Spray Applied Fire Resistive Materials

Onshore and Offshore
W.R. Grace Inc. & Co. at a glance

• Founded in 1854
• Headquarter in Cambridge – U.S.A.
• 2010 Worldwide Sales — $ 2.7 billion
• Listed on the New York Stock Exchange
• +6000 employees worldwide
• www.graceconstruction.com
Grace worldwide presence

Offices:  ●
Fireproofing production facilities:  ●
Grace business units

W.R. GRACE INC. & CO.

GRACE DAVIDSON

REFINING CATALYSTS

CHEMICAL CATALYSTS

SILICA PRODUCTS

GRACE CONSTRUCTION PRODUCTS

SPECIALTY BUILDING MATERIALS

CONCRETE ADMIXTURES

CEMENT ADDITIVES

FIRE PROTECTION AND MATERIALS

WATERPROOFING SYSTEMS
Grace Global Market Positions in 2010

- World #1 in Cellulosic Structural Fireproofing
- Hydrocarbon Structural Fireproofing:
  - #1 in ME; #2 in EU; #3 in the USA
- World #1 in Fluid Cracking Catalysts
- World #1 in Resid Hydroprocessing Catalysts
- World #1 in Independent Polyethylene Catalysts
- World #1 in Micronized Silica Gel
- World #1 in Can Sealants
- World #1 in Cement Additives
- World #2 in Concrete Admixtures
Different fire curves and fire scenarios

Every fire is different, Grace offers a full range of materials

Commercial or cellulosic fire

Petrochemical or hydrocarbon fire

Tunnels

Figure 1

Comparaison des courbes temps/température « cellulosique » et « hydrocarbure »
Mostly adopted international hydrocarbon fireproofing standards:

- **UL 1709** (globally accepted and most well-known hydrocarbon fire test)
- **BS 476 Part 21 Appendix D** (fairly known hft mainly in the UK, Australia and India)
- **ASTM E-1529** (hydrocarbon fire test fairly known mainly in the USA)
- **API RP 2218** (fireproofing guideline globally accepted)
- **OTI HSE 95634** (jet fire test – globally accepted)
- **Factory Mutual** (LPG structural protection & hose stream test – globally accepted)
- **DNV** (mainly accepted in the offshore industry)
- **Lloyd’s Register** (mainly accepted in the offshore industry)
Typical areas that need fire protection

- Structural elements (beams and columns)
- Storage tanks (especially LPG)
- Divisional protections (underdecks and bulkheads)
- Concrete structures (to avoid spalling)
- Vessels skirts
- Pressure vessels supports
- … others
The Monokote family in the world

– MONOKOTE Z-146 PC
  • High Density, insulating inorganic coating (40 pcf - 640 Kg/m³)

– MONOKOTE Z-156 PC
  • Ultra High Density, insulating inorganic coating (50 pcf - 800 Kg/m³)

Developed to meet the harsh conditions found in Petrochemical Processing and Refinery Facilities
The Monokote family in the Middle East

- AVIKOTE AV650 (same as Z-146 PC)
  - High Density, insulating inorganic coating (40 pcf - 640 Kg/m³)

- AVIKOTE AV800 (same as Z-156 PC)
  - Ultra High Density, insulating inorganic coating (50 pcf - 800 Kg/m³)
Features of Grace fireproofing products

- RWS, UL 1709, FM, Jet-fire* tested and approved products
- Lloyds Register approved for offshore installations
- Over 50 years of experience in fire protection, extensive track record
- The only products containing a special corrosion inhibitor
- Long term durability and excellent in-place “real” performances
- Explosion tested with 227 Kg (500 lb) of TNT placed 19 meters (20 yd) away
- Easy to trowel, to spray and to cast
- Application by Grace certified companies
- Worldwide technical service and presence

* 2 hrs according to HSE OTI 95634 with 2 tons of propane; >2 bar pressure; 45 m/sec velocity (49 yd/sec); 0.3 L/sec (10.6 ounce/sec) flow rate
Benefits of Grace fireproofing products

- Based on Bauxite (not poor aggregates like sand and vermiculite)
- Lightweight, about 65-75% lighter than regular concrete
- UL certified for exterior exposure under thaw/freeze cycles, rain, wind
- Superior bonding and mechanical characteristics
- Lower overall costs if compared to similar products
- Stock availability and speed of delivery anywhere in the world
- Low thermal conductivity
- Up to 25 mm (1 in) thickness per coat
- High yield rates
- Tested for cryogenic conditions
Benefits of Grace fireproofing products

• Non flammable and non combustible
• Asbestos, chlorides and sulphides free
• Suitable for upgrading regular concrete fire resistance
• No smoke and no gas generation during a fire
• Ready to use products – just add potable water
• Endothermic insulating coating with subliming characteristics
A steel plate coated with 25 mm (1 in) of Monokote Z-146 PC has been submerged for 60 minutes into a liquid nitrogen bath at a temperature of -198°C (-324 °F).

