METALWORKS™

Airtite® Radiant Ceiling Systems

Armstrong®
CEILING SOLUTIONS

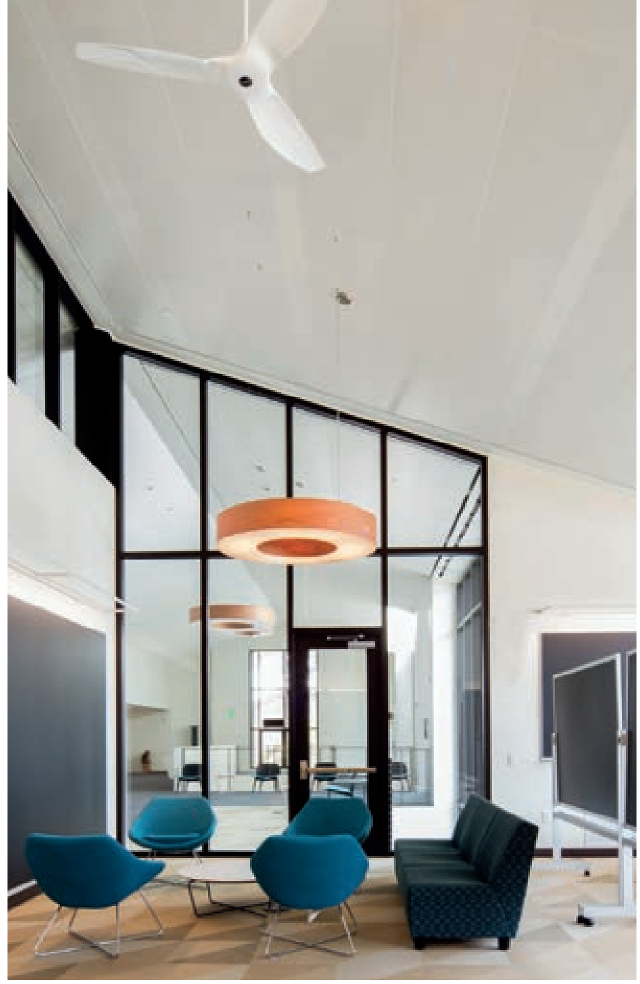
AIRTITE®

Radiant Ceiling Systems

MetalWorks™ Airtite® radiant ceiling systems circulate hot or cold water through concealed copper tubing, providing sustainable heating and cooling with minimal air ventilation requirements. Hydronic radiant ceiling systems heat and cool your space more efficiently than traditional heating and cooling systems, bringing comfort to all occupants. They can be incorporated in various ceiling solutions including lay-in and torsion spring, providing unrestricted floor space and layout flexibility.

MetalWorks™ Airtite® AR-B architectural panels
Pomona College, Claremont, CA

▲ MetalWorks™ Airtite® AR-L architectural panels; Kresge Hall, Northwestern University, Evanson, IL



AWARD WINNING PRODUCTION

Hydronic radiant ceilings and chilled beams perform efficiently while adding beauty and drama for ovation-worthy interiors.

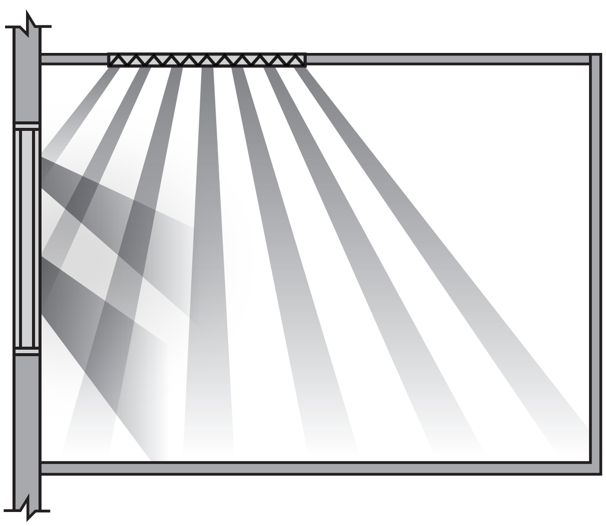
CONCEPTS AND HISTORY

A TIME-TESTED METHOD OF PROVIDING EXCEPTIONAL OCCUPANT COMFORT

BASIC CONCEPT OF RADIANT ENERGY

As radiant energy travels through the air and reaches objects, it is absorbed and is then converted into heat. This is not unlike the sun that sends out radiant energy in straight lines until it reaches a solid object where it is absorbed and warms that object.

All surfaces in a room receive and reradiate energy so that the floor is kept as warm as other surfaces. Panels installed in the perimeter of the ceiling provide a warm, draft-free environment. Radiant heat, unlike convection heat, does not rise.



Radiant energy, the transmission of electromagnetic waves, travels through the air in straight lines. When it reaches an object, it's absorbed and converted into heat. Surfaces in the room receive and reradiate the energy until the room temperature reaches equilibrium.

THE BEGINNINGS OF RADIANT HEAT

Radiant heat got its start at the time of the Roman Empire. Many buildings at that time used underground tunnels where hot gases from fires were redirected into hollow masonry walls. Occupants were then warmed by radiant heat from the walls.

In the 1800s, hot water pipes in floors and ceilings were employed in Europe to heat castles and palaces.

These designs were comfortable, but not efficient due to poor conduction of both walls and floors. In the last century both hot water piping and electric cables were imbedded in floors and ceilings to radiantly heat homes and buildings. The comfort levels were excellent but the control of these systems was difficult due to the large thermal mass of the ceilings and floors having slow response times.

RADIANT ENERGY COMES TO AMERICA

In 1950, Airtite Contractors supplied and installed the first commercial aluminum radiant heating and cooling ceiling in the United States. This lightweight aluminum system had greater heat conduction to the panel surface with increased radiant output than previous systems. The

▲ MetalWorks™ Airtite® AR-B architectural panels James B. Hunt Jr. Library, North Carolina State University, Raleigh, NC

lighter panels provided quicker response to the temperature changes thus overcoming the slower response of older systems.

In the 1960s, technology was developed to metallurgically bond copper tubing to the aluminum ceiling panels.

In the early 1970s, extruded radiant ceiling panels were developed. Copper tubes were mechanically inserted into the extrusion's heat transfer saddle. This new panel design increased panel output as well as lowered manufacturing and installation costs.

In 2014, the next generation of radiant heating was introduced which incorporated convection technology in the new AR-L and AR-C systems. We have continued to provide innovative designs including our integral linear air bar diffuser extruded panel which provides excellent air-side performance with increased output.

THEORY AND FUNDAMENTALS

There are three basic types of heat transfer: conduction, convection, and radiation.

Radiant energy is the transmission of electromagnetic waves that travel in straight lines and are absorbed, heating objects that they strike. These objects reradiate to other colder surfaces.

The best example of radiant heat is provided by the sun. On a cold but sunny day, a person standing outside will absorb the sun's radiant energy and will feel the warmth. However, the moment a cloud blocks the sun's radiation and the body can no longer absorb the sun's heat, that person will immediately feel cool, even though the air temperature has not varied.

The ability of a surface to emit or absorb radiant energy is known as emissivity. It is expressed as a decimal ratio of its ability to radiate and is compared to that of a "blackbody". Blackbody radiation has an emissivity of 1.00. Practically, a surface that emits well will absorb well. Unpainted aluminum has a low emissivity ratio but painted aluminum surfaces will have an emissivity ratio from .91 to .96, depending on the type of paint. Therefore radiant panels that are made of extruded or formed aluminum must be painted to provide good radiant performance.

Radiant ceiling panels have surface temperatures that transmit radiant energy in the infrared portion of the spectrum to which glass is opaque. Radiant energy travels in straight lines heating solid objects such as walls, floors, furniture, people, etc. In turn, all these surfaces in the space reradiate to one another until equilibrium is attained.

ASHRAE defines thermal comfort as "that condition of mind which expresses satisfaction with the thermal environment." The areas of a heating system that can affect human comfort are room air temperature, air velocities, humidity, and mean radiant temperature (MRT) of surroundings. Over the years, studies have been done indicating that MRT strongly influences the feeling of comfort. Perimeter walls with significant amounts of glass will have much lower surface temperatures than the air temperature of the space. Forced convective air reheat systems are not able to effectively counteract discomfort due to large radiant losses of occupants to the outside wall.

Room air temperatures and humidity are designed and maintained by the air system, but perimeter surface temperatures of walls, and especially glass, are usually not part of any design. Low-surface temperatures of outside perimeter wall/glass can cause discomfort due to occupant radiant losses to these surfaces and downdrafts.

Floor temperatures will be kept equal-to or greater-than the ambient air temperature. Bringing these surface temperatures (MRT) to higher levels by perimeter radiant systems offset human radiant losses and downdrafts.

Ceiling radiant panels have an excellent view of the outside wall, floor, nearby furniture, and occupants. This form of asymmetric radiant energy transfer provides optimal comfort. The performance of the radiant panels is directly related to the structure in which it's located. Exhaustive testing of ceiling mounted radiant panels has been well established for rectangular rooms where the primary heat losses are from outside walls.

ASHRAE studies indicate radiant systems can achieve excellent occupant comfort with room temperatures at a minimum of three to four degrees lower than normal set points for convective air heating systems. It should be noted that overly conservative design calculations increase panel square footage and should not be used because panel effectiveness and efficiency is reduced and material costs are increased.

In conclusion, the principal benefits of radiant heating in the ceiling are:

- Mean radiant temperature is achieved since all solid objects absorb radiant energy and re-release the energy until equilibrium is reached
- Downdrafts from cold outside walls are reduced
- The side of the human body adjacent to the outside wall receives direct radiant energy, offsetting heat loss to that surface

BENEFITS OF HYDRONIC RADIANT HEATING AND COOLING PANELS

OPERATING COSTS
Hydronic systems generally require 20% of the energy used by all air systems. Recent studies by the New Building Institute on buildings remodeled using radiant heating and cooling systems have shown that energy efficiencies of 31% to 32% can be obtained. Since there are no moving parts in the radiant system, maintenance costs are minimal.

SUPERIOR COMFORT
Because surfaces are uniformly heated or cooled, occupant comfort is achieved at lower winter design temperatures and higher summer design temperatures.

ENERGY CONSUMPTION
Energy consumption is reduced by using hydronic heating/cooling and design temperatures as described above.

AESTHETICS
Panels provide excellent architectural appearance with a large array of existing and new design creations.

FLEXIBILITY
Hydronic radiant panels can be incorporated in various ceiling types: lay-in, drywall, soffits, and exposed structure ceilings, providing unrestricted floor space.

DURABILITY
Ceiling panels minimize the possibility of being scratched, bumped, or dented.

CONTROL RESPONSE
Efficient, lightweight, radiant panels will heat up and cool down quickly.

INDOOR AIR QUALITY
High-quality air filtration can be achieved due to reduced make-up air quantities (100% outside air) needed for ventilation and dehumidification.

SPACE REQUIREMENT
For cooling, slab-to-slab height can be reduced, resulting in smaller ducts, reduced plenum heights, and lower air flows. Mechanical equipment rooms are smaller and the radiant system is located in the ceiling giving full utilization of floor space.

CONSTRUCTION SAVINGS
Mechanical construction costs are reduced by utilizing smaller air handlers, smaller duct sizes, and elimination of VAV systems. In addition, reduced slab-to-slab heights are realized.

LIFE CYCLE COSTS
Radiant systems previously evaluated against other typical HVAC systems have shown to have a life cycle cost advantage.

NOISE CONTROL
Perforated panels with insulation can provide noise reduction levels that are lower than standard acoustical ceilings.

GREEN BUILDING DESIGN
A combined radiant panel cooling system designed with a dedicated outdoor air mechanical system offers the potential to earn LEED® certification points. Radiant heating and cooling systems can help with Living Building Challenge℠ certification as well as Passive House certification.

RADIATION EXCHANGE FORMULA

A GRAPHIC DEPICTION AND ENGINEERING FORMULA FOR RADIANT HEATING ENERGY

The basic equation for radiation exchange is the Stefan-Boltzmann equation. This equation may also be expressed as:

$$Q_r = 0.1713\ F_a F_e\ [(\frac{T_r}{100})^4 - (\frac{T_p}{100})^4]$$

Q_r = Heat transferred by radiation, BTU per (hour) (sq. ft.)

T_r = Mean radiant temperature of unheated surface, Fahrenheit, absolute

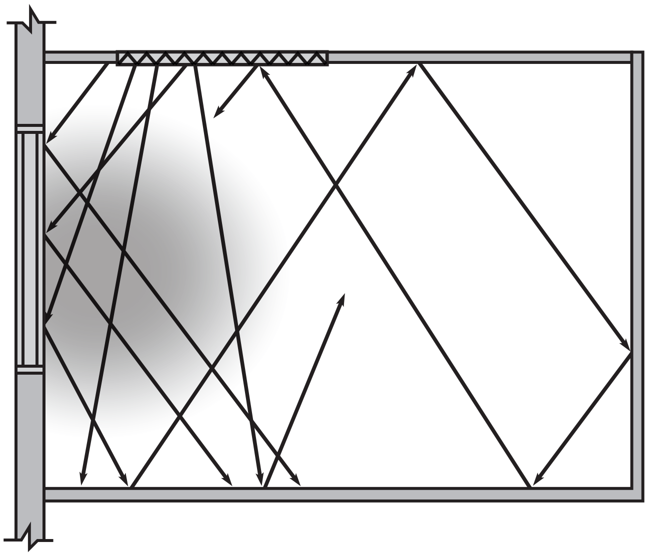
T_p = Average surface temperature of heated panel, Fahrenheit, absolute

F_a = The configuration factor (dimensionless)

F_e = The emissivity factor (dimensionless)

0.1713 = Stefan-Boltzmann radiation constant, BTU per (hour) (sq. ft.)

