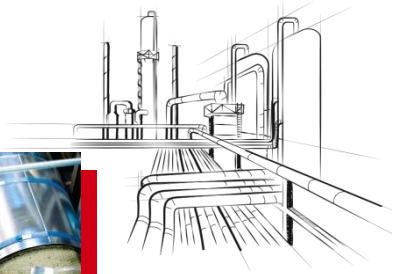
Corrosion Under Insulation - and The Insulation Systems



ROCKWOOL

ProRox | SeaRox

TECHNICAL INSULATION

Who is ROCKWOOL?

- The ROCKWOOL Group is the world's leading supplier of innovative products and systems based on stone wool
- Insulation production started in 1937 near Copenhagen, Denmark

80TH ANNIVERSARY

Release the natural power of stone to enrich modern living

ROCKWOOL

ProRox | SeaRox | TECHNICAL INSULATION

Our Purpose

This simple statement means a lot to us. It marks a shift in how we describe ourselves, it's about why we do what we do as well as how.

ROCKWOOL

Fire safe insulation for all types of buildings and installations
– Building insulation
– Technical insulation
– Core solutions

Grodan

Precision Growing for the horticultural industry

Lapinus

Engineered stone wool for composite applications, noise and vibration control, and water management

Rockfon

Acoustic ceiling and wall solutions

Rockpanel

Exterior cladding for buildings

We unlock potential

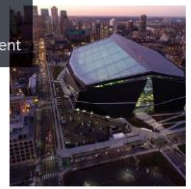
Natural power is:
– Self-sustaining
– Resilient
– Inexhaustible

Release the natural power of stone to enrich modern living

Stone is:
– The common denominator
– Where our core expertise lies
– Our differentiator

We enrich through:
– Cultivation
– Innovation
– Providing versatility

Our products support:
– Urbanisation
– Safe & comfortable living
– Food production
– Waste disposal
– Human development



39
countries

45
Manufacturing facilities

11,000+
highly skilled individuals

5
brands

7
strengths of stone

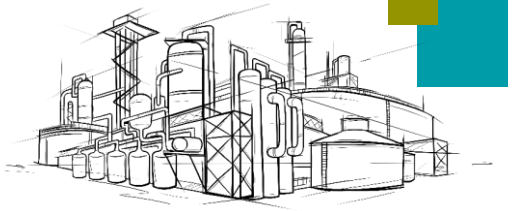
1937 - 2019

In 1937, the ROCKWOOL Group starts the first stone wool production in Hedehusene, Denmark

World Leader with Local Presence

Why choose ROCKWOOL?

- Proven track record over 75+ years
- Recognized and approved by plant owners, engineering companies, contractors and distributors



bp
Chevron
MITSUBISHI POWER SYSTEMS
Formosa Plastics
SUNCOR ENERGY
HITACHI Inspire the Next
GASCO
ExxonMobil
ConocoPhillips
ارامكو السعودية Saudi Aramco
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TOTAL
FINA
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cape Intelligent solutions for industrial services
ruhrgas
BASF
KAEFER
FLUOR
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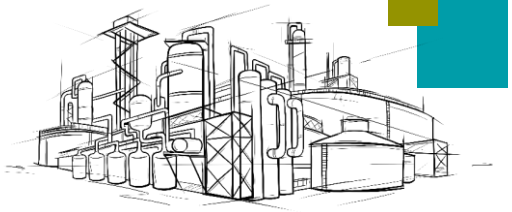
Reliance Industries Limited

Technical support and expertise



Working with our stakeholders

Understanding of the importance of insulation

- Cost saving benefits
- Sustainability
- Corrosion improvements
- Understanding of test methods

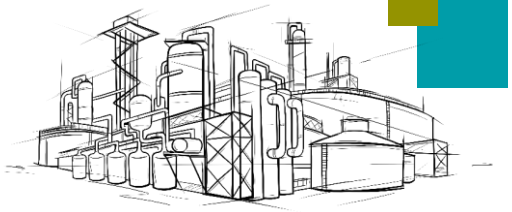
Technical seminars and training

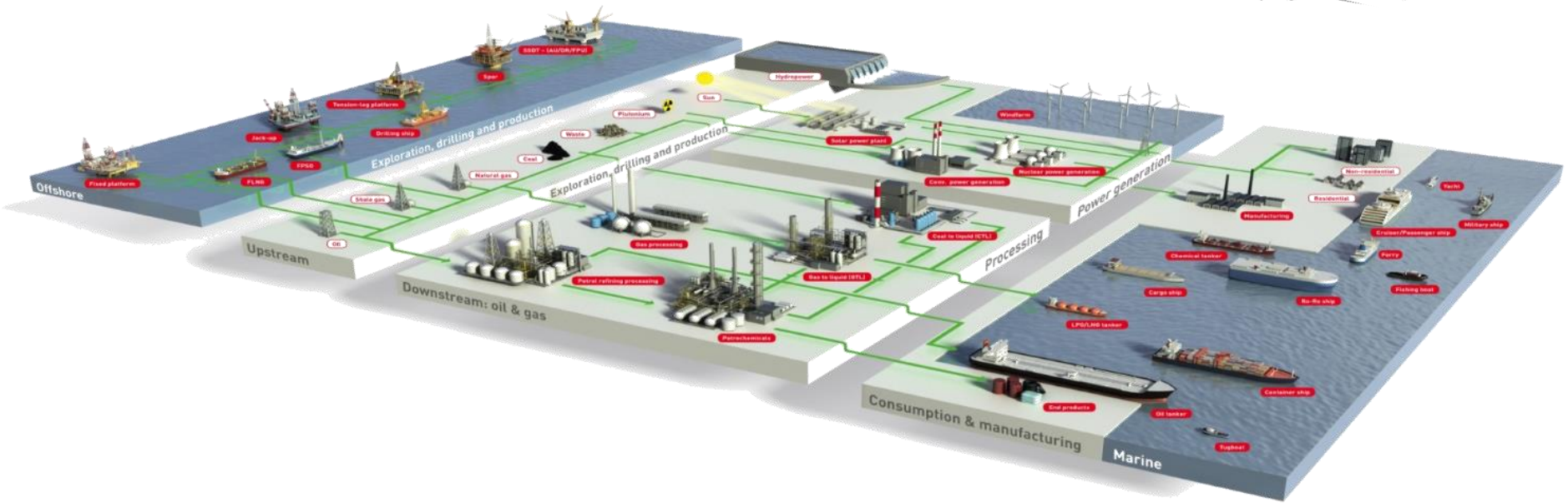
Focused audience of owners and specifiers

- Energy efficiency
- Educating on ProRox & SeaRox and the global marketplace
- Insulation long term benefits
- 3E plus. Technical support providing personnel protection and heat loss calculations

Active presence at local trade shows

Industrial business segmentation





Why insulate?

