

Cryogenic Air Supply Storage Time After a Loss of Electrical Power

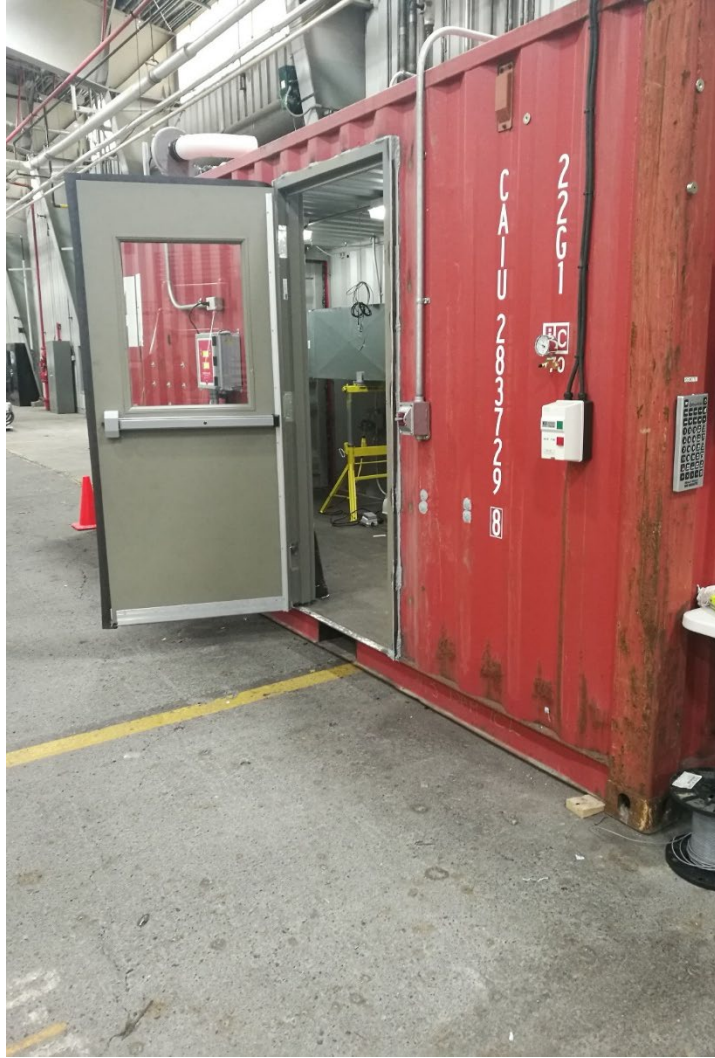


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RA Partnership**

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Objective



- To investigate the maximum storage time and venting pattern for cryogenic storage systems when their cryocoolers were turned off
- Two different cryogenic systems were evaluated at: a 425-liter vertical dewar system and a 2,000-liter horizontal dewar system

Test Method

- Similar test procedures were followed for both CryoRASS units.
- Before the tests, both dewars were filled with the necessary amounts of liquid nitrogen and liquid oxygen to create liquid air.
- Next, the cryocooler for each CryoRASS unit was operated to cool and maintain the air in a liquid state.
- Then, power to each cryocooler was shut off, and the loss of liquid air from each CryoRASS, due to periodic venting was documented

The Cryogenic Refuge Alternative Supply Systems (CryoRASS)— prototypes developed under contract



