GO TRANSIT

IN-FLOOR RADIANT HEATING SYSTEMS

DESIGN GUIDELINES AND SPECIFICATIONS

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1. APPLICABILITY AND LIMITATIONS

1.1 This specification section pertains to the supply and installation of an in-floor radiant heating system.

1.2 This section shall be read in conjunction with the GO Transit/Metrolinx specifications: “Snow Melting Systems”.

1.3 In the context of these specifications, “heating fluid” means either the polypropylene glycol used for the snow melting system (since the heating plant is common) or water (in the absence of a concurrent snow melting system). The designer shall adjust the calculations to suit the fluid used.

1.4 The following components are not covered by this section:

- The heating source for the heating agent and all associated components; they are included in the “Snow Melting Systems” specification and are fully applicable to this section.
- The building automation system (BAS) central hardware and software components (control panels, software and graphics, server, etc); they are included in the “Snow Melting Systems” specification and are fully applicable to this section.
- Mechanical General Conditions including but not limited to duties of contractors, material substitutions, shop drawings, contractual obligations; they are included in the “Snow Melting Systems” specification and are fully applicable to this section.
- Requirements for testing, adjusting and balancing (TAB) of hydronic systems are included in the in the “Snow Melting Systems” specification and are fully applicable to this section.

1.5 The following components are covered by this section:

- The in-floor heating piping, manifolds and accessories
- The rigid piping and accessories connecting the heating source to the in-floor heating manifolds
- The pumping equipment associated with the in-floor heating system
- The digital control components (sensors, valves, operators, wiring, relays, etc) associated with the in-floor heating system

2. REFERENCES

2.1 Publications listed here are part of this specification to the extent they are referenced. Where no specific edition of the standard or publication is identified, the current edition shall apply.

- ASTM F876, Standard Specification for Crosslinked Polyethylene (PEX) Tubing
• ASTM F2014, Standard Specification for Non-Reinforced Extruded Tee Connections for Piping Applications
• ASTM F2080, Standard Specification for Cold-Expansion Fittings With Metal Compression-Sleeves for Cross-Linked Polyethylene (PEX) Pipe
• CSA B137.5, Crosslinked Polyethylene (PEX) Tubing Systems for Pressure Applications
• CSA B214, Installation Code for Hydronic Heating Systems
• ISO 9001, Quality Management Systems – Requirements
• CAN/ULC S102.2, Surface Burning Characteristics of Flooring, Floor Covering and Miscellaneous Materials
• PPI TR-3 / 2007, Policies and Procedures for Developing Hydrostatic Design Basis (HDB), Pressure Design Basis (PDB), Strength Design Basis (SDB), and Minimum Required Strength (MRS) Ratings for Thermoplastic Piping Materials or Pipe

3. DESIGN CRITERIA AND PRINCIPLES

3.1 General

The building’s structure and the floor finish installation influences the decision regarding the best radiant heating construction method. For best results, the floor construction should be coordinated with the architect and structural engineer. Floor construction methods play an important role in the performance of the radiant heating system. The floor should allow for the heat from the pipes to dissipate readily and evenly to the heated space. Downward heat flow should be minimized by employing adequate insulation.

3.2 Heating Loads

The system shall be sized to offset the building heat losses through the envelope. The heat losses through walls, windows, roofs, floors, skylights, doors, etc. shall be calculated using an industry-accepted software such as Carrier HAP program or similar.

Infiltration loads through static envelope elements (such as window frames, etc) shall not be considered, since the buildings are to be maintained at a slight positive pressure by the ventilation equipment.

In areas exposed to high indoor/outdoor traffic, the infiltration rate due to frequent exterior doors opening shall be calculated based on the estimated doors operation, opening areas and temperature differential between indoor and outdoor. The methodology is described in detail in the ASHRAE Fundamentals Manual (Ventilation and Infiltration – Air Leakage Through Exterior Doors).

At the latitude of the designer, a safety coefficient can be added to account for the heat losses through the system (un-insulated manifolds, expansion tanks, etc.).
3.3 Indoor Setpoints

The indoor setpoints will vary with the designation and use of the space where the in-floor heating system is used. Additional variables are the occupied/unoccupied schedules. The default values shall be coordinated with GO Transit for each application.

For the purpose of heat loss calculations with radiant heating systems the indoor setpoints noted above may be lowered 2 to 4°F (1 to 2°C) compared to conventional perimeter baseboards or forced-air heating systems.

3.4 Maximum Floor Surface Temperatures

In order to determine the required floor temperature outside the perimeter band, use the following methodology:

Based on the total heat load calculation, calculate the radiant floor heat output requirement in Btu/h-ft² (W/m²) for each thermal zone using the following formula:

Floor Heat Output = \( \frac{\text{Total Heat Load}}{\text{Available Area}} \)

Available area is normally less than total area. Deduct non-heated areas where heating pipe cannot or should not be installed, such as under walls, vending machines, islands or furniture.

Calculate the radiant floor surface temperature that is needed to achieve the required heat output into the room. The floor surface temperature is the temperature at the outer surface of the finished floor. To calculate the floor surface temperature in °F (°C), use the following equation:

Floor Surface Temp = \( \frac{\text{Floor Heat Output}}{\text{HTC}} + \text{Indoor Temperature} \)

where the Heat Transfer Coefficient (HTC) is recommended as 2.0 Btu/(hr-sq.ft.-°F) or 11.36 W/m²-°K

The maximum floor surface temperature shall not exceed 85°F (29°C), except for the 3 ft wide perimeter band, where the temperature may be raised up to 90°F (32°C).

If the floor surface temperature exceeds the advisable temperature set in these guidelines or the allowable floor covering temperatures (see below), take the following actions:

- Reduce the heat requirements by improving building envelope efficiency
- Increase the radiant surface area to include not only the floor but also walls and/or ceilings
- Use supplemental heat (baseboards, reheat coils)
3.5 Maximum Under-Floor Covering Temperature

Every floor covering has a thermal resistance. The type and material used for flooring shall be coordinated with the architect. Floor products used with radiant heating systems should have high heat transmission values (low R-values) to achieve the best possible heat transfer from the pipes to the room. Floor coverings should also be as thin and dense as possible and be able to withstand the heat output of the radiant panel.

In order to achieve the required Floor Surface Temperature, the temperature of the slab at the underside of the floor covering needs to be higher, in order to overcome the thermal resistance of the floor covering. The thermal resistance of the floor covering shall be calculated taking into account all the layers involved (such as mortar bed, final grout, ceramic tiles, etc.)

Floor covering materials have temperature limits dictated by their composition. The calculated temperature at the underside of the floor covering shall not exceed the value recommended by the manufacturer. For specific floor finishes materials and thicknesses, coordinate with the architect.

Avoid under-floor covering temperatures in excess of 100°F (38°C). If the under-floor covering temperature resulting from calculations exceeds 103°F (39.5°C), re-select the in-floor pipe diameter and the pipe spacing.

Typically, floor and under-covering temperatures are controlled and monitored by embedded temperature sensors.

3.6 Thermal Zoning

A thermal zone is an area of temperature control. Typically, a group of offices or similar will constitute a separate zone. Larger areas (such as common waiting areas in a GO Transit station) may be subdivided in several thermal zones, based on geographical orientation and proximity to exterior walls.

3.7 Thermal expansion

The design must allow for absorption of the movement of the thermal mass of the floor slab. To prevent uncontrolled cracking and/or damage to the embedded piping, the architect shall segment the thermal slab into smaller sections called thermal bays by employing an appropriate arrangement of movement joints. The development of cracks in the floor or distortion in the piping are unacceptable.

The layout of the heating pipe and the floor slab joints must be coordinated with the architect and the structural engineer. Pipe circuits are to be planned and installed such that they do not cross movement joints. Movement joints should only be crossed by the connection piping (circuit supply and return tails).
3.8 **Pipe spacing**

GO Transit recommends the pipe spacing be selected to provide the most comfortable floor surface temperature and the most energy efficient system. Closer pipe spacing improves the uniformity of the floor surface temperature and lowers the heating fluid temperature, resulting in greater energy efficiency.