Design objectives:

- Personal protection
- Energy efficiency
- Noise reduction
- Fire protection
- Condensation control
- Process control/performance
- Freeze protection
- Reduced CO2 emissions

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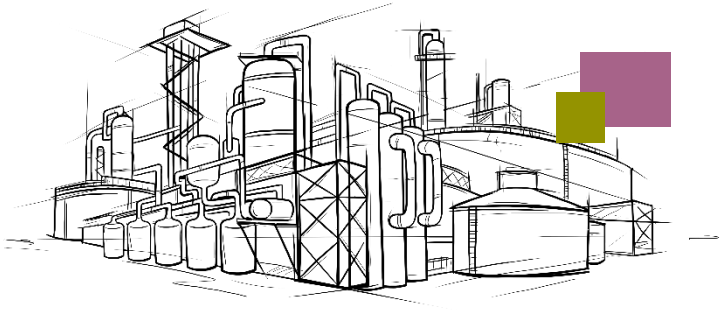
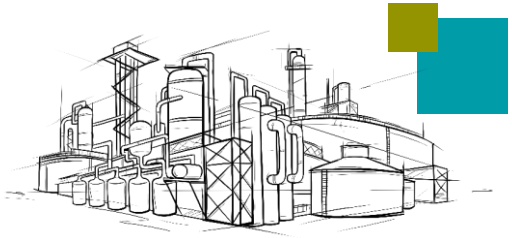


Insulation systems are intended to fulfill one or more key design **objectives**

Insulation protects:

- **People**
- **Equipment**
- **The system**
- **Cost**

The production process



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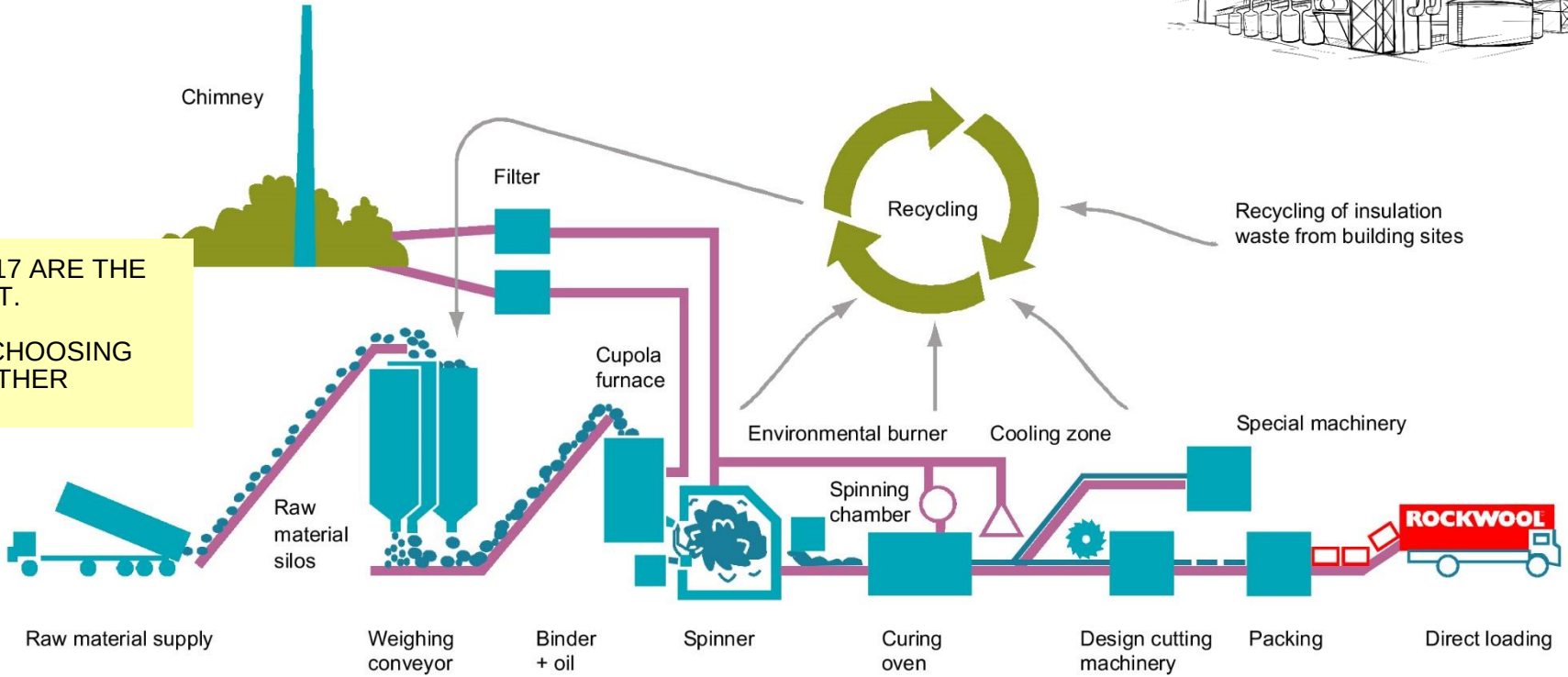
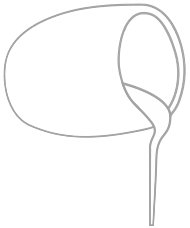
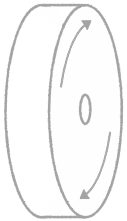


What is stone wool insulation? Spinning Process

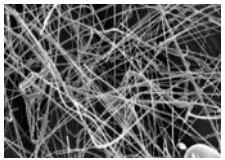
1 Stone is melted in oven to approx. 2700°F (1500°C) then the lava is poured into spinners rotating at high speed

