

Superwool® Plus and Superwool Prime Low Biopersistent Fibres Portfolio



Thermal Ceramics

Innovative,
low biopersistent,
market leading
Superwool® Products

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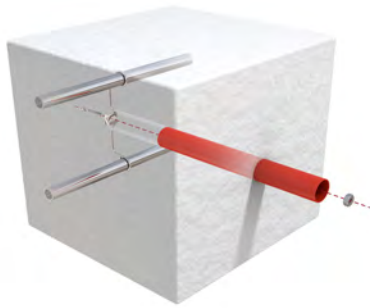
Thermal Ceramics

We innovate to meet the challenges of a changing world

The Thermal Ceramics business of Morgan Advanced Materials makes advanced ceramic products and systems for thermal insulation in high-temperature environments. We engineer products and systems for equipment in demanding applications and for the safety of people.

Our portfolio and engineering capabilities help customers, especially those operating energy-intensive processes, to reduce energy consumption, emissions, and operating costs.

At Morgan, our purpose is to use advanced materials to help make more efficient use of the world's resources and improve the quality of life. To extend the application's life cycle, we enable people and processes to be safer and more energy efficient.



Safe and Reliable Products

Our products and systems protect lives and processes 24 hours a day and 365 days of each year.



A Truly Global Footprint

We have operations on 5 Continents and in 30 Countries to efficiently serve our Customers.



Commitment to Innovation

For you, for us, for our people and our planet our commitment to innovation is paramount in all we do.



Trusted Engineering Services

Our global resources and dynamic engineering services efficiently support our Customers application demands.

Superior thermal management solutions
Enabling sustainability and safety of
people and processes



Why Superwool[®] Fibres

Low biopersistence

- Helps you be compliant with meeting your environmental and Health & Safety obligations
- An environmental solution, potential savings on waste disposal, may be disposed in a non-hazardous waste landfill

Higher energy savings compared to RCF and other commercial AES fibres

- Up to 30% lower thermal conductivity than other tested AES blanket materials

Improved handling

- Soft and smooth material improving operator comfort
- Less irritation to the skin, throat, nose and eyes

Longer life time

- 30% more fibres result in improved, stronger fibre matrix and thus longer life time under vibration conditions
- Lowest shrinkage of any comparable insulation up to its classification temperature

Benefits and Features from our two chemistry grades

- Lower thermal conductivity, improves insulation by 20% compared to other tested AES fibres
- Up to 30% more fibres due to low shot content, efficient prevention of heat transfer and greater strength
- Improved handling, operator satisfaction

Superwool[®] Plus
Insulating fibre

Superwool[®] Prime
Energy | Emissions | Environment

What are Superwool Low Biopersistent Fibres

Our Superwool Plus and Superwool Prime are patented low biopersistent insulating high performance fibres offering a versatile alternative to traditional insulation materials for industrial, transportation and commercial applications.

Morgan's pioneering development in low biopersistent fibres have led the revolution in their use for high-temperature insulation applications over the last 20+ years.

Exonerated globally from classification, Superwool Plus and Superwool Prime products manufactured by our Thermal Ceramics business, using ISO 9002-certified processes, are uniquely engineered to offer advantages in high-temperature insulation applications:

Classification Temperatures:

- Superwool Plus Fibres 1200°C (2192°F)
- Superwool Prime Fibres 1300°C (2372°F)

Key features, benefits and value to our Customers when choosing Superwool Plus and Superwool Prime products:

- Up to 30% lower thermal conductivity improves heat storage, reducing cold face and may possibly save space by reducing lining thickness
- Classification temperature up to 1300°C (2372°F) various application options and performs well in both high temperature and cyclical processes
- Excellent flexibility, tensile strength and handleability due to its chemistry and manufacturing technologies resulting in low shot content
- Global manufacturing footprint meets regional supply demands
- Low biopersistent fibre benefits safety of people handling materials due to chemistry
- Engineering global services and support through application performance evaluation, thermal lining performance and heat flow calculations and design to meet or exceed your process demands



Value to our Customers Processes

- Improved energy efficiency and fuel savings
- Reducing CO₂ emissions
- Improve operational costs and overall performance
- Design flexibility and variety of application opportunities
- Improved total cost of ownership
- Local supplier relationships and engineering team support

Blankets

Superwool® Plus and Superwool Prime Blankets offer a high temperature thermal insulation material, efficient at restricting heat flow, while maintaining other key material properties such as low shrinkage and good mechanical durability.

