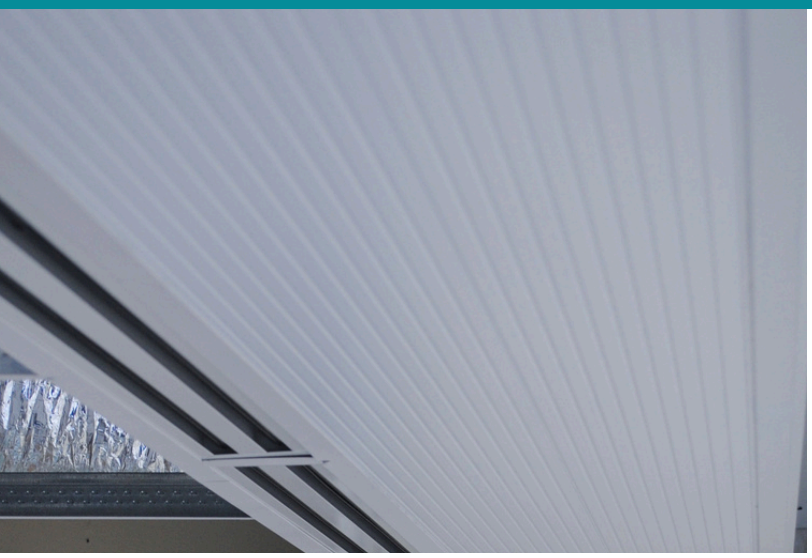
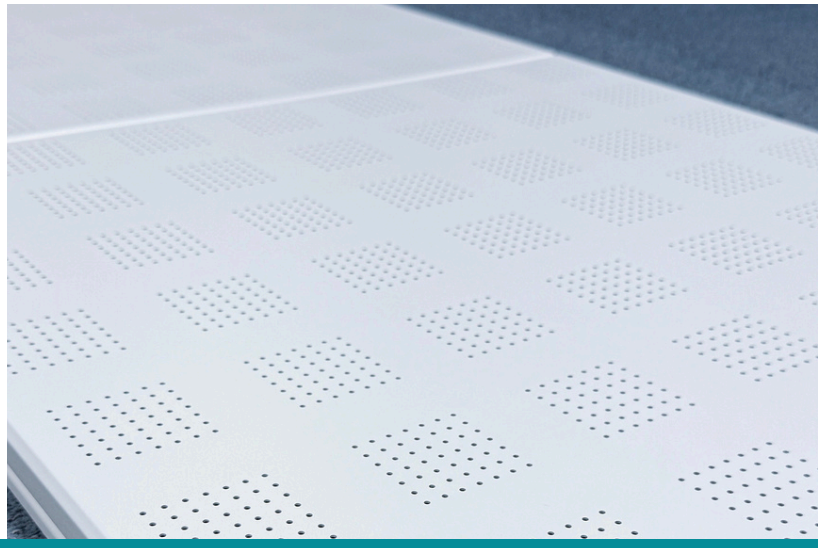
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RADIANT PANEL ENGINEERING MANUAL

INSTALLATION | OPERATION | MAINTENANCE | PERFORMANCE

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Radiant Panel Engineering Manual

THE COMPANY

Aero Tech Manufacturing Inc. is a leading producer of Radiant Ceiling Panels and systems. With headquarters in metropolitan Salt Lake City, Aero Tech's 70,000 square foot facility is located just minutes away from major airport and transportation centers.

Our company and personnel are members of numerous professional organizations including the American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE), Ceilings and Interiors Systems Contractors Association (CISCA) and several technical committees.

PRODUCTS

Aero Tech manufactures ceiling systems. Our ceiling product lines include radiant, security and hybrid ceiling systems. Additionally, we have expertise in, and are developing, precision sheet metal product lines.

PHILOSOPHY

Aero Tech is a service-oriented manufacturer of radiant panels and a precision sheet metal fabricator. We believe in providing extensive technical support to ensure successful and proper installation of our products.