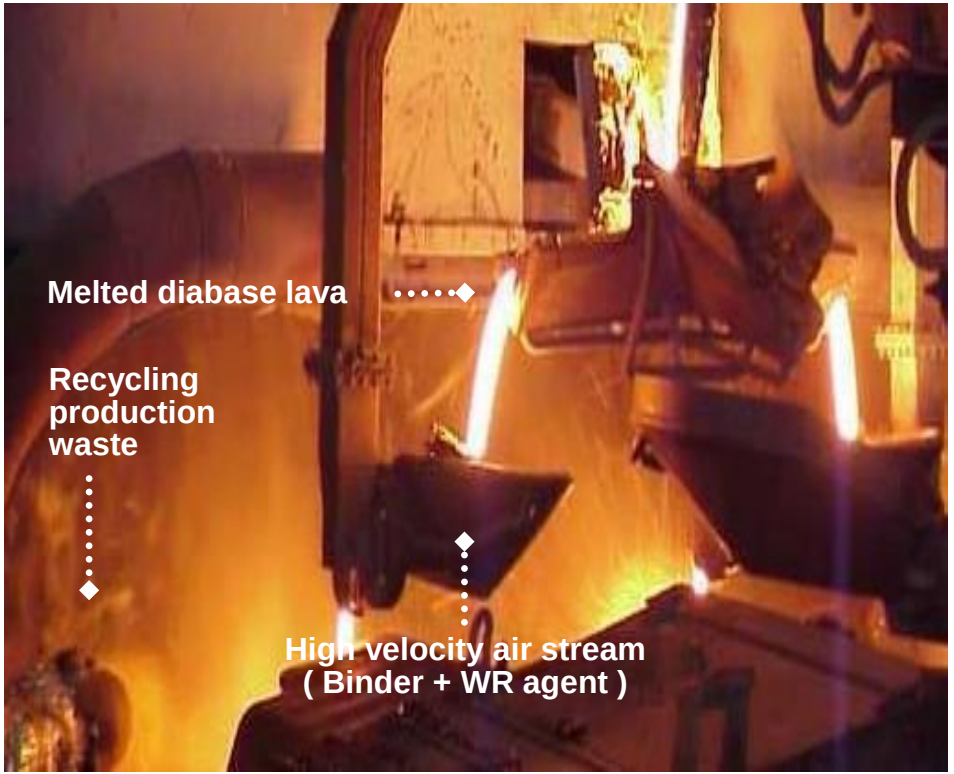


2 Lava droplet hits spinning wheel, which rotates at high speed

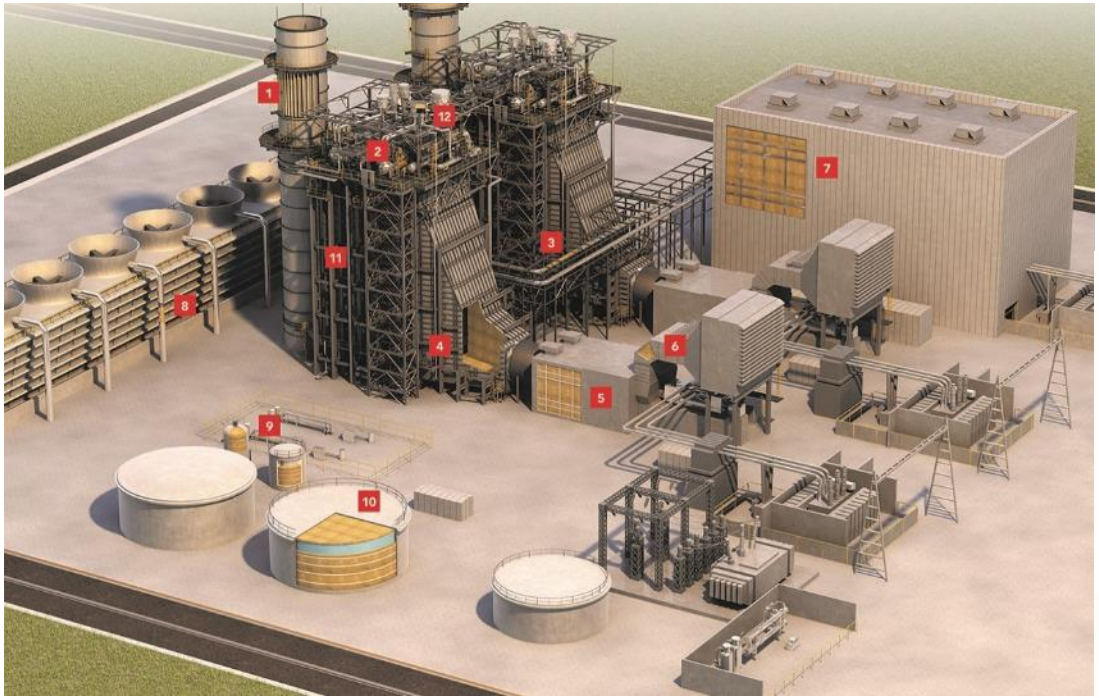


3 Droplet is launched and forms a fiber





What needs to be insulated in an industrial plant?



1. Exhaust silencers
2. Steam boilers (drums)
3. Piping
4. Inlet ducts
5. Gas turbine enclosure
6. Ductwork
7. Steam turbine enclosure
8. Cooling tower piping
9. Demineralized water system
10. Storage tanks
11. Heat Recovery Steam Generator (HRSG) internals
12. Silencers

ProRox®
Industrial insulation

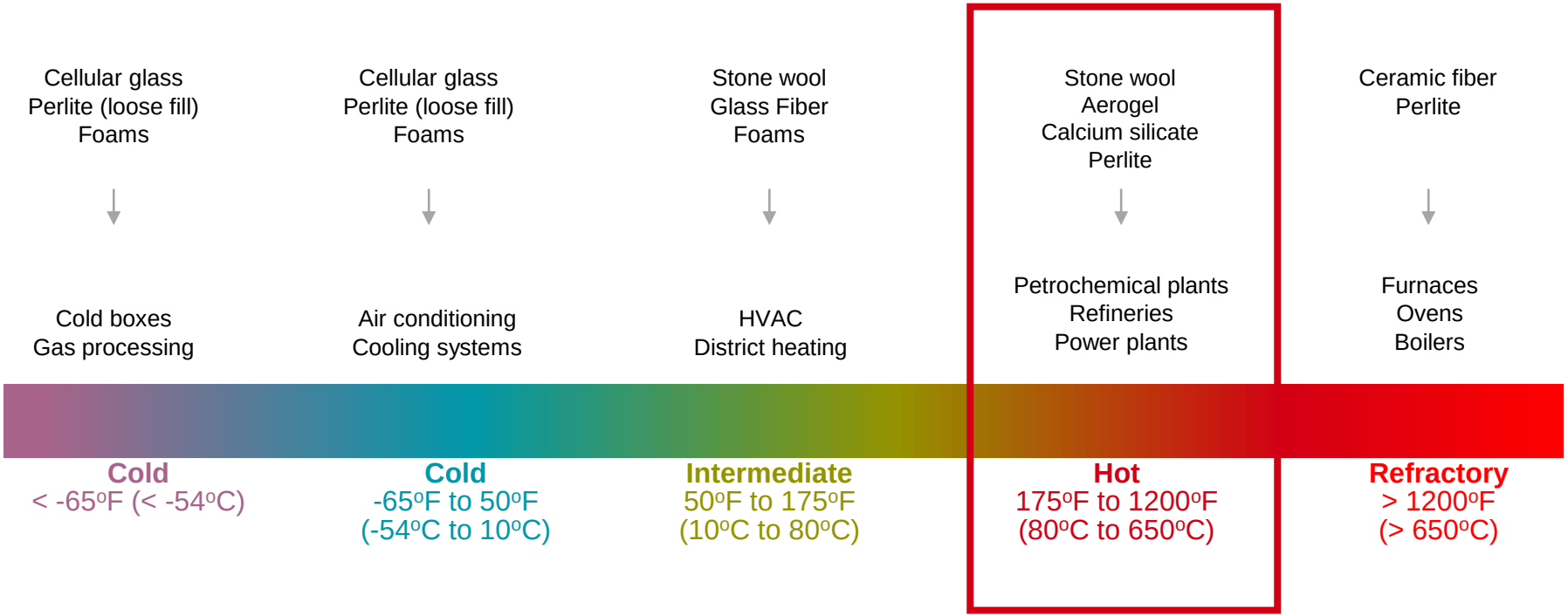
What material is most common for pipe insulation?

Pipe sections
for thermal and acoustic insulation

— Pipe sections are the most common configuration for process **piping applications**

In process plants, around **80%** of the equipment is **pipework**

Typical products for technical insulation by temperature



Key Selection Criteria for Technical Insulation

Selecting an insulation material requires an understanding of the key properties that will ***satisfy design requirements*** and contribute to ***long-term operational success***

Fire Resilience

Circularity

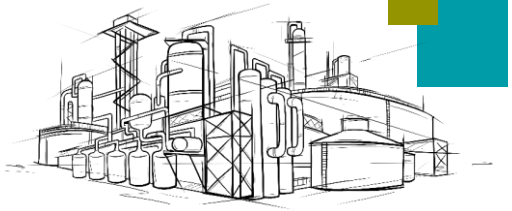
Thermal Properties

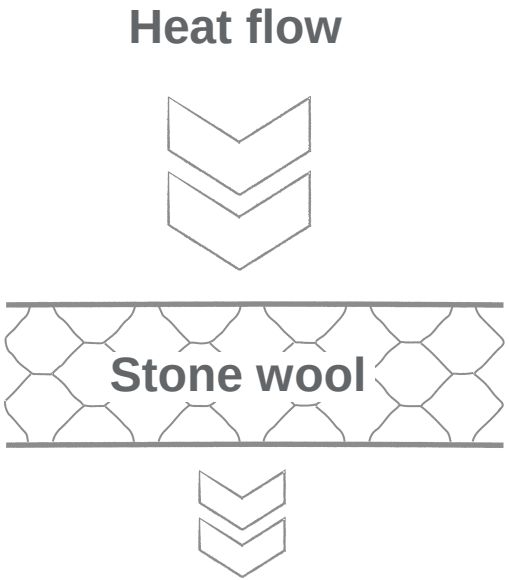
Water Properties

Acoustic Capabilities

Robustness

Thermal Properties





— Derives great thermal properties from tiny pockets of air trapped within the physical structure

— Air is a good insulator. This is because heat cannot be conducted through a void

— These air pockets allow the insulation to keep the service at its necessary temperature

Water Properties

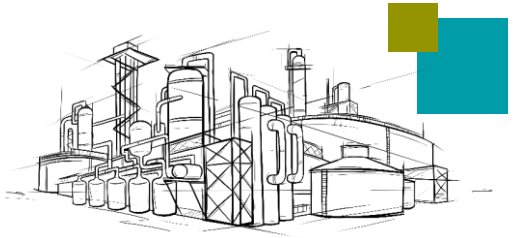
Keeping water out is not that simple!

