**

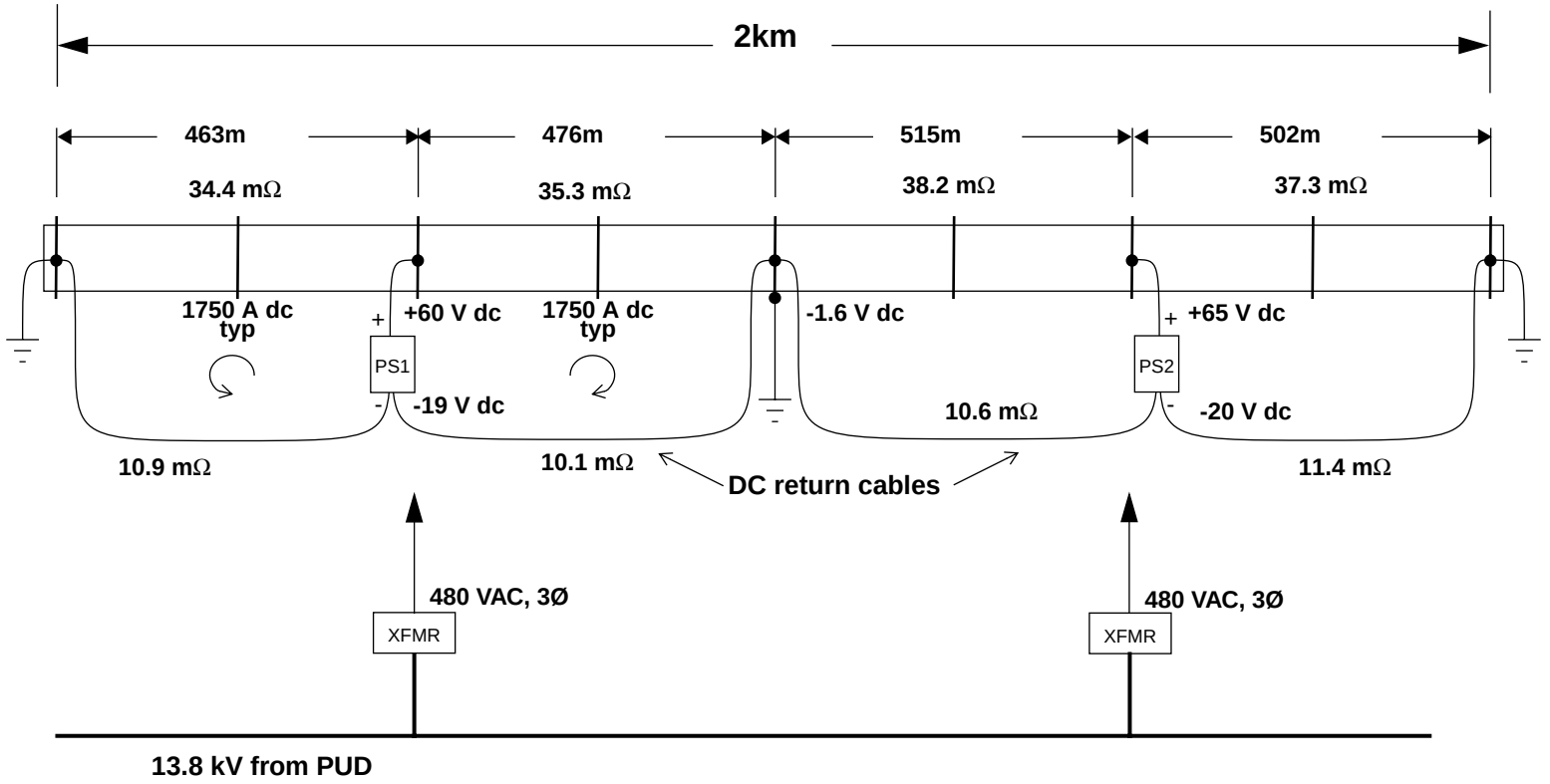
DESIGN REQUIREMENTS (CON'T)

