Designing the Next Generation Liquid Nitrogen Biological Repository

Innovation. Experience. Performance.®

Traditional Temperature Modalities

- Ambient
  - Temperature / Humidity Control
- +4˚C, -20˚C
  - Mechanical refrigeration
    - Walk-in
    - Reach-in refrigerator
  - Very reliable, least complex mechanical refrigeration system
- -80˚C
  - Mechanical refrigeration
    - Walk-in
    - Chest or upright freezer
  - Increasingly complex, decreasing reliability
- < -135˚C
  - Mechanical refrigeration, highly complex and prone to mechanical failure
  - Liquid Nitrogen Refrigeration, least complex, most reliable refrigeration system

Common Components of Biorepository

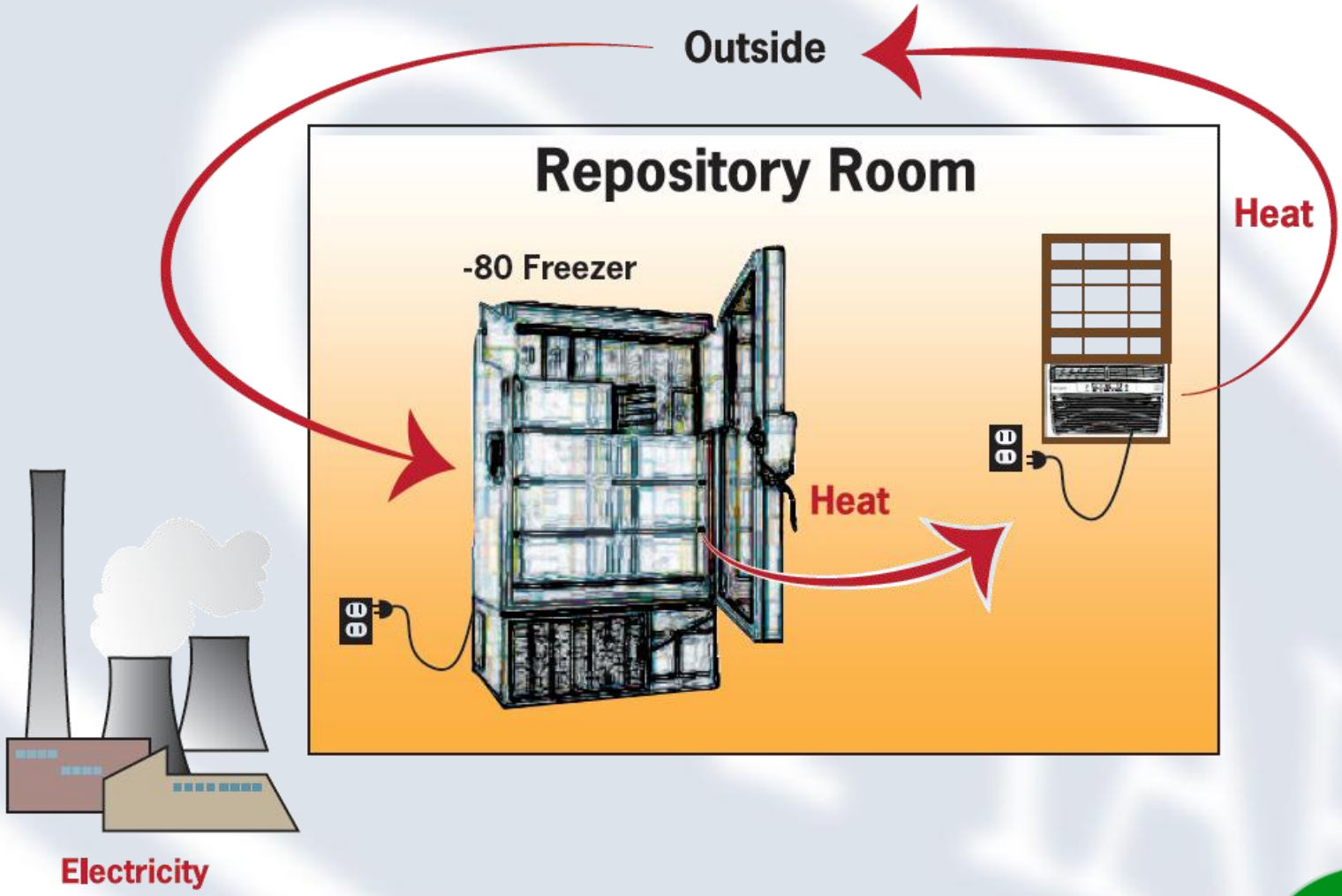
- Secure facility
- Emergency Backup power
- Enhanced HVAC capacity
- Centralized alarm system
- Bulk LN2 and piping system
- O2 monitoring
- Freezers…

Infrastructure to Support a Modern Biorepository
ULT Storage

- ULT Storage
  - Complex electrical distribution system
    - Emergency power generation
    - Line conditioning
    - High voltage / high amperage capacity to building
  - Highly enhanced HVAC system
    - Multiple HVAC systems added based on number of mechanical freezers
    - Complicated duct work to evenly distribute cooling capacity
  - Significant backup specimen storage
    - Capacity requirement increases with average freezer age
  - Highly qualified refrigeration service technician, in-house or contracted

