ECOPAN

MODULAR RADIANT PANELS

Radiance

energy savings

General information on radiance

Radiance is a process by which thermal energy is transferred between two bodies at different temperatures.

Thermal radiance lies within the wider phenomenon of propagation or electromagnetic radiation emitted by bodies and it is transmitted from a warmer body to a cooler one at the speed of light without heating the air.
It is common experience, in fact, that on sunny days our body is in a condition of thermal well-being even at extremely low air temperatures. On the contrary, when moving to the shade, the sensation of thermal comfort is immediately lost, even though in both cases the air temperature is the same.
It is clear that with a radiant heating system, conditions of well-being can be maintained even though the air temperature is kept low.

The temperature that determines the state of well-being is not only the air temperature, but also the so-called operating temperature, which derives from the combined effect of the air temperature (t_a) and of the average radiant temperature (t_{mr}) of all the surfaces in the room, such as the ceiling, floor and walls, and of course the radiant panels.
Analytically, the operating temperature can be approximated as an arithmetical average of the two temperatures, that is:

$$t_{op} = \frac{t_a + t_{mr}}{2}$$

The transmission of heat by radiance of a body is a value determined by its temperature and by the composition of its surface.

For the evaluation of the thermal balance in a building, it is necessary to calculate the average radiant temperature of the internal surfaces. This temperature depends on their thermal conductivity, on the external temperature, on the internal air temperature, and on the exchange by radiance with other surfaces including the panels.
Basically, the radiant panels with its warm surfaces compensates for the cold surfaces of the walls and heats the air.

The thermal energy emitted by a good ceiling mounted radiant panel is transmitted 70% by radiance and the rest by convection.
During the design phase, it will be determined how many panels in that specific context are capable of ensuring the desired operating temperature.
To obtain this result, the study requires a profound knowledge of the problem with all applicable variables.

Advantages of radiance heating

Hereunder are the reasons why radiance heating from above is the most valid and advantageous system for large volumes, from the three viewpoints of efficiency, effectiveness and savings, as compared with any other sort of alternative system (thermo-ventilation, hot air, hot air generators, gas panels, etc.):

- The system possesses extremely limited thermal inertia. This makes it possible to rapidly reach the desired temperature without long preheating periods, which results in energy savings.
- The system is able to perform its functions as soon as it is started. This is because, by eliminating the heat loss of the body by radiation, people reach a satisfying state of well-being even when the ambient temperature is relatively low.
- It is a directional system, which means it can assure well-being in the heated zones, those occupied by persons, with modest interference in adjacent zones.
- The system is practically free of thermal gradient, whose influence on thermal requirement is substantial in taller buildings. Most of the heat loss in large rooms is through the roof, and it only takes a few extra degrees in the air at roof level to substantially increase lost heat.
- Ventilation can take place with less energy consumption, since the same level of comfort is attained with a lower ambient air temperature.
- Due to the radiant effect of the panels, the surface of the floor and every other exposed body is heat up rapidly. Clearly, this favourably influences the state of well-being of persons in the room or passing through.
- The system does not occupy space on the floor, does not obstruct movement and does not condition the use of floor space (holes, machine bases, movement of production lines, etc.).
- The system does not cause air movement, as instead happens with hot air systems. Therefore, it can be also be used in dusty environments.
- The absence of air movement means that people are not disturbed by this.
- The system does not produce any noise which might cause it to be turned off.
- With new lifting means (elevator platforms and so on) which are readily available today, installation is especially safe and economical.
- The system does not require any special maintenance as it does not have any moving parts and remains unchanged over time.
- There is no risk of fire, there are no flammable parts, and with the exception of the heating plant, no fuels are used which would limit use based on safety considerations.
- Installation does not normally require masonry work.

Standard EN 14037 on ceiling mounted radiant panels

European standard EN 14037, by providing the specifications and technical requirements that ceiling mounted radiant panels must meet, ensures the quality of these products. The requirements concern the protection of surfaces, stability and hold of the panels and suspensions, resistance to pressure, and dimensional tolerances.
The standard defines the test method for determining the thermal emission of the panels.
Emissions are measured in a closed test chamber, with the six internal surfaces cooled. Above the panel, thermal insulation is placed that has certain characteristics. During the test, the six surfaces of the chamber must show no difference in temperature. The flow of water in the pipes must be turbulent. The temperature of the room is measured by two thermometers. One of them is sensitive to radiance, and the other is shielded to measure the air temperature.
These tests also provide the average surface temperature of the panel and the percentage of thermal power emitted by radiance.
Actually, a panel installed in a room interacts differently depending on the elements around it. Just consider the how difficult it is to determine the configuration factors of the various surfaces with respect to the position of the occupant. Therefore, its actual emission may be different from what was determined in the laboratory tests.
Based on emissions obtained as per standard EN 14037, it is now possible to make a serious comparison of the various products on the market.

