KNOW-HOW – PART IV

Risk of corrosion under insulation

Corrosion under insulation (CUI) is insidious, because it is often only noticed when extensive damage has already taken place. As independent studies have shown, ArmaFlex insulation materials minimize the risk of corrosion under the insulation. Open-cell insulation materials, on the other hand, are not protected against moisture absorption and pose a higher CUI risk.

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2.5 trillion US $ of damage

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MAKING A DIFFERENCE AROUND THE WORLD

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RUST NEVER SLEEPS

Some 40 % of global steel production is used to replace parts destroyed by corrosion. Every year, corrosion damage costs the global economy 2.5 trillion US dollars – that is 3 % of the global gross domestic product. Corrosion under insulation (CUI) is particularly insidious, because it is often only noticed when extensive damage has already taken place. So when selecting an insulation material, the crucial question is how well it can protect equipment against corrosion.

Corrosion under insulation costs the global economy billions

The fight against rust has been going on for over 3000 years and there is no end in view. When man learnt to melt iron ore, he discovered a widespread material which soon replaced much more expensive bronze. To this day, iron is still one of the most important raw materials in the global economy. When exposed to water or humid air, iron oxidizes with oxygen. Unlike the oxide layer of chrome, aluminium or zinc, the corrosion product rust is porous. As the metal decomposes it becomes more and more brittle and due to the larger volume it can flake off to the point of total destruction. The weathering of ferrous materials into rust causes damage amounting to billions of euros every year. Corrosion consumes around three to four per cent of economic output annually – in Germany alone that amounts to around 70 billion euros.

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Some 45 % of the costs – i.e. around 1 trillion US dollars – arise in the oil, gas and petrochemical industry. According to a study by the US American ExxonMobil Chemical Company, 40 to 60 % of maintenance costs for pipework are due to corrosion under insulation (CUI). And that is without taking into account the indirect costs as a result of downtime. Experts in the mineral oil industry assume that CUI is the main reason for unscheduled plant shutdowns and responsible for more downtime than all other causes together. In extreme cases, leakages as a result of corrosion can even lead to fires or explosions, thus endangering human life.

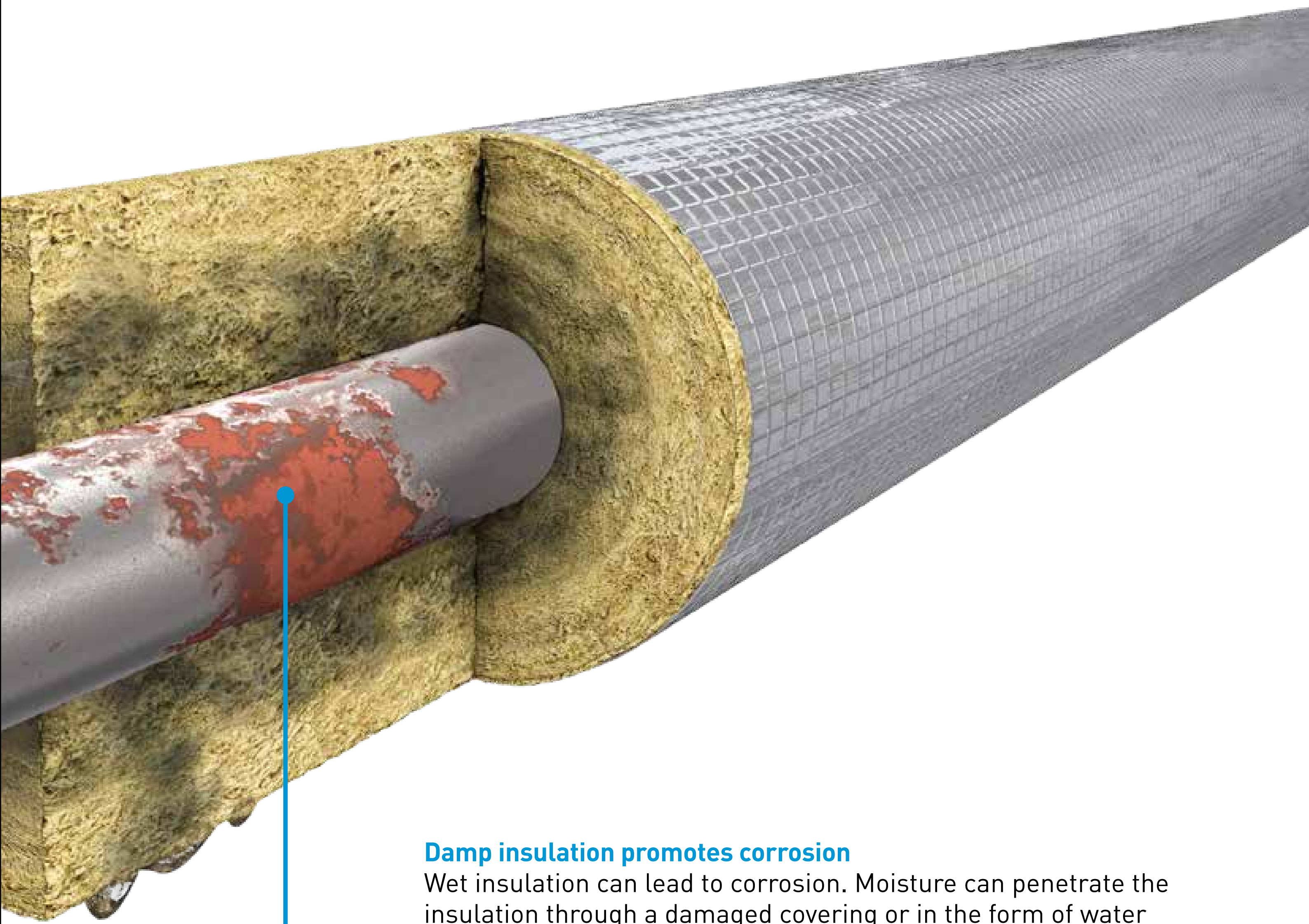
Suitable insulation systems mitigate the risk of corrosion