The typical pipe spacing shall be:

- tiled floors: 6” to 8” in the perimeter band and 6” to 9” in the field of the thermal zone (to prevent concentrated hot and cold spots)
- carpeted floors: 6” to 8” in the perimeter band and 6” to 12” in the field of the thermal zone (to prevent concentrated hot and cold spots)
- bare finished concrete: depends of heat loss, up to 18” possible.

3.9 **Pipe sizes**

The embedded pipe sizes shall be selected as follows:

- 5/8" diam for circuits up to 400 ft
- 3/4" diam for circuits up to 500 ft
- 1" diam for circuits larger than 500 ft.

The length of a particular circuit shall be based on the area of each thermal zone and the following criteria:

- pipe spacing 6" - 2 ft pipe length per sq.ft of space.
- pipe spacing 8" - 1.5 ft pipe length per sq.ft of space.
- pipe spacing 9" - 1.3 ft pipe length per sq.ft of space.
- pipe spacing 10" - 1.2 ft pipe length per sq.ft of space.
- pipe spacing 12" - 1.0 ft pipe length per sq.ft of space.

The total resulting length for each circuit shall not exceed the maximum value allowed for a particular pipe diameter.

3.10 **Piping Layout Guidelines**

Following are some basic pipe layout recommendations:

- Do not run pipes under built-ins (e.g., cabinets, window seats, large appliances, raised hearths, stairs)
• Keep pipes a minimum of 6 in (15 cm) away from the edge of the slab, walls and nailing surfaces, and other locations where plates, fixtures or built-ins might be fastened into the floor
• Keep balanced circuit lengths within 10% of each other
• Design separate circuits for different rooms, allowing better room temperature control
• Keep thermal zones reasonably sized
• Do not run circuit pipes across movement joints
• Select the pipe size that is large enough for the application

3.11 Fluid Heating Temperature

GO Transit recommends the lowest heating fluid temperature that will provide the required panel surface temperature. This will minimize thermal stress on slabs and floor coverings, and minimize overshooting of the desired ambient room temperature.

GO Transit suggests the following criteria:

• temperature drop across the embedded circuits: 20°F (11°C).
• average fluid temperature (between supply and return): 110°F (43.5°C).

To be noted: floor coverings, pipe spacing and selected indoor temperature may have a significant impact on the average fluid temperature. Highly resistive floor coverings (e.g., carpet and padding) require the fluid temperature to be increased to overcome the resistance to heat flow through the floor. Highly conductive floor coverings (e.g., tile) require a lower fluid temperature to provide the same heat output.

The heating fluid temperature is also affected by the selected indoor setpoint selected and the pipe spacing. The consultant will check with the equipment manufacturer and make corrections to the GO Transit temperature guidelines if so required. Optimizing the average fluid temperature may require changing previously selected values for pipe size and spacing. The designer will need to reiterate the previous calculations with the newly selected values.

3.12 Manifold Sizing

When sizing a manifold, several criteria must be taken into account:

• Manifolds are selected according to the pipe size, number of circuits and circuit flow rates. Smaller manifolds (up to 6 circuits), in various building locations, are usually preferred to a large, central manifold (such as 10, 11, 12 or more circuits).
• With large manifolds, the designer should consider the effect of manifold location on the radiant heating system design and the impact of bringing numerous pipes into one area. For example, a 12 circuit manifold has 24 inlet/outlet pipes which result in a congested pipe layout and an excessively warm area near the manifold.

Based on the above, determine the number of circuits for each manifold. Zoning the building usually increases the number of circuits resulting in manifolds with more outlets.

Preferably, a manifold will serve multiple thermal zones with similar heating requirements (such as exterior zones facing East, etc). Avoid connecting core areas and perimeter areas to the same manifold.

The fluid flow for each thermal zone shall be calculated based on the heat output of the respective circuit, the nature of the fluid used (water, glycol) and the temperature differential (usually 20°F or 11.1°C).

The fluid flow through the manifold shall be calculated as the sum of all the circuits flows served by the respective manifold.

Verify fluid velocities through each pipe section; ensure that no pipe section conveys fluid at more than 4.5 fps (1.37 m/s)

3.13 Manifolds Location

Identify the manifold location before beginning the pipe layout.

Use the following criteria:

• Manifolds must always be installed within the heated space, and not be located in an unheated area.
• Manifolds should be installed close to the heating zones in a convenient location for both the installation and for future accessibility (to reduce the length of pipe tails)
• Ensure that the manifolds fit in the available space
• Review the proximity to the heat source to minimize the distribution piping
• Review the area security to prevent tampering, especially areas open to the public.
• Review maintenance clearances

Typical manifold locations include mechanical rooms, closets (behind an access panel), below subfloors (mounted horizontally), underneath stairwells, inside cabinetry, in window boxes or benches or hallways (in a recessed manifold cabinet)
3.14 Piping Layout

Circuit connections branch off from the manifold headers and balancing valves shall control the flow rate to each circuit connection. A valve actuator shall be installed to the header balancing valve to open and close the circuit.

Heat requirements are higher near exterior walls and windows and diminish toward the center of the room. A 3 ft wide band along the perimeter area of the building shall be supplied by separate supply and return manifolds and maintain a higher slab temperature; for the perimeter band, it is permitted to serve multiple thermal zones from a single pair of dedicated manifolds, provided they face the same geographical orientation.

Following are some basic pipe layout recommendations:

- Do not run pipes under built-ins (e.g., cabinets, window seats, large appliances, raised hearths, stairs)
- Keep pipes a minimum of 6 in (15 cm) away from the edge of the slab, walls and nailing surfaces, and other locations where plates, fixtures or built-ins might be fastened into the floor
- Keep balanced circuit lengths within 10% of each other
- Design separate circuits for different rooms, allowing better room temperature control
- Keep area types reasonably sized
- Do not run circuit pipes across movement joints
- Select the pipe size that is large enough for the application

Counter Flow Spiral Pattern: with fewer bend radius constraints, counter flow spirals allow closer pipe spacing and distribute heat more evenly than serpentine patterns.

Serpentine Pattern: provides more heat to the perimeter areas than to the interior of the room, where occupants are more likely to gather.

Typically, the most effective way to heat a room is to use a serpentine pattern at the edges and a counter flow spiral pattern in the middle.

3.15 Pump Selection

Circulator pumps should be sized to achieve the radiant system design flow rate. To size a pump, determine the required flow for the radiant heating system and the total friction losses to be overcome from all components.

Use manufacturer-supplied tables for pressure drop rates in under-slab pipes and fittings. For above-ground rigid piping (copper or steel) use information available in ASHRAE handbooks to determine the pressure drops in pipes and fittings.
The pump outlet pressure must not exceed the embedded pipe ratings. Failure to follow this instruction may damage the pipe resulting in leaks and operational failures.

3.16 Control Strategies

The temperature of the slab is controlled and limited by separate embedded sensors, to prevent damage to the slab and floor coverings.

The heating output of the circuits served by each manifold is determined by a 3-way mixing valve at the interface between the in-floor heating secondary loop and the heating plant primary loop. The valve can combine fluid returning from the under-floor loop with fluid supplied by the primary heat source, to maintain the optimum median fluid temperature in the under-floor piping system. The goal is to maintain the supply fluid at the pre-determined under-floor covering temperature and the optimum temperature differential between the supply and return manifolds at between 18°F and 22°F (10°C to 12.5°C).

The comfort level in each thermal zone is maintained by a space sensor; the space sensor has the ability to close or open a 2-way valve associated with each circuit within a manifold. The two-way valve may be 2-position or modulating type.