[Rankin (absolute Fahrenheit) temperature to the fourth power]



Graphic depiction of radiant energy

▼ MetalWorks™ Airtite® perimeter radiant panels and radiant torsion spring; James B. Hunt Jr. Library, North Carolina State University, Raleigh, NC

DESIGN PROCEDURE FOR COOLING/HEATING
AR-X, AR-B, AR-M, AR-L & AR-C

The design of a radiant cooling/heating system should follow the usual guidelines of an air-water system. To create such a system, we need to find the following:

1. Establish inside room design dry bulb temperature, relative humidity, and dew point
2. Calculate the room's internal loads (sensible and latent)
3. Calculate air side room requirements
4. Select mean water temperature
5. Determine panel area required
6. Check panel capacity for heating
7. Determine flow and pressure drop

DESIGN EXAMPLE:

Single Patient Hospital Room
Outside design conditions:
Summer: 95°F Dry Bulb, 78°F Wet Bulb
Winter: -10°F Dry Bulb

1. Establish inside room design conditions and parameters

Room dimensions: 12' x 12' (144 SF)
Glass: 25% of outside wall
Toilet dimensions: 6' x 8' x 8'

Inside design conditions:
76°F Dry Bulb
Relative humidity: 45%
Dew point: 53°F
Absolute humidity: 60 GR/LB of dry air
Primary chilled water temp: 42°F

2. Internal Loads

Sensible Load:
Summer: 5200 BTUH gain
Winter: 6800 BTUH loss
Latent Load: 580 BTUH gain (people infiltration)

3. Calculate air side room requirements

Air quantity must meet minimum code/design requirements. The air must handle the latent load and CFM/SF must be adequate for comfort and odor removal.

Code Requirement
Code requires 4 AC (air changes)/HR of outside air be supplied to the room and 10 AC/HR be exhausted from the toilets.

Supply CFM

$$\frac{144 \text{ SF} \times 9 \text{ ft. Ceiling} \times 4\text{AC}}{60 \text{ min/hr}} = 86.4 \text{ CFM}$$

Toilet exhaust

$$\frac{6' \times 8' \times 8' \times 10 \text{ AC}}{60 \text{ min/hr}} = 64 \text{ CFM}$$

Soiled Linen Cabinet Exhaust
15 CFM   Total Exhaust = 79 CFM

For good air motion, use 0.6 CFM.
144 SF x .6 CFM/SF = 86.4 CFM
Code and comfort calculations indicate 86.4 CFM.
Design at 90 CFM

Calculate Latent Capacity
The internal moisture pickup with 90 CFM

$$\text{IMP} = \frac{\text{Internal latent load}}{\text{CFM conditioned} \times 0.68}$$

$$\text{IMP} = \frac{580 \text{ BTUH}}{90 \text{ CFM} \times 0.68} = 9.5 \text{ GR/LB}$$

$$\mathbf{0.68 = \frac{1060 \times 60}{7000 \times 13.34}}$$

1060 BTU = Heat of Vaporation
60 = minutes/hour
7000 = GR/LB
13.34 = cubic ft./lb. of std. air

Use 10 GR/LB (grains of water/pound)
Determine the required delivered air conditioning to offset this 10 GR/LB pickup.
Grains maintained – Grains pick up =
Grains to be delivered
60 GR/LB – 10 GR/LB = 50 GR/LB
maximum in delivered air.

Referring to a psychrometric chart, air entering the air handling unit in the summer at 95°F DB, 78°F WB, has .118 GR/LB. Air leaving the unit has been cooled and dehumidified, leaving the coil at 52°F DB and 50°F WB having 50 GR/LB, allowing for ample latent load pickup. Air will be delivered to the room at 54-55°F.

4. Select the mean water temperature

The secondary supplied chilled water temperature to the ceiling should be a minimum of 1° above the design dew point of the room panels:

Room dew point of 53°F + 1°F = 54°F

Supply Water Temp

Normally a 4-6°F water temperature rise (WTR) is used. For this example use a 5°F WTR.

MWT = Supply Water Temp + .5 x design WTR
MWT = 55°F + 2.5°F = 57.5°F MWT

5. Determine the panel area required

Refer to the Cooling Performance Table.
Room Air Temperature – MWT
76°F Dry Bulb – 57.5°F = 18.5°F difference

At 25% glass from the performance chart with an 18.5 difference panel capacity for above conditions = 44 BTUH/SF (sensible cooling)

Cooling

Required panel cooling =
Total Sensible Cooling – Air Sensible Cooling

Sensible Cooling w/Air = Conditioned
CFM x 1.08° x (Room Air °F. – Supply Air ° F)

$$1.08 = \frac{60 \times 0.24}{13.34}$$

13.34 = CUFT/LB of standard air 60 = MIN/HR 0.24 = Specific heat of air

90 CFM x 1.08 x (76 – 55) = 2041 BTUH

Required cooling =
5200 BTUH – 2041 BTUH = 3159 BTUH

Panel area required =

$$\frac{3159 \text{ BTUH}}{44 \text{ BTUH/SF}} = 71.8 \text{ SF}$$

6. Check panel capacity for heating

The radiant panel must pick up the winter design load plus the air side reheat.

Air side reheat = 90 CFM x 1.08 x (76-55) = 2041 BTUH
Total load = 6800 BTUH + 2041 BTUH = 8841 BTUH

According to perimeter and interior performance tables, a 150°F MWT is adequate for heating.

7. Determine the water flow (GPM) and pressure drop (ft of water)

Refer to Pressure Drop Table for design data on pressure drops for heating and cooling.

$$\text{GPM} = \frac{\text{Total BTUH for panels}}{500 \times \text{Water Temp. Difference}}$$

500 = 8.43 x 60 8.34 = LB / Gal 60 = MIN/HR

$$\text{Cooling GPM} = \frac{3159 \text{ BTUH}}{500 \times 5°F} = 1.26 \text{ GPM}$$

Use 1.3 GPM

$$\text{Heating GPM} = \frac{8841 \text{ BTUH}}{500 \times 20°F} = .89 \text{ GPM}$$

Use 1.0 GPM

8. Pressure loss for copper tubing

Select the proper table for the type of pipe. Type K copper pipe has the thickest wall and highest pressure ratings of the common copper tubing types. In order of wall thickness, common copper tubing types are Type M (thinnest), Type L, and Type K (thickest).

Type L is commonly used for household plumbing. If you don't know what Type the pipe is, assume it is the thickest Type K. Locate the proper column on the table for the pipe size.

Read down the column to the row for the flow rate (GPM) in the pipe section. You will find a PSI loss value (given as PSI/100).

Multiply the PSI loss value shown by the total length of the pipe section, then divide the product by 100. (PSI loss on these tables is given in PSI per 100 feet of pipe.)
Value * Length / 100 = PSI loss

See next pages for water pressure loss in copper tubing and pressure loss in metric tubing (tables from Geberit Mapress Stainless Steel).

PRESSURE LOSS OF WATER DUE TO FRICTION IN TYPES K, L, AND M COPPER TUBE

(PSI PER LINEAR FOOT OF TUBE)

COPPER TUBE DIAMETER

FLOW	3/8"			1/2"		
GPM	K	L	M	K	L	M
1	0.036	0.023	0.021	0.01	0.008	0.007
2	0.13	0.084	0.075	0.035	0.03	0.024
3	0.275	0.177	0.159	0.074	0.062	0.051
4				0.125	0.0106	0.086
5				0.195	0.161	0.13

NOTES

1. Fluid velocities in excess of 5-8 feet per second are not recommended.
2. Friction loss values shown are for the flow rates that do not exceed a velocity of 8 feet per second.
3. Table based on the Hazen-Williams formula below:
   $P = 452Q^{1.85}/C^{1.85}d^{4.87}$
4. Calculations are theoretical

Where:
P = friction loss, PSI per linear foot
Q = flow, GPM
d = average I.D. in inches
C = constant, 150

▼ MetalWorks™ Airtite® AR-B radiant panels incorporated and Optima® Vector® 4' x 4' panels; Pomona College, Claremont, CA

PRESSURE LOSS IN METRIC TUBING:

Pipe pressure gradient due to friction **R** and calculated flow velocity **v** as a function of peak flow rate $\mathbf{V_p}$ at T = 10°C

Copper pipes to DVGW Code of Practice GW 392/DIN EN 1057

k = 0.0015 mm

NOMINAL SIZE	PIPE OUTSIDE DIAMETER X WALL THICKNESS	
D X T (MM) ID (MM) NOMINAL DIA.	**15 X 1.0 13 DN12**	
PEAK FLOW RATE V_p (LITERS/SEC.)	**R (MBAR/M)**	**V (M/S)**
0.05	2.2	0.38
0.06	3.0	0.45
0.07	4.0	0.53
0.08	5.0	0.60
0.09	6.1	0.68
0.10	7.3	0.8
0.15	14.8	1.1
0.20	24.5	1.5
0.25	36.2	1.9
0.30	49.9	2.3
0.35	65.6	2.6
0.40	83.1	3.0
0.45	102.4	3.4
0.50	123.6	3.8
0.55	146.5	4.1
0.60	171.1	4.5
0.65	197.5	4.9
0.70	225.5	5.3

NOTE: Calculations are theoretical

PANEL CONTROL CONSIDERATIONS

Radiant systems can be controlled the same as any perimeter hot water heating system. Radiant panels operate best with indoor/outdoor water supply temperature reset. This allows the radiant output to most closely match the perimeter load at design flow. When modulating control valves are used with a 20°F delta temperature, a 50% reduction in flow reduces the M.W.T. by 10°F with a corresponding 10% reduction in panel output.

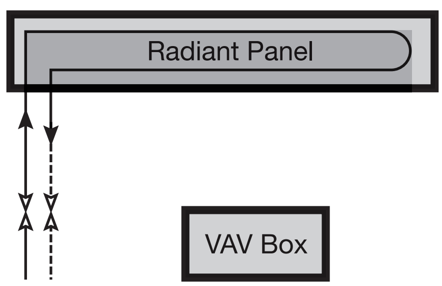
Many systems supplied and installed have successfully operated with constant water flow and variable water temperature as shown in 1. In this arrangement the VAV box operating with supply economizer air modulates to meet the thermostat set point. The addition of a hydronic modulating valve as shown in 2 adds further control.

Schemes 3 & 4 utilize hydronic reheat coils in the VAV boxes. The control sequence must be that the radiant panels heat first and if additional heat is required then airside reheat is provided. If room temperatures rise above the thermostat set point, the flow to the airside hydronic reheat coil would first modulate down and lastly the water flow to the radiant panels. In all cases the radiant panel must be the first on providing heat and the last off.

Solenoid valves (on/off) are not recommended because they cycle, not allowing continuous radiant energy transfer to the walls, floors, furniture, and occupants for the best level of comfort.

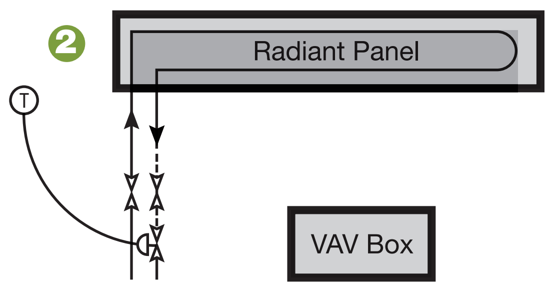
NOTE: Only water-side control shown. VAV BOX airside control not shown.

1



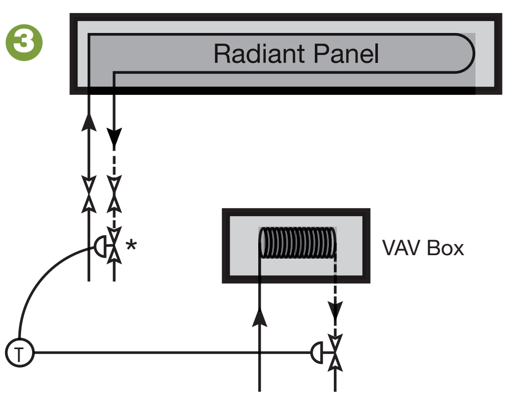
Constant flow using indoor/outdoor reset for water temperature. No reheat in the air.

2



Variable flow using indoor/outdoor reset for water temperature. No reheat in the air.

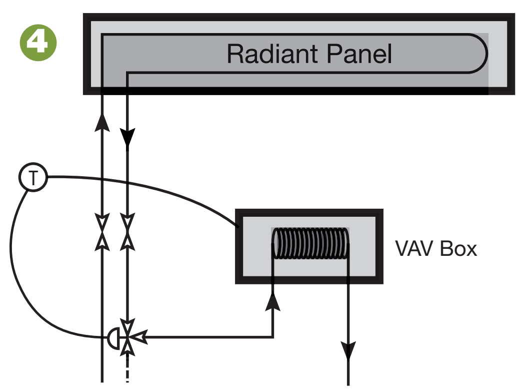
3



Variable flow using indoor/outdoor reset for water temperature. Reheat in the air with two independent control valves. Sequence of operation is radiant panels first and only, then reheat in the air.

This valve can be eliminated if variable temperature water is provided, based on an indoor/outdoor reset.

4



Variable flow using indoor/outdoor reset for water temperature. Reheat in the air with 3-way modulating valve. Sequence of operation is radiant panels first and only, then reheat in the air.