We offer the services of our highly trained engineers and technically oriented representative organizations. In conjunction with Aero Tech, our representatives provide assistance to engineers and contractors from the application and design considerations of radiant ceiling panels through contract execution, start-up and change over procedures.

Our engineers are available for consultation regarding special situations that may not be covered by standard performance ratings or projects that require special sized panels.

Aero Tech's hydronic radiant ceiling panels are supplied on a materials-only basis, with installation performed by the customer's contractor.

BACKGROUND

Aero Tech Manufacturing Inc. was founded in 1967. At that time our business was exclusively precision sheet metal fabrication primarily for the computer industry where tolerances were very tight and paint finishes and cosmetics were class A. We continue in this business for companies such as GE, Oshkosh, Ovivo, FL Smidth, and many others that require precision sheet metal fabrication. We are currently one of the largest and most highly regarded fabricators in the intermountain region.

In 1977, Aero Tech was acquired by Toromont Industries. The following year, the company relocated to a new 70,000-square-foot facility in North Salt Lake, Utah.

In 1982, Aero Tech conceived and implemented manufacturing methods for

radiant panels which were unique and superior to products then on the market. Although the initial cost of research, development and tooling of this method was substantial, it has resulted in Aero Tech's ability to produce superior and more cost-effective products.

In 2008, Aero Tech's management team purchased the business from Toromont, establishing the company as an employee-owned business.

Today, Aero Tech is the largest manufacturer of radiant panels in the United States. Over the years, Aero Tech has manufactured more than a million square feet of ceiling panels. Installations include hospitals, laboratories, aircraft hangars, schools, athletic facilities and office buildings.

Advantages of Aero Tech Metal Ceilings

VARIATIONS

Panels are available in a variety of materials, patterns and sizes resulting in ceilings of superior beauty and compatibility with architectural style.

PERMANENCE

The use of metal ceiling panels ensures permanent ceilings which last for the life of the building.

REDUCED MAINTENANCE

A simple, occasional cleaning will maintain the original beauty of Aero Tech's ceilings. Metal panels are less susceptible to damage than other ceiling materials.

SOUND CONTROL

Aero Tech's formed metal perforated ceiling panels offer excellent sound control when backed with acoustical pads.

COLOR RETENTION

Using baked on finishes provide permanent color and finish.

INCOMBUSTIBILITY

The use of aluminum ensures that ceiling panels are non-combustible.

Benefits of Aero Tech Radiant Ceiling Panels

Aero Tech Radiant Ceiling Panel Systems combine controlled room surfaces with central air conditioning.

Some of the benefits of Aero Tech Radiant Ceiling Panel Systems are:

- Effective life cycle costing is due to reduced maintenance costs and energy requirements when compared with other systems.
- Improved comfort when compared with other air conditioning systems because radiant loads are treated directly and air motion is reduced to ventilation requirement levels.
- Wall, floor and structural systems are simplified because mechanical equipment is not required at the outside walls.
- There is no mechanical equipment requiring maintenance or repair located within the occupied space.
- No space is required within the conditioned room for mechanical equipment. This is of particular value for applications in existing buildings, hospital patient rooms and where space is at a premium or maximum cleanliness is essential.
- Centrally located equipment simplifies and reduces maintenance and operation costs.
- Central zoning and seasonal changeover are not required. Simultaneous heating and cooling may be obtained when three and four pipe systems are utilized.
- Air quantities are minimized and usually do not exceed those required for ventilation and dehumidification, thus minimizing costs for duct work, fans and filters.
- Unified panel concept allows flexibility to meet changes in partitioning.
- Due to reduced air quantities, a 100% outdoor air system may be installed with minimum cooling and heating load.
- Both interior and exterior zones can be served by a common central air system.
- The system operates quietly because there is no mechanical equipment in the conditioned space and air flow requirements are minimal.
- Total system energy requirements are lower due to minimum air quantities, the inherent ability of radiant panels to provide a higher degree of human comfort at reduced (winter) and increased (summer) room air temperatures and the higher (summer) and lower (winter) supply water temperature required.
- Wet surface cooling coils are eliminated from the occupied space reducing the potential for septic contamination.