After 60 minutes the sample has been removed from the liquid nitrogen bath and allowed to return to ambient temperature.

The sample was tested for bond strength according to ASTM E-736.

RESULTS:

Bond strength values showed no significant difference between a sample submerged into liquid nitrogen and a sample not been submerged.

No degradation of material has been observed.
UL - exterior ambient exposure test

- **Accelerated Aging**
  - In a circulating air oven at 80°C for 135 days

- **High Humidity**
  - 35°C and 100% relative humidity for 180 days

- **Salt Spray Exposure**
  - Salt spray (fog) testing in accordance with the methods described in ASTM B 117-97 for 90 days

- **Cycling Effects of Freeze/Thaw**
  - Simulated rainfall of 18 mm/h for 72 h (extremely heavy rainfall)
  - Followed by a temperature of –43°C to –37°C for 24 h
  - Followed by a temperature of +57°C to +62 °C for 72 h
  - This cycle is repeated 12 times, so the entire test lasts 84 days

- **Industrial Atmosphere Exposure**
  - Gas contains 1% SO₂ (sulfur dioxide) and 1% CO₂ (carbon dioxide)
  - 30 days
Monokote includes a high density aggregate which contains water that is chemically released during a fire. Vermiculite is a soft and weak aggregate contained in many products. Sand is a high density poor aggregate contained in many products. Monokote is free from Vermiculite and Sand.
Mohs’ scale is used to measure the hardness of minerals

1- Talc
2- Gypsum
3- Calcite
4- Fluorite
5- Apatite
6- Orthoclase
7- Quartz
8- Topaz
9- Corundum (used for blasting metal)
10- Diamond

Vermiculite – 1.5 Mohs

Bauxite is 500% harder than Vermiculite

Bauxite – 9 Mohs

Soft - Scratched with a finger nail
Semi hard - Scored by a metal cutting tool
Hard - Not scored by a metal cutting tool
Melting points:

Bauxite: 2050 °C (3722 °F)
Vermiculite: 1350 °C (2462 °F)

Most typical uses:

Bauxite: refractory materials
Vermiculite: horticultural market (95%)

Abrasion:

Bauxite: low
Vermiculite: very high

Water/moisture absorption:

Bauxite: lower
Vermiculite: Higher

Fireproofing materials should have the lowest possible water/moisture absorption. Vermiculite based fireproofing contain as much as 30-40% vermiculite, leading to high water uptakes.
## Bauxite Vs. Vermiculite

<table>
<thead>
<tr>
<th>Manufacturer:</th>
<th>Product formulation based on:</th>
</tr>
</thead>
<tbody>
<tr>
<td>W. R. Grace</td>
<td>Bauxite</td>
</tr>
<tr>
<td>Monokote Z series</td>
<td></td>
</tr>
<tr>
<td>Carboline Pyrocrete’s range</td>
<td>Vermiculite</td>
</tr>
<tr>
<td>Cafco-Promat-Isolatek Fendolite MII</td>
<td>Vermiculite</td>
</tr>
</tbody>
</table>
Vermiculite drawbacks

- Extremely soft and weak
- Highly hygroscopic (attracting water and moisture)
- More prone to cracks generation and CUI/CUF issues
- Particles may contain certain levels of asbestos
- Particles cause severe eye irritation and coughing

MONOKOTE DOES NOT CONTAIN VERMICULITE
Why is the corrosion inhibitor relevant?

Galvanized wire mesh condition after just 5 years

Competitor’s product **without** corrosion inhibitor

Monokote Z-series **with** corrosion inhibitor
Why is the corrosion inhibitor relevant?

One of the main purposes of using a metal mesh is to hold in place the fireproofing product during a fire and/or during an explosion.

Corroded meshes cannot hold in place the fireproofing during a hydrocarbon fire because they have lost most of their original thickness through oxidation.