AR-X Extruded Radiant Panel

The AR-X hydronic extruded aluminum radiant panel is a well-tested, proven design. The panel has a very attractive fluted face and a highly efficient heat transfer saddle on the back of the panel.

Copper tubes are mechanically reformed within the saddle providing superior tube contact. The panel efficiency is over 90% of a full-flooded hollow panel of the same width. Panels with larger tube diameters have been comparatively tested against this design and have shown no increase in performance. Panel widths from 8 to 24 inches in standard ceiling heights have provided excellent human comfort long associated with radiant systems.

A perimeter hot water radiant ceiling eliminates downdrafts and increases exterior wall surface temperatures providing a very comfortable thermal environment especially with perimeter walls having large glazed areas.

The unique, attractive design becomes an aesthetic enhancement to the overall architectural interior design while providing increased space utilization, flexibility, and lower first-installed costs. The elimination of perimeter baseboard with expensive architectural covers and other floor-mounted heating systems provide flexibility in design, full utilization of floor space, and unrestricted furniture location.

The MetalWorks™ Airtite® AR-X radiant extruded aluminum panel can easily be integrated in lay-in ceilings, drywall ceilings, soffit rises, or drops—and no ceilings at all. This system lends itself to either new construction or retrofits.

Retrofits can be accomplished without shutting down multiple floors or large areas of the building that would cause loss of revenue due to interruption of occupancy.

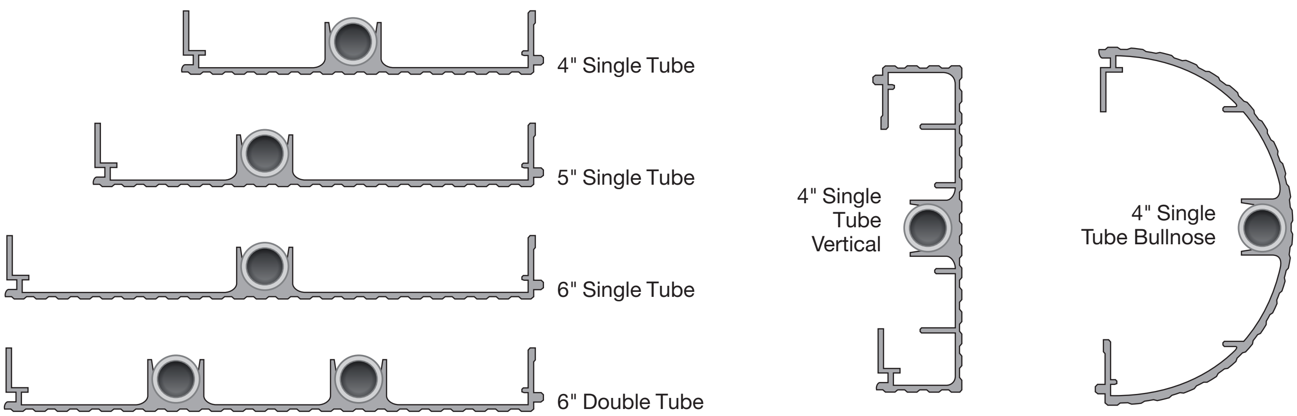
Airtite AR-X extruded radiant panels have a higher STC rating than most acoustical ceilings minimizing sound transmission.

As with any hydronic system, fuel savings are realized through the highly efficient use of energy. Rising energy costs make this system very competitive in fuel savings, especially because comfort levels are excellent at air temperatures 3-4° lower (thermostat set point) than conventional systems. The panels themselves are maintenance-free and lend themselves to lower life-cycle costs.

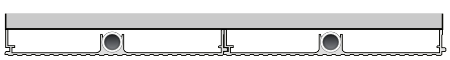
Perimeter radiant systems have been effectively used for over 50 years and have become a system of choice by both architects and engineers.

▼ MetalWorks™ Airtite® AR-X radiant panels; Northwest Community Patient Care Center Chicago, IL

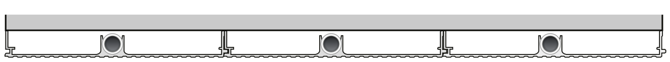
STANDARD AR-X EXTRUDED SECTIONS



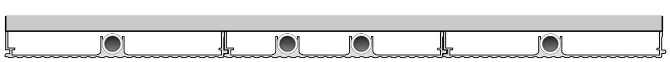
ASSEMBLED RADIANT PANEL SECTIONS



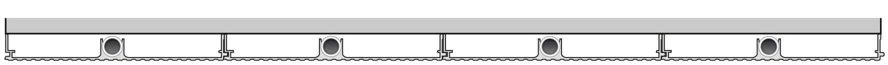
12" Two-Tube Radiant Panel



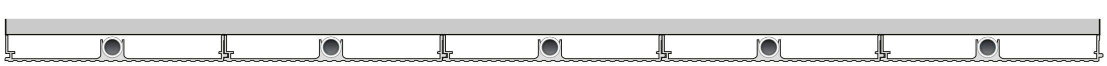
18" Three-Tube Radiant Panel



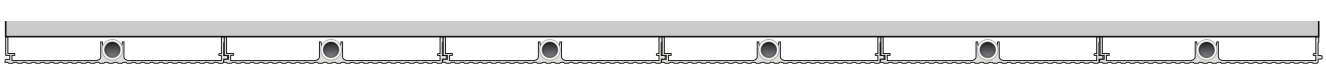
18" Four-Tube Radiant Panel



24" Four-Tube Radiant Panel



30" Five-Tube Radiant Panel



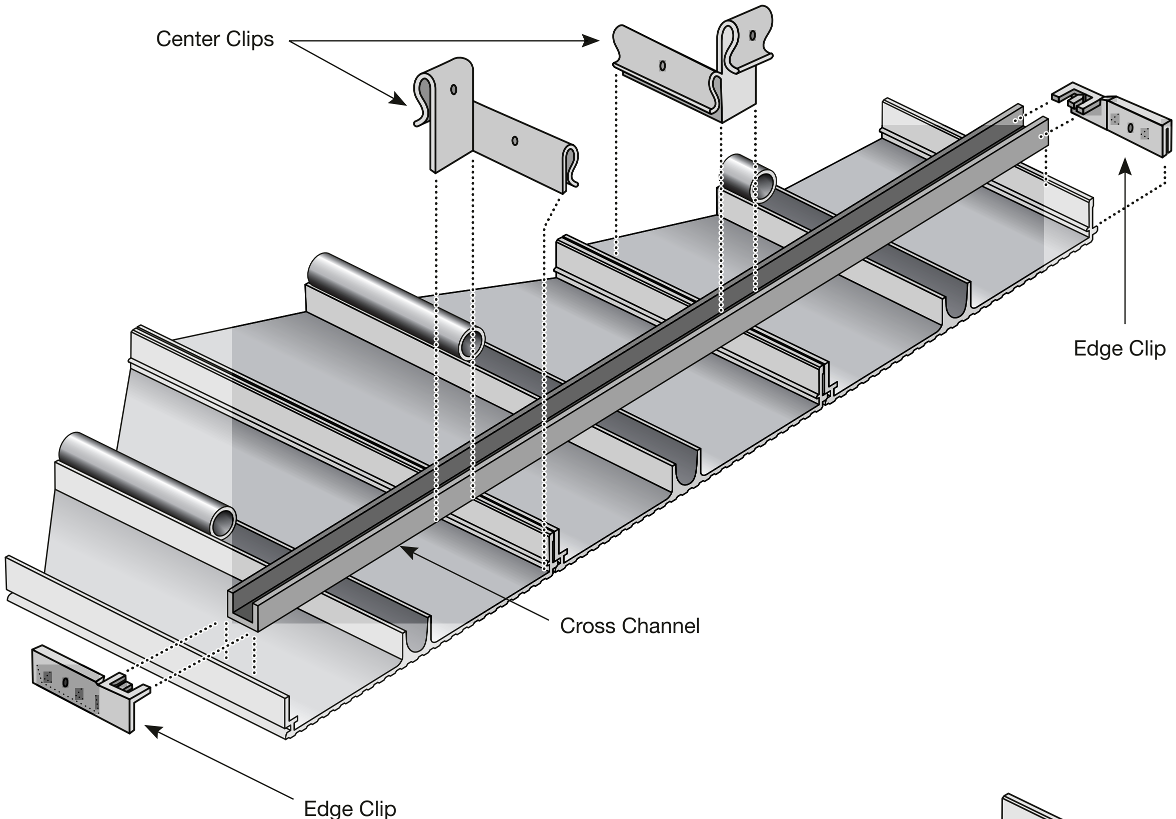
36" Six-Tube Radiant Panel

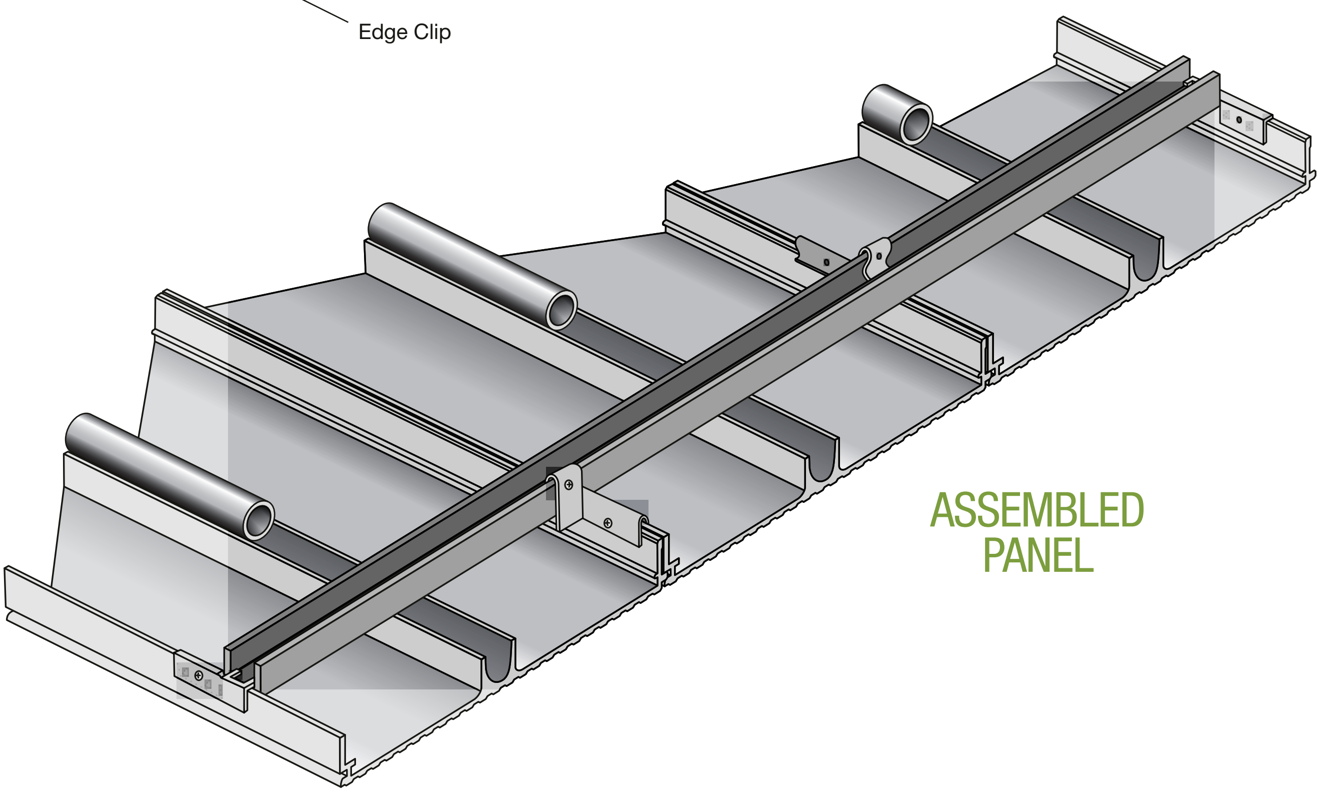
Ceiling Opening Schedule

The radiant panels shown on drawings are stock lengths and are to be field-cut to fit the job site conditions. These conditions include miters, notches, etc. Consult the chart below for ceiling width opening requirements.

NOMINAL PANEL WIDTH	CEILING OPENING WIDTH
12"	12-1/4"
18"	18-3/16"
24"	24-1/8"
30"	30"
36"	36"

EXPLODED PANEL ASSEMBLY





ASSEMBLED PANEL

AR-X COOLING PERFORMANCE:
COOLING PERFORMANCE FOR EXTRUDED PANELS

ROOM CONDITIONS AND PERCENT GLASS

ROOM AIR TEMPERATURE (MINUS MWT °F)	INTERIOR ROOM	NO GLASS IN SUN OR FULLY SHADED GLASS AND WALL	25% CLEAR EXTERIOR WALL IN SUN	50% CLEAR EXTERIOR WALL IN SUN	75% CLEAR EXTERIOR WALL IN SUN	100% CLEAR EXTERIOR WALL IN SUN
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
24	46	51	56	63	66	67
27	48	53	58	64	67	68
28	49	55	60	65	69	72

Performance shown in BTUH/SF of Panel
NOTE: Calculations are theoretical

AR-X PANEL HEATING PERFORMANCE

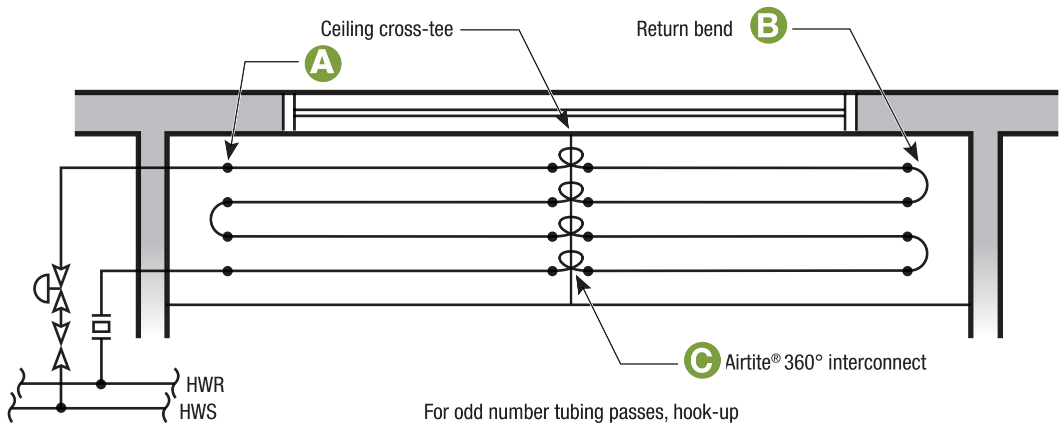
Total certified output shown is per lineal foot of panel at the perimeter of the space. Output is based on 70°F air temperature; 67°F average unheated surface temperature (A.U.S.T.), with one inch of 3/4" PCF unfaced fiberglass batt insulation on top of the panel, and natural convection. Actual output with minimum ventilation significantly increases panel output (approximately 10-15%).