Basic Concepts of Radiant Ceiling Systems

Heat transfer by radiation occurs in the form of wave motion similar to light waves, wherein energy is transmitted from warmer bodies to cooler bodies without the need for intervening matter.

If the temperature of a body is above or below that of its surroundings, it radiates or absorbs heat. When no temperature difference exists, the energy exchange is in equilibrium and the body neither gains nor loses energy.

All of us have experienced the pleasant effect of radiant heat from the sun on a cool but sunny day.

If a cloud passes over the sun, there is an instantaneous sensation of cold even though the surrounding air temperature does not change. This phenomenon verifies that comfort can be achieved independently of air temperature. Aero Tech Heating and Cooling Radiant Ceiling Systems function on the basis of providing a comfortable environment by controlling surface temperature and minimizing excess air motion and temperature within the conditioned space.

Several types of radiant systems have been used over the years, however, most of them utilized pipe coils or electric heaters embedded in masonry floors or plaster ceilings. This type of construction produces massive radiant surfaces resulting in slow response, lag and override effect which made the systems virtually unresponsive to load changes.

Aero Tech's lightweight metal panel ceiling systems provide quick response to load changes and can be used for heating and cooling.

The ceiling of the conditioned space is the most logical location for radiant panels because:

- It is not subject to unpredictable coverings as are floors or walls.
- Since radiant energy travels in straight lines, like light waves, the panels should "see" all surfaces and objects in room. Only the ceiling location fulfills this requirement.
- Higher surface temperatures can be used and the ceiling, when utilizing Aero Tech metal panels, is a relatively small mass and therefore quick to respond to load changes.
- The piping and control valve for this system is easily accessible for service.

When the surface temperature of the outside walls, particularly those with large amounts of glass, begins to deviate excessively from the ambient air temperature of the space, it becomes increasingly difficult for connective systems to counteract the discomfort resulting from body radiation to or from hot or cold walls. Radiant heating and cooling panels neutralize these deficiencies and minimize excessive radiation gains or losses from the body.

Most building surfaces have high emissivity and therefore absorb and radiate energy from radiant ceiling panels. This is significant because all surfaces within the room tend to assume an equal temperature resulting in even thermal comfort within the space. In much the same way that light energy from a lighting fixture illuminates the room so that all surfaces can be seen, a radiant ceiling panel emits thermal energy which is absorbed and radiated by all elements in the room.

Studies have shown that, in winter conditions, the use of warm radiant ceiling panels will result in surface temperatures of well-constructed and properly insulated floors at two to three °F above the ambient air temperature and the inside surface temperature of walls and glass are increased significantly. As a result, down drafts are minimized to the point where no discomfort is felt.

Aero Tech Ceiling Systems Applications

The possibilities for using Aero Tech Radiant Ceiling Systems for heating, cooling or healing and cooling applications are numerous. Some of the more popular applications are presented here.

HOSPITALS

Hospitals have been the most frequent users of radiant ceiling panel systems for heating and cooling patient rooms because these systems:

- Require no mechanical equipment or other operational systems that can collect bacteria and viruses in the conditioned space.
- Provide a draft free, thermal stable environment.
- Do not take up any space in the room.

Individual room control is obtained by throttling the water flow through the panels. The air supply is often 100% outdoor air with minimwn air quantities delivered to the room for ventilation and exhaust of the toilet and soiled linen closet. Piping configurations are determined by panel width and may include single or multiple passes, as required. Water control valves are located in the corridor outside patient rooms so they are available for adjustment or service without entering the room.

OFFICE BUILDINGS

Radiant ceiling panels are applied for heating or as a total heating and cooling system. A single zone central air supply system provides ventilation, dehumidification and any additional cooling required. Panel systems readily accommodate changes in partitioning. Installations can be made wherein complete flexibility is accomplished on a modular basis.

SCHOOLS

Ceiling panel systems are similar to those for office buildings. In classroom areas, ceiling panel systems offer the additional advantage of eliminating noise from mechanical equipment which may interfere with instructional activities. For heating applications, a radiant ceiling panel system may be used with any type of ventilation system.