Outdoor weather compensating controls (outdoor reset controls) shall adjust the rate of heat delivered by the primary source to more closely match the heat loss of a building, allowing the indoor air temperature to remain relatively constant. The outdoor reset control measures the outdoor air temperature, then calculates the target supply fluid temperature for the radiant system. This target supply temperature is constantly updated throughout the day as outdoor conditions change. The control can operate upon the heat source, upon a primary/secondary loop mixing valve or a variable speed injection pump to adjust the heating fluid temperature toward the calculated target value.

4. GENERAL SYSTEM REQUIREMENTS

4.1 Certification Equipments

Certification of flame spread/smoke development rating of 25/50 in accordance with ASTM E84 for the following PEX tubing sizes when installed un-insulated at a tube spacing not less than 18 inches (457.2mm) apart.

4.2 Performance Requirements:

Provide hydronic radiant heating system that is manufactured, fabricated and installed to comply with regulatory agencies and authorities with jurisdiction, and maintain performance criteria stated by the PEX tubing manufacturer without defects, damage or failure.
4.3 Regulatory Compliance

- Show compliance with ASTM F877.
- Show compliance with DIN 4726 regarding oxygen diffusion concerns.
- Show compliance with ASTM E119 and ANSI/UL 263 through certification listings through Underwriters Laboratories, Inc. (UL).

4.4 Manufacturer Credentials

Hydronic radiant system manufacturer shall have successfully completed five installations of similar type and scope. Manufacturer shall provide from the factory a full-time representative to supervise the complete design, detailing, coordination, installation and commissioning of the hydronic radiant system.

The contractor shall furnish all labor, materials, tools, equipment, appliances and services necessary to deliver and install all hydronic radiant dimensions to the hydronic radiant manufacturer.

5. SUBMITTALS

5.1 Product Data: Submit manufacturer’s product submittal data and installation instructions.

5.2 Submit the following shop drawings, calculations and reports.

- Submit shop drawings for piping installation in the project. Indicate all valves, pumps and items of equipment that are required to control and operate the hydronic radiant system for heating and/or cooling as shown on the drawings and described in the sequence of operations. Submit a valve and pump schedule listing each number, type, size, model and service. Cross reference to supporting product data.
- Submit manufacturer’s detailed drawings showing layouts, fixing details and piping details of all areas where hydronic radiant systems are indicated along with product and performance data for each component.
- Provide calculations that support the heating and/or cooling performance requirements of the hydronic radiant system. These calculations should show the flow through the system for heating and/or cooling as well as the primary heating and/or cooling connections to the radiant system headers and control circuits. Provide system pressure-drop calculations as well.
- Submit drawings showing details of manifolds, including all connections and valves. If manifolds are to be installed on a wall, then the details should include all fixture details. If the manifolds are to be installed in wall cavities, then provide all fixture and access details.
- Specify piping materials and temperature/pressure ratings.
- Provide drawings showing the location of all expansion and penetration sleeves, showing coordination with concrete slab expansion joints. Provide confirmation of concrete slab expansion requirements and the use of any concrete additives.
- Provide drawings showing piping manifold locations and installation details.
• Provide control sequences and requirements for control hardware devices. Indicate compliance and coordination with requirements of other specification sections.
• Provide piping sample with certification of properties.
• Submit manufacturer’s report detailing that the hydronic radiant system has been installed in accordance with this specification and the manufacturer’s specified instructions.
• Submit report indicating that installation was performed according to the manufacturer’s instructions. Include pressure testing documentation as required in related specification sections.
• Submit start-up report demonstrating that system meets required capacity, is fully functional and commissioned to the satisfaction of system manufacturer.
• Provide installation drawings indicating tubing layout, manifold locations, zoning requirements and manifold schedules with details required for installation of the system. Provide sectional drawing of floor slab demonstrating coordination with other construction trades and showing insulation, if required.

5.3 Submit the following support documentation:

• Manufacturer’s certificate indicating products comply with specified requirements.
• Manufacturer’s detailed room-by-room heat-loss analysis for the structure.
• Documentation indicating the installer is trained to install the manufacturer’s products.

5.4 Submit the following close-out documents.

• Warranty documents specified herein
• Operation and maintenance data
• Manufacturer’s field reports specified herein
• Final as-built tubing layout drawing

6. DELIVERY, STORAGE AND HANDLING

6.1 Comply with manufacturer’s ordering instructions and lead-time requirements to avoid construction delays.

6.2 Deliver materials in manufacturer’s original, unopened, undamaged containers with identification labels intact.

6.3 Store materials protected from exposure to harmful environmental conditions and at temperature and humidity conditions recommended by the manufacturer.

6.4 Store PEX tubing in cartons or under cover to avoid dirt or foreign material from entering the tubing.

6.5 Do not expose PEX tubing to direct sunlight for more than 30 days. If construction delays are encountered, cover the tubing to prevent exposure to direct sunlight.
7. WARRANTY

7.1 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

7.2 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

7.3 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

7.4 Warranty may transfer to subsequent owners.

8. IN-FLOOR HEATING SYSTEM COMPONENTS

8.1 Tubing

Material: Cross linked polyethylene (PEX) manufactured by PEX-a or Engle method with an oxygen diffusion barrier does not exceed an oxygen diffusion rate of 0.10 grams per cubic meter per day at 104 degrees F (40 degrees C) fluid temperature in accordance with German DIN 4726.

Pipe shall be rated for continuous operation of 100 psi gauge pressure at 180°F temperature (690 kPa @ 82°C), and 80 psi gauge pressure at 200°F temperature (550 kPa @ 93°C).

Material Standard: Manufactured in accordance with ASTM F876 and ASTM F877 and tested for compliance by an independent third-party agency.

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).

Minimum Bend Radius (Cold Bending): No less than six times the outside diameter. Use the PEX tubing manufacturer's bend supports if radius is less than stated.

Pipe to have a Flame Spread Index of less than 25, and a Smoke Developed Index of less than 50 when tested in accordance with ASTM E84 (in U.S.) or CAN/ULC S102.2 (in Canada).

The unrestrained linear expansion (thermal) rate for the in-floor tubing shall be approximately 1.1 inches per 10°F temperature change per 100 feet of tubing (16.5 mm/°C-100m of tubing)
8.2 Manifolds

Install valved manifolds primarily for wall-hung or boxed applications. Use manifolds with an isolation valve or a combination isolation and balancing valve on each outlet.

**Brass Manifolds (¼” diam)**

- For system compatibility, use 1¼-inch brass manifolds offered by the tubing manufacturer.
- Use manifolds constructed of dezincification-resistant brass.
- Use appropriately sized manifolds boxes to allow the manifold assemblies to be mounted inside the wall cavity.
- Use manifold mounting brackets offered by the tubing manufacturer.
- Manifolds must be capable of individual flow control for each loop on the manifold through valve actuators available from the manifold supplier.
- Manifolds must feature manual flow balancing capability within the manifold body for balancing unequal loop lengths across the manifold.
- Install flow setter on the return leg from the manifold to provide flow balancing between manifolds.
- Manifolds support 5/16 inch through ½ inch PEX tubing.
- Each manifold location should have the ability to vent air manually from the system.

**Copper Manifolds (2” diam.)**

- For system compatibility, use 2-inch valved copper manifolds manufactured from Type L copper material, offered by the PEX tubing manufacturer.
- Install valved copper manifolds primarily for wall-hung or boxed applications.
- Use manifolds with an isolation valve or a combination isolation and balancing valve on each outlet.
- Use manifolds that support ⅝ inch or ¾ inch PEX tubing.
- Ensure manifold end cap offers tapping for ⅛ inch FNPT and ½ inch FNPT for vent and drain.
- Install supply-and-return piping to the manifold in a reverse-return configuration to ensure self-balancing.
- If the supply-and-return piping is in direct-return configuration, install and balance flow setters on the return leg of each manifold to the mains.

