VACUUM INSULATED CONTAINERS

ADVANCEMENTS IN VACUUM INSULATED CONTAINERS

Vacuum-insulated containers are a cornerstone of **high-performance** thermal management. By suppressing convective and conductive heat transfer and strongly limiting radiative exchange, vacuum insulation enables thermal performances un-achievable with conventional polymer foams.

This paper reviews the **physical principles, strengths, and limitations** of **vacuum insulated panels and legacy Dewar-type containers**, and introduces the **Crìa High Vacuum Multilayer Technology**, a new architecture combining high vacuum and optimized multi-layer thermal insulation in a fully welded metal structure.

Crìa approach overcomes reliability, orientation and performance constraints of legacy systems, enabling higher thermal insulation, superior mechanical robustness and consistent performance through time.

VACUUM INSULATED PANELS – VIPs

VIPs are composed of a porous core material, typically fumed silica, enclosed within a vacuum-sealed, metallized polymer envelope. The combination of reduced gas pressure and nanometric pore size suppresses residual gaseous conduction, while the metallized envelope limits radiative transfer. This makes **VIPs good for applications requiring better insulation than conventional polyurethane or polystyrene foam**, but still in a standard box format

CHALLENGES

- **Thermal bridges at assembly** - unavoidable gaps between VIP panels create thermal bridges, reducing overall insulation performance from day one
- **Progressive insulation decay** - atmospheric gases permeate the metallized polymer envelope, raising internal pressure (often to tens of mbar within a few years) and reducing insulation performance by a factor of two or more[1]
- **Mechanical fragility** - the porous core and thin envelope make VIPs fragile and unsuitable for high mechanical loads

DEWAR

The **Dewar flask**, invented by Sir James Dewar in **1892**[2], established the fundamental architecture of double-walled containers separated by vacuum. Its **combination of vacuum insulation and reflective surfaces** remains the basis of modern cryogenic storage systems. Over time, two families emerged:

HIGH VACUUM FLASKS

High vacuum flasks, popularized by Thermos, consist of **stainless-steel double walls** separated by a **high vacuum gap**, typically evacuated below **10^{-4} mbar**. High vacuum suppresses convection and residual gas conduction, while a single reflective surface of copper coating, reduces radiative heat transfer. The vacuum gap is typically a few millimeters thick, and they have long-term performance stability & high robustness

CHALLENGES

- **Radiative losses at low T** - as temperature decreases, radiative exchange dominates, making a single reflective layer insufficient
- **Conductive losses through the neck** - despite overall vacuum insulation, the metallic neck remains a significant thermal bridge due to its mechanical robustness
- **Limited low-T applicability** - the combined effect of radiative and conductive losses restricts high-vacuum flasks to applications close to room temperature

LOW VACUUM CRYOGENIC DEWARS

Modern cryogenic Dewars use a combination of **Multi-Layer Insulation** and a **low vacuum gap** typically evacuated by mechanical pumps between **10^{-2} and 10^{-3} mbar**. The MLI consists of hundreds to thousands of aluminized polymer foils separated by low thermal conductivity spacers. When cryogenic liquids such as LN_2 are introduced, **cryopumping** further reduces the pressure in the innermost layers, locally improving vacuum & insulation[3]

CHALLENGES

- **Inefficient MLI use** - cryopumping is effective only at cryogenic temperatures, on the innermost layers, leaving most MLI inactive[4]
- **Vacuum degradation over time** - adhesives allow gas permeation[5], progressively reducing vacuum quality and performance
- **Mechanical fragility** - plastic and adhesives force upright use to prevent joint failure
- **Increased size** - partly active MLI requires centimeter-scale gaps, resulting in bulkier and less compact containers

CRIA HIGH VACUUM MULTILAYER TECHNOLOGY

THE
COLD CHAIN
REVOLUTION

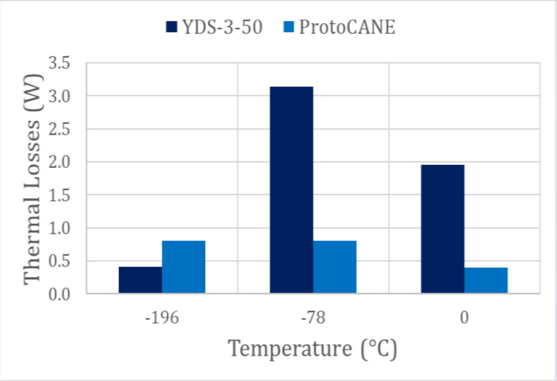
Crìa High Vacuum Multilayer Technology introduces a new Dewar architecture that combines **high vacuum** and **MLI within a fully welded metal envelope**. This design simultaneously addresses the mechanical, vacuum-stability, and thermal-performance limitations of legacy systems

FULLY WELDED CONSTRUCTION AND ORIENTATION INDEPENDENT USAGE

The **entire vacuum envelope** is made of **stainless steel**, and **parts are joined by welding** rather than adhesives. This approach virtually **eliminates gas permeation** and enables **long-term vacuum stability** and insulation performance comparable to classical high vacuum flasks. **The fully welded neck** (patent pending) **enables safe operation in any orientation** without any risk of structural or vacuum integrity compromise

ALL MLI LAYERS ALWAYS ACTIVE

In the new Crìa architecture, the **MLI is placed in a high vacuum environment** typically **below 10^{-6} mbar**. At these pressures, **residual gas conduction becomes negligible**, and the system operates in the molecular flow regime, where **radiative heat transfer dominates**. This makes every reflective layer fully effective irrespective of the temperature because no cryopumping is involved. Under these condition, typical **heat flux values of 0.3|0.6 $W \cdot m^{-2}$** are achieved with just 20–30 layers, while equivalent values in low-vacuum cryogenic Dewars (assisted by cryopumping) require more than 80-100 layers. This is possible by a careful choice of the MLI materials, the passive getter pumps used to maintain high vacuum through time as well as a special manufacturing process



Thermal losses of a 3 L standard low-vacuum cryogenic Dewar & a Cria GO prototype container having 2x the neck diameter (100 mm vs. 50 mm). The 4-times lower thermal losses at −80 °C (when cryopumping is not effective) are due to Cria Technology. Measurements are made using the mass loss method with: boiling liquid nitrogen, sublimating dry ice & melting ice.

CONCLUSION

Crìa High Vacuum Multilayer Technology establishes a **new performance class** for vacuum-insulated containers by unifying **three essential design principles**:

1. **High vacuum without reliance on cryopumping, stable over time**
2. **Fully active MLI layers across the entire insulation stack**
3. **Fully welded, adhesive-free construction enabling orientation-independent use**

This combination delivers **superior thermal performance**, **mechanical robustness**, and **long-term vacuum stability**. It transforms MLI from a cryogenic-only optimization into a general-purpose insulation technology applicable from ambient temperature down to ultra-low and cryogenic temperatures

FUTURE OUTLOOK

The Crìa High Vacuum Multilayer Technology provides a **platform for next-generation cold-chain systems**. When combined with phase-change materials, it **enables dry-ice-free transport** solutions for ultra-low temperature applications. **Integration with low-power Stirling coolers** allows the realization of portable freezers operating **down to cryogenic temperatures**. In addition, compatibility with low-temperature qualified sensors and IoT systems opens the way to **real-time thermal performance monitoring** and **predictive maintenance**.

Together, these developments position Crìa's technology as a foundation for the next generation high-performance thermal transport systems.

References:

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