Consequently during a fire the fireproofing may be easily detached from the substrate leading to its temperature increase and structural collapse.
Why is the corrosion inhibitor relevant?

Monokote has been formulated with a unique and special Corrosion Inhibitor (DCI) capable of neutralizing high levels of chloride ion concentrations existing in potable waters.
Key features in fireproofing materials

LOOK FOR THESE KEY FEATURES WHEN SELECTING YOUR PASSIVE FIRE PROTECTION

High bond strength (= stronger cohesion and long term performance)
High hardness (= better impact resistance)
Low thermal conductivity (= lower heat transmission)
Corrosion inhibitor (= better corrosion protection)
High yield rates (= less material consumption)
High thickness per coat (= higher production rate)
Fully tested products (= maximum performance)
## Physical properties

<table>
<thead>
<tr>
<th>Product commercial name</th>
<th>Monokote Z-146 PC</th>
<th>Monokote Z-156 PC</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type</strong></td>
<td>High density</td>
<td>Ultra high density</td>
</tr>
<tr>
<td><strong>Minimum density when dry and in place</strong></td>
<td>640 Kg/m³ (40 pcf)</td>
<td>800 Kg/m³ (50 pcf)</td>
</tr>
<tr>
<td><strong>Bond Strength, recommended values</strong></td>
<td>4.9 Kg/cm² (10,000 psf)</td>
<td>4.9 Kg/cm² (10,000 psf)</td>
</tr>
<tr>
<td><strong>Bond Strength, independent laboratory test</strong></td>
<td>8.8 Kg/cm² (17,967 psf)</td>
<td>&gt;13 Kg/cm² (&gt;26,536 psf)</td>
</tr>
<tr>
<td><strong>Shore D hardness, recommended values</strong></td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td><strong>Shore D hardness, independent laboratory test</strong></td>
<td>49</td>
<td>91</td>
</tr>
<tr>
<td><strong>Compressive strength at 10% deformation, recommended values</strong></td>
<td>35 Kg/cm² (500 psi)</td>
<td>60 Kg/cm² (850 psi)</td>
</tr>
<tr>
<td><strong>Compressive strength at 10% deformation, independent laboratory test</strong></td>
<td>38 Kg/cm² (541 psi)</td>
<td>74 Kg/cm² (1,059 psi)</td>
</tr>
<tr>
<td><strong>Corrosion Inhibitor</strong></td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td><strong>Type of aggregate</strong></td>
<td>Bauxite (hard aggregate)</td>
<td></td>
</tr>
<tr>
<td><strong>Yield rate per bag (theoretical)</strong></td>
<td>39 m² at 1 mm (16.7 ft)</td>
<td>31 m² at 1 mm (13.3 ft)</td>
</tr>
</tbody>
</table>
Thickness of Monokote depends upon:

- Fire rating (up to 4 hours)
- Standard adopted (UL 1709, BS 476, LLOYDS, etc.)
- Section factor of the element (massivity)
- Critical temperature (usually 538°C or 1000 °F)
### Monokote vs. epoxy intumescents

<table>
<thead>
<tr>
<th>Product commercial name</th>
<th>CEMENT BASED</th>
<th>EPOXY INTUMESCENT</th>
<th>KEY DIFFERENCES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monokote Z-146 PC</td>
<td></td>
<td>Several</td>
<td>-</td>
</tr>
<tr>
<td>UL 1709 - avg. 2 hours fire rating</td>
<td>28.5 mm (1 1/8&quot;)</td>
<td>15 mm (10/16&quot;)</td>
<td>-</td>
</tr>
<tr>
<td>Density</td>
<td>640 Kg/m³ (40)</td>
<td>1200 Kg/m³ (75 pcF)</td>
<td>Intumescents over 87% higher density than Monokote</td>
</tr>
<tr>
<td>Average weight per square meter applied at given thicknesses</td>
<td>18.5 Kg (40.8 lb)</td>
<td>18 Kg (39.7 lb)</td>
<td>Intumescents only 3% less weight per m² than Monokote</td>
</tr>
<tr>
<td>Average waste during application (i.e. H section)</td>
<td>7%</td>
<td>25%</td>
<td>Intumescents waste 57% higher than Monokote</td>
</tr>
<tr>
<td>Average cost of product</td>
<td>1 €/Kg (0.66 $/lb)</td>
<td>13 €/Kg (8.75 $/lb)</td>
<td>Intumescents cost 1200% more than Monokote</td>
</tr>
<tr>
<td>Average product cost per square meter considering waste + mesh</td>
<td>€ 20 (29.67 $)</td>
<td>€ 295 (437.6 $)</td>
<td>Intumescents cost per m² 1375% more than Monokote</td>
</tr>
</tbody>
</table>
## Monokote vs. epoxy intumescents

