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HYDRONICALLY COOLED RADIANT PANEL SYSTEM

DESCRIPTION

Radiant cooling panels, although relatively rare in North America, have been used successfully in European applications for at least 15 years. Radiant cooling follows the same principles as radiant heating. Consequently, thermal energy is exchanged between the heat loads present in the space and the cool ceiling. To ensure air quality and removal of the moisture load in the room, radiant cooling panels do need to be used in conjunction with a small ventilation system. However, since radiant cooling systems do not use forced air flow to facilitate cooling, a uniform temperature gradient in the room space is created. With this reduction in draft, radiant cooling panels provide a very comfortable environment for the occupants of the cooled space.

ADVANTAGES

- Operational costs are reduced for the mechanical chilling system since cooled ceilings operate at relatively high temperatures (average surface temperature of 16°C or 61°F).
- Chillers can operate at higher temperatures resulting in an increase in efficiency and reduction in energy costs.
- Radiant panels can be used as both heating and cooling panels reducing the amount of equipment and piping required compared to conventional heating and cooling system.
- Cooled ceilings are silent and virtually draft free since air flow volumes are reduced compared to conventional systems (typical radiantly cooled office building: 2 to 3 air exchanges per hour compared to 6 to 10 with conventional systems).
- Radiant cooling panels can be retrofitted into the false ceilings of older buildings as the plenum space requirement is minimal relative to fan coil units or VAV systems.
- Smaller plenums result in savings in building height compared to air conditioning systems.

APPLICATIONS

Radiant cooling panels are mainly used in public buildings. These include, hospitals, office buildings, libraries, museums, schools, nursing homes and many more. Radiant cooling panels can be installed anywhere radiant heating panels are used.

GENERAL SPECIFICATIONS

The panels are insulated on the inactive side and may be of either a linear or a modular design.

The extruded aluminum linear panels are offered as castellated and smooth faced planks. Both these type of extrusions come in a variety of widths providing for flexible design. The castellated face plates are used for peripheral panels and provide invisible seams between the planks. The smooth face plates are mainly used for non-peripheral installations with the seams between the planks emphasized by a groove.

On the other hand, modular panels can fit in suspended ceilings and can be silk-screen finished to simulate the surrounding acoustic ceiling tiles. Modular panels come with either 4 pass tubing or 6 pass (used as peripheral panels when both cooling and heating are required within the same panel). If the panel area required for cooling covers most of the ceiling, a total ceiling system is needed (with both active and inactive panels). With this system, the ceiling panels are perforated and insulated in order to provide an acoustic value similar to that of acoustical tiles.

Cooled ceilings are usually grouped into zones where water flow can be controlled by conventional control valves. If the prevention of condensation on the panels is required, a sensor monitors the dew point temperature of the room and is used in conjunction with a controller which modulates the inlet water temperature accordingly.

RADIANT COOLING

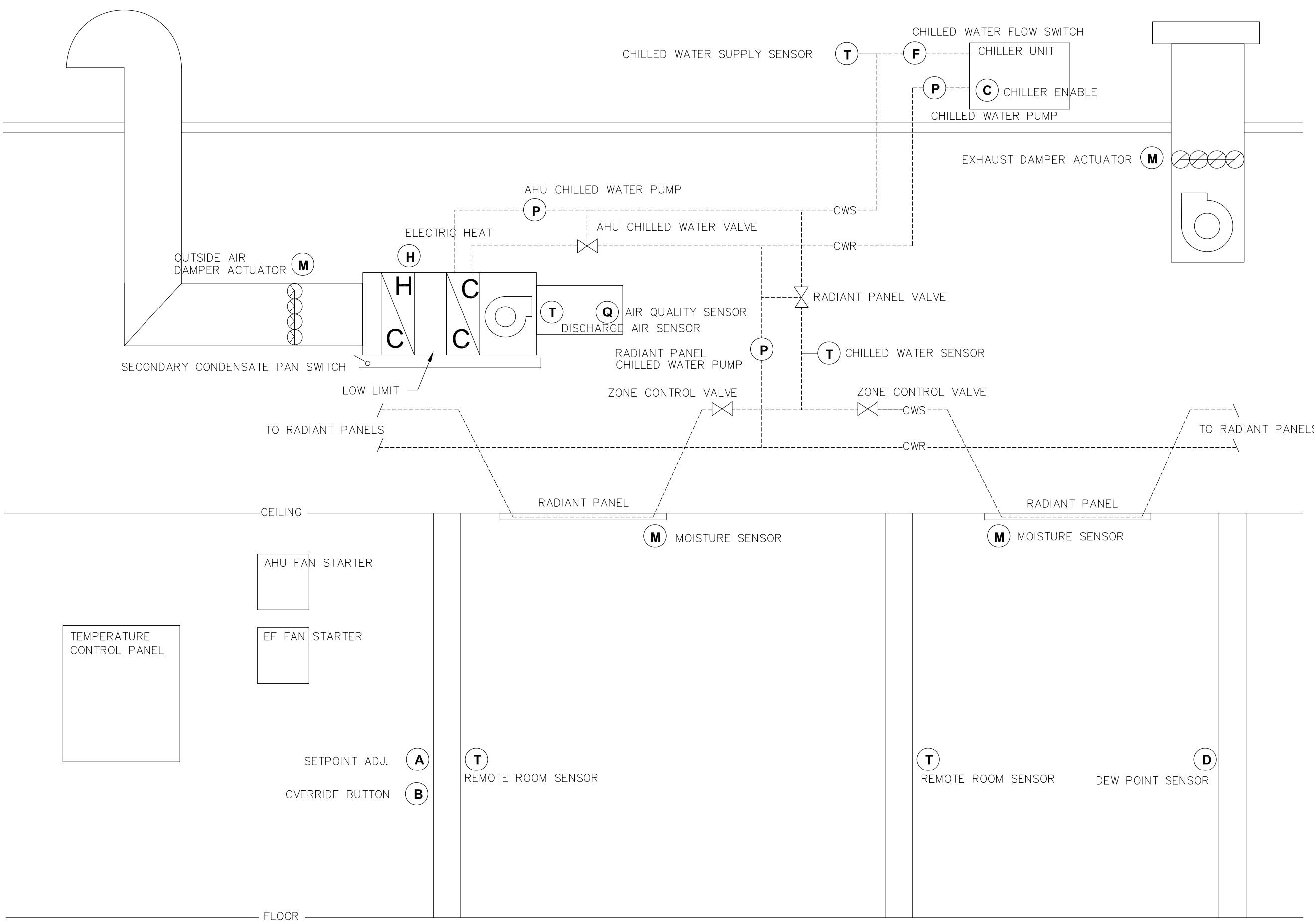
Radiant cooling follows the same principles as radiant heating. The heat transfer occurs between the space and the panels through a temperature differential. However, unlike radiant heating, the colder ceiling is absorbing thermal energy radiating from people and their surroundings. The major difference between cooled ceilings and air cooling is the heat transport mechanism. Air cooling uses convection only, whereas cooled ceilings use a combination of radiation and convection. This amount of radiative heat transfer can be as high as fifty five per cent while convection accounts for the remainder. With cold ceilings the radiative heat transfer occurs through a net emission of electromagnetic waves from the warm occupants and their surroundings to the cool ceiling. On the other hand, convection first cools the room air due to contact with the cold ceiling, creating convection currents within the space which transfers the heat from its source to the ceiling where it is absorbed.