- DATA ACQUISTION, 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

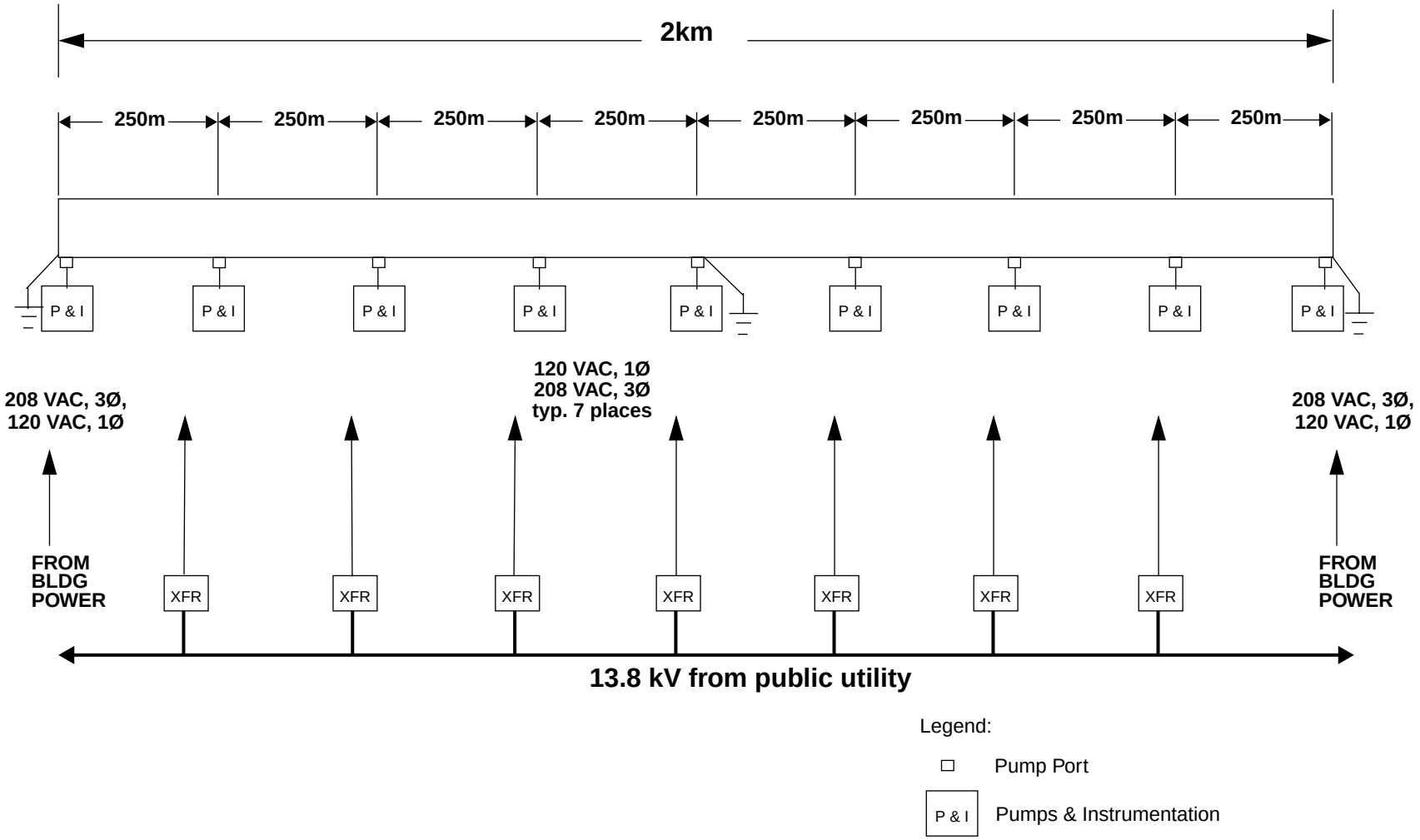


Legend:

PS — **Low voltage, high current DC power supply**

XFMR — **Power Transformer**

ELECTRICAL POWER FOR HEATER JACKETS, PUMPS AND INSTRUMENTATION

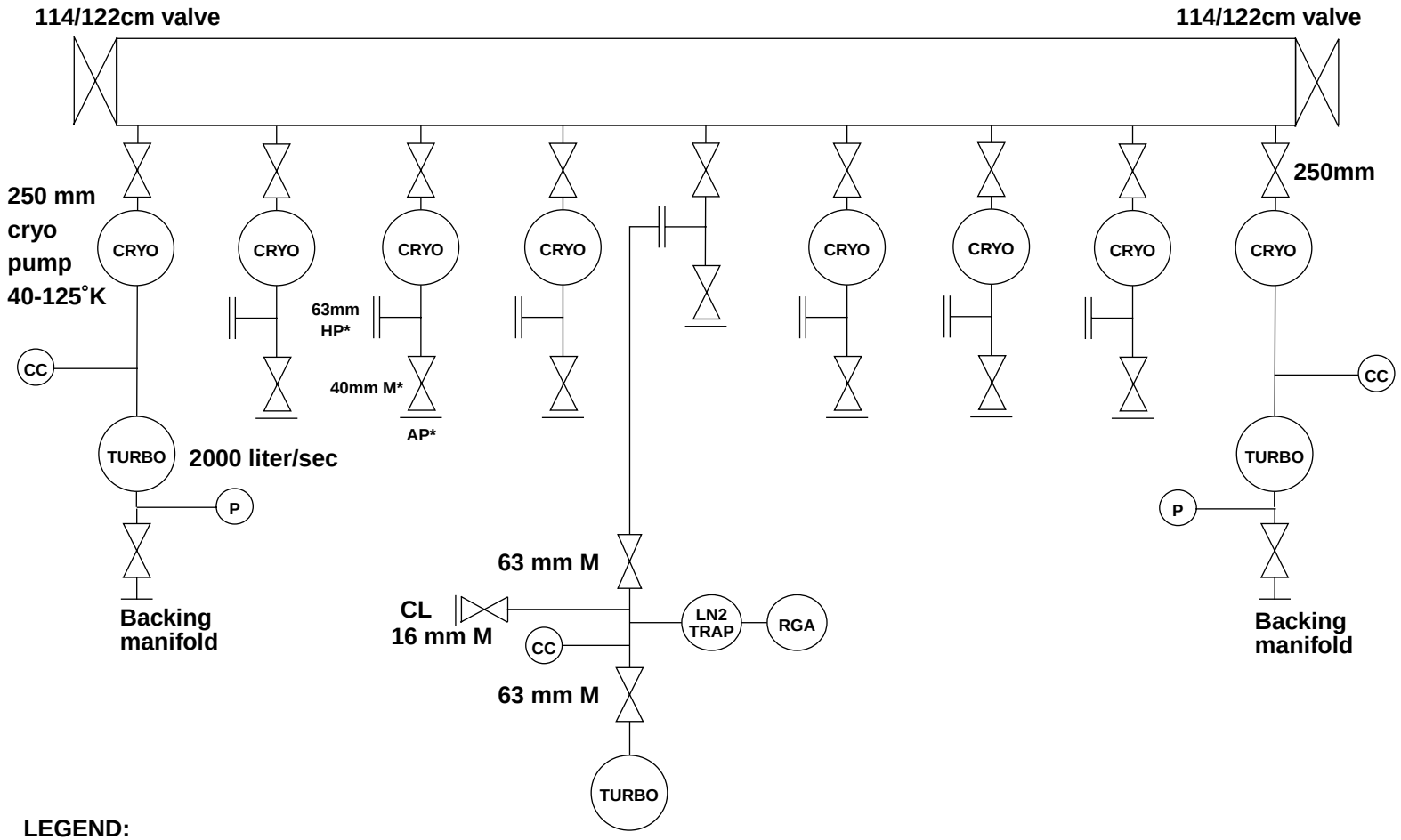


Legend:

□ Pump Port

P & I Pumps & Instrumentation

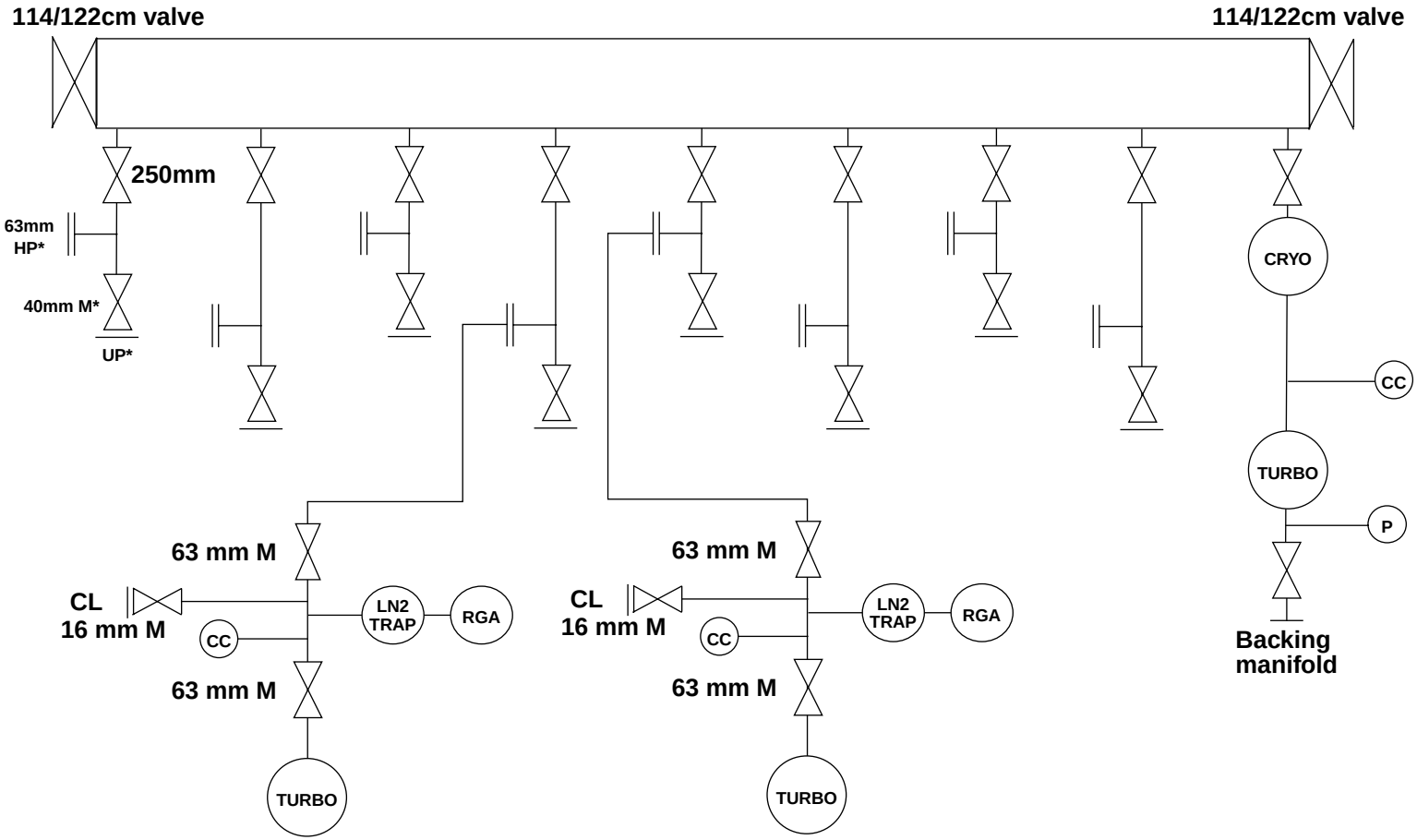
SCHEMATIC OF PUMPS AND RGA DURING BAKEOUT



