TECHNICAL LIBRARY

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All calculations based on ArmWin AS V1.0 - the calculation programme from Armacell - are based on ISO EN 12241:1998. The calculations of water-vapour diffusion were developed by Dr. Ernst W. Behrens: Bauphysik 25/1 (2003), pp. 35-38, and 26/4 (2004), p. 204.

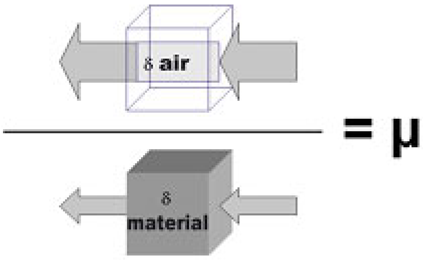
Water Vapour Diffusion Resistance Factor μ

The water vapour diffusion resistance factor μ is obtained by dividing the water vapour diffusion coefficient in air, by the moisture permeability of a porous material.

The values will be related to the different driving mechanisms that are used to consider the water vapour transmission through the porous material, which may be either humidity by volume or partial pressure of water vapour. The values measured will also be dependent upon temperature.

For air at 0°C the water vapour diffusion coefficient is
658,07 · 10-9 kg/(m·h·Pa).

The Water Vapour Diffusion Resistance Factor μ



The water vapour resistance factor, commonly called μ-factor, is therefore a dimensionless number describing how many times better a material or product is at resisting the passage of water vapour, compared with an equivalent thickness of air.

Thus high μ-factor = high resistance to water vapour transmission.

If you compare different products, if the reduction of diffusion is the same, the equivalent thickness of air must always the same.

Example:

- μ = 10.000 d = 0,014 m -> μ·d = 140 m
- μ = 7000 d = 0,020 m -> μ·d = 140 m
- μ = 5000 d = 0,028 m -> μ·d = 140 m
- μ = 3000 d = 0,047 m -> μ·d = 140 m

Here you see, the lower the μ-factor, the thicker the insulation required to achieve the same reduction of diffusion.

Armaflex with additional boundary layer

To prevent condensation within the industrial process, refrigeration and air conditioning sectors, it is necessary to select a thickness of insulation such that the surface temperature of the insulation is at least the dew point temperature of the ambient air. As the difference in temperature between the cold medium (or surface) and the warm ambient air causes also partial pressure difference, one must minimise moisture diffusion into the insulation.
Armaflex has a closed-cell material structure which offers a high resistance to water vapour diffusion, minimising the detrimental effect this process can have on insulation efficiency.

In practice a boundary layer is often applied on the Armaflex insulation. In this case the insulation thickness of elastomeric materials has to be increased by the size of the drilling of the sheet drift screw when taking into consideration the change of the surface coefficient of heat transfer.
In the past , in order to reduce the inevitably increasing costs, application specialists often chose, as an alternative to thicker elastomeric insulation, a boundary layer made of open-cell material to catch up the drilling of the sheet drift screw. As a consequence, the surface temperature of the flexible insulation material decreases to a large extent and the critical dew point temperature (ingressing zone) moved into the open-cell material. Therefore, the additional layer as water storage was and still is responsible for corrosion at the inside of the boundary layer.

With the update in year 1996 the DIN 4140 "Insulation work on industrial installations and building equipment - Execution of thermal and cold insulation" deleted the additional layer as protection for insulation material within the area of cold insulation.

As an alternative, there is the execution of an additional air gap with an open up of the boundary layer. The air gap should be at least 15 mm thick. In addition, there should be weep- and vent holes of at least 10 mm thickness with differences of 300 mm at a maximum.

This installation, also valid for objects installed outside and having an operating temperature below +120°C, creates a separation of the boundary layer and the insulation material, so that a kind of ventilation of the insulation material happens and the creation of moisture can be excluded in advance. Besides that, it is possible, that condensate is able to drip through the air gap and will not ingress the insulation material. Of course, this has to be taken into consideration correspondingly with regard to the structural setting of the spacing blocks.

