Hydronic Radiant Floor Heating System Specification

Specification 23 21 12

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Amendment Record Sheet

Amendment in Clause No.	Date of Amendment	Description of Changes
Various	September 2018	Revised to coordinate with corresponding specifications.
Various	March 2023	Revised to ensure provision and operation of radiant floor heating system is independent of snow melt system.
1.9.5 a)	September 2025	Removed requirement for ISO certification qualification for manufacturers.
2.3.6	September 2025	Deleted reference to US standard for flame spread and smoke developed indices.

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1. GENERAL

1.1. SCOPE OF WORK

1.1.1. Provide hydronic radiant floor heating as required, scheduled and specified herein.

1.2. DESIGN CRITERIA AND PRINCIPLES

1.2.1. General

a) Supply and install a hydronic radiant floor heating system in line with this specification and sections of the Glycol Solution Snow Melting System specification that are applicable;

b) The building's structure and the floor finish installation influence 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 the required insulation;

c) This section shall be read in conjunction with Glycol Solution Snow Melting System specification 23 21 18;

d) In the context of this specification, "heating fluid" means polypropylene glycol as described in Glycol Solution Snow Melting System Specification 23 21 18. As described in the Glycol Solution Snow Melting System specification and herein this specification, there are requirements in the Glycol Solution Snow Melting System specification that are applicable to the provision of the radiant floor heating system and hence both specifications shall be read in conjunction but note that the two system types shall not be interconnected in anyway and should be designed to run independently of each other. The components of the radiant floor heating system shall only serve the respective radiant floor heating system. The operation of the radiant floor heating system shall be solely for the function of the radiant floor heating system;

e) As described in the Glycol Solution Snow Melting System specification is the provision of the microprocessor-based programmable control system. The control system, as described in the Glycol Solution Snow Melting System specification, shall also have the capacity to control the radiant floor heating system in cases where both snow melt system and radiant floor heating system exist on the same site. In scenarios where only one system (i.e., snow melt system or radiant floor heating system) exists, the control system shall be provided to only control that one system;

f) The radiant floor heating system shall operate in accordance with the sequence of operation described herein this specification;

g) The operation of the radiant floor heating system shall be independent of the operation of the snow melt system. The control system shall operate each system under its respective sequence of operation and programming, which controls and monitors their respective dedicated components (i.e., heating plant, distribution pumps, control valves, sensors, manifolds, etc.) independently of each other;

h) The outdoor air temperature sensor provided for the operation of the radiant floor heating system and the snow melting system can be common where both systems exist on the same site; and

i) The following components are not covered by this section:

1) The heating source for the heating agent and all associated components; they are included in the Glycol Solution Snow Melting System specification and are applicable to this Section;

2) The Building Automation System (BAS) central hardware and software components (control panels, software and graphics, server, etc.); they are included in the Glycol Solution Snow Melting System specification and are applicable to this section;

3) Mechanical General Conditions, including but not limited to duties of contractors, material substitutions, shop drawings, contractual obligations; they are included in the Glycol Solution Snow Melting System specification and are applicable to this Section; and

4) Requirements for testing, adjusting, and balancing (TAB) of hydronic systems are included in testing, adjusting and balancing specification and are applicable to this section.

1.2.2. Heating Load

a) 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;

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

c) 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); and

d) At the latitude of the designer, a safety coefficient can be added to account for the heat losses through the system (uninsulated manifolds, expansion tanks, etc.)

1.2.3. Indoor Setpoints

a) The indoor setpoints shall 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 Metrolinx for each application; and

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

1.2.4. Maximum Floor Surface Temperatures

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

1) Based on the total heat load calculation, calculate the radiant floor heat output requirement in W/m^2 ($Btu/h\text{-}ft^2$) for each thermal zone using the following formula: Floor Heat Output = Total Heat Load/Available Area;

2) 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;

3) 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 °C (°F), use the following equation:
Floor Surface Temp = Floor Heat Output/HTC + Indoor Temperature;

4) Where the Heat Transfer Coefficient (HTC) is recommended as 11.36 $W/m^2\text{-}K$ or 2.0 $Btu/(hr\text{-}ft^2\text{-}°F)$;

5) The maximum floor surface temperature shall not exceed 29 °C (85 °F), except for the 1.0 m (3 ft) wide perimeter band, where the temperature shall be raised up to 32 °C (90 °F); and

6) 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:

i) Reduce the heat requirements by improving building envelope efficiency;

ii) Increase the radiant surface area to include not only the floor but also walls and/or ceilings; and

iii) Use supplemental heat (baseboards, reheat coils).