CUI is insidious: the processes take place hidden beneath the insulation and are often only discovered when extensive damage has already taken place. CUI usually occurs on pipes with a line temperature between 0 °C and 175 °C and is particularly critical above 50 °C. The risk increases on equipment which is operated discontinuously or at dual temperatures. If the temperature fluctuates, condensation can form in the insulation material and water can reach the surface of the pipes. In the salty air of off-shore facilities at high sea, there is a much higher risk of water containing chlorides or sulphates penetrating the insulation and triggering corrosion processes.

Insulation alone cannot safeguard plant components against corrosion, but appropriate insulation systems can effectively support corrosion protection. The choice of material decides whether the insulation mitigates the risk of corrosion or favours corrosion processes.

CUI facts:

- 40 to 60 % of maintenance costs for pipework are due to CUI.
- CUI is the main reason for unscheduled plant shutdowns and responsible for more down-time than all other causes together.



Damp insulation promotes corrosion
Wet insulation can lead to corrosion. Moisture can penetrate the insulation through a damaged covering or in the form of water vapour transmission. On cold pipes, the difference in temperature between the cold medium and the warm ambient air results in a difference in vapour pressure which acts on the insulation from the outside. There is then a risk of the water vapour contained in the air penetrating the insulation layer, condensing there and soaking the material. The consequences are not only a serious deterioration in the insulation properties and high energy losses; if the water spreads over the metal surface of the pipe and air is present, corrosion processes begin.

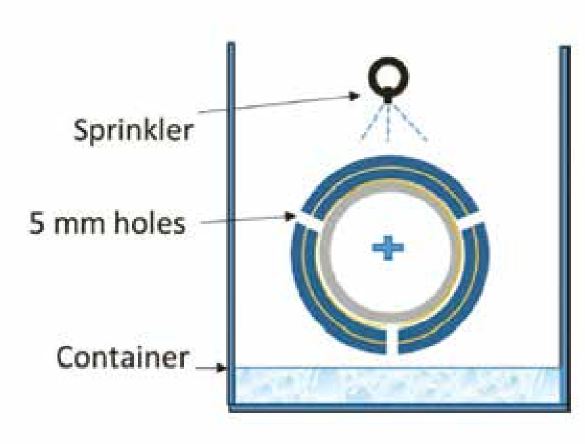
Nowadays, the oil and gas industry are aware of the interrelationships between insulation systems and the risk of CUI. However, while there are recognized standards and test methods for assessing the performance of corrosion protection systems, the influence of insulation materials on the CUI risk is hardly taken into account in international standards. As yet there is no standardized test for examining the performance of insulation systems in reducing the risk of CUI in an installation scenario.