LEGEND:

AP Port for auxiliary turbo 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



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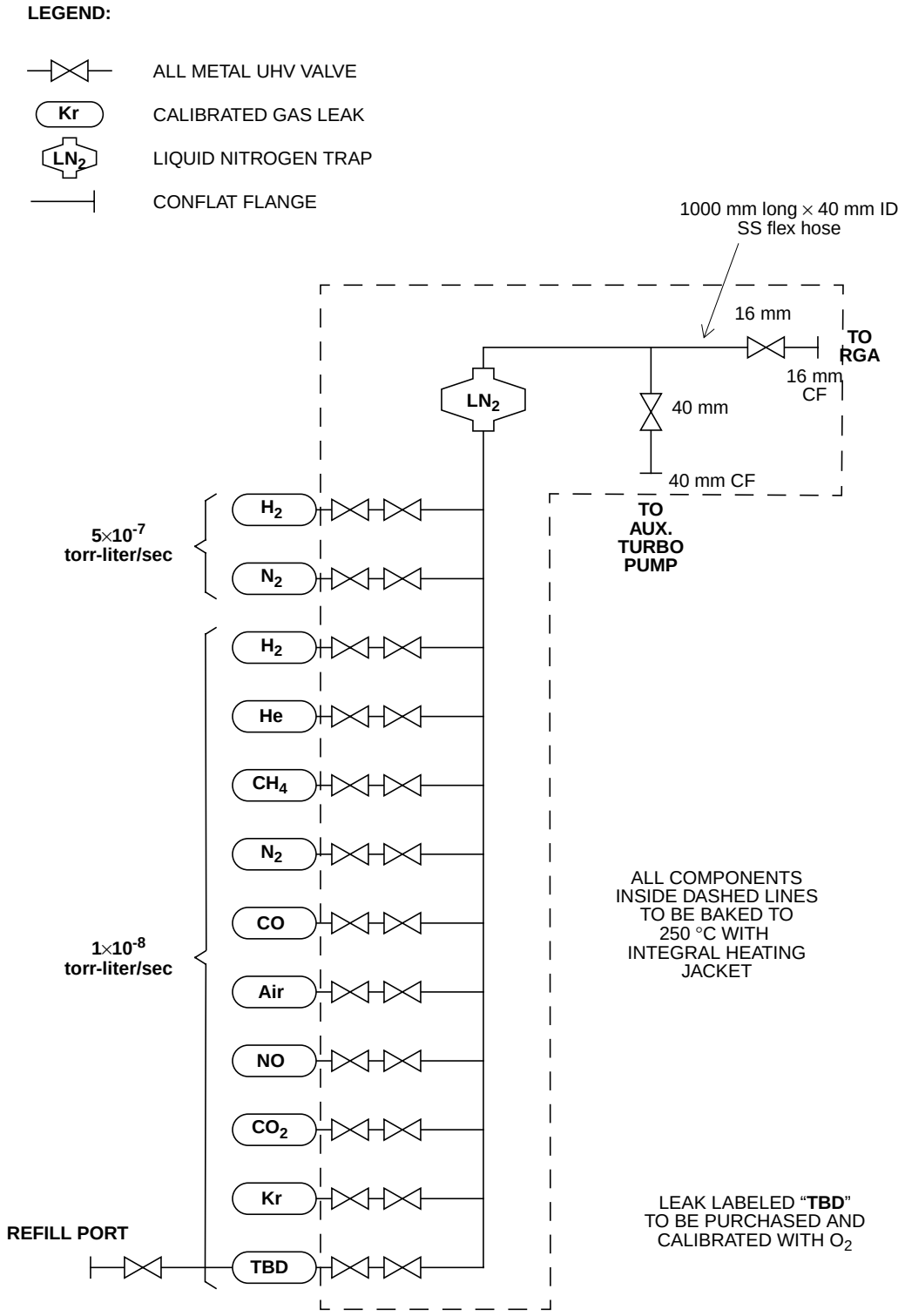
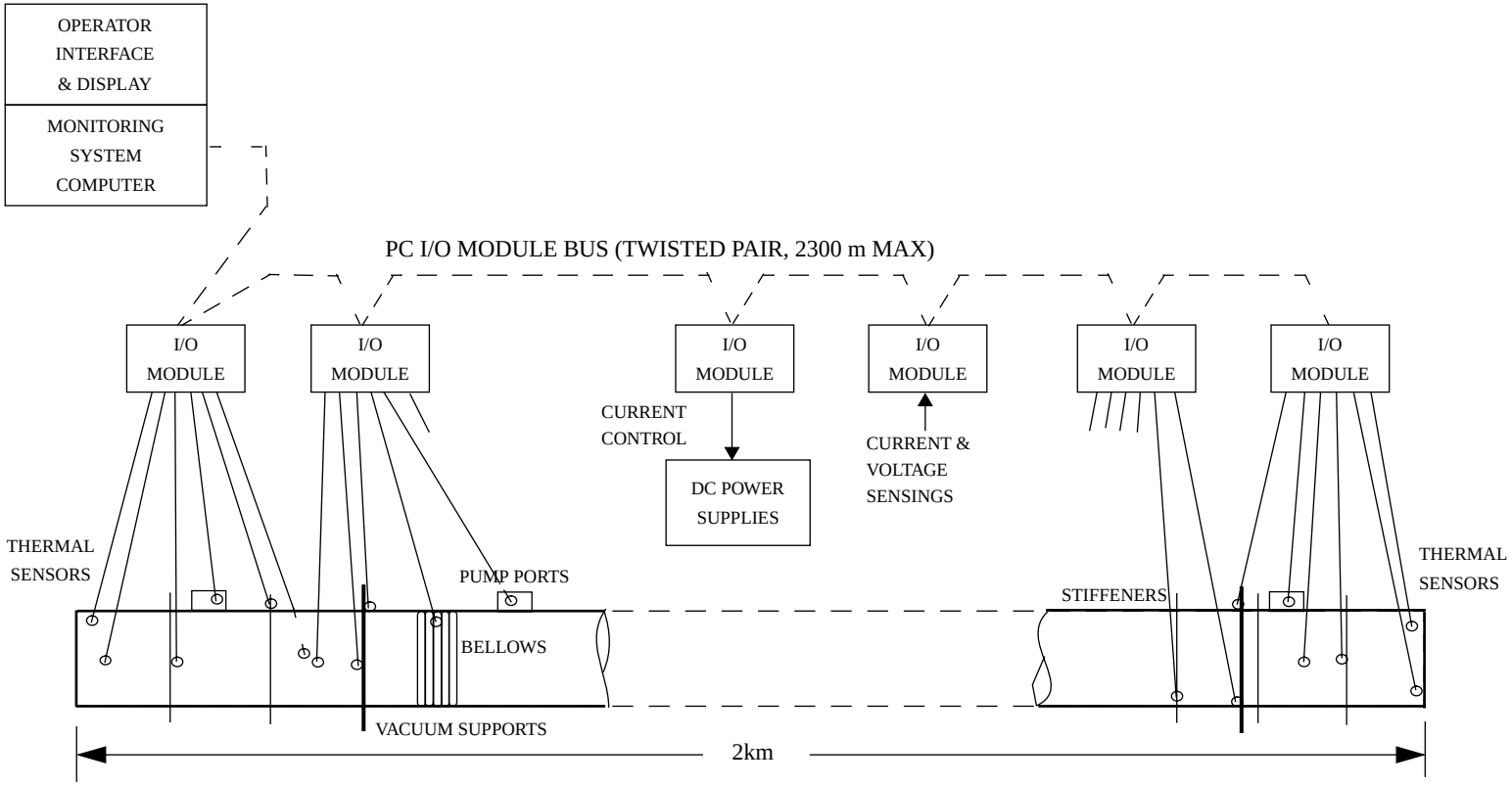
CALIBRATION ASSEMBLY



