Thermal Insulation Products
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RUAG Space is the leading European supplier of Multi-Layer Insulation for spacecraft and global market leader of superinsulation for cryogenic medical systems. The experience we have gained in more than two decades of thermal design and production enables us to increase your competitiveness with RUAG’s leading edge technology solutions.

Our vision is to be the leading competence center for vacuum thermal insulation solutions for space and industrial applications.

Our mission is the development and production of Multi-Layer Insulation for space and cryogenic industry to support our customers in increasing their competitiveness. To achieve this mission we focus on first-class products and reliable and long-standing partnerships with our customers.

RUAG Space activities for development and production of Multi-Layer Insulation for space applications (satellites and instruments) started in 1991. Since then we have developed our competencies and skills in more than 80 projects to become the leading European supplier of Multi-Layer Insulation for spacecraft.

Moreover, RUAG Space has developed great expertise in the field of cryogenic insulation. Today RUAG also offers the development and the production of cryogenic superinsulation for various applications such as Helium liquefiers or superconducting magnets.

Our development and production process comprises of:
- Thermal and mechanical engineering
- Layout and design
- Production and integration

Our value creating chain includes:
- Selection of the insulation composition with attachment and grounding
- CAD Design (3-D and 2-D)
- Prototyping, support during first installation
- Production (standard and tailor-made products and also build to print)
- Delivery logistics

We also produce superinsulation based on customer drawings. We accept the definition of blanket shapes in DXF, IGES or STEP format.

RUAG Space GmbH is certified to ISO 9001, ISO 14001 and EN 9100 by DNV.

Restriction
We have taken care to collect and present technical and performance data which are based on supplier data, own measurements and tests. These data are meant to help our customers in their design process and support the selection of the best insulation type for the application. However, these data are indicative only and have to be proven by specific measurements in the relevant environment.
Cryogenic Insulation (COOLCAT Line)

Our product family COOLCAT comprises of standard insulation and tailor made insulation. Our insulation is composed of aluminized polyester foils interleaved with polyester spacer materials or is made of aluminium foils interleaved with glass spacer materials. In addition, we supply, amongst other things, welding protection materials, tapes and sensors.

Laser Cutting
Polyester superinsulation blankets are cut to shape using our numerically controlled (NC) cutting machines. Polyester superinsulation is laser cut whereas aluminium/glass insulation is cold cut. The laser cutting process assembles the multi-layered package around its cutting edges. Bridges of molten polyester hold the edges together.

However, laser cut edges are open for edge pumping (see picture below). In the comparative calorimeter test between Multi-Layer Insulation with cold cutting and laser cutting, no significant difference in thermal performance was found: Laser cutting does not increase the edge effects!

We can NC laser cut to a maximum width of 2.7 m. The length of the cutting area is 3.0 m, which does not limit the length of individual superinsulation blankets, as the superinsulation is fed into the cutting machine on a conveyor, forwarding the material band when needed.

This method of producing polyester superinsulation has proven to be very efficient, because no additional assembly of the layers (pins, staples, welding points or similar) is required to attain a robust blanket with very good handling properties. The thermal performance is optimized by minimizing thermal shortcuts through assembly elements.

When compared to cold cut blankets, where cracks could start from the edge of each single reflector foil, laser cut/welded blankets combine the strength of several thin layers. The tear strength of laser cut edges is 20–30% higher than the tear strength of cold cut edges. No crack stopper holes are needed at the end of laser cuts or inside corners (<180 °C).

During the evacuation of the vacuum space, the air and outgassing products enclosed within the multi-layer package of the insulation can be pumped at the open edges (edge pumping) and through perforation holes of the reflector foils (broadside pumping). Most of our COOLCAT superinsulation is made of perforated foils to allow broadside pumping. Thus, the insulation gap can be evacuated more quickly and the residual vacuum pressures are lower than for edge pumping only.

We supply standard sheets and rolls of polyester superinsulation such as COOLCAT 2 NW. COOLCAT 1 and COOLCAT 2 have been replaced by superior insulation. Please request our recommendations for your technical solution. These standard superinsulation products are held together by a grid of ultrasonic spot welds. The standard pitch of these welds is 0.3×0.3 m. These welds assemble the multilayered package and ensure that the different foils and spacers will not fall apart when our customers cut their own shapes using scissors, scalpels or similar.
COOLCAT B-R50 tape is recommended for closing superinsulation blanket joints. Depending on the configuration of the cryostat it may be possible to completely enclose the cold parts to be insulated with a shell of insulation blankets. In this case, the taping of superinsulation joints may be sufficient to hold the insulation in place. In other cases, it may be necessary to use additional fixation elements such as plastic pins.

Superinsulation types such as COOLCAT 2 NF, COOLCAT 2 LOX and COOLCAT H, which are not made of polyester but contain other materials such as aluminium foil or glass-fibre fleece are cold cut on our NC cutting machines using oscillating knives. This process does not assemble the multi-layer package and so we use tag pins to hold the blanket together. We offer NC cold cutting up to a blanket size of 3.0 x 0.95 m. We cold cut larger blankets by hand if required.

The superior performance of COOLCAT insulation is based on:

• High quality polyester film, 6 or 12 µm thick, double-sided aluminized at minimum 40 nm (400 Angstrom).
• Reflector foils are separated with pure polyester spacer material.
• 10 layers of foil and 10 layers of spacer are combined as a semi-finished insulation lay-up, ready for cutting.
• The insulation is perforated for perfect evacuation of the vacuum chamber.
• RUAG Space thermal insulation is designed based on CAD models and is cut accurately on the numerically controlled laser cutting machine.
• The insulation is easy to handle due to the laser cut edges.
• The insulation performance is long term stable, no degradation of insulation due to the spacer material, no flattening, limited gravitational compression, no severe compression effect over edges.
• The reproducibility of performance in a serial production is very high, only a very small deviation is measured.