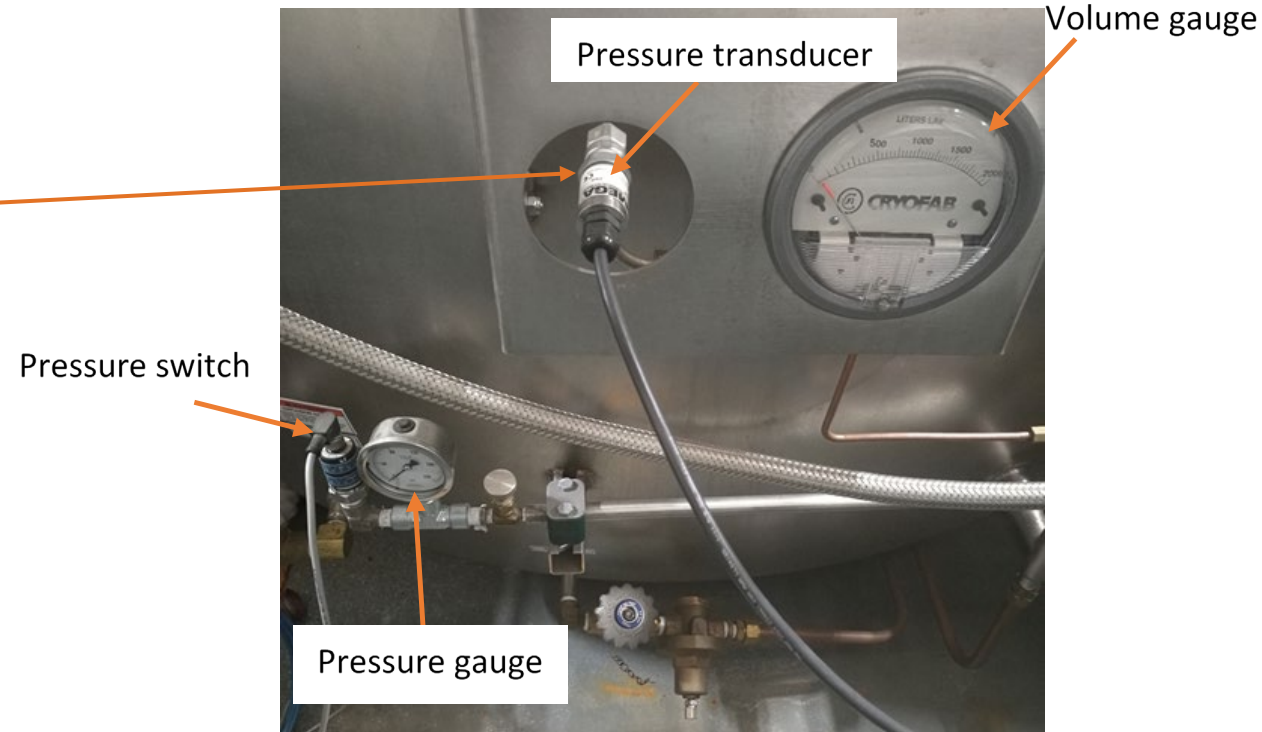