8.3 Fittings

- Fittings shall be third-party certified to applicable standards ASTM F877, ASTM F2080 and CSA B137.5 as part of the manufacturer’s PEX piping system, with independent listings from IAPMO, NSF, CSA and ICC, as applicable.
- Compression nut manifold fittings shall be manufactured of corrosion-resistant brass with a barbed insert and a reusable split compression ring.
• Compression-sleeve fittings shall be manufactured of brass and shall be supplied by the piping manufacturer as part of a proven cataloged system.
• Fittings embedded within the thermal mass or encased behind walls or ceilings shall be cold-expansion compression-sleeve fittings certified to ASTM F2080. Where required by the manufacturer, fittings shall be protected from external environmental conditions.

8.4 Accessories:
• Pressure gauge on each manifold
• Temperature gauge on each manifold

8.5 Standards of Acceptance:
• Wirsbo
• Uponor
• Stadler
• Roth

9. ABOVE GROUND PIPING BETWEEN HEAT SOURCE AND MANIFOLDS

9.1 Pipe And Tubing
• Steel: ASTM A53 Grade B, seamless or ERW, Schedule 40.
• Copper: ASTM B88, Type K or L, hard drawn. Soft drawn tubing, 20 mm (3/4 inch) and larger, may be used for runouts to floor mounted fan coil units or perimeter convectors

9.2 Fittings For Steel Pipe
• 65 mm (2 ½ inches) and Larger: Welded or flanged joints. Butt welding fittings: ASME B16.9 with same wall thickness as connecting piping. Elbows shall be long radius type, unless otherwise noted.
• 50 mm (2 inches) and Smaller: Screwed or welded. 150 pound malleable iron, ASME B16.3. 125 pound cast iron, ASME B16.4, may be used in lieu of malleable iron. Bushing reduction of a single pipe size, or use of close nipples, is not acceptable. Unions: ASME B16.39.

9.3 Fittings For Copper Tubing
• Solder Joint: Joints shall be made up in accordance with recommended practices of the materials applied. Apply 95/5 tin and antimony on all copper piping.
9.4 **Screwed Joints**

- Pipe Thread: ANSI B1.20. Lubricant or Sealant: Oil and graphite or other compound approved for the intended service.

9.5 **Valves**

- Asbestos packing is not acceptable.

- All valves of the same type shall be products of a single manufacturer. Provide gate and globe valves with packing that can be replaced with the valve under full working pressure.

- Provide chain operators for valves 100 mm (4 inches) and larger when the centerline is located 2400 mm (8 feet) or more above the floor or operating platform.

9.6 **Butterfly Valves**

- Provide stem extension to allow 50 mm (2 inches) of pipe insulation without interfering with valve operation.

- MSS SP 67, flange lug type (for end of line service) or grooved end rated 1205 kPa (175 psig) working pressure at 93 degrees C (200 degrees F).

- Body: Cast iron, ASTM A126, Class B. Malleable iron, ASTM A47 electro-plated, or ductile iron, ASTM A536, Grade 65 45 12 electro-plated.

- Trim: Bronze, aluminum bronze, or 300 series stainless steel disc, bronze bearings, 316 stainless steel shaft and manufacturer’s recommended resilient seat. Resilient seat shall be field replaceable, and fully line the body to completely isolate the body from the product. A phosphate coated steel shaft or stem is acceptable, if the stem is completely isolated from the product.

- Actuators: Field interchangeable. Valves for balancing service shall have adjustable memory stop to limit open position.

- Valves 150 mm (6 inches) and smaller: Lever actuator with minimum of seven locking positions, except where chain wheel is required.

- Valves 200 mm (8 inches) and larger: Enclosed worm gear with handwheel, and where required, chain wheel operator.

9.7 **Ball Valves**
• Brass or bronze body with chrome-plated ball with full port and Teflon seat at 2760 kPa (400 psig) working pressure rating. Screwed or solder connections. Provide stem extension to allow operation without interfering with pipe insulation.

9.8 Water Flow Balancing Valves

• For flow regulation and shut off. Valves shall be line size rather than reduced to control valve size and be one of the following types. Butterfly valve as specified herein with memory stop.

9.9 Gages, Pressure And Compound

• ASME B40.100, Accuracy Grade 1A, (pressure, vacuum, or compound for air, oil or water), initial mid scale accuracy 1 percent of scale (Qualify grade), metal or phenolic case, 115 mm (4 1/2 inches) in diameter, 6 mm (1/4 inch) NPT bottom connection, white dial with black graduations and pointer, clear glass or acrylic plastic window, suitable for board mounting. Provide red "set hand" to indicate normal working pressure.

• Provide brass lever handle union cock. Provide brass/bronze pressure snubber for gages in water service.

• Range of Gages: Provide range equal to at least 130 percent of normal operating range.

9.10 Thermometers

• Mercury or organic liquid filled type, red or blue column, clear plastic window, with 150 mm (6 inch) brass stem, straight, fixed or adjustable angle as required for each in reading.

• Case: Chrome plated brass or aluminum with enamel finish.

• Scale: Not less than 225 mm (9 inches), range as described below, two degree graduations.

• Separable Socket (Well): Brass, extension neck type to clear pipe insulation.

• Scale ranges may be slightly greater than shown to meet manufacturer's standard. Required ranges in degrees C (F)

9.11 Pressure/Temperature Test Provisions

• Pete's Plug: 6 mm (1/4 inch) MPT by 75 mm (3 inches) long, brass body and cap, with retained safety cap, nordel self closing valve cores, permanently installed in piping where shown, or in lieu of pressure gage test connections shown on the drawings.

• Provide one each of the following test items to the Owner:
• 6 mm (¼ inch) FPT by 3 mm (1/8 inch) diameter stainless steel pressure gage adapter probe for extra long test plug. PETE’S 500 XL is an example.

• 90 mm (3 ½ inch) diameter, one percent accuracy, compound gage, 100 kPa (30 inches) Hg to 700 kPa (100 psig) range.

• 0 - 104 degrees C (220 degrees F) pocket thermometer one half degree accuracy, 25 mm (one inch) dial, 125 mm (5 inch) long stainless steel stem, plastic case.

10. ABOVE-GROUND PIPING INSULATION

10.1 Fiberglass Pipe Insulation

• Rigid molded in compliance with ASTM C547, Class 1, minimum density 3.5 pounds/cubic foot, K-factor of approximately 0.24 at 75 degrees F, suitable for temperatures from minus 20 degrees F to 450 degrees F.

• Vapor Barrier: Factory applied vapor barrier all-service type with self-sealing lap and butt strips.

• Valves and Fitting Covers: Pre-molded PVC covers with fiber glass insert. Manufacturers: Proto Corp., CeeCee.

10.2 Adhesive, Mastic, Cement

• ASTM C449: Mineral fiber hydraulic setting thermal insulating and finishing cement.

• Other: Insulation manufacturers' published recommendations.

10.3 Mechanical Fasteners

• Wire: 1.3 mm thick (18 gage) soft annealed galvanized or 1.9 mm (14 gage) copper clad steel or nickel copper alloy.

• Bands: 20 mm (3/4 inch) nominal width, brass, galvanized steel, aluminum or stainless steel.

10.4 Canvas Jacketing

• Apply in all exposed areas, including mechanical rooms: compact, firm ULC listed heavy plain weave, cotton fabric at 220 g/m sq.

10.5 Metal Jacketing

• At all locations where the pipe is located outdoors or in heavy abuse areas, use metal jacketing to protect piping or ductwork insulation.
• Jacketing: Aluminum, 0.016 inches thick, embossed surface, with factory bonded moisture barrier.

• Valve and Fitting Insulation Covers: Fabricate from same material as jacketing or use prefabricated insulation covers made in two matching halves.

• Metal Jacketing Bands: ½ inch wide, aluminum or stainless.

11. VERTICAL IN-LINE PUMPS

11.1 Pumps

• Refer to pump schedule for pump flows and heads and motor speed, enclosure, efficiency and power requirements and other system conditions.