Calculation Methods

The following calculation methods are available

- Condensation Control
- Outer Surface Temperature
- Thermal Transmittance
- Heat Flow
- Temperature Change of Flowing Medium
- Temperature Change of Stationary Medium
  - time to be calculated
  - temperature change to be calculated
- Prevention from freezing of standing water in a pipe
- Long-term Behaviour
- Energy Saving

Calculation Rules
» EN ISO 12241:1998
» Thermal insulation for building equipment and industrial installations - Calculation rules

Condensation Control

Condensation water can be prevented by ensuring that the insulation is dimensioned so that its surface temperature is above the temperature of dew point, even at critical points (="thermal bridge").

The necessary minimum insulation thickness is determined by the following influencing variables:

- minimum line temperature
- maximum ambient temperature
- maximum relative humidity
- external surface coefficient
- internal surface coefficient (for gases)
- thermal conductivity of the insulation material under the given temperature conditions

The engineered wall thickness does concern an important role for dimensioning.

When an additional system, e.g. sheet metal lagging on a air layer is applied to the correctly dimensioned Class O Armaflex insulation, this results in a change of the temperature profile in the insulation. The Armaflex surface temperature falls considerably, i.e. the critical dew-point temperature (moisture penetration zone) is displaced in the air layer.

Conduction

Heat is the transfer of energy between communicating systems due solely to a difference in temperature. There are three mechanisms recognised for the transfer of heat and, depending on the circumstances, they may occur separately or simultaneously.

- Conduction
- Convection
- Radiation

Conduction is the transfer of heat in a solid material due to the temperature difference.The energy is transferred through movement of the constituent molecules and particles of the solid.

Thermal conductivity is a measure of the rate of heat transfer through the material. Metals are generally very good conductors of heat. Thus copper has a thermal conductivity of 401 W/(m.K).

Dew Point Temperature

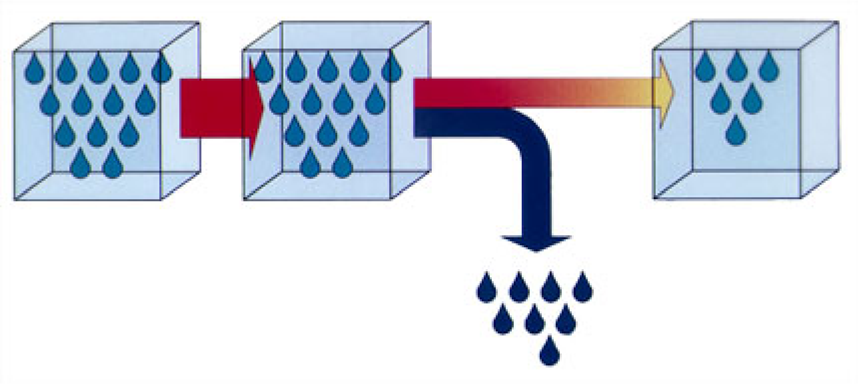
The dew-point temperature - also called saturation temperature - is that temperature at which the air is saturated with water vapour and where water condenses if the air temperature drops further.

In general warm air can absorb more water than cold air.

Atmospheric air with a certain temperature and water vapour content cools down when in the vicinity of a pipe whose medium temperature is lower that the temperature of the ambient air. As the amount of water vapour which is present does not decrease as the air cools down, the air is 100 % saturated with water vapour at a certain temperature.

If the air now continues to cool down on the object, part of the water will no longer be absorbed in the form of water vapour and will therefore become liquid water. Thus condensation, which is also known as perspiration water, is formed.

υ = + 22 °C	**υ = + 19,4 °C**	**υ = + 22**



φ = 85%	**φ = 100%**	**φ = 100%**

For installations in refrigeration applications, this means that the insulation thicknesses must be designed so that temperatures are not lower than the dew point temperature anywhere on the surface of the insulation material.

Convection

Heat transferred by the motion of fluid particles is known as convection. A liquid or gas is warmed up by contact with a hot surface, the liquid or gas fluid moves away carrying the heat within the particles as they move away.

Heat transfer by convection may be forced or natural. Forced convection requires an external agency such as a pump, stirrer, fan. The cooling effect of wind is also an example of forced convection.