Since air quality must be maintained and radiant panels remove only the sensible heat from the space, radiant cooling panels are used in conjunction with a small ventilation system. The ventilation system not only ensures the air quality to recommended levels but also regulates the latent, or moisture load, of the space. To prevent high humidity levels within a room, the supply air must be drier than that of the supplied space especially in light of additional sources of moisture within the room. Consequently, outdoor air must be dehumidified which is usually done by cooling to a dew point of approximately 15°C (59°F). If the environment is dry, the ventilation system is used to humidify the air. Since the ventilation system is used only to maintain the air quality and to regulate the latent load of the space, the air flow required is small relative to conventional cooling systems. The best results are usually attained with a straight displacement ventilation system with no air recirculation. This system typically supplies air through outlets near or at the floor at temperatures below that of the room air which provides for a uniform layer of fresh air at the floor level. In turn, people and other heat sources will provide for a passive convective flow of fresh air to the ceilings where it can be exhausted. With this reduction in air flow and the fact that radiant panels operate at a relatively high surface temperature (mean temperature of 16°C or 61°F), radiant cooling is a more comfortable way of cooling a space than the conventional cooling systems. Therefore, in a radiant cooling ceiling, the panels provide most of the sensible cooling while the air system provides ventilation and air moisture control.

A cooled ceiling operates in direct proportion to the heat load in the room. Typically, a person sitting at a desk will emit 130 W of energy while a computer emits 90 to 530 W to its surroundings. The greater the number of people and/or appliances and exposure to sunlight, the greater the temperature gradient and therefore an increased capacity of the cold ceiling. Generally, cold ceilings are able to handle between 100 and 225 watts per square meter with up to 50% of the ceiling space utilized for cooling.

CONDENSATION CONTROL

Condensation on the surface of the panels is not a problem with radiant cooling. Since condensation of water occurs when the dew point temperature is reached, proper water temperature control will help avoid any condensation. To prevent the formation of condensation, the following schematic shows a sensor monitoring the dew point temperature of the room used in conjunction with a controller which modulates the inlet water temperature accordingly. Therefore, if a risk of condensation is present, the water temperature is raised or the water flow is shut off. However, since the lower the panel's inlet temperature is, the more work the panels do, the inlet temperature should be determined to be as close as possible to the room's dew point temperature. Consequently, the cooling capacity of a radiant cooling system is generally limited by the minimum allowable temperature of the inlet water relative to the dew point temperature of the room air.



TEMPERATURE CONTROL SCHEMATIC

NOTE: REFER TO C-5 FOR CONTROL SEQUENCE

CONTROL SEQUENCE

Displacement Air Handling Unit and Exhaust Fan:

- The AHU and EF turn on and off by a time schedule.
- The AHU is constant volume/constant temperature, and the heat and chilled water 3-way valve are controlled by discharge air temperature.
- The chilled water pump for the AHU can be turned on and off by a call for cooling or time schedule.
- The low limit stat opens the chilled water valve and turns on the pump when the temperature at the coil is below 3.3°C (38°F).
- The dampers at the AHU and EF open when the units turn on and close when the units are off.
- The condensate float switch will shut the AHU down if water is present in the secondary drain pan.

Chiller:

- The chiller's integral controls maintain the discharge temperature of the water.
- A field supplied flow switch is wired into the chiller safeties.
- The control panel enables the chiller based on a time schedule and a call for cooling from the AHU or Radiant Panels.
- The chiller pump is turned on when the chiller is on.

Radiant Panels:

- The room sensors monitor the space temperature and open the 2-way zone valves in response to a call for cooling.
- The dew point sensor monitors the dew point temperature in the space and the
- Radiant Panel 3-way valve modulates the temperature of the chilled water to the panels in response to the dew point temperature.
- The chilled water supply to the panels is maintained at 0.5 to 2°C (1 to 3°F) above the dew point.
- The panel pump is turned on when there is a call for cooling from the panels.

TOTAL CEILING SYSTEM

If the panel area required for cooling covers most of the ceiling (70% and more), a total ceiling is needed. In a total ceiling system, the panels must be perforated and covered with acoustic blanket insulation. The diameter of the perforations and the type of blanket insulation can be varied to give the ceiling an acoustical value comparable to that of any acoustical ceiling systems as seen in the following table.

PERFORATED PANELS - SOUND ABSORPTION DATA

ACOUSTIC BLANKET	SOUND ABSORPTION COEFFICIENTS						NOISE REDUCTION COEFFICIENT
	125Hz	250Hz	500Hz	1000Hz	2000Hz	4000Hz	
1-1/2" Thick, 0.75 pcf	0.76	0.79	0.79	0.91	0.74	0.53	0.80
3' Thick, septum type, 1.08 pcf.	0.90	0.91	0.99	0.96	0.73	0.52	0.90

DESIGN PROCEDURES

In order to design a radiant cooling system, the following procedure, also found in Chapter 6 of the 1992 ASHRAE Handbook, should be followed:

Step 1. Determine the sensible and latent hourly heat gain for each room.