• Pump Construction: Pump Casing - Cast Iron with 125 psig ANSI/PN16 flanges for working pressure below 175 psig (12 bar) at 150°F (65°C) and Ductile Iron with 250 psig ANSI/PN25 flanges for working pressures to 375 psig (25 bar) at 150°F (65°C). Suction and discharge connections shall be flanged and the same size and shall be drilled and tapped for seal flush and gauge connections.

• Impeller - Bronze, fully enclosed type. Dynamically balanced. Two-plane balancing is required where installed impeller diameter is less than 6 times the impeller width.

• Shaft - Provide Stainless Steel pump shaft.

• Coupling - Rigid spacer type of high tensile aluminum alloy. Coupling to be designed to be easily removed on site to reveal a space between the pump and motor shafts sufficient to remove all mechanical seal components for servicing and to be replaced without disturbing the pump or motor.

• Mechanical Seals - Shall be Stainless Steel multi-spring outside balanced type with Viton secondary seal, carbon rotating face and silicon carbide stationary seat. Provide 316 stainless steel gland plate. Provide factory installed flush line with manual vent.

• All split coupled pumps shall be provided with a lower seal chamber throttle bushing to ensure seals maintain positively cooling and lubrication.

• Seal flush line accessories, if required to improve seal chamber cleanliness: Supply in the flush line to the mechanical seal a 50 micron cartridge filter and sight flow indicator, to suit the working pressure encountered.
11.2 Vibration isolators

- Flexible pipe connectors shall be used on all piping connected to rotating equipment (chiller, pumps, air handling equipment) to reduce the transmission of noise and vibration, and to eliminate stresses in piping systems due to misalignment and thermal movement of the piping.

- Flexible connectors shall be of the single- or double-sphere molded joint configuration and shall meet or exceed specifications of the Rubber Expansion Joint Division, Fluid Sealing Association.

- Connectors shall be made of molded neoprene reinforced with nylon tire cord and shall have mild steel floating flanges or female union ends.

- Control rods shall be used with unanchored systems or with spring-mounted equipment where the pressures and movements exceed those the connectors are designed to withstand.

11.3 Accessories

- Triple Duty Valve
  
  o Furnish and install on the discharge side of each pump a triple duty combination valve. The valve is to incorporate the following three functions in one body:
    - Tight shut-off
    - Spring-closure type silent non-slam check
    - Effective throttling design capability
  
  o The body shall have two \( ¼'' \) connections on each side of the valve seat. One connection on each size shall have brass pressure and temperature metering ports, with Nordel check valves and gasketed caps. The other connection on each side shall be supplied with brass drain plugs. Metering ports are to be interchangeable with drain plugs to allow for measurement flexibility when installed in tight locations. The valve disk shall be bronze plug & disc type with high impact engineered resin seat to ensure tight shut-off and silent check operation.

  o The valve stem shall be stainless steel with flat surfaces provided for adjustment with open-end wrench.

- Suction guide
  
  o Furnish and install on the suction of each pump a suction guide, with outlet flow stabilizing guide vanes, removable stainless steel strainer and fine mesh start-up strainer.

- Standard of Acceptance: Taco, Armstrong, Bell & Gossett
12. DIGITAL CONTROLS

12.1 General

- The digital controls operating the in-floor radiant heating shall be an extension of the BAS operating the snow melting system.
- The same standards of acceptance will remain applicable as those for the snow melting system.

12.2 Devices and Operators

- Outdoor Air Temperature Sensors
  - Outdoor temperature sensor supplied and installed with the snow melting system; the information collected by the outdoor temperature sensor shall be used by the BAS to operate and reset the in-floor heating system.

- Immersion Temperature Sensors
  - Provide well-mounted fluid temperature sensors with the following minimum characteristics:
    - The sensors shall be 10k ohm thermistor encapsulated in a 6mm OD, 50m long probe, with screw fitting for insertion into a standard thermowell.
    - Operating range -10 to +100 degrees C.
    - End-to-end accuracy +/- 0.3 °C over the entire operating range.
    - The sensors shall be complete with brass thermowell. Provide a stainless steel thermowell where exposed to corrosive liquids.
    - Use conductive gel when mounting the sensor in the thermowell.
    - The sensors to be mounted on insulated piping shall be installed clear of the insulation.

- Space Temperature Sensors
  - Temperature sensors shall be Resistance Temperature Device (RTD).
  - Uses a 100 ohm thin film element to DIN 43 760 (IEC 751) with a tolerance of 0.3 deg C.
  - Local setpoint override with integrated slide potentiometer. This provides a variable 1 to 11K resistance signal at built-in terminals. The DDC panel can change the setpoint by +/- 3°C dependent on the resistance value.
  - The plastic housing of these sensors is suitable for use in environments of up to 80°C.
  - End-to-end accuracy +/- 0.3 °C over the entire operating range.
• **In-Slab Sensors**
  - Ambient Conditions: 32°F to 105°F (0°C to 41°C), 10% to 90% humidity (non-condensing)
  - Sensor Type: 10K J-curve
  - Tolerance: +/- 0.54°F (+/- 0.3°C)
  - Connections: Terminal screws
  - Sensor Length: 1"
  - Lead Length: 10'
  - Diameter (OD): 0.37"

• **Current Sensors (Analog)**
  - Current sensors (CT) shall be used for status monitoring of all motor-driven equipment, where specified.
  - Technical Performance – Output should be only 4-20mA only. Voltage output will not be accepted. End-to-end accuracy +/- 1% of full scale at each range.
  - The current sensors shall be mounted inside the starter cabinets whenever possible. If this is not possible due to space limitation, provide an enclosure to house the sensor.

• **Status Relays (Solid State)**
  - The status relays shall be mounted inside newly provided enclosures mounted near the respective equipment starter cabinets.

• **Automatic Control Valves**
  - Automatic control valves shall be supplied by the Controls Contractor and installed by the Mechanical Contractor.
  - Automatic control valves, unless otherwise specified, shall be globe type valves. Valves and actuators shall be ordered as one factory-assembled and tested unit.
  - Submit to the Consultant for review, a valve schedule containing the following information for each valve:
    - Valve type and size
    - Connection type
    - Line size
    - Valve manufacturer and model number
    - Valve flow coefficient
    - Design flow
    - Pressure drop across valve
    - Maximum close-off pressure
    - Actuator manufacturer and model number
    - Actuator maximum torque
o Valves 2” (50mm) and smaller shall be constructed of bronze. Valves 2½” (65mm) and larger shall have iron bodies and bronze mountings.
o All control valves shall have stainless steel stems.
o The bronze in bodies and bonnets of all bronze valves shall conform to ASTM B62 for valves rated up to 150psig (1035 Kpa) working pressure and to ASTM B61 for valves rated at 200 psig (1380 Kpa) working pressure. The bodies and bonnets of iron body valves shall conform to ASTM A126, Class B.
o Control valve discs and seats shall be of bronze for 100°C or less fluid temperature and of stainless steel for fluid temperatures above 100 °C.
o The control valves shall have tight shut-off. Flat disk valves are not acceptable.
o Control valves 2” (50mm) and smaller shall be complete with screwed ends type, except for bronze valves installed in soldered copper piping which shall be complete with soldering ends. Control valves larger than 2” (50mm) shall be complete with flanged end type and proper flanged adapters to copper shall be provided where flanged valves are installed in copper piping.
o The fluid control valves shall be sized for a pressure drop of 6 ft. water column or as indicated on mechanical drawings.
o Each automatic control valve must provide the design output and flow rates at pressure drops compatible with equipment selected. Each automatic control valve must be suitable for the particular system working pressure.
o Each automatic control valve shall be fitted with a position indicator. All the same type control valves shall be the products of a single manufacturer and have the manufacturer’s name, pressure rating and size clearly marked on the outside of the body.
o Unless otherwise indicated, control valves for proportional operation shall have equal percentage characteristics, while the control valves for open/shut two-position operation shall have straight line flow characteristics.