If the school is cooled with a central air system and uses panels for perimeter heating, a single zone piping system may be used to control panel heat output. The room thermostat can modulate air temperature or volume delivered to the room.

Radiant heating and/or cooling ceiling systems are also well suited to building, housing, swimming pools, industrial applications, airport terminals, convention halls, museums and lobbies. Because radiant energy travels through the air without heating it, ceilings may be installed at any height and remain effective by selection of the proper panel temperature.

General Design Considerations for Aero Tech Radiant Ceiling Panel Systems

The application, design and installation of Aero Tech Radiant Ceiling Panel Systems have certain requirements and techniques that should be recognized:

- As with any hydronic system, close attention should be paid to the piping system design. Piping should be designed to assure that water of the proper temperature and in sufficient quantity will be available to every grid or coil at all times.
- The cooling coils and air distribution should be carefully designed to ensure proper performance. Most problems occur when air equipment is not capable of delivering air quantities at the specified rates.
- Individual ceiling panel coils may be connected for parallel flow using headers or for series flow.
- Attention must be given to avoid noise from entrained air, high-velocity or high-pressure-drop devices or from pump or pipe vibrations. Water velocities should be high enough to prevent air from accumulating and causing air binding. Air venting devices should be manual rather than automatic and, where possible, should not be located over the ceilings of occupied spaces.
- Piping systems must be designed to adequately accept thermal expansion. Forces from pipe expansion must not be transmitted to ceiling panels. Attention must be given to the thermal expansion of the ceiling panels.
- Interconnecting piping between panels should be of soft drawn copper and sufficiently looped to provide access to the panel from below if necessary. All

piping should be tested to at least three times working pressure, but not less than 150 PSI.

- Radiant ceiling panels should be located adjacent to the outside wall and in as close proximity as possible to the areas of maximum load. The panel area within five feet of the outside wall should have a heating capacity equal to or greater than 50% of the wall transmission load.
- Systems designed to pass return air through the ceiling panels are not recommended since much of the panel heat transfer will be lost to the return air system.
- Sufficient space above the ceiling must be allowed for installing and connecting the radiant ceiling panel piping.
- Room thermostat should be located on a side wall where it can "see" the outside wall and not the warm ceiling. The normal thermostat cover reacts to the warm ceiling panel and the radiant effect of the ceiling on the cover tends to alter the control point so that the thermostat controls two to three degrees lower when the outdoor temperature is at a minimum and the ceiling temperature is at a maximum.
- When the panel area for cooling is greater than the area for heating, two panel arrangement may be used. One panel, or grid of panels, is supplied with hot or chilled water year-round. The other panel, or grid of panels, is supplied with chilled water only during the cooling season.
- To prevent condensation on the cooling panels, the panel water supply temperature should be maintained at least 1 °F above the dew point temperature of the air in contact with the panel.
- Selection of summer design room dew point temperature below 50°F generally does not prove to be economical.
- Because air quantity requirements are generally small when compared to a conventional system, it is not advisable to use an air volume control in any part of a radiant panel cooling system.
- Proper design of a variable volume system for use with a radiant panel cooling system requires that the latent load be based on the minimum air volume capacity. This is possible only if the room thermostat is staged with the radiant cooling valve port and the variable volume control operator. However, the system cannot be properly balanced if the exhaust air system is not controlled in conjunction with the supply air variations.
- Aero Tech Radiant Ceiling Panels are of lightweight construction, so the system responds to changes in environmental conditions with a speed comparable to conventional systems. This allows the use of heating and cooling controls similar to those used in conventional systems.

