Brookhaven National Laboratory

U.S. DEPARTMENT of ENERGY

DUNE CRU Cold Test Nitrogen Delivery System

Brandon Bozeat, Russell Feder, Pratik Patel, Roberto Than

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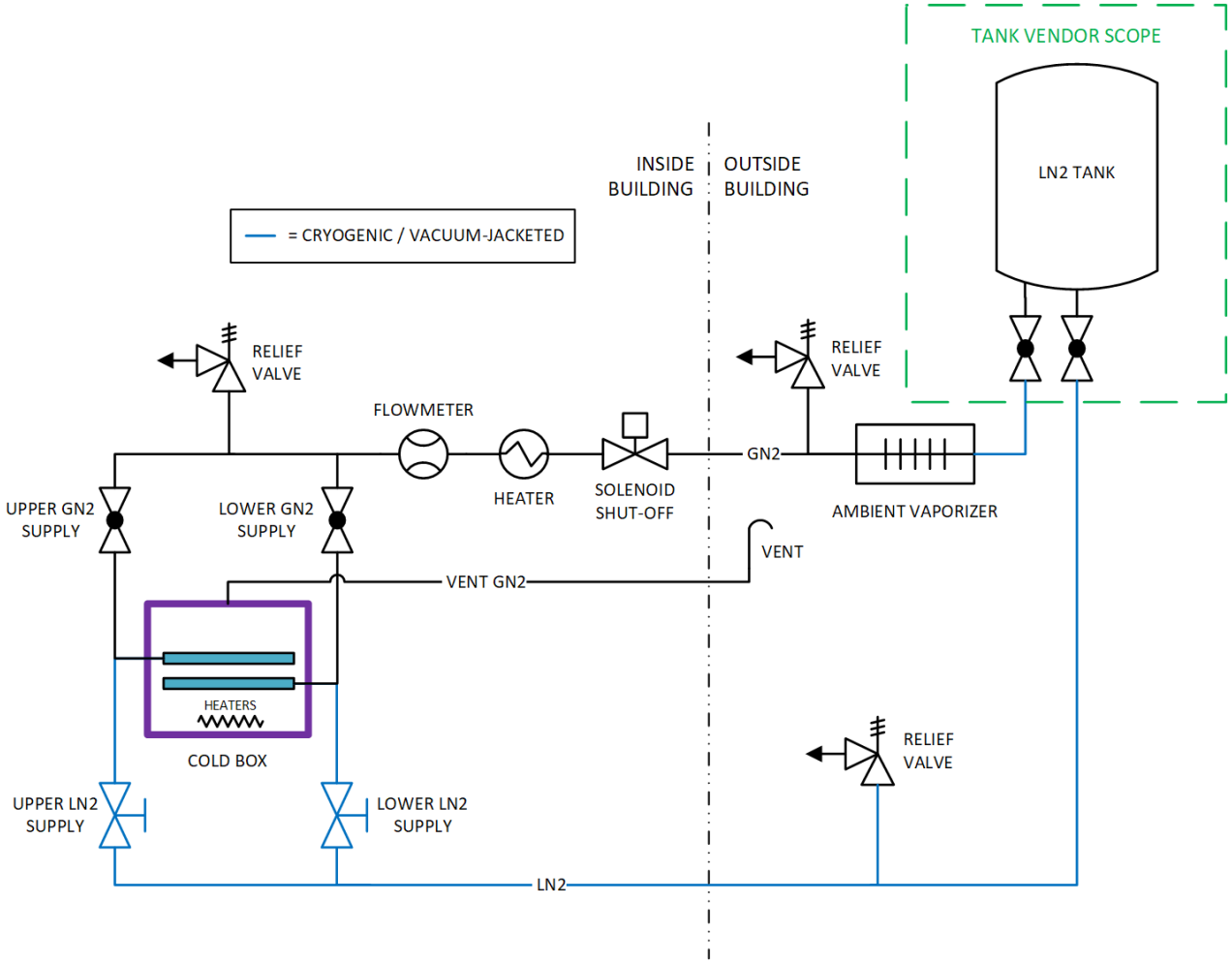
Outline