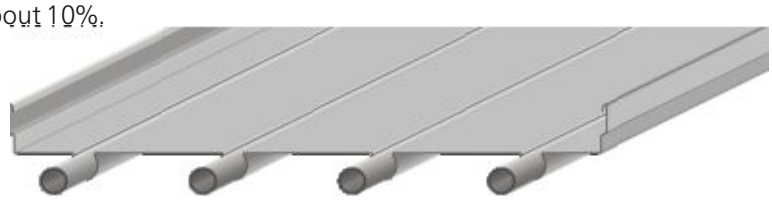
ECOPAN ceiling mounted radiant panels

Long experience of installers, along with studies and technical research carried out both in the field and in laboratories, have made it possible to develop solutions for which the ECOPAN panel distinguishes itself. These solutions are:

- the particular profile stamped onto the sheet metal
- the ease of installing the insulation
- the wide range of models with pipes of ½" and ¾"
- the dip-coat painting
- the joint covers that adhere to the pipes
- the attention placed on dilation between the pipe and the sheet metal

Profile of the sheet metal

The surface temperature of the sheet metal of the panel is of fundamental importance in radiance heating. In fact, the thermal power emitted by the panel varies according to the fourth power of the temperature of the sheet metal (Stefan-Boltzmann law).
Increasing the average temperature of the surface of the sheet metal by two or three degrees means increasing the emission by radiance by about 10%.



As the figure shows, in ECOPAN panels, the pipe, which is the hottest part of the panel, faces fully downwards, and 70% of it is covered by sheet metal.

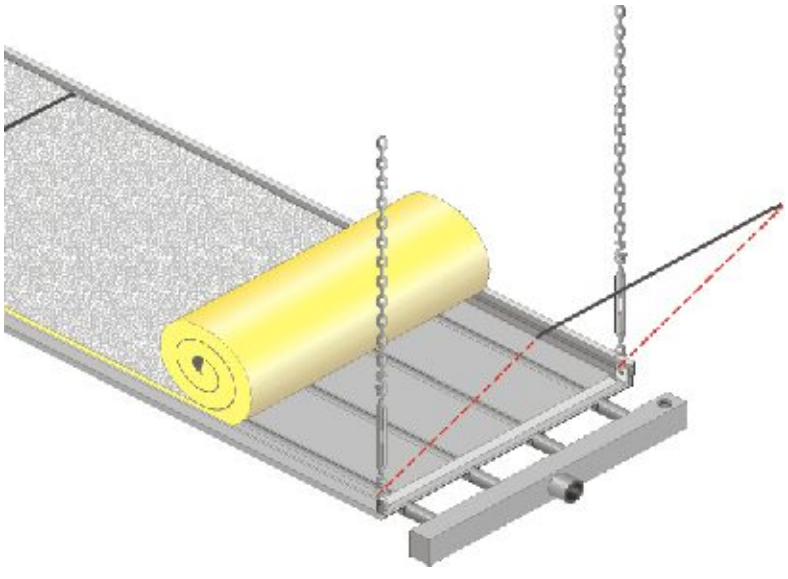
The pipes, which protrude completely under the sheet metal, create cushions of still air that reduce convective motion and increase radiance. This partially replaces the effect of the anti-convection flaps.

Thanks to its special profile, the ECOPAN panel releases a high percentage of energy through radiance. In fact, with the same surface, interval and pipe diameter, not only are the emissions as per EN 14037 of ECOPAN panels greater than those of the competition, but so is the surface temperature of the plate.
In some cases, the ECOPAN panel, even though it has one pipe less and the same width as the competition's same model, provides greater yield. One pipe less means less welding to be done at the worksite, less weight to move, and as a result lower costs.

Ease of installing insulation

The insulation material used to cover the upper surface of the ECOPAN panel is a mat of rock wool with a thickness of 40 mm, with conductivity of 0.048 W/mK at 40°C and density of 14 Kg/m^3. It is covered on one side with aluminium foil. This material has a thermal resistance that is slightly higher than the insulation used in the laboratory tests.

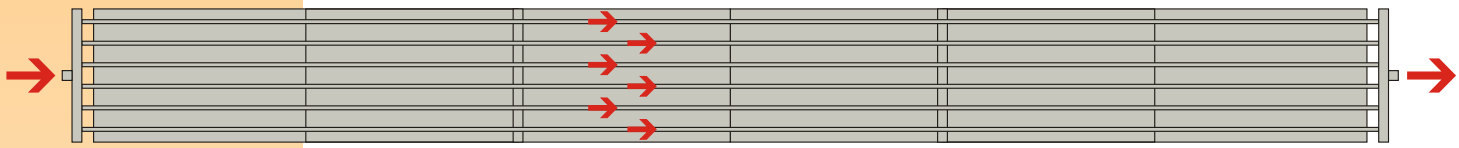
During tests in accredited laboratories, the insulation is placed on the upper surface of the panels in a uniform, regular manner.
However, the panels available on the market are do not make it possible to have insulating material of the same accuracy at the worksite. The bracket that is attached to the upper part of the panel makes this operation difficult and discontinuous.