1.2.5. Maximum Under-Floor Covering Temperature

a) 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 optimal 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;

b) In order to achieve the required Floor Surface Temperature, the temperature of the slab at the underside of the floor covering shall 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.);

c) 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;

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

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

1.2.6. Thermal Zoning

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

1.2.7. Thermal Expansion

a) The design shall 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 known as thermal bays by employing an arrangement of movement joints. The development of cracks in the floor or distortion in the piping is unacceptable; and

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

1.2.8. Pipe Spacing

a) 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;

b) The typical pipe spacing shall be:

1) Tiled floors: 150 mm (6”) to 200 mm (8”) in the perimeter band and 150 mm (6") to 225 mm (9") in the field of the thermal zone (to prevent concentrated hot and cold spots);

2) Carpeted floors: 150 mm (6”) to 200 mm (8”) in the perimeter band and 150 mm (6") to 300 mm (12") in the field of the thermal zone (to prevent concentrated hot and cold spots); and

3) Bare finished concrete: depends on heat loss, up to 450 mm (18") possible.

1.2.9. Pipe Sizes

a) The embedded pipe sizes shall be selected as follows:

1) 15 mm (5/8"Ø) for circuits up to 120 m (400 ft)

2) 18 mm (3/4"Ø) for circuits up to 150 m (500 ft)

3) 25 mm (1"Ø) for circuits larger than 150 m (500 ft)

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

1) Pipe spacing 150 mm (6") to 0.6 m (2 ft) pipe length per sq ft of space;

2) Pipe spacing 200 mm (8") to 0.45 m (1.5 ft) pipe length per sq ft of space;

3) Pipe spacing 225 mm (9") to 0.39 m (1.3 ft) pipe length per sq ft of space;

4) Pipe spacing 250 mm (10") to 0.36 m (1.2 ft) pipe length per sq ft of space;

5) Pipe spacing 300 mm (12") to 0.3 m (1.0 ft) pipe length per sq ft of space.

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

1.2.10. Pipe Layout Guideline

a) Following are some basic pipe layout recommendations:

1) Shall not run pipes under built-ins (e.g., cabinets, window seats, large appliances, raised hearths, stairs);

2) Keep pipes a minimum of 15 cm (6”) 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;

3) Keep balanced circuit lengths within 10% of each other;

4) Design separate circuits for different rooms, allowing better room temperature control;

5) Keep thermal zones reasonably sized;

6) Shall not run circuit pipes across movement joints; and

7) Select the pipe size that is large enough for the application;

1.2.11. Fluid Heating Temperature

a) Use lowest heating fluid temperature that shall provide the required panel surface temperature. This shall minimize thermal stress on slabs and floor coverings, and minimize overshooting of the desired ambient room temperature;

b) Include the following criteria:

1) Temperature drop across the embedded circuits: 11 °C (20 °F); and

2) Average fluid temperature (between supply and return): 43.5 °C (110 °F).

c) Floor coverings, pipe spacing and selected indoor temperature shall have a significant impact on the average fluid temperature. Highly resistive floor coverings (e.g., carpet and padding) require the fluid temperature shall 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; and

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

1.2.12. Manifold Sizing

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

1) 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 to be provided to a large, central manifold (such as 10, 11, 12 or more circuits); and

2) 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.

b) Based on 1.2.12(a), determine the number of circuits for each manifold. Zoning the building usually increases the number of circuits, resulting in manifolds with more outlets;

c) A manifold shall 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;

d) 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 11.1 °C or 20 °F);

e) The fluid flow through the manifold shall be calculated as the sum of all the circuit flows served by the respective manifold; and

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

1.2.13. Manifold Location

a) Identify the manifold location before beginning the pipe layout;

b) Use the following criteria:

1) Manifolds shall always be installed within the heated space, and not be located in an unheated area;

2) 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);

3) Ensure that the manifolds fit in the available space;

4) Review the proximity to the heat source to minimize the distribution piping;

5) Review the area security to prevent tampering, especially areas open to the public; and

6) Review maintenance clearances.

c) 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).