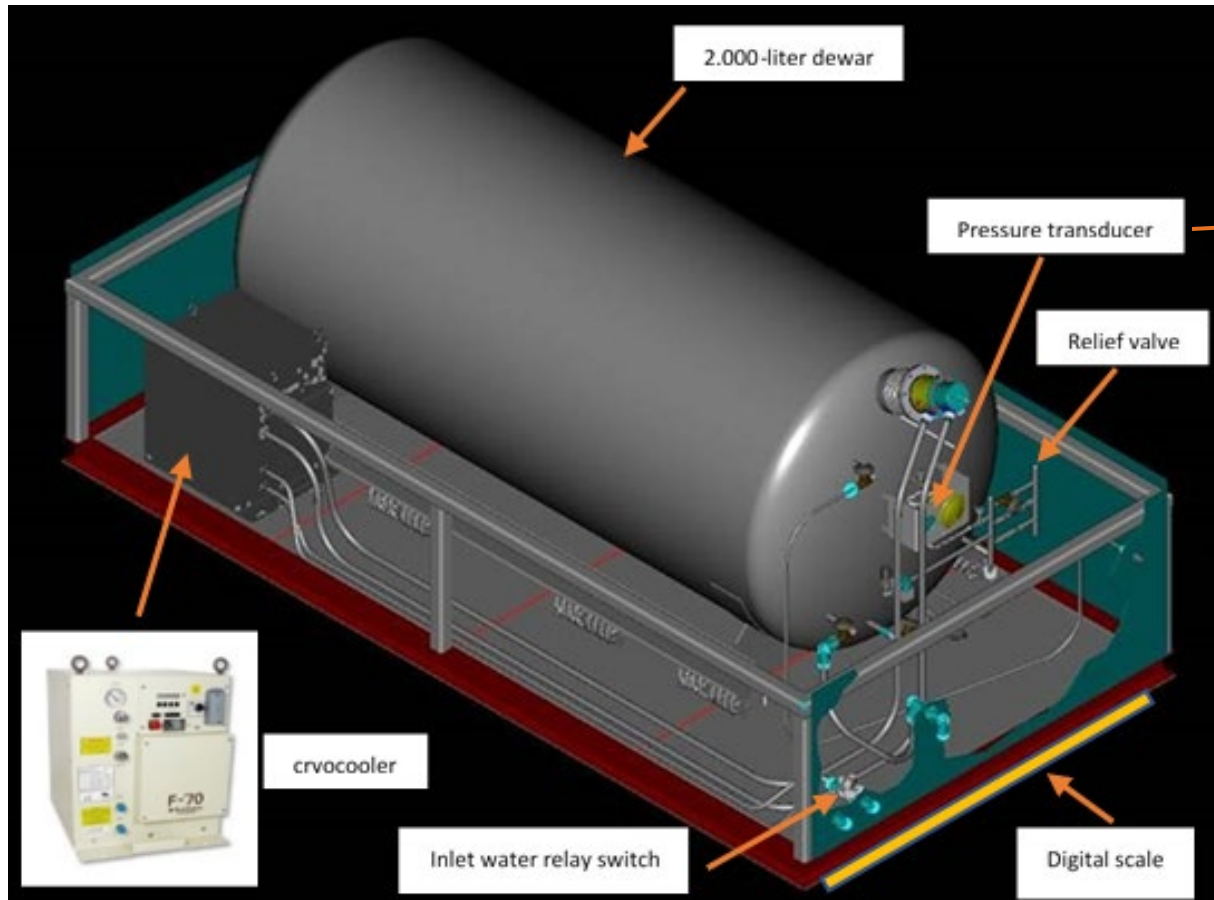
Vertically oriented, 425-liter