1. N2 Delivery System Overview
2. LN2 Usage Estimates
3. Budgetary Estimates
4. Pending Topics

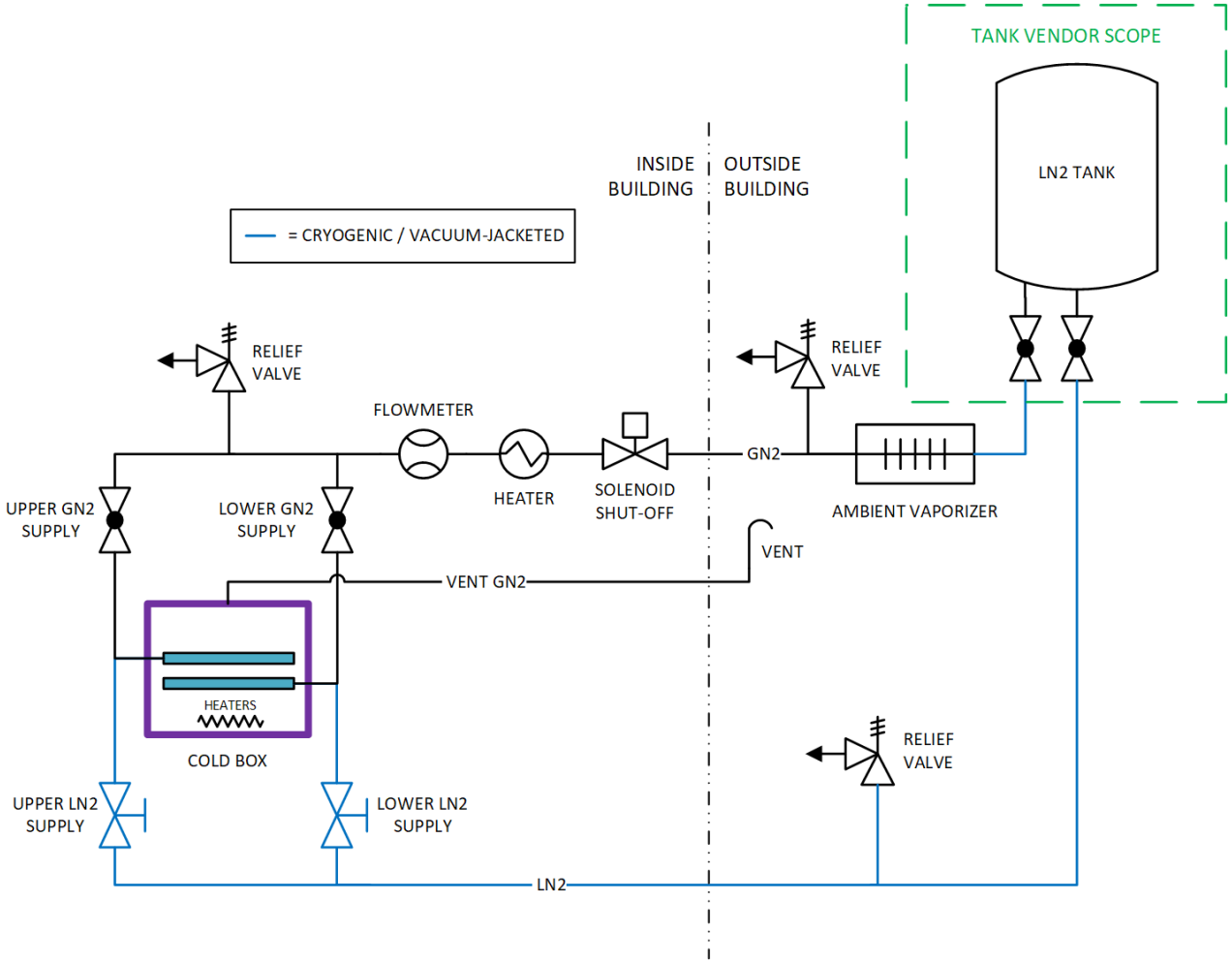
System Overview

- Nitrogen Delivery System provides liquid and gas nitrogen to the CRU cold box
  - Liquid is supplied through vacuum-jacketed piping and valves
  - Gas nitrogen is provided using an ambient vaporizer and heater to bring the gas temperature above the dew point
- A vent path is always open to prevent pressurizing the cold box
- Pressure relief valves are implemented where trapped volumes may occur



