
PART 1 GENERAL**1.1 RELATED DOCUMENTS**

- A. Section 23 05 10 – General Requirements
- B. Section 23 00 20 – HVAC Scope of Work
- C. Section 23 05 93 – Testing, Adjusting and Balancing
- D. Section 23 07 00 – Thermal Insulation
- E. Section 23 21 13 – Pipes, Valves, Fittings, and, Accessories
- F. Section 23 21 23 – Pumps
- G. Section 23 52 16 – Condensing Boilers
- H. Section 23 57 00 – Heat Exchangers for HVAC

1.2 SUMMARY

- A. Furnish and install radiant hydronic system herein specified and as indicated on the Drawings including, at minimum, the following:
 - 1. Complete hydronic radiant floor heating/cooling system as shown on the Drawings and as specified. This system shall be fully integrated with the construction of the floor slab completed by others.
 - 2. Floor slab insulation and vapor barrier.
 - 3. Coordination with the selection and installation of circulating pump(s), heat exchangers, manifolds and distribution piping (tubing).
 - 4. System controls and automation.
 - 5. Manufacturer system start-up and commissioning service.

1.3 RELATED DOCUMENTS

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1.4 REFERENCE STANDARDS

- A. ASTM – American Society for Testing and Materials
 - 1. ASTM 08.04 – 2009: Plastic Pipe and Building Products
 - 2. ASTM D 2683 – 2004: Standard Specification for Socket-Type Polyethylene Fittings for Outside Diameter-Controlled Polyethylene Pipe and Tubing
 - 3. ASTM D 3350 – 2008: Standard Specification for Polyethylene Plastics Pipe and Fitting Materials

4. ASTM E 84 – 2009: Standard Test Method for Surface Burning Characteristics of Building Materials
 5. ASTM E 119 – 2009: Standard Test Methods for Fire Tests of Building Construction and Materials
 6. ASTM E 814 – 2009: Standard Test Method for Fire Tests of Penetration Firestop Systems
 7. ASTM F 876 – 2010: Standard Specification for Cross-linked Polyethylene (PEX) Tubing
 8. ASTM F 877 – 2007: Standard Specification for Cross-linked Polyethylene (PEX) Plastic Hot- and Cold-Water Distribution Systems
 9. ASTM F 1960 – 2009: Standard Specification for Cold Expansion Fittings with PEX Reinforcing Rings for Use with Cross-linked Polyethylene (PEX) Tubing
- B. CSA – Canadian Standards Association: CAN/CSA B137.5 Cross-linked Polyethylene (PEX) Tubing Systems for Pressure Applications
- C. DIN – Deutsches Institut für Normung i.e. the German Institute for Standardization: DIN 4726:2008-10 – Warm Water Surface Heating Systems and Radiator Connecting Systems - Plastics Piping Systems and Multilayer Piping Systems
- D. IAPMO – International Association of Plumbing and Mechanical Officials
UMC – Uniform Mechanical Code
- E. ICC – International Code Council
1. ICC-ES – Evaluation Service: Evaluation Report No. ESR 1099
 2. IBC – International Building Code
 3. IMC – International Mechanical Code
- F. PPI – Plastics Pipe Institute
1. Technical Report TR-3 Policies and Procedures for Developing Recommended Hydrostatic Design Stresses for Thermoplastic Piping Materials
 2. Technical Report TR-4 Recommended Hydrostatic Strengths and Design Stresses for Thermoplastic Piping and Fitting Compounds
- G. UL – Underwriters Laboratories Inc.: UL 263 - 2007 – Standard for Fire Tests of Building Construction and Materials

1.5 QUALITY ASSURANCE

- A. Radiant Panel Association (RPA) Standard Guidelines sections 16.2(d) and 19.3
- B. Hydronic radiant floor manufacturer and installer shall have successfully completed five installations of similar type and scope.
- C. Comply with ASTM Standards, PPI Technical Reports and all applicable local codes.
- D. Standard Grade hydrostatic pressure ratings from Plastics Pipe Institute in accordance with TR-3 as listed in TR-4. The following three standard-grade hydrostatic ratings are required:
1. 200 degrees F at 80 pounds per square inch
 2. 180 degrees F at 100 pounds per square inch
 3. 73.4 degrees F at 160 pounds per square inch
- E. Certification of flame spread/smoke developed rating of 25/50 in accordance with ASTM E 84 for PEX tubing sizes between 5/16-inch and 2-inch when encased with 1/2-inch fiberglass insulation at tube spacing of not less than 4 inches apart.