— Water ingress cannot be avoided and will occur under ***every*** type of insulation

— Because CUI is a product of wet metal exposure duration, the insulation system that ***holds the least amount of water*** and ***dries most quickly*** should result in the least amount of corrosion damage to equipment

5% (vol.) water evenly distributed in the insulation = thermal conductivity is increased by approximately 25%

What is stone wool insulation?



Mandrel wound pipe section

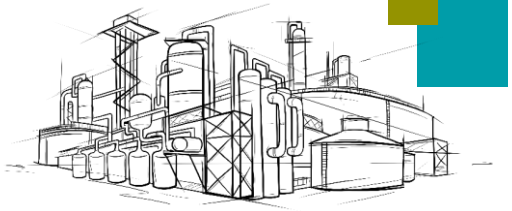
Slab / board

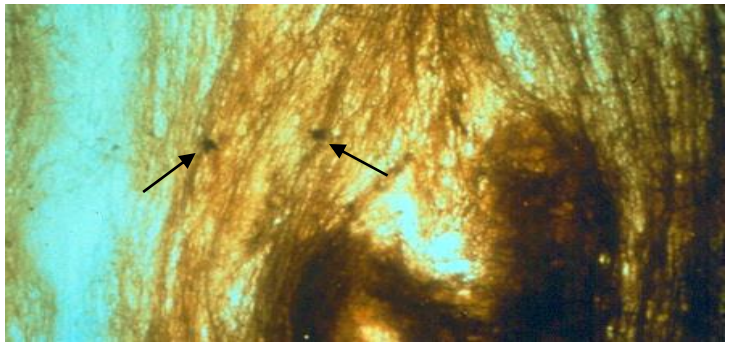
V-groove

Wrap / blanket / mat

Cut pipe

Quality can be different



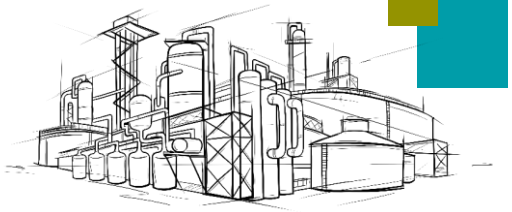


Visible differences

- Defects, damages
- Hard to install
- Non-fibrous particles (shot)
- High water absorption
- Corrosive to steel
- Not applicable above 250°C
- Poor performance

Stone wool is not slag wool

Stone wool vs. mineral (slag) wool



Fibers or rock

- Thermal and mechanical properties of stone wool are almost exclusively determined by fibers.
- Non-fibrous particles (shot) **increase** the weight

Raw materials

- Quality stone wool is manufactured out of volcanic rock
- Waste materials such as slag can lead to corrosive material in the absence of experience and advanced technology

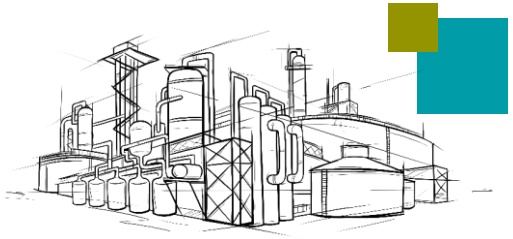
Production

Advanced technology is needed to ensure the quality of insulation

Performance

Does your supplier declare nominal values?

Key selection criteria for technical insulation



Conservation of the steel work

- Installation of the insulation
- Manufacturer declaration
- According to what standard is the product property tested?
- Nominal or best values?

Product performance

- Density -> shot content
- Thermal conductivity
- Maximum service temperature

CUI issues

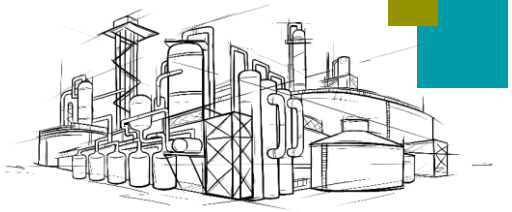
- Water repellency, pH value and water leachable chloride content

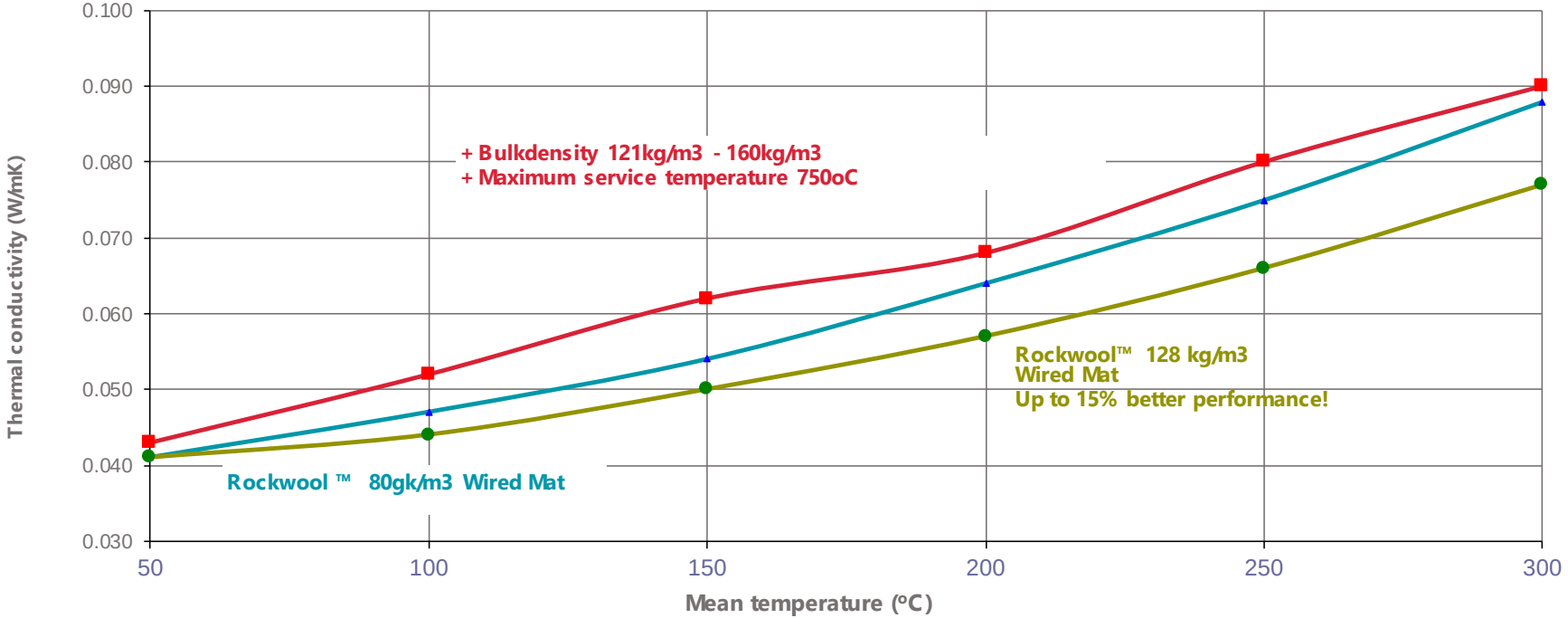
No insulation is perfect….