PANEL WIDTH IN INCHES (BTUHR/LF) EXTERIOR APPLICATION

		Mean Water Temperature in Degrees Farenheit																				
Inches	Tubes	120	125	130	135	140	145	150	155	160	165	170	175	180	185	190	195	200	205	210	215	220
6	**1**	47	55	63	71	79	87	95	104	112	120	128	136	144	152	160	168	176	184	193	201	209
6	**2**	49	57	66	74	83	91	99	109	117	125	134	142	150	159	167	176	184	192	202	210	218
8	**2**	60	70	81	91	101	111	121	131	141	151	161	171	181	191	201	211	221	231	241	252	262
9	**2**	62	74	86	97	108	119	130	141	152	163	174	185	196	207	218	230	241	253	263	275	286
10	**2**	64	77	90	102	114	126	138	150	162	175	187	199	211	223	235	248	260	272	284	297	309
12	**2**	69	83	98	112	126	140	155	169	183	198	212	226	241	255	269	284	298	312	326	341	355
12	**3**	72	88	103	118	133	147	163	177	192	207	222	237	259	274	281	297	311	326	348	363	371
12	**4**	73	88	104	119	134	149	165	180	194	201	225	240	263	278	285	301	316	331	353	369	376
15	**3**	80	97	113	128	144	160	176	193	208	224	240	256	272	288	304	320	336	352	368	383	400
16	**4**	89	107	125	143	161	179	198	216	234	252	270	288	307	325	343	361	379	397	416	434	452
18	**3**	96	116	135	154	173	192	211	231	250	269	288	307	326	345	365	384	403	422	441	460	480
18	**4**	117	136	154	173	192	210	229	248	266	285	303	322	341	359	378	397	415	434	453	471	490
18	**5**	123	144	163	183	203	222	242	262	281	301	320	340	369	388	398	418	437	457	487	506	516
18	**6**	124	144	163	183	204	223	243	263	282	302	321	341	361	381	401	421	440	460	480	499	519
24	**4**	145	170	194	218	243	267	291	316	340	364	389	413	438	462	486	511	535	559	584	608	632
24	**5**	150	178	202	227	253	278	302	328	353	377	403	428	465	490	503	528	553	578	616	640	653
24	**6**	152	179	205	230	256	281	306	332	357	382	408	433	472	497	510	536	560	586	625	650	662
24	**7**	153	180	206	231	258	283	308	334	360	385	411	437	475	501	514	540	565	591	630	655	667
24	**8**	154	181	207	232	259	284	310	336	361	387	413	439	478	503	516	543	568	594	633	659	671
30	**5**	153	183	212	241	270	299	329	358	387	416	446	475	504	533	562	592	621	685	679	708	738
30	**6**	160	190	220	249	279	309	339	369	398	428	458	488	518	547	577	607	637	667	696	726	756
30	**7**	167	199	230	260	292	323	354	386	416	447	479	510	541	572	603	634	666	697	727	759	790
30	**8**	170	201	233	264	296	328	359	391	422	454	485	517	549	580	612	643	675	707	738	770	801
30	**9**	174	207	240	271	304	337	370	402	434	467	499	532	565	596	639	662	694	727	759	791	824
30	**10**	179	213	246	279	312	346	380	413	446	479	513	547	580	613	646	680	713	747	780	813	847
36	**6**	198	231	264	297	331	364	397	430	464	497	530	563	597	630	663	696	730	763	796	829	863
36	**7**	207	241	276	310	346	380	415	449	485	519	554	588	624	658	693	727	763	797	832	866	902
36	**8**	210	245	280	315	351	386	421	456	492	527	562	597	633	668	703	738	774	809	844	879	915
36	**9**	216	252	288	324	361	397	433	469	506	542	578	614	651	687	723	759	796	832	868	904	941
36	**10**	222	259	296	333	371	408	445	482	520	557	594	631	669	706	743	780	818	855	892	928	967
36	**11**	228	266	304	342	381	419	457	495	534	572	610	647	687	725	762	800	840	877	915	953	992
36	**12**	234	273	312	350	391	430	468	507	548	586	625	664	704	743	782	821	861	900	939	978	1018

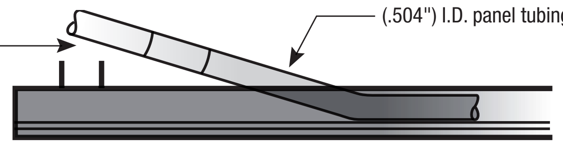
Total certified output shown is per lineal foot of panel at the perimeter of the space. Output is based on 70-degree F air temperature; 67-degree F average unheated surface temperature (A.U.S.T.) with one inch of three-quarter pound density fiberglass batt insulation on top of the panel and natural convection. Actual output with minimum ventilation significantly increased panel output (approximately 10%-15%).
NOTE: Calculations are theoretical

TYPICAL AR-X PANEL DESIGN
CONNECTION DETAILS

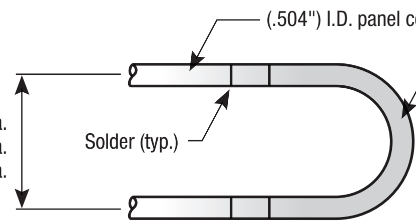


For odd number tubing passes, hook-up supply, and return at opposite ends

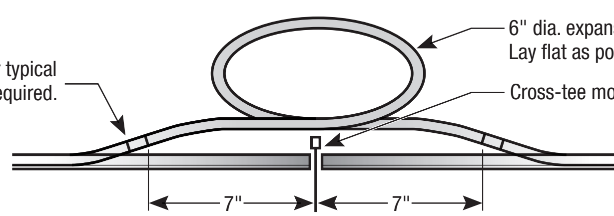
Standard panel tubing size is 0.544" OD – 0.504" ID ALLOY 122 COPPER and is rated at 400 P.S.I.G.



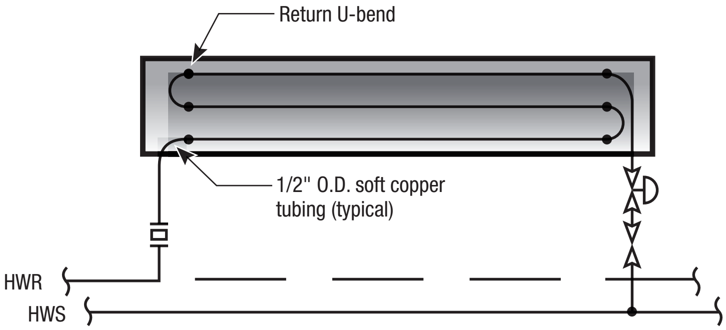
A Connection to Airtite panel tubing



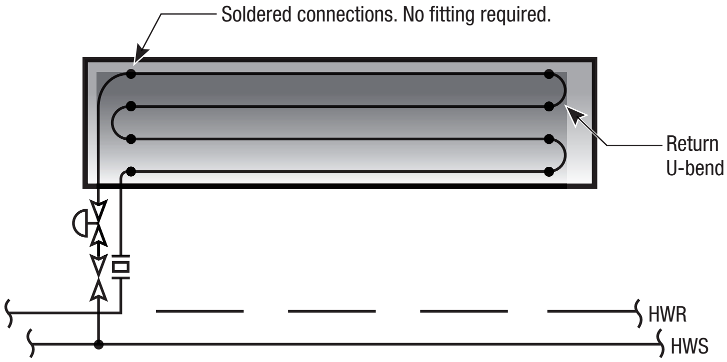
B Airtite return U-bend



C Airtite 360° interconnect

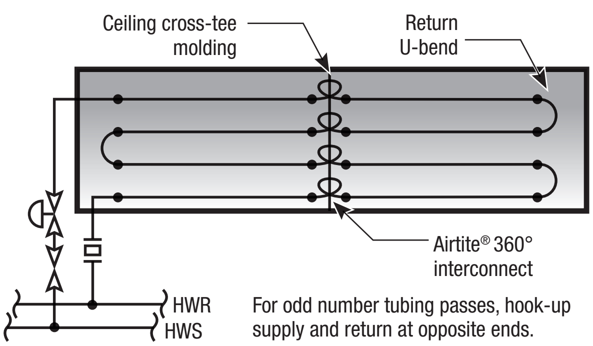


Odd number tubing passes; opposite end connections

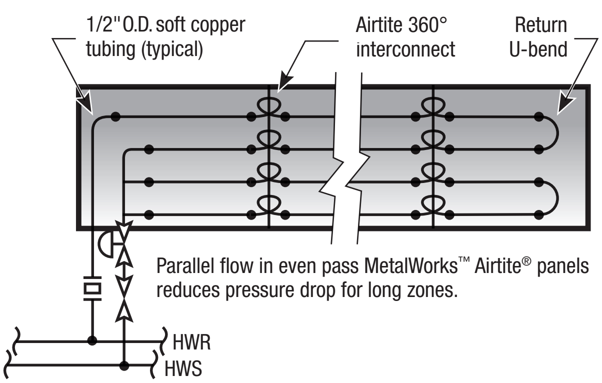


Even number tubing passes; same end connections

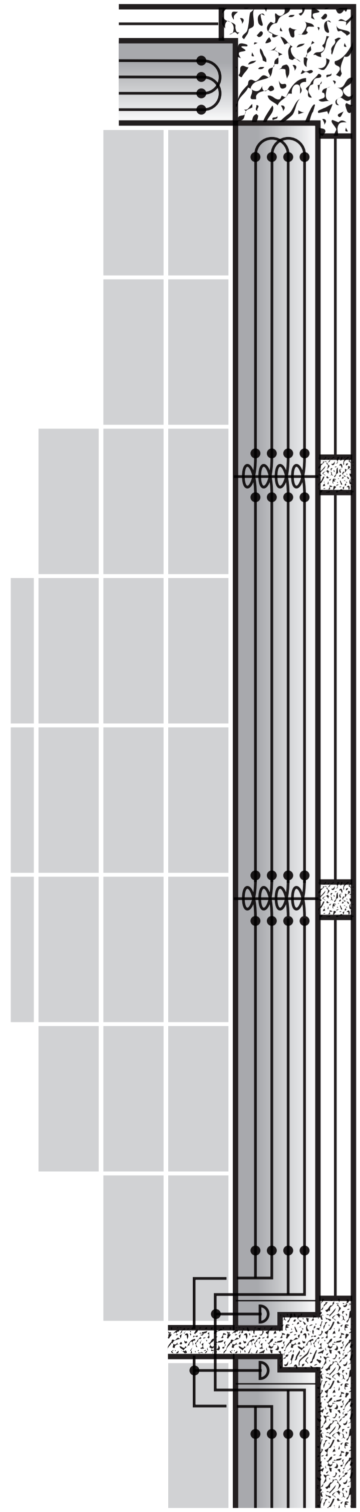
- Maximum single-panel length = 16'
- Refer to architectural details for typical sections



For odd number tubing passes, hook-up supply and return at opposite ends.



Parallel flow in even pass MetalWorks™ Airtite® panels reduces pressure drop for long zones.



Long zones fed from risers.

AR-X DESIGN PROCEDURE AND EXAMPLES

DESIGN PROCEDURE

The design of a radiant ceiling panel heating system should follow the usual guidelines of a closed water system. To design such a system, we need to find the following:

1. Calculate the heat loss per zone or room.
2. Determine the panel width.
3. Determine the panel layout and water flow.
4. Calculate the water pressure drop based upon piping arrangement.

DESIGN EXAMPLE: RECTANGULAR BUILDING

Given conditions:

- 100 ft. rectangular building
- 12 ft. floor-to-floor
- Inside design = 72°F Dry Bulb
- Supply Water Temp = 200°F
- Return Water Temp = 180°F
- Heat Loss for each floor = 170,000 BTUH
- Assume a 60 LF zone

Design A

1. Calculate the perimeter heat loss per lineal ft. and heat loss per zone.

$$\frac{\text{Total Load}}{\text{Floor Perimeter}} = \frac{170{,}000\ \text{BTUH}}{500\ \text{LF}} = 340\ \text{BTUH/LF}$$

$$\text{For 60 LF zone} = 340\ \text{BTUH/LF} \times 60\ \text{LF} = 20{,}400\ \text{BTUH}$$

2. Determine Panel Width.

From the performance tables, a 16"-wide 4-tube panel at 190°F MWT has an output of 343 BTUH/LF.