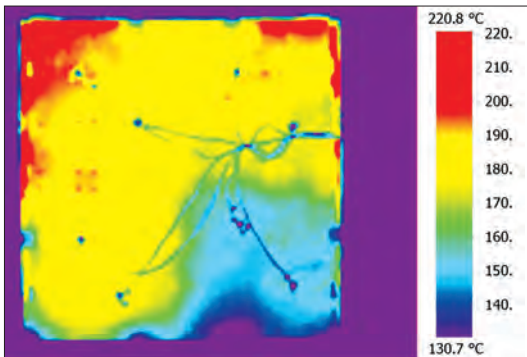
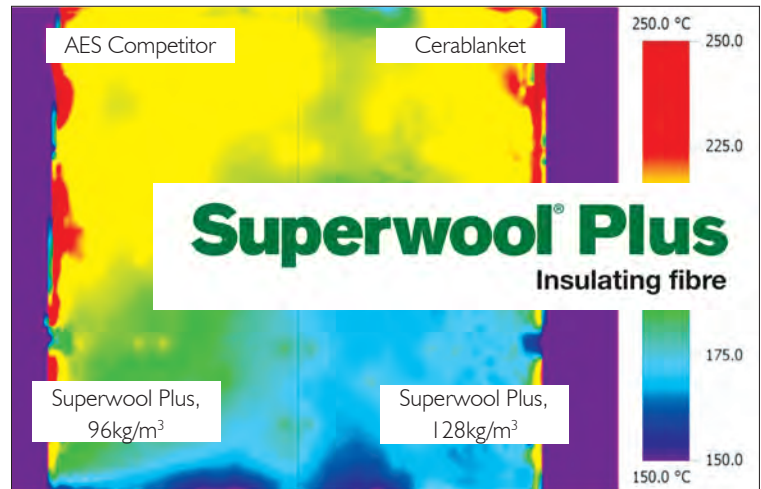
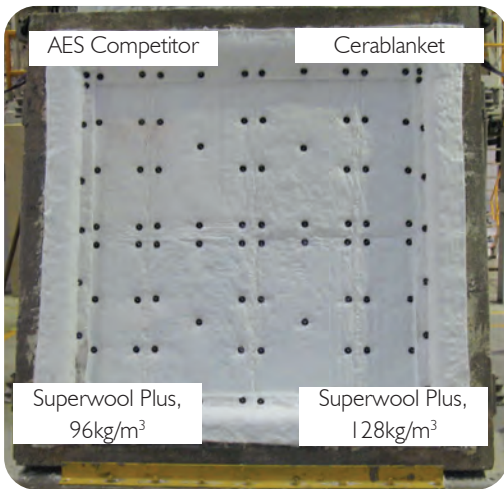
- Reduces energy loss due to higher fibre index and reduced fibre diameter resulting in greater surface area
- With greater fibre surface area more insulating material for energy to pass through
- Resulting in reduced energy losses and better thermal insulation

Lower thermal conductivity with improved insulation by 20% compared to other tested AES blanket materials.

- Energy savings. Material weight savings up to 25%
- 20% lower thermal conductivity than other tested AES blanket materials
- Lower thermal conductivity with lower density comparisons



The results outline the thermal insulation superiority of Superwool Plus fibre with energy savings up to 25%.



The panel was heated to a temperature of 1000°C for 2 hours until steady state was achieved. Thermocouples were placed on the cold face (casing) of the 4 zones to follow the temperature evolution in real time.

On the same panel, 1 m² blanket was installed with 4 different insulation layers:

2x25mm	128kg/m ³	Competitor AES blanket
2x25mm	128kg/m ³	Cerablanket® RCF
2x25mm	96kg/m ³	Superwool Plus blanket
2x25mm	128kg/m ³	Superwool Plus blanket

- Superwool Plus Blanket 128kg/m³ provides a significantly lower cold face temperature than a 128kg/m³ competitor AES Blanket and Cerablanket RCF
- Superwool Plus Blanket 96kg/m³ provides a lower cold face temperature compared to a 128kg/m³ Competitor AES Blanket and Cerablanket RCF