1.2.14. Piping Layout

a) 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;

b) Heat requirements are higher near exterior walls and windows and diminish toward the center of the room. A 1.0m (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;

c) Following are some basic pipe layout recommendations:

1) Do not run pipes under built-ins (e.g., cabinets, window seats, large appliances, raised hearths, stairs);

2) 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;

3) Keep balanced circuit lengths within 10% of each other;

4) Design separate circuits for different rooms, allowing better room temperature control;

5) Keep area types reasonably sized;

6) Do not run circuit pipes across movement joints; and

7) Select the pipe size that is large enough for the application;

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

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

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

1.2.15. Pump Selection

a) 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 shall be overcome from all components;

b) 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; and

c) The pump outlet pressure shall not exceed the embedded pipe ratings. Failure to follow this instruction shall damage the pipe, resulting in leaks and operational failures.

1.2.16. Control Strategies

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

b) 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 10 °C to 12.5 °C (18 °F and 22 °F);

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 shall be 2-position or modulating type; and

d) 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.

1.2.17. Design requirements are also based on Part 2 specified requirements of products.

1.3. RELATED WORKS

1.3.1. Section 20 05 05 - Mechanical Work General Instructions.

1.3.2. Section 20 05 10 - Basic Mechanical Materials and Methods.

1.3.3. Section 20 05 40 – Mechanical Work Commissioning.

1.3.4. Section 20 05 55 - Firestopping and Smoke Seal Systems.

1.3.5. Section 23 20 00 – HVAC Piping and Pumps.

1.3.6. Section 23 21 18 - Glycol Solution Snow Melting System.

1.3.7. Section 23 52 19 - Wall Hung Condensing Hot Water Boilers.

1.4. REFERENCE STANDARDS

1.4.1. Standards and codes shall be latest editions adopted by and enforced by local governing authorities.

1.4.2. CSA B214, Installation Code for Hydronic Heating Systems.

1.4.3. CAN/CSA B137.5, Crosslinked Polyethylene (PEX) Tubing Systems for Pressure Applications.

1.4.4. ASTM F876, Standard Specification for Crosslinked Polyethylene (PEX) Tubing.

1.4.5. ASTM F877, Standard Specification for Crosslinked Polyethylene (PEX) Hot and Cold Water Distribution Systems.

1.4.6. ASTM F1960, Standard Specification for Cold Expansion Fittings with PEX Reinforcing Rings for Use with Cross-linked Polyethylene (PEX) Tubing.

1.4.7. CAN/ULC S102, Surface Burning Characteristics of Building Materials and Assemblies.

1.4.8. CAN/ULC S102.2, Standard Method of Test for Surface Burning Characteristics of Flooring, Floor Coverings, and Miscellaneous Materials and Assemblies.

1.4.9. Local governing building code.

1.5. TRAINING

1.5.1. Training shall be a full review of all components, including but not limited to a full operation and maintenance demonstration, with abnormal events.

1.5.2. Include for 3 training sessions of maximum 7 hours duration per session for 6 Metrolinx people per session.

1.5.3. Refer to Section 20 05 05 for additional general requirements.

1.6. WARRANTY

1.6.1. Warranty shall be in line with Contractual Requirements.

1.6.2. Submit, at Substantial Performance of the Work, a non-prorated transferable repair or replacement warranty in name of Metrolinx, issued by and signed by system component manufacturer, covering materials against failure due to defects in material and/or workmanship as follows:

a) PEX Tubing:

1) 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.

b) Manifolds and Fittings:

1) Minimum 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.

c) Controls and Electrical Components:

1) Minium 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.

d) Minimum 2 years for other product and labour requirements.

