KNOW-HOW – PART III

Prevention of condensation

The function of an insulation material can be greatly impaired by moisture. Damp insulation is as useless as a wet woollen coat in winter. Consequences of moisture absorption are not only higher energy losses, but also an increased likelihood of corrosion under the insulation (CUI) and the risk of high maintenance and repair costs.

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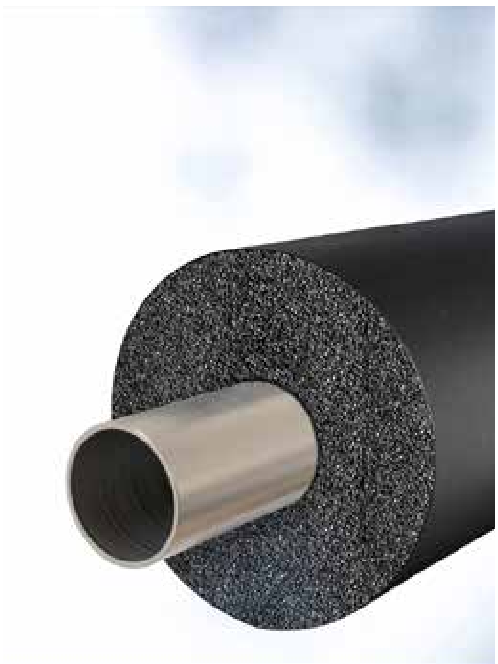

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MAKING A DIFFERENCE AROUND THE WORLD

Elastomeric insulation materials are closed-cell and have a high resistance to water-vapour transmission. The vapour barrier is not restricted to an easily damaged aluminium foil, but built up over the entire insulation thickness.

DAMP INSULATION DOESN'T INSULATE!

The function of an insulation material can be greatly impaired by moisture. Damp insulation is as useless as a wet woollen coat in winter. Consequences of moisture absorption are not only higher energy losses, but also an increased likelihood of corrosion under the insulation (CUI) and the risk of high maintenance and repair costs. Armacell has investigated how well various insulation materials are protected against inadmissible moisture penetration.

How do penguins endure the icy climate of Antarctica? How do polar bears survive temperatures as low as -50 °C in the Arctic Ocean? Both animals benefit from a physical principle often found in the animal world: their plumage or fur is arranged in such a way that the feathers or hairs trap air. And a multitude of tiny self-contained air pockets provide ideal protection against heat losses. The static, partially trapped air is responsible for the insulation properties of the polar bear's coat. Humans make use of this principle too, not just when it comes to winter clothing (e.g. in the form of modern down jackets), but also for insulating buildings.

Static air stems the heat flow

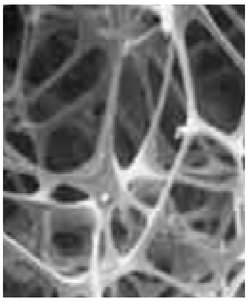
It is not usually the insulation material itself that has a thermal insulation effect, but the trapped air. In the case of vacuum insulation panels, however, an airless cavity provides the insulation. There are various ways of systemizing the many insulation materials available on the market. In terms of their raw materials they can be divided into two main groups: organic and inorganic products. Furthermore, a distinction is made between natural and synthetic materials. Depending on the structure, it is possible to differentiate between fibrous insulation, foams and granulates.

STRUCTURE OF DIFFERENT TYPES OF INSULATION MATERIAL

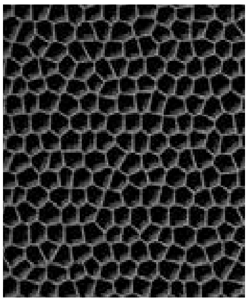
Fibrous insulation materials consist of small-diameter organic (wool, textiles) or inorganic (glass, stone) fibres, which are woven or glued together. The most common products in this group are glass fibres, mineral fibres and polyester.

Fibre

Foam insulation materials are made up of individual small cells. Depending on whether the cavities are connected or the cell walls are completely separated from each other, a distinction is made between open- and closed-cell foams. There are flexible products and rigid foams. The best-known foam insulation materials are manufactured on the basis of elastomers, polyethylene, PUR/PIR, polystyrene, phenolic resin and cellular glass.