Infrastructure to Support a Modern Biorepository

ULT Storage



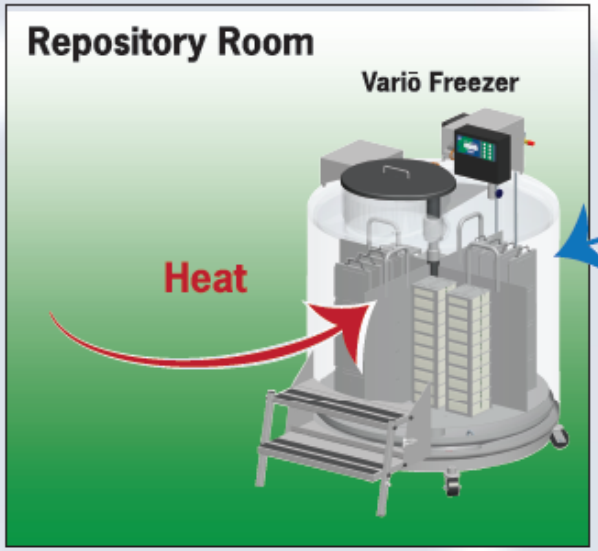
Infrastructure to Support a Modern Biorepository

Cryogenic Storage

- Liquid nitrogen source, Dewars or bulk distribution
- Oxygen depletion alarms
- Standard electrical installation with optional backup power
  - Household power requirements
  - Units available with battery backup to limit backup power requirement
- Standard HVAC system with enhanced ventilation capacity
  - Most commercial HVAC systems adequate for installation

Infrastructure to Support a Modern Biorepository

Cryogenic Storage



LN2

LN2

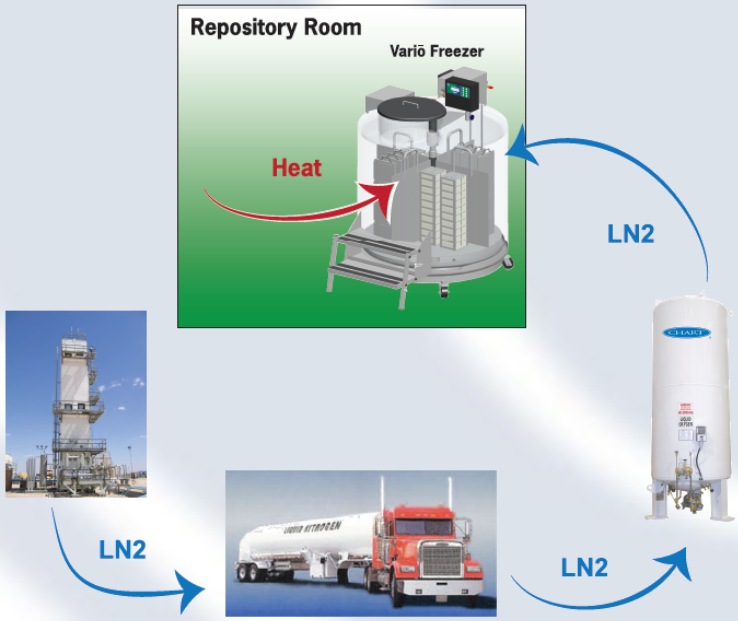
LN2

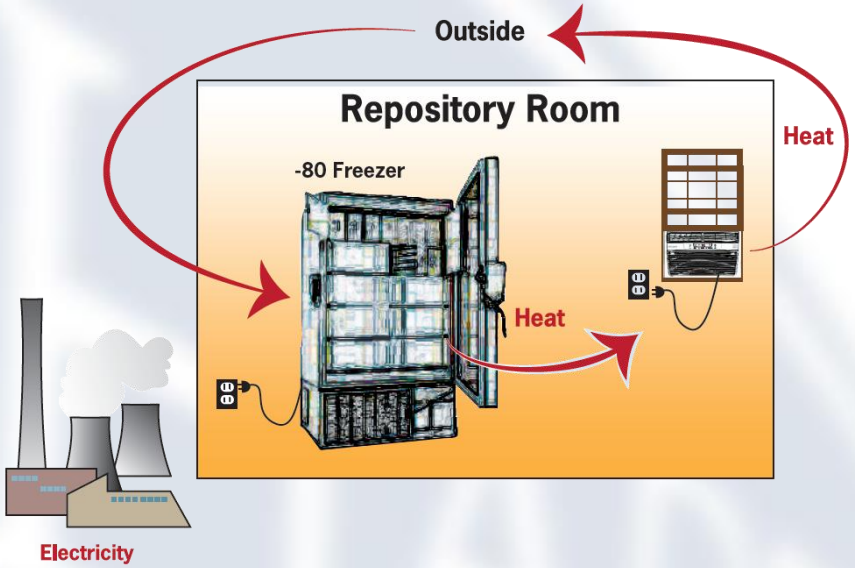
Innovation. Experience. Performance.®

ULT vs Cryogenic

Complexity Scale

Increasing Complexity





Innovation. Experience. Performance.®

What Keeps You Up at Night?