- Control zones are similar to those used in conventional systems. A multi-story commercial building will typically have nine zones: four corner zones, four exterior zones and one interior zone. Since interior zones require cooling year round, radiant panel cooling can be used in the interior zone in conjunction with a heat pump cycle. This can reduce total operating costs particularly in an all-electrical building.
- Aero Tech Radiant Heating and Cooling Panel Systems usually allow utilization of constant air volume and constant ventilation air temperature. However, during freezing weather the owner may wish to set the ventilation air temperature higher. In this situation, it is recommended that the ventilation air temperature be maintained at least 3 to 5 °F below the space design temperature since ventilation air should handle the latent loads and not the sensible loads.
- During the winter, radiant panel heating of perimeter zones can be scheduled according to the outdoor temperature and/ or solar sensors. Modulating control valves will function properly if water temperature is increased as outdoor temperatures drop. Temperature control of the interior zone and the radiant panel cooling system should not be a function of outdoor weather.
- As with all Radiant Ceiling Panel systems, the supply air dew point should be reduced during extremely cold weather in accordance with the type of glazing installed to prevent condensation on window surfaces.
- Aero Tech formed metal panels consist of copper coil metallurgically bonded to a formed aluminum sheet resulting in a unified panel. These panels can be perforated to achieve required acoustical characteristics. Radiant ceiling panels are usually designed into an integrated metal ceiling system. Panels are available in 2' x 2' or 2' x 4' sizes. Formed metal panels are available for lay-in or snap-in ceiling suspension systems.
- Aero Tech also offers extruded aluminum linear panels where the tube is mechanically attached in a channel on the back of an extruded aluminum strip that wraps more than 70% around the copper tube. Panels are provided in various lengths up to 12'-0" maximum, with widths in increments of 6", 8", or 9" or any combination of these increments. Lengths up to 16’ can be accommodated upon special request and at additional cost. Extruded panels are most typically used in perimeter heating lay-in applications.

System Design

The design of a radiant ceiling perimeter system follows the usual design for re-circulating water systems which incorporate remote terminals for space heating.

Standard controls adjust the supply of heated water to the panels on demand from the room or zone thermostat. The aluminum panels respond almost instantaneously and the space quickly receives the desired heat. The piping and controls are similar to those used with conventional perimeter hot water systems but all pipes are in the ceiling plenum where they are readily accessible.

As Aero Tech radiant panels raise the mean radiant temperature in the space they produce greater thermal comfort at ambient temperatures lower than those required with convective systems. An inside dry bulb design temperature 3 to 4 °F below that normally used with convective systems is recommended.

Room loads should be calculated in a normal manner using the procedures set forth in the ASHRAE Guide.

Circuit Analysis Example

The purpose of these tables is to demonstrate calculation procedures that correlate panel length, temperature drop, flow rate and head loss.

Given	
$\Delta T = 20°F$	*water temperature drop*
L = 43 ft	*total length of panels in series circuit*
W = 18 in	*panel width (std. 0.505" ID tube)*
n = 3	number of passes on standard 18" panel
MWT = 180°F	*mean water temperature*

Constants Used	
c = 1 BTU/lb • F	*specific heat of water*
p = 8.345 lb/gal	*density of water*

Calculate total heat requirement for circuit	
q = 341 BTU/Hr Ln Ft	*from ATMI performance table for 18" wide panel at perimeter with 180°F MWT*
Q = qL Q = 341 (43) Q = 14,663 BTU/HR	*total circuit output*

Calculated volumetric flow rate	
$V = \frac{Q}{C \bullet p \bullet \Delta T}$ $V = \frac{14{,}663}{(1)(8.345)(20)(60)}$ V = 1.46 gal/min	*volumetric flow rate*

Since the panels in the circuit are arranged in series, the entire flow is routed through one tube with an effective length of three times the length of the panels (there are three passes in example panel). Finally, the pressure drop is calculated.

Calculated pressure drop	
H = 7 ft / 100 ft	*pressure drop from ATMI table*
$H = h_1 \bullet L \bullet n / 100$ $H = \frac{7(43)(3)}{100}$ H = 9.03 ft H_2O	*volumetric flow rate*

RADIANT FORMED METAL PANELS

WATER PRESSURE DROP		
Water Flow Rate (GPM)	*Head Loss in Feet of Water Per 2' x 2' Pnl (.505 ID Tube)*	*Head Loss in Feet of Water Per 2'x4' Pnl (.505 ID Tube)*
2.1	2.78	
2.0	2.48	4.00
1.9	2.21	3.69
1.8	2.00	3.35
1.7	1.79	3.03
1.6	1.59	2.73
1.5	1.39	2.41
1.4	1.19	2.15
1.3	1.00	1.89
1.2	0.84	1.61
1.1	0.78	1.41
1.0	0.65	1.20
0.9	0.55	1.00
0.8	0.45	0.81
0.7	0.35	0.62
0.6	0.28	0.48
0.5	0.20	0.37

To ensure proper system performance, design flow rates below 0.5 U.S. gallons per minute are not recommended.