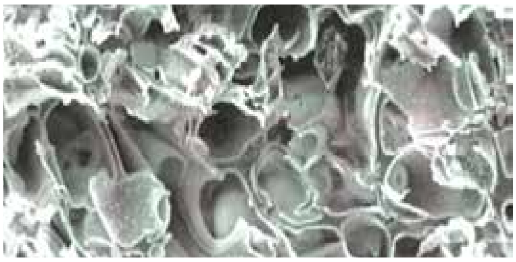


Open-cell foam



Closed-cell foam

Granulates are either supplied as loose materials (small nodules, pellets or nuggets) or bonded together to form insulation boards or sections. Examples here are calcium silicate, perlite, vermiculite.



Granulate

The insulation materials presented here are very different in terms of their physical and mechanical properties. They have strengths and weaknesses and, depending on the application in question, they can be rated as being suitable, less suitable or even unsuitable.

Figure 2

Protection against moisture absorption

To ensure that insulation materials installed in cold applications work well in the long-term too, it is essential that they are protected against moisture penetration. Water has a much higher thermal conductivity than insulation materials. Therefore, the absorption of moisture leads to a rise in the thermal conductivity and a deterioration in the insulation properties.

If moisture penetrates the insulation material

- energy losses increase,
- corrosion can occur under the insulation,
- mould can grow and
- maintenance and repair costs are incurred.

The insulation effect declines rapidly and in the long term the material will no longer perform its function. So when selecting an insulation material the key question is how well it is protected against moisture absorption.

Insulation materials tested

Having explained the impact of moisture on thermal conductivity, we would now like to present a practical test which the Fraunhofer Institute conducted on behalf of Armacell.

Three different insulation materials were investigated:

- mineral fibre,
- PUR and
- an elastomeric material.

AF/ArmaFlex does not need an additional vapour barrier. The closed-cell material has an "integrated" vapour barrier and the resistance to water-vapour transmission is built up – cell by cell – throughout the insulation thickness. Open-cell mineral fibre and PUR products, on the other hand, are equipped with an aluminium or PVC foil which acts as a vapour barrier. Under practical conditions, it is difficult to apply this foil in such a way that the water vapour flow directed into the insulation material is adequately stemmed. Furthermore, there is a danger of the delicate vapour barrier being impaired if the foil is damaged during installation or operation. Even if the work is carried out with great care, it is almost impossible to achieve adequate water-vapour tightness with conventional vapour barriers, especially at fixing points and on complex objects, elbows, T-pieces, valves, fittings, etc.

Test conditions in the climate chamber

To simulate damage to the insulation system, which is the rule rather than the exception in practice, in the second part of the test two small holes (Ø 5 mm) were drilled on opposite sides 5 mm deep into the surface of the tube or pipe section. The test was carried out in a climate chamber in which the temperature and humidity were maintained at a defined level for the duration of the measurements.

Moderate test conditions were deliberately chosen: the pipes were run at a line temperature of 20 °C. The ambient temperature was defined as 35 °C and the relative humidity as 55 %. The test was conducted under these conditions for 33 days.

Test results

Resistance to water vapour transmission

After the test had been completed and the specimens removed, the resistance to water vapour transmission (μ) of the different insulation materials was measured. While the μ-value of the elastomeric material had not changed despite the damage and was still over 10,000, the resistance to water vapour transmission of the PUR pipe section had declined from 2,163 to 672 and the aluminium-covered mineral wool had a μ-value of only 467 (compared to 7,053 originally).