Storage conditions:
In our workshop COOLCAT superinsulation is packaged into polyethylene bags with desiccant. These bags are pumped and sealed to prevent the insulation from moving inside the bags during transport. Then the goods are packed into sturdy cardboard or wooden boxes.

We recommend to store COOLCAT products at room temperature and a relative humidity of 40 – 60 %. Direct exposure to salt atmosphere must be avoided.
COOLCAT 2 NW

Common usage: MRI and NMR Systems

COOLCAT 2 NW is a spacered superinsulation composed of 10 layers of polyester foil, double-sided aluminized, perforated and interleaved with 10 layers of non-woven polyester spacer material.

Due to its high thermal performance and good handling properties, it is used in serial production of MRI, NMR and accelerator cryostats at an industrial scale.

Spacered superinsulation offers more robust thermal performance than crinkled superinsulation (for example at corners and under compression).

Non-woven spacers are dimensionally stable and therefore, COOLCAT 2 NW offers easier handling and more efficient installation than insulation with knit-woven spacer.

COOLCAT 2 NW has a nominal compressed thickness of 1.4 mm per 10 layers. For a good thermal performance, compression of the superinsulation should be avoided. It is recommended to allow a minimum insulation gap thickness of 3 mm per 10 layers and to install the insulation in a loose way.

All polyester reflector foils are aluminized to provide a specific surface resistance of < 0.8 ohms per square (coating thickness > 40 nm).

For low outgassing, COOLCAT 2 NW contains 100 % polyester spacer without binder. For short pumping times all double-sided aluminized polyester foils are perforated at an open area of 0.05 to 0.1 %.

Maximum baking temperature: 423 K

<table>
<thead>
<tr>
<th>Temperature range [K]</th>
<th>Number of layers</th>
<th>Heat flux [W/m²] *</th>
</tr>
</thead>
<tbody>
<tr>
<td>300 to 77</td>
<td>10 foils + 10 spacers</td>
<td>&gt; 1.00</td>
</tr>
<tr>
<td></td>
<td>20 foils + 20 spacers</td>
<td>&gt; 0.75</td>
</tr>
<tr>
<td></td>
<td>30 foils + 30 spacers</td>
<td>&gt; 0.60</td>
</tr>
<tr>
<td></td>
<td>40 foils + 40 spacers</td>
<td>&gt; 0.55</td>
</tr>
<tr>
<td>77 to 4</td>
<td>10 foils + 10 spacers</td>
<td>&gt; 0.02</td>
</tr>
</tbody>
</table>

* Heat flux values measured under laboratory conditions at good vacuum (< 1 E-3 Pa); for the sizing of superinsulation for real applications it is recommended to multiply these heat flux values with a factor of 1.3–1.5. This is assuming good design, installation and vacuum conditions.

Standard rolls available up to 1.9 m wide, wider rolls available on request:

<table>
<thead>
<tr>
<th>Article no.</th>
<th>Dimensions [m]</th>
<th>Foil thickness [µm]</th>
<th>Nominal area weight for 10 layers [kg/m²]</th>
</tr>
</thead>
<tbody>
<tr>
<td>PL100297</td>
<td>3 x 1.5</td>
<td>6</td>
<td>0.224</td>
</tr>
<tr>
<td>PL100045</td>
<td>50 x 1.5</td>
<td>6</td>
<td>0.224</td>
</tr>
<tr>
<td>PL100047</td>
<td>50 x 1.9</td>
<td>12</td>
<td>0.308</td>
</tr>
</tbody>
</table>

The minimum width of narrow rolls is 25 mm. Narrow Multi-Layer Insulation (MLI) bands having widths between 25 mm and 100 mm are wound on one common core. Starting from a width of 100 mm each individual roll has its own plastic core.

Narrow rolls are available to custom dimensions, for example:
3 foils + 3 spacers: min. 100 mm wide x 200 m long;
5 foils + 5 spacers: min. 100 mm wide x 50 m long;
10 foils + 10 spacers: min. 100 mm wide x 50 m long.

The grid of ultrasonic spot welding points on standard material is 0.3 x 0.3 m, details see page 4.

Caution Notes: Polyester superinsulation is flammable and suitable welding protection is required (we recommend the use of COOLCAT H). COOLCAT 2NF and COOLCAT 2 LOX are the only types of superinsulation in this catalogue which are liquid oxygen compatible. For all applications, a separate risk assessment is required to confirm the use of polyester superinsulation.
COOLCAT 2 NF
Common usage: Hydrogen, LNG- & LOX-Systems

COOLCAT 2 NF is a spacered superinsulation composed of multiple layers of glass fibre fleece spacer interleaved with multiple layers of 9 µm pure aluminium foil.

COOLCAT 2 NF is high temperature tolerant and non-flammable. COOLCAT 2 NF was tested to and successfully met the requirements of ISO 21010 Cryogenic vessels – Gas/materials compatibility, Section 4.4.4 Insulation Test, which is based on EN 1797. COOLCAT 2 NF does not sustain combustion when touched with a glowing platinum wire in a 100 % oxygen atmosphere at 1 bar absolute pressure. It is therefore considered suitable for the insulation of automotive cryogenic hydrogen storage tanks.

Glass fibre diameter: 16 µm (non-respirable).

COOLCAT 2 NF sheets consist of 11 layers of glass fibre fleece spacer and 10 layers of 9 µm pure aluminium foil, which are provisionally held together by PEEK tag pins along their short ends at a pitch of 0.2 m (Nylon tag pins are available on request).