- Power loss
- False alarms
- Everyday something breaks…
  - Compressor failure
  - Electronic failure
  - HVAC failure
  - You name it: _____

90% of your headaches arise from mechanical refrigeration

Reasons LN2 storage helps you sleep easy

- Simplicity of LN2 has made storage of material at cryogenic temperatures a highly reliable segment of a biorepository facility
  - Long freezer hold time increases your safety margin and response time window
  - Bulk storage of LN2 guarantees on-site refrigeration
    - LN2 supply highly reliable
  - Minimal moving parts assures a highly reliable and robust system
    - No compressors: freezers or HVAC system

Chart MVE and Cryo Associates Introduce the Reliability of LN2 at ULT

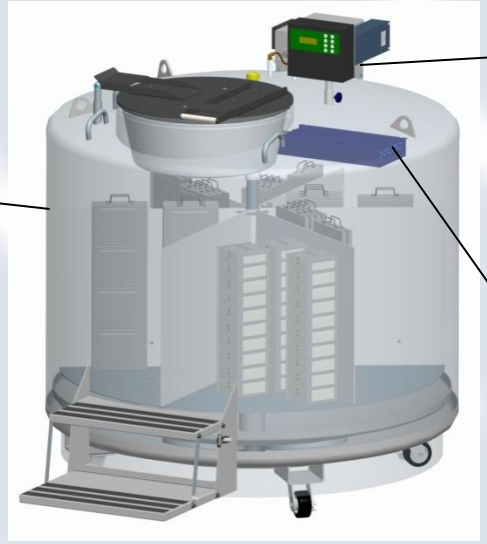
- For years we tried to convince you that colder is better
- With great pain, we have accepted that the -80˚C freezer is here to stay.
- With great excitement, we are introducing the Vario Freezer.

Variō Series

Innovation. Experience. Performance.®

MVE Variō Design

- Innovative and energy efficient alternative for ultra-low temperature to cryogenic storage
- User-defined temperature anywhere between -50˚C and -150˚C
- Dry sample space
  - Significantly reduces risk of sample contamination via contact with LN2
- Consistent temperature profile
  - Even with the lid open
- Extended hold time safety margin
- Less than 1% of power consumption compared to leading upright mechanical freezers



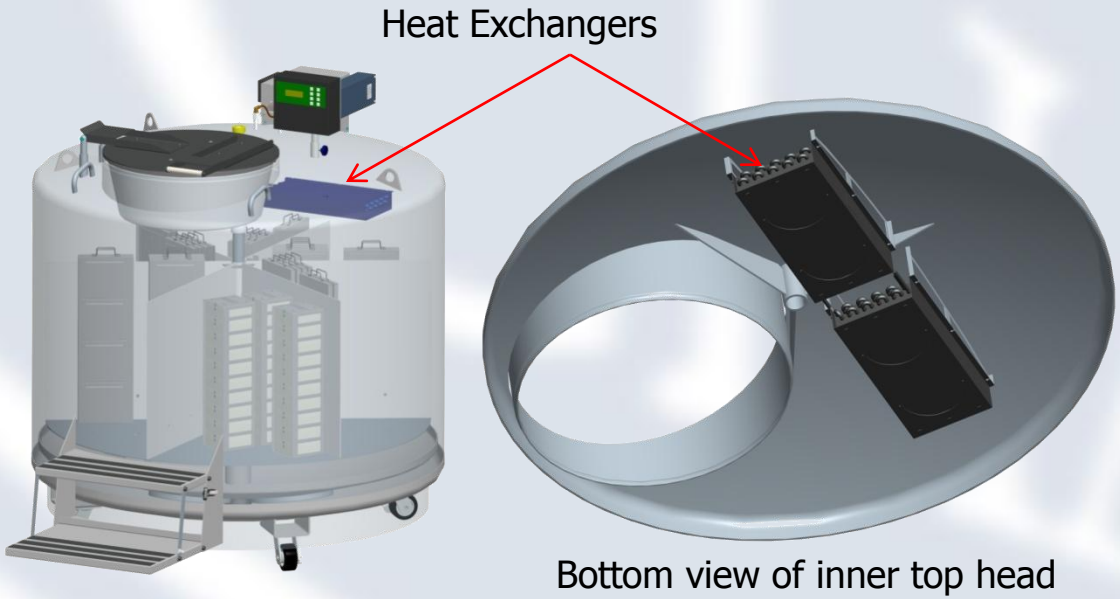
Advanced MVE Variō™ Pro controller

Low maintenance and long lasting doubled-walled, vacuum insulated, all-stainless steel construction

Interior heat exchange system: LN_2 flows through heat exchangers and the vaporization energy provides low-cost refrigeration