3. Determine panel layout and water flow.

Based on either room size or zone length, panel lengths range from 8 LF to 16 LF. Therefore, a 60-ft. zone (circuit) without perimeter walls would have five @ 12 LF panels.

$$\text{GPM} = \frac{\text{Total BTUH /zone}}{500 \times \text{water temp. drop °F}}$$

500 = 8.34 lbs/gal x 60 min/hr)

$$\text{GPM} = \frac{60\ \text{LF} \times 340\ \text{BTUH/LF}}{500 \times 20°\text{F}}$$

$$\text{GPM} = 2.04$$

4. Calculate the water pressure drop based upon piping arrangement.

For this example, a 16"-wide 4-tube panel would have two parallel circuits at 1.02 GPM/each. Calculate the total lineal foot of panel tubing.

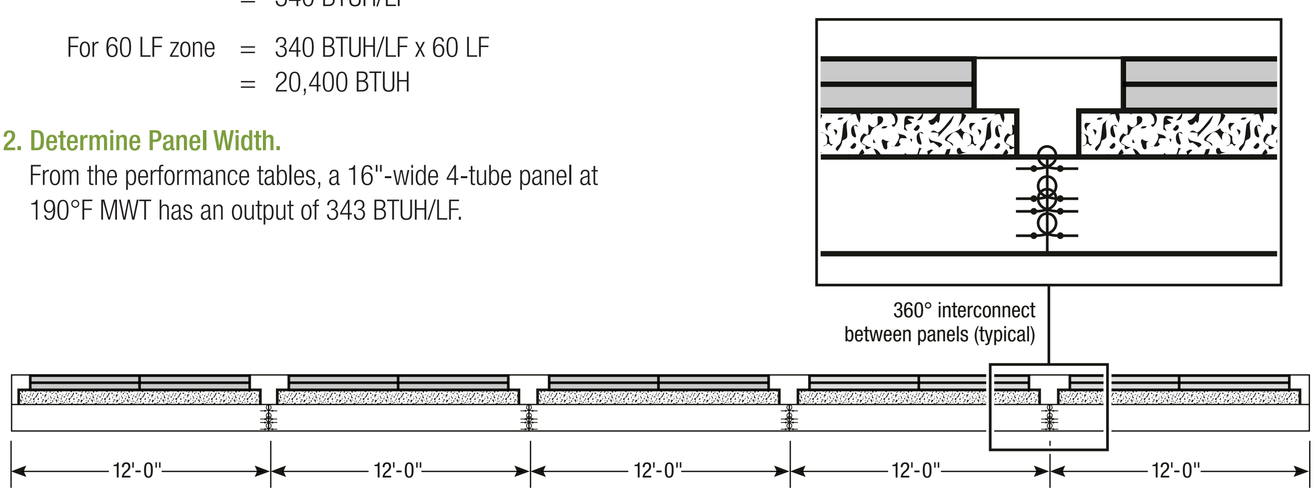
LF of tubing = 2 crts x 5 pnls x 12 LF/section length
= 120 LF of panel tube

Interconnects/crt = 2 x 4 = 8

Each interconnect is equal to 1.5 LF of tube. Therefore 8 interconnects = 12 LF
Total = 120 LF + 12 LF = 132 LF of tube.

Per the pressure drop table at 1.0 GPM shows 3.26 ft. of W.P.D per 100 ft. of tube. Total pressure drop for this circuit:

$$\frac{132 \times 3.26}{100} = 4.30\ \text{ft. of water}$$



60' LF Zone - 5 Panels @ 16" x 12'-0"

Design B

Using the same example, if panels were between columns and there were six columns in the zone at 10" each, the load per LF of panel would increase.

1. **Calculate the perimeter heat loss per lineal ft. and heat loss per zone.**
   60 LF x 340 BTUH/LF = 20,400 BTUH
   Available panel = 55 LF

   $\underline{\text{Heat loss/LF of panel}} = \frac{26{,}250 \text{ BTUH}}{55 \text{ LF}}$

   BTUH/LF = 371

2. **Determine Panel Width.**
   From the performance tables, an 18 in. wide 4-tube panel at 90°F MWT has an output of 378 BTUH/LF

3. **Determine panel layout and water flow.**
   This panel layout is as described below with the same GPM = 1.0 GPM

4. **Calculate the water pressure drop based upon piping arrangement.**

   LF of tubing
   = 2 x 11 LF/panel x 5 panel sections
   = 110 LF

   LF of 3/8 in. copper
   = 10 LF /col. x 4 cols.
   = 40 LF

Per the pressure drop table at 1.0 GPM shows 3.26 ft. of W.P.D per 100 ft. of tube.

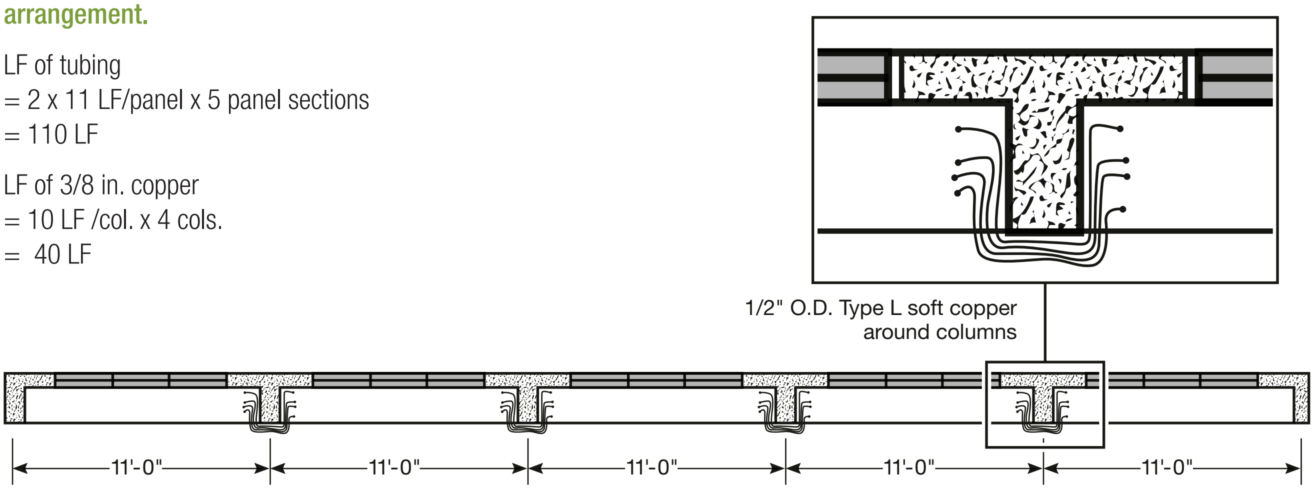
Pressure drop for panel tube on this circuit:

$\frac{110 \times 3.26}{100} = 3.59$ ft. of water

Per the pressure drop table for 3/8" L copper, at 1.0 GPM shows 7.07 ft. of W.P.D per 100 ft. of tube.

Pressure drop for 3/8 in. copper:
$\frac{40 \times 7.07}{100} = 2.82$ ft. of water

Total pressure drop = 3.59 + 2.82
= 6.41 ft. of water



60" LF Zone - 5 Panels @ 18" 4T x 11'-0"

▼ MetalWorks™ Airtite® AR-B architectural panels; Portland PDX Airport Headquarters, Portland, OR

▲ MetalWorks™ Airtite® AR-D radiant panels

AR-D panels are a product which consists of a linear air bar diffuser integrated into an extruded aluminum radiant panel.

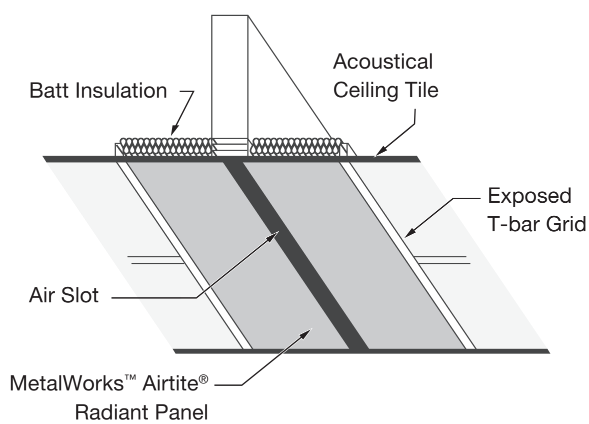
This combination of air diffuser and radiant panel makes for a narrower, more aesthetic assembly, utilizing the sides of the radiant panel for the vertical sides of the diffuser.

This unique assembly lends itself to longer, continuous extruded air bar/radiant panels, which in many cases extend wall-to-wall without joints. The combination increases the delivered air temperature and the heat output from the panel. There can be as much as a 35% increase in total heating capacity. The pattern controller can be located anywhere along the air slot with supply plenums installed directly above the diffuser section. Blank-offs are used where there is no diffuser giving a continuous slot appearance.

AR-D Integral Diffuser Panel

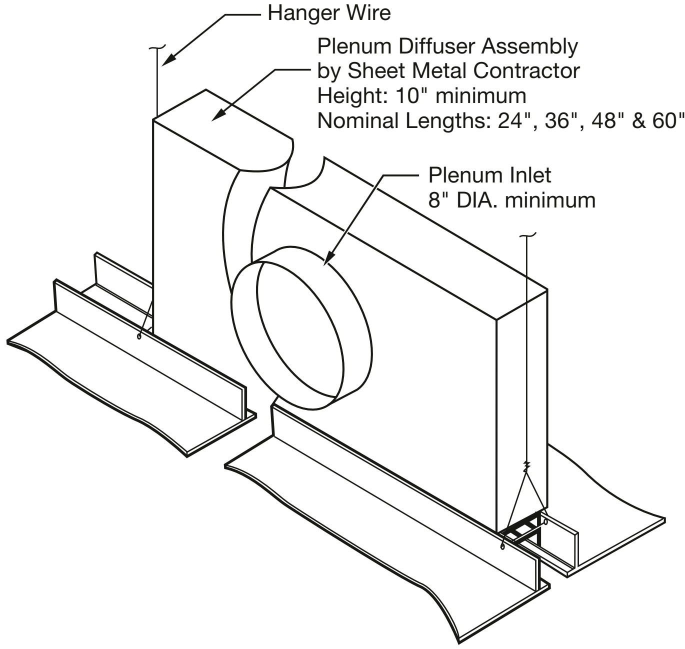
The integral air pattern controllers can be 12" to 60" long and will allow the airstream to be vectored for left, right, or vertical airflow distribution. As with other extruded radiant panels, the design is similar to AR-X systems, having the same piping advantages and flexibility. For radiant panel design, refer to the extruded design procedure outlined in the AR-X extruded panel section.

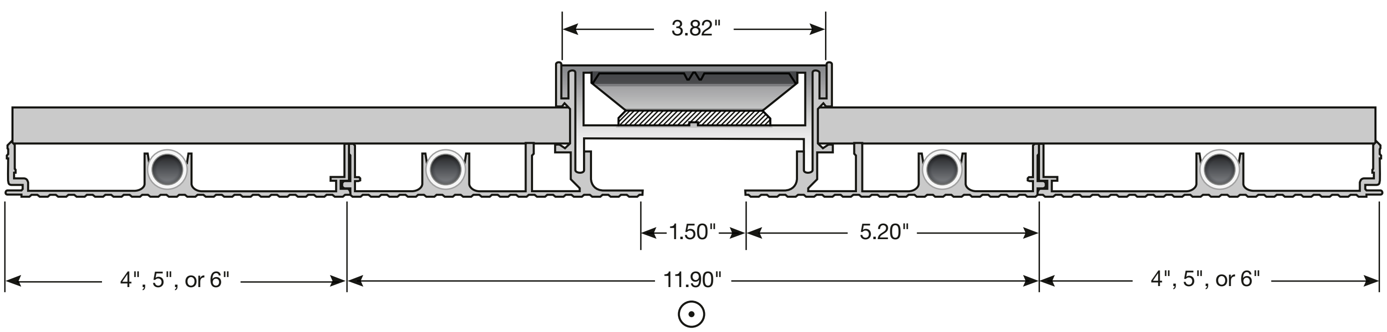
In conclusion, this combined product takes up less space, provides better comfort, and enhances the appearance of the ceiling. This combination diffuser panel can be provided and installed at lower costs than separate heating and linear air diffuser systems.