1.7. DELIVERY, STORAGE AND HANDLING.

1.7.1. Manufacturer’s ordering instructions and lead-time requirements shall be followed to avoid construction delays.

1.7.2. Materials shall be delivered in manufacturer’s original, unopened, undamaged containers with identification labels intact.

1.7.3. Materials shall be stored and protected from exposure to harmful environmental conditions and at temperature and humidity conditions recommended by the manufacturer.

1.7.4. All PEX tubing shall be stored in cartons or under cover to avoid dirt or foreign material from entering the tubing.

1.7.5. PEX tubing shall not be exposed to direct sunlight for more than 30 days. If construction delays are encountered, the tubing shall be covered to prevent exposure to direct sunlight.

1.8. SUBMITTALS

1.8.1. Refer to submittal requirements in Section 20 05 05.

1.8.2. Submit shop drawings and/or product data sheets for the following:

a) Cross-linked polyethylene (PEX) floor heating grid tubing, fittings and accessories, manifold assembly, control components and controls;

b) Copy of system manufacturer's loop layout design indicating water flows and temperatures, floor profiles with floor coverings, and heating outputs;

c) Certified tubing and piping layout and schematic for each system zone;

d) Certified power wiring schematic and a certified control wiring schematic with sequence of operation for each system zone;

e) Letter from system component manufacturer stating system components proposed meet all requirements of Specification; and

f) Copy of manufacturer's training certificate.

1.8.3. Submit, prior to application for Substantial Performance of the Work, start-up or test data specified in Part 3 of this Section.

1.8.4. Submit letters of installation certification from system manufacturer's representative as specified in Part 3 of this Section.

1.8.5. Submit shop drawings/product data sheets as follows:

a) To regulatory authority for review and approval prior to submitting to Consultant; and

b) Copies of all calculations, stamped and signed by same engineer who signs layout drawings, and a listing of all design data used in preparing the calculations, system layout and sizing requirements.

1.8.6. Product Data

a) Submit product data sheets indicating:

1) Technical data, supplemented by bulletins, component illustrations, detailed views, technical descriptions of items, and parts lists;

2) Performance criteria, compliance with reference standards, characteristics, limitations, and troubleshooting protocol;

3) Product transportation, storage, handling, and installation requirements; and

4) Product identification in accordance with Metrolinx requirements;

1.8.7. Shop Drawings

a) Submit shop drawings indicating:

1) Capacity and ratings;

2) Mounting details to suit locations shown, indicating methods and hardware used; and

3) Applicable control components and control wiring schematic.

1.8.8. Commissioning Package

a) Submit the following in accordance with Sections 20 05 05 and 20 05 40:

1) Commissioning Plan;

2) Commissioning Procedures;

3) Certificate of Readiness;

4) Complete test sheets specified in Section 20 05 40 and attach them to the Certificate of Readiness; and

5) Source Quality Control inspection and test results, and attach to the Certificate of Readiness.

1.8.9. Commissioning Closeout Package:

a) Submit the following in accordance with Section 20 05 05:

1) Deficiency Report;

2) Commissioning Closeout Report; and

3) Submit the following for each Product for incorporation into the Operation and Maintenance Manuals in accordance with Section 20 05 05:

i) Identification: manufacturer’s name, type, year, serial number, number of units, capacity, and identification to related systems;

ii) Functional description detailing operation and control of components;

iii) Performance criteria and maintenance data;

iv) Safety precautions, including product SDS of all chemical components in the system;

v) Operating instructions and precautions;

vi) Component parts availability, including names and addresses of spare part suppliers;

vii) Maintenance and troubleshooting guidelines/protocol;

viii) Product storage, preparation, handling, and installation requirements;

ix) Commissioning Report; and

x) Any relevant permits or inspection records for radiant floor heating components.

1.9. QUALITY ASSURANCE

1.9.1. Products and work shall comply with codes, regulations and standards listed above and applicable local codes and regulations.

1.9.2. Site personnel shall be licensed in jurisdiction of the work and under continuous supervision of a foreman who is an experienced system installer.

1.9.3. PEX tubing used shall be listed and rated (temperature and pressure) for radiant floor heating applications.

1.9.4. Prior to installation of system components, meet on-site with system component manufacturer's representative and trades whose work is related to successful installation of systems to confirm floor areas involved are ready for tubing installation.