Innovative, patent-pending refrigeration system

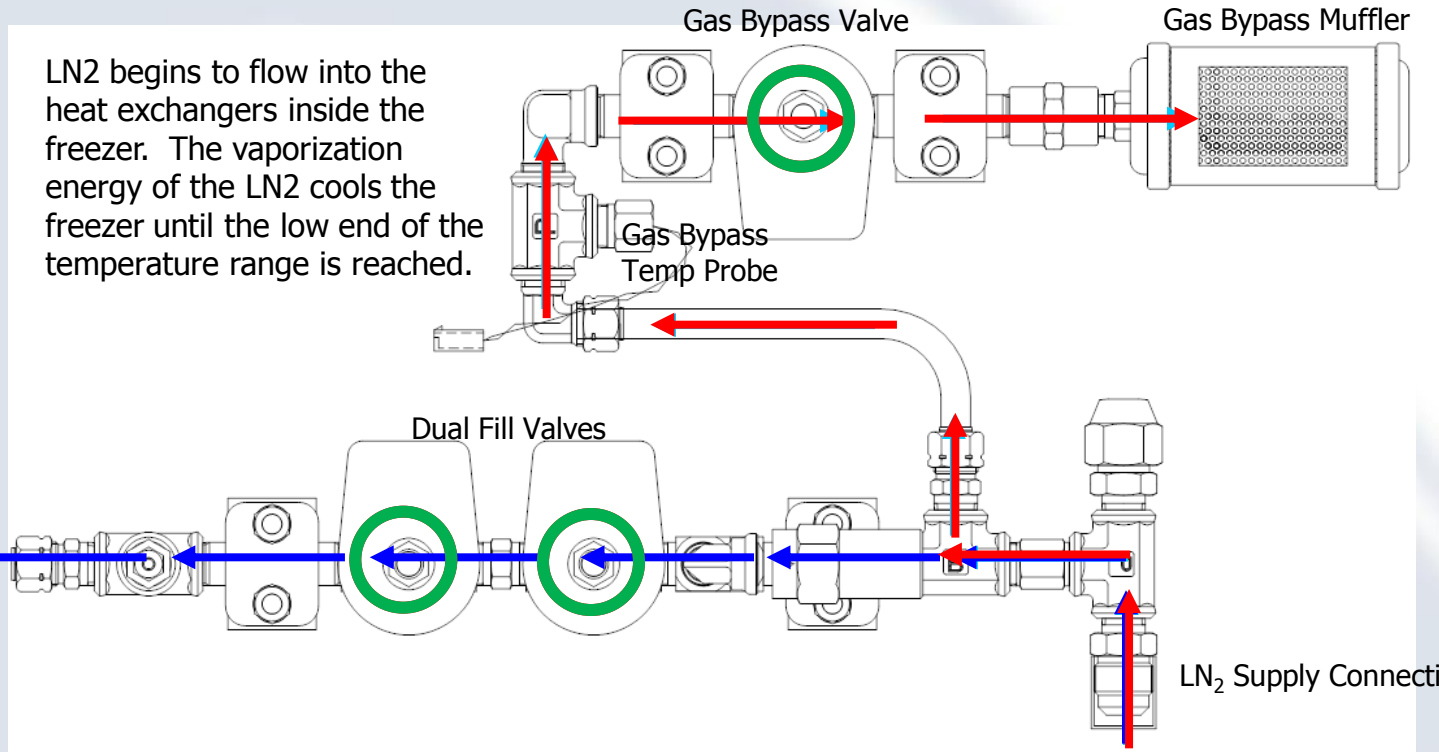
- LN_2 flows through a heat exchange system inside the freezer
- Vaporization energy of LN_2 cools the freezer
- Fully utilizes the heat capacity of LN_2 while purging moisture from the system
- LN_2 metered and monitored to maintain user-defined temperature

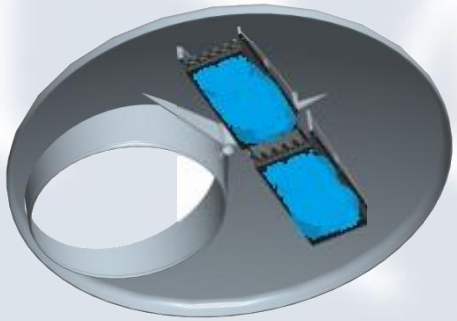


Bottom view of inner top head

Cooling Cycle

LN2 begins to flow into the heat exchangers inside the freezer. The vaporization energy of the LN2 cools the freezer until the low end of the temperature range is reached.