Figure 3: Test set-up: The test specimens in the climate chamber

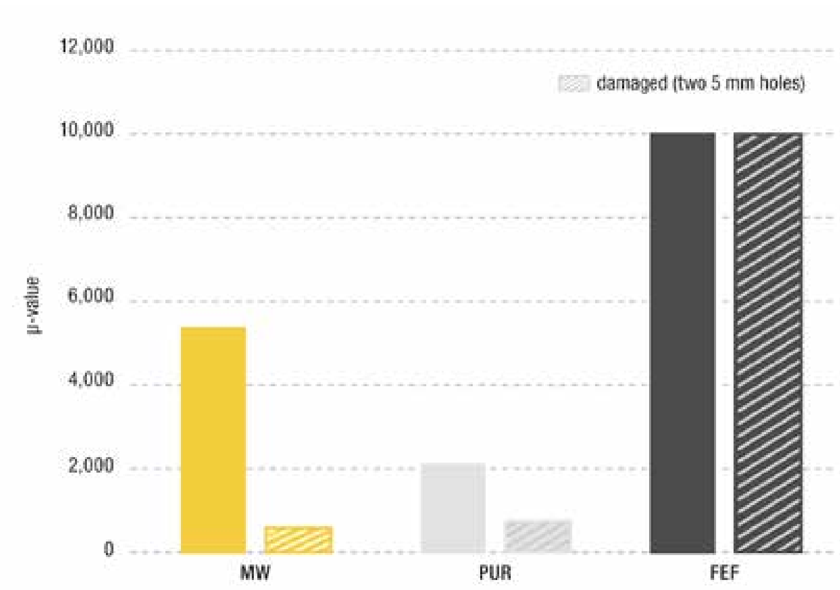


Figure 4: Resistance to water vapour transmission of the insulation materials after the test

Condensation on the pipes

Because the test only lasted a short time and the conditions were moderate, the insulation materials show only slight moisture absorption in their entire thickness. However, significant differences are evident if one looks at the inner insulation layer (5 mm). Even in this short period of time, a considerable amount of moisture has accumulated in this area of the mineral fibre specimens and even more so in the PUR pipe sections. The FEF insulation materials, on the other hand, show no moisture absorption in this critical zone.

In the case of both the PUR and mineral wool insulation, it seems that the diffusion flow of humid ambient air was directed from the outside to the inside and water vapour has precipitated there as condensation. In contrast, no moisture has penetrated the FEF material. The photos of the respective pipe surfaces after the removal of the insulation material

