THERMAL PROTECTION SYSTEMS
BRINGING NATURE INTO SPACE

Efficient & Easy integration

THERMAL PROTECTION SYSTEMS
Our History

Amorim Cork Composites has been manufacturing and supplying Cork based materials to be used in Thermal Protection Systems (TPS) for the Aerospace industry, since the beginning of space exploration.

Amorim Cork Composites is part of Amorim Group, world leader in cork products, dedicated to industrial customers, with production sites in Portugal, Spain and United States.
Perfection, by Nature

“Cork is the bark of the Cork Oak tree (Quercus Suber), is nature's foam, a foam with a unique combination of properties”,

In NASA Report: “Moldable Cork ablation material”.

Cork cells structure

Sample of P50 collected from the Space Shuttle SRB

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Perfection, by Nature

Cork cells are small, irregular pentagonal or hexagonal prisms. Fifty per cent of cork is an air-like gas enclosed in the cork cells. Cork retains unique qualities of flexibility, elasticity and compressibility.

Very low heat transfer:

- Low solid fraction
- Gas enclosed in the cells has low conductivity
- No convection between cell structure
- Radiation is reduced through the repeated absorption and reflection at the cell walls
Product range

Cork chemical constituents and structure, make it an ideal ablative material with excellent insulating properties, maintaining low weight to low thermal conductivity results.

<table>
<thead>
<tr>
<th>Product range</th>
<th>P45</th>
<th>P50</th>
<th>P60</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cork particle size (mm)</td>
<td>1/2</td>
<td>0,5/1</td>
<td>0,5/1</td>
</tr>
<tr>
<td>Sheet dimension (mm)</td>
<td>1270x710</td>
<td>1270x710</td>
<td>1000x500</td>
</tr>
<tr>
<td>Sheet dimension (inch)</td>
<td>50x28</td>
<td>50x28</td>
<td>40x20</td>
</tr>
<tr>
<td>Density @ 20℃¹</td>
<td>0,32</td>
<td>0,48</td>
<td>0,45</td>
</tr>
<tr>
<td>Tensile Strength (psi)²</td>
<td>125</td>
<td>250</td>
<td>160</td>
</tr>
<tr>
<td>Tensile Strength (MPa)²</td>
<td>0,86</td>
<td>1,50</td>
<td>1,10</td>
</tr>
<tr>
<td>Elongation (%)²</td>
<td>30</td>
<td>13</td>
<td>7</td>
</tr>
<tr>
<td>Thermal Conductivity (Btu in)/(h ft²°F)³</td>
<td>0,45</td>
<td>0,50</td>
<td>0,55</td>
</tr>
<tr>
<td>Thermal Conductivity (W/(m °K))</td>
<td>0,06</td>
<td>0,07</td>
<td>0,08</td>
</tr>
<tr>
<td>Specific Heat (Btu/lb °F)⁴</td>
<td>0,6</td>
<td>0,5</td>
<td>0,4</td>
</tr>
<tr>
<td>Specific Heat (KJ/Kg/°C)⁴</td>
<td>2,5</td>
<td>2,1</td>
<td>1,9</td>
</tr>
</tbody>
</table>

Substrates to bond: Metal and Composite

References:
(1) ASTM F1315
(2) ASTM F 152, Method B
(3) ASTM C 177
(4) ASTM C 351

Other sheet sizes may be available.
**Product range**

**P45 Sheets**
Cork composition material made with 10/20 cork granule and a special binder for high heat resistance.

**Customer Specification Approvals:**
- Boeing STM0585-02

**P50 Sheets**
Cork composition material made with 20/40 cork granule and a special binder for high heat resistance.

**Customer Specification Approvals:**
- Pratt & Whitney TS10433
- Pratt & Whitney CMS0041C
- Thiokol SP733
- Navy WS16603
- Navy WS24865
- Hercules S13034
- Boeing STM0585-01
- Boeing BMS8-70M
- Lockheed 0-06125