Thermal Performance Benchmarking

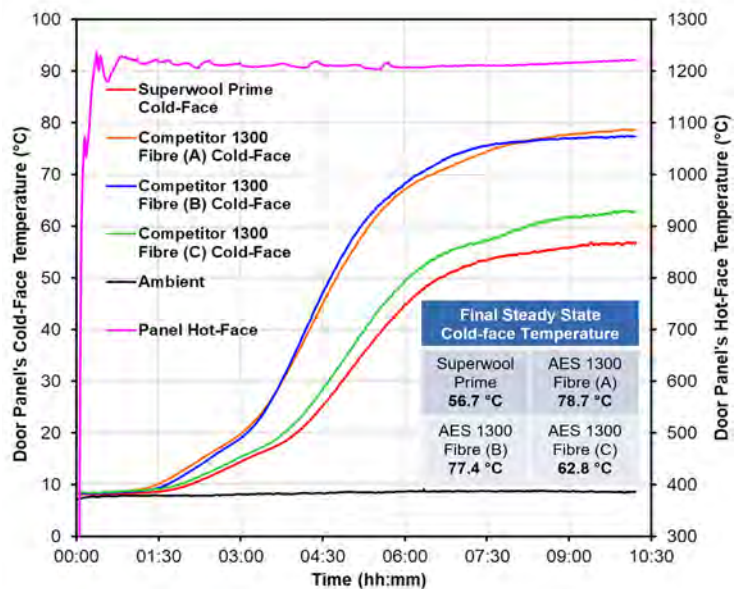
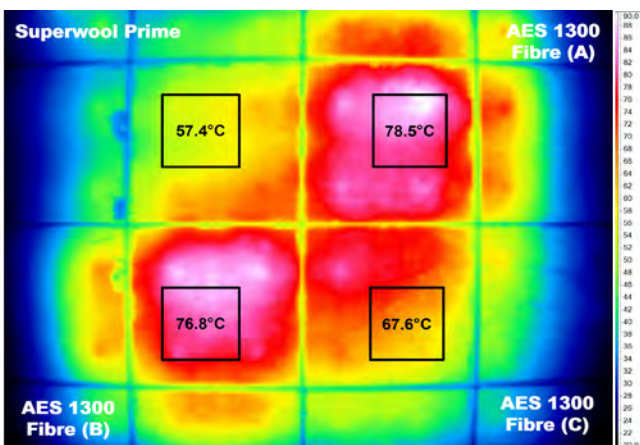


The newest evolution in our Superwool low biopersistent fibre portfolio, Superwool Prime is developed for high-performance applications with a classification temperature of 1300°C (2370°F).

Superwool Prime features physical and thermal performance equivalent or better to our market leading Superwool Plus.

- High-temperature capability providing **increased resiliency for processes and safety of employees**
- Superior thermal conductivity: 0.28 W/m•K, 1000°C, 128 kg/m³ (2.25 BTU•in/hr•ft²•°F @ 2000°F), **18% lower** than Superwool HT
- Excellent handleability, flexibility and tensile strength due to low shot fibre technology and chemistry

A panel test at our Fibre Center of Excellence was completed to compare the real-world thermal performance of blanket-stack modules made from Superwool Prime with 1300°C (2370°F) grade LBP fibre insulation with market competition.



- The thermal image above illustrates, through colour, transitioning from the blue of the cold face panel to formed hot spots in red/pink on the panel.
- All modules used in panel tests were 300mm (12in) thick, 182 kg/m³ (11.4 pcf) density installed using the M-type anchors. No backup insulation.

Applications



Ceramics and Glass

- Float glass pre-heating and start-up covers
- Kiln expansion joints, roof and wall Insulation
- Back-up applications



Metals

- Annealing furnace doors
- Ladle side gate insulation
- General heat containment
- Coke oven repairs
- Furnace linings



Consumer Goods

- Chimney insulation for gas fireplaces
- Oven wrap insulation
- Insulation for boilers and water heaters

Modules

Pyro-Bloc® Modules set the standard for superior performance and versatility in furnace and boiler lining systems; they excel in cyclic environments.

Pyro-Bloc Modules comprise two sections of Superwool® fibre slabs in edge-grain orientation. These are held in position with two stainless steel tubes mounted transversely through the modules and remote from the hot face and they are anchored to the furnace casing with the patented Pyro-Bloc hardware. Pyro-Bloc Modules contains an agent which automatically hardens the surface upon initial heat up.

- Unlike folded or stack modules, Morgan's Thermal Ceramics exclusive Pyro-Bloc modules can be compressed in two directions, across and along the module. This reduces the need for additional batten strips and increase natural resistance to natural shrinkage, enhanced by Superwool Pyro.
- Better resistance than folded systems to high velocity gas erosion thanks to the monolithic edge grain surface. Pyro-Bloc is rated to 30.5m/sec (100 ft/sec) untreated. Treatments can improve this rating up to 35%.
- Ease of installation: the patented support yoke system allows the module cold face to conform to any discontinuity of the furnace shell allowing easy installation and high on-the-wall densities.
- 20% better thermal efficiency than like density RCF products resulting in energy savings and safer work environment.
- High longevity due to improved linear shrinkage vs. RCF Pyro-Bloc up to classification temperature and multi-directional compression.



HRSB Application: Pyro-Bloc Modules withstand higher gas velocity than other insulating materials



Insulation CHALLENGE:

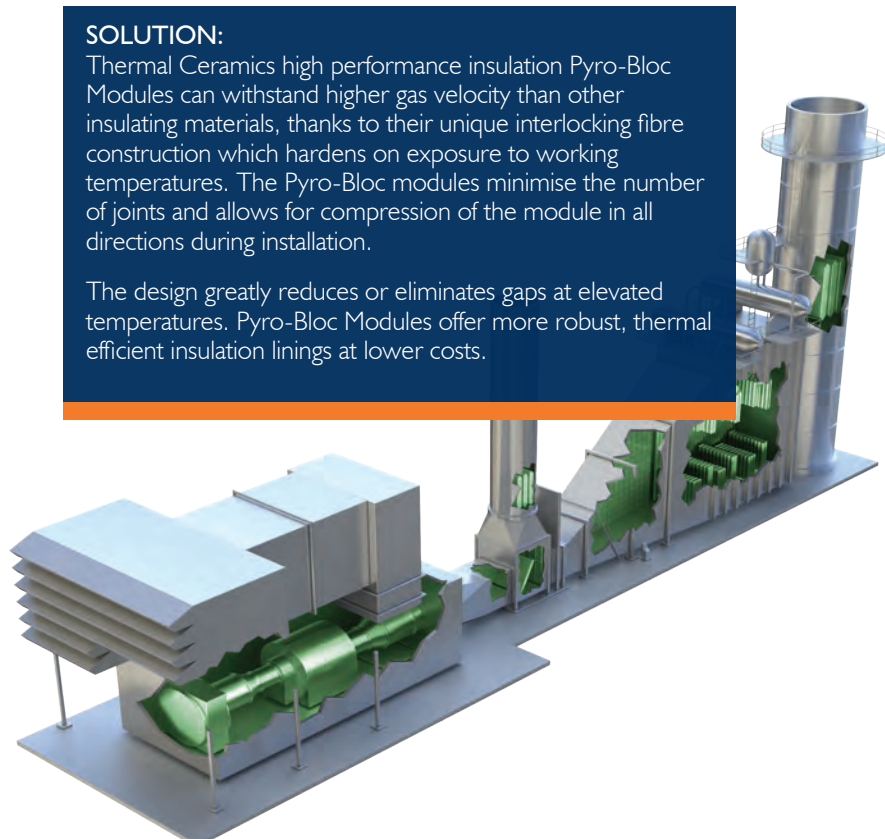
The possibility of hot spots in the HRSB boiler lining caused by erosion of the insulation blanket under harsh conditions of high gas velocity 20-30m/s (66-98ft/s) and high-temperatures 600 - 700°C (1112 - 1292°F).

Traditionally, a stainless steel shroud is installed as a lining to protect the boiler insulation from direct contact with the high velocity gas. This is expensive and requires the use of steel studs, which transfer heat and vibration to the boiler casing.

SOLUTION:

Thermal Ceramics high performance insulation Pyro-Bloc Modules can withstand higher gas velocity than other insulating materials, thanks to their unique interlocking fibre construction which hardens on exposure to working temperatures. The Pyro-Bloc modules minimise the number of joints and allows for compression of the module in all directions during installation.

The design greatly reduces or eliminates gaps at elevated temperatures. Pyro-Bloc Modules offer more robust, thermal efficient insulation linings at lower costs.