MONITORING SYSTEM



MONITORING SYSTEM CHANNELS

- Temperature channels (353 total):
  - **28 channels “prime” tube wall temperatures - 7 locations, 4 clock angles**
  - **119 channels at each end (1st 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

PRELIMINARY DESIGN REVIEW RECOMMENDATIONS

Recommendation/Comment	Response
1. Bigger turbopumps at RGAs	180 l/s turbos incorporated
2. Magnetic shielding for RGAs	Need TBD
3. Replace cal cart air inlet valve w/ capillary leak	Done.
4. FEA for support thermal design	Not done.
5. Freeze protection for PS cooling units	50% ethylene glycol
6. Valve between RGA head and LN2 trap	Not done
7. Cabling and I/O module mounting carefully defined	Done
8. Consider RGAs other than Balzers	Considered
9. Check electrical isolation of supports	Done
10. Put as-built bellows spring rates into model	Not done
11. Control 44” gate valve temp rate of change	Incorporated into bakeout procedure
12. Test corrosion due to insulation in LA	Mockup wrapped in insulation at LA site

BAKEOUT STATES

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 one end only, bake and post-bake RGAs installed**
   - **4c. Pumped at one end only, post-bake RGAs installed**
5. Post-bake - connected to and pumped by Vacuum Equipment

EQUIPMENT CHECKOUT PROCEDURE

- One-time procedures
  - DC cable length matching
  - Power supply coolant leak test
  - Power supply functional check
  - Power supply return current shunt calibration
- Routine pre-bake end-to-end system checkout
  - Equipment configuration checklist
  - Data channel checklist
  - 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

- Requires that Equipment Checkout Procedure be completed
  - ›› Initiates data acquisition
  - ›› Initializes turbopump and cryopump operation
  - ›› Sets cryopump heating at ports Y22, Y23, Y24, Y26, Y27, Y28 to 150 °C
- Establish thermal equilibrium over the tube and ends
- Ramp temperature up to 150 °C at 2 °C per hr (e.g., 60 hr from 30 °C)
  - ›› Requires changing setpoint on each of 44 heater jacket controllers - initially 6 C steps each 3 hrs
- Hold temp at 150 °C for 30 days or < 2×10^{-8} torr
- Ramp temperature down at 2 °C per hr
  - ›› At T=30 C shutdown DC power (τ = 9 hr)
- Move to post-bake state - procedure TBD

BEAM TUBE ENCLOSURE ENTRY PROCEDURE

- Special bakeout-specific lock tumblers installed at doors
- Part A - for use near grounded ends of beam tube
  - ›› 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

- 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

- 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

BAKEOUT PLAN

- Conduct first 2 km module bakeout to:
  - **Validate insulation, heating and pumping designs**
  - **Evaluate beam tube mechanical behavior during bake**
  - **Shakedown the setup, bakeout and post-bake procedures (and maybe the post-bake leak localization and repair procedures)**
- Iterate procedures and designs as needed
- Bake 3 remaining modules at Hanford, ship equipment to Louisiana, and bake 4 modules
- On-site staffing:
  - **Site scientist/engineer to supervise setup, bakeout, data evaluation**
  - **2 site technicians for equipment installation, checkout and removal**
  - **4 temporary technicians for 1-person-24 hr. bake monitoring**