- **Automatic Control Valve Actuators**

  o Each automatic control valve shall be fitted with a “fail-safe” operator capable of tight shut-off against the differential imposed by the system.
  o Operators for valves in electric-electronic control systems shall be single phase AC, 24V electric motor operators.
  o Valve actuators on valves 3” diameter and larger shall be provided with a manual position override.
  o Valve actuators shall accept a 0-10VDC or 4-20mA control signal for all proportional applications. Floating point control of valves is not acceptable under any circumstances.

- **By-pass Relief valve**

  o Self-acting automatic differential pressure by-pass valve used in multi-zones systems that
  o have fluctuations in flow due to transient opening and closing of zones.
- The valve is supplied with male NPT thread
- Setting range: 1.67 to 16.72 feet of head (5 kPa to 50 kPa)
- Max. differential: 16.72 feet of head (50 kPa)
- Max. operating pressure: 145 psi (1,000 kPa)
- Max. flow temperature: 248°F (120°C)
- Max. leakage at closed valve: 0.22 gpm (0.83 l/min)

• **LAN Cabling**
  - All LAN cabling shall be Category V as defined by EIA/TIA 568A. The contractor shall test all cabling to verify that 100Mb bandwidth is supported. See commissioning requirements.
  - Cabling shall be 4 pair, 100 ohm UTP, #24 AWG solid copper conductor PVC insulated, with blue or grey colour coded jacket. FT6 rated cable shall be used unless otherwise required to meet building codes or by-laws.
  - Data outlets shall be RJ45, 8 pin connectors, with 50 microns of hard gold over nickel, minimum durability of 750 mating cycles and contact pressure of 100 grams per contact. Transmission characteristics shall meet TSB-40 Category V.
  - Provide one RJ45 data outlet adjacent to each device to be terminated (e.g. workstation PC, DDC panel, hub, etc.) Use a flexible patch cable to connect from the data outlet to the end device.
  - Provide protection from EMI sources in accordance with CSA-T530 article 4
  - The contractor shall test all cabling to verify conformance with TIA /EIA TSB-67 - Basic Link Test using a Level 2, bi-directional tester. See commissioning requirements.
  - Where there are more than 2-90 degree in a conduit run, provide a pull box between sections so that there are two bends or less in any one section.
  - Where a conduit run requires a reverse bend, between 100 degrees and 180 degrees, insert a pull box at each bend having an angle from 100 degrees to 180 degrees.
  - Ream all conduit ends and install insulated bushings on each end. Terminate all conduits that protrude through the structural floor 2” above the concrete base. Do not use a pull box in lieu of a conduit bend. Align conduits that enter a pull box from opposite ends with each other.

### 13. EXECUTION

13.1 **Examination**

- Verify that site conditions are acceptable for installation of the hydronic radiant heating system.
- Inspect the condition of the building site. The sub-grade should be level and drained; if required, a vapor barrier is installed; insulation is installed and is of correct type and thickness; wire mesh or rebar is installed correctly, and will not be moved after installation of pipe; the subfloor is properly installed. Correct any discrepancies before installing pipe.
• Inspect the site for possible hazards that could damage the flexible pipe, such as nails, staples, materials or tools from other trades, or chemicals that could spill and damage the pipe. Eliminate or remove any items or potential hazards before installing pipe.

• Do not proceed with installation of the hydronic radiant heating system until unacceptable conditions are fully met.

13.2 In-Floor Tubing Installation - Concrete Slab-on-Grade

• Sub-grade should be compacted, flat and smooth to prevent damage to pipe or insulation. Approved vapor barrier material should be installed.

• Approved thermal insulation, according to the design, shall be installed. If the design requires under-slab insulation, the structural engineer determines the vertical compressive strength of the high-density extruded board insulation. The radiant floor design determines the required insulation resistance value (R-value). Use edge insulation when the heated system directly contacts an exterior wall or beam.

• Reinforcing wire mesh, if required by structural design, must be flat and level, with all sharp ends pointing down. Fasten the tubing to the flat mesh or reinforcing bar in accordance with the tubing manufacturer’s installation recommendations. Install tubing at a consistent depth below the surface elevation as determined by the project engineer.

• Ensure sufficient clearance to avoid control joint cuts. 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.

• Finished grade of the thermal mass must be a minimum of ¾ inch (19 mm) above the top of PEX heating pipes.

• Do not install tubing within 6 inches (152mm) of any wall. Refer to the submitted radiant floor design layout for actual on-center information.

• Flexible pipe must be fastened at least every 36” (90 cm) when installed on wire mesh, insulation, or a wood subfloor. Pipe must be fastened at the beginning, midpoint and end of each 180° bend

• For tubing that exits the slab in a 90-degree bend, use metal or PVC bend supports.

• Preparation of wall cavity for Manifold installation:
o See drawings to determine the width of the wall cabinet and required wall opening dimensions. Mount the manifold cabinet allowing space for the screed to fill up the front of the pipe opening.

o If a cabinet is not used, prepare a suitable cavity for the manifold, with a secure mounting plate that will secure the manifold at least 30 inches (75 cm) above floor level.

o Manifold must be installed in an area that will allow easy access for supply/return piping as well as future access maintenance.

13.3 Under-slab Insulation

Under-slab insulation must be rated for use in that application. Insulation below heated concrete slabs must withstand the weight of the slab along with any additional dead or live loads. The long-term compressive creep (the ability of the slab to move relative to the plane of the insulation surface) should be accommodated; insulation manufacturers provide specific recommendations regarding the limits of live and dead loads, compressive creep and the proper application of their products.

Use under-slab insulation when high water tables and/or moist soil conditions are present. If a known moist soil condition exists, ensure an effective drainage system is installed beneath the intended radiant floor slab. After proper compaction, install a vapor barrier over the soil, and then install the high-density insulation.

13.4 Site Tests – In-Floor Tubing

• To ensure system integrity, pressure test the system before covering tubing in concrete or when other trades are working in the vicinity of the tubing. Pressure gauges used in testing and balancing shall show pressure increments of 1 psig and shall be located at or near the lowest points in the distribution system.

13.5 Air Test - In-Floor Tubing

• Charge the completed, yet unconcealed pipes with air at a minimum of 40 psig. Do not exceed 150 psig. Use liquid gas detector or soap solution to check for leakage at manifold connections.

13.6 Fluid Test - In-Floor Tubing

• Purge air from pipes. Charge the completed, yet unconcealed pipes with fluid. Perform a preliminary pressure test pressurizing the system to the greater of 1.5 times the maximum operating pressure or 100 psig for 30 minutes. Check the system for leakage, especially at all pipe joints.
• As the piping expands, restore pressure, first at 10 minutes into the test and again at 20 minutes. At the end of the 30-minute preliminary test, pressure shall not fall by more than 8 psig from the maximum, and there shall be no leakage.

• At the successful conclusion of the preliminary test, continue immediately with the main test. The main test pressure shall proceed at the same pressure as the preliminary test and shall last for 2 hours. The main test pressure shall not fall more than 3 psig after 2 hours. No leakage shall be detected.

• Pressure shall be maintained and monitored during installation of the thermal mass.

• If any leak is detected during installation of thermal mass, leak shall be found immediately and the area cleared for repair using manufacturer’s approved repair coupling. Retest before covering repair.

• Complete inspection and furnish test reports supplied by the manufacturer of the system. Test all electrical controls in accordance with respective installation manuals.

13.7 Cleaning - In-Floor Tubing

• Clean exposed surfaces upon completion of installation using clean, damp cloth. No cleaning agents are allowed. Comply with manufacturer’s recommendations.

13.8 Balancing Across the Manifold - In-Floor Tubing

• Balance all loops across each manifold for equal flow resistance based on actual loop lengths and total manifold flow. Refer to flow design values indicated in the equipment schedules.

