

# Wrapped Multilayer Insulation

## *Thermal insulation for cryogenic piping*

New NASA vehicles, such as Earth Departure Stage (EDS), Orion, landers, and orbiting fuel depots, need improved cryogenic propellant transfer and storage for long-duration missions. Current cryogen feed line multilayer insulation (MLI) performance is 10 times worse per area than tank MLI insulation. During each launch, cryogenic piping loses approximately 150,000 gallons (equivalent to \$300,000) in boil-off during transfer, chill down, and ground hold. Quest Product Development Corp., teaming with Ball Aerospace, developed an innovative advanced insulation system, Wrapped MLI (wMLI), to provide improved thermal insulation for cryogenic feed lines.

wMLI is high-performance multilayer insulation designed for cryogenic piping. It uses Quest's innovative discrete-spacer technology to control layer spacing/density and reduce heat leak. The Phase I project successfully designed, built, and tested a wMLI prototype with a measured heat leak 3.6X lower than spiral-wrapped conventional MLI widely used for piping insulation. A wMLI prototype had a heat leak of 7.3 W/m<sup>2</sup>, or 27 percent of the heat leak of conventional MLI (26.7 W/m<sup>2</sup>).

The Phase II project is further developing wMLI technology with custom, molded polymer spacers and advancing the product toward commercialization via a rigorous testing program, including developing advanced vacuum-insulated pipe for ground support equipment.

## Applications

### NASA

- ▶ New NASA vehicles
- ▶ Orbiting fuel depots
- ▶ Vacuum-insulated pipe used to transfer cryogens

### Commercial

- ▶ Food, research, medical, and industrial applications:
  - Transfers of cryogenic liquid into and from cryogenic dewars for liquid nitrogen (LN<sub>2</sub>), hydrogen (LHe), and oxygen (LOX)
- ▶ Industrial:
  - Handling LN<sub>2</sub>, LOX, and liquefied natural gas (LNG)
- Handling piping, automatic filling equipment, dewar manifolds, and gas panels
- ▶ LNG:
  - High-performance insulated cryogenic transfer piping to reduce LNG losses from vaporization during liquid transfer
- ▶ LN<sub>2</sub> equipment:
  - Semiconductor, electronics, and aerospace environmental temperature testing
  - Special effects (fogging), biological freezing applications, inerting of food and beverage containers, container pressurization, and food freezing



## Phase II Objectives

- ▶ Design and develop a custom, molded polymer spacer
- ▶ Further develop assembly and installation processes
- ▶ Develop and test wMLI for three different piping diameters
- ▶ Conduct testing to optimize spacer and wrap geometries
- ▶ Perform thermal testing on 12 different wMLI test configurations
- ▶ Perform thermal testing on advanced "clam-shell" netting MLI
- ▶ Design, develop, and test MLI in a vacuum-insulated pipe prototype for use in ground support equipment

## Benefits

- ▶ Low heat leak (3.6X less than conventional MLI)
- ▶ Easy assembly
- ▶ Few layers
- ▶ Low cost
- ▶ Less mass

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