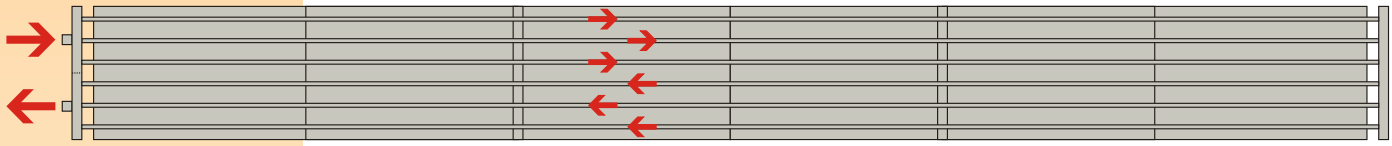
ECOPAN has focused special attention on the choice of especially low brackets with a rectangular cross section. This solution makes it possible to lay the mat rapidly and continuously. The fibreglass wool adheres perfectly to the sheet metal. This adherence is further improved and made safer through the use of upper fastening plugs.
In order to hold the insulating mat on the sides and conceal it, the ECOPAN panel is also provided with side edges obtained from the radiant plate itself. They also contribute to making the installation of the insulation quick and accurate.

Wide range of models with pipes of ½″ and ¾″

Panels used to be made by craftsmen, who followed the instructions of a designer who decided the most suitable construction parameters for his needs on a case-by-case basis.
Panels were constructed with pipes of ½″- ¾″- 1″- 1¼″, with sheet metal with a thickness from 0.6 up to 1.2 mm, and a distance between pipes of 100 up to 300 mm.
Nowadays, the market demands standardized products.
In an attempt to meet any need, the ECOPAN range of products is widely varied. It includes models with varying distances between pipes (111 mm and 150 mm), and with various pipe diameters (½″ and ¾″). The pipes can be electro-welded or without welding, depending on the temperature and pressure of the carrier fluid.
Each panel is connected to the hot water distribution network by headers.
There can be panels with headers with opposite connections, where the water enters on one side and exits on the other, as shown in the following figure.



Or there can be panels with headers with the connection on the same side, where the water enters and exits on the same side.



The distribution pipes normally extend high up, nearly at the level of the roof. Installing them requires the use of scaffolding or elevator platforms.
Panels with same-side connections have the delivery and return pipes coupled. This makes it possible to use the same brackets and the same scaffolding for both pipes, resulting in reduced installation costs.
Buildings to be heated may be of the most widely varying dimensions and thermal characteristics. To create a good system, it is important to evaluate and consider all of the factors that come into play.
The wide range of ECOPAN products, with panels that have pipes of different diameters at different intervals, offers the designer an ample selection.
Based on the temperature of the plate, one can choose panels with a distance between pipes of 111 mm or 150 mm. Depending on the water flow rate, panels are available with pipes of ½″ or of ¾″. To obtain even distribution of heat in the room, there are models with widths from 300 up to 1,200 mm.

When designing a radiant panel system, it is advisable to consider the Stefan-Boltzmann formula. Compatible with the installation height, one should consider the highest possible average fluid temperature. The higher this temperature is, the higher the average temperature of the sheet metal will be. The emission by radiance will increase according to the fourth power of this temperature.

Painting

A panel made of stainless steel, aluminium, or galvanized sheet metal does not radiate. If it is painted smoke black, it has an emissivity of 1.

In creating radiant panels, painting is a very important step. It provides the product with good radiance, and also protects it from corrosion.

The ECOPAN panel, after passing through the washing and hot de-greasing system, undergoes phosphating. It is then completely immersed in a tub that contains epoxy resin-based water-soluble non-toxic enamel. The paint penetrates all points, even those which are hidden or angled. It adheres perfectly to the sheet metal in a uniform manner, and remains unchanged over time.

After being dipped into the tub, the panel moves on to the baking kiln.

This painting system is highly reliable. Products that were treated 20 years ago are still perfectly covered.

The paint that covers the ferrous surface remains unaltered at a temperature of up to 170°C for water systems and 140°C for steam systems.

The thickness, opacity and high emissivity of the paint allow for improved conditions of radiance.

For other than standard colours, after washing and phosphate degreasing, the panels are covered with powder paints.

Joint covers

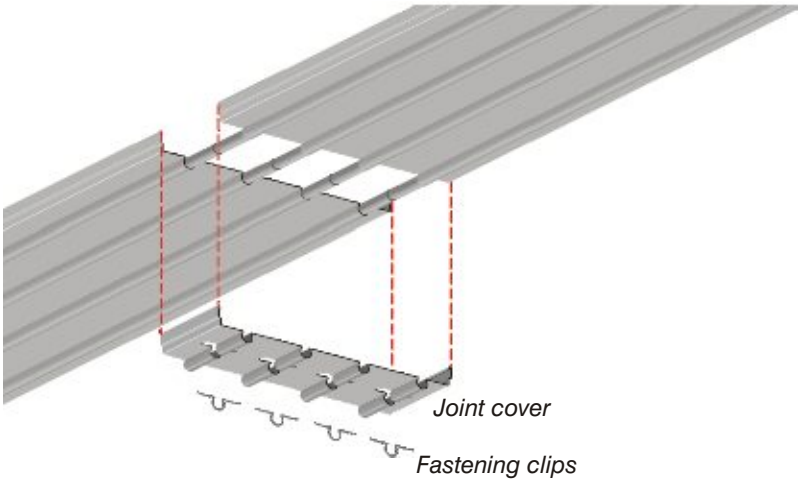
The radiant panels are composed of modules of 4 and/or 6 metres. Therefore, they are made by welding the pipes of the single modular elements to one another. Nowadays, instead of welding, installers often use clamp-tightened sleeves.