The sensible and latent hourly heat gain of a room are determined by considering the heat loads from the sun, occupants, lights, etc. using accepted ASHRAE procedures.

Step 2. Determine the mean water temperature required for cooling.

The mean water temperature is determined by adding a minimum of 0.5°C (1°F) above the room dew point temperature and averaging the inlet and outlet temperatures assuming a temperature rise of 3°C (5°F).

Step 3. Determine the minimum air supply required for each room.

The minimum air supply required for a room is determined using governing codes.

Step 4. Determine the latent load capacity of the air.

From the minimum air supply found in Step 3, the following equation is used to calculate the latent load capacity of the air:

$$q_L = Q p h_{fg} (w_{room} - w_{supp})$$

Where: q_L = Latent heat loads (W)
Q = Airflow rate (m^3/s)
p = Air density (kg/m^3)
h_{fg} = Latent heat of vapour at appropriate air temperature (J/kg)
w_{room} = Humidity ratio of room air (unit mass of water/unit mass dry air)
w_{supp} = Humidity ratio of supply air (unit mass of water/unit mass dry air)

The resulting value is compared to the latent gain of the room found in Step 1. If it is found that the moisture pick up of the supply air is less than that required, supply air quantity or the moisture content will have to be adjusted (through design temperature).

Step 5. Determine the sensible load capacity of the air.

From the minimum air supply found in Step 3, the following equation is used to calculate the sensible load capacity of the air:

$$q_S = Q \rho C_p (t_{room} - t_{supp})$$

Where: q_S = Sensible heat load (W)
Q = Airflow rate (m^3/s)
ρ = Air density (kg/m^3)
C_p = Specific heat of air (J/kg°K)
t_{room} = Room air temperature (°K)
t_{supp} = Supply air temperature (°K)

Step 6. Determine the sensible cooling load required from the panels.

The sensible cooling load required by the panels is found using the following equation:

Room Sensible Heat Gain - Supply Air Sensible Load Capacity = Panel Sensible Cooling Load

Step 7. Determine the area of the panels.

The area of the panels is determined from the following equation:

Panel Sensible Cooling Load / Panel Cooling Capacity = Panel Area

If the panel area required for cooling is greater than the area available, the supply air quantity should be increased to provide additional cooling. On the other hand, if the panel area required covers most of the ceiling area available, a total ceiling system should be used.

DESIGN EXAMPLE

A 4m x 5m x 2.44m interior office with a 600mm x 1200mm T-Bar ceiling and a maximum occupancy of 7 people, is to be maintained at 24°C (75°F) and a 45% RH. From the psychrometric chart, this gives a dew point temperature of 12.5°C (55°F) and a moisture content of 9.0 g of moisture/kg of dry air.

Step 1. Determine the sensible and latent hourly heat gain for the room.

The sensible and latent hourly heat gains are found using accepted procedures found in the ASHRAE handbooks. For this example, we will assume:
Sensible hourly heat gain: 2000 Watts
Latent hourly heat gain: 200 Watts

Step 2. Determine the mean water temperature required for cooling.

Inlet water temperature: 12.5°C + 0.5°C = 13°C (55°F)
Assuming a temperature rise of 3°C, add half of this temperature rise to the inlet water temperature
MWT: 13°C + 3°C / 2 = 14.5°C (58°F)

Step 3. Determine the minimum air supply required for the room.

According to ASHRAE tabulated data, the minimum air supply for an office is:
10 L/sec per person x 7 persons = 70 L/sec

Step 4. Determine the latent load capacity of the air with the following equation:

$$q_L = Q \rho h_{fg} (w_{room} - w_{supp})$$

Assuming that the air supplied has been conditioned to 7.5 g of moisture/kg of dry air, we get:

$$q_L = 70 \text{ L/s} \times 1.2 \text{ kg/m}^3 \times 2500 \text{ kJ/kg} (9.0 - 7.5) \text{ g/kg}$$

$$q_L = 315 \text{ W}$$

The resulting value is found sufficient when compared to the latent gain of the room found in Step 1.

Step 1. Determine the sensible load capacity of the air.

With the following equation:

$$q_s = Q\rho C_p(t_{room} - t_{supp})$$

Assuming that the air supplied has been conditioned to 15°C (288°K), we get:

q_s = 70 L/s x 1.2 kg/m x 1.0 kJ/kg°K (297 - 288)°K
q_s = 756 W

Step 1. Determine the sensible cooling load required from the panels.

q_s(PANEL) = 2000 Watts - 756 Watts
q_s(PANEL) = 1244 Watts

Step 1. Determine the area of the panels.

From the cooling performance table (found on pp.12-13) and the following values:

Room air temperature - MWT = 24°C - 14.5°C = 9.5°C (17°F)
Room Designation: A (Interior Room)

We interpolate to get:

Absorbed Energy: 96.0 W/m^2

Use this value to determine the panel area:

$$A_{panel} = \frac{1244\text{ W}}{96\text{ W/m}^2}$$

$$A_{panel} = 13.0\text{ m}^2$$

Since this value is less than the available ceiling area (20 m), no design changes are required. However, most of the ceiling space (70%) is covered with cooling panels. Therefore a total ceiling system will be used.

With a 600mm x 1200mm T-Bar ceiling system, perforated modular panels should be used. To determine the number of active panels required, use the following equation:

13.0 m^2 (0.6 x 1.2)m^2/panel = 18.0 panels

Therefore we must use 18 active panels to deliver the required cooling.

If 6 pass modular panels are used, we need the following amount of tubing:

6 pass/panel x 1.2m/pass x 18 panels = 129.6 m of tubing

Step 5. Determine the sensible load capacity of the air with the following equation:

$q_S = Q \rho C_p (t_{room} - t_{supp})$

Assuming that the air supplied has been conditioned to 15°C (288°K), we get:

$q_S = 70\ L/s \times 1.2\ kg/m^3 \times 1.0\ kJ/kg°K\ (297 - 288)°K$
$q_S = 756\ W$

Step 6. Determine the sensible cooling load required from the panels.