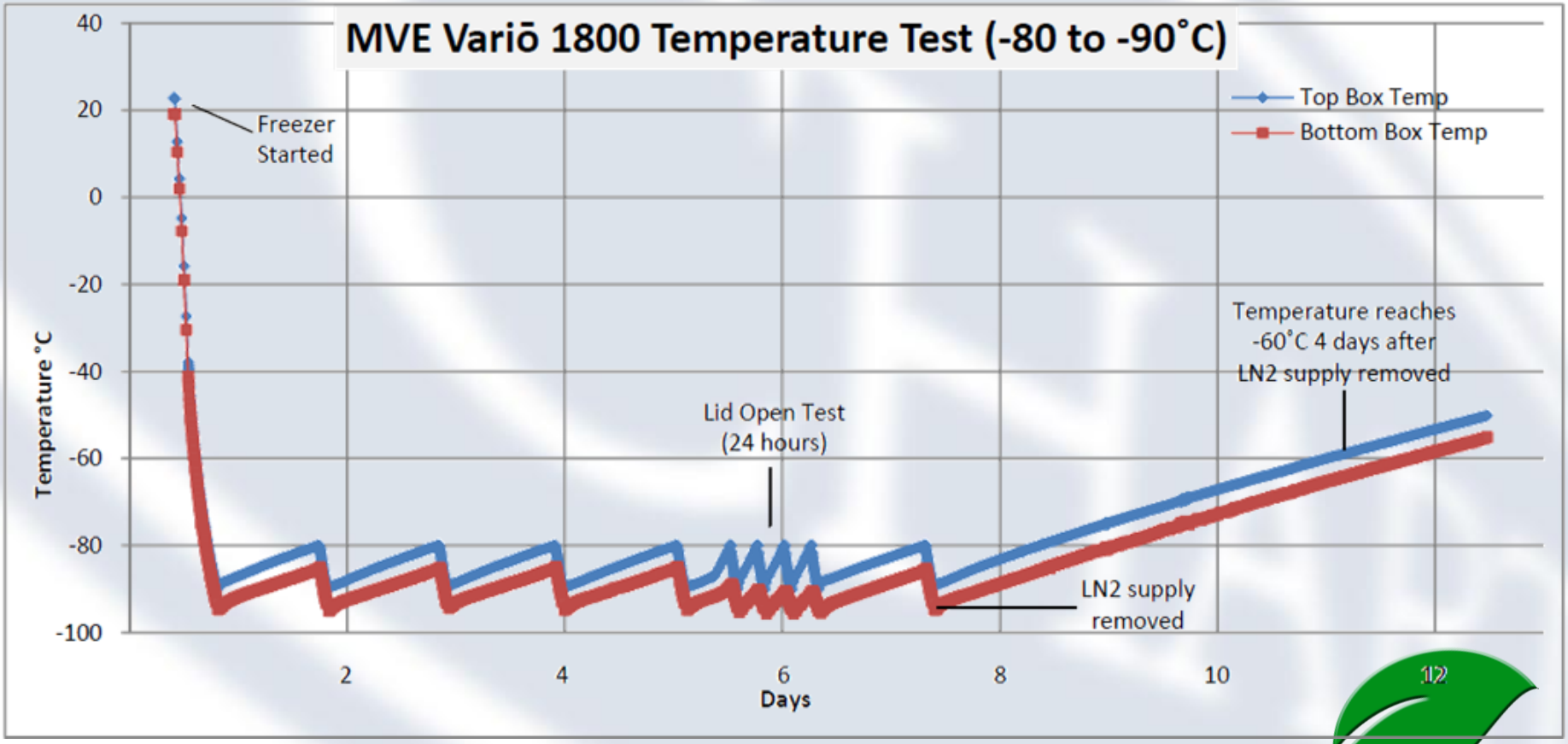




Temperature Profile -80˚C

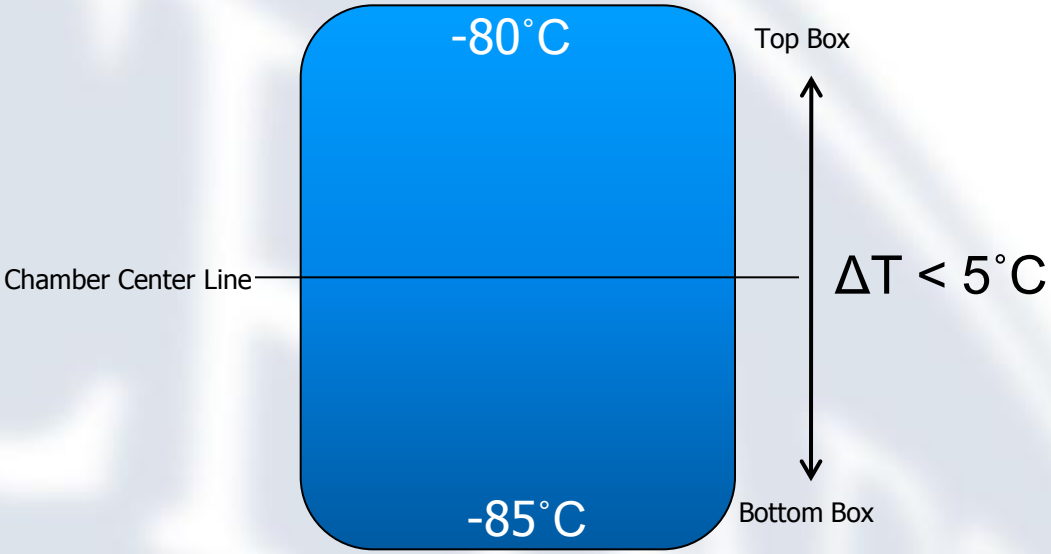
Consistent temperature profile throughout the storage space, even with the lid open.

While the lid is open, the cooling cycle interval is compressed, but the storage space temperature does not increase outside of the set range.