Select the appropriate insulation material that best meets the requirements of system

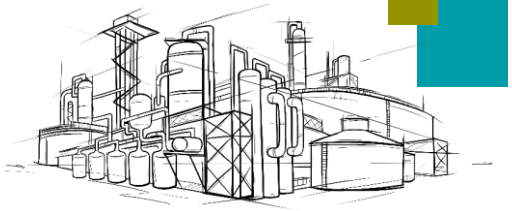
Thermal conductivity

The best of the rest costs you money





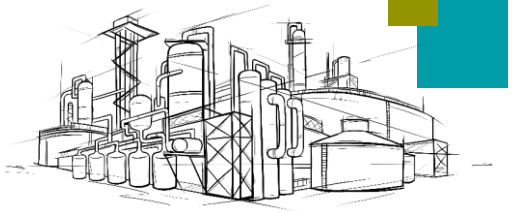
Important to focus on CUI



– Major issue affecting health and safety

To help avoid CUI:
– Design properly
– Anti-corrosive treatments
– Select the right insulation
– Select the correct weather protection system

Preventing corrosion



Three issues

- Protecting steelwork
- Designing and planning insulation work
- Inspection and maintenance

Important to note

- Best practices may vary by country and/or standard
- ROCKWOOL's stone wool is inert to steelwork and meets the latest American & European standards for use over carbon and stainless steel
- Stone wool should be hydrophobically treated
- ProRox/SeaRox reduces the risk of condensation
- ProRox/SeaRox stone wool is non-capillary – does not absorb water at high temperatures

Best practices may vary by country and/or standard

ISO 12944-1 to 7

Corrosion protection is often designed in accordance with EN ISO 12944-1 to 7 "Coating materials – Protection against the corrosion of steelwork by means of coating systems". However, since this standard does not adequately take into account the specific features of corrosion protection in insulation systems, the requirements of AGI Q151 "Protection against corrosion in the case of hot and cold insulation in industrial plants" must also be considered.

DIN 4140

DIN 4140 gives the following advice on corrosion protection:

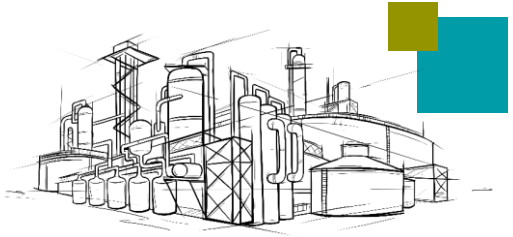
- In the case of cold insulation, if the object is made of non-alloy or low alloy steel, it must be protected against corrosion
- In the case of objects made from austenitic stainless steel or copper, the installation must be tested in each individual case by the planner to determine whether corrosion protection is necessary
- Objects made from austenitic stainless steel do not require corrosion protection if the temperature never exceeds 50°C, even briefly

CINI

CINI recommends applying corrosion protection prior to insulation work at any time.

- In all phases, pay attention to corrosion under insulation prevention: design, construction, paint & coating work, application of the insulation system, inspection and maintenance. Equipment and piping sections, such as nozzles and supports, should be designed and maintained to prevent water ingress into the insulation system.
- Paint specifications are split into: construction materials (carbon steel, stainless steel) and temperature ranges -30°C to 540°C with special attention for the temperature range between -20°C and 150°C.
- Corrosion protection can be achieved using aluminium foil wrapping, thermal sprayed aluminium (TSA) or paint
- Corrosion protection is not necessary for plants operating continuously under extremely cold conditions (< -30°C)

Water leachable chloride content



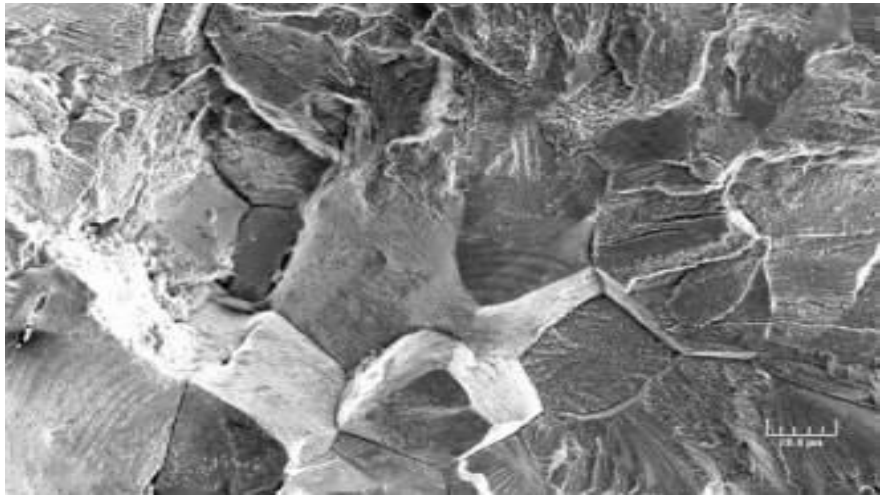
- The corrosion resistance of steel is increased by the addition of elements like chromium, nickel and molybdenum
- The alloying results in a so-called austenitic (face-centered cubic) atomic structures, these types of steel are also called austenitic steels (stainless steel)

These types of steels tend to exhibit

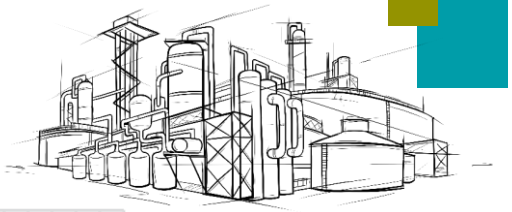
- stress corrosion (ESCC) which is often caused by chloride ions (=salt)