COOLCAT 2 NF rolls consist of 6 layers of glass fibre fleece spacer and 5 layers of 9 µm pure aluminium foil, which are co-wound on plastic core. The layers are not assembled.

Max. layer offset: 10 mm

Max. finished roll width: 1.02 m

COOLCAT 2 NF has a nominal compressed thickness of 5.0 mm per 10 layers. For good thermal performance, compression of the superinsulation should be avoided. It is recommended to allow a minimum insulation gap thickness of 7 mm per 10 layers and to install the insulation in a loose way.

Maximum baking temperature: 523 K.

It is highly recommended to execute a risk analysis for the intended usage regarding non-flammability requirements. Alternatively, COOLCAT 2 LOX shall be considered.

<table>
<thead>
<tr>
<th>Temperature range [K]</th>
<th>Number of layers</th>
<th>Heat flux [W/m²] *</th>
</tr>
</thead>
<tbody>
<tr>
<td>300 to 77</td>
<td>20 foils + 20 spacers</td>
<td>&gt; 1.25</td>
</tr>
</tbody>
</table>

* Heat flux values measured under laboratory conditions at good vacuum (< 1 E-3 Pa); For the sizing of superinsulation for real applications it is recommended to multiply these heat flux values with a factor of 1.5–2. This is assuming good design, installation and vacuum conditions. The thermal conductance of aluminium foils is much higher than the one of aluminized polyester foils and therefore thermal edge effects are more severe.

COOLCAT 2 NF is available in standard sheets and rolls:

<table>
<thead>
<tr>
<th>Article no.</th>
<th>Dimensions [m]</th>
<th>Foil thickness [µm]</th>
<th>Nominal area weight for 10 layers [kg/m²]</th>
</tr>
</thead>
<tbody>
<tr>
<td>PL110206</td>
<td>3 x 1</td>
<td>10</td>
<td>0.540</td>
</tr>
<tr>
<td>PL107156</td>
<td>50 x 1</td>
<td>5</td>
<td>0.284</td>
</tr>
</tbody>
</table>

* Nominal area weight for 10 layers calculated assuming 9 µm pure aluminium foil.
COOLCAT 2 LOX

Common usage: Liquid Oxygen Systems

COOLCAT 2 LOX is a spaced superinsulation composed of 5 layers of pure aluminium foil interleaved with 5 layers of glass fibre cloth spacer.

COOLCAT 2 LOX is high temperature tolerant and liquid oxygen compatible: COOLCAT 2 LOX was tested to and successfully met the requirements of ISO 21010 Cryogenic vessels – Gas/materials compatibility, Section 4.4.4 Insulation Test, which is based on EN 1797. COOLCAT 2 LOX does not sustain combustion when touched with a glowing platinum wire in a 100% oxygen atmosphere at 1 bar absolute pressure. It is therefore considered suitable for the insulation of liquid oxygen equipment. The glass fibre spacer has been de-sized and heat cleaned. The insulation is free of organic constituents.

Glass fibre diameter: 5 µm (non-respirable).

COOLCAT 2 LOX sheets are provisionally held together by PEEK tag pins along one short end at a pitch of 0.2 m (Nylon tag pins available on request).

COOLCAT 2 LOX has a nominal compressed thickness of only 0.4 mm per 10 layers. For good thermal performance, compression of the superinsulation should be avoided. It is recommended to allow a minimum insulation gap thickness of 1 mm per 10 layers and to install the insulation in a loose way.

Maximum baking temperature: 623 K.

<table>
<thead>
<tr>
<th>Temperature range [K]</th>
<th>Number of layers</th>
<th>Heat flux [W/m²] *</th>
</tr>
</thead>
<tbody>
<tr>
<td>300 to 77</td>
<td>10 foils + 10 spacers</td>
<td>&gt; 4.41</td>
</tr>
<tr>
<td></td>
<td>20 foils + 20 spacers</td>
<td>&gt; 3.35</td>
</tr>
</tbody>
</table>

* Heat flux values measured under laboratory conditions at good vacuum (< 1 E-3 Pa); for the sizing of superinsulation for real applications it is recommended to multiply these heat flux values with a factor of 1.2–1.5. This is assuming good design, installation and vacuum conditions. The thermal conductance of aluminium foils is much higher than the one of aluminized polyester foils and therefore thermal edge effects are more severe.

COOLCAT 2 LOX is available in standard sheets:

<table>
<thead>
<tr>
<th>Article no.</th>
<th>Dimensions [m]</th>
<th>Foil thickness [µm]</th>
<th>Nominal area weight for 10 layers [kg/m²]</th>
</tr>
</thead>
<tbody>
<tr>
<td>PL110205</td>
<td>3 x 1</td>
<td>9</td>
<td>0.247</td>
</tr>
</tbody>
</table>
COOLCAT 2 NI
Common usage: SQUIDS and Superconducting Machines

COOLCAT 2 NI is a spacered superinsulation composed of 10 layers of polyester foil, single-sided aluminized in squares of 10 mm x 10 mm or double-sided aluminized in squares of 20 mm x 20 mm, interleaved with 10 layers of non-woven polyester spacer material.

COOLCAT 2 NI minimizes eddy currents and still offers a high thermal performance. It has been developed for applications where the insulation is exposed to varying magnetic fields:

- SQUID sensors: Reduction of magnetic thermal noise
- Superconducting machines (fault current limiters, motors, generators etc): Reduction of heat dissipated in the superinsulation coatings

For low outgassing COOLCAT 2 NI contains 100% polyester spacer without binder. COOLCAT 2 NI is not perforated.

Maximum baking temperature: 423 K.