1.6 SUBMITTALS

- A. Submit shop drawings/calculations indicating:
1. Tubing materials and temperature/pressure ratings.
 2. Tubing layout and zone loop sizes and lengths.

3. Location of all expansion and penetration sleeves, showing coordination with concrete slab inserts, sleeves, control joints, construction joints, cold joints, expansion joints, floor electrical and telecom/data outlets or conduits.
 4. Tubing manifold locations and installation details.
 5. Radiant system flow and capacity calculations.
 6. Radiant system pressure drop calculations.
 7. Pump submittal drawings and pump curves with certification from hydronic radiant floor manufacturer and installer indicating that components are fully coordinated as a complete system.
 8. Wiring diagram, control sequences, and control hardware devices. Indicate compliance and coordination with requirements of other specification sections.
 9. Installation drawings of the joist layout, panel layout, tubing layout, and other system components with detail notes to aid in the installation of the system.
 10. Provide mechanical schematic indicating heating and cooling source, mechanical tubing and accessories from source to manifolds, circulators, water tempering and zone controls. Indicate supply water temperatures and flow rates to manifolds.
 11. Samples: Submit selection and verification samples of tubing, slab insulation and pipe fittings.
- B. Submit report indicating installation was performed according to manufacturer's instructions. Include pressure-testing documentation as required in related specification sections.
- C. Submit start-up report demonstrating that system meets required capacity, is fully functional and has been commissioned to the satisfaction of system manufacturer.
- D. Final as-built PEX tubing layout drawing.

1.7 PRE-INSTALLATION MEETINGS

- A. Verify project requirements, substrate conditions, floor coverings, manufacturer's installation instructions and warranty requirements.
- B. Review project construction schedule and timeline to ensure compliance or discuss modifications as required.
- C. Interface with other trade representatives to verify areas of responsibility.

1.8 DELIVERY, STORAGE AND HANDLING

- A. Delivery: Deliver materials in manufacturer's original, unopened, undamaged containers with identification labels intact.
- B. Storage and Protection: Store materials protected from exposure to physical damage or harmful environmental conditions and at temperature and humidity conditions recommended by the manufacturer.
1. Store PEX tubing in cartons or under cover to avoid dirt or foreign material from entering the tubing.
 2. Do not expose PEX tubing to direct sunlight for more than 10 days. If construction delays are encountered, cover the tubing that is exposed to direct sunlight.

1.9 WARRANTY

- A. Manufacturer's Warranty: Submit manufacturer's standard warranty document executed by authorized company official. Manufacturer's warranty is in addition to, and not a limitation of, other rights Owner may have under Contract Documents.
1. Warranty covers the repair or replacement of any tubing or fittings proven defective.
 2. Warranty may transfer to subsequent owners.
 3. Warranty Period for PEX Tubing: 30-year, non-prorated warranty against failure due to defect in material or workmanship, beginning with date of substantial completion when installed by a factory-trained contractor.
 4. Warranty Period for Manifolds and Fittings: 5-year, non-prorated warranty against failure due to defect in material or workmanship, beginning with date of substantial completion when installed by a factory-trained contractor.

5. Warranty Period for Controls and Electrical Components: 2-year, non-prorated warranty against failure due to defect in material or workmanship, beginning with date of substantial completion when installed by a factory-trained contractor.
- B. If a factory-trained contractor does not install the system, then the most recent limited warranty published by the PEX tubing manufacturer takes precedence.

PART 2 PRODUCTS

2.1 ACCEPTABLE MANUFACTURERS

- A. Radiant Thermal PEX Floor Tubing and Accessories: Wirsbo, Radiant Pro, Rehau, Thermoval, Uponor.
- B. Manifolds: Wirsbo, Rehau, Radiant Pro, Uponor.
- C. PEX Fittings: SFI, Wirsbo, Rehau, Uponor.
- D. Pumps: Taco, Grundfos, B&G, Armstrong.
- E. Controller: Tekmar, Heatimer, Uponor, Danfoss.
- F. Radiant Floor Insulation: TVM, or approved equal.
- G. Structural/Radiant Panel Floor Sheathing: Warmboard, or approved equal.