System Overview *continued*

- LN2 tank to provide ~7,000 Liters per week (estimates in later slides)
- Supply valves provide operator control over liquid and gas supplies to the cold box
- Solenoid valve can be used for automatic shutoff if warm-up left unattended
- Flowmeter allows operator to set correct warm-up rate
- Flanged, threaded, bayonet connections will be utilized for ease of assembly



LN2 Estimates

LN2 consumption is estimated for each step of the CRU test process:

1. **Purge**: A small flow of GN2 overnight removes water vapor from cold box.
2. **Cool Down**: LN2 is supplied to cool the stainless steel tank, while the vapor generated pre-cools the CRU mass. Then, the liquid supply completes cool down of CRU mass.
3. **Fill-up**: Continue supplying LN2 to submerge both units.
4. **Cold Test**: Level is maintained for 4 hours with minimal losses due to heat loads.
5. **Boil-off**: After testing, heaters are powered up to remove liquid from the cold box.
6. **Warm-up**: Once liquid is fully vaporized, heaters are turned off and warm GN2 is used to warm the cold box and test mass to room temperature.

LN2 Estimates *continued*

Test Phase	Time [hours]	LN2 Use [liters]	Notes & Assumptions
Purge	12.0	161	3 g/s (~5 SCFM) for 12 hours
Cool Down	1.0	632	1-hour *minimum* cooling time. CRU test assembly reaches ~140K once tank is cold and takes on liquid
Fill-up	2.9	5008	Assume ~0.5 L/s (7.5 gpm); fill to 59% depth
Cold Test	4.0	151	Assume ~1.3 kW heat load (static + electronics)
Boil-off	14.9	0	15kW heater power applied
Warm-up	5.6	1239	Flow 50 g/s (~90 SCFM) 295K gas
Total	**40.4**	**7192**	(1900 gallons)

Notes:
Does not include time for setup, warm testing, removal, etc.
Does not include losses for cooling down transfer lines.

Cost Estimates

Item	Unit Cost ($)	UOM	Qty	Total Cost ($)	Note
LN2 Bulk Storage Tank (monthly rental)	1,985.00	month	60	119,100.00	5-year contract
LN2 Deliveries	0.21	liter	360000	75,600.00	Estimated 30kL/mo, 12mo
LN2 sub-total				*194,700.00*	
Ambient Vaporizer	3,600.00	each	1	3,600.00	Price from recent BNL project (8500 SCFH)
Relief Valves	150.00	each	3	450.00	REGO 19434 PRV or similar
Solenoid Valve	200.00	each	1	200.00	McMaster 3/4" solenoid
Inline Heater	1,000.00	each	1	1,000.00	based on McMaster 1/2" NPT 2.5kW
Flowmeter	1,000.00	each	1	1,000.00	IFM inline thermal flowmeter
Warm valves	150.00	each	2	300.00	~Average for globe valves 1/2"-1" NPT, McMaster-Carr
Vacuum-jacketed valves	3,700.00	each	2	7,400.00	Quote from PHPK 3/4" x 2" VJ globe valve
Vacuum-jacketed piping	400.00	ft	75	30,000.00	Budgetary estimate from Technifab
Small warm piping (<=1") for purge line	20.00	ft	75	1,500.00	3/4" 304 SST sch 40
Large warm pipig (~2-3") for vent line	60.00	ft	50	3,000.00	2-1/2" 304 SST sch 40
Small pipe fittings	20.00	each	10	200.00	elbows, tees, etc.
Large pipe fittings	100.00	each	3	300.00	elbows
Heater (per 5kW) with integrated RTD	9,300.00	each	3	28,000.00	Budgetary quote from Kelvin. Note: Chromalox alternate
Heater controller, circuit breaker, etc.	15,000.00	group	1	15,000.00	Estimate from BNL project experience
Misc. pipe supports & fittings	300.00	group	6	1,800.00	pipe clamps, strut, etc.
Parts sub-total				*93,650.00*	
Total				**288,350.00**	