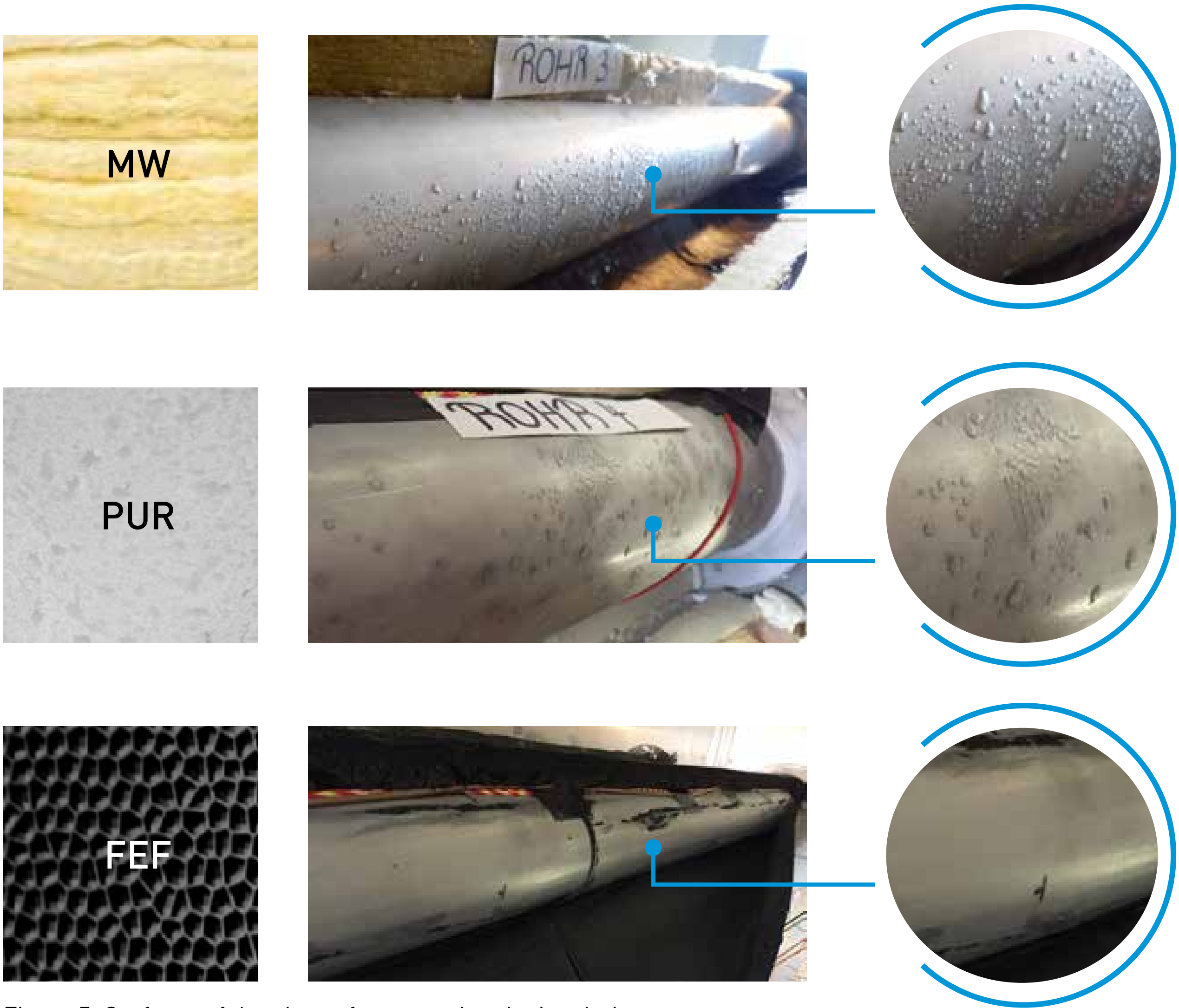


Figure 5: Surfaces of the pipes after removing the insulation

Figure 6: In the case of the mineral fibre insulation, humid air has penetrated especially around fittings, yet even these areas have remained dry under the FEF insulation.

confirm this. While considerable amounts of moisture have accumulated under both the PUR and mineral wool insulation, there is no condensation on the pipe surface under the FEF insulation (see Figure 5).

As the photo documentation shows, the vapour barrier has failed especially on fittings and humid air has penetrated the insulation (see Figure 6).

Even under these moderate test conditions, the mineral fibre and PUR materials could not stop moisture diffusing into the insulation and condensing on the surface of the pipe. The vapour barrier could not hinder the absorption of water vapour effectively. Only the FEF insulation material has prevented moisture penetration.
It is also interesting to take a look at the development over time. While the pipe insulated with FEF shows no signs of condensation even after 33 days, the mineral fibre insulation fails right at the beginning of the test, both with and without damage. Condensation occurs on the pipes under the PUR insulation after 21 (damaged covering) or 23 days.