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# Main Advantages

<table>
<thead>
<tr>
<th>PROCESS FRIENDLY MATERIALS</th>
<th>FLEXIBLE SUPPLY</th>
<th>PROVEN TECHNOLOGY</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Easily bonded to most substrate materials, using common adhesive systems.</td>
<td>- Materials are made of cork granules agglomerated with special phenolic binders that can be tailored to suit a particular requirement (fire-proof, anti-fungi, etc).</td>
<td>- Our materials are used in TPS applications based in ablative heat shields in rocket applications as well as in space probes entry heat shields.</td>
</tr>
<tr>
<td>- Can be trimmed and machined with regular tools or equipment without the need of any specific protection equipment.</td>
<td>- Sheet thickness according with customer requirements.</td>
<td>- Internal thermal insulation in hot structures.</td>
</tr>
<tr>
<td>- Easily covered with specific coatings or varnishes.</td>
<td>- Specially graded cork granules can be supplied for your own products.</td>
<td>- Impact protection due to debris mitigation or pyrotechnic solutions, in several launch vehicles.</td>
</tr>
<tr>
<td>- Easily integrated on sandwiches (CFRP composites); no need for complex fitting techniques.</td>
<td>- Orders shipped worldwide from our two production sites (Europe and North America).</td>
<td></td>
</tr>
</tbody>
</table>

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Success Records

SCOUT Rockets

“A series of five flight experiments was conducted aboard the NASA Scout, RAM, and four-stage research vehicles for the purpose of testing lightweight phenolic cork as a thermal protection material."...

in NASA report :“Free-flight test results on the performance of Cork as a thermal protection material”, from Sept. 1964

APOLLO Spacecraft Systems

The boost-protective cover protects the command module from aerodynamic heating during boosted flight and from heat and soot from the launch escape and Jettison motors of the launch escape system.
It is made of ablative Cork and Teflon-impregnated glass cloth, supported by glass honeycomb in the upper portion.

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Success Records

Since the beginning of the space age Amorim Cork Composites is supplying sheet materials or specially graded cork granules for European and USA customers. Here’s where we have been present…

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Our “CV”

Amorim Products on the DELTA IV rocket

“..... materials made by Amorim were used in the Delta IV for thermal insulation of the rocket's engines.”

Our involvement in this project is the result of a joint strategy that we have been working on in this market for a number of years. With our involvement in this and other similar projects, Amorim has revealed its full potential in Research & Development and, above all, the capacity to develop and engineer products for critical applications. This capacity is the result of the large investment in R & D that Amorim began back in the 1990’s and has continued into this decade. Cork as a raw material is, in fact, unique and allows infinite applications.
Applications

P45 and P50 are used as TPS materials in several locations of Delta IV Rocket, where the thermal requirements are necessary, like:

- Booster Nose Cone
- Frustum
- Forward Skirt & Aft skirt
- Tunnel covers
- ETR ring covers
Applications

P45 and P50 are used as TPS materials in several locations on the SRB of Space Shuttle, like:

- Booster Nose Cone
- Frustum
- Bolt catcher
- External Skirt insulation
- ETR ring covers
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Amorim
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CASE STUDIES
CASE I – Cork behaviour

- Thermal expansion (down to -160°C)
- Thermal conductivity (down to -160°C)
- Thermal decomposition
- Loss factor

Thermal behaviour of cork, together with its stable damping response in a wider temperature range, makes it possible to integrate in non-critical structural elements in CFRP composites.
CASE I – Cork behaviour

Thermal Conductivity of a cork composition material at -160°C
**CASE I – Cork behaviour**

Thermal Expansion of a cork composition material at -160°C

A significant dependence of the thermal expansion coefficient from the direction of the axis was not observed.

<table>
<thead>
<tr>
<th>material</th>
<th>cork x-direction</th>
<th>cork y-direction</th>
<th>cork z-direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>sample</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1.244</td>
<td>1.246</td>
<td>1.256</td>
</tr>
<tr>
<td>2</td>
<td>1.248</td>
<td>1.246</td>
<td>1.252</td>
</tr>
<tr>
<td>Δl / l₀</td>
<td>0.01233</td>
<td>0.01235</td>
<td>0.01248</td>
</tr>
<tr>
<td></td>
<td>0.01241</td>
<td>0.01236</td>
<td>0.01241</td>
</tr>
<tr>
<td>Δl / l₀ / ΔT</td>
<td>0.0000563</td>
<td>0.0000563</td>
<td>0.0000569</td>
</tr>
<tr>
<td></td>
<td>0.0000566</td>
<td>0.0000564</td>
<td>0.0000566</td>
</tr>
<tr>
<td>a(l₀,l) x 10 (-5) / K</td>
<td>5.83</td>
<td>5.83</td>
<td>5.89</td>
</tr>
<tr>
<td></td>
<td>5.86</td>
<td>5.74</td>
<td>5.66</td>
</tr>
</tbody>
</table>
Mass loss of cork is relatively small (6% of initial mass) until 200\(^\circ\)C. It increases until complete carbonization at about 450\(^\circ\)C. The structure of the cork cells however are now completely destroyed.