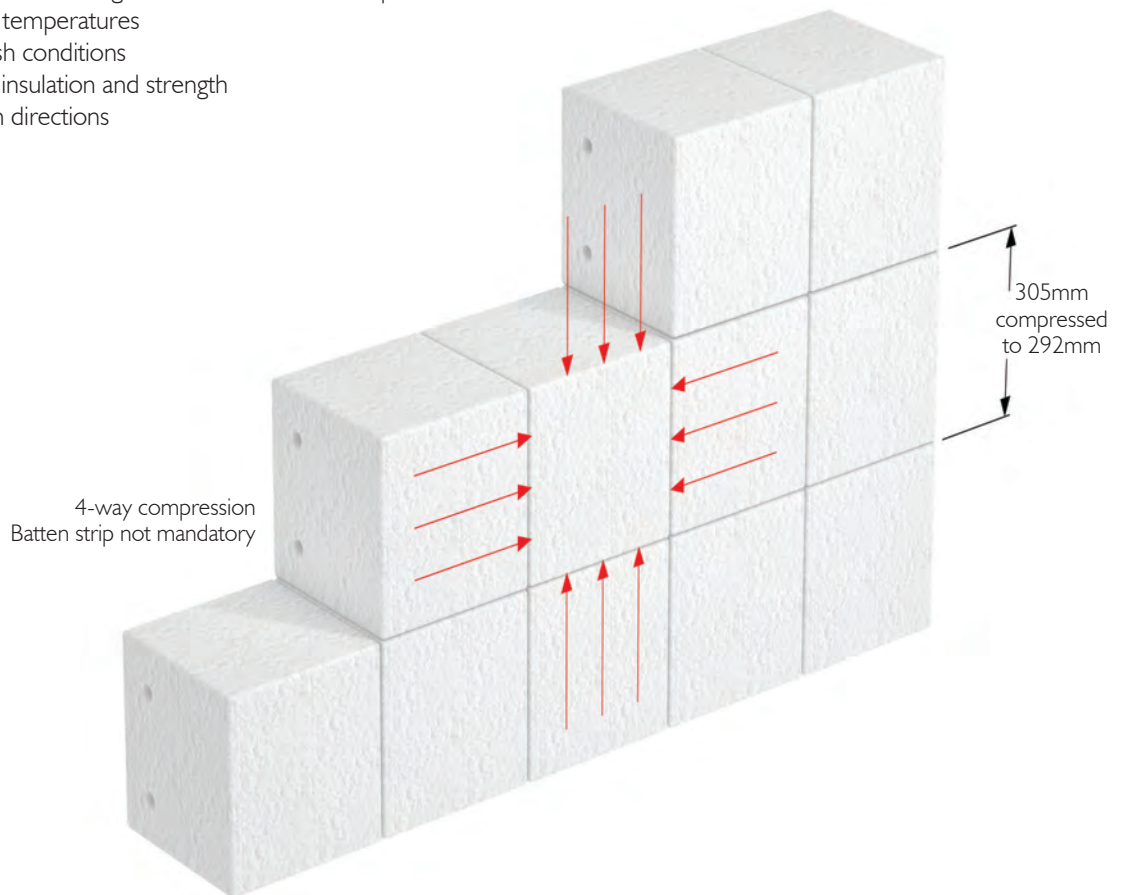
Features and Benefits

Made from Pyro-Log™ Superwool in edge-grain orientation offers high temperature insulation.

- 20% better thermal efficiency
- Excellent resistance to gas velocity
- Modular format for rapid, cut-to-fit field installation
- Resilient and compressible during installation but hardens upon exposure to working temperatures
- High longevity in harsh conditions
- High density for best insulation and strength
- Compressible in both directions

Superwool® Plus
Insulating fibre

Superwool® Prime
Energy | Emissions | Environment



Applications



Metals

- Annealing furnace doors
- Reheat and Heat treating furnace
- Carbonizing and lift-off furnaces



Power Generation

- Co-generation ducts and silencers



Petrochemical and Refinery

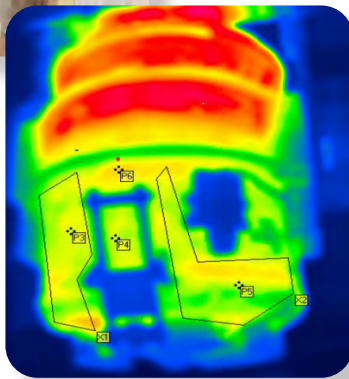
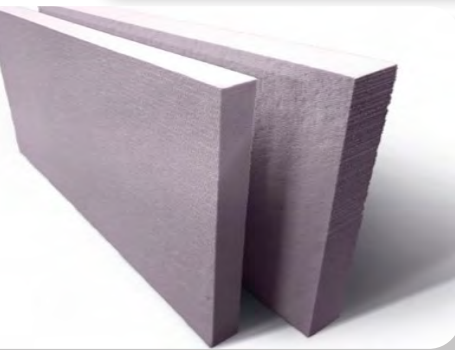
- Process heaters
- Reformers
- Ductwork
- Pyrolysis heaters

Boards and Shapes

Our Superwool Plus and Prime Vacuum-Formed Boards and Shapes cover an entire temperature and mechanical strength range.

With excellent insulating performance and high-temperature strength, they can be custom designed for various uses.

- Excellent thermal shock resistance
- Superior insulating performance, excellent molten metal resistance
- Low heat storage
- Dimensional stability up to 1300°C (2372°F)
- Linear shrinkage below 2% at recommended continuous use limits



Our new Superwool I 650SI Board ensures the highest efficiency for back-up insulating systems. The main benefits include:

- Reduce shell temperature and thermal strain on the ladle
- Reduced heat loss (lower energy costs)
- Possible to reduce safety lining thickness due to enhanced insulating performance
- Extends holding time and operations
- Reduced preheating time
- Reduced skull formation

When compared to alternative structural insulation products, the Superwool I 650SI Board offers a considerable reduction in cold face temperature, which results in reduced heat loss and contributes to reduced CO₂ emissions.



Custom shape technology allows for male, female, and combination moulds that are constructed from plastics, stainless steel, wood, and fasteners.

Applications



Metals

Benefits using Superwool for hot pour ladles:

- Reduced thermal conductivity
- Embedded handle to reduce iron contamination of aluminum melt
- Environmentally better working environment for the workforce

Papers, Felts, Mastics and Textiles

Morgan's high performance paper and felt products are the preferred choice over traditional fiberglass, textile, or metal products for thermal, acoustical or filtration management.

Our QS 9000/ISO 9002 certified quality, lightweight papers and felts feature equal or superior performance with reduced costs, low thermal conductivity, durability, compressibility and flexibility.