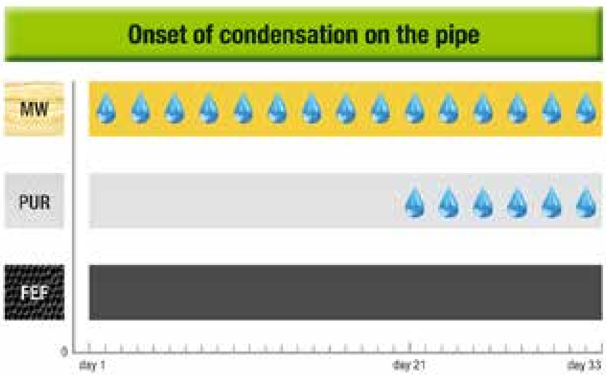


Figure 7

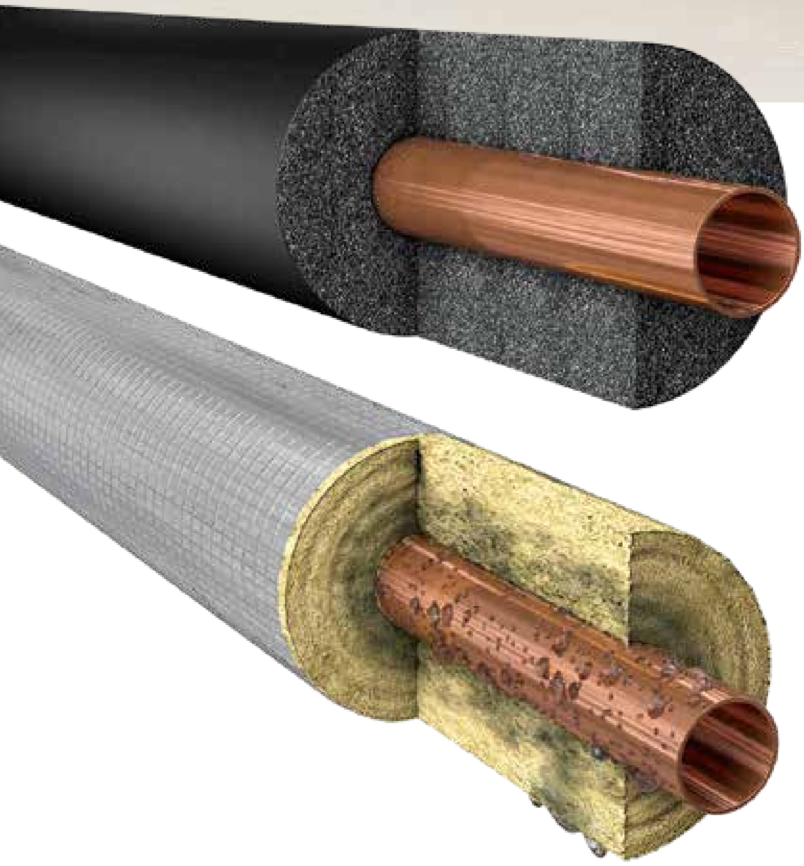


Figure 8: FEF insulation
materials protect pipes against condensation

Long-term consequences of moisture penetration

To investigate the long-term effects of moisture absorption, the Fraunhofer Institute carried out calculations based on these results and simulated how the insulation materials behave over a period of ten years. The following assumptions were made for these calculations: the pipe is run at a line temperature of 5 °C. A temperature of 35 °C and relative humidity of 80 % were defined as the ambient conditions.

Figure 9 shows how much moisture the insulation materials would absorb over an operating period of ten years. While the moisture content in the FEF insulation material is still under 5 % after ten years, it has risen to almost 20 % in the mineral fibre insulation and even 25 % in the PUR material.

The thermal conductivity increases with every vol.-% of moisture content and the insulation effect deteriorates rapidly. The consequences are not only steadily rising energy losses over the operating period, but also a fall in the surface temperature. If this drops below the dew-point temperature, condensation occurs. Only if the thermal conductivity of the insulation material does not increase significantly over time as a result of moisture penetration can it be ensured that the surface temperature remains above the dew point even after many years of operation.

Higher thermal conductivity

During the short test period, the thermal conductivity of the insulation materials has not increased significantly. This was not to be expected in view of the moderate conditions and short time-frame. But if the test results are extrapolated to an operating period of ten years, considerable differences between the materials become apparent.

While the λ-value of the FEF has only risen by around 15 % after ten years, the thermal conductivity of the mineral wool has increased by 77 % and that of the PUR insulation by 150 % (see Figure 10).