1.9.5. Manufacturers Qualifications:

a) Manufacturer of product shall have produced similar product for a minimum period of five years. When requested by Consultant, an acceptable list (minimum of 5) installations with similar product shall be provided demonstrating compliance with this requirement; and

b) Where manufacturers provide after installation onsite inspection of product installations, include for manufacturer's authorized representative to perform onsite inspection and certificate of approvals.

1.9.6. Installers Qualifications:

a) Installers for work shall be performed by or work under a licensed Mechanical Contractor;

b) Installers shall be journeyman tradesmen with a minimum of three years of successful installation of PEX radiant floor system components supplied by manufacturer of components;

c) Installers shall furnish all labour, materials, tools, equipment, appliances, and services necessary to deliver and install all hydronic radiant dimensions to the hydronic radiant manufacturer; and

d) Where manufacturers provide training sessions to installers and certificates upon successful completion, installers to have obtained such certificates and submit copies with shop drawings.

1.9.7. Regulatory Requirements:

a) Products and work to comply with applicable local governing authority regulations, bylaws, and directives; and

b) Include for required inspections and certificate of approvals of installation work from local governing authorities.

2. PRODUCTS

2.1. BOILER

2.1.1. Refer to Wall Hung Condensing Hot Water Boilers specification.

2.2. IN-LINE CIRCULATOR PUMP

2.2.1. General:

a) Refer to pump schedule for pump size, flows, heads, motor speed, enclosure, efficiency, power requirements and other system conditions; and

b) Pump shall be BF (Bronze Fitted) construction, three-piece design featuring the Armstrong shaft and bearing module, which shall fit all models S25 through S57 and H32 through H54. The shaft oil-lubricated bronze sleeve bearing. Pump shall be equipped with a water-tight, long-life, "ARMSEAL" mechanical seal and be required for 225 °F, 125 psi.

2.2.2. Circulator Pump Circuit Balancing Valve

a) Furnish and install, downstream of each in-line circulator pump, a circuit balancing valve. Valves shall be of the Y-Pattern, equal percentage globe-style and provide three functions:

1) Precise flow measurement;

2) Precision flow balancing; and

3) Positive drip-tight shut-off.

b) Valve shall provide multi-turn, 360° adjustment with micrometre-type indicators located on the valve hand wheel. Valves shall have a minimum of five full 360° hand wheel turns. 90° 'circuit-setter' style ball valves are not acceptable. Valve handle shall have hidden memory feature, which shall provide a means for locking the valve position after the system is balanced.

c) Valves shall be furnished with precision precision-machined venturi built into the valve body to provide highly accurate flow measurement and flow balancing. The venturi shall have two, ¼" threaded brass metering ports with check valves and gasketed caps located on the inlet side of the valve. Valves shall be furnished with flow smoothing fins downstream of the valve seat and integral to the forged valve body to make the flow more laminar. The valve body, stem and plug shall be brass. The hand wheel shall be high-strength resin.

2.3. TUBING

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

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

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

2.3.4. 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).

2.3.5. 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.

2.3.6. 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 CAN/ULC S102.2 (in Canada).

2.3.7. 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/OC-100m of tubing)

2.4. MANIFOLD

2.4.1. 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.

2.4.2. Brass Manifolds (¼” diameter)

a) For system compatibility, use 1¼” brass manifolds offered by the tubing manufacturer;

b) Use manifolds constructed of dezincification-resistant brass;

c) The manifold assemblies shall be mounted inside the wall cavity. Provide manifold boxes sized accordingly;

d) Use manifold mounting brackets offered by the tubing manufacturer;

e) Manifolds shall be capable of individual flow control for each loop on the manifold through valve actuators available from the manifold supplier;

f) Manifolds shall feature manual flow balancing capability within the manifold body for balancing unequal loop lengths across the manifold;

g) Install flow setter on the return leg from the manifold to provide flow balancing between manifolds;

h) Manifolds support 5/16" through ⅝" PEX tubing; and

i) Each manifold location shall have the ability to vent air manually from the system.