Horizontally oriented, 2000-liter

Sensors upgrades were installed on the 2000-liter dewar

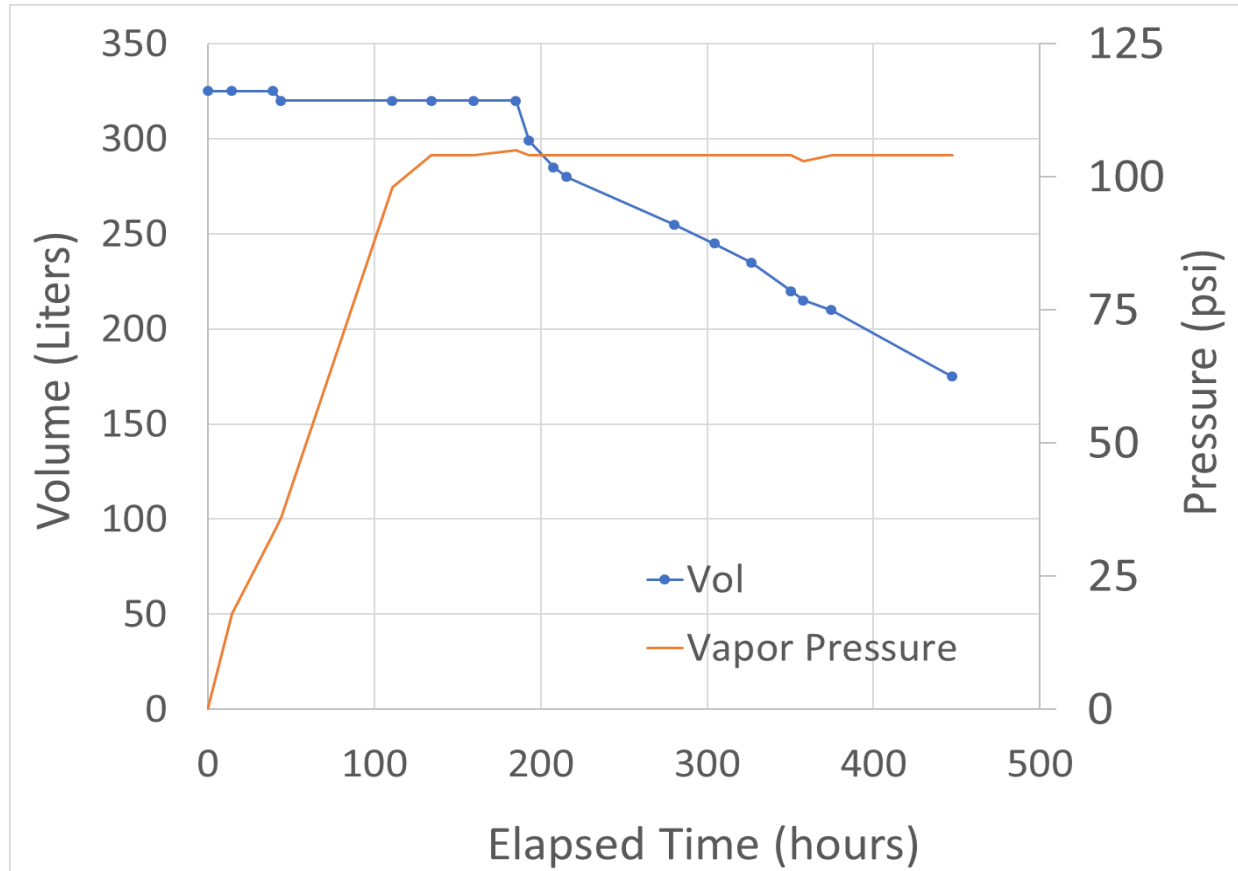
- Digital scale—continually monitor and record gross weight
- Pressure transducer—continually monitor and record interior pressure