2.2 RADIANT FLOOR EQUIPMENT

- A. All equipment except controllers and pumps used shall be furnished from one radiant floor manufacturer and be fully compatible to work as one integrated system.
- B. Tubing:
 1. Minimum wall thickness:
 - a. 0.083 inches for 5/8-inch diameter
 2. Material: Cross-linked polyethylene (PEX) manufactured by PEX-a or Engel method(s).
 3. Material Standard: Manufactured in accordance with ASTM F 876 and ASTM F 877 and tested for compliance by an independent third-party agency.
 4. Pressure Ratings: Standard Grade hydrostatic design and pressure ratings as issued by the Plastics Pipe Institute (PPI), a division of the Society of the Plastics Industry (SPI).
 5. Show compliance with ASTM E 119 and UL 263 through certification listings through UL.
 - a. UL Design No. K913 – 2-hour concrete floor assemblies
 6. Minimum Bend Radius (Cold Bending): Six times the tubing outside diameter. Use the PEX tubing manufacturer's bend supports if radius is less than stated.
 7. Barrier Tubing Type:
 - a. Tubing oxygen-diffusion barrier shall not exceed an oxygen diffusion rate of 0.10 grams per cubic meter per day at 104 degrees F water temperature in accordance with German DIN 4726.
 - b. Nominal Inside Diameter: Provide tubing with nominal inside diameter in accordance with ASTM F 876, as indicated. Tubing shall be available in the following sizes:
 - 1) 5/8 inch
 8. Tubing shall be permanently marked at 5-foot intervals with:
 - a. Lengths in feet.
 - b. Manufacturer.
 - c. Nominal size.
 - d. Design pressure and temperature ratings, relevant ASTM standards numbers, manufacturing date and production code.
 - e. Logo confirming certification to appropriate standards.
 9. Tubing shall be rated:
 - a. Continuous operation: 180 degrees F at 100 psig
 - b. Continuous operation: 200 degrees F at 79 psig
 - c. Continuous operation: 73.4 degrees F at 145 psig

- 10. Minimum burst pressure:
 - a. 425 pounds per square inch at 73.4 degrees F (ASTM F 876/F 877)
 - b. 210 pounds per square inch at 180 degrees F (ASTM F 876/F 877)
- 11. Density: 59.4 pounds per cubic foot (ASTM D 792)
- 12. Flexural modulus at 68 degrees F: 150,000 pounds per square inch
- 13. Coefficient of Expansion at 68 degrees F: 0.0008 per degree F (ASTM D 696)
- 14. Vicat Softening Point: 255 degrees F (ASTM D 1525)
- 15. Maximum pressure drop (pounds per square inch per 100 feet of tubing):

	5/8
0.5 gallons per minute	0.21
1 gallon per minute	0.71
2 gallons per minute	2.12
3 gallons per minute	4.36
4 gallons per minute	7.36
5 gallons per minute	11.00

- C. Fittings shall be machined solid brass compression type, engineered specifically for PEX tubing. Brass shall be resistant to de-zincification.
 - 1. For system compatibility, use only fittings offered by the PEX tubing manufacturer.
 - 2. The fitting assembly shall comply with ASTM F 877 and CAN/CSA B137.5 requirements.
 - 3. Compression Fittings:
 - a. Fitting assembly shall be manufactured from UNS C3600 series brass material.
 - b. The fitting assembly shall consist of a barbed insert, a compression ring and a compression nut. The barbed insert shall be manufactured with an O-ring to facilitate air-pressure testing.
 - 4. PEX Fittings:
 - a. Fittings shall be manufactured in accordance with ASTM F 1960.
 - b. Fitting assembly shall be manufactured from material listed in paragraph 5.1 of ASTM F 1960.
 - c. The fitting assembly shall consist of a barbed adapter and an appropriately sized PEX ring. The barbed insert may include an O-ring to facilitate pressure-testing with air.