Natural convection is the transfer of heat between a solid and a fluid due only to the temperature difference between the two. The fluid motion is due entirely to natural buoyancy forces arising from a changing density of the fluid in the vicinity of the surface.

The flow within the fluid medium may be laminar or turbulent which will affect the rate of heat transfer. In addition the shape and orientation of the solid will affect the type of flow.

Energy saving per insulated pipe or flat surface

For investors it is often required that the future energy consumption of heating installation be estimated. The energy consumption depends, amongst other factors, on thickness of applied insulation. Provided the calorimetric values of fuel (gas or oil) are known and input into the calculation sheet together with the unit price of oil, gas and electricity, ArmWin AS will calculate energy savings over required period of time in comparison to an uninsulated pipe or tank. The time period considered consists of the operation time of the heating system: years, working days per year (heating season) and working hours per day (average number over the whole heating season). The energy savings are calculated as fuel quantity or electrical energy in kWh saved over the required period of time, these savings are also converted into direct cost value savings using the price of the fuel or electricity as appropriate.

More information of the saving potential of pipe insulation is available from Armacell Technical Service.

External surface coefficient

For calculation it is generally accepted that the following values or external surface coefficients can be used in calculations of normal situation conditions for plants (internal and external) insulated with:

Class O Armaflex, **NH / Armaflex, HT / Armaflex** or Unpainted black and / or painted with Armafinish 99	9 $W/(m^2 \cdot K)$
Metal jacketing, eg. galvanised	7 $W/(m^2 \cdot K)$
Bright metallic surface, eg. aluminium or stainless steel	5 $W/(m^2 \cdot K)$
Uninsulated	18 $W/(m^2 \cdot K)$

Remark for calculation "Condensation control":
One could not take the higher external surface coefficient values which arise when air movements (forced convection) are present as the basis for calculations since the thicknesses of the insulation layers calculated in this manner would have an indequate water vapor diffusion resistance (µd value). Restricted convection due to "congested areas" (too little space, badly ventilated cavities) results in lower external surface coefficients. In such cases a calculation according to ISO 12241:1998 Standard is necessary.

Flexible Elastomeric Foam (FEF)

Closed cell flexible foam made synthetic rubber and containing other polymers and other chemicals which may be modified by organic or inorganic additives.

Heat Flow

In order to save energy it is often required in practice that a certain heat flow is not exceeded.

One necessary value is the:
- external surface coefficient
- internal surface coefficient

The density of heat-flow rate q is the heat-flow rate related to the unit of the surface transgressed. The unit is W/m^2.

In the insulation technology, the density of heat-flow rate is related to the surface of the insulation system.

The linear density of heat-flow rate is the heat-flow rate divided by length; the unit is W/m.

Internal Surface Coefficient

According to the EN ISO 12241 the internal surface coefficient for flowing medium (liquid) is very high and can be ignored for flowing media in pipes.

Appr. value: 1000 $W/(m^2 \cdot K)$

However, this should be taken into consideration for ventilation lines or ducts. In such cases a calculation according to EN ISO 12241 is required.

Appr. value: 30 $W/(m^2 \cdot K)$ (gasous)

Long-Term Behaviour of Low-Temperature Insulations

The most important tasks of low-temperature insulation are to prevent condensation and minimize energy losses over the entire service life of an installation. When selecting and determining the thickness for low-temperature insulation it is necessary to bear in mind that over the service life energy losses can increase dramatically as a result of moisture penetration.

A reliable insulation system must therefore provide protection against inadmissible moisture penetration. With every vol.-% of moisture content the thermal conductivity increases and the insulation effect deteriorates. The results are not only higher energy losses but also a drop in the surface temperature. If this falls below the dew-point temperature, condensation occurs. Only if the thermal conductivity of the insulation material does not increase significantly as a result of moisture penetration, is it possible to guarantee that the surface temperature remains above the dew point even after many years of operation.