COOLCAT 2 NI has a nominal compressed thickness of 1.4 mm per 10 layers. For good thermal performance, compression of the superinsulation should be avoided. It is recommended to allow a minimum insulation gap thickness of 3 mm per 10 layers and to install the insulation in a loose way.

Magnetic thermal noise measurements were performed with 20 layers on a sample size of 100 mm x 100 mm.

<table>
<thead>
<tr>
<th>Frequency [Hz]</th>
<th>Noise spectral density for 0.8 Ω per square [fT/√Hz] 10 x 10 mm</th>
<th>1.6 Ω per square [fT/√Hz] 10 x 10 mm</th>
<th>0.8 Ω double sided per square [fT/√Hz] 20 x 20 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>0.61</td>
<td>0.41</td>
<td>1.71</td>
</tr>
<tr>
<td>100</td>
<td>0.91</td>
<td>0.89</td>
<td>1.85</td>
</tr>
<tr>
<td>500</td>
<td>0.79</td>
<td>0.66</td>
<td>1.81</td>
</tr>
<tr>
<td>1000</td>
<td>0.76</td>
<td>0.62</td>
<td>1.79</td>
</tr>
<tr>
<td>10000</td>
<td>0.73</td>
<td>0.61</td>
<td>1.82</td>
</tr>
</tbody>
</table>

Temperature range [K] | Squares | Number of layers | Heat flux [W/m²]* | Number of layers | Heat flux [W/m²]* |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>300 to 77</td>
<td>10 x 10</td>
<td>10 foils + 10 spacers</td>
<td>&gt; 4.60</td>
<td>20 foils + 20 spacers</td>
<td>&gt; 3.40</td>
</tr>
<tr>
<td></td>
<td>20 x 20</td>
<td>10 foils + 10 spacers</td>
<td>&gt; 1.54</td>
<td>20 foils + 20 spacers</td>
<td>&gt; 1.38</td>
</tr>
</tbody>
</table>

* Heat flux values measured under laboratory conditions at good vacuum (< 1 E–3 Pa); for the sizing of superinsulation for real applications it is recommended to multiply these heat flux values with a factor of 1.3–1.5. This is assuming good design, installation and vacuum conditions.

COOLCAT 2 NI is laser cut, which assembles the layers along the edges. COOLCAT 2 NI is available in sheets of 3 m long and 0.75 m wide, other sizes on request:

<table>
<thead>
<tr>
<th>Article no.</th>
<th>Squares</th>
<th>Electrical surface resistance [Ohms per square]</th>
<th>Dimensions [µm]</th>
<th>Foil thickness [µm]</th>
<th>Nominal area weight for 10 layers [kg/m²] *</th>
</tr>
</thead>
<tbody>
<tr>
<td>PL101416</td>
<td>10 x 10</td>
<td>0.8</td>
<td>3 x 0.75</td>
<td>12</td>
<td>0.308</td>
</tr>
<tr>
<td>PL101417</td>
<td>10 x 10</td>
<td>1.6</td>
<td>3 x 0.75</td>
<td>12</td>
<td>0.308</td>
</tr>
<tr>
<td>PL102015</td>
<td>20 x 20</td>
<td>0.8</td>
<td>3 x 0.75</td>
<td>12</td>
<td>0.308</td>
</tr>
</tbody>
</table>

* Squares are aluminized to this surface resistance. These squares are electrically insulated from each other by uncoated lines, which are typically 0.1 mm wide.

Caution Notes: Polyester superinsulation is flammable and suitable welding protection is required (we recommend the use of COOLCAT H).
COOLCAT H
Common usage: Welding Protection for Polyester Insulation

COOLCAT H is a welding protection made of aluminium foil and fiber-glass cloth.

It is recommended for the protection of polyester superinsulation against welding heat. This welding protection is needed because the polyester superinsulation is flammable and melts at 250 degrees Celsius (523 K).

COOLCAT H insulates by reflecting the welding heat at its aluminium surface and by featuring the low conductivity of fiberglass cloth in air under ambient pressure.

The maximum service temperature of the E-Glass cloth is at 500 degrees Celsius (773 K). The adhesive of the laminate fails above 150 degrees Celsius (423 K). Welding trials are recommended to confirm if one layer of COOLCAT H is sufficient for the customer application.

COOLCAT H was tested to and successfully met the requirements of ISO 21010 Cryogenic vessels – Gas/materials compatibility, Section 4.4.4 Insulation Test, which is based on EN 1797. COOLCAT H does not sustain combustion when touched with a glowing platinum wire in a 100 % oxygen atmosphere at 1 bar absolute pressure. It is therefore considered suitable for the insulation of liquid oxygen equipment.

The glass fibres have a diameter of larger than 6 µm and are not respirable.

COOLCAT H is available in rolls of 150 mm wide and 50 m long.

We offer customized COOLCAT H sheets to a maximum width of 1 m. These sheets are cut to customer specification using our cost efficient automated NC cutting machine.

COOLCAT H is also used as a robust cover layer of large liquid oxygen or liquefied natural gas tank insulation.

<table>
<thead>
<tr>
<th>Article no.</th>
<th>Foil thickness [mm]</th>
<th>Nominal area weight for 10 layers [kg/m²]</th>
</tr>
</thead>
<tbody>
<tr>
<td>PL100782</td>
<td>0.9</td>
<td>0.68</td>
</tr>
</tbody>
</table>
COOLCAT 4K
Common usage: Liquid Helium Vessel Surface

COOLCAT 4K is a low absorptance helium vessel laminate for thermal insulation of cold masses at 4K.

It is a laminate of a 6 µm pure aluminium foil and a 12 µm polyester foil, double-side aluminized.

COOLCAT 4K laminate combines the very low absorptance of a pure aluminium foil with the good handling properties of a polyester foil.