2.4.3. Copper Manifolds (2" diam.)

a) For system compatibility, use 2" valved copper manifolds manufactured from Type L copper material, offered by the PEX tubing manufacturer;

b) Install valved copper manifolds primarily for wall-hung or boxed applications;

c) Use manifolds with an isolation valve or a combination isolation and balancing valve on each outlet;

d) Use manifolds that support ⅝" or ¾" PEX tubing;

e) Ensure manifold end cap offers tapping for ⅛" FNPT and ½" FNPT for vent and drain;

f) Install supply-and-return piping to the manifold in a reverse-return configuration to ensure self-balancing; and

g) If the supply-and-return piping is in direct-return configuration, install an balance flow setter on the return leg of each manifold to the mains.

2.5. FITTING

2.5.1. 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.

2.5.2. Compression nut manifold fittings shall be manufactured of corrosion-resistant brass with a barbed insert and a reusable split compression ring.

2.5.3. Compression-sleeve fittings shall be manufactured of brass and shall be supplied by the piping manufacturer as part of a proven cataloged system.

2.5.4. 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.

2.6. ACCESSORIES

2.6.1. Pressure gauge on each manifold.

2.6.2. Temperature gauge on each manifold.

2.7. DIGITAL CONTROLS

2.7.1. General

a) The digital controls operating the in-floor radiant heating shall be an extension of the BAS operating the snow melting system; and

b) The same standards of acceptance shall remain applicable as those for the snow melting system.

2.7.2. Devices and Operators

a) Outdoor Air Temperature Sensors

1) 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.

b) Immersion Temperature Sensors

1) Provide well-mounted fluid temperature sensors with the following minimum characteristics:

i) The sensors shall be 10k ohm thermistors encapsulated in a 6mm OD, 50m long probe, with screw fitting for insertion into a standard thermowell;

ii) Operating range -10 to +100 °C;

iii) End-to-end accuracy ± 0.3 °C over the entire operating range;

iv) The sensors shall be complete with brass thermowell. Provide a stainless steel thermowell where exposed to corrosive liquids;

v) Use conductive gel when mounting the sensor in the thermowell; and

vi) The sensors shall be installed clear of the insulation when mounted on insulated piping.

c) Space Temperature Sensors

1) Temperature sensors shall be Resistance Temperature Device (RTD);

2) Uses a 100 ohm thin film element to DIN 43 760 (IEC 751) with a tolerance of 0.3 °C;

3) 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;

4) The plastic housing of these sensors is required for use in environments of up to 80 °C; and

5) End-to-end accuracy ± 0.3 °C over the entire operating range.

d) In-Slab Sensors

1) Ambient Conditions: 32 °F to 105 °F (0 °C to 41 °C), 10% to 90% humidity (non-condensing);

2) Sensor Type: 10K J-curve;

3) Tolerance: ±0.54 °F (± 0.3 °C);

4) Connections: Terminal screws;

5) Sensor Length: 1"

6) Lead Length: 10'

7) Diameter (OD): 0.37"

e) Current Sensors (Analog)

1) Current sensors (CT) shall be used for status monitoring of all motor-driven equipment, where specified;

2) Technical Performance – Output should be only 4 to 20 mA only. Voltage output shall not be accepted. End-to-end accuracy ±1% of full scale at each range; and

3) The current sensors shall be mounted inside the starter cabinets whenever possible. If this is not possible due to space limitations, provide an enclosure to house the sensor.

f) Status Relays (Solid State)

1) The status relays shall be mounted inside newly provided enclosures mounted near the respective equipment starter cabinets.

g) Automatic Control Valves

1) Automatic control valves shall be supplied by the Controls Contractor and installed by the Mechanical Contractor;

2) Automatic control valves, unless otherwise specified, shall be globe-type valves. Valves and actuators shall be ordered as one factory-assembled and tested unit;