The amount of moisture which is able to penetrate the insulation as a result of vapour diffusion depends on water vapour diffusion resistance (µ-factor) which the insulation material has. The lower the µ-factor of an insulation material, the more the moisture content – and therefore the energy losses – will rise over the years. It is essential to bear this in mind when selecting the insulation material.

Under normal conditions the probability of water vapour condensing in the insulation material and thus contributing to an increase in thermal conductivity is less than usually assumed. One of the reasons is that the calculation of the insulation thicknesses needed to prevent condensation is based on the maximum ambient conditions. However, it is unlikely that the maximum ambient temperature and the maximum humidity assumed for the purposes of calculation will occur simultaneously. Furthermore, in borderline cases it is usual in low-temperature applications – also for the sake of energy saving – to use a slightly thicker layer of insulation than is necessary purely to prevent condensation.

As a result of revisions, the calculation equations have found their way into the VDI 2055, part 1.

Metric / American Units

1 inch (in)	=	25.4 mm
1 foot (ft)	=	0.3048 m
1 yard (yd)	=	1.609 km
1 nautrical mile (nm)	=	0.9144 m
1 mile, statue (USA) (stm)	=	1.852 km

Outer Surface Temperature

For operational reasons it is often stipulated in practice that a certain surface temperature or temperature of the surface higher than that of the ambience should be maintained.

The surface temperature is no measure for the quality of the thermal insulaltion.

This depends not only on the heat transmission but also on operating conditions which cannot be readily determined or warranted by the manufacturer. These include among other things: ambient temperature, movement of the air, state of the insulation surface, effect of adjacent radiating bodies, meteorological conditions etc. Further, it will be necessary to make assumptions for the operating parameters. With all these parameters it is possible to calculate the required insulation thickness.

Permeability Units

The common unit is: kg/(m · h · Pa)

Other units are:

1 kg/(m×s×Pa)	=	kg/(m×h×Pa) × 3600
1 kg/(m×s×Pa)	=	µgm/(Nh) × 2.778 × 10^{13}
1 kg/(m×s×Pa)	=	gm/(s×MN) × 10^{-9}
1 kg/(m×s×Pa)	=	g/(m×h×mmHg) × 479,17 × 10^{-6}
1 kg/(m×s×Pa)	=	g/(m×s×bar) × 10^{-8}
2,97 × 10^{-10} kg/(m×h×Pa)	=	g/(m²×24h)
3,6 × 10^{-8} kg/(m×h×Pa)	=	g/(MN×s)
0,52 ×10^{-8} kg/(m×h×Pa)	=	gr × in/(h×ft²×inHg) "perm-in"

Pressure Units

The common unit is Pa.

Other units are:

1 bar	=	10^{-5} Pa
1 N/m²	=	1 Pa
1 kp/m²	=	9.81 Pa
1 Torr	=	133 Pa

Prevention from freezing of standing water in a pipe

It is impossible to prevent the freezing of a liquid in a pipe, although insulated, over an arbitrary long period of time. As soon as the liquid (normally water) in the pipe is stationary the process of cooling starts. The freezing time is dependent on the heat flow and the diameter of the pipe.The heat flow of a stationary liquid is determined by the initial energy stored in the liquid, the insulation material and the pipe material as well as by the latent heat of water to ice.

In principle any freezing of pipe cross-section should not take place as pipe cross-sections are dimensioned according to demand. However, concessions can be made in individual cases and ice formation can be chosen according to demand.

Radiation

Heat transfer by radiation differs from the other two mechanisms (conduction and convection). Radiation is a transfer of energy which occurs most freely in a vacuum and occurs between all material phases. All materials which are above Absolute Zero temperature (-273°C) emit radiation due to the vibration of the electrons within the molecules of a material.

The amount of energy emitted depends on the absolute temperature of the body in accordance with the Stefan-Boltzmann equation.

The equation is only strictly applicable to a "black body" which is a perfect radiator. A real material will emit less energy and its proportion to the energy emitted from the "black body" is defined as the emissivity of the material.