HEATING PERFORMANCE		
MWT (Deg. F)	*Interior Panels BTU/Hr Sq Ft*	*Perimeter Panels BTU/Hr Sq Ft*
120	70	82
125	78	92
130	86	101
135	96	113
140	104	124
145	114	135
150	123	145
155	133	156
160	142	167
165	152	179
170	162	190
175	172	203
180	183	215
185	194	228
190	204	240
195	213	251
200	223	262
205	234	275
210	245	288
215	256	301
220	266	313
225	276	325
230	287	337

Use these performance values directly in standard ASHRAE heat loss calculations. Performance values are from certified data based on 70°F AUST (Average Unheated Surface Temperature), natural convection and 1" thick, 3/4 Pound/Cubit Foot insulation on top of panel. Due to actual conditions, stated performance values can vary plus or minus 3%.

RADIANT LINEAR EXTRUDED PANELS – STANDARD

Water Pressure Drop

Water Flow Rate (GPM)	*Head Loss in Feet of Water per 100 Feet of .505 ID Tube*
2.5	17.90
2.4	16.50
2.3	15.30
2.2	14.10
2.1	12.90
2.0	11.90
1.9	10.70
1.8	9.60
1.7	8.70
1.6	7.80
1.5	7.00
1.4	6.30
1.3	5.70
1.2	5.10
1.1	4.60
1.0	4.10
0.9	3.10
0.8	2.40
0.7	1.90
0.6	1.50
0.5	1.10

To ensure proper system performance, design flow rates below 0.5 U.S. gallons per minute are not recommended.

Heating Performance

	Perimeter BTU/Hr Lineal Foot								
MWT (Deg. F)	6" Wd 1 Tube	8" Wd 2 Tubes	12" Wd 2 Tubes	16" Wd 4 Tubes	18" Wd 3 Tubes	24" Wd 4 Tubes	30" Wd 5 Tubes	36" Wd 6 Tubes	Interior BTU/Hr Square Foot
120	47	62	90	117	129	164	195	231	70
125	53	70	102	131	145	183	219	258	78
130	60	78	113	145	161	202	243	285	86
135	66	86	125	161	178	225	269	318	96
140	72	94	137	177	196	248	295	351	105
145	78	103	149	192	213	269	320	378	114
150	84	111	161	207	229	290	345	405	123
155	91	120	174	224	247	312	369	437	133
160	98	129	187	240	265	334	393	468	142
165	104	137	199	256	283	357	421	500	152
170	111	145	211	272	301	380	450	531	162
175	118	155	225	290	321	405	479	561	172
180	126	165	239	308	341	430	508	591	183
185	133	175	253	326	361	455	538	624	193
190	141	184	267	344	381	480	568	657	204
195	148	194	280	361	399	502	591	685	213
200	155	203	294	377	417	524	615	713	223
205	162	213	308	396	437	550	645	748	234
210	170	223	323	415	458	576	675	783	245
215	177	232	337	433	478	601	706	819	255
220	185	242	351	451	498	626	738	855	266
225	192	251	364	468	517	650	766	888	276
230	199	261	378	485	536	674	795	921	286

Use these performance values directly in standard ASHRAE heat loss calculations. Performance values are from certified data based on 70°F AUST (Average Unheated Surface Temperature), natural convection and 1" thick, 3/4 Pound/Cubit Foot insulation on top of panel. Due to actual conditions, stated performance values can vary plus or minus 3%.

Please see the RLEP AXO Standard Manual for a more comprehensive list of panel options.