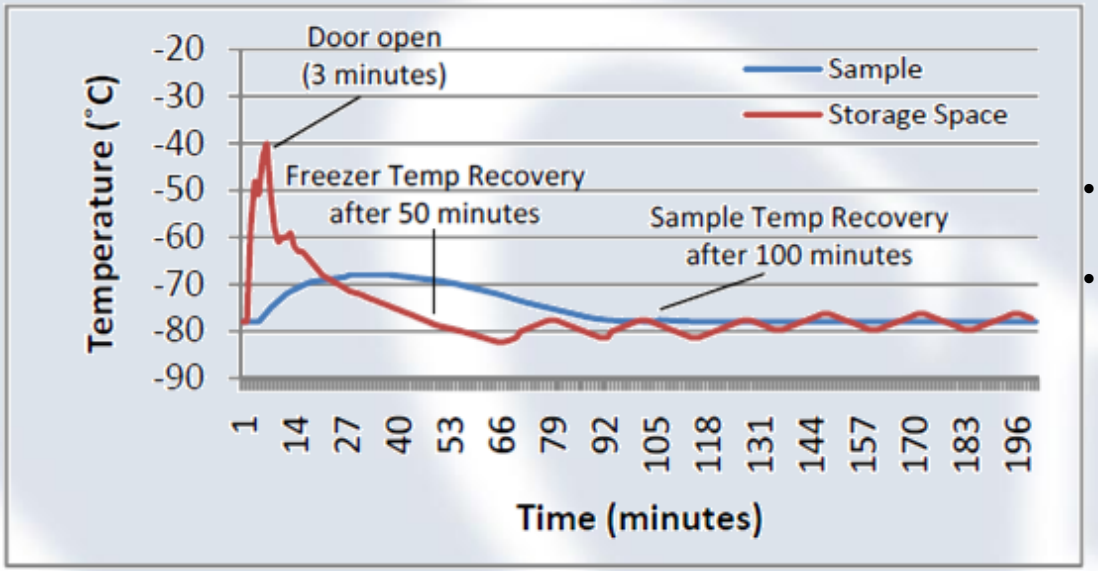


Temperature Gradient

Temperature gradient within storage space (top box to bottom box) is between 2˚C and 5˚C



Lid Open Security

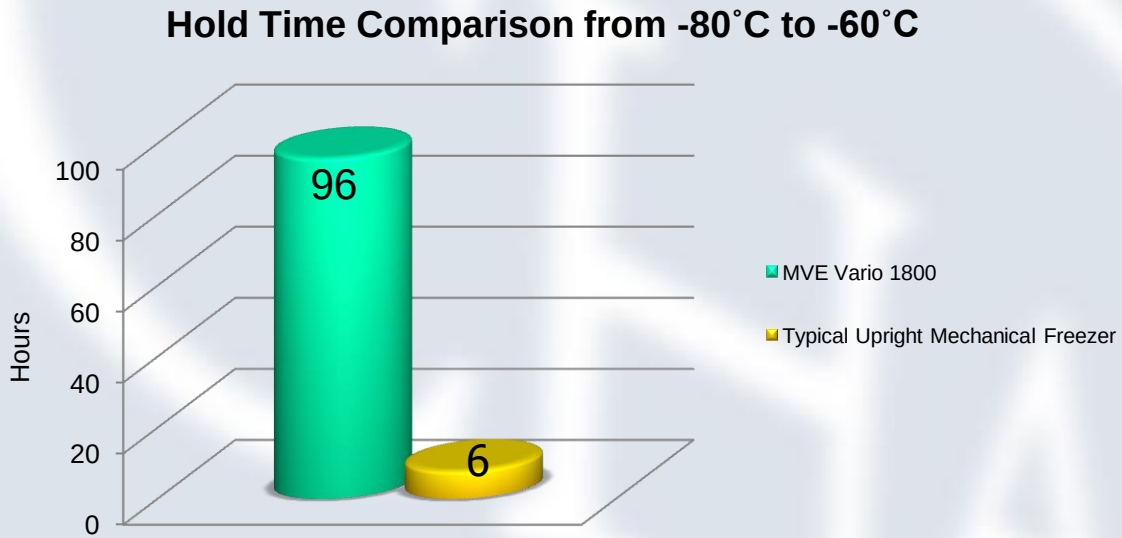


- Typical upright mechanical freezer
- Significant temp change and recovery time

Does not compare to MVE's sample security

Hold Time Safety Margin

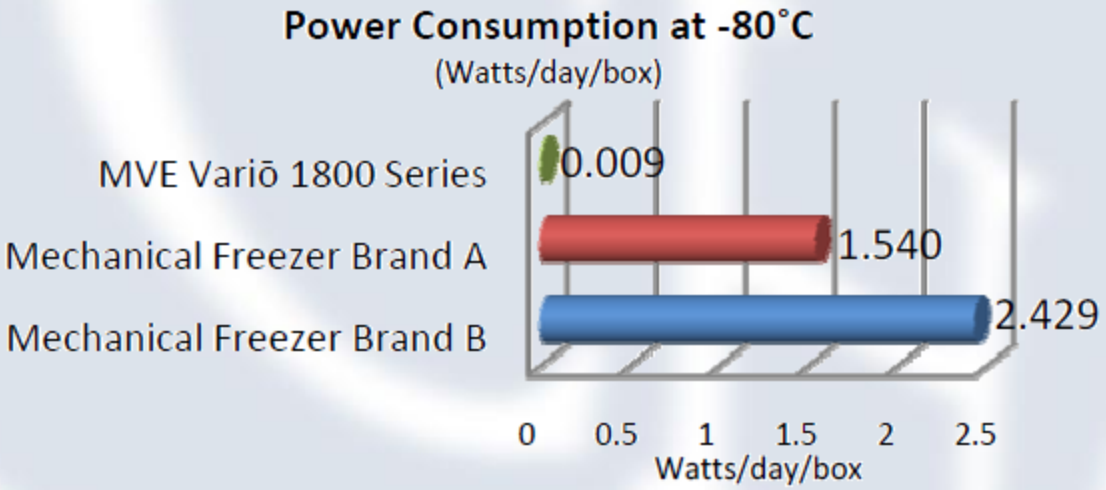
- Refrigeration system failure until critical temperature is reached
- The MVE Varīō™ 1800 Series provides by far the longest hold time in the industry.
- When the LN2 supply is depleted, it takes 4 days (96 hours) when storing at -80˚C to rise above -60˚C