<table>
<thead>
<tr>
<th>Features</th>
<th>Monokote</th>
<th>Epoxy Intumescents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product, application &amp; labor cost</td>
<td>lower</td>
<td>higher</td>
</tr>
<tr>
<td>Sound absorption properties</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Ease of maintenance</td>
<td>easy</td>
<td>complicated</td>
</tr>
<tr>
<td>Maximum hydrocarbon fire resistance</td>
<td>4 hours</td>
<td>3 hours for most</td>
</tr>
<tr>
<td>Maximum jet-fire resistance</td>
<td>2 hours</td>
<td>30-45 minutes</td>
</tr>
<tr>
<td>Hardness Shore D</td>
<td>up to 90</td>
<td>up to 55</td>
</tr>
<tr>
<td>Maximum RH% allowed during application and curing</td>
<td>90%</td>
<td>70-75%</td>
</tr>
<tr>
<td>Compatibility with existing primer</td>
<td>yes, most likely</td>
<td>no, in most cases</td>
</tr>
<tr>
<td>Primer applied at specified thickness range</td>
<td>no</td>
<td>yes (3-5 mils)</td>
</tr>
<tr>
<td>Concerns about primer maximum over-coating window</td>
<td>no if proper lath is used</td>
<td>yes, always</td>
</tr>
<tr>
<td>Smoke and gas generation during a fire</td>
<td>no</td>
<td>yes (HCL, CO, NH3)</td>
</tr>
<tr>
<td>Application in closed spaces</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Minimum ambient temperature during application and curing</td>
<td>5°C (40 °F)</td>
<td>10°C (50 °F)</td>
</tr>
<tr>
<td>Primer approval</td>
<td>generally not required</td>
<td>yes, always mandatory</td>
</tr>
<tr>
<td>Maximum thickness per coat</td>
<td>25 mm (1”)</td>
<td>7 mm (1/4”)</td>
</tr>
<tr>
<td>Application over hot dip galvanized steel without tie-coat</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Fire performance over CHS</td>
<td>high</td>
<td>low</td>
</tr>
<tr>
<td>Application in shop with on-site erection</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Degradation over time</td>
<td>no</td>
<td>yes, due to the epoxy nature</td>
</tr>
<tr>
<td>Thermal conductivity</td>
<td>lower</td>
<td>higher</td>
</tr>
</tbody>
</table>
• Sublimation requires a phase change from a solid state into a gas, absorbing large amounts of energy in the form of heat
• One of the main characteristics of sublimation is that it is an endothermic process
• When Monokote is exposed to fire it enters an endothermic process similar to sublimation because the binder absorbs heat as the chemical water is converted from its crystal structure into a vapor gas
• Unlike epoxy subliming/intumescent products which are totally sacrificial because they are physically consumed as they absorb heat (leaving less protection to the steel over time), Monokote undergoes the endothermic process retaining most of its original thickness, and therefore providing better and longer protection to the steel during a fire through its tough insulating coating.
Surface finishing

- The most typical application requires a smooth surface finish. The finish facilitates subsequent cleaning, is easily paintable and provides a ‘concrete like’ appearance. Top-coating with acrylic, epoxy and polyurethane paints according to specific requirements.
- Texture can be attained by adjusting the nozzle orifice size, air pressure, and product density. These adjustments will give different degrees of finished texture.
A typical protective system resistant to corrosion and fire depends very much upon the environmental corrosion class as specified by ISO 12944-2. Every case should be evaluated specifically, nevertheless a typical example could be:

- One coat of zinc rich epoxy or zinc phosphate primer
- One coat of high build epoxy coating (optional)
- Monokote Z series
- A topcoat in any RAL color, such as acrylic, epoxy or a polyurethane coating (topcoat is optional)
A typical protective system resistant to corrosion and fire depends very much upon the environmental corrosion class as specified by ISO 12944-2. Every case should be evaluated specifically, nevertheless an example could be:

- One coat of zinc rich epoxy or zinc rich silicate primer*
- One coat of high build epoxy coating or epoxy tie-coat*
- Monokote Z series
- A topcoat in any RAL color, such as epoxy or polyurethane
A look at Corrosion Under Insulation

Carbon steel is more prone to CUI when operating at temperatures between -4°C (25 °F) up to 150°C (300 °F). More specifically CUI is also called CUF (Corrosion Under Fireproofing)

CUI starts when water, moisture or other electrolytes penetrate into the anticorrosive primer down to the substrate.