RADIANT LINEAR EXTRUDED PANELS – LOW PRESSURE DROP

Water Pressure Drop

Water Flow Rate (GPM)	*Head Loss in Feet of Water per 100 Feet of .578 ID Tube*
3.0	12.00
2.9	11.50
2.8	10.90
2.7	10.30
2.6	9.50
2.5	9.00
2.4	8.50
2.3	7.80
2.2	7.30
2.1	6.60
2.0	6.20
1.9	5.70
1.8	5.30
1.7	4.80
1.6	4.40
1.5	4.00
1.4	3.60
1.3	3.20
1.2	2.90
1.1	2.50
1.0	2.10
0.9	1.90
0.8	1.50
0.7	1.30
0.6	0.90
0.5	0.70

To ensure proper system performance, design flow rates below 0.5 U.S. gallons per minute are not recommended.

Heating Performance

MWT (Deg. F)	Perimeter BTU/Hr Lineal Foot								
	6" Wd 1 Tube	8" Wd 2 Tubes	12" Wd 2 Tubes	16" Wd 4 Tubes	18" Wd 3 Tubes	24" Wd 4 Tubes	30" Wd 5 Tubes	36" Wd 6 Tubes	Interior BTU/Hr Square Foot
120	47	62	90	117	129	164	195	231	70
125	53	70	102	131	145	183	219	258	78
130	60	78	113	145	161	202	243	285	86
135	66	86	125	161	178	225	269	318	96
140	72	94	137	177	196	248	295	351	105
145	78	103	149	192	213	269	320	378	114
150	84	111	161	207	229	290	345	405	123
155	91	120	174	224	247	312	369	437	133
160	98	129	187	240	265	334	393	468	142
165	104	137	199	256	283	357	421	500	152
170	111	145	211	272	301	380	450	531	162
175	118	155	225	290	321	405	479	561	172
180	126	165	239	308	341	430	508	591	183
185	133	175	253	326	361	455	538	624	193
190	141	184	267	344	381	480	568	657	204
195	148	194	280	361	399	502	591	685	213
200	155	203	294	377	417	524	615	713	223
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225	192	251	364	468	517	650	766	888	276
230	199	261	378	485	536	674	795	921	286

Use these performance values directly in standard ASHRAE heat loss calculations. Performance values are from certified data based on 70°F AUST (Average Unheated Surface Temperature), natural convection and 1" thick, 3/4 Pound/Cubit Foot insulation on top of panel. Due to actual conditions, stated performance values can vary plus or minus 3%.

RADIANT PANEL COOLING PERFORMANCE CHART

ΔT* (ºF)	Room Interior	Perimeter Panels Exterior Wall Conditions BTU/Hr Lineal Foot					
		0% Glass Full Sun	25% Glass Full Sun	50% Glass Full Sun	75% Glass Full Sun	100% Glass Full Sun	100% Glass Full Shade
	BTU / Hr Sq Ft **						
10	18	21	28	34	38	40	21
11	19	23	30	36	40	42	23
12	21	25	32	37	42	43	25
13	23	27	34	39	43	45	27
14	25	29	35	41	45	47	29
15	26	31	37	43	47	48	31
16	28	32	39	44	48	50	32
17	30	34	41	46	50	52	34
18	32	36	42	48	52	54	36
19	33	38	44	50	54	55	38
20	35	40	46	51	55	57	40
21	37	42	48	53	57	59	42
22	39	44	50	55	59	60	44
23	40	46	51	57	61	62	46
24	42	48	53	58	62	64	48
25	44	49	55	60	64	65	49
26	46	51	57	62	66	67	51
27	48	53	58	63	67	69	53
28	49	55	60	65	69	70	55
29	51	57	62	67	71	72	57
30	53	59	64	69	73	74	59

* (Room Temperature) - (Mean Water Temperature)

** From Certified Data

Due To Actual Conditions, Stated Performance Values Can Vary +/- 3%

AERO TECH MANUFACTURING

RADIANT CEILING PANEL SYSTEMS

395 West 1100 North
North Salt Lake, UT 84054

866-390-2376
aerotechmfg.com

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