ARMAFLEX INSULATION MATERIALS IN THE CUI ENDURANCE TEST

In the absence of such a standard, Armacell had its insulation materials examined in a test developed by TNO-ENDURES (Den Helder, Netherlands) for the international oil and gas company Shell. This test is widely recognized in the oil and gas industry.

Test set-up

In the standardized test, ArmaFlex insulation materials were subjected to a worst case scenario: an insulated, unalloyed steel pipe with a line temperature of 80 °C was continuously sprayed with warm saltwater. One half of the pipe was insulated with two layers of ArmaFlex sheets each 25 mm thick (case A). The other half of the pipe was prepared in the same way and then clad with a glass-reinforced plastic weather barrier (case B). To simulate a failure mode, in case A several holes were drilled through the entire insulation thickness. In case B, on the other hand, the holes were deliberately only drilled in the cladding, the insulation remained undamaged. In both cases, it was ensured that water could penetrate the insulation. These artificial conditions, ideal for the formation of corrosion, were maintained for six months.

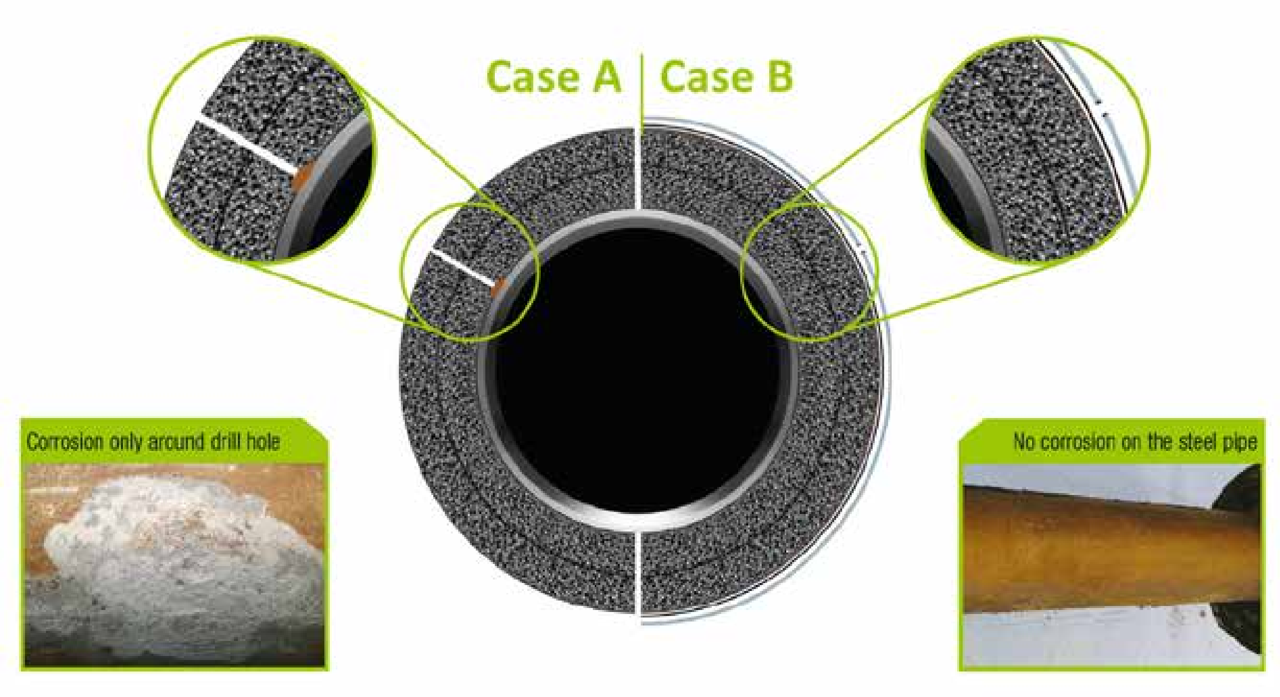


Test set-up of the CUI test carried out by TNO/ENDURES

Test results

At the end of the test phase, the specimens were examined thoroughly. In case A condensation had occurred as expected – however the processes were restricted to the immediate vicinity of the drill holes. There were no signs of corrosion in any other areas of the pipe, including the entire underside. The saltwater had obviously not reached these regions. Expectations were surpassed again in the second case examined in which the holes had only been drilled in the cladding. While the outer insulation layer felt damp at the end of the test, the inner insulation layer was completely dry. No corrosion was detected on the steel pipe. The ArmaFlex insulation had prevented moisture reaching the surface of the pipe.