• Balancing between manifolds is accomplished with a flow-control device installed on the return piping leg from each manifold. Refer to flow design values indicated in the equipment schedules.

• Accuracy: +/-5% of the design data indicated in the equipment schedules.

13.9 Above-Ground Piping Installation

• Install piping generally parallel to walls and column center lines, unless shown otherwise on the drawings. Space piping, including insulation, to provide 25 mm (one inch) minimum clearance between adjacent piping or other surface.

• Locate and orient valves to permit proper operation and access for maintenance of packing, seat and disc. Generally locate valve stems in overhead piping in horizontal position. Provide a union adjacent to one end of all threaded end valves. Control valves usually require reducers to
connect to pipe sizes shown on the drawing. Install butterfly valves with the valve open as recommended by the manufacturer to prevent binding of the disc in the seat.

13.10 Leak Testing Aboveground Piping

- Inspect all joints and connections for leaks and workmanship and make corrections as necessary, to the satisfaction of the Consultant. Tests may be either of those below, or a combination, as approved by the Owner.

- An operating test at design pressure, and for hot systems, design maximum temperature. The design maximum pressure would usually be the static head, or expansion tank maximum pressure, plus pump head

- A hydrostatic test at 1.5 times design pressure.

13.11 Flushing And Cleaning Piping Systems

- Initial flushing:
  - Remove loose dirt, mill scale, metal chips, weld beads, rust, and like deleterious substances without damage to any system component. Provide temporary piping or hose to bypass coils, control valves, exchangers and other factory cleaned equipment unless acceptable means of protection are provided and subsequent inspection of hide out areas takes place. Isolate or protect clean system components, including pumps and pressure vessels, and remove any component which may be damaged. Open all valves, drains, vents and strainers at all system levels. Remove plugs, caps, spool pieces, and components to facilitate early debris discharge from system. Sectionalize system to obtain debris carrying velocity of 1.8 m/S (6 feet per second), if possible. Connect dead end supply and return headers as necessary. Flush bottoms of risers. Install temporary strainers where necessary to protect downstream equipment. Supply and remove flushing water and drainage by various type hose, temporary and permanent piping and Contractor's booster pumps. Flush until clean as approved by the Consultant.

- Cleaning
  - Using products supplied by the chemical treatment manufacturer, circulate systems at normal temperature to remove adherent organic soil, hydrocarbons, flux, pipe mill varnish, pipe joint compounds, iron oxide, and like deleterious substances not removed by flushing, without chemical or mechanical damage to any system component. Removal of tightly adherent mill scale is not required. Keep isolated equipment which is "clean" and where dead end debris accumulation cannot occur. Sectionalize system if possible, to circulate at velocities not less than 1.8 m/S (6 feet per second). Circulate each section for not less than four hours. Blow down all strainers, or remove and clean as frequently as necessary. Drain and prepare for final flushing.
• **Final Flushing**
  
  o Return systems to conditions required by initial flushing after all cleaning solution has been displaced by clean make up. Flush all dead ends and isolated clean equipment. Gently operate all valves to dislodge any debris in valve body by throttling velocity. Flush for not less than one hour.

13.12 **Above-Ground Piping Insulation**

• Required pressure tests of piping joints and connections shall be completed and the work approved by the Consultant for application of insulation. Surface shall be clean and dry with all foreign materials, such as dirt, oil, loose scale and rust removed.

• Except for specific exceptions, insulate entire specified equipment, piping (pipe, fittings, valves, accessories). Insulate each pipe and duct individually. Do not use scrap pieces of insulation where a full length section will fit.

• Insulation materials shall be installed with smooth and even surfaces, with jackets and facings drawn tight and smoothly cemented down at all laps. Vapour barriers and insulation to be complete over full length of pipe or surface, without penetration for hangers, and without interruption at sleeves, pipe and fittings.

• Insulation on hot piping and equipment shall be terminated square at items not to be insulated, such as access openings and nameplates. Cover all exposed raw insulation with white sealer or jacket material.

• Piping work not to be insulated:
  
  o In hot piping: Unions, flexible connectors, control valves, PRVs, safety valves and discharge vent piping, vacuum breakers, thermostatic vent valves, exposed piping through floor for convectors and radiators. Insulate piping to within approximately 75 mm (3 inches) of uninsulated items.

• Apply insulation and coverings on hot piping while surface is between 50 to 60°C

13.13 **Circulating Pumps**

• Ensure that pump body does not support piping or equipment. Provide stanchions or hangers for this purpose. Refer to drawings and manufacturer’s installation instructions for details.

• Provide vibration isolation between the pumps and pipes, and between the pumps and the concrete housekeeping pads.
• Pipe drain tapping to floor drain. Provide drip pan and piped to nearest drain for each pump. Drip pan shall be sized to suit pump dimensions.

• Install volute venting pet cock in accessible location. Contractor to follow the manufacturer’s instructions for start-up and venting of mechanical seal. Change cartridge filter on regular basis prior to, and at turn over to owner.

• Contractor to provide and install one pressure gauge, piped to pump suction, pump discharge and strainer inlet. Pressure gauge tappings with necessary isolating valves to enable differential pressure reading across pump and strainer to be taken.

• Contractor shall cover motor during construction and have area clean of construction debris before starting the motor. If pump is used during temporary heating or flushing of system, contractor shall be responsible for changing mechanical seal or replacing motor bearings if so instructed by the board representative.

• The pump manufacturer shall coordinate with the hydronic balancer to balance the system to the required flows.

14. BAS EXECUTION

14.1 Sequence of Operation

• The in-floor heating system shall be constructed to operate as a secondary loop off the primary loop serving the heating plant. The interface between the primary loop and the in-floor heating loop shall be via a 3-way mixing valve.

• The system will be energized by the BAS if the outdoor temperature drops below 55°F (12°C) for more than 30 minutes. The system shall be de-energized by the BAS if the outdoor temperature raises above 60°F (15°C) for more than 30 minutes.

• When energized by the BAS, the secondary pump serving the in-floor heating shall start; the pump shall run continuously while the in-floor heating is energized.

• Note: if specifically instructed by GO Transit, the designer shall provide two secondary pumps, operating in a lead/lag arrangement. The lead/lag status of the pumps shall alternate at 168 hrs.

• Upon proof of flow, the 3-way mixing valve shall modulate as required to maintain the return glycol temperature at a temperature dependent in a linear fashion on the outdoor temperature as follows:
  
  o Outdoor temperature 45°F (7.5°C) and above: 80°F (26.5°C).
  o Outdoor temperature 5°F (-15°C) and below: 100°F (37.5°C).
• The individual zone thermostats shall actuate the two-way control valves for each circuit (in each manifold), such as to maintain the desired setpoint (occupied/unoccupied).

• The slab sensor shall monitor the floor temperature and shall close the 3-way mixing valve port connection to the primary loop if the slab temperature exceeds the high-limit determined by the floor covering manufacturer. This action shall over-ride any call for heat from the return loop sensor. The valve shall have its primary loop port closed for 30 minutes, after which the return temperature sensor shall regain control over the 3-way valve. The process shall be repeated as necessary to avoid exceeding the maximum slab temperature and damaging the floor finish.

• The mechanical by-pass relief valve shall operate to limit the pressure differential across the circulation pump at 110% of the design value noted in the equipment schedule.

• Alarms: the BAS shall generate alarms in case of:
  
  o Circulation pump failure - in lead/lag arrangements, the lag pump will start automatically.
  o Space temperature in any zone deviates +/-5°F (2.5°C) from the setpoint
  o Slab maximum temperature is exceeded by 5°F (2.5°C) - in addition to alarm, the pump will stop
  o Return loop temperature drops below 75°F (24°C) – only when system active.
  o Temperature differential between the glycol supply and return to/from the manifolds rises above 25°F (13°C) or drops below 10°F (5.5°C)

14.2 Power Sources And Wiring Methods

• All wiring shall be installed in EMT conduit unless specified otherwise. Exposed wiring in finished areas shall be installed in wiremold

• Wiring from DDC controllers to sensors and actuators and control system network and low voltage wiring running in accessible ceilings may be installed using LVT cable. Where the ceiling is used as a return air plenum, plenum rated cable shall be used in lieu of LVT cable.