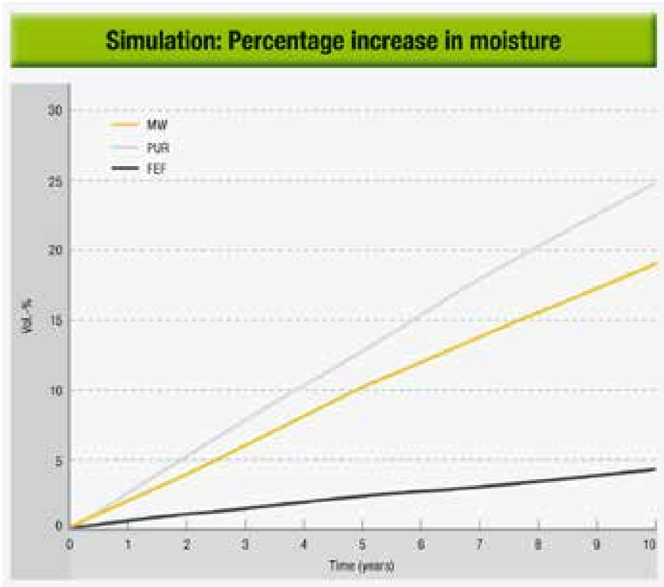


Figure 9

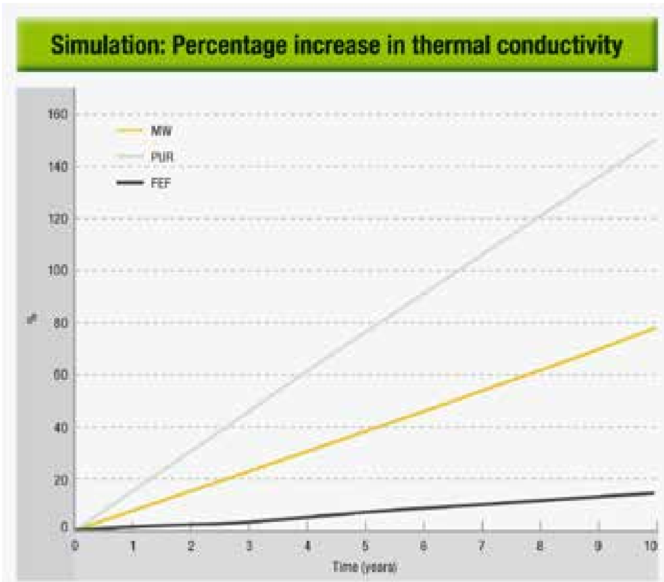


Figure 10

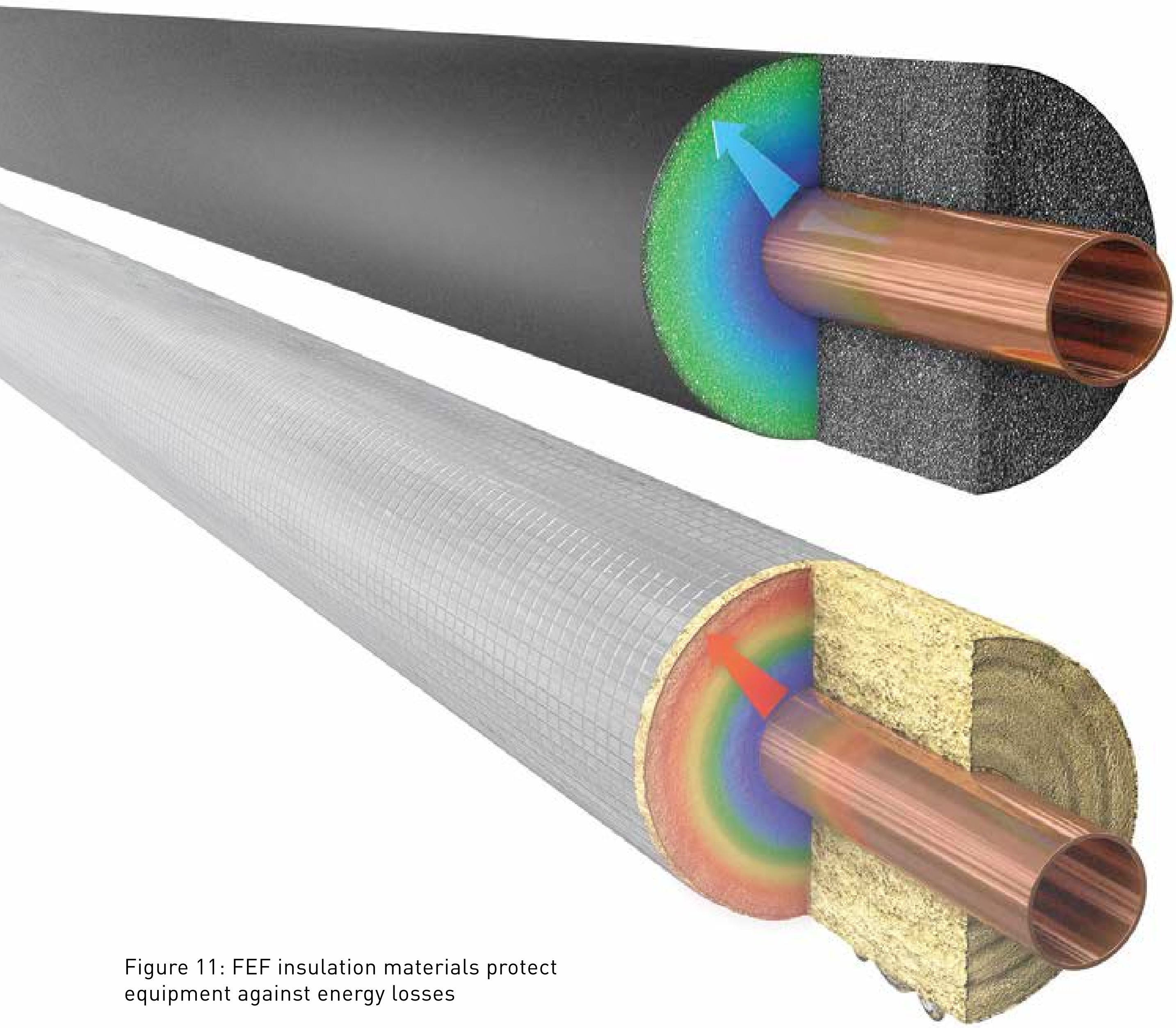


Figure 11: FEF insulation materials protect equipment against energy losses

Conclusion

As the investigation has shown, the thermal conductivity of a material must not be the sole criterion when selecting insulation materials. In order to rule out condensation on the pipe surface and an increase in the thermal conductivity over the service life, the insulation material must also be protected against moisture absorption. Therefore, specifiers and refrigeration plant constructors should understand the thermal conductivity stated by manufacturers as being the initial thermal conductivity or "dry λ-value" and compare the resistance to water vapour transmission of the materials when selecting a product. In FEFs the resistance to water vapour transmission is built up throughout the entire insulation thickness and is 7,000 or in the case of AF/ ArmaFlex even 10,000. But in mineral fibre and PUR products it is restricted to a thin vapour barrier which cannot protect the insulation material effectively against moisture absorption. Even very minor damage has an impact on the effectiveness of the vapour barrier and especially at fixing points, on elbows, T-pieces and fittings condensation is inevitable.

If the insulation material is completely soaked, the increase in energy consumption is often the least of the problems. Mould, structural damage, e.g. to sus-

pended ceilings, or disruption to industrial processes due to maintenance work and down-time can result in huge costs.

By using open-cell insulation materials in cold applications specifiers and installers are taking an incalculable risk, which can cost them dearly. Manufacturers of mineral-fibre products currently promote insulation materials especially developed for cold applications. Even if these systems are explicitly marketed as cold insulation materials, they are open-cell mineral-fibre products with an aluminium foil. The manufacturer's 15-year guarantee does not alter the fact that in the event of a complaint the user is required to prove that the product was installed correctly.

In Germany, the use of mineral wool in cold applications is contrary to the requirements of DIN 4140 (Insulation work on industrial installations and building equipment – Execution of thermal and cold insulation). It is practically only allowed if a double jacket is installed (an air- and diffusion-tight, welded or soldered metal cladding). However, as this is both time-consuming and expensive it is unlikely to be done.

On cooling water pipes, it is highly advisable to install closed-cell insulation materials with a high resistance to water-vapour transmission and low thermal conductivity. This ensures that potential diffusion processes are reduced to a minimum in the long-term, too.

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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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