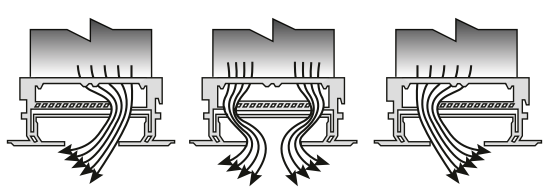
Typical installation

AR-D DIFFUSER PANEL
WITH CENTER SLOTTED AIR DIFFUSER



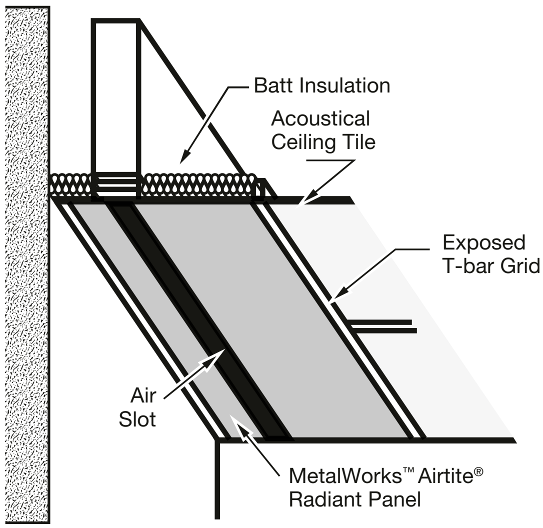


Standard finish is white.
Nominal sizes with centered diffuser: 12", 20", 22", 24"

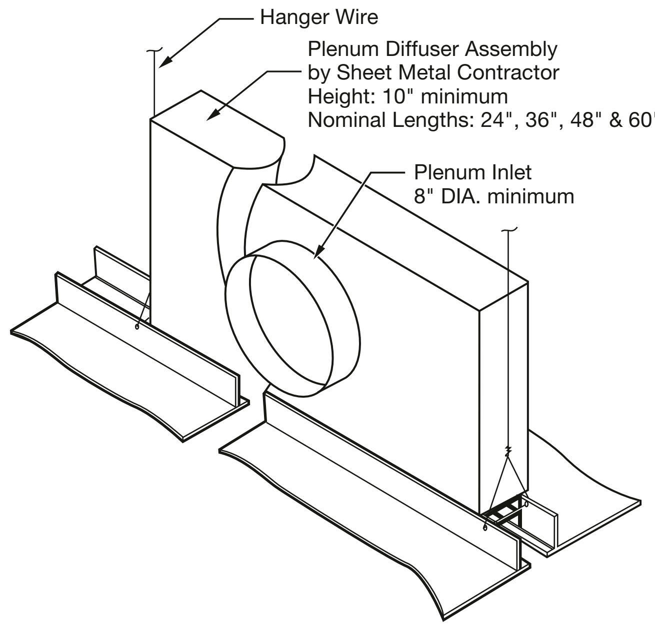


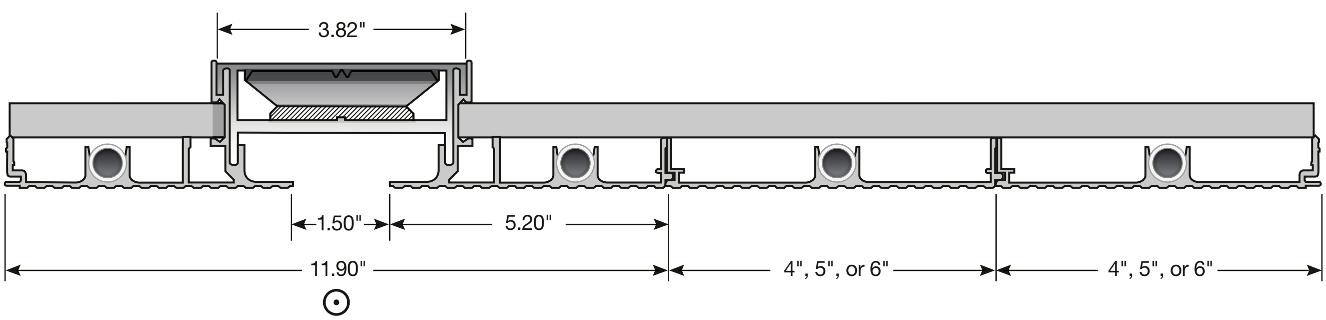
Integral pattern controllers are on 48" or 24" centers, which allow the air stream to be vectored left and right for horizontal and vertical air flow.

AR-D DIFFUSER PANEL
WITH OFFSET SLOTTED AIR DIFFUSER

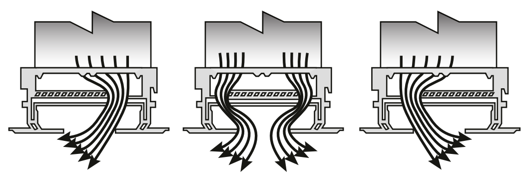


Typical installation





Standard finish is white.
Nominal sizes with off-center diffuser: 12", 16", 17", 18", 19", 20", 21", 22", 23", 24"



Integral pattern controllers are on 48" or 24" centers, which allow the air stream to be vectored left and right for horizontal and vertical air flow.

AR-D ENERGY EFFICIENCY:
PERIMETER HEATING OUTPUT (BTUH/LF)

Table performance values from certified curves. Total certified output shown is per lineal foot of panel at the perimeter of the space.

Output is based on 70°F air temperature; 67°F average unheated surface temperature (A.U.S.T) with one inch of 3/4" PCF unfaced fiberglass batt insulation on top of the panel, and natural convection. Actual output with minimum ventilation significantly increases panel output.

FOR OFFSET DIFFUSER PANEL WITH 1-1/2" SLOT WIDTH

	PANEL WIDTH					
MEAN WATER TEMPERATURE (°F)	HEF-A-12"	HEF-A-16"	HEF-A-18"	HEF-A-20"	HEF-A-22"	HEF-A-24"
120	77	116	118	124	136	148
125	90	132	137	144	158	173
130	103	148	156	163	180	197
135	117	164	175	185	202	220
140	130	181	194	208	227	246
145	143	197	213	231	252	270
150	156	214	232	252	273	295
155	169	231	251	275	298	320
160	182	248	270	298	320	343
165	196	265	290	320	343	367
170	210	282	309	342	367	392
175	223	299	328	364	390	416
180	236	316	348	387	413	440
185	249	333	367	412	438	465
190	262	350	386	435	462	489
195	276	367	407	457	485	514
200	289	384	428	480	508	538
205	302	401	449	502	532	562
210	315	419	470	525	556	587
215	329	437	491	548	580	611
220	332	455	512	570	602	635

For performance when air is being supplied through diffuser, use these multiplier values (delivered air temperature must be below room temperature):

- If air is delivered through 25% of total slot length, **multiplier is 1.20**
- If air is delivered through 50% of total slot length, **multiplier is 1.25**
- If air is delivered through 75% of total slot length, **multiplier is 1.30**
- If air is delivered through 100% of total slot length, **multiplier is 1.35**

AR-D PERFORMANCE DATA:
SINGLE SLOT DIFFUSER PANEL

Table performance values from certified curves. Total certified output shown is per lineal foot of panel at the perimeter of the space.

Output is based on 70°F air temperature; 67°F average unheated surface temperature (A.U.S.T) with one inch of 3/4" PCF unfaced fiberglass batt insulation on top of the panel, and natural convection. Actual output with minimum ventilation significantly increases panel output.

2 FT.	**AIRFLOW (CFM)**	40	70	100	130	160	190	220
	TOTAL PRESSURE (IN./H_20)	0.008	0.025	0.051	0.087	0.130	0.183	0.254
	STATIC PRESSURE (IN./H_20)	0.007	0.023	0.046	0.077	0.117	0.164	0.221
	NOISE*	<15	<15	18	25	30	33	36
	THROW**	3-7-13	3-8-16	4-11-17	5-14-18	6-16-21	7-19-24	8-21-26
4 FT.	**AIRFLOW (CFM)**	80	130	180	230	280	330	380
	TOTAL PRESSURE (IN./H_20)	0.01	0.028	0.053	0.086	0.128	0.176	0.235
	STATIC PRESSURE (IN./H_20)	0.008	0.019	0.030	0.058	0.085	0.120	0.160
	NOISE*	<15	<15	15	22	28	33	36
	THROW**	4-8-16	4-9-18	5-12-19	6-16-21	7-17-24	8-20-26	10-23-28
5 FT.	**AIRFLOW (CFM)**	90	150	210	270	330	390	450
	TOTAL PRESSURE (IN./H_20)	0.001	0.027	0.054	0.089	0.132	0.186	0.246
	STATIC PRESSURE (IN./H_20)	0.006	0.016	0.031	0.051	0.076	0.107	0.144
	NOISE*	<15	<15	16	23	34	34	37
	THROW**	4-19-17	5-10-18	6-14-20	7-17-23	8-18-25	9-22-27	11-24-29

* Noise criteria (NC) was obtained by subtracting 10 dB room effect from the sound power level data.
** Throw distances are given in feet and are for terminal velocities of 50, 100, and 150 FPM. The throw data values were obtained using isothermal air conditions.

AR-M
Modular Panel

AR-M MODULAR PANELS

MetalWorks™ Airtite® AR-M modular panels are 2' x 2' and 2' x 4' formed metal .040-inch aluminum panels. These highly efficient lightweight radiant panels have a 4-pass sinuous coil inserted in 3" extruded aluminum heat sinks providing 80% active panel area.

The panels are sized to fit into standard ceiling grids and can be supplied in standard white, silk screened to match acoustical ceiling, or block-perforated. All panels come with a standard 1-inch-thick sheet of insulation.

AR-B PERFORATED MODULAR PANELS

The AR-B panels are architectural perforated metal ceiling panels that can be designed for various suspension systems such as Torsion Spring, Lay-In, etc.

The panels can be provided in various sizes, metal, thicknesses and perforation patterns. Typical panels are fabricated with aluminum which provides the best heat transfer that results in the best radiant performance.

The AR-B panels are activated by bonding aluminum extrusions (heat transfer rails) incorporating integral sinuous copper coils to the back of the panels. Fleece can be installed between the extrusions for both appearance and noise reduction. With the fleece or other insulation (such as encapsulated fiberglass or recycled cotton), these architectural perforated panels can achieve high NRC values that exceed typical standard mineral tile ceilings. Flexible braided SST hoses with oxygen barrier and push fit fittings (ideal for installation and facilities personnel) are used to interconnect the panels and connect to the piping supply and return.

AR-M AND AR-B MODULAR PANELS

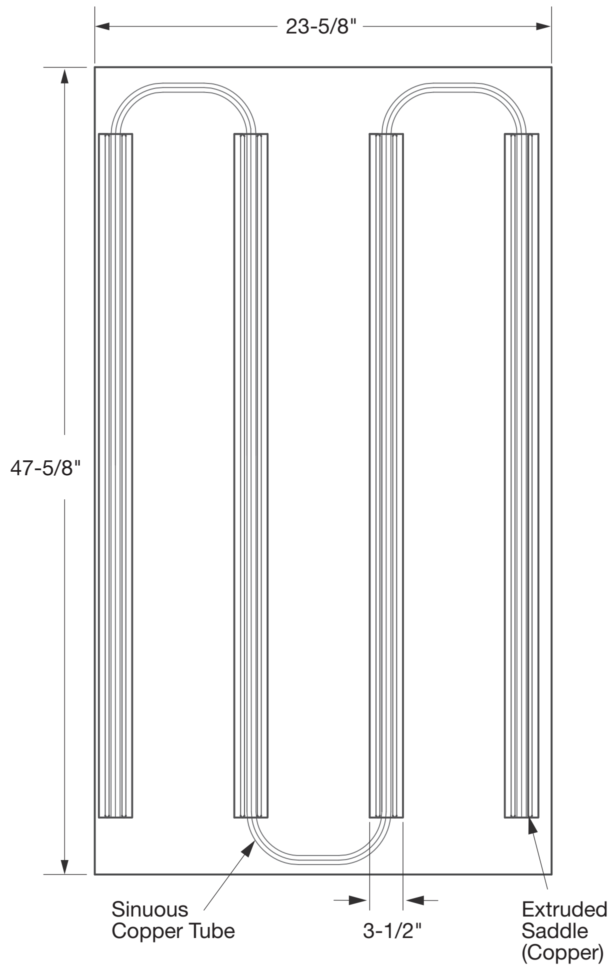
The panels can be installed in acoustical ceilings, recess-mounted in drywall or surface-mounted. In acoustic ceilings, the grid itself is able to support the panels which weigh less than 2 lbs. per square foot when filled with water without additional suspension. The panels are piped with 12 mm copper tubing. The use of longer interconnecting piping allows for the panels to be pushed up out of the grid and moved over to gain access to the plenum above.

The highly durable polyester powder coat paint finish is scratch-resistant and easily cleaned.

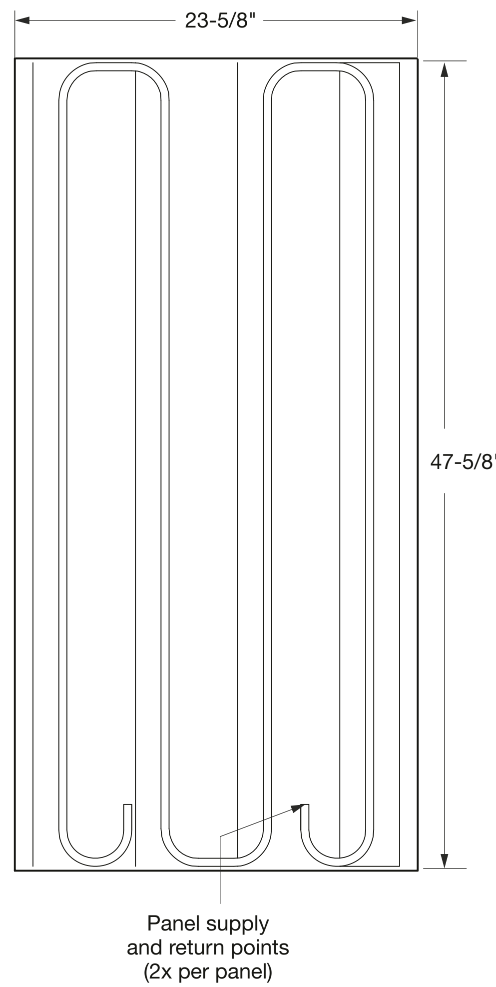
AR-B
Perforated Modular Panel

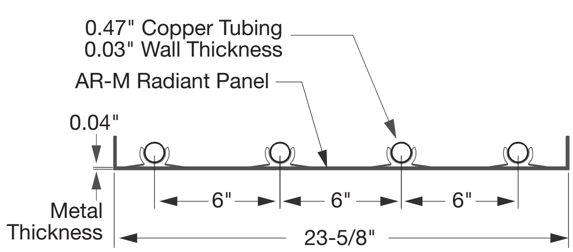
AR-M AND AR-B SCHEMATIC AND FINISHES

FOUR-PASS SINUOUS COIL ON BACK OF PANEL – AR-M MODULAR PANEL

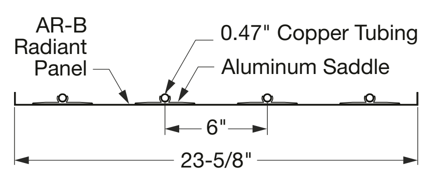


PANEL ACTIVATION DETAIL – AR-B MODULAR PANEL





AR-M Modular Panel Section View 6" O.C.