To make this possible without damaging the painted sheet metal, the pipes are left longer that the sheet metal on both sides.

Once the tubes have been joined, a joint cover is inserted between the metal sheets.

The joint cover has the same profile as the main sheet metal. Laboratory tests confirm that its yield is exactly the same as the active sheet metal where it is installed.

After the paint on the welded pipes is touched up, the joint covers can be easily inserted between the plates from underneath and secured with clips. This reduces installation time to a minimum.



Dilations

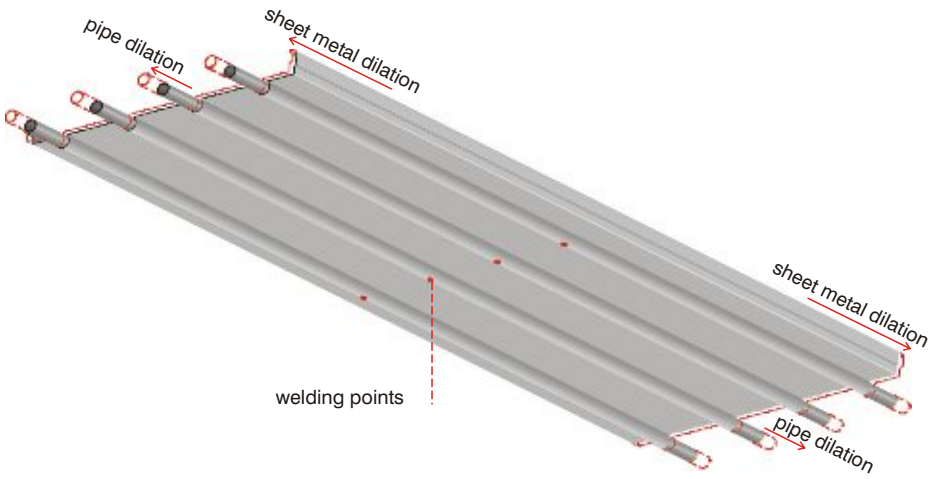
Dilations are an aspect of fundamental importance in the construction of a radiant panel.

A generic panel is basically composed of pipes and sheet metal joined together.

Under normal conditions of use, the heating fluid (hot water, superheated water, steam, etc.) passes through the pipes. The pipes heat up, and they become hotter than the sheet metal to which they transmit heat.

Each time the fluid in the pipe increases its temperature, the pipe rapidly reaches a temperature that is near that of the fluid, while the sheet metal heats up afterwards. This is a temporary condition which may last a few minutes.

Even when the system is running at normal operating power, there is still a difference between the pipe and the sheet metal. In other words, the pipe and the sheet metal dilate at different rates.



This situation occurs repeatedly in the life cycle of the panel. It may cause permanent deformations and tensions in the sheet metal that encloses the pipe.

In steam systems, the high forces in play make it necessary to take special measures in order to hold pipes and sheet metal together. This phenomenon also occurs in hot water systems, although less obviously.

By its nature, a radiant panel system allows shutdown at night or on holidays, resulting in the boiler being switched off.

Consider an extreme case in which, when the system is re-started, the temperature of the water in the panels is + 3°C and the temperature of the water in the boiler is 120°C. Due to this variation in temperature, a modular element of 6 metres will undergo lengthening of $0.012 \times (120 - 3°C) \times 6\,m = 8.4\,mm$.

The time for the heating of the pipe and the sheet metal are different. The housing of the pipe deforms, which is easily understanding if one considers a dilation of 8.4 mm per 6 metres.

Most new radiant panel systems run on hot water at 85°C. At this temperature, the lengthening of pipes is about 6 mm in a module with a length of 6 metres and 4 mm in a module that is 4 metres long.

In the past, the system would come up to operating temperature slowly, and it would remain there for the rest of the day. Today, almost all systems are equipped with automatic controls, and the temperature of the fluid in the panels varies constantly.

The dilations tend to create deformation in the sheet metal that surrounds the pipe, reducing the contact surface that surround the pipe and hence the emission of the panel.

This problem has led a good deal of German manufacturers to look for a solution by welding the pipes to the sheet metal, more or less continuously. This solution is expensive since it requires especially thick pipes and sheet metal.

To limit this thermal shock, experience has led ECOPAN to construct modules with metal sheets that are 2 metres long.

The modules of 4 metres are made of two sheets with a length of 2 metres each, whereas the modules of 6 meters are made of three sheets, each with a length of 2 metres.

At the point where the 2-metre sheets come together, a dilation joint is created.

Each 2-metre sheet has a welding point at the centre. Therefore, the dilation on each side is less than 1 mm. This ensures that the panel does not undergo deformation over time.

In confirmation of this, even for high pressure steam systems, ECOPAN provides standard panels. The only thing that changes is the paint, which needs to be able to withstand high temperatures.

In ECOPAN systems that have been in operation for twenty years, the panels have sheet metal that still adheres perfectly to the pipes and are free of any deformation. Therefore, their original thermal emission has remained unchanged over time.

Dividing the sheet metal of a 6-metre module into three parts has turned out to be a successful decision which sets the ECOPAN product apart from its competitors.

Installation

Installation time of ceiling mounted radiant panels substantially effects the total cost of the system.