$q_S(PANEL) = 2000\ Watts - 756\ Watts$
$q_S(PANEL) = 1244\ Watts$

Step 7. Determine the area of the panels.

From the cooling performance table (found on pp.12-13) and the following values:

Room air temperature - MWT = 24°C - 14.5°C = 9.5°C (17°F)
Room Designation: A (Interior Room)

We interpolate to get:
Absorbed Energy: 96.0 W/m²
Use this value to determine the panel area:

$$A_{panel} = \frac{1244\ W}{96\ W/m^2}$$

$A_{panel} = 13.0\ m^2$

Since this value is less than the available ceiling area (20 m), no design changes are required. However, most of the ceiling space (70%) is covered with cooling panels. Therefore a total ceiling system will be used.

With a 600mm x 1200mm T-Bar ceiling system, perforated modular panels should be used. To determine the number of active panels required, use the following equation:

13.0 m²/(0.6 x 1.2)m²/panel = 18.0 panels

Therefore we must use 18 active panels to deliver the required cooling. If 4 pass modular panels are used, we need the following amount of tubing:

4pass/panel x 1.2m/pass x 18 panels = 86.4 m of tubing

FIGURES

Twa's radiant cooling panels are available as either linear or modular panels. Since cooling is achieved with panels identical to those used for radiant heating, dimensions and details for the panels can be found in the linear and modular heating sections.

However, if a total ceiling system is required, a perforated panel design, as shown in the following pages, complete with non-combustible acoustic blanket insulation is used throughout the ceiling. This ensures an acoustical value for the ceiling similar to that of acoustic tiles. Also, for non-peripheral applications, a smooth faced linear extrusion is available.

The following Figures also include piping schematics for ceilings used as both heating and cooling surfaces. All the different panel arrangements use a 4 pipe system to supply and return both hot and cold water.

Room Air Temperature minus MWT (°C)	Room Designation: A	B	C	D	E	F
5.5	54	66	88	110	120	126
6.1	60	73	95	117	126	132
6.7	66	79	98	120	129	136
7.2	69	85	104	126	136	142
7.8	76	88	110	132	142	148
8.3	82	95	120	139	148	151
8.9	88	101	123	142	151	158
9.4	95	107	129	148	158	164
10.0	98	114	136	155	164	167
10.6	104	120	142	158	170	173
11.1	110	126	145	164	173	180
11.7	117	132	151	170	180	183
12.2	123	136	158	177	186	189
12.8	126	142	164	183	192	196
13.3	132	148	167	186	196	199
13.9	139	154	174	192	202	205
14.4	145	161	177	199	208	211
15.0	151	167	183	202	205	214
15.6	155	174	189	205	218	227

Absorbed Energy (Watts / Square Metre)

ROOM DESIGNATIONS IN TABLE ARE AS FOLLOWS:

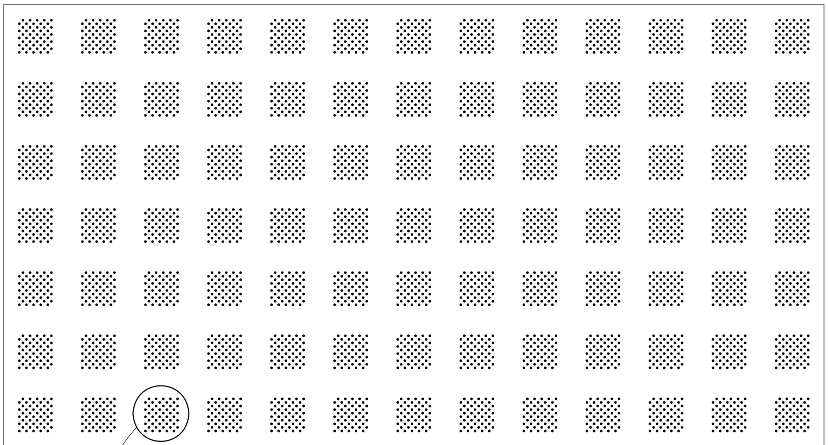
A - Interior room
B - No glass, exterior wall
C - 25% Clear glass, exterior wall
D - 50% Clear glass, exterior wall
E - 75% Clear glass, exterior wall
F - 100% Clear glass, exterior wall

Room Air Temperature minus MWT (°F)	Room Designation: A	B	C	D	E	F
10	17	21	28	35	38	40
11	19	23	30	37	40	42
12	21	25	31	38	41	43
13	22	27	33	40	43	45
14	24	28	35	42	45	47
15	26	30	38	44	47	48
16	28	32	39	45	48	50
17	30	34	41	47	50	52
18	31	36	43	49	52	53
19	33	38	45	50	54	55
20	35	40	46	52	55	57
21	37	42	48	54	57	58
22	39	43	50	56	59	60
23	40	45	52	58	61	62
24	42	47	53	59	62	63
25	44	49	55	61	64	65
26	46	51	56	63	66	67
27	48	53	58	64	67	68
28	49	55	60	65	69	72

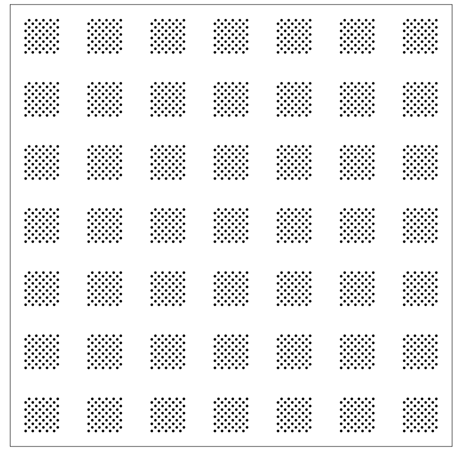
Absorbed Energy (BTUH / Square Foot)

ROOM DESIGNATIONS IN TABLE ARE AS FOLLOWS:

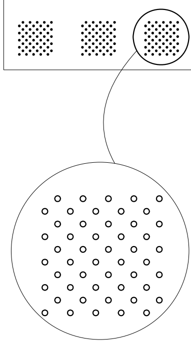
A - Interior room
B - No glass, exterior wall
C - 25% Clear glass, exterior wall
D - 50% Clear glass, exterior wall
E - 75% Clear glass, exterior wall
F - 100% Clear glass, exterior wall