3) Submit to the Consultant for review, a valve schedule containing the following information for each valve:

i) Valve type and size;

ii) Connection type;

iii) Line size;

iv) Valve manufacturer and model number;

v) Valve flow coefficient;

vi) Design flow;

vii) Pressure drop across valve;

viii) Maximum close-off pressure;

ix) Actuator manufacturer and model number; and

x) Actuator maximum torque

4) Valves 2” (50 mm) and smaller shall be constructed of bronze. Valves 2½” (65 mm) and larger shall have iron bodies and bronze mountings;

5) All control valves shall have stainless steel stems;

6) The bronze in bodies and bonnets of all bronze valves shall conform to ASTM B62 for valves rated up to 150 psig (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;

7) 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;

8) The control valves shall have tight shut-off. Flat disk valves are not acceptable;

9) Control valves 2" (50 mm) 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" (50 mm) shall be complete with flanged end type and proper flanged adapters to copper shall be provided where flanged valves are installed in copper piping;

10) The fluid control valves shall be sized for a pressure drop of 6 ft water column or as indicated on mechanical drawings;

11) Each automatic control valve shall provide the design output and flow rates at pressure drops compatible with equipment selected. Each automatic control valve shall be required for the particular system working pressure;

12) Each automatic control valve shall be fitted with a position indicator. All the same type of 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; and

13) 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.

h) Automatic Control Valve Actuators

1) Each automatic control valve shall be fitted with a "fail-safe" operator capable of tight shut-off against the differential imposed by the system;

2) Operators for valves in electric-electronic control systems shall be single-phase, 24 VAC electric motor operators;

3) Valve actuators on valves 3" diameter and larger shall be provided with a manual position override; and

4) Valve actuators shall accept a 0 to 10VDC or 4 to 20 mA control signal for all proportional applications. Floating point control of valves shall not be provided.

i) By-pass Relief Valve

1) Self-acting automatic differential pressure by-pass valve used in multi-zone systems shall:

i) Be capable of managing flow variations caused by zone openings and closures

ii) Be supplied with male NPT thread

iii) Setting range: 1.67 to 16.72 feet of head (5 kPa to 50 kPa)

iv) Max. differential: 16.72 feet of head (50 kPa)

v) Max. operating pressure: 145 psi (1,000 kPa)

vi) Max. flow temperature: 248 °F (120 °C)

vii) Max. leakage at closed valve: 0.22 gpm (0.83 l/min)

j) LAN Cabling

1) All LAN cabling shall be Category V as defined by EIA/TIA 568A. Test all cabling to verify that 100 Mbps bandwidth is supported. See commissioning requirements;

2) 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;

3) 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;

4) Provide one RJ45 data outlet adjacent to each device shall 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;

5) Provide protection from EMI sources in accordance with CSA-T530 article 4;

6) Test all cabling to verify conformance with TIA /EIA TSB-67 - Basic Link Test using a Level 2, bi-directional tester. See commissioning requirements;

7) Where there are more than two 90-degree bends in a conduit run, provide a pull box between sections so that there are two bends or fewer in any one section;

8) 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; and

9) 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. Shall not use a pull box in lieu of a conduit bend. Align conduits that enter a pull box from opposite ends with each other.

3. EXECUTION

3.1. BOILERS

3.1.1. Refer to Wall Hung Condensing Hot Water Boilers specification 23 52 19.

3.2. PUMPS

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

3.2.2. Provide vibration isolation between the pumps and pipes, and between the pumps and the concrete housekeeping pads.

3.2.3. 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.

3.2.4. Install volute venting pet cock in accessible location. Follow the manufacturer's instructions for start-up and venting of mechanical seal. Change cartridge filter on the required schedule prior to, and at turnover to owner.

3.2.5. Provide and install one pressure gauge, piped to pump suction, pump discharge and strainer inlet. Pressure gauge tapings with necessary isolating valves to enable differential pressure reading across pump and strainer shall be taken.

3.2.6. Cover motor during construction and have area clean of construction debris before starting the motor. If a 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.

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

3.3. TUBINGS

3.3.1. Provide hydronic radiant floor heating zones and piping manifold assemblies. System installation shall be in strict accordance with manufacturer’s instructions.