- D. Provide flow-balancing manifolds pre-assembled with manual air vent, drain and refill cock, supply module with built-in shut-off valve, return module with manual flow-regulating and -balancing valve, purge fitting, drain fitting and thermometers and pressure gauges on the inlet and outlet.
 - 1. For system compatibility, use 1.25-inch diameter brass manifolds offered by the PEX tubing manufacturer.
 - 2. Use manifold mounting brackets offered by the PEX tubing manufacturer.
 - 3. Manifolds shall provide individual flow control for each loop on the manifold through valve actuators available from the manifold supplier.
 - 4. Manifolds shall include manual flow-balancing capability within the manifold body for balancing unequal loop lengths across the manifold.
 - 5. Manifolds shall include combination sight flow indicators and flow meters at each loop.
 - 6. Manifolds shall accommodate 5/16-inch through 3/4-inch PEX tubing.
 - 7. Each manifold location shall have the ability to vent air manually from the system.

- E. Provide commercial-grade radiant floor insulation suitable for in-slab applications. Insulation shall consist of linear low-density polyethylene bubbles enclosing a reflective opaque foil material providing an integral airspace between both sides of the foil and the radiating surface. Bubble-foil shall be permanently bonded to 1-inch of rigid insulation.
 - 1. Thickness: 5/16 inch
 - 2. Density: 1.16 ounces per square foot
 - 3. Temperature rating: Minus 50 to plus 180 degrees F
 - 4. Compressive strength (ASTM 1621-94) required for this installation: 85 pounds per square inch with no bursting of any bubbles
 - 5. Maximum deflection: Less than 10 percent under a 0.5 pounds per square inch load
 - 6. Minimum effective thermographic R-value: R9 to R10
 - 7. R-value (ASTM C 236): R6 minimum
 - 8. Reflectivity (ASTM C 5180): 57 percent minimum
 - 9. Emissivity: 42 percent
 - 10. Water permeance (ASTM 16231): Less than 0.01 perms
 - 11. Tensile strength: 21.13 pounds per square inch

12. Provide bubble-foil-bubble plus rigid board type to be used in the radiant floor assembly
 13. Insulation shall act as a vapor barrier with a permeability rating of less than 0.01 perms
 14. Provide 15-year manufacturer's warranty
- F. Provide circulating pumps with replaceable permanently lubricated bearing cartridge. The cartridge design shall isolate the bearing from the effects of system temperatures to extend bearing life.
1. Motors shall be NEMA Standard, resilient mounted with open drip-proof enclosure.
 2. Provide tapped ports on suction and discharge flanges.
 3. Operating pressure: 175 pounds per square inch in accordance with ANSI B 16.1 Class 125.
 4. Operating temperature: 300 degrees F.
 5. Pump shall be cast iron bronze-fitted construction with a one-piece enclosed cast bronze impeller, dynamically-balanced.
 6. Provide a cupro-nickel shaft sleeve.
 7. Pumps shall be designed to accept standard mechanical seals.
 8. Flexible coupler shall dampen system sound and prevents misalignment forces from being transmitted to the pump casing and piping system.
 - a.