In terms of physics, this remarkable result can be put down to the “built-in vapour barrier” of the closed-cell insulation material. The test demonstrated impressively that ArmaFlex mitigates CUI processes even under the most extreme conditions. It must be emphasized that the corrosion processes in this test were induced deliberately. Neither the ambient conditions nor the damage caused to the ArmaFlex material reflect real-life conditions.



Despite extensive damage to the cladding, in case B the pipe shows no sign of corrosion. In case A corrosion occurred as expected. However, the processes were restricted to the immediate vicinity of the drill holes.

The deliberately induced corrosion in case A is only observed in the vicinity of the drill holes (see also the close-up). No traces of corrosion are to be seen in any other areas, such as the entire underside of the pipe (photo 3). Here the ArmaFlex insulation has prevented the spread of corrosion effectively.

COMPARATIVE TEST OF DIFFERENT INSULATION SYSTEMS

Which insulation materials can mitigate the risk of CUI to what extent? To assess the resistance of commonly used insulation systems to the ingress of water vapour and the onset and spread of corrosion in a high-humidity environment, Armacell commissioned the renowned corrosion specialist institute InnCoa (Neustadt/Donau, Germany) to carry out a further test.

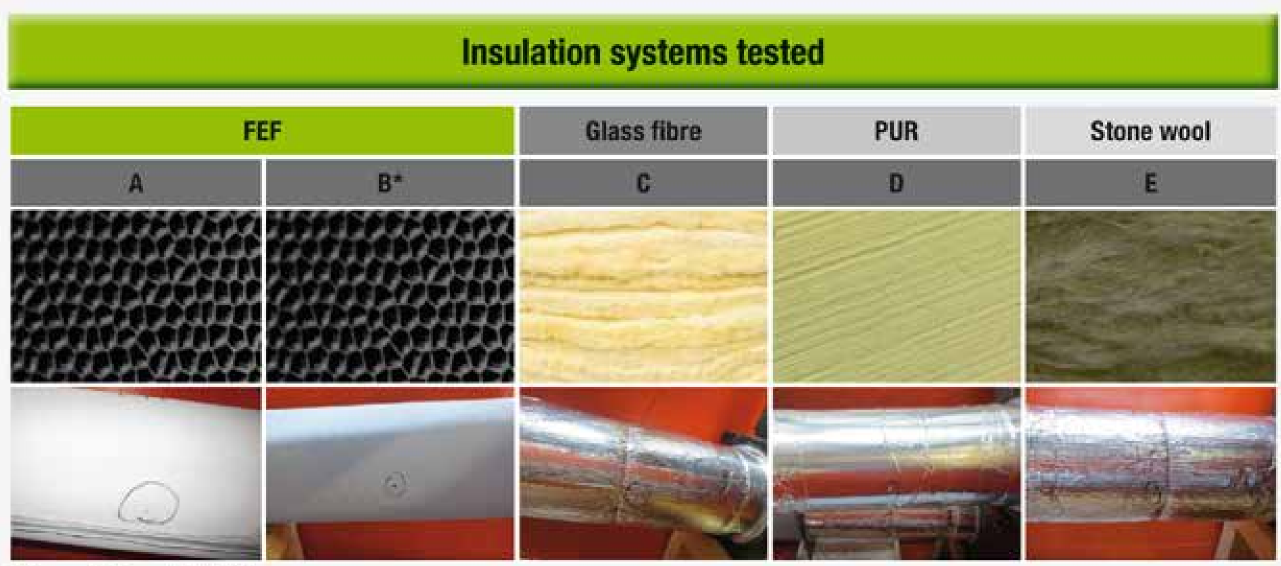
Five different insulation systems were investigated:

- System A: two layers of flexible elastomeric foam (FEF) with a flexible polymeric covering (HT/ArmaFlex Industrial & Arma-Chek R)
- System B: as A, but with all-over adhesion of both FEF layers (HT/ArmaFlex Industrial & Arma-Chek R)
- System C: glass fibre with an aluminium cover,
- System D: PUR with an aluminium cover, and
- System E: Stone wool with an aluminium cover.