Some of the features of the ECOPAN panels, such as side edges shaped in the plate itself, the ease of placing the insulation, the head welding of the perfectly aligned pipes and the simplicity of fastening the joint cover allow for substantial reductions in installation time, resulting in savings.

For models of other products currently on the market (diameter, number, interval of pipes and width of panel), ECOPAN panels have a greater thermal emission. This makes it possible to use less of them, resulting in savings in both material and installation time.

The wide range of available models and accessories also makes it possible to meet any design, functional or aesthetic need.

Use of thermal strips for cooling

For some years now, ceiling mounted radiant panels have also been used for cooling.
Given the high emission of ECOPAN radiant panels, it is also possible to obtain good results with this type of application.
Also in this case, all of the positive features of a panel system used for heating hold true. These include low thermal inertia, possibility for application in zones, lack of air movement, no space taken up on wall or floor, no noise or maintenance.
Ceiling mounted radiant panels supplied with chilled water partially lower the perceived temperature in the room. The insertion of their cold surfaces contrasts the radiance of hot surfaces and makes occupants comfortable.
In these systems, it is very important to ensure that the surface temperature of the panels does not drop below the dew point of the ambient air. Otherwise, the water vapour in the air would condense on the cold surface and cause dripping.
To deal with the latent heat produced in the room or due to uncontrolled entry of external air with high specific humidity, an auxiliary dehumidification system can be used.

Conclusions

Today, the market offers various radiant heating systems for large areas. The main ones include gas panels, floor panels and ceiling mounted panels in steel or aluminium.
In terms of economic operation, it is essential to keep rooms at the desired temperature only when they are in use. In fact, a room loses heat outwards based on the ambient temperature. The higher the ambient temperature and the longer it is maintained, the more operating costs increase.
Gas-fired ceiling mounted radiant panels are used for rooms that only need to be heated for a few hours a day or for a few days a week. These are places where the system needs to come up to operating power quickly. These systems meet these needs well, and although they have high consumption, poor heat distribution, high thermal gradients and discontinuous radiance, they are still more economical because of the few hours of operation.
The floor panels normally use as heat-carrying fluid hot water between 20 and 40°C. They are composed of pipes (copper, steel, plastic) sunk into the floor. Because of the substantial mass that needs to be heated before heat is released into the environment, they have a high thermal inertia.
It takes a few days for them to come up to operating power. This makes them especially suitable for homes and hospitals, which are heated 24 hours a day, 7 days a week.
Steel or aluminium ceiling mounted radiant panels may use a the carrier fluid hot water, superheated water, steam or heat-transmitting oil, with temperatures between 50 and 180°C.

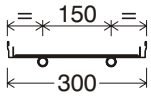
They have low thermal inertia and are especially suited to heat industrial warehouses, offices, gymnasiums, shops, supermarkets and so on, where heat is required 8÷9 hours a day, 5÷6 days a week.
This heating system has limited operating costs, since it offers the possibility to stop heating partially or totally, minimum pre-heating time based on the external temperature, a low thermal gradient, continuity and uniformity of radiance on all heated surfaces. Given its characteristics, it is suited for all climates, especially temperate climates due to its high flexibility. In Italy, the outdoor winter temperature is highly variable. Intense, continuous cold usually occurs for short periods. During the rest of the year there are low temperatures at night and early in the morning, but the temperature increases during the day.
At the same level of well-being, no other type of system in use today has operating costs that are as low as a good radiant system. If the system is well designed and installed, the investment of capital is among the lowest on the market.
If one considers that the system has no moving parts, does not require maintenance and has a period of depreciation of over 50 years, it is clear to see how this is the most economical solution for heating large volumes.

We started installing ceiling mounted radiant panels in the early 1070's.
These panels were made in our workshop. Our technical department, with the advice and assistance of engineer Mr Franco Palmizi, designed various types of panels that ran on hot water, steam, and superheated water. They were intended for use in warehouses of varying sizes and heights, with varying diameter, distance, number of pipes and thickness of sheet metal, so that each system would achieve excellent economical and technical results.
In 1984, the ECOPAN company was founded. It absorbed these years of experience, and provided the market with standard pre-fabricated panels that were valid, reliable products.
ECOPAN offers long technical experience that is constantly updated. Results are compared and analyzed to improve the product and the design, so that the levels of well-being are provided at the lowest operating costs.

Many types of systems use the ceiling as a radiant surface. This surface does not take up floor space, does not obstruct people's movements, does not limit the use of the floor and walls, and allows everything exposed to it to take advantage of the effect of radiance.
To take advantage of these characteristics, along with thermal strips, we have experimented with various types of radiant ceilings with different new technologies. The results have always been excellent.
The knowledge and experience gained in this field are available to all our clients, not only to provide them with a quality product, but also to assist them and advise them during the dimensioning phase. In fact, a good system requires special attention during the design phase.