As a superconducting magnet thermal insulation, the small aluminium foil thickness offers lower heat dissipation at 4K (incurred by eddy currents) and lower Lorentz forces at quench.

COOLCAT 4K does not crinkle and tear the way aluminium foils do. At room temperature, it has the higher tear resistance of a laminate. This makes the installation of the insulation easier and saves labour costs.

COOLCAT 4K is available at a maximum width of 1.83 m. We offer customized COOLCAT 4 K sheets to a maximum width of 1.75 m. These sheets are cut to customer specification using our cost efficient automated NC laser-cutting machine.

According to cryogenic tests COOLCAT 4K contracts by 0.44 % at 4K.

In order to prevent cracking of COOLCAT 4K at cryogenic temperatures, stress concentrations must be avoided or appropriate local reinforcement of the laminate must be provided.

Installation: The mat (dull) side of the foil is the aluminium foil side and shall be used for thermal insulation. The shiny side is the aluminized polyester side and shall face the cold surface. An adhesive transfer film can be applied to the aluminium coating of the shiny side of the laminate for its attachment to the cold helium vessel surface.

Coolcat 4K: Infrared Absorptance at 4 K for Radiation Temperature $T_R$
**COOLCAT 1050**

Common usage: Liquid Helium Vessel Surface, applications at 4K

COOLCAT 1050 is a high purity, low absorptivity aluminum tape for use in cryogenic applications. COOLCAT 1050 is applied directly onto 4K surfaces to provide lowest absorption of thermal radiation.

COOLCAT 1050 is composed of an 80 µm high purity (99.5 %) aluminum foil carrier and a pressure sensitive acrylic adhesive.

Due to its very high reflection COOLCAT 1050 offers excellent insulation quality.

COOLCAT 1050 is most recommended for covering surfaces with high absorptivity of thermal radiation like stainless steel or aluminium in a cryogenic environment such as helium vessels of superconducting magnets or any other cold mass.

COOLCAT 1050 was especially developed for and tested at a temperature of 4K.

<table>
<thead>
<tr>
<th>Holding strength / Substrate</th>
<th>Peel strength [N/(12mm width)]</th>
<th>Shear strength [N/144 mm²]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stainless steel</td>
<td>2.9</td>
<td>104.0</td>
</tr>
<tr>
<td>Aluminium</td>
<td>3.7</td>
<td>99.8</td>
</tr>
<tr>
<td>Glass Fibre Reinforced Epoxy (cleaned with acetone)</td>
<td>4.5</td>
<td>71.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Article no.</th>
<th>Dimensions [m]</th>
<th>Packing unit</th>
<th>Liner</th>
</tr>
</thead>
<tbody>
<tr>
<td>PL108430</td>
<td>50 x 0.05</td>
<td>18</td>
<td>no</td>
</tr>
<tr>
<td>PL108431</td>
<td>50 x 0.05</td>
<td>18</td>
<td>yes</td>
</tr>
<tr>
<td>PL108432</td>
<td>50 x 0.10</td>
<td>6</td>
<td>yes</td>
</tr>
<tr>
<td>PN100148</td>
<td>Tape dispenser</td>
<td>Automatically winds up the release liner (up to 50 mm wide tape)</td>
<td></td>
</tr>
</tbody>
</table>

**Infrared absorptance at 4 K for radiation temperature**

(low value required for good radiative insulation)

---

**Table Data**

<table>
<thead>
<tr>
<th>Radiation temperature [K]</th>
<th>COOLCAT 1050 without Liner</th>
<th>Aluminium tape 1100</th>
<th>12µm Double aluminized PET foil</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>0.4</td>
<td>0.6</td>
<td>0.8</td>
</tr>
<tr>
<td>60</td>
<td>0.5</td>
<td>0.7</td>
<td>0.9</td>
</tr>
<tr>
<td>70</td>
<td>0.6</td>
<td>0.8</td>
<td>1.0</td>
</tr>
<tr>
<td>80</td>
<td>0.7</td>
<td>0.9</td>
<td>1.2</td>
</tr>
<tr>
<td>90</td>
<td>0.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>0.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>110</td>
<td>1.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>120</td>
<td>1.1</td>
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</tbody>
</table>
COOLCAT B-R50
Common usage: Closure of Insulation

COOLCAT B-R50 is a low emissivity adhesive tape optimized for use under cryogenic environment. It is composed of a 25µm polyester foil carrier, double-sided aluminized and a high purity pressure sensitive acrylic adhesive.

COOLCAT B-R50 cryogenic adhesive tape has been developed specifically for thermal insulation in cryogenic applications, to provide lowest infrared emittance on its outer surface. This tape has been developed to replace tapes, which have a shiny appearance, but are second surface mirrors only.

It is most recommended for the closing of superinsulation joints e.g. for COOLCAT 2 NW layups. Bonding strength at room temperature:
- Peel strength: min. 16 N / 25 mm width (AFERA 5001)
- Shear strength: min. 60 N / 625 mm² (AFERA 5012)

**Tested bonding strength to stainless steel at 4K:**
- Peel strength: 3 N / 12 mm width
- Shear strength: 47 N / 144 mm²

The procedure for cryogenic tests follows AFERA as far as possible and is adapted to cryogenic temperatures as necessary.

The tape meets the standard outgassing requirements for satellites of the European Space Agency ESA.

The adhesive of the tape is protected by a release liner. We offer tape dispensers, which automatically wind up the release liner.