Relative humidity

A given volume of air is able to hold a small amount of water vapour and this (maximum) amount of water vapour depends upon the air temperature.
The air will not always hold the maximum possible quantity of water vapour so that it is usual to express the amount of water vapour present as a percentage of the maximum:-

$$\text{Relative humidity} = \frac{\text{actual amount of water vapour present}}{\text{maximum amount of water vapour that may be held at a particular temperature}}$$

or

$$\text{Relative humidity} = \frac{\text{actual partial pressure of water vapour}}{\text{saturated vapour pressure}}$$

At a temperature of 22°C the maximum amount of water vapour that the air can hold, i.e. saturated, is 16.6 g per kg at normal pressure. Thus at a relative humidity of 85% the actual amount of water vapour will be 14.1 g/kg. If the air temperature is now reduced to 19.4°C the actual amount of water vapour will not change but the relative humidity will be increased to 100%, i.e. at 19.4°C the maximum quantity of water vapour that the air can hold is 14.1 g/kg. Warm air can hold more water vapour than cooler air, hence when warm air comes into contact with a cold surface then the air next to the surface will be cooled and may exceed its saturation level leading to condensation.

Specific Heat Capacity

The heat capacity of a material is the amount of energy required to raise the temperature through one degree Kelvin.

Hence the specific heat capacity relates to unit weight of material and is measured in J/(Kg·K) i.e. kilojoules per kilogram per degree Kelvin.

An insulating material of high heat capacity tends to impart thermal stability to an insulated system since under fluctuating temperature conditions the heat will be absorbed by the material and not lead to rapid heating or cooling of the medium.

Some typical specific heat capacities are:

Medium	Mean temperature °C	Density kg/m^3	Spec. Heat Capacity KJ/(kg·K)
Ammonia	-50	695	4.450
	+50	561	5.080
Fuel Oil	-	920	1.670
Glycerine	0	1273	2.260
	+100	1209	2.810
Nitrogen	-180	730	2.150
Water	±0	1000	4.220
	+50	998	4.180
Air	-50	1563	1.005
	±0	1275	1.005
Steel	+10	7850	0.502
Copper	+20	8900	0.398
Cast Iron	+10	7250	0.628
Zinc	±0	7100	0.398

Stationary Medium

This calculation option allows to calculate cooling (or heating) effect of stationary (stand-still) medium. There are two calculation options for a given, known insulation thickness:
» time to be calculated,
» temperature change to be calculated.
Should the insulation thickness be calculated, then both above values must be known.

For operational reasons it is often required that in practice a certain final medium (service) temperature or certain standstill time may not be exceeded.

For calculation the necessary values are (among others):
» External surface coefficient
» Internal surface coefficient (for gaseous media)
» Specific heat capacity

For gaseous media the heat capacity of the container (tank, pipe, duct) is taken into account and thus the input data refering to the container (specific heat capacity, density) is required.

Surface Coefficient

The surface coefficient of heat transfer is the density of heat flow rate divided by the temperature difference between the surface and its suroundings.

$$h = \frac{q}{T_s - T_a} \quad [W/(m^2 \cdot K)]$$

For a more detailed understanding of surface coefficients it is necessary to consider:

Temperature difference between the surface and surroundings.Outer diameter of the insulation. Orientation of the pipe.Nature of the surface. Movement of air over the pipe i.e. laminar or turbulent. Any radiative heat transfer.

The thermal surface coefficient is the sum of the ***convective*** and ***radiative contributions.***

$$h = h_{cn} + h_r$$

where the convective contribution is dependent on air movement, relative orientation and the type of material. The radiative contribution is dependent on the nature of the surface and its emissivity.

A number of equations are available to calculate values for surface coefficients under different operating conditions.

Temperature Change of Flowing Medium

This calculation option allows to calculate cooling (or heating) effect of the medium flowing in a container (usually pipe or duct, but may be also a tank). For a given, known insulation thickness temperature change (final medium temperature) can be calculated. Should the insulation thickness be calculated, then the temperature change (final medium temperature) must be known must be known.

For operational reasons it is often required that in practice a certain final medium (service) temperature may not be exceeded.