The 425-liter dewar test result—O₂ level went up slowly with venting

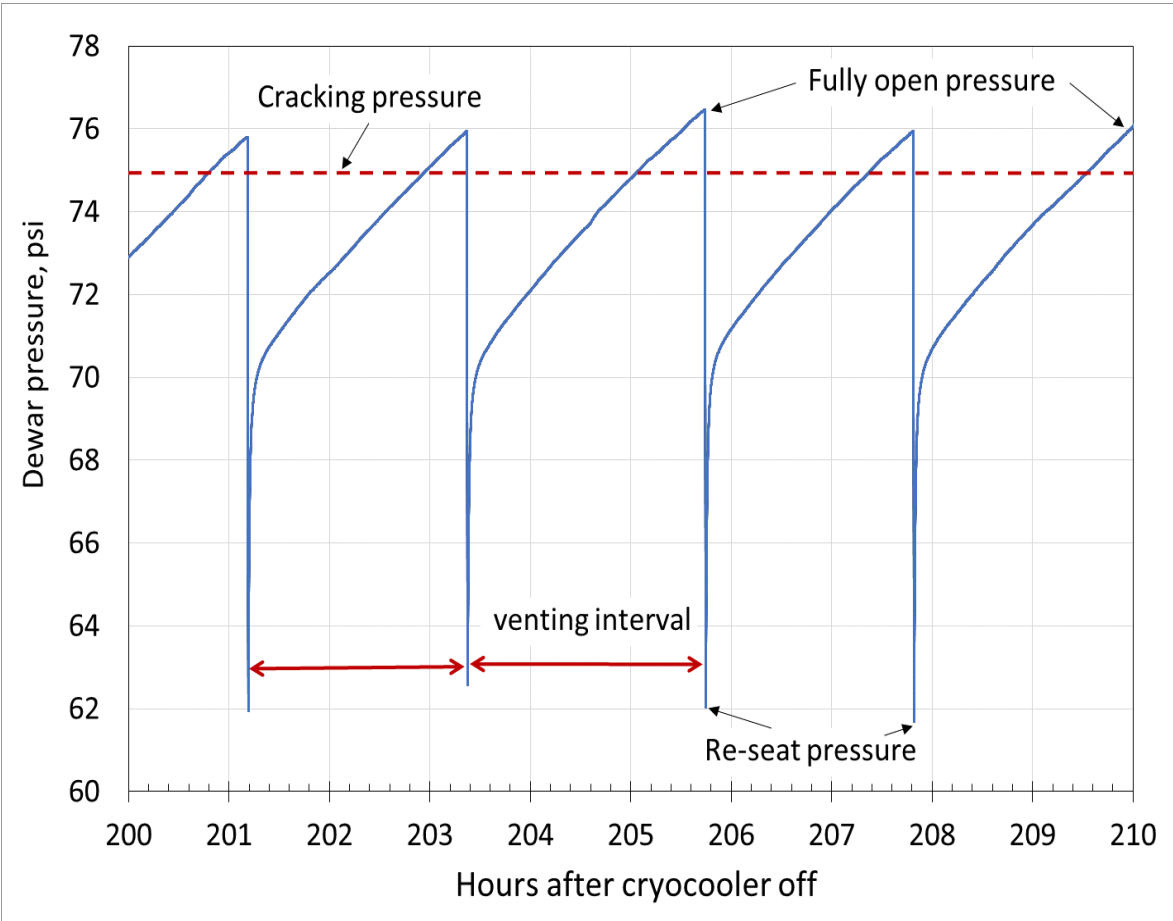
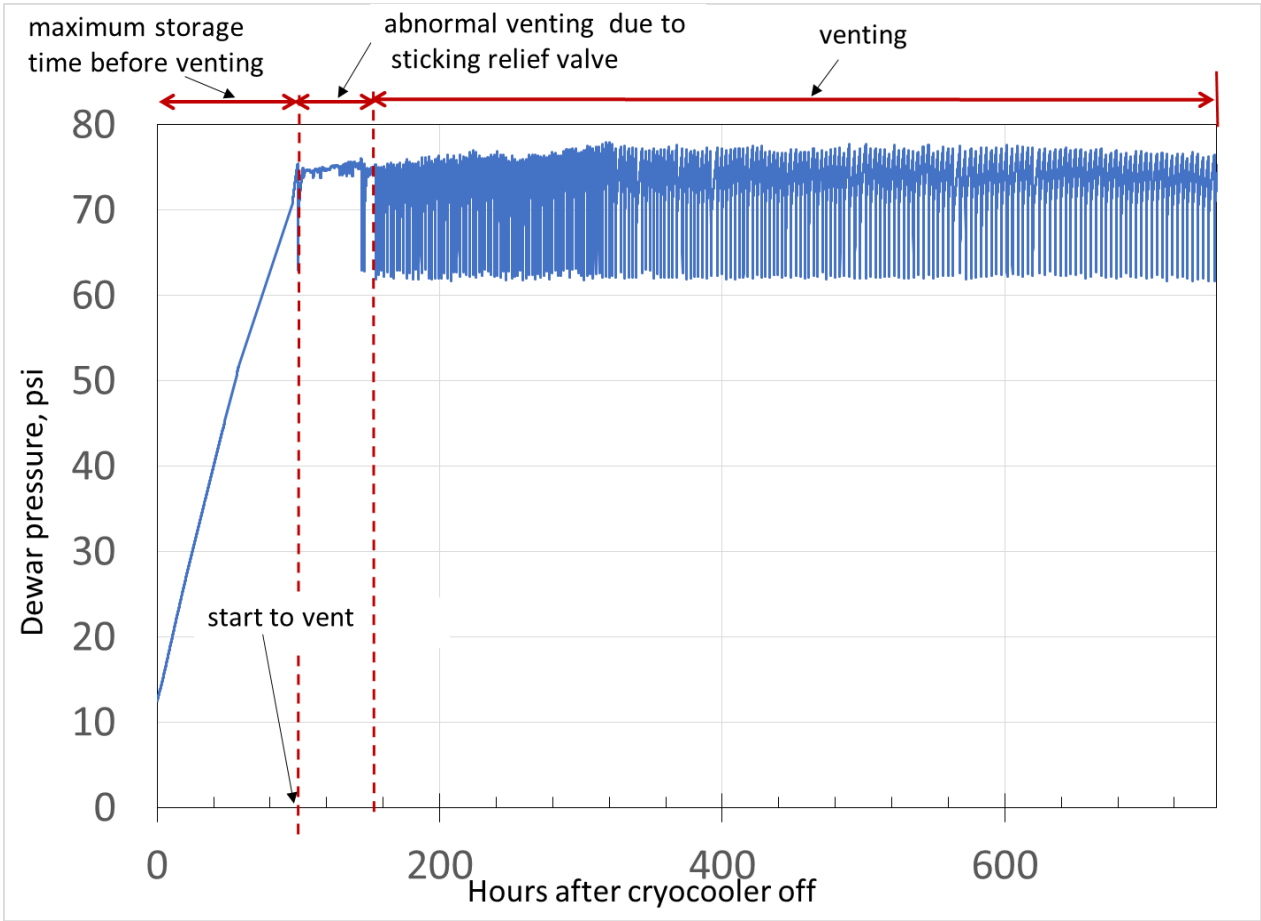
Day/ Time	Elapsed Time (hrs)	Vapor Pressure (psi)	Liquid Volume (Liters)	Venting Occurred (Y/N)	Air Sample (O ₂ %)
Day 1 - 5:10 PM	0.0	0	325	N	21.3%
Day 2 - 7:30 AM	14.3	18	325	N	
Day 3 - 8:15 AM	39.1	33	325	N	
Day 3 - 1:00 PM	43.8	36	320	N	
Day 6 - 8:00 AM	110.8	98	320	N	
Day 7 - 7:30 AM	134.3	104	320	Y	
Day 8 - 8:40 AM	159.5	104	320	Y	
Day 9 - 10:13 AM	185.1	105	320	Y	
Day 9 - 6:00 PM	192.8	104	299	Y	
Day 10 - 8:56 AM	207.8	104	285	Y	
Day 10 - 4:53 PM	215.7	104	280	Y	
Day 13 - 9:20 AM	280.2	104	255	Y	
Day 14 - 9:30 AM	304.3	104	245	Y	
Day 15 - 7:30 AM	326.3	104	235	Y	
Day 16 - 7:30 AM	350.3	104	220	Y	
Day 16 - 3:00 PM	357.8	103	215	Y	25.5%
Day 17 - 7:50 AM	374.7	104	210	Y	
Day 20 - 8:30 AM	447.3	104	175	Y	