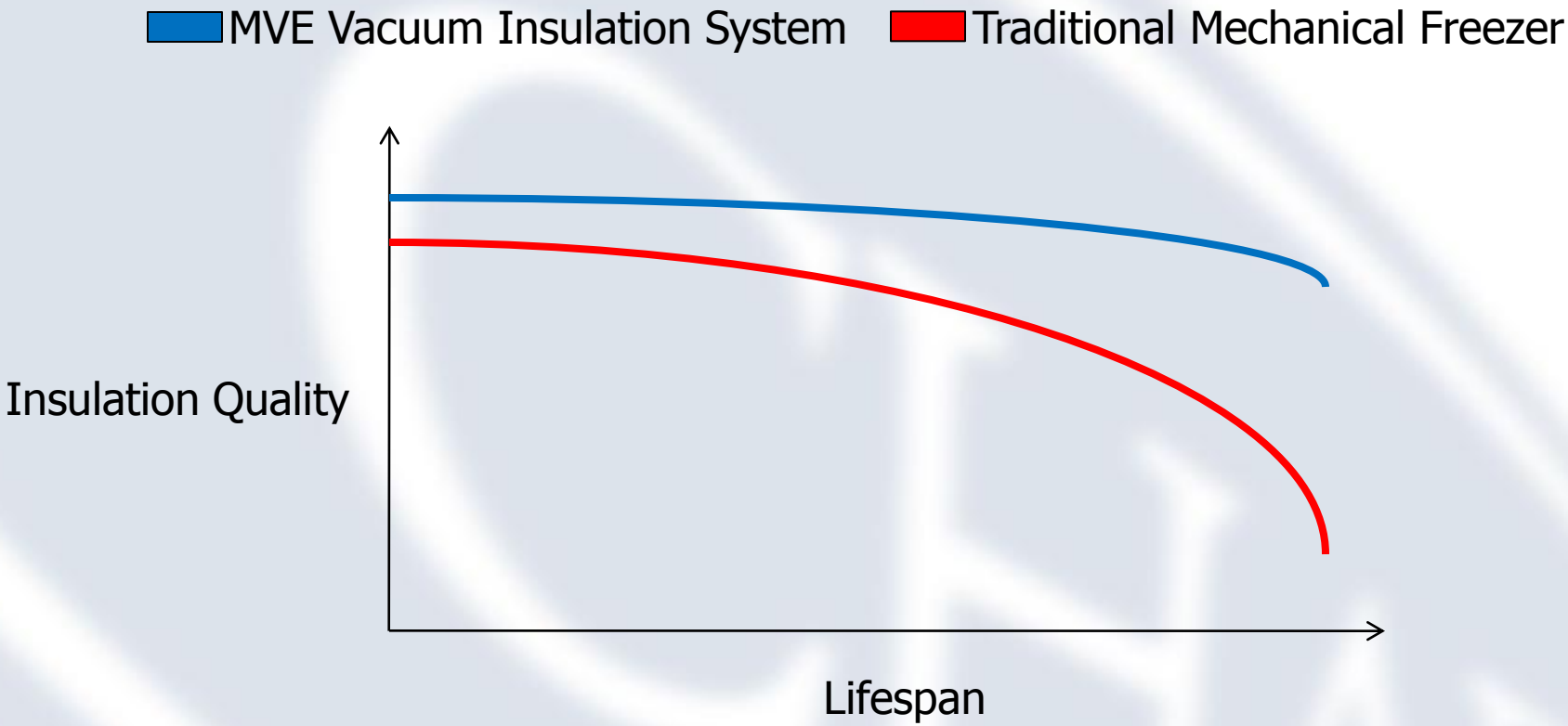
Power Consumption

Up to 81,900 2mL vials while consuming less than 1% of the power compared to the leading upright mechanical freezers, only 8 W continuous.

Does not account for the additional HVAC requirements for mechanical freezers.



Insulation Deterioration over time



Summary

- Highest sample security
  - Lid open temperature security
  - Hold Time Safety Margin
  - Reduced risk of LN2 contamination
- ROI Potential
  - Less than 1% of the power consumption compared to mechanical freezers
  - Significantly reduced operating costs
  - Highest sample storage density
- Energy efficient and environmentally friendly alternative
  - Minimal power consumption – similar to that of an alarm clock
  - No additional HVAC requirements
  - Zero CO2 emissions
  - No ozone depleting refrigerants; CFC or HFC
  - No disposal issues – over 90% recyclable

Case Study: 4M Sample Repository

- Chart and Cryo Associates surveyed several repositories over the past two years to understand the Capital Investment and Operating Costs of a repository.