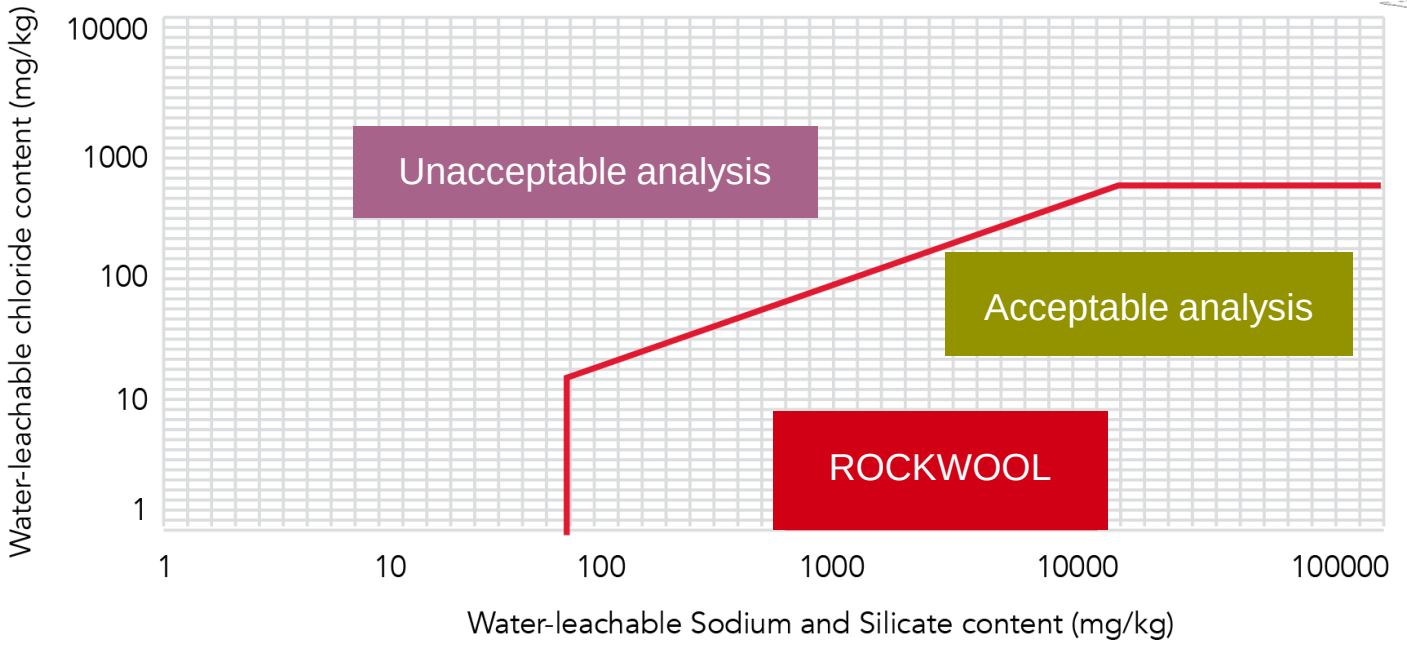
In case of austenitic steels the

- insulation may not contain any water leachable chloride ions

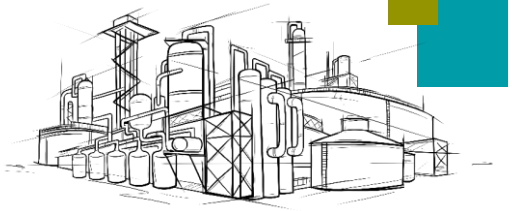


ASTM C795 – acceptability



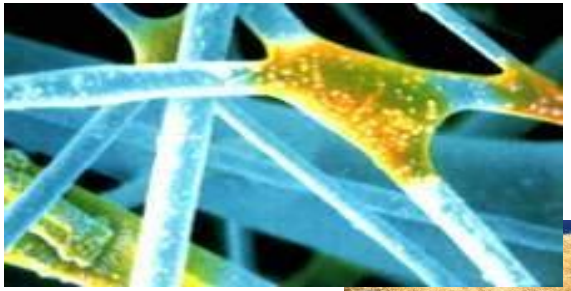


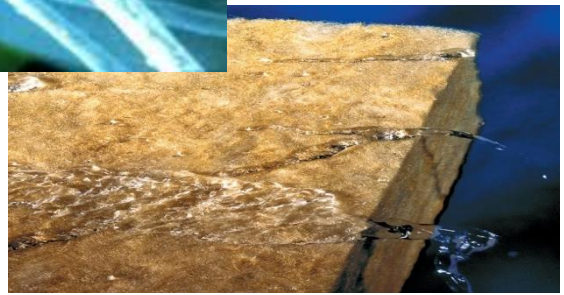
Water repellency



The thermal conductivity of mineral wool increases when water penetrates the material

Wet insulation can also contribute to corrosion





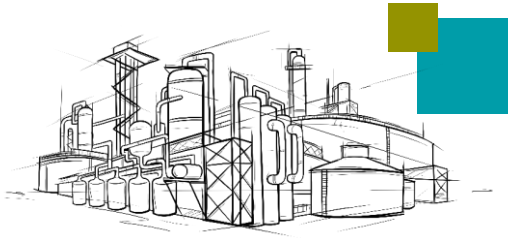
Note: 1% moisture = +25%λ

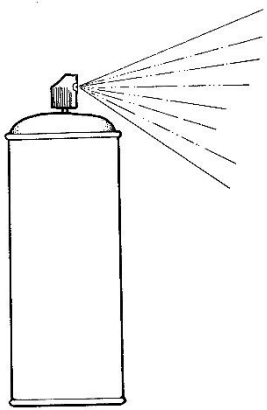
What to do?

- Use only materials with a hydrophobic treatment
- Water absorbance < 1%

Application of the additive

Surface treatment vs individual fiber treatment





Individual fiber treatment:
Coating of the fibers initial in the production process can secure a uniform distribution of the additive

Surface treatment:
Application of coating later in the process or even just on the surface of the finished products results in a more uneven distribution and in some cases only a short term superficial performance.

CUI is a system challenge

Corrosion under insulation is a system challenge and should be adressed as such - from design to decommisioning.

- **Surrounding environment**
  - Indoor/outdoor
  - Land / oceanic climate
  - Acidic environment
- **Operation of the plant**
  - Cyclic or continous
  - OperationTemperatures
- **Equipment design**
- **Choise and installation of coating system**
- **Design, choice and installation of the insulation system**
- **Actual operation**
  - Prompt, promptly maintenance
  - Foot traffic
  - Risk based inspection procedures

How does the insulation material affect corrosion?

How does the insulation material affect corrosion?

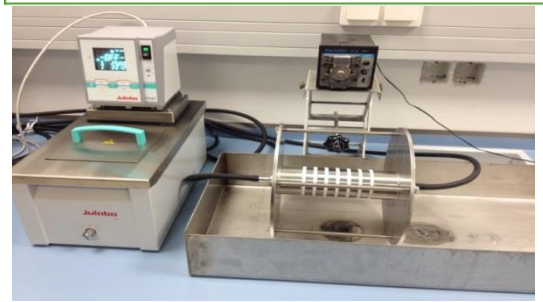
We tested it at an independant corrosion laboratory according to ASTM G189-07 (CUI Simulation Measurements):

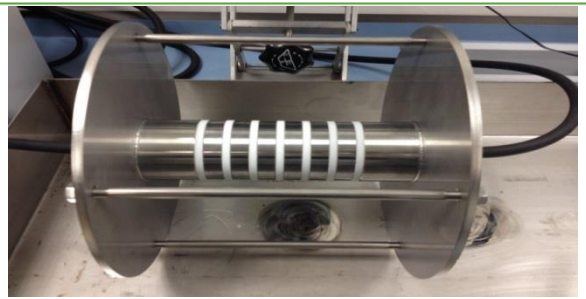
METALogic

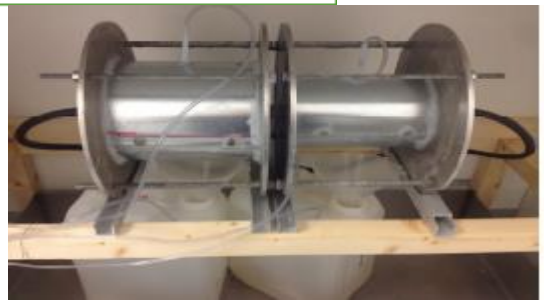
CUI Simulation Measurements – ASTM G189-07

- The test apparatus was constructed such that it contains six separate test samples in one test.
- Test samples were carbon steel.
- The insulation was wetted and dried in set cycles of cold (60°C/140°F) and hot (150°C/302°F).
- The liquid (demi water) used was recycled so that leaching products of the specific insulation influence the corrosion.

Cyclic test	One cycle		No of cycles
Duration	20 hours	4 hours	21 (21 days)
Temperature	60°C	150°C	
Wet/dry	Wet	Dry	

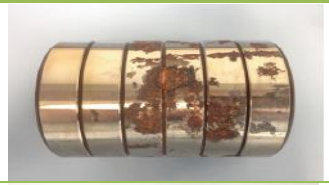






Results - photos

Insulation material	Aerogel blanket ASTM C1728	Calcium silicate ASTM C533	Cellular glass ASTM C552
Top side			
Bottom side			

Insulation material	Fiberglass ASTM C547	Polyisocyanurate (PIR) ASTM C591	Stone wool ASTM C547
Top side			
Bottom side			

Conclusions from the test – overall:

Corrosion occured under all the tested insulation materials.