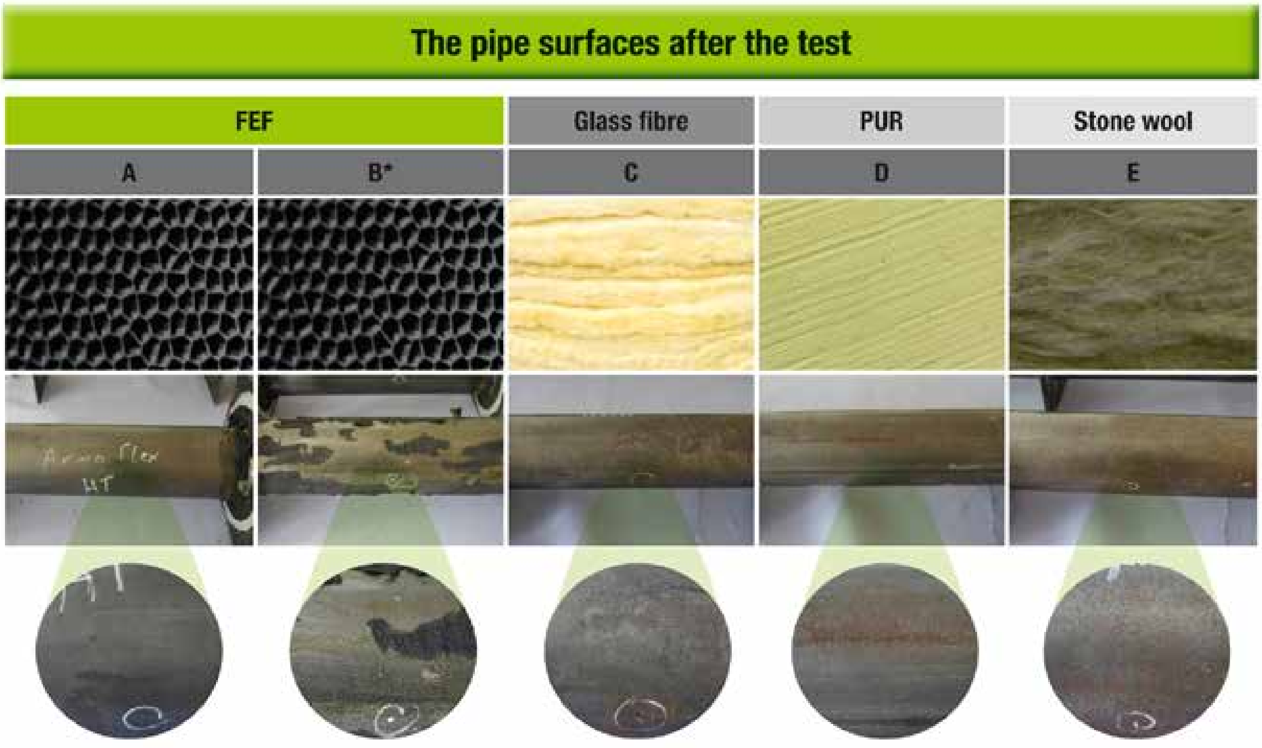
Test set-up

The insulation systems were properly mounted on steel pipes and exposed to a high-humidity environment in a climate chamber. In order to simulate surface damage to the insulation system, a hole with a diameter of 5 mm and a depth of approximately 10 mm was punched through the covering into the outer insulation on each of the five test objects. This ensured that moisture could penetrate the insulation during the test.