• Power and control wiring shall be copper conductor (RW90). For power wiring, provide #12 AWG (minimum) with a 3% maximum voltage drop in accordance with CEC requirements. Control wiring shall be a minimum of #14 AWG, unless otherwise specified.

• The wires smaller than 18 gauge shall not be used and will not be accepted on the project except for: wiring between terminal computer devices, wire in standard communication cables, such as printers and short haul modems, wire used in communication networks, i.e. any cable transferring digital data, using twisted shielded pairs.
• The wiring from panels to devices shall be installed without splices. The use of crimp connectors is not allowed when connecting field wiring to sensor or device leads. The use of wire nuts is acceptable in this application.

• Power for control system shall not be obtained by tapping into miscellaneous circuits that could be inadvertently switched off. Only dedicated circuit(s) shall power the control system. Provide additional breakers or electrical panels as required.

• Mount transformers and other peripheral equipment in panels located in serviceable areas. Provide line-side breakers/fuses for each transformer.

• All 120 VAC power for any controls equipment shall be from dedicated circuits. Provide a breaker lock for each breaker used to supply the control system. Update the panel circuit directory.

• A dedicated power circuit may be used to power DDC panels and equipment within the same or adjoining mechanical rooms. The use of one power circuit to power DDC panels distributed throughout the building is not acceptable.

• For all DC wiring, positive conductors shall be WHITE or RED in colour while negative conductors shall be BLACK in colour.

14.3 Installation Of Temperature Sensors In Piping

• The Controls Contractor shall supervise and direct the Mechanical Contractor to ensure that thermowells are installed as described herein.

• For each immersion sensor, provide a compatible thermowell to the Mechanical Contractor for installation. Provide stainless steel thermowells where installed in piping carrying corrosive or chemically reactive fluids.

• Install thermowells in piping such that the bottom of the well does not make contact with the pipe. Install the well at a 90 degree elbow or tee where the pipe diameter is less than the well length.

14.4 Installation of Slab Temperature Sensor

• Place the slab sensor between two flexible tubes in the floor. If the floor is concrete or like construction, place the sensor no deeper than the mid-point of the slab.

• Place the sensor wire in a conduit for easy replacement. Ensure the sensor is in direct contact with the floor material.

14.5 Installation of Space Temperature Sensor
• Mount sensors at a height of 5’-6” above the finished floor.

• Provide a heavy-duty metal guard for all sensors or thermostats mounted in public areas such as stairways, vestibules, lobbies, waiting areas, etc. On the approval of the Consultant, a stainless steel, ventilated plate-type sensor may be used in lieu of guard or cage.

• Do not mount sensors on outside walls or other locations influenced by external thermal sources (e.g. computers, boiler rooms).

14.6 **Installation Of Automatic Control Valves And Actuators.**

• All control valves shall be supplied by the Controls Contractor and installed by the Mechanical Contractor, unless specified otherwise.

• The Controls Contractor shall test, adjust and verify the operation of each control valve to ensure that it is properly functioning, as required and left in safe working order.

14.7 **Cutting And Patching**

• All cutting, patching, painting and making good for the installation of the BAS work shall be done by the BAS Contractor. All cutting shall be performed in a neat and true fashion, with proper tools and equipment.

14.8 **Identification And Labeling Of Control Equipment**

• All field sensors or devices must have a laminoid tag (min. 3”x1”) attached with tie-wrap or adhesive indicating the point software name and hardware address (i.e. AHU1_MAT, 2.IP4). Tags must be secured by screws where mounted outside of the building, in un-heated spaces, in high humidity areas or where subject to vibration.

• All BAS panel power sources must be identified by a label (min. 3”x1”) indicating the source power panel designation and circuit number (i.e. “120vac fed from LP-2A cct #1).

• All wires shall be identified with the hardware address with a band-type self-adhesive strips or clip-on plastic wire markers at both ends.

• All rotating equipment controlled by the BAS shall have a tag or label affixed indicating that the equipment may start without warning.

• All BAS panels will be supplied with a point’s list sheet (within a plastic sleeve) attached to the inside door. Provide laminated wiring diagrams for all field mounted relay enclosures. Securely attach to the inside door. Identify power panels and circuit numbers of the equipment being controlled.
14.9 Systems Hardware Commissioning

- This contractor shall be responsible for the “end to end” commissioning, testing, verification and start-up of the complete control system hardware including panels, sensors, transducers, end devices, relays and wiring. Where applicable, this shall include any points from an existing and/or re-used automation system in the building.

- The Contractor shall prepare a hardware commissioning report containing the following information and test results:
  
  o Analogue inputs (i.e. temperatures, pressure, etc.) shall be verified with an approved calibration device. All actual temperature readings should be with +/- 1°C of the readings observed at the workstation. Record calibration adjustments and settings.

  o Analogue outputs shall be verified by manually commanding the output channel from the operator workstation to two or more positions within the 0-100% range and verifying the actual position of the actuator or device. All devices shall operate over their entire 0-100% range from a minimum control range of 10-90%. Record the actual output scale range (channel output voltage versus controller command) for each analogue end device.

  o Digital outputs shall be verified by witnessing the actual start/stop operation of the equipment under control.

  o Digital inputs shall be verified by witnessing the status of the input point as the equipment is manually cycled on and off.

  o Record all out-of-season or unverified points in the commissioning report as “non-commissioned”.

  o The BAS field panel power source shall be toggled on and off to ensure reboot functionality and power down memory retention of all parameters. During the power down test, all controlled system outputs shall go to their fail-safe position.

  o Verify PID loop tuning parameters by applying a step change to the current setpoint and observing the response of the controlled device. Setpoint should be reached in an acceptable period of time without excessive cycling or hunting of the controlled device. Provide a graph of the trend response to setpoint change for important controlled devices (e.g. valves 1-inch or larger, dampers on major air handlers, etc.).

  o Provide confirmation that a series of test alarms has been successfully received at a designated remote monitoring workstations.
- Include with the hardware commissioning report a site floor plan indicating the location of all equipment installed in concealed or recessed locations (e.g. interposing relays in ceiling spaces).

- Provide testing of all LAN cabling to ensure that 100Mb bandwidth is supported.

- Verify conformance with TIA /EIA TSB-67 - Basic Link Test using a Level 2, bi-directional tester. Provide all equipment necessary to carry out the required tests.

- The hardware commissioning report must be signed and dated by the Contractor’s technician performing the tests and participating Go Transit trades staff.

- At the completion of site commissioning, submit four (4) copies of hardware commissioning report to Go Transit.

14.10 **Substantial Completion Inspection**

- At the completion of the site hardware inspection, the Contractor shall test and verify that the system programming, graphics and alarm software is operating correctly and is in compliance all requirements of the specifications.

- The Contractor shall provide written notification to the Go Transit that the site is ready for the Substantial Completion Inspection by the Consultant.

- At the conclusion of the Substantial Completion Inspection, the Consultant shall issue a comprehensive site deficiency report to the Contractor for his immediate action.

- The Contractor shall correct all items noted in the site deficiency report within ten (10) business days of receipt.

- The Contractor shall provide written notification to the Go Transit that all items on the Consultant’s site deficiency report have been corrected.

14.11 **Training**

- Provide four (4) hours of operator training and four (4) hours of advanced maintenance level training per facility. The allocation of training hours and the number of participants shall be determined by Go Transit. The training hours may be divided up over several training sessions. The number of trainees to be determined by Go Transit but shall not exceed 8 for any one session. Training may take place on site, at another Go Transit location, at the Contractor’s office or any combination thereof.

- Submit a proposed training lesson plan for each session the Go Transit for review and approval.