CASE I – Cork behaviour

Thermal decomposition

Mass loss vs temperature graph:
- Mass loss (M/Mo) decreases from 1.2 to 0.0 as temperature increases from 200\(^\circ\)C to 600\(^\circ\)C.
CASE I – Cork behaviour

Loss Factor of a cork (temperature sweep)

Loss factor of cork is about 0.1 with a weak dependence on frequency up to 10KHz, but increasing to nearly 0.3 for high strain amplitudes.

Cork Tg is located around 20°C.
CASE I I – Titan IV

P45 coated with white silicone rubber on engine of the Titan IV rocket.

P45 applied to:
- Chamber
- Main Skirt
- Lower Skirt
- Exit closure

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CASE I I – Titan IV

P45 coated with white silicone rubber on engine of the Titan IV rocket.

Depending of the location of the ablative protection, 50% to 70% is transformed into char/recession after the flight.
CASE III – SRB, Skirt Joint System

Forward and aft skirt JPS is primarily to provide thermal protection, weather protection and to retain the pins.

Cork is bonded with adhesive and painted.
The purposes of the FJPS are to maintain an optimal temperature for O-ring tracking and to prevent environmental contaminants such as rainwater from entering the joint area.
During ascent phase, there is the need to separate the tanks from the rocket at a precise time. That must be accomplished at the same time by exploding the nuts that connect the tanks to the body.

Any debris of the explosion is caught by a structure that contains cork to protect all the pyrotechnic system to avoid any damage during the ascent phase.
CASE IV – Specially graded Cork Granules

MCC1 from NASA is an formulation and method of spray deposition of a cork-and-glass-filled epoxy ablative thermal-insulation material.

Applied to SRB in:
- nose cap
- forward skirt
- aft skirt
- tunnel covers

Used by Boeing on Sea Lunch Programme:
- Delta IV
- Air force Titan IV

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SLA-561 from Lockheed Martin, is a low density, low conductivity ablator/insulator. It is a highly filled elastomeric silicone composition containing cork as one filler ingredient.

The material is available in moulded panels with or without honeycomb support. The panels can be bonded with silicone adhesive using vacuum bag processes.

Used in the Mars Rovers.
Norcoat Liege from EADS, is an ablative material based on phenolic resin and cork.

This thermal protection material is used on parts of Ariane 5, space probes and on ARD, especially on large surfaces.
COMUNICATION & TOOLS
THERMAL PROTECTION SYSTEMS

Amorim Cork Composites have a long history of developing and supplying cork-based materials for thermal protection systems, including in the aerospace industry. Our advanced cork-based materials offer excellent thermal insulation properties, making them ideal for use in engines, exhaust systems, and other high-temperature applications.

The combination of natural cork and advanced composite materials provides a solution that is both lightweight and durable. Our materials are designed to withstand extreme temperatures and maintain their structural integrity over time.

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Our team of experts is dedicated to providing innovative solutions that meet your specific requirements. Contact us today to learn more about how Amorim Cork Composites can help you solve your thermal protection challenges.
ENVIRONMENTAL RESPONSIBILITY
Environmental Responsibility

Several Amorim Divisions are FSC (Forest Stewardship Council) certified. Recent studies in the Iberian Peninsula state that cork oak forest contributes with more than 20 Millions tons of CO₂ sequestration, making it a significant world resource for the environmental balance.

Each time cork is harvested, cork bark regenerates itself. Cork oak trees store CO₂ in order to regenerate, and therefore a harvested cork oak tree absorbs 3 to 5 times more than one which is not harvested, thus benefiting the atmosphere.

<table>
<thead>
<tr>
<th>CORK OAK LIFE CYCLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
</tr>
</tbody>
</table>

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