The pipes were installed in a series configuration with air circulation. A temperature of 35 °C ±5 % and a relative humidity of 80 % ±10 % were defined as the ambient conditions. The humidity was regulated by two open pots with a saturated salt solution of ammonium sulphate ((NH4)2SO4) and four fans with a volume flow rate of approximately 2.5 m^3/min. This ensured that the air within the chamber was well circulated. Water ran within the pipes at a rate of approximately 27 litres/min for both



*All-over adhesion of both FEF layers



*All-over adhesion of both FEF layers

the cooling and heating cycles. The temperature of the circulating water flow was adjusted in a 24-hour cycle between 5 °C and 80 °C and the cycles ran continuously in an infinite loop for the duration of the test. The test conditions were maintained for a period of 65 days. During this time, conditions and samples were checked visually at least once a day through the clear hood of the climate chamber, without opening the chamber.

At the end of the test, the insulation systems were dismantled and the surface of the pipes was photographed. The pipes were examined and the corrosion assessed. Then the surfaces were classified according to ISO 10289. The standard describes the methods for corrosion testing of metallic and other inorganic coatings on metallic substrates and the rating of test specimens and manufactured articles subjected to corrosion tests. It defines the protection rating Rp and the protection defects and assesses the appearance in the category R_A.

The degree of protection, R_p, is classified using a simple scale from 0 to 10. An R_p rating of 10 means 0% of the surface shows corrosion or other defects (best rating). An R_p rating of 0 means 50 % or more of the surface has corrosion (worst rating).

Corrosion protection rating (R_p) and assessment of the appearance (R_A) acc. to ISO 10289

Area of defects A (%)	Rating R_p or R_A
no defects	10
$0 < A \leq 0.1$	9
$0.1 < A \leq 0.25$	8
$0.25 < A \leq 0.5$	7
$0.5 < A \leq 1.0$	6
$1.0 < A \leq 2.5$	5
$2.5 < A \leq 5.0$	4
$5.0 < A \leq 10$	3
$10 < A \leq 25$	2
$25 < A \leq 50$	1
$50 < A$	0

Test results

The five specimens were assessed according to ISO 10289 and the capability to protect against corrosion was measured. Corrosion products were analysed using scanning electron microscopy (SEM) and the chemical composition was investigated with energy dispersive x-ray (EDX) spectroscopy.

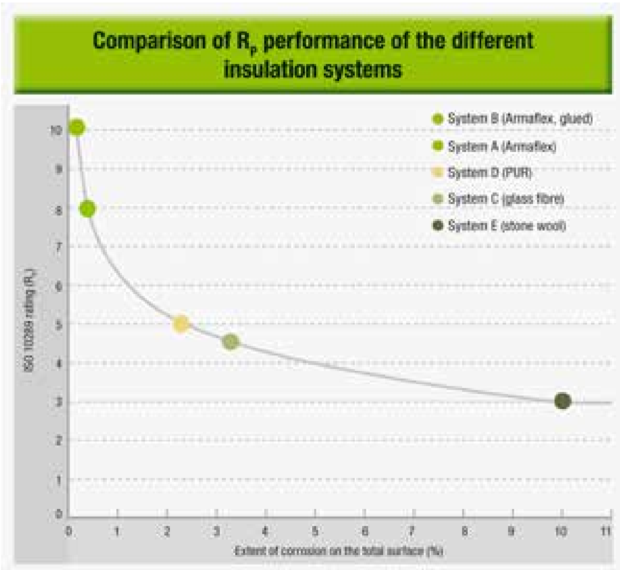
Corrosion protection ratings of the insulation systems