PART 3 EXECUTION

3.1 INSTALLATION

- A. Comply with manufacturer's product data, including product technical bulletins, installation instructions and design drawings.
- B. Verify that site conditions are acceptable for installation of the radiant floor system. Do not proceed with installation of the radiant floor system until unacceptable conditions are corrected.
- C. Radiant floor system shall be provided by manufacturer to achieve the performances shown on the equipment schedules.
- D. Tubing: Length of loops and tubing location/spacing shown on the Drawings shall be verified by the manufacturer and reviewed by the Architect.
1. Tubing installed in the slab shall be polyethylene (cross-linked PEX) piping installed in loops with spacing and length as shown and tied to wire mesh rebar on an even grid (i.e., 6 by 6-, 12 by 12- or 6 by 12-inch spacing) using plastic tie bindings. The tubing may be secured with wire only after approval of the Architect. The installation shall be in strict accordance with the manufacturer's instructions. If rebar is not used, secure tubing to slab using PEX rail clips anchored to the slab.
 2. Insulation and vapor barrier shall be installed prior to placement of concrete rebar and coordinated with other trades.
 3. Insure that a minimum bending radius of six times tubing diameter is obtained (i.e., 3-inch radius for 1/2-inch tubing, 4.5-inch radius for 3/4-inch tubing).
 4. Tubing shall have fully enclosed protective conduit where tubing penetrate walls or flooring materials.
 5. Provide a 1-foot long continuous rigid protective sleeve where tubing crosses construction joints, cold joints, expansion joints and walls or partitions. Sleeve shall extend 3 inches beyond both sides of joint or wall.
 6. Insure a minimum of a 1/2-inch thick foam or "sill gasket" expansion strip is placed against all inner and outer walls (i.e., where topping comes in contact with a wall plate).
 7. All tubing shall be identified with loop numbers marked on tubing wall before connecting to manifold using a permanent tag. Room identification plus loop number shall be printed and placed on each individual module in the manifold tag slot with the identification tags provided. All loops shall be continuous from supply manifold to return manifold and identified to allow for rebalancing.
 8. Insulate all exposed PEX tubing used for cooling and any exposed PEX tubing longer than 12 inches used for heating. Use closed cell non-outgassing elastomeric foam insulation. Refer to Section 23 07 00 – HVAC Insulation.
 9. Provide an expansion tank upstream of each supply manifold, 15-gallon expansion volume, Vent-Rite VRF90F or equal.

3.2 FLOOR TYPES

- A. Slab-on-grade Installation:
1. Fasten the tubing to the flat mesh or reinforcing bar in accordance with the PEX tubing manufacturer's installation recommendations.
 2. Use closer tubing on-center distances along exterior walls. Increase tubing on-center distances as the installation moves away from the exterior wall(s).
 - a. Do not install tubing within 6 inches of any wall.
 - b. Refer to the submitted radiant floor design layout for actual on-center information.
 3. Under-slab insulation vertical compressive strength shall be rated for weight of concrete.
 4. When using high-density board insulation, staple the tubing to the insulation board with foam staples.
 5. Provide edge insulation when the radiant floor slab is adjacent to an exterior wall or panel.
 6. Install tubing at a consistent depth below the surface elevation. Ensure sufficient clearance to avoid control joint cuts.
 7. In areas where tubing must cross metal expansion joints in the concrete, ensure the tubing passes below the joints. Depending on the manufacturer's and structural engineer's recommendation, fibrous expansion joints may tolerate penetration.
 8. For tubing that exits the slab in a 90-degree bend, use metal or PVC bend supports.

3.3 OPERATION

- A. Radiant system shall be operated to offset heat gains, heat losses and glass surface temperature. System shall be controlled per Section 25 80 00 BMCS schedules, Diagrams and Sequences.

3.4 HYDROSTATIC TESTING

- A. Pressure-test tubing to 60 psig for a minimum of 24 hours prior to and during the concrete pour. Continue to maintain this test pressure for a minimum of 24 hours after the concrete has cured.
- B. Pressure-test entire hydronic system (tubing, boiler, heat exchanger etc.) prior to start-up as required by other specification sections.

3.5 SYSTEM START-UP

- A. Thoroughly clean and flush the system in accordance to manufacturer's instructions and as required by other specification sections.
- B. Balancing across the manifold:
1. Balance all loops across each manifold for equal flow resistance based on actual loop lengths and total manifold flow.
 2. Balancing is unnecessary when all loop lengths across the manifold are within 3 percent of each other in length. Install the supply and return tubing to the manifold in a reverse-return configuration to ensure self-balancing.
- C. Balance the flow between manifolds with a flow-control device installed on the return tubing leg from each manifold.

3.6 PIPING PRECAUTIONS

- A. PEX tubing shall not be installed:
1. If exposed to UV light or direct sunlight for over 24 hours.
 2. If adhesives or tapes have been in direct contact with tubing.
 3. Within 18 lineal inches of any soldering.
 4. If PEX tubing has come in direct contact with any petroleum product, fuel or solvent or constant persistent moisture.
 5. If PEX tubing has come in direct contact with sharp fill or any copper pipe or fittings.
 6. If oxygen-diffusion barrier is damaged, torn or scratched.

3.7 DEMONSTRATION

- A. Demonstrate operation of hydronic radiant floor system to Owner's personnel.

END OF SECTION