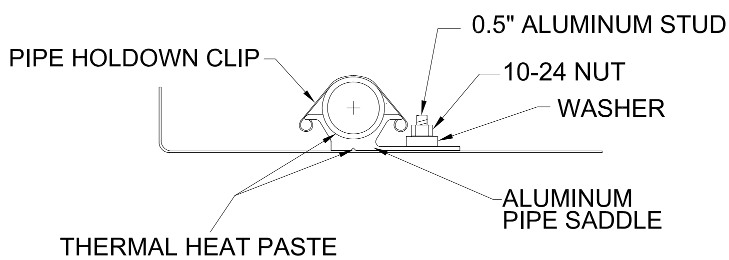
PANEL FACE
2' x 4' 6 PASS
600 mm x 1200 mm

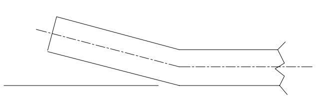


PANEL FACE
2' x 2' 6 PASS
600 mm x 600 mm



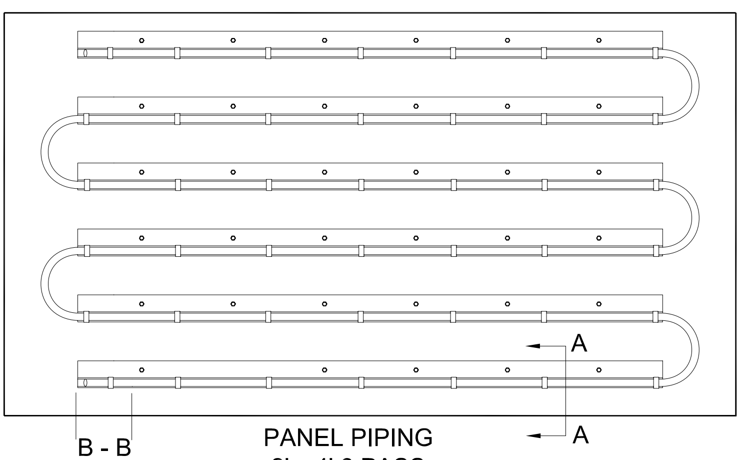
MAGNIFICATION OF PERFORATIONS
PERFORATION DIAMETER:
2.01mm (.079")



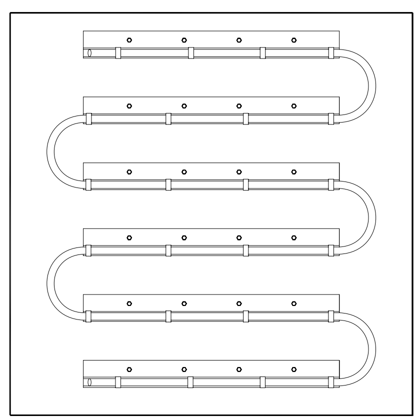


VIEW B-B

SECTION A-A



PANEL PIPING
2' x 4' 6 PASS
600 mm x 1200 mm

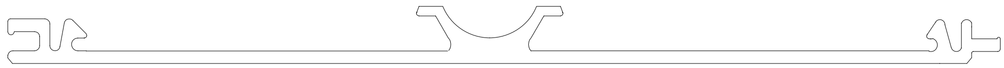


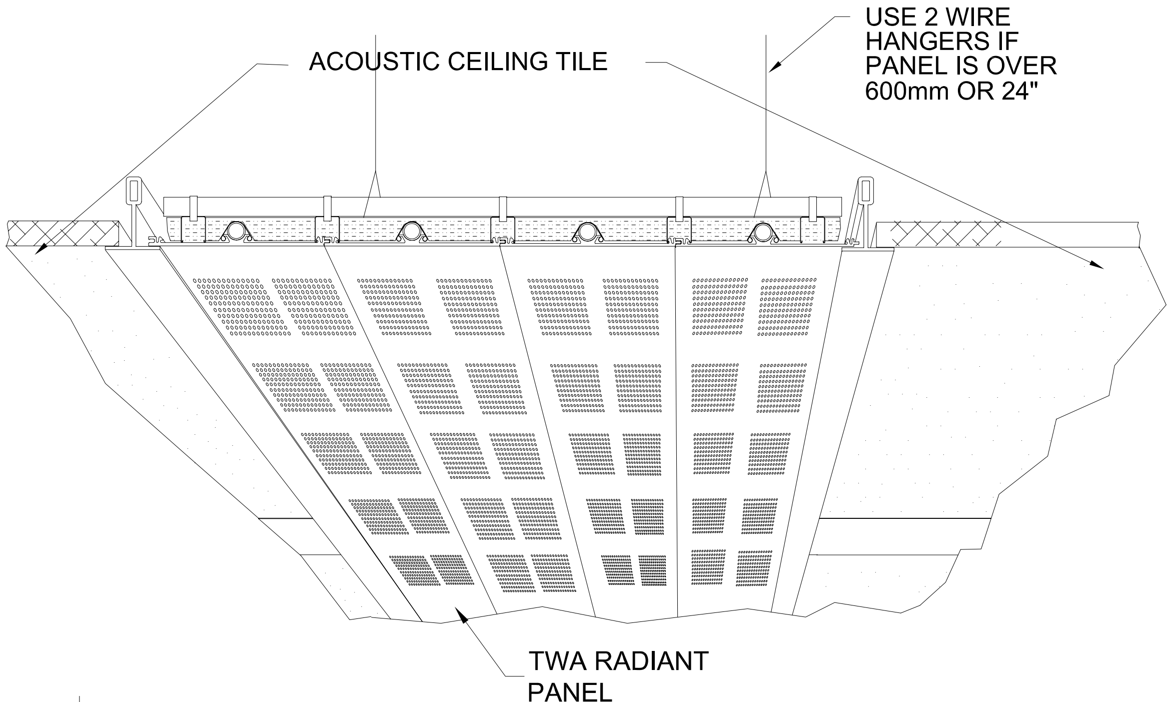
PANEL PIPING
2' x 2' 6 PASS
600 mm x 600 mm

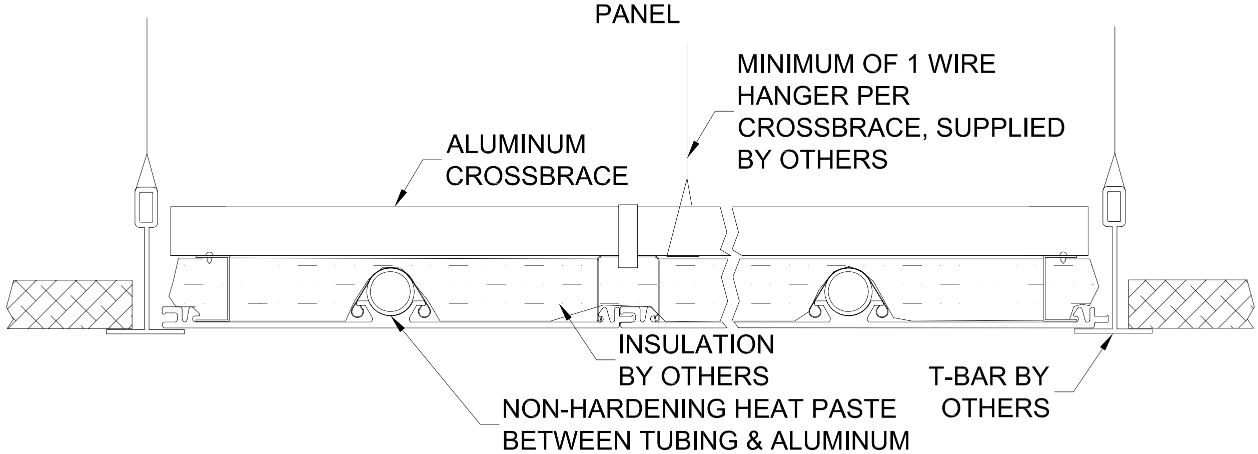
TOTAL CEILING SYSTEM - PERFORATED PANEL

Twa Panel Systems, Inc. | FRENGER® | C-14

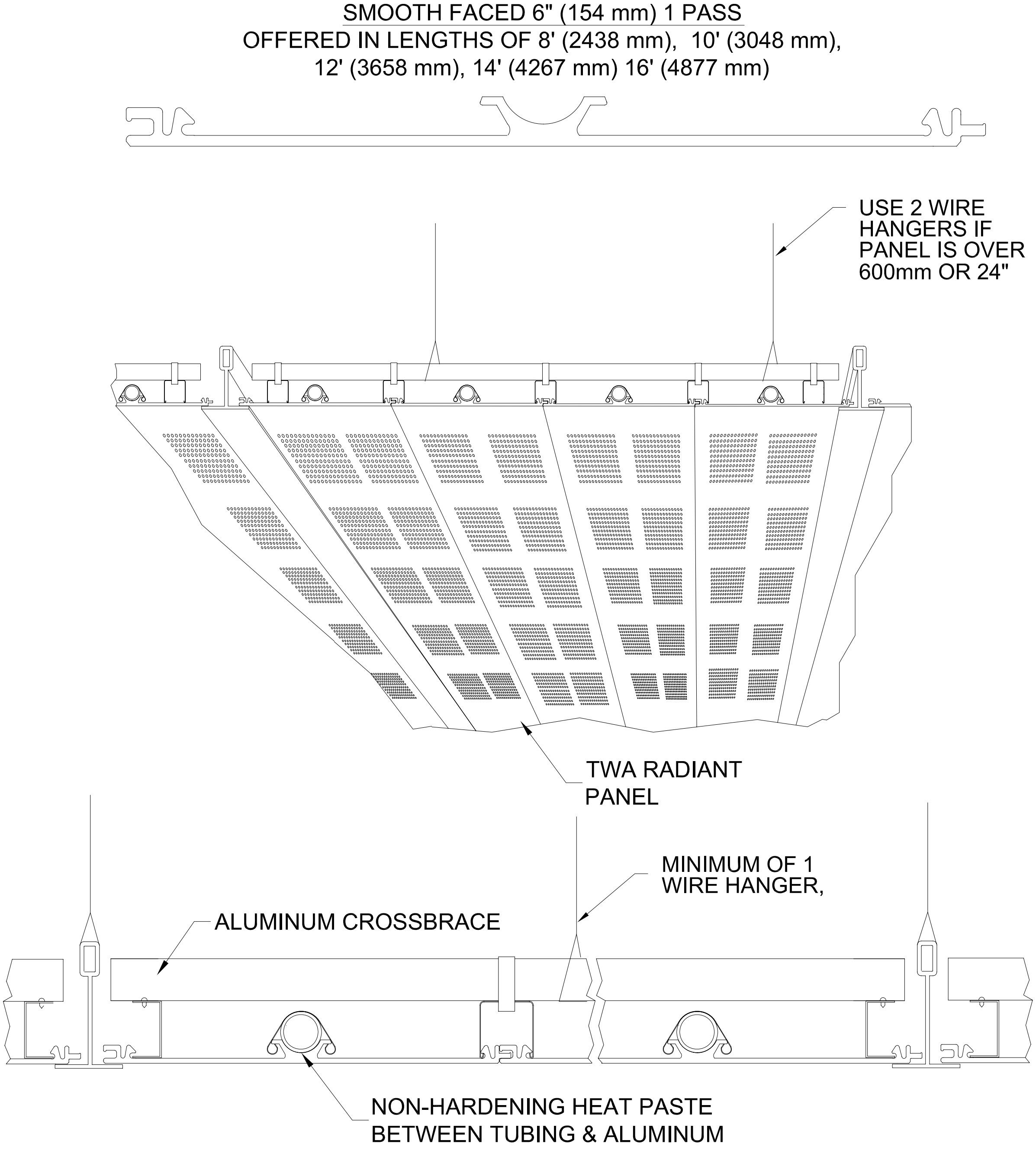
SMOOTH FACED 6" (154 mm) 1 PASS
OFFERED IN LENGTHS OF 8' (2438 mm), 10' (3048 mm),
12' (3658 mm), 14' (4267 mm) 16' (4877 mm)







SMOOTH FACED LINEAR EXTRUSION		
Twa Panel Systems, Inc.	FRENGER®	C-15



SMOOTH FACED LINEAR EXTRUSION		
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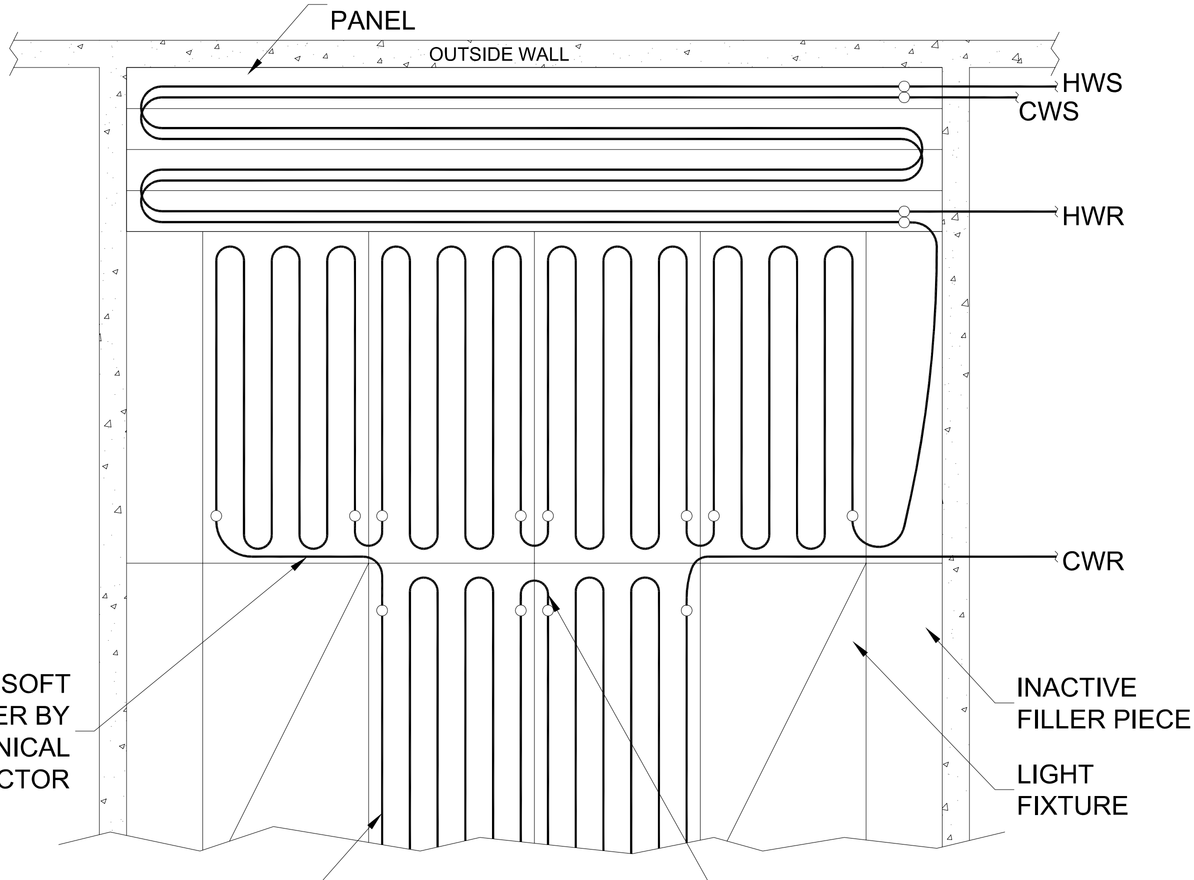
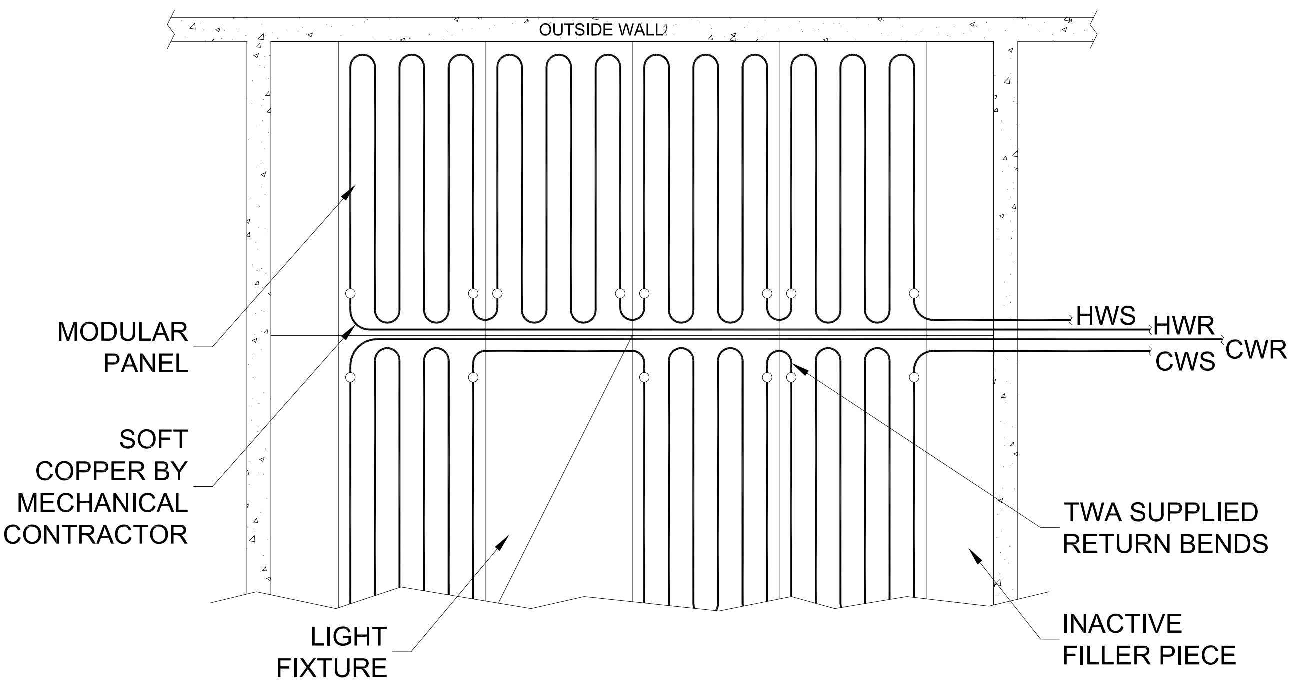


LINEAR AND MODULAR 4 PIPE ARRANGMENT

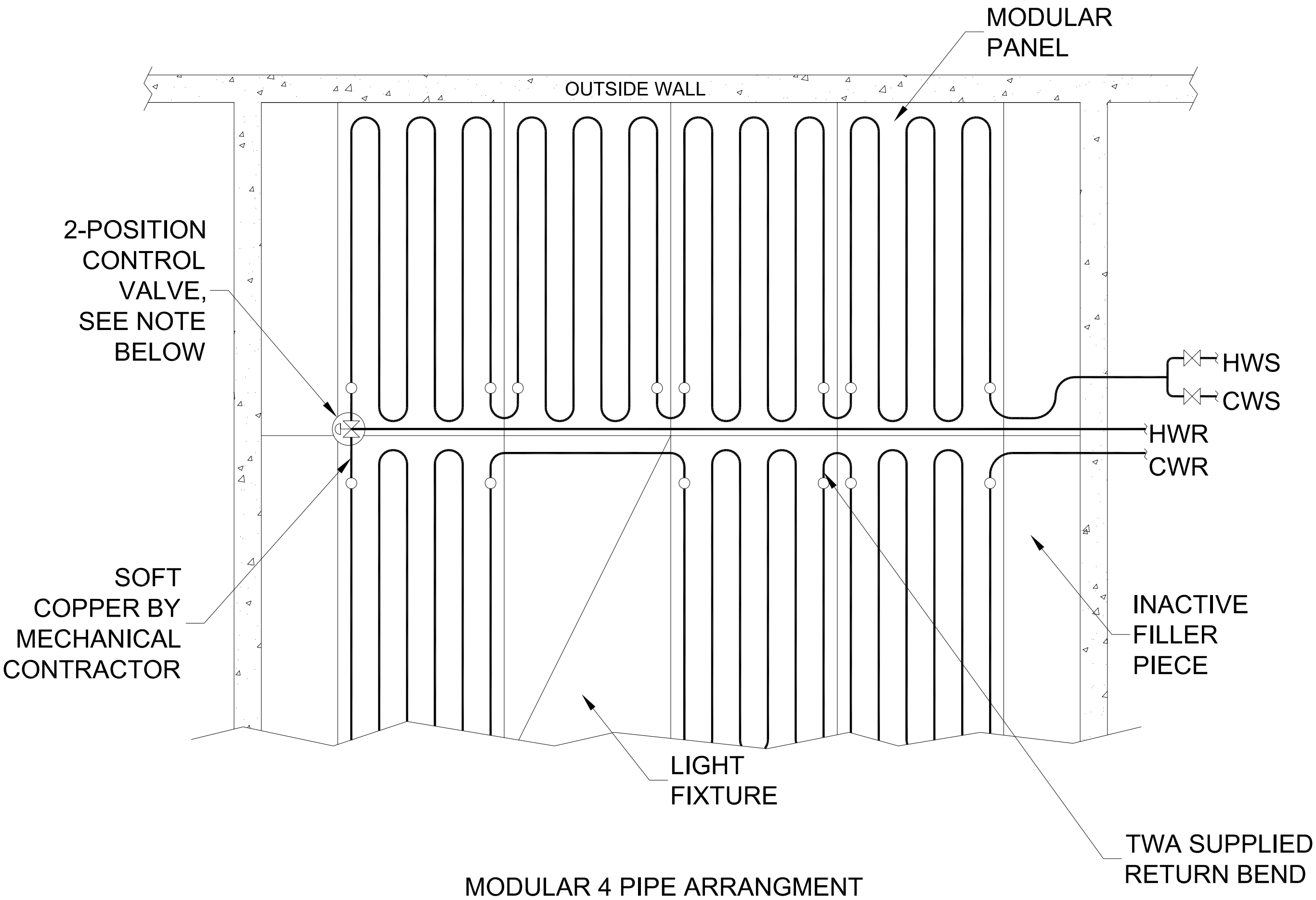
NOTES:
- LINEAR PANEL MADE OF 4x6" 2-PASS CASTELLATED ALUMINUM EXTRUSION
- MODULAR PANELS CAN BE SILKSCREENED TO DESIRED PATTERN, OR CAN BE PERFORATED FOR ACOUSTIC ABSORPTION
- HOT WATER CANNOT MIX WITH COLD WATER WITH THIS CONFIGURATION
- CIRCLES DENOTE SOLDER JOINTS

RADIANT HEATING & COOLING - PIPING SCHEMATIC		
Twa Panel Systems, Inc.	FRENGER®	C-16



MODULAR 4 PIPE ARRANGMENT

NOTES:
- MODULAR PANELS AND FILLER PIECES CAN BE SILKSCREENED TO DESIRED PATTERN, OR CAN BE PERFORATED FOR ACOUSTIC ABSORPTION
- HOT WATER CANNOT MIX WITH COLD WATER WITH THIS CONFIGURATION
- CIRCLES DENOTE SOLDER JOINTS



MODULAR 4 PIPE ARRANGMENT

NOTES:
- MODULAR PANELS AND FILLER PIECES CAN BE SILKSCREENED TO DESIRED PATTERN, OR CAN BE PERFORATED FOR ACOUSTIC ABSORPTION
- 2-POSITION VALVE DIRECTS HOT WATER TO HWR, COLD WATER TO OTHER PANELS. VALVE CAN BE MOVED NEAR OTHER VALVES FOR EASE OF ACCESS.
- CIRCLES DENOTE SOLDER JOINTS
- ONLY PANELS AGAINST OUTSIDE WALL ARE USED FOR HEATING, ALL PANELS ARE USED FOR COOLING.