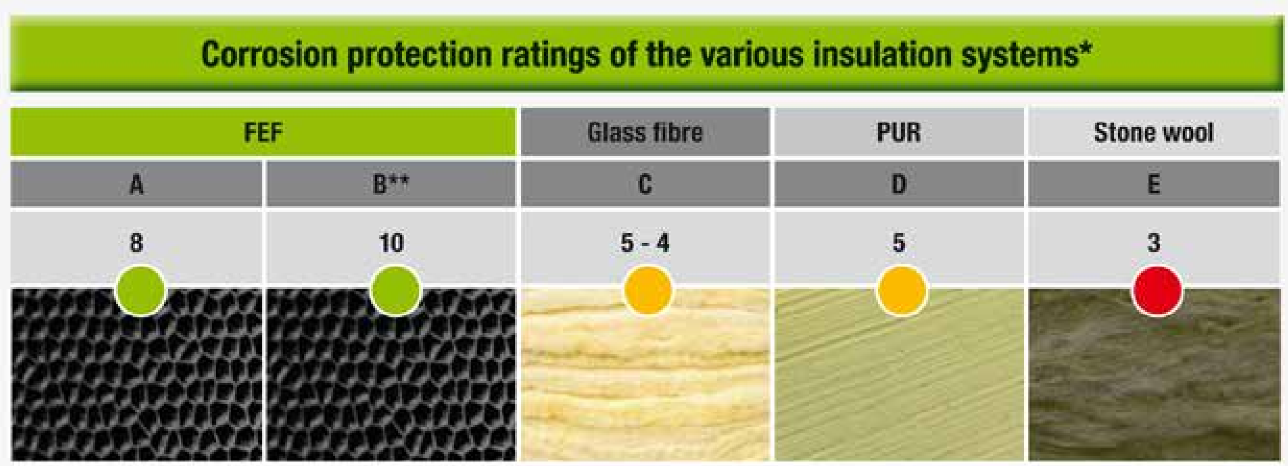
The two FEF insulation systems performed best in the test. While system A achieved a degree of protection rating of R_P 8, the elastomeric foam with all-over adhesion (system B) even attained the top rating, R_P 10. No signs of corrosion were found anywhere on the surface of the pipe after 65 days of testing. All-over adhesion of the insulation material further increases the already high corrosion protection of FEFs.

The glass-fibre insulation system (system C), on the other hand, only had an R_P of 4 to 5. Corrosion had formed on the pipe in the area under the damage hole. The analysis showed iron oxides with some silicon possibly from glass fibres. In the case of the polyurethane insulation (system D) increased corrosion was detected on the pipework in the area under the seam of the insulation shells. This indicates that the seam is a potential weak spot in this insulation system. System D achieved an R_P of 5.

The greatest corrosion damage was observed on the stone wool specimen, decreasing towards the ends of the pipe. The surface area of defects was between 5 and 10% of the total pipe surface, resulting in an R_P of 3.

The test demonstrated impressively that closed-cell flexible elastomeric foams which have an "integrated vapour barrier" are more tolerant towards small defects in the covering and insulation than other insulation systems. If moisture penetrates these other insulation systems and reaches the surface of the pipe, it usually leads to CUI.





*Corrosion protection classes (R_P) acc. to ISO 10289 (10 = no corrosion)

**All-over adhesion of both FEF layers

ArmaFlex insulation materials mitigate the risk of corrosion: whilst in service, the decompression chamber insulated with ArmaFlex and covered with Arma-Chek had regularly been exposed to green-water washover. After the chamber had been decommissioned the ArmaFlex insulation was cut open. As can be seen on the photograph on the right, the metal surface of the chamber is completely free of corrosion.

Long service life of elastomeric insulation systems

The CUI tests carried out by independent external institutes confirm the excellent results which have been achieved with ArmaFlex insulation materials for decades. The closed-cell insulation material with low thermal conductivity and high resistance to water-vapour transmission provides plant components with long-lasting protection against condensation and energy losses. The highly flexible material fits snugly even around the most complex components and can be installed easily under very difficult conditions on the building site. As is often noticed during maintenance work, equipment insulated with ArmaFlex shows no sign of corrosion decades after its installation. Internal and external tests have shown that even after it has been installed for well over 25 years ArmaFlex still has the values guaranteed at the time of manufacture. To ensure that the insulation system works reliably for many years to come, it is crucial that the insulation thickness is calculated correctly, system-compatible accessories are used and the materials are installed professionally following the manufacturers instructions.

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ABOUT ARMACELL

As the inventors of flexible foam for equipment insulation and a leading provider of engineered foams, Armacell develops innovative and safe thermal, acoustic and mechanical solutions that create sustainable value for its customers. Armacell's products significantly contribute to global energy efficiency making a difference around the world every day. With 3,135 employees and 24 production plants in 16 countries, the company operates two main businesses, Advanced Insulation and Engineered Foams. Armacell focuses on insulation materials for technical equipment, high-performance foams for high-tech and lightweight applications and next generation aerogel blanket technology. For more information, please visit www.armacell.com

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