- In this test, with water introduced on the steel surface, **insulation materials open for water vapor diffusion performed better** than closed cell materials and materials with a membrane, confirming that it is **water retention at the steel surface that determine the speed of corrosion.**
- Products with higher concentrations of **leached Chloride give higher corrosion rates** (independent of type of insulation material)

For more details see:
C. Zwaag & S. N. Rasmussen, “Cyclic CUI testing of Insulation materials”, NACE CORROSION 2017, paper no. 8877

Insulation selection

NACE SP0198-2016 (2.1.2):

CUI of carbon steel is possible under **all types of insulation**. The insulation type may only be a contributing factor. The insulation characteristics with the most influence on CUI are:

- Water-leachable salt content in insulation, such as chloride, sulphate and acidic materials that may contribute to corrosion;
- Water retention, permeability, and wettability of the insulation; and
- Foams containing residual compounds that react with water to form hydrochloric or other acids.

Because CUI is a product of wet metal exposure duration, the insulation system that **holds the least amount of water and dries most quickly** should result in the least amount of corrosion damage to equipment.

Corrosion can be reduced by careful selection of insulation materials.

How can mineral wool be optimised in relation to CUI?

Go beyond the obvious (λ, MST, …): To minimize the risk of CUI, it is **important that the insulation does not affect the steel, does not absorb water and is open to vapour** so that moisture can easily egress the insulation

- Essential properties and test methods:

Water absorption should be less than 1kg/m2	EN1609
Water vapour resistance (μ) is close to 1,0	EN12086
pH is neutral to slightly alkaline	
Conforms to the stainless steel corrosion specification as per ASTM test methods C692 and C871	ASTM C795
Water leachable chloride content < 10mg/kg [AS-Quality]	EN13468
Mass Loss Corrosion Rate < reference test	ASTM C1617

- Additionally, the insulation should not be abrasive or in other ways damaging to the coating

Are additional improvements possible?

YES!

ROCKWOOL Technical Insulation has developed the next generation of stone wool pipe sections with a unique binder technology to mitigate the risk of CUI:

ROCKWOOL ProRox PS with WR-Tech

("WR-Tech" – Water Repellency Technology)

ROCKWOOL ProRox PS 960/970/980 with WR-Tech

with WR TECH

MP MATERIALS PERFORMANCE
CORROSION
INNOVATION OF THE YEAR AWARDS
WINNER 2019

- Winners were selected by a panel of corrosion-control experts
- To be considered an innovation, nominated technology is required to show the potential for a *significant positive impact in corrosion-control*

ROCKWOOL

ProRox | SeaRox TECHNICAL INSULATION

ROCKWOOL ProRox PS with WR-Tech

What is WR-Tech?

WR-Tech® incorporates a revolutionary coating-friendly binder technology (inorganic hydrophobic resin) that coats the fibers of our stone wool pipe insulation during the production process.

NO SILICONE OIL

What is the advantage of WR-Tech?

ProRox mandrel wound pipe sections with WR-Tech has a 5 X lower water absorption than the standard available EN classified stone wool. This reduced water absorption contributes to a mitigation of the risk of CUI.

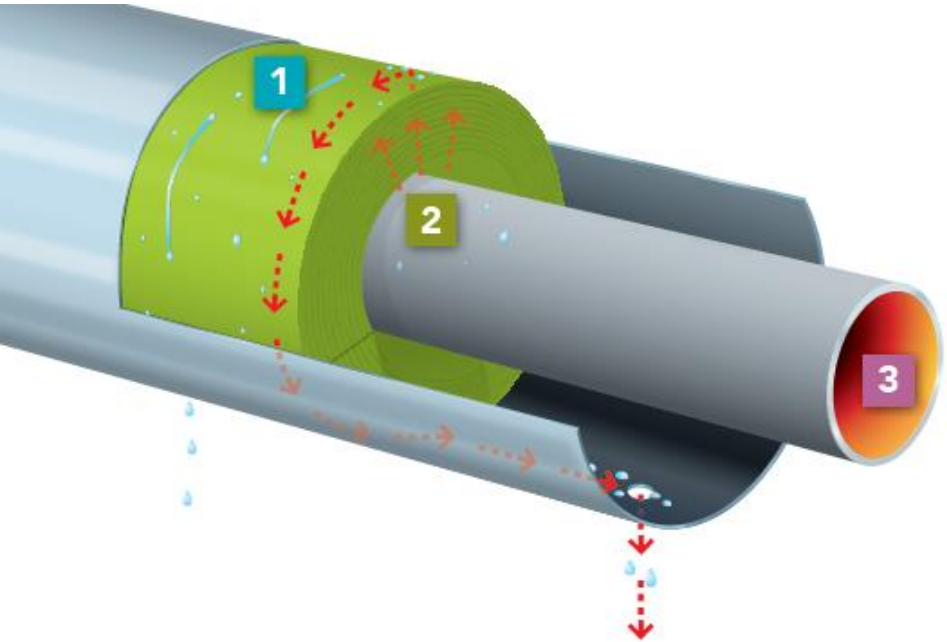
How do ProRox mandrel wound pipe sections with WR-Tech mitigate the risk of CUI?

The 5 X lower water absorption increases water repellency of the stone wool, making it difficult for water to penetrate the wool. At the same time, the wool remains open for water vapour diffusion, allowing any water inside the system to egress.

Lower amount of water at the pipe surface = Reduced risk of CUI

ROCKWOOL ProRox PS with WR-Tech

Product features:



1

LOWEST WATER ABSORPTION

HIGHEST WATER REPELLENCY

5x lower absorption than best available standard EN 13472, minimizing water absorption and maximizing water flow away from insulation material.

2

QUICK RELEASE

FASTEST WATER DISSIPATION

The vapor open structure ensures that water can evaporate freely if it might reach the pipe surface. The low water absorption ensures the fastest dry-out time.

3

DURABLE PERFORMANCE UP TO 250°C

NO REDUCTION OF REPELLENCY

Fully durable water repellency performance up to 250°C over the whole CUI range.

<10PPM Cl
LOW LEACHABLE SUBSTANCES

Complies with EN 13468 & ASTM C795, the most strict standards

COATING FRIENDLY
SILICONE OIL FREE

Complies with VW test 3.10.7, does not result in fish-eyes, usable in paint shops

PRODUCT TOUGHNESS
FLEXIBLE & STRONG

No cracks when exposed to external impact

Water absorption

Summary of EN 13472 test:

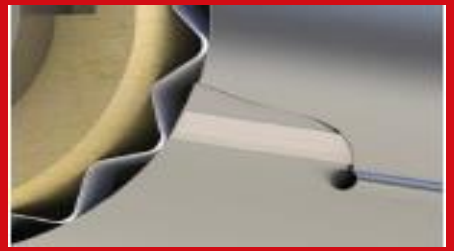
EN 13472

“Rain” (one side immersion) – 24 hrs

ROCKWOOL PS 960/970 with WR-Tech	Pipe section A	Pipe section B	Pipe section C
Water absorbed (kg/m^2): **Non-heat aged**			
0.1 (declared < 0.2)	0.1 (declared < 1)	0.5 (declared < 1)	1.4 (declared < 1)
Water absorbed (kg/m^2): **Heat aged @ 250°C/482°F for 24 hours**			
0.1 (declared < 0.2)	62.5 (no declaration)	30.1 (no declaration)	43.8 (no declaration)

Pipe sections A, B and C are commercially available mineral wool based pipe sections in Europe, with Ws declarations of < 1 kg/m^2

Insulation system tools in the CUI battle

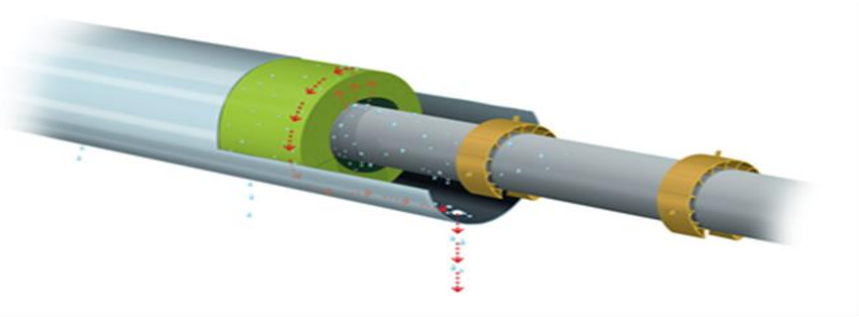


1) Non contact insulation

Spacers ensure an air gap between the steel pipe and the insulation.