The tape is available 25 mm (1 inch) or 50 mm (2 inches) wide. It is delivered on plastic core. The minimum order quantity is one roll, but it is more economic to order complete packing units:

<table>
<thead>
<tr>
<th>Article no.</th>
<th>Dimensions [m]</th>
<th>Packing unit [rolls]</th>
<th>Liner</th>
</tr>
</thead>
<tbody>
<tr>
<td>PL100134</td>
<td>50 x 0.025</td>
<td>32</td>
<td>yes</td>
</tr>
<tr>
<td>PL100138</td>
<td>50 x 0.050</td>
<td>16</td>
<td>yes</td>
</tr>
<tr>
<td>PN100148</td>
<td>Tape dispenser</td>
<td>Automatically winds up the release liner (up to 50 mm wide tape)</td>
<td></td>
</tr>
</tbody>
</table>

Shelf life: 2 years from date of production

**Caution Notes:** Polyester superinsulation is flammable and suitable welding protection is required (we recommend the use of COOLCAT H).

**Emittance of aluminized tapes**
(Low value required for good radiative insulation)

![Graph showing infrared emittance comparison between COOLCAT B-R50 and 25µm Second Surface Mirror tape]

<table>
<thead>
<tr>
<th>Infrared emittance</th>
<th>COOLCAT B-R50</th>
<th>25µm Second Surface Mirror tape</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>0.00</td>
<td>0.57</td>
</tr>
<tr>
<td>0.20</td>
<td>0.03</td>
<td></td>
</tr>
<tr>
<td>0.40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.60</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table of Materials:**
- Alu coating
- Mylar Carrier
- Adhesive
- Mylar carrier
- Alu coating
- Adhesive
RUAG Space offers the full range of thermal insulation materials used for Single-Layer-Insulation, Multi-Layer Insulation and radiator surfaces consisting of polymeric or metal foils. We source raw materials for insulation from the leading suppliers from all over the world.

RUAG Space is very active in research and development to improve the performance and the characteristics of thermal control materials and components. We are constantly focusing on developing and qualifying novel thermal control products with emphasis on mass and performance.

We also have business contact to the suppliers of all thermal components needed for satellite or cryostat thermal control (e.g. heaters, thermostats, thermistors, doublers, interfillers heatpipes etc) and thus can operate as a one stop shop for our customers thermal control needs.

<table>
<thead>
<tr>
<th>(ext. surface)</th>
<th>α</th>
<th>εH</th>
<th>εH</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 mil polyimide / VDA</td>
<td>≤ 0.39</td>
<td>≥ 0.62</td>
<td>≥ 0.64</td>
</tr>
<tr>
<td>1 mil ITO polyimide / VDA</td>
<td>≤ 0.44</td>
<td>≥ 0.62</td>
<td>≥ 0.64</td>
</tr>
<tr>
<td>2 mil polyimide / VDA</td>
<td>≤ 0.44</td>
<td>≥ 0.71</td>
<td>≥ 0.71</td>
</tr>
<tr>
<td>2 mil ITO polyimide / VDA</td>
<td>≤ 0.49</td>
<td>≥ 0.71</td>
<td>≥ 0.75</td>
</tr>
<tr>
<td>1 mil black Kapton® / VDA</td>
<td>≤ 0.9</td>
<td>≤ 0.82</td>
<td></td>
</tr>
<tr>
<td>1 mil Upilex® / VDA</td>
<td>≤ 0.40</td>
<td>≥ 0.59</td>
<td></td>
</tr>
<tr>
<td>2 mil Upilex® / VDA</td>
<td>≤ 0.59</td>
<td>≥ 0.75</td>
<td></td>
</tr>
<tr>
<td>Betacloth® / VDA</td>
<td>≤ 0.45</td>
<td></td>
<td>≥ 0.80</td>
</tr>
<tr>
<td>2 mil FEP / VDA</td>
<td>≤ 0.14</td>
<td>≥ 0.60</td>
<td>≥ 0.60</td>
</tr>
<tr>
<td>5 mil FEP / Silver / Inconel VDA</td>
<td>≤ 0.09</td>
<td>≥ 0.75</td>
<td>≥ 0.75</td>
</tr>
</tbody>
</table>

ITO: Indium Tin Oxide
We offer a large variety of special foil materials, high temperature materials, RF-transparent etc.
ITO: Indium Tin Oxide

We offer a large variety of special foil materials, high temperature materials, RF-transparent etc.
**Innovation in Thermal Control**

RUAG Space is the leading innovator for new and advanced solutions in thermal control for spacecraft and launch vehicles. We continually take part and exercise projects funded internally as well as supported by external entities to develop new solutions and to broaden our expertise and knowledge on thermal hardware. Knowledge transfer among our highly skilled engineering specialists is a firmly implemented and living process.

Almost 30 years of continuous evolution and our ability to always look ahead of the current technologies enabled us to provide improved and advanced concepts for thermal control hardware.

We co-operate with our long standing supply partners to advance current technologies and use them in different ways but also to create new products that will change thermal control in the future.

RUAG is constantly working to identify and qualify new thermal components, foils and spacer nettings to be able to provide the customers with solutions for their challenges.

But also new systems are regularly devised such as our patented Versatile Thermal Insulation, a thermal insulation for launch vehicle stages that is deployed after the initial ascent without any electrical power from the stage and reduces the heat load on tanks with liquid fuel.

RUAG teams with our customers when the challenges in thermal environments in space combined with other mission requirements such as protection against micro-meteorite damage and electrostatic charging become the key for the mission success.

RUAG Space is your partner for these missions. However, RUAG also innovated processes and workflows, meeting the challenges of New Space and constellation programs.

Drawing from the lessons learned in our industrial mass production of cryogenic supersinsulation, RUAG Space successfully adapted the tools and machines as well as the workflow in manufacturing and assembly to meet the most demanding cadencies of the current and future spacecraft clouds.