- From the data collected, we created cost models for two different types of repositories, both with a 4M sample capacity

  - Repository A:
    - Mechanical -80 Capacity: 75%
    - Liquid Nitrogen Capacity: 25%
  - Repository B:
    - Vario -80 Capacity: 75%
    - Liquid Nitrogen Capacity: 25%

- Vario -80 based repository shows a substantial reduction in operating costs over traditional -80 mechanical storage

Repository A: 75% Upright Mechanical

	Primary	Backup	Total Freezers	Samples/Freezer	Total Samples
LN2 Freezers	20	2	22	67,080	1,341,600
Upright -80	70	7	77	38,880	2,721,600
				Grand Total:	4,063,200

Assumptions:

- 81 cell boxes
- Standard size rack use only – no “Mini Racks”
- Total sample capacity does not include backup freezers

Repository A: Capitol Costs

Capital Costs	LN2	Upright -80	Initial Investment	Additional Cost Year 10	Additional Cost Year 20
Freezer Cost (including racks)	$38,000	$9,962	$1,603,074	$280,544	$359,117
Bulk Tank / VIP 3000 gallon	$178,000		$178,000	$0	$0
Alarm System	$2,000	$1,000	$121,000	$0	$121,000
Backup Power (250 kW)		$80,000	$80,000	$0	$80,000
HVAC			$176,000	$0	$140,000
O2 Monitoring			$6,000	$0	$6,000
			$2,164,074	**$280,544**	**$706,117**
		Total Capital Investment over 30 years			**$3,150,735**

Assumptions:

- Cost analysis based on freezer storage components
- Freezer costs include racking systems
- Upright Mechanical Replacement every 10 years
- Annual price increase for replacements 2.5%
- 116 Ton HVAC system priced at $1,500/ton installed, $1200/ton replacement costs

Repository A: Operating Costs

Operating Costs	LN2	Upright -80	1 Year	10 Years	20 Years	30 Years
Electricity (including HVAC)	1	75	$69,564	$695,640	$1,391,280	$2,086,920
LN2	60		$15,840	$158,400	$316,800	$475,200
Generator PM	0	2,800	$2,500	$25,000	$50,000	$75,000
Freezer PM	135	85	$9,515	$95,150	$190,300	$285,450
Freezer Repair	190	380	$33,440	$334,400	$668,800	$1,003,200
Freezer Labor	115	725	$58,355	$583,550	$1,167,100	$1,750,650
			$189,214	**$1,892,140**	**$3,784,280**	**$5,676,420**
					Total Operating + Capital	**$8,827,155**

Assumptions:

- Includes re-vac of freezer every 10 years
- Includes periodic de-icing/defrosting of freezers
- Includes daily performance check of all freezers
- Does not include after hour/emergency repairs

Repository A: Summary

	At Start-up	After 30 Years
Capitol Costs	$2,100,000	$3,100,000
Operating Costs	$190,000	$5,700,000
Total:	$2,190,000	$8,800,000

Repository B: 75% Vario N_2 Vapor

	Primary	Backup	Total Freezers	Samples/Freezer	Total Samples
LN2 Freezers	20	2	22	67,080	1,341,600
Vario 1881R	40	4	44	67,080	2,683,200
				Grand Total:	4,024,800

Assumptions:

- 81 cell boxes
- Standard size rack use only – no “Mini Racks”
- Total sample capacity does not include backup freezers

Repository B: Capitol Costs

Capital Costs	LN2	Vario 1881R	Intial Investment	Additional Cost Year 10	Additional Cost Year 20
Freezer Cost (including racks)	$38,000	$40,000	$2,596,000	$0	$0
Bulk Tank / VIP (9000 gallon)			$320,000	$0	$0
Alarm System	$2,000	$1,000	$88,000	$0	$88,000
Backup Power (250 kW)	$0	$0	$8,000	$0	$8,000
HVAC	$0	$0	$17,600	$0	$14,000
O2 Monitoring			$6,000	$0	$6,000
			$3,035,600	**$0**	**$116,000**
			Total Capital Investment over 30 years		**$3,151,600**

Assumptions:

- Freezer costs include racking systems
- HVAC costs approximately 10% of requirement for Mechanical

Repository B: Operating Costs

Operating Costs	LN2	Vario 1881R	1 Year	10 Years	20 Years	30 Years
Electricity (including HVAC)	$1	$1	$792	$7,920	$15,840	$23,760
LN2	$60	$60	$47,520	$475,200	$950,400	$1,425,600
Generator PM	$0	$0	$0	$0	$0	$0
Freezer PM	$135	$135	$8,910	$89,100	$178,200	$267,300
Freezer Repair	$190	$190	$12,540	$125,400	$250,800	$376,200
Freezer Labor	$115	$115	$7,590	$75,900	$151,800	$227,700
			$77,352	**$773,520**	**$1,547,040**	**$2,320,560**
					Total Operating + Capital	**$5,472,160**

Assumptions:

- Includes re-vac of freezer every 10 years
- Includes daily performance check of all freezers
- Does not include after hour/emergency repairs

Repository B: Summary

	At Start-up	After 30 Years
Capitol Costs	$3,100,000	$3,100,000
Operating Costs	$77,000	$2,300,000
Total:	$3,177,000	$5,400,000

Comparison Summary

	Repository A	Repository B	Difference
Initial Capital Costs	$2,100,000	$3,000,000	+$900,000
Capital Costs after 30 years	$3,100,000	$3,100,000	-
1st year operating costs	$189,000	$77,000	-$112,000
Operating Costs 30 years	$5,700,000	$2,300,000	-$3,400,000
Operating + Capital 30 yrs	$8,800,000	$5,400,000	-$3,400,000

Assumptions

- Price of peace of mind not factored into analysis