INTERVAL BETWEEN PIPES 150 mm - PIPES ½″ or ¾″

2/150



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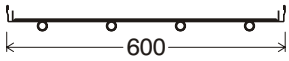

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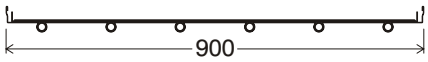

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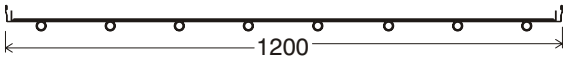
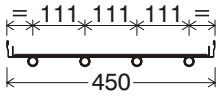


INTERVAL BETWEEN PIPES 111 mm - PIPES ½″ or ¾″

4/100



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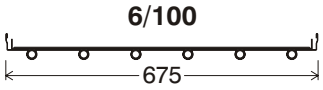

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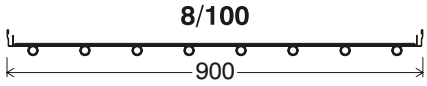

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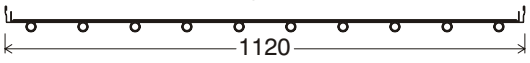
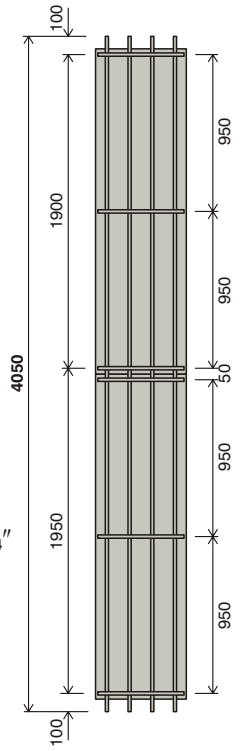
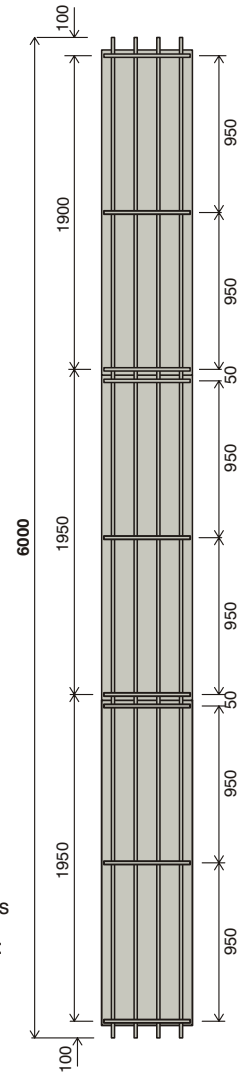


On request, ECOPAN provides panels with 3-5-7 pipes of ½″ or ¾” with interval of 150 mm and panels of 5-7-9 pipes of ½″ or ¾” interval 111 mm.

LONGITUDINAL DIMENSIONS

SUSPENSION POINTS





CE

04

EN 14037-1

Ceiling mounted radiant panels

Maximum operating pressure: 6 bar

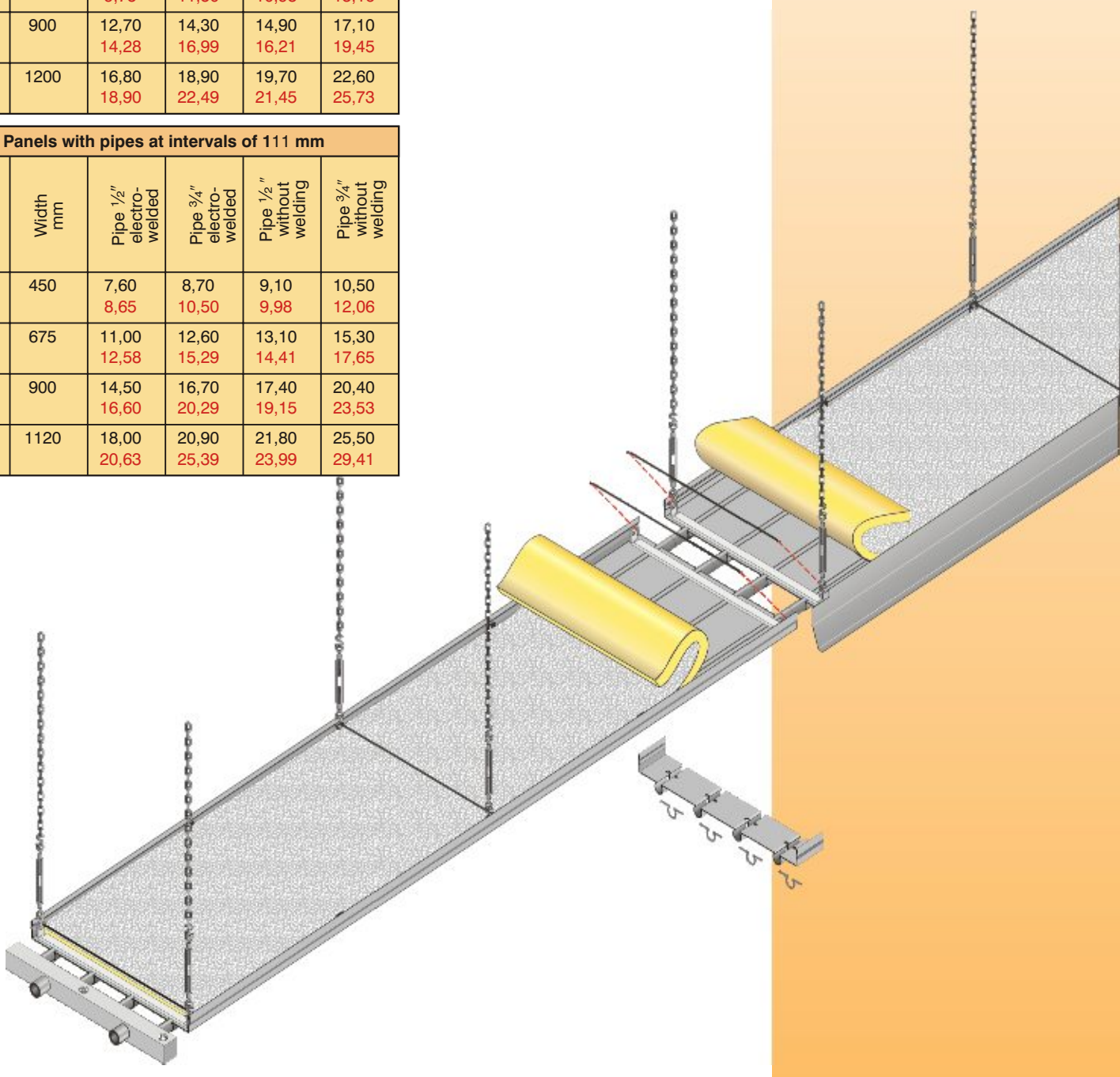
TABLE OF WEIGHTS OF MODULAR RADIANT PANELS
prefabricated modular complete with:

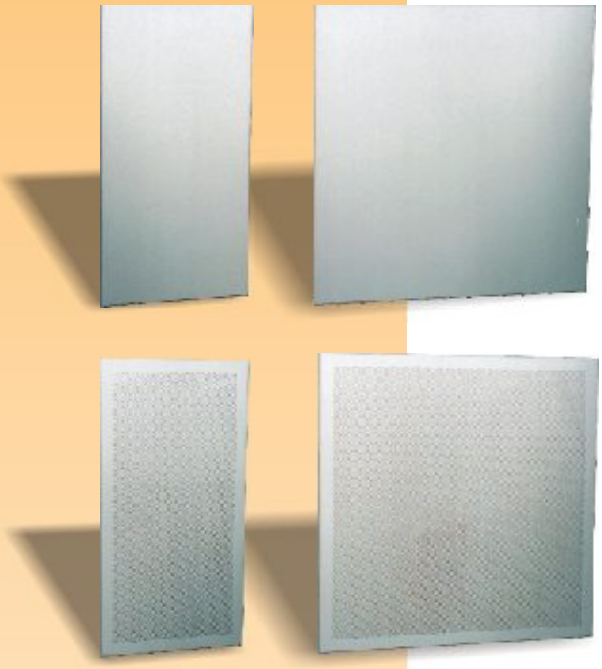
- side edges
- joint covers
- suspension brackets
- insulation mat with fastening plugs
- silicon grey painting

top line: empty weight in kg/m
Bottom line: weight with water in kg/m

Panels with pipes at intervals of 150 mm					
Model	Width mm	Pipe ½" electro-welded	Pipe ¾" electro-welded	Pipe ½" without welding	Pipe ¾" without welding
2/150	300	4,70 5,23	5,10 6,00	5,40 5,84	6,10 6,88
4/150	600	8,70 9,75	9,70 11,50	10,10 10,98	11,60 13,16
6/150	900	12,70 14,28	14,30 16,99	14,90 16,21	17,10 19,45
8/150	1200	16,80 18,90	18,90 22,49	19,70 21,45	22,60 25,73

Panels with pipes at intervals of 111 mm					
Model	Width mm	Pipe ½" electro-welded	Pipe ¾" electro-welded	Pipe ½" without welding	Pipe ¾" without welding
4/100	450	7,60 8,65	8,70 10,50	9,10 9,98	10,50 12,06
6/100	675	11,00 12,58	12,60 15,29	13,10 14,41	15,30 17,65
8/100	900	14,50 16,60	16,70 20,29	17,40 19,15	20,40 23,53
10/100	1120	18,00 20,63	20,90 25,39	21,80 23,99	25,50 29,41





ECOPAN aluminium false ceilings

Our first conditioning system consisting of a radiant false ceiling in aluminium panels dates back to 1969.
These aluminium false ceilings have been suitably perfected, and are now one of ECOPAN's standard products.
ECOPAN radiant false ceilings are composed of an electro-welded steel pipe coil of ½". This is inserted into grooves in the aluminium, and it heats or cools the plates, which thus radiate heat or cold.
The carrier fluid in the pipe is heated or chilled water.
These false ceilings are completely free of the masonry structure. Their average temperature depends on the temperature of the carrier fluid, the interval between pipes and the thickness of the radiant sheet metal.

Models

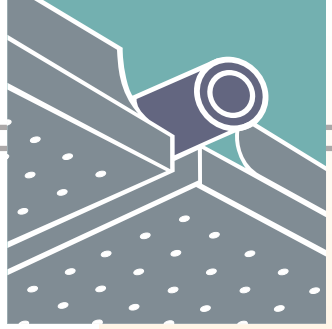
The radiant false ceilings that ECOPAN produces are made of pre-painted aluminium panels with a thickness 0.78 mm. The standard colour is RAL 9010 matt white. They come in the standard formats of 600×600 mm, 300×600 mm and 200×2.500 mm, each available in the perforated or non-perforated version.
Two types of radiant false ceilings can be made, either without primary air inserted above it or with air inserted.