Notes: ROM cost of materials and nitrogen only, no labor. For dual CRU cold box. Cost is per test site. Excludes cost of cold box itself.

Pending Topics

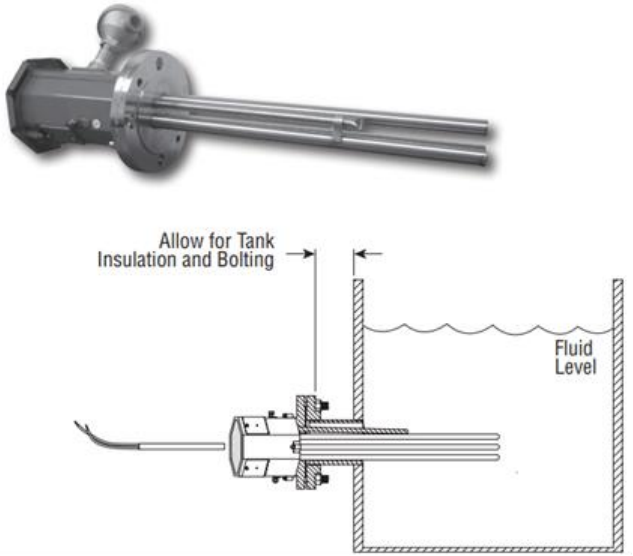
- ODH analysis and monitoring system requirements, design, cost
- Facility-specific layouts of piping systems
- Interface plan between delivery system and cold box proper
- Level, temperature, and other instrumentation plans

Backup

Heaters

Kelvin style

- Elements lay at bottom of tank
- Cables connect to junction box
- 480 VAC
- 0.50 Watts/cm^2



Chromalox style

- Flanged connection
- 208V 3 Phase 3 Wire (Delta)
- 25.0 W/in^2

Alternative Concepts

Alternative setups were considered, including:

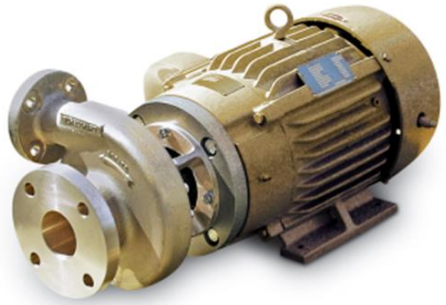
- Two single cold boxes with a pump
  - Single shared pump recycles LN2 between cold boxes
- Two single cold boxes with heaters

Setup	LN2/month (kL)	Total Cost ($)	Notes
Dual cold box, with heaters	28.8	288,350.00	Baseline (see prev. slide)
Two single cold boxes, with heaters	24.4	290,730.00	10kW heaters per box; slightly more piping; slightly less LN2 consumed
Two single cold boxes, with pump	15.7	290,470.00	Lower LN2 consumption; increased cost for pump, motor, instrumentation; added VJ piping/valving

Notes: Cost per test site. Excludes cost to build cold box(es).

Other considerations: pacing of testing and assembly, space constraints, …

LN2 Pumps



Pumps may reduce LN2 consumption by recycling

Cost to implement is ≥ heaters

- Nikkiso-ACD ~$20k - $45k excluding controls
- Barber Nichols ~$50k excluding controls

Technical barriers: cold box setup requires low flow and has very low NPSH available

- Available pumps require higher inlet pressures than available at bottom of cold box
- Most pumps minimum speed is too fast for the controlled cool down required