For calculation the necessary values are (among others):
» External surface coefficient
» Internal surface coefficient (for gaseous media)
» Specific heat capacity

Temperature Units

Kelvin:	Tk	= 273,15 + tc	= 5/9 TR	(K)
Rankine:	TR	= 459,67 + tF	= 1.8 TK	(Ra)
Celsius:	tC	= 5/9 (tF-32)	= TK - 273,15	(°C)
Fahrenheit:	tF	= 1.8 tC + 32	= TR - 459,67	(F)

Absolute Zero of the temperature is:

0K = -273,15°C = 0Ra = -459,67F

Thermal Conductivity

The thermal conductivity is a measure of the ability of a material to allow heat to pass through it. The value is a property of the material and is dependent only on the temperature of measurement and the moisture content of the insulation.

When comparing the thermal conductivity of different insulation materials then lower values are better.

Common unit is: W/(m · K)

Other units are:

1 W/(m·K)	=	kcal/(m·h·K) · 1.163
1 W/(m·K)	=	Btu in / h· ft^2 ·deg F · 0.1443

Thermal Insulation (ISO 9229:1991)

A material or product which is intended to reduce heat transfer through the structure against which, or in which, it installed.

Heat transfer (ISO 9251:1987 clause 2.5) is defined as the transmission of energy by thermal conduction, thermal convection or thermal radiation, or a combination of these.

The properties of a practical insulation material are more than just the reduction in heat transfer, since the most efficient is a vacuum which is not always practical.

For a practical insulation material the following properties should be considered:

» Low thermal conductivity
» Good fire performance
» High resistance to water vapour
» Long term structural stability
» Ease of installation
» Health and safety for personnel
» Environmental factors
» Technical support

and materials should be selected so as to provide the best combination of the above properties.

Thermal Resistance

Thermal resistance is defined by the equation:

$$R = \frac{T_1 - T_2}{q}$$

i.e. the temperature difference divided by the density of heat flow rate in the steady state condition.

The thermal resistance can be related to either the material, structure or surface.

$$R = \frac{d}{\lambda}$$

For a plane layer of material
where d = the thickness of the layer and lambda is the thermal conductivity of the material.
The unit of thermal resistance is $(m^2 \cdot K)/W$.

To calculate that total thermal resistance of a structure it is necessary to consider also the appropriate surface resistances. Thus for pipe insulation the linear thermal resistance is calculated, i.e. the thermal resistance per meter length of pipe run, where RL is measured in $(m \cdot K)/W$.

For pipes, the material thermal resistance:

$$R_L = \frac{\ln \dfrac{D_e}{D_i}}{2 \cdot \pi \cdot \lambda}$$

where
De = outer (external) diameter of insulation.
Di = inner (internal) diameter of insulation (external pipe diameter).
p = 3.1416

In order to calculate the total thermal resistance of a structure, to the material thermal resistance the inner and outer surface resistance, Rsi and Rse must be added respectively.

Where (for pipe insulation):

$$R_{si} = \frac{1}{h_i \cdot \pi \cdot D_i} \quad \text{and} \quad R_{se} = \frac{1}{h_e \cdot \pi \cdot D_e}$$

and hi and he are the internal (between medium and a pipe) and external (between insulation and the ambient air) surface coefficients of heat transfer respectively. In this approach the thermal resistance of the pipe material is neglected (due to its usually high thermal conductivity and small thickness - compared to the insulation material).

Thermal Resistivity (EN ISO 7345)

This is the reciprocal of thermal conductivity.

It therefore has units of (m·K)/W.

Thermal Transmittance (ISO 7345 2.12)

It is often required in practice that a specified level of thermal transmittance is not exceeded.

For the calculation of thermal transmittance it is necessary to know among others the values of:
» external surface coefficient
» internal surface coefficient

Thermal transmittance, which is the heat flow rate in the steady state divided by area and by the temperature difference, i.e.

$$U = \frac{q}{(T_{se} - T_{si})} \quad [W / (m^2K)]$$

where q = quantity of heat transferred divided by the time, hence units are Watts.
By comparison with thermal resistance, it can be seen that

$$U = \frac{1}{R}$$

Thus for a simple structure the U value, or thermal transmittance, is given by

$$U = \frac{1}{R_{si} + R + R_{se}}$$

U-values are used by regulating authorities (normally national governments) to specify the levels of insulation required in residantial houses, officies and other buildings. A typical regulation may state that the U value for an exposed wall or roof should not be greater than 0.3 (W/m²K) in dwellings. It will then be necessary to calculate the overall U value from the thermal resistance of the components with due allowance for any air spaces and surfaces.