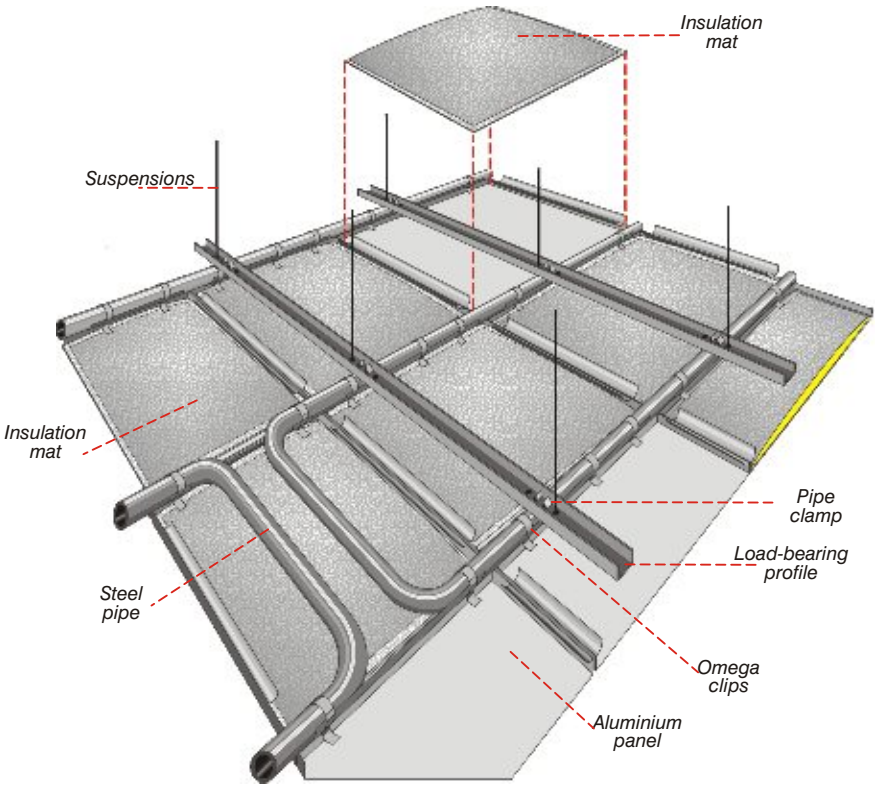
Radiant false ceilings without air

When using a false ceiling for heating, one needs to consider that a high average temperature of the ceiling may cause problems for people's well-being.
For this reason, it is necessary to comply with the values that indicate, based on the height of the height of the false ceiling, the maximum thermal emission that must not be exceeded. For example, a radiant false ceiling installed at a height of 3 metres may emit a maximum of 200 W/m^2.
For heating, the hot water in the coils may reach an average temperature of approximately 50°C.
For cooling, cold water must not drop below 18÷19°C because it is limited by the dew point of the ambient air.

Radiant false ceilings with air

Above the radiant false ceiling, in the space that is created between the false ceiling and the ceiling, primary air may be forced in. This increases the emission of the false ceiling substantially.
When used for heating, the false ceiling may emit over 300 W/m^2. This makes it capable of satisfying almost any need.
If the false ceiling is used for summer air conditioning, the air placed above it must be at a temperature of 16°C with relative humidity of 80%. In these conditions, the dew point of the air drops to 12.5°C. Therefore, with a water temperature of 13°C÷16°C there is no risk of condensation.
The difference between the ambient temperature and the average temperature of the water in circulation is great enough to allow strong cooling emission, which may reach 80÷100 W/m^2.
This combined air conditioning system of air and radiant ceiling requires less overall cooling power than a traditional air-only system. Since it is a radiant system, what is considered is the operating temperature. This means that the air temperature can be a few degrees higher while offering the same degree of comfort.





Since part of the load is lowered by the false ceiling, the amount of air required as compared to an air-only system is much less. This results in a decrease in the size of the ducts, since the air in the space above the false ceiling expands, and it is possible to have a fairly high air speed in the main ducts.
The distribution of air in the room does not disturb people, since it occurs through the slots in the panels that are 1.5 mm wide, with a lamellar flow with an inductive rainfall effect over the entire surface of the ceiling. It is possible to achieve up to 20 vol/h of air forced into the room without the users experiencing any discomfort.
This system technology is easy to design and create. It does not require any masonry work. Installation times are very short both in existing and new buildings. Also, because of its natural tendency to absorb sound, it is especially suitable for air conditioning in large, crowded areas such as dining facilities, sports arenas, swimming pools and so on.

The main advantages offered by this type of system are:

- between the ceiling and the false ceiling, a space is created for air expansion that also acts as an accessible service area
- it adapts to a number of architectural needs
- it may act as a sound absorber
- it does not take up any floor space and does not obstruct the movement of people
- it allows the use of various lighting solutions
- it has low thermal inertia
- it evenly distributes the air
- there is no thermal gradient
- it does not produce noise
- it does not require maintenance
- it is indispensable if high levels of air circulation are required
- since it is a combined air-radiance system, it allows substantial energy savings.

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Radiance

energy savings

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