AR-B Modular Panel Cross-Sectional Detail

AR-B HEATING PERFORMANCE

Heating performance

AR-B panel performance based on 98% active surface area
Water flow rate at 1.47 GPM average

Water inlet temp, degrees F	104	111	94
Water outlet temp, degrees F	95	100	88
Floor surface temp, degrees F	75	75	75
Air temp, degrees F	72	72	72

Perimeter (exterior) condition considered for outside wall to 15' into room space
Emissivity of coating is at or greater than 0.93

MEAN WATER TEMPERATURE (DEGREES FAHRENHEIT)	PANEL SIZE AND LOCATION			
	PERIMETER 2' x 4'	INTERIOR 2' x 4'	PERIMETER 2' x 2'	INTERIOR 2' x 2'
110*	54.5	58.0	55.7	57.7
115*	64.5	63.7	65.2	63.6
120	75.0	70.0	75.0	70.0
125	86.3	76.9	86.3	77.0
130	97.5	84.4	97.5	84.5
135	108.8	91.3	108.8	91.3
140	120.0	98.8	120.0	96.3
145	131.3	106.3	131.3	106.3
150	142.5	113.1	142.5	113.3
155	153.8	120.0	153.8	120.0
160	165.0	128.1	165.0	128.3
165	176.3	135.6	176.3	135.8
170	187.5	142.5	187.5	142.5
175	198.8	150.0	198.8	150.0
180	210.0	158.1	210.0	158.3
185	221.3	165.0	221.3	165.0
190	231.3	171.9	232.5	172.0
195	243.8	180.0	243.8	180.0
200	255.0	186.9	255.0	187.0
205	266.3	195.0	266.3	195.0
210	277.5	201.9	277.5	202.0
215	288.8	–	288.8	–
220	300.0	–	300.0	–

* Results extrapolated from actual test data.
Performance shown in BTUH/SF.

AR-B COOLING PERFORMANCE:

Cooling performance for modular panels

AR-B panel performance based on 98% active surface area
Water flow rate at 0.75 GPM average

Water inlet temp, degrees F	62.4	58.8	67.8
Water outlet temp, degrees F	66.2	63.5	69.3
Floor surface temp, degrees F	79.0	79.0	79.0
Air temp, degrees F	79.3	79.3	79.3

Perimeter (exterior) condition considered for outside wall to 15' into room space
Emissivity of coating is at or greater than 0.93

ROOM CONDITIONS AND PERCENT GLASS

ROOM AIR TEMPERATURE (MINUS MWT °F)	INTERIOR ROOM	NO GLASS IN SUN OR FULLY SHADED GLASS & WALL	25% CLEAR EXTERIOR WALL IN SUN	50% CLEAR EXTERIOR WALL IN SUN	75% CLEAR EXTERIOR WALL IN SUN	100% CLEAR EXTERIOR WALL IN SUN
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

Performance shown in BTUH/SF.

AR-M HEATING PERFORMANCE

Heating performance

AR-M panel performance based on 88% active surface area
Water flow rate at 1 GPM average

Water inlet temp, degrees F	195.3	165.0	135.0
Water outlet temp, degrees F	186.0	156.0	125.4
Floor surface temp, degrees F	75.0	75.0	75.0
Air temp, degrees F	71.0	71.0	71.0

Perimeter (exterior) condition considered for outside wall to 15' into room space
Emissivity of coating is at or greater than 0.93

MEAN WATER TEMPERATURE (DEGREES FAHRENHEIT)	PANEL SIZE AND LOCATION			
	PERIMETER 2' x 4'	INTERIOR 2' x 4'	PERIMETER 2' x 2'	INTERIOR 2' x 2'
110*	49	52	50	52
115*	58	57	59	57
120	68	63	68	63
125	78	69	78	69
130	88	76	88	76
135	98	82	98	82
140	108	89	108	87
145	118	96	118	96
150	128	102	128	102
155	138	108	138	108
160	149	115	149	115
165	159	122	159	122
170	169	128	169	128
175	179	135	179	135
180	189	142	189	142
185	199	149	199	149
190	208	155	209	155
195	219	162	219	162
200	230	168	230	168
205	240	176	240	176
210	250	182	250	182
215	260	–	260	–
220	270	–	270	–

* Results extrapolated from actual test data.
Performance shown in BTUH/SF.

AR-M COOLING PERFORMANCE:

Cooling performance for modular panels

AR-M panel performance based on 88% active surface area

Water inlet temp, degrees F	62.4	58.8
Water outlet temp, degrees F	66.2	63.5
Floor surface temp, degrees F	79.0	79.0
Air temp, degrees F	79.3	79.3

Perimeter (exterior) condition considered for outside wall to 15' into room space
Emissivity of coating is at or greater than 0.93

ROOM CONDITIONS AND PERCENT GLASS

ROOM AIR TEMPERATURE (MINUS MWT °F)	INTERIOR ROOM	NO GLASS IN SUN OR FULLY SHADED GLASS & WALL	25% CLEAR EXTERIOR WALL IN SUN	50% CLEAR EXTERIOR WALL IN SUN	75% CLEAR EXTERIOR WALL IN SUN	100% CLEAR EXTERIOR WALL IN SUN
10	15	19	25	32	34	36
11	17	21	27	33	36	38
12	19	23	28	34	37	39
13	20	24	30	36	39	41
14	22	25	32	38	41	42
15	23	27	34	40	42	43
16	25	29	35	41	43	45
17	27	31	37	42	45	47
18	28	32	39	44	47	48
19	30	34	41	45	49	50
20	32	36	41	47	50	51
21	37	42	48	54	57	58

Performance shown in BTUH/SF.

PRESSURE DROP TABLE

Pressure Drop

Both panels and connecting tubing pressure drops must be included in the circuit pressure drop calculation.

Flow rated below .5 GPM are not recommended.

WATER PRESSURE DROP

(SHOWN IN FT/PANEL EXCEPT FOR CONNECTING TUBE)

	PANEL TUBING		PANEL CONNECTION TUBING
GPM PER CIRCUIT	**2' x 4'**	**2' x 4'**	**3/8" TYPE LF/100FT.**
.2	.04	.02	.36
.3	.09	.05	.76
.4	.15	.08	1.30
.5	.23	.12	1.96
.6	.32	.17	2.75
.7	.42	.22	3.62
.8	.54	.28	4.68
.9	.67	.35	5.81
1.0	.82	.42	7.07
1.1	.82	.42	8.43
1.2	1.14	.59	9.90
1.3	1.33	.69	11.48
1.4	1.52	.79	13.17
1.5	1.73	.90	14.96

AR-B AND AR-M PANEL DESIGN

COOLING 2290 BTUH 72 SF 1.3 GPM
HEATING 8841 BTUH @ 150 MWT 1.0 GPM
MAX λP @ TWO CIRCUITS 0.65 GPM/CRT

At 0.65 GPM, pressure drop per modular panel is 0.37 ft. of water.

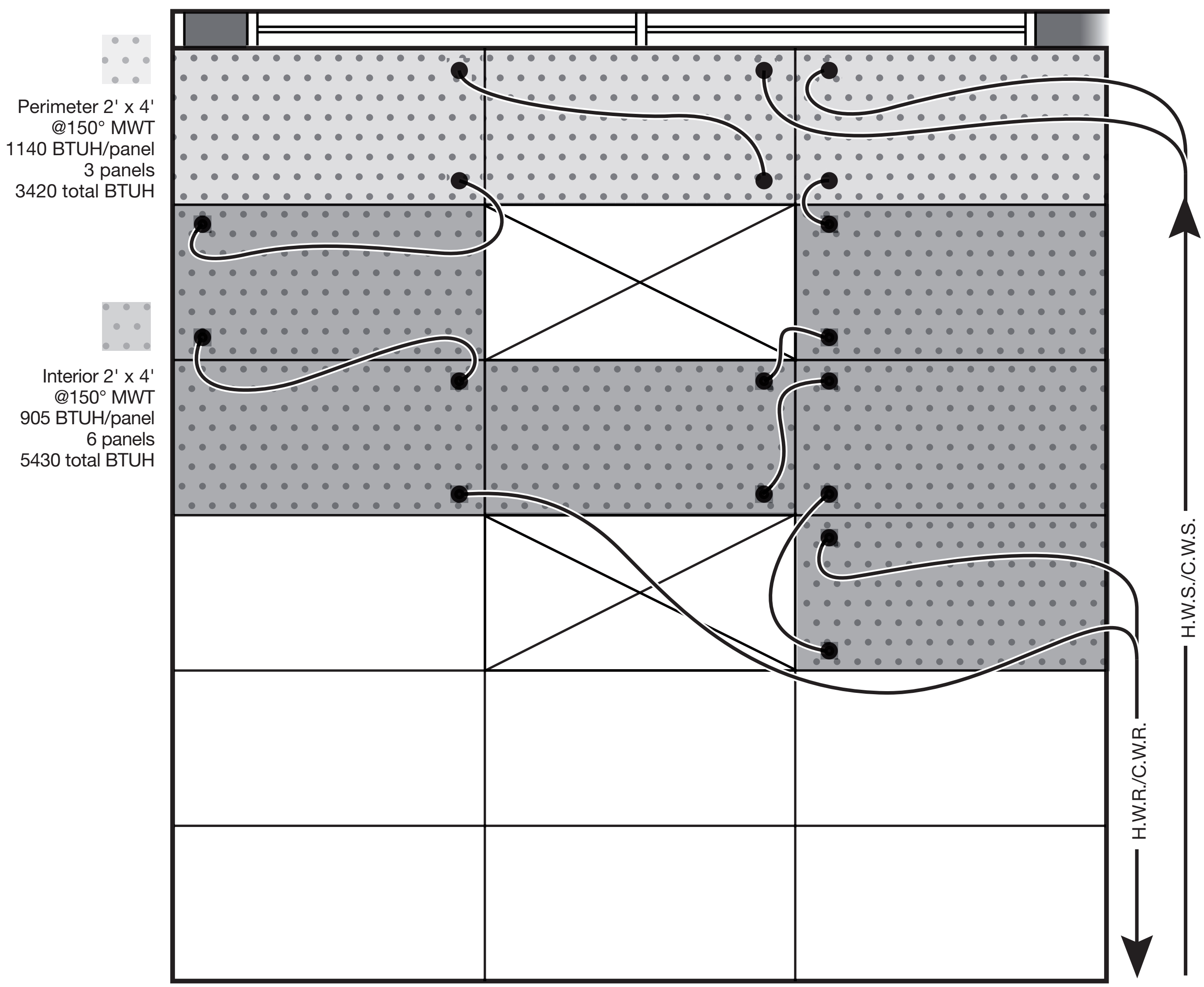
At 0.65 GPM, 3/8" L CU is 3.2 ft. of water/100' CU

λP = 5 panels: 5 @ 0.37 GPM/panel + 22' -3/8" L CU x 3.2 ft. of water/100' CU = 2.55 ft. of water

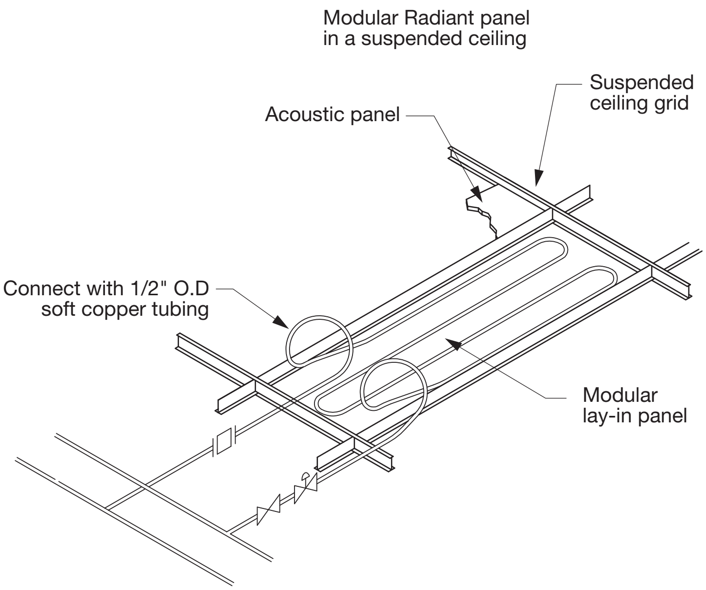
1.85 ft. of water + 7.04 ft .of water = 2.55 ft. of water

λP = 4 panels: 4 @ 0.37 GPM/panel + 35' -3/8" L CU x 3.2 ft. of water/100' CU = 2.66 ft. of water

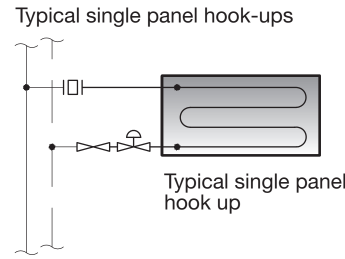
1.48 ft. of water + 1.12 ft. of water = 2.6 ft. of water