3.3.2. In-Floor Tubing Installation - Concrete Slab-on-Grade

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

b) 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.

c) Reinforcing wire mesh, if required by structural design, shall 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.

d) Ensure the required clearance to avoid control joint cuts. In areas where tubing shall cross metal expansion joints in the concrete, ensure the tubing passes below the joints. Depending on the manufacturer's and structural engineer's recommendations, fibrous expansion joints shall tolerate penetration.

e) Finished grade of the thermal mass shall be a minimum of ¾" (19 mm) above the top of PEX heating pipes.

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

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

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

i) Preparation of wall cavity for Manifold installation:

1) 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;

2) If a cabinet is not used, prepare a required cavity for the manifold, with a secure mounting plate that shall secure the manifold at least 30" (75 cm) above floor level; and

3) Manifold shall be installed in an area that shall allow easy access for supply/return piping as well as future access maintenance.

3.3.3. Under-slab Insulation

a) Under-slab insulation shall be rated for use in that application. Insulation below heated concrete slabs shall withstand the weight of the slab, along with any additional dead or live loads.

b) 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.

c) 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 vapour barrier over the soil, and then install the high-density insulation.

3.4. CONTROLS

3.4.1. Sequence of Operation

a) 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 (secondary) loop shall be via a 3-way mixing valve.

b) The system shall 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 rises above 60 °F (15 °C) for more than 30 minutes.

c) 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.

d) Provide two secondary pumps, operating in a lead/lag arrangement. The lead/lag status of the pumps shall alternate at 168 hours unless specified otherwise.

e) 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:

1) Outdoor temperature 45 °F (7.5 °C) and above: 80 °F (26.5 °C);

2) Outdoor temperature 5 °F (-15 °C) and below: 100 °F (37.5 °C).

3.4.2. The individual zone thermostats shall actuate the two-way control valve for each circuit (in each manifold), such as to maintain the desired setpoint (occupied/unoccupied).

3.4.3. 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 override 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.

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

3.4.5. Alarms: the BAS shall generate alarms in case of:

a) Circulation pump failure - in lead/lag arrangements, the lag pump shall start automatically;

b) Space temperature in any zone deviates ±5 °F (±2.5 °C) from the setpoint;

c) Slab maximum temperature is exceeded by 5 °F (2.5 °C) - in addition to alarm, the pump shall stop;

d) Return loop temperature drops below 75 °F (24 °C) – only when system active; and

e) 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).

3.4.6. Power Sources And Wiring Methods

a) Exposed wiring is not allowed in any areas. All wiring shall be installed in conduit type as follows:

1) All conduit that is located in damp and wet spaces shall be RGSEC (Rigid Galvanized Steel Epoxy Coated); and

2) Conduit that is exposed and in dry, indoor, temperature-controlled spaces shall be RGS (Rigid Galvanized Steel)

b) Wiring from DDC controllers to sensors and actuators and control system network, and low-voltage wiring running in accessible ceilings shall 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;

c) 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;

d) The wires smaller than 18 gauge shall not be used and shall 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;

e) 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;

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

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

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

i) A dedicated power circuit shall be used to power DDC panels and equipment within the same or adjoining mechanical rooms. One power circuit shall not be used to power DDC panels distributed throughout the building; and

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

3.4.7. Installation Of Temperature Sensors In Piping

a) The Controls Contractor shall supervise and direct the Mechanical Contractor to ensure that thermowells are installed as described herein;

b) 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; and

c) Install thermowells in piping such that the bottom of the well shall 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.

3.4.8. Installation of Slab Temperature Sensor

a) 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; and

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

3.4.9. Installation of Space Temperature Sensor

a) Mount sensors at a height of 5′ 6′′ above the finished floor;

b) 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 shall be used in lieu of guard or cage; and

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

3.4.10. Installation Of Automatic Control Valves And Actuators.

a) All control valves shall be supplied by the Controls Contractor and installed by the Mechanical Contractor, unless specified otherwise; and

b) 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.

3.5. SYSTEMS HARDWARE COMMISSIONING

3.5.1. 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.

3.5.2. Prepare a hardware commissioning report containing the following information and test results:

a) Analogue inputs (i.e., temperatures, pressure, etc.) shall be verified with an approved calibration device. All actual temperature readings should be within ±1 °C of the