RUAG Space in Austria built the MLI for the first Galileo “In orbit Validation” Satellites (IOV) and consequently for the full Galileo “Full Operational Capability” Fleet (FOC) as the first miniseries. The next logical step was the contract for the MLI for Iridium Next for more than 80 spacecraft MLI sets to be built and delivered within two years.

This gained expertise in rapid manufacturing technologies with unchanged performance and space quality in combination with a sound financial background of RUAG resulted in the contract for the OneWeb Multi-Layer Insulation blankets.

For these serial productions, RUAG developed and improved the Quality Assurance workflow using barcodes and automated checks to maintain our excellence in quality but reduce the manpower efforts per item.

Innovation does not stop at hardware but is a mindset deeply embedded in our experts.
RUAG successfully equipped crucial missions such as GAIA, Rosetta, Herschel, Planck, ExoMars and the Copernicus programme with sophisticated high performance Multi-Layer Insulation (MLI) contributing to their mission success. RUAG is also developing highly sophisticated insulation for the European launch systems for highest temperatures under ambient and space environment.

Below two typical layups, the performances for very clean and high temperature resistant MLI are given. RUAG MLI also covers temperature ranges within and beyond the two examples.

**Standard Temperature MLI (Clean MLI)**
10 layer package with polyester foils and non-woven polyester netting. -270 °C to +150 °C temperature range, 140 g/m² to 160 g/m² area mass.

**High Temperature MLI**
22 layer package with polyimide foils, glass spacer in hot section and polyester netting in medium temperature section. -270 °C to up to +350 °C temperature range, 625 g/m² to 665 g/m² area mass.
RUAG developed an extremely light variant of their standard insulation operating in vacuum at temperatures up to +150 °C. RUAG blankets using this variant provide comparable performance at cryogenic temperatures and even improved thermal performance at higher average temperatures with the advantage of a considerable mass reduction. Blankets are typically composed of several layers of 3 µm polyester foils interleaved with high performance non-woven polyester spacer and two outer layers (≥ 25 µm). Any outer layer with thermo-optical properties selectable out of a wide range of materials and thicknesses available at RUAG Space can be combined in this variant. The number of internal ultrathin layers will be selected based on the needed thermal performance.

Typical fields of application are narrow gaps, low mass demand or higher performance at equal (to standard MLI) mass.

Typical Characteristics of blankets built as Ultrathin variant

**Layup**

1. 1x Outer layer
2. 4x Ultrathin Non-woven Polyester fleece
3. 1x Ultrathin Non-woven Polyester fleece
4. 1x Outer layer

Foil: Polyester (3 µm) both sides aluminized
Spacer: PV-4g (Polyester non-woven fleece)
Coatings: Foils are aluminized with approx. 350 Angstrom (<1 Ohm/square measured to ASTM D257-92)

**Temperature Range:**

“Standard” -270 °C to +150 °C

Extremely Low Area Weight (excluding outer layers): 50 % weight saving compared to standard MLI

**Dimensions:**

Width: 750 mm max.
Length as needed

The thermal performance is

- Comparable at cryogenic temperatures
- Even improved at higher average temperatures

A mass reduction of the internal package (excluding outer layers) of almost 50 % is achieved.
Advanced Insulation Performance

Thermal Performance in MLI blankets is strongly driven by optimizing the radiative de-coupling of individual reflective layers. This can be achieved by using low emissivity coatings on the reflective shields and by reduction of the conductive coupling between them. Besides low emissivity coatings on the reflective foils RUAG developed an innovative family of spacing layers, which significantly outperform the commonly used woven type of spacer nets.

RUAG blankets built with the spacer set developed by RUAG offer increased thermal performance and are also available as extremely light variants which offer better performance as standard MLI at the same weight.

Furthermoe RUAG blankets built with the spacer set developed by RUAG offer improved cleanliness compared to the conventional used spacer types.

Typical Characteristics of the RUAG spacer family and RUAG blankets produced with it

Spacer PV-8g
Material: non-woven polyester
Area weight: 8g/m²
Temperature range: -270 °C to +200 °C

Spacer HELPAC 1
Material: non-woven polyimide
Area weight: 8 g/m²
Temperature range: -270 °C to +250 °C

Outgassing (ECSS-Q-70-02)

<table>
<thead>
<tr>
<th></th>
<th>TML</th>
<th>RML</th>
<th>CVCM</th>
</tr>
</thead>
<tbody>
<tr>
<td>PV-4g</td>
<td>1.16 %</td>
<td>0.65 %</td>
<td>0.07 %</td>
</tr>
<tr>
<td>PV-8g</td>
<td>0.89 %</td>
<td>0.81 %</td>
<td>0.10 %</td>
</tr>
<tr>
<td>HELPAC 1</td>
<td>1.77 %</td>
<td>0.75 %</td>
<td>0.05 %</td>
</tr>
<tr>
<td>HELPAC 2</td>
<td>1.33 %</td>
<td>0.62 %</td>
<td>0.05 %</td>
</tr>
</tbody>
</table>

Radiation stability
The spacer family developed by RUAG was tested with an equivalent GEO radiation environment of at least 15 years.

Spacer PV-4g
Material: non-woven polyester
Area weight: 4 g/m² (very light variant)
Temperature range: -270 °C to +150 °C

Spacer HELPAC 2
Material: non-woven polyimide
Area weight: 4 g/m² (very light variant)
Temperature range: -270 °C to +250 °C

Thermal Performance

Compared to conventional state-of-the-art spacers, the spacer family developed by RUAG performs significantly better.

1): tested at +120 °C
2): tested at +200 °C
3): tested at +250 °C
Insulation for Space Launch Vehicles

RUAG develops and builds insulation for the launcher industry.

From cryogenic tank insulation at liquid hydrogen and oxygen temperatures to protection of crucial engine components directly on the engine nozzle, RUAG delivers the solutions that will enable launchers to reliably achieve mission success.