Superwool Papers

- Bespoke specialty papers for battery systems that mitigate thermal runaway
- Intumescent, expandable papers (up to 400%) with a continuous use limit of 704°C
- Non-wetting to molten aluminium
- Flexible tear resistant paper with a use limit of 1150°C

Superwool Felts

- Superwool Felts are insulating, strong tensile strength and handleability

Superwool Mastics, Coatings and Cements

- An extensive range of pumpables, mouldables, cements and coatings

Superwool Textiles

- Superwool Textiles are uniquely suitable for temperatures covering up to 1370°C
- Range of forms with either glass or steel reinforcements

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Applications

Non Ferrous

- Aluminum casting tip fabrication
- Backup for aluminum troughs
- Metal transfer parts
- High temperature seals and gaskets

Ceramic and Glass

- Glass tank refractory backup
- Glassware separator/parting agent
- Glass sagger mold linings

Consumer Goods

- Appliance/radiant heater insulation
- Fireplace
- Gasketing

Metal Working

- Investment casting mould wrap
- Ladle refractory backup
- Parting agent in brazing, heat treating and metal forming processes
- High-temperature expansion joint packing, filtration, gaskets and seals

Automotive and Aerospace

- Heat shields
- Battery separators
- Muffler insulation
- Airbag filtration
- Catalytic converter

Environmental, Health and Safety

Our Superwool brand is globally recognised as the leading brand in high temperature low biopersistent fibre insulation, noted for its reliability and environmental benefits.

Our commitment to research and development ensures we continue to deliver Superwool fibre products enabling you to be proactive in meeting your environmental and health and safety (EHS) obligations and ensuring the Superwool brand continues to succeed for you.

A key component in achieving effective EHS performance is to meet governmental, regional and worldwide legislation. At Morgan Advanced Materials we are dedicated to ensuring the requirements of REACH legislation (Registration, Evaluation, Authorisation and Restriction of CHemicals) and are actively working towards achieving ISO 14001 accreditation for the environment management systems in our worldwide locations.

Our aim is to:

- Comply with environmental, health and safety legislation, regulations and other applicable requirements through communications, and establishing measurement controls for continual monitoring in our production process.
- Minimize the environmental impact of historic, current and likely future operation.
- Conduct operations in such a manner as to avoid unacceptable risk to human health and safety.
- Supply products that reduce risk to human health and safety when used in compliance with product safety communications and common practices.
- Set objectives for the continuous improvement of environmental, health and safety performance.

Superwool fiber products enabling you to be proactive in meeting your environmental and health and safety obligations



Superwool regulation by region

	European Union (EU)	United States & Canada	Asia & Australia
Classification of Superwool portfolio	<ul style="list-style-type: none"> • Alkaline Earth Silicate • Not RCF 	<ul style="list-style-type: none"> • Alkaline Earth Silicate • Not RCF 	<ul style="list-style-type: none"> • Alkaline Earth Silicate • Not RCF
Superwool stats	<ul style="list-style-type: none"> • Fully exonerated from any carcinogen classification in the EU under the Provisions of Directive 97/69/EC 	<ul style="list-style-type: none"> • Viewed as nuisance dust • May cause temporary, mild mechanical irritation to the eyes, skin, nose, throat 	<ul style="list-style-type: none"> • Not classified as hazardous • Viewed as a nuisance dust or in same category as rockwool and glass wool (general MMVF)
PEL / Regulatory Control	<ul style="list-style-type: none"> • No PEL • Not regulated 	<ul style="list-style-type: none"> • No PEL • Not regulated 	<ul style="list-style-type: none"> • Not regulated • Some countries (China/Australia) have OELs in place

PEL : permissible exposure limit

OEL : occupational exposure limit

Fraunhofer Exoneration Statements

Testing and Classification of Superwool Prime Fibres

Superwool Prime is exonerated and here is why.

Superwool Prime is the newest evolution of our Superwool Low Biopersistent Fibre (LBP) portfolio. Superwool Prime, is developed for high-performance applications with a classification temperature of 1300°C (2372°F). The chemistry of Superwool Prime fibre is sufficiently similar to our existing Superwool Alkaline Earth Silicate (AES) fibres that a new exoneration certification is not required.

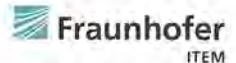
Historically several variations in chemistry under the Unknown of Variable Composition (UCVB) substance definition are tested using Note Q tests. Most commonly, the short term biopersistence test by intratracheal instillation is an example that includes chemistry that falls within the Superwool Plus and Superwool HT fibres.

In recent years Morgan has decided to minimise animal testing and look for alternatives wherever possible, following the principles of Regulation for Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) and the 3R's of animal testing.

Whilst the exact chemical range that Superwool Prime encompasses has not been subject to in vivo testing, it is essential to consider that Superwool Prime chemistry is within the chemical range accepted by European Chemicals Agency (ECHA) for the existing AES fibre registration and like other specific sub-chemistries that have already demonstrated low biopersistence. Re-analysis of what is ostensibly the same REACH registered UVCB substance by animal testing should not be taken lightly and is actively discouraged under the REACH testing requirements.

Instead, Morgan has used chemico comparisons between the chemistry variations to ensure a high degree of safety of marketed fibres and fulfil our duties to avoid unnecessary animal testing.