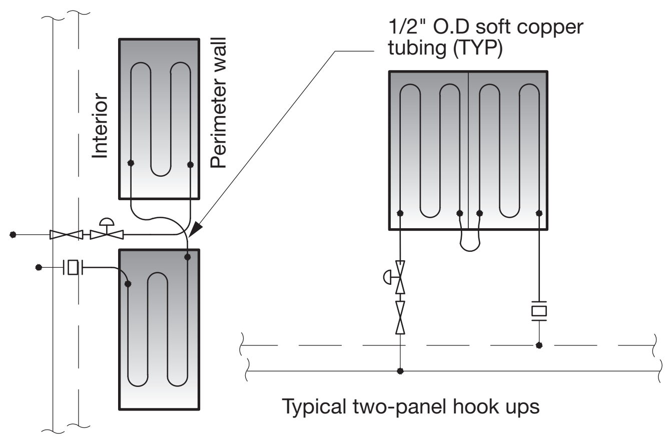
AR-B AND AR-M TYPICAL PANEL LAYOUTS



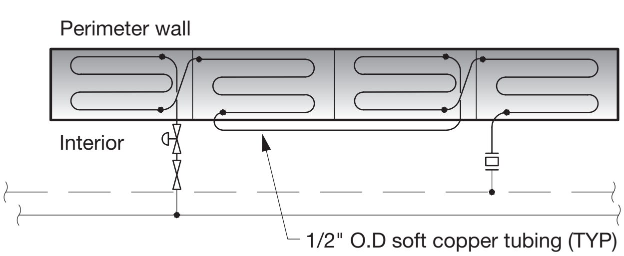
Typical single panel hook-up

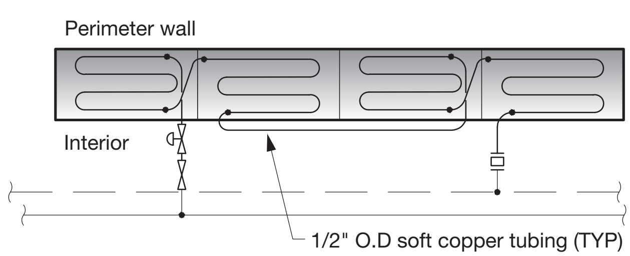


Typical two panel hook-ups



Typical multiple panel hook-ups





AR-B AND AR-M DESIGN PROCEDURE AND EXAMPLE

DESIGN PROCEDURE

The design of a radiant ceiling panel heating system should follow the usual guidelines of a closed water system. To design such a system, we need to find the following:

1. Calculate the heat loss per zone or room
2. Determine the number of 2' x 2' or 2' x 4' modular panels
3. Determine the panel layout and water flow
4. Calculate the water pressure drop based upon panel layout and piping arrangement

DESIGN EXAMPLE: RECTANGULAR BUILDING

Given conditions:

- 100 ft. x 150 ft. floor plan
- 12 ft. floor-to-floor
- Inside design = 72°F Dry Bulb
- Supply Water Temp = 180°F
- Return Water Temp = 160°F
- Heat loss for each floor = 175,000 BTUH

1. Calculate the heat loss per zone per lineal foot of perimeter, and per zone.

$$\text{Heat loss/LF of perimeter} = \frac{175{,}000 \text{ BTUH}}{500 \text{ LF}} = 350 \text{ BTUH/LF}$$

$$\text{50 LF zone heat loss} = 50 \text{ LF} \times 350 \text{ BTUH/LF} = 17{,}500 \text{ BTUH}$$

2. Determine the number of panels.

The ceiling has a 2' x 4' grid layout. The perimeter performance of a 2' x 4' modular panel at 170°F mean water temperature = 1500 BTUH per panel.

3. Determine panel layout and water flow.

Based on either room size or zone size, determine modular arrangement. Therefore, a 50-ft. zone (circuit) without perimeter walls would have 12 – 2' x 4' modular panels in series.

$$\text{Total GPM} = \frac{\text{Total BTUH/zone}}{500 \times \text{water temp. drop °F}}$$

500 =
8.34 lbs/gal x 60 min/hr)

$$\text{GPM} = \frac{17{,}500 \text{ BTUH}}{500 \times 20°\text{F}} = 1.75 \text{ GPM}$$

This zone will be divided up into two circuits of six – 2' x 4' modular panels.

4. Calculate the water pressure drop based upon piping arrangement.

Each circuit of six – 2' x 4' modular panels would have a flow of .9 GPM per the pressure drop table.

Per the pressure drop table, at .9 GPM shows .67 ft. of W.P.D. per panel.
Pressure drop for the panels on this circuit:

6 x .67 = 4.02 ft. of water

Per the pressure drop table, for 3/8" L copper at .9 GPM shows 5.81 of WPD per 100 ft. of tube.

Per example below, there will be 45 LF of 3/8" L copper:

$$\frac{45 \times 5.81}{100} = 2.61 \text{ ft. of water}$$

$$\text{Total pressure drop} = 4.02 + 2.61 = 6.34 \text{ ft. of water}$$

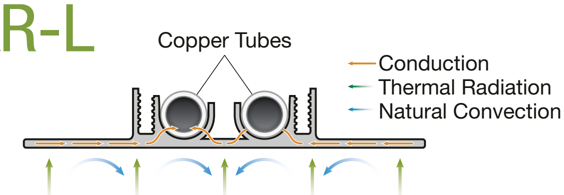
AR-L & AR-C Radiant and Convection Panels

AR-L – LINEAR PROFILE
AR-C – CURVED PROFILE

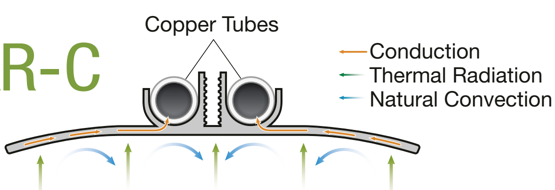
The AR-L and AR-C are high-capacity radiant-cooling linear systems based on the principles of radiant technology. By separating the linear radiant elements with a gap, the AR-L and AR-C couples the radiant cooling effects of standard radiant panels with a convective component. Chilled AR-L and AR-C ceilings create natural convection by cooling the surrounding air as it passes over the surface facing the plenum.

As the denser air falls into the occupied zone, warmer air is pulled over the element, incorporating convective cooling capacity of the AR-L and AR-C with the radiant capacity of the cool surface (see below). The approximate breakdown of heat transfer of the chilled radiant system is 30% by thermal radiation and 70% by natural convection.

AR-L



AR-C



When used for heating, the AR-L and AR-C transfers heat mainly through thermal radiation with room surfaces, where it increases the average unheated surface temperature of the room. As warmer air rises past the heated sails, natural convection occurs, which results in warmer return air.

ENERGY EFFICIENCY

The specific heat capacity of water is four times higher than air. This means that the energy 1-cubic-foot of water can remove requires an equivalent of 3,480-cubic-feet of air (due to the density of water versus air). Therefore, to remove a given amount of heat from a building, less than 25% of the transport energy is required to remove the same amount of heat compared to an all-air system. Because AR-L and AR-C are water-only systems, they can handle the sensible portion of a building load and must be paired with a fresh air system for ventilation and latent load removal.

MODELS

The AR-L and AR-C profiles cover both a flat and a concave face as shown at left. The surface profile is dependent on the application, the need for excellent aesthetics, and broad design flexibility. Contact us for more information on which profile to use for your application.

AR-L and AR-C are designed to allow air movement through openings between the slats, increasing the capacity of the unit and providing an effective means of dealing with sensible cooling loads. AR-L and AR-C can be installed in a variety of applications including full or cloud ceiling areas.

The visible surfaces of the aluminum extrusion and bracing are usually painted white. Optional custom colors are available which meet the emissivity requirements.

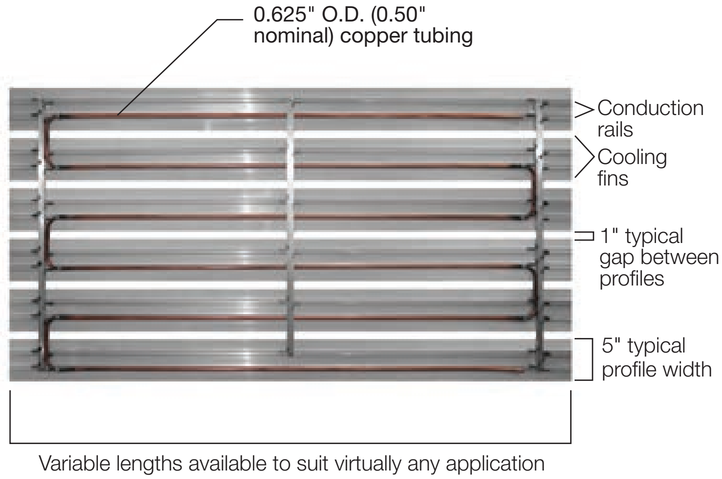
TYPICAL DESIGN

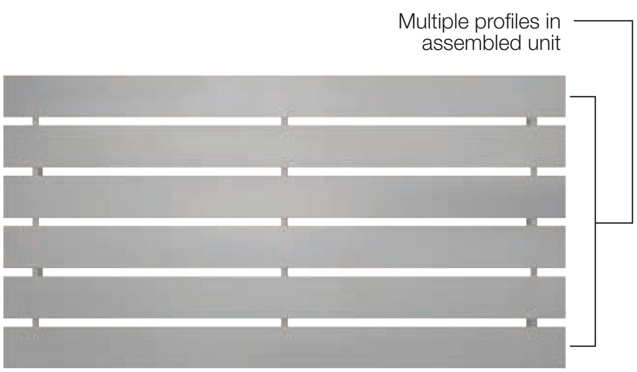
The precision extruded aluminum profiles are optimally formed with one or two conduction rails to accommodate copper tube and provide cooling fins which are rounded off at the outer end. The extruded profiles are 5" wide with a typical length of 160" long.

The gap between the extruded profiles is typically 1.0 inches with up to 8 profiles wide per assembled unit. The copper tube is press-fit into the conducting rails of the extrusion, ensuring continuous contact between the copper and the aluminum along the entire length and providing optimal heat transfer. Copper tubing with a 0.625" O.D. (1/2" nominal) is used in the fabrication of the system.

The connections between the modules and the distribution lines can be made via copper tubing and/or flexible metal hoses with stainless steel sheathing. After installation, the entire system must be checked for leaks. The cold water inflow temperature should be selected so that this never falls below the dew point, which would create condensation. It is recommended that a dew point sensor be incorporated in the overall design of the system to adjust the water temperature.

Special design options such as folding modules, sprinklers, lighting openings, air intake, etc. are available.





ACCESS PANEL DESIGN

Panels can be designed into the AR-L and AR-C modules to allow access to the plenum area. The access panels are designed with torsion springs allowing the panel to be pulled straight down without any special tools and swung out of the way. Access panels can have the same radiant heating and cooling capacity as a fixed panel, or be a non-active panel and can be placed within the ceiling system, where needed.

AR-L AND AR-C HEATING PERFORMANCE CHART

Testing conducted to Test Specifications EN 14037-5

Testing is considered an interior application, increased performance will be achieved if condition is considered an exterior application.
Test results are based on active area
Flow Rate at 1.365 GPM
Installation area 80.29 SF
Active area 68.33 SF (85% active area ratio)
Two sails connected in a series

Water inlet temp, degrees F	107.9	88.9	127.5
Water outlet temp, degrees F	101.0	85.5	116.6
Interior Surface Temp, degrees F	64.6	66.2	63.0
Surface Temp at Floor, degrees F	64.6	66.2	63.0
Air temp at 5.6', degrees F	68.4	68.4	68.2

SPECIFIC HEATING CAPACITY IN BTUH/SF	DELTA T °F
26.0	15.0
28.0	16.0
30.0	17.0
32.0	18.0
34.0	19.0
36.0	20.0
40.0	22.0
45.0	24.7
50.0	27.3
55.0	29.6
60.0	32.0
65.0	34.0
70.0	36.0
80.0	41.0
85.0	43.0
90.0	46.0
95.0	48.0
100.0	50.0
110.0	56.0
120.0	59.0
130.0	62.0
140.0	69.0

AR-L AND AR-C COOLING PERFORMANCE CHART

Testng conducted to Test Specifications EN 14240

Testing is considered an interior application, increased performance will be achieved if condition is considered an exterior application.
Test results are based on active area
Flow Rate at 1.541 GPM
Installation area 80.29 SF
Active area 68.33 SF (85% active area ratio)
Two sails connected in a series

Water inlet temp, degrees F	62.3	66.5	58.6
Water outlet temp, degrees F	66.0	69.4	63.2
Interior Surface Temp, degrees F	78.5	78.5	78.4
Surface Temp at Floor, degrees F	78.5	78.4	78.3
Air temp at 5.6', degrees F	78.9	79.3	79.0

SPECIFIC COOLING CAPACITY IN BTUH/SF	DELTA T °F
25.0	9.3
26.0	9.6
27.0	9.8
28.0	10.2
29.0	10.5
30.0	10.8
31.0	11.2
32.0	11.5
33.0	11.8
34.0	12.2
35.0	12.5
36.0	12.8
37.0	13.2
38.0	13.4
39.0	13.8
40.0	14.1
41.0	14.2
42.0	14.6
44.0	15.5
46.0	16.1
48.0	16.9
50.0	17.5
52.0	18.0
54.0	18.8
56.0	19.1
58.0	20.0

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