- **Reduced time of ”Wetness” = lower corrosion rates**
- **Hot water immersion like situations are avoided/limited = extended lifetime of the protective coating system**

Combining a spacer with an insulation material with a high water vapour permeability allow the water to move to the cladding where it can condense, run to a lower point and be drained out.



Class	Operating temperature	Coating status when new or last applied	Cladding or insulation condition	Insulation type	Remnant corrosion allowance (example values only)	External coil or steam tracing	External environment	Score
CS-1	Constantly >175 °C or <−4 °C	Full quality assurance coating 8 years, or thermally sprayed aluminium coating 15 years	Good to engineering standards or renewed (<5 years)	Contact-free insulation, with regular inspection (every 5 years)	0 mm	Not present	Inside building, not steam traced and not sweating Default negligible risk	?
CS-2	150–175 °C	Full quality assurance coating 8–15 years or conventional coating 8 years or thermally sprayed aluminium coating 15–20 years	Average condition, overall high-integrity design and construction	Expanded perlite, foam glass, closed-cell foam (good type)	2–4 mm	High-integrity design	Low wetting rate (<20% of the time)	?
CS-3	−4–49 °C and 111–175 °C	Conventional coating 8–15 years or thermally sprayed aluminium coating >20 years	Average condition, conventional design and construction	Fibreglass, asbestos, regular perlite, mineral-rock wool (<10 ppm Cl)	1–2 mm	Medium-integrity design	Medium wetting rate (20–50% of the time)	?
CS-4	50–110 °C or sweating conditions	Full quality assurance or conventional coating >15 years or unpainted or unknown	Poor condition, damaged, wet or broken seals	Calcium silicate, rock wool (no specification), unknown	<1 mm	Low-integrity design or leaking	High wetting rate (>50% of the time) (e.g. cooling-tower or deluge systems	?

Non contact insulation is considered the best insulation system for CUI mitigation by industry experts

ASTM G189-07 testing of non-contact insulation

CUI simulation tests carried out by METALogic on behalf of ROCKWOOL Technical Insulation in accordance with ASTM G189-07.

Comparing ASTM C547 pipe sections direct on pipe and via use of spacer rings

- 21 cycles of 24 hours (20 hrs. 60°C wet – 4 hrs 150°C dry)
- Use of demineralized water

Direct to metal

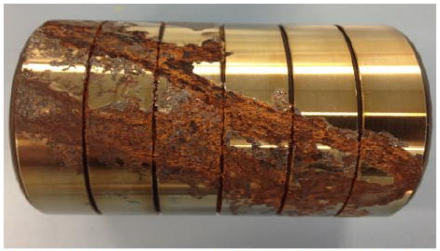


Figure 5: Top side coupons belonging to ProRox PS960

Figure 6: Bottom side coupons belonging to ProRox PS960

Non-Contact Insulation

Figure 11: Top side coupons belonging to "non-contact"

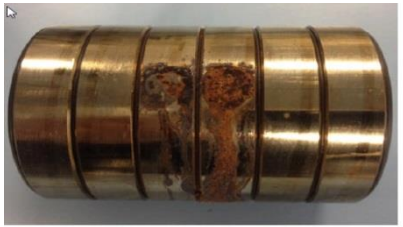
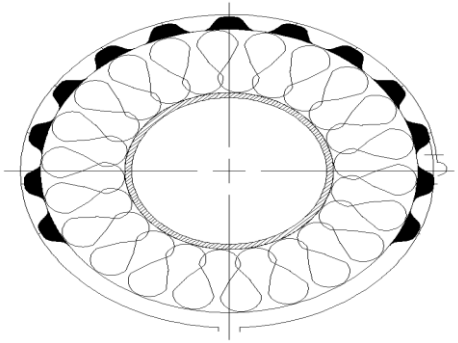


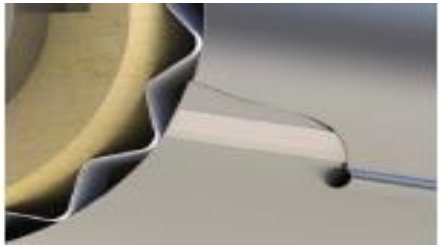
Figure 12: Bottom side coupons belonging to "non-contact"

ROCKWOOL

ProRox | SeaRox TECHNICAL INSULATION

2) Spacer between insulation and cladding - DIN 4140





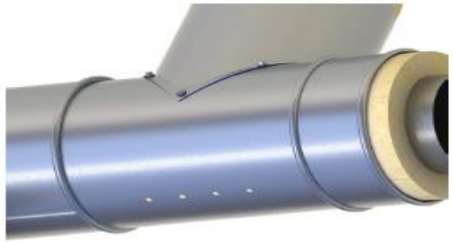
A spacer between the cladding and the insulation secures that externally incoming water can run on the inner side of the cladding - towards a lower point for draining out (via drain hole). Where the insulation is protected by additional water barriers – e.g. aluminium foil the spacers reduce the risk of puncturing the barrier by screws during the cladding installation and impact during service.

The German standard DIN 4140:2014 require that for insulated equipment positioned outside (and not covered), spacers shall be used between the insulation and the cladding. The air space between the insulation and the cladding should be at least 15 mm.

3) Draining

Water drainage is relevant for the insulation temperature range where mineral wool is used;

- Drain holes of minimum 0.4 inch diameter and at intervals of 1-10 feet should be provided on the underside or at the lowest point of the cladding.
- Where no water vapor barriers are installed, the drain hole should penetrate the entire insulation system
- The drainage of fire rated insulation systems shall be of certified/approved type.
- Drain plugs can make water draining more efficient,
- Precautions shall be taken to avoid damage to the coating system and heat tracing cables



Drain holes at low point of cladding

4) Seamless cladding

Seamless cladding based on wet applied UV cured GRP is an alternative tool in the CUI fight.

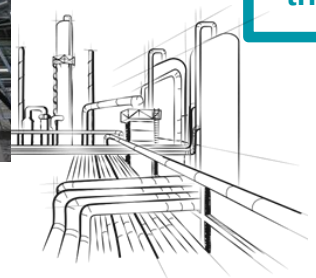
- Eliminate/minimize water ingress
- Cladding with higher mechanical and chemical resistance

Wrap up

CUI is found under all types of insulation when you have installation issues or damages

CUI is a system challenge and must be addressed and planned from design phase to de-commissioning

The choice of insulation material do influence corrosion rates. Care should be given to the selection



Tools for CUI mitigation can extend the lifetime and provide longer maintenance free periods

Thank you