The continuous wet/humid condensation processes taking place beneath the primer will dramatically increase the corrosion rate of the substrate.
How to face CUI over carbon steel

CUI on carbon steel can be limited, and in most cases even solved, by specifying a proper anti-corrosive system.

When CUI is suspected to take place, the use of zinc rich silicate primers should be avoided if possible, or alternatively they should be protected with an epoxy tie-coat because these products show very critical performances in wet/humid confined conditions.

Last but not least, a good quality application along with a good maintenance program are the best tools to keep the integrity of the total protective system. More details on CUI/CUF prevention can be found on NACE RP 0198-98 standard.
Durability of inorganic products

- Bauxite inorganic products with DCI (Monokote Z)
- Vermiculite/Perlite inorganic products
- Gunite
- Concrete

Quality and fire performance:
- High
- Low

Durability and life expectancy:
- Low
- High
4 easy steps for application

1. MONOKOTE
2. WATER

MIXING

APPLICATION

3. PLASTERING MACHINE

4.
## Benefits of using Monokote Z series

<table>
<thead>
<tr>
<th>For the Engineering Company</th>
<th>For the PFP Contractor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fully tested products with proven in-place reliability</td>
<td>High yield rates (less material consumption)</td>
</tr>
<tr>
<td>Production facilities with top quality manufacturing control</td>
<td>Ease of application even in high-rise installations (lower labor cost and high production rate)</td>
</tr>
<tr>
<td>Highest life expectancy</td>
<td>Products far less abrasive than vermiculite based products (longer life for equipments)</td>
</tr>
<tr>
<td>New generation products that can also be used instead of epoxy intumescent</td>
<td>High thickness per coat (higher productivity)</td>
</tr>
<tr>
<td>Global products availability and technical assistance</td>
<td>Stock availability</td>
</tr>
<tr>
<td>Excellent physical properties of Monokote Z series. New generation products</td>
<td>Speed of deliveries</td>
</tr>
<tr>
<td>You will have qualified professionals helping you defining pfp specifications</td>
<td>Competitive prices</td>
</tr>
<tr>
<td>Grace balanced business and financial stability</td>
<td>Regular training offered by Grace</td>
</tr>
<tr>
<td>Choosing Grace systems means getting maximum performance and cost-savings</td>
<td>Lower overall costs when compared to any other fireproofing system</td>
</tr>
<tr>
<td>Choosing Grace means getting a complete service rather than just products</td>
<td>Single source supplier (paints, lath, fixing devices)</td>
</tr>
</tbody>
</table>
... just a few references

<table>
<thead>
<tr>
<th>Company</th>
<th>Company</th>
<th>Company</th>
</tr>
</thead>
<tbody>
<tr>
<td>Repsol</td>
<td>Kuwait Oil</td>
<td>Sasol</td>
</tr>
<tr>
<td>Lukoil</td>
<td>Avon Chemicals</td>
<td>World Trade Center</td>
</tr>
<tr>
<td>Agip (ENI)</td>
<td>Mobil Aimcor</td>
<td>UN buildings</td>
</tr>
<tr>
<td>Esso</td>
<td>Qatar Gas</td>
<td>Enagas</td>
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<tr>
<td>Shell</td>
<td>Emirates Gas</td>
<td>Fluor</td>
</tr>
<tr>
<td>Hyundai</td>
<td>QP Refinery</td>
<td>Saipem (ENI)</td>
</tr>
<tr>
<td>LG</td>
<td>Gasco, Foster Wheeler</td>
<td>OPF Shakalin</td>
</tr>
<tr>
<td>Samsung</td>
<td>Laffan Refinery</td>
<td>Infineum</td>
</tr>
<tr>
<td>Abu Dhabi Gas</td>
<td>Texaco</td>
<td>... and others</td>
</tr>
<tr>
<td>Q-Chem</td>
<td>Aramco</td>
<td></td>
</tr>
</tbody>
</table>
Ing. Giuseppe de Luca
Sales Development Manager - Fireproofing EMEA
Grace Construction Products
SSPC Certified P/C Specialist – Frosio Certified Coatings Inspector Level III

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