The physicochemical properties of fibre, including bio-durability, composition, size and shape, play a leading role in biopersistence and potential for retention in the lung. Significant differences in these properties may suggest divergence in biopersistence values and hence, the need for independent testing. However, where test samples show a high degree of similarity across critical parameters, then they are likely to behave in a very similar manner, limiting the justification for further testing, mainly where it requires animal testing.



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Hannover, March 3, 2018

Certificate

The biopersistence of fibres was investigated after intratracheal instillation within the following study:

Fraunhofer ITEM study no.: 02G99003C
Test substance: Superwool Plus (code name fibre 3)
Sponsor: European Ceramic Fibres Industry Association
Title: The biopersistence of high temperature insulation fibre 3 (CMS) in rats after intratracheal instillation

This animal study was conducted in compliance with the Principles of Good Laboratory Practice (German Chemicals Law § 19a Appendix 1 pp. 1724-1732, July 25, 1994, amended on May 14, 1997). The protocol of the European Commission (ECB/TM 27 Rev. 7, 1998) with slight changes according study protocol was followed.

The treatment of rats was performed in January 1999 by intratracheal instillation of a total dose of 2 mg per rat. The fibre retention data up to sacrifice date 3 months after instillation were used for analysis.

Following halftimes were calculated by the method according to the protocol of the European Commission:

WHO fibre fraction (L>5 µm, D<3µm, L/D>3/1): < 40 Days

In Germany, Man-Made Vitreous (Silicate) Fibres for high temperature applications (classification temperature > 1000°C) with more than 18% of sodium, potassium, calcium, magnesium and barium oxides do not fall under the production and use ban regulation (Appendix IV n° 22 of the German Dangerous Substances Act and Appendix to § 1 section 23 of the German Chemical Ban Regulation) if the WHO fibres halftime is less or equal to 65 days.

Long fibres fraction (length > 20 µm, L/D>3/1): < 40 Days

According to Guideline 87/548/EWG (revised by guideline 97/69/EC of the Commission dated 5. December 1997) Appendix Q the classification as carcinogenic material is not applicable for Superwool Plus because the halftime for fibres longer than 20 µm is less than 40 days in the biopersistence test by intratracheal instillation.

Prof. Dr. Uwe Heinrich
Executive director of Fraunhofer ITEM

Dr. Otto Creutzenberg
Deputy Study director

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Superwool Plus and Superwool Prime
are exonerated as a potential carcinogen under Note Q

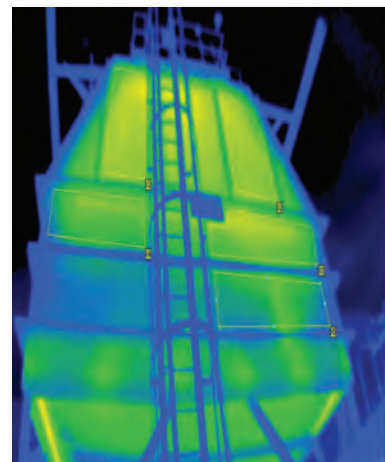
Applications Engineering

Our engineering capabilities are available across the globe to any of our business partners.

Each region has an Engineering Services team to support your unique business and application needs locally with the experience of a global network and resources.

A brief overview of our engineering services capabilities:

- Root cause and failure analysis
- Heat Transfer calculations for various surfaces and atmospheres, including proprietary thermal software modelling program
- CO₂ emissions saving analysis
- Detailed 2D and 3D modelling software providing detailed drawings and bill of material resources
- Proprietary high temperature testing regime for severe service brick linings
- Project Teams experienced for on-site supervisory to ensure quality of install and design



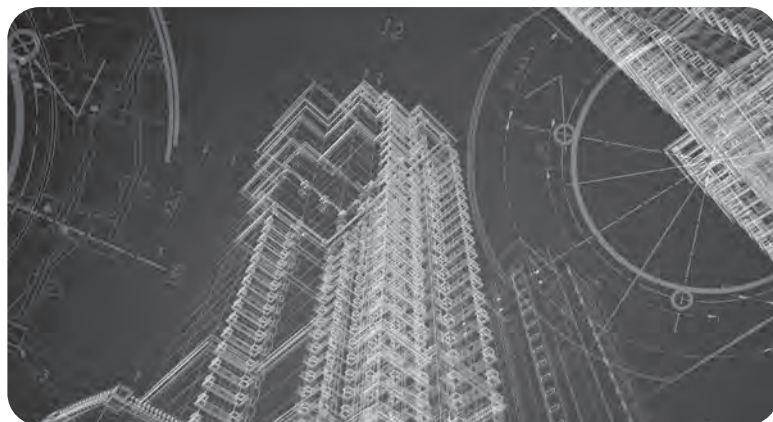
Our capabilities and services from design to material selection and to installation

Engineering Design and Collaboration

Integrated thermal management for effective process solutions.