Cryogenic insulation is typically installed on tank domes of cryogenically fueled stages and consists of coated polyester layers separated by thick polyester felt. Thermal insulation performance is given in ambient and vacuum conditions from approximately -250 °C to ambient temperatures.

Thermal insulation on upper-stages typically covers HIGH TEMPERATURE VACUUM INSULATION made of glass-fabric and high-performance polymers for a temperature range up to 550 °C.

Drawing from our broad experience in satellite MLI a wide variety of manufacturing techniques, materials and hardware attachment options can be offered to ideally suit your stage requirements.

RUAG built FLEXIBLE THERMAL PROTECTION is applied to areas in direct vicinity to rocket motors or nozzles. The insulation is suitable to temperatures up to 1500 °C in ambient pressure condition and typically consists of coated or laminated Nextel® ceramic fabric and ceramic felt insulators.

Depending on environmental and temperature conditions polymeric-, metallic- glass- or ceramic sewing yarns are chosen from our qualified portfolio. We apply these yarns in customized sewing machines which limit blanket compression resulting in improved insulation thermal performance.
**Space Radiator with Solar Reflectors**

This product is a high efficiency thermal radiating system made from reflectively coated glass tiles. These Optical Solar Reflectors (OSR) are electrically conductively bonded to flat metallic surfaces using a pick-and-place machine. The product provides good thermal coupling between the OSR and the structure underneath resulting in a high performance heat-radiating device.

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**Characteristics**

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Materials</td>
<td>Borosilicate glass Optical Solar Reflector (OSR) with reflective back coating</td>
</tr>
<tr>
<td>Available glass finishes</td>
<td>Plain surface, Electrically conductive coating (ITO), Low UV absorptance coating</td>
</tr>
<tr>
<td>Area Weight</td>
<td>470 g/m² all inclusive (using 150 µm thick OSR)</td>
</tr>
<tr>
<td>No silicone contamination</td>
<td></td>
</tr>
<tr>
<td>Temperature range</td>
<td>-70 °C to +90 °C</td>
</tr>
<tr>
<td>Thermo-Optical</td>
<td>$\alpha_s \leq 0.06, \varepsilon_n \geq 0.83$ (OSR with ITO and low UV coating)</td>
</tr>
<tr>
<td>Front to back resistance</td>
<td>&lt;200 kΩ</td>
</tr>
</tbody>
</table>

**Process Information**

Application of mirrors by high-precision automated machine process using electrically conductive pressure sensitive adhesive. Automated machine pick-and-place process provides for competitive processing time of the application. No post curing required. Panels up to 2.4 x 2.6 m can be processed in one run. Standard bonding surface is plain aluminium surface (e.g. ALCLAD), other surface types on request.
RUAG Space Product Portfolio

Our vision: Number one independent space product supplier
The vision of RUAG Space is to be the leading supplier of space products. From the very beginning, we have created the conditions to realise this vision as a partner in institutional European space programs. RUAG Space has taken part in all major European missions, where we have acquired the know-how that our customers all over the world benefit today.

Our values: Collaboration, high performance, visionary thinking
Our corporate culture is based on the values of collaboration, high performance and visionary thinking. These values determine our actions and characterize our relationships with our customers and partners.

For more than four decades, RUAG Space has been an industrial partner to national and European space agencies. In addition, we have been supplying our products to the manufacturers of satellites and launchers for just as long.

Outstanding product performance and consistency in meeting delivery deadlines are the benchmarks by which we measure success. And above all, we focus on reliability, because there is no room for failure in space.

At the heart of RUAG Space’s strategy is a clearly structured product portfolio, which we are expanding according to a definite plan. In expanding the portfolio, we place particular emphasis on space products that are attractive in growth markets outside the institutional European sphere.

The cornerstone of our success: Our employees
In Switzerland, Sweden, Finland, Germany, Austria and the USA, around 1300 RUAG Space employees develop, manufacture and test products for satellites and launchers. Teamwork, trust and respect characterize the work environment at RUAG Space. Our employees work in close cooperation with customers and partners. The success of RUAG Space is based on the skills and commitment of our staff, on the accuracy and reliability of our mechanics and on the creativity and know-how of our engineers. With their ideas, their innovations and their products, they go a little further every day to the limits of what is just technically feasible.

RUAG Space: Part of an international technology group
RUAG Space is a dedicated division within RUAG, an international technology group for aerospace and defense. RUAG has production sites in Switzerland, Germany, Austria, France, Sweden, Finland, Hungary, Australia and the USA. RUAG employs some 8200 people worldwide.
<table>
<thead>
<tr>
<th>Product areas</th>
<th>Product lines</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electronics</td>
<td>Navigation Receivers &amp; Signal Processing</td>
</tr>
<tr>
<td></td>
<td>Satellite &amp; Launcher Computers</td>
</tr>
<tr>
<td></td>
<td>Microwave</td>
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<td>Antenna</td>
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<tr>
<td>Spacecraft</td>
<td>Satellite Structures</td>
</tr>
<tr>
<td></td>
<td>Satellite Mechanisms (OSR with ITO and low UV coating)</td>
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<tr>
<td></td>
<td>Slip Rings</td>
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<tr>
<td></td>
<td>Mechanical Ground Support Equipment</td>
</tr>
<tr>
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<td>Multi-Layer Insulation</td>
</tr>
<tr>
<td>Launcher</td>
<td>Launcher Fairings &amp; Structures</td>
</tr>
<tr>
<td></td>
<td>Adapters &amp; Separation Systems</td>
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<tr>
<td></td>
<td>Sounding Rocket Guidance Systems</td>
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<td>Dispensers</td>
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