The 425-liter dewar test results—started to vent in 5-6 days

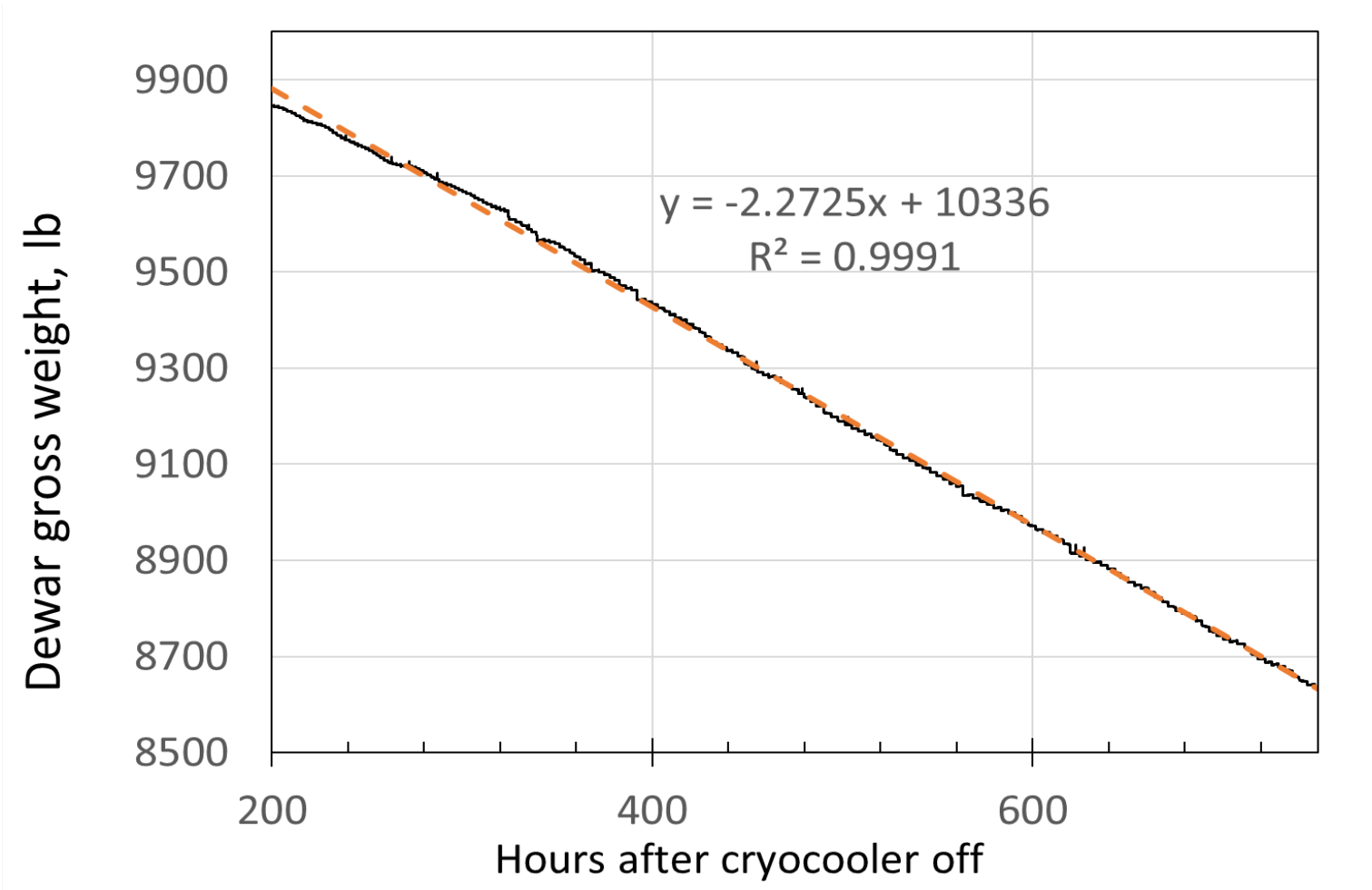


- Started with ~325 liters of liquid air inside
- After 5 to 6 days without its cryocooler operating, the unit reached its relief pressure of 717.1 kPa (104 psi)
- Lost liquid air at a rate of ~11 liters per day over a 13-day period

The 2000-liter dewar test results—started to vent in ~100 hours



The 2000-liter dewar test results—lost cryo air at rate of 2.27 lb/hr



The 2000-liter dewar test results

- Started with 1,440 kg (3,175 lbs, or 1,655 liters) of liquid air.
- The dewar started to vent approximately 100 hours after the cryocooler was turned off.
- Sticky relief valve between $t = 100 - 160$ hours.
- Venting interval: ~ 2.2 hours.
- After reaching the cracking pressure of 75–76 psi, vapor was released until the relief valve closed at a pressure of 62 psi.
- Vapor was vented for $\sim 30 - 60$ seconds before the relief valve closed.
- Lost liquid air at a rate of 2.27 lbs/hour.
- The average weight loss is ~ 5.0 lbs ($2.27 \text{ lbs/hour} \times 2.2 \text{ hours}$) or 2.6 liters for every venting cycle and 54.5 lbs/day (28.4 liters/day).
- Over 550 hours (about 23 days), the dewar lost 1,209 lbs or a volume of 630 liters of liquid air.

Conclusion

- For both CryoRASS units, regardless of the amount of liquid remaining in the dewar, the rate of air loss due to venting was almost constant.
 - The 425-liter unit lost ~2.6% of the dewar capacity daily.
 - The 2,000-liter unit lost ~1.4% of the dewar capacity daily.
- Because the vented gas contains more nitrogen than oxygen, the oxygen concentration of the liquid air left in the dewar increased with time after venting.
 - The liquid air remaining in the dewar became slightly oxygen rich.
 - The oxygen enrichment was not significant in these cases and is not detrimental to health.
- Venting from either of these systems during moves and power outages would not affect their ability to deliver breathable air during a disaster.
 - For the 425-liter dewar, a power outage of up to 6 days would not cause any loss of liquid
 - For the 2,000-liter dewar a power outage of less than 4 days would not cause a loss of liquid.

Thank you!

Yan, L., R. D. Fernando, D. S. Yantek, J. L. Carr, M. A. Reyes, C. R. DeGennaro, J. A. Yonkey, and J. R. Srednicki. "Storage Time and Venting Characteristics for Cryogenic Air Supplies on Cryocooler Shutdown", International Cryocooler Conference, 2021.

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