For pipe insulation a typical regulation imposes insulation thickness straightforwardly. However the U-values in [W/m·K] for insulated and uninsulated pipes are given as default values in the relevant EN standards for calculation of the energy performance of buildings.

Water Vapour Barrier

Defined in ISO 9229 as a layer intended to prevent water vapour diffusion. The vapour barrier may be a relatively thin layer of impermeable material which is applied to the outer surface or warm side of the insulation. Alternatively the vapour barrier may be "built in" to the material, as in closed cell structures.

However it is important to realise that a closed cell structure does not, in itself, guarantee a vapour barrier which is sufficient to meet performance requirements. We must also consider the nature of the insulation material and ensure that the integral vapour barrier is associated with a very high resistance to water vapour transmission.

Vapour barriers which are applied as additional protection usually incorporate aluminium foil which is laminated and re-inforced with glass or polyester mesh and then coated with adhesive. With such surface vapour barriers it is very important to ensure that they are properly installed to give complete protection, even a small tear or puncture will be sufficient to render the vapour barrier ineffective.

For the insulation of low temperature systems the use of a proper vapour barrier is a technical requirement to provide the long term efficiency of the system. It may be necessary to have some additional protection for the vapour barrier by means of a weather-barrier or opposite: the additional weather-barrier can significantly improve the existing vapour barrier of the insulation material structure as is the case with e.g. Arma-Chek T surface protection system.

Water Vapour Permeability

The effectiveness of a vapour barrier is expressed in terms of the rate at which water vapour is transmitted through it under defined conditions. Similarly for an insulation material the permeability to water vapour determines its efficiency for low temperature installations.

Permeability is a property of the material and is defined as the amount of water vapour which passes through unit thickness, normally one metre, in unit time under a given pressure. Typical units would therefore be:-

kg/(m·s·Pa) or g·m/(s·MN) where one Pascal = one Newton per square metre (Pa = N/m^2).

Further Permeability unitsee separately.

Materials which have a very high resistance to water vapour transmission will have very low permeability values, i.e. less than 0.2·10-9 kg/(m·h·Pa). When comparing permeability values quoted by different manufacturers it is necessary to consider the test method.

Thus permeability according to EN 12086 and EN 13469 (previously DIN 52615) is measured at 23°C with a relative humidity of 50% on one side of the sample and 0% RH on the other side. Under these conditions the water vapour partial pressure difference is 1400 Pa. For the BS 4370 Part 2 test conditions are 25°C and 75% RH which give a water vapour partial pressure difference of 2380 Pa.

For a system operating at low temperature, to determine the partial pressure for water vapour it is also necessary to consider the service (medium) temperature and relative humidity. Thus for a chilled water system operating at service temperature of 6°C with ambient conditions of 22°C and 85% RH we have:

Partial pressure on surface of pipe = 935 Pa
Partial pressure ambient = 2247 Pa

Hence partial pressure of water vapour acting on the outer surface of the insulation is 1312 Pa.

Value for vapour pressure can be obtained from published tables. In this instance the Handbook of Physics and Chemistry values are quoted with the conversion factors 1mm Hg = 133.316 Pa.

Water Vapour Permeance

As explained in the index "Water vapour permeability" permeability is a property of the material. However when it is required to compare the performance of different materials then permeance values are needed. Thus permeance is the transmission of water vapour through a known thickness of a given material under defined conditions. Vapour barrier requirements will be quoted as a minimum permeance value.

The units of water vapour permeance are similar those of permeability, typically, g/(s·MN) or kg/(m²·h·Pa).

Water Vapour Resistance

This is the reciprocal of water vapour permeance.