As greater demands are made on industries to reduce greenhouse gas emissions, we partner to support the enhancements required to reach your commitments to reduce your carbon footprint.

Our engineering partnership begins with a conversation to understand the needs of your processes. From Petrochemical and Refinery to Power Generation to Energy Storage to Metals, our global and regional networks are here to support your application demands.



- Engineering Drawing and Design, 2D and 3D
- Material Selection
- Installation Supervision and Services
- Turnkey Service
- Thermal Imaging; Pre and Post Installation

Superwool[®] Prime
Energy | Emissions | Environment

Superwool[®] Plus
Insulating fibre

Thermal Management Simulation and Assessment

Infrared thermography inspection to validate assumptions and performance after installation. Assessment and simulation of your application process

Thermal Management Assessment, Simulation and Analysis for selecting the best material for the application, lining optimisation to identify energy and cost savings and for design comparison modelling.

Our thermal simulation capabilities include:

- Steady state heat flow calculation and steady state with non-typical atmosphere
- Transient (time-dependent) calculation
- FEA/CFD 3D Simulation
- Slow Cool Heat Flow

Lab technologies for testing materials including fibre, refractory and microporous product analysis.

When the situation presents, we offer failure analysis that provides:

- Thermal Shrinkage
- Chemical Attack
- Mechanical
- Wind Erosion

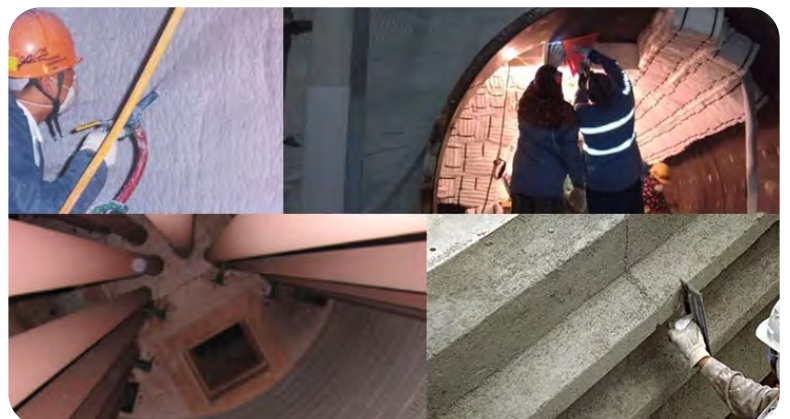
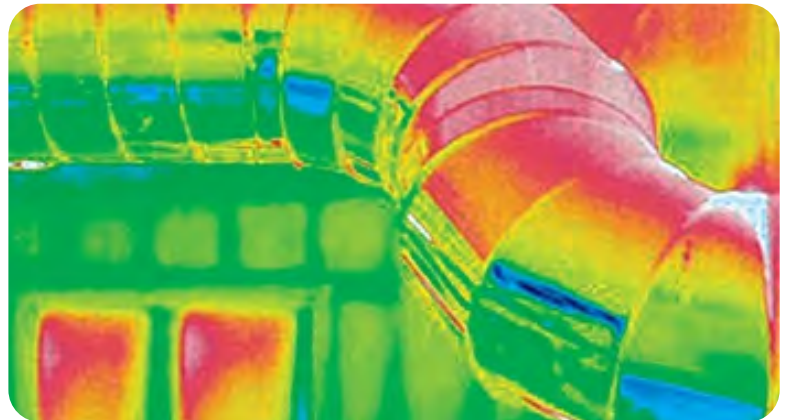
Installation Supervision and Services

Focused on construction driven execution capabilities throughout our collaborative partnership. Supporting through Installation.

From Petrochemical to Power Generation to Metals to Ceramics applications our network of installation supervisors and teams are able to support your project locally or globally.

Service continues through process start-up to provide installation inspection and assessment through infrared imaging.

Ensure installation to specification with correct installation techniques by partnering with your local Morgan team.



Integrated thermal management for effective design,
material selection and installation

Morgan Advanced Materials

Significant trends shape our modern world, accelerating the demand for new and more sustainable advanced materials.

At Morgan Advanced Materials, we use advanced carbon and ceramics materials to support the move to a more sustainable world. Our people are driven to solve complex customer problems: from managing heat and enabling greener technologies, to supporting improved medical diagnostics and protecting life.

Our purpose is 'to use advanced materials to make the world more sustainable, and to improve the quality of life'. This purpose is underpinned by our safe, ethical and inclusive culture, embraced by our 7,800 employees spanning over 25 countries. Working across many industries and in a number of markets, we deliver the materials science and technologies the world needs now.

Our Strategy

We are a global advanced manufacturing organisation with leading capabilities in three areas: materials science, application engineering and customer focus.

Our Business Model

We operate as two global divisions and five global business units. We empower our global business unit teams, giving them considerable autonomy and enabling them to act quickly and support their customer needs. Our broad manufacturing footprint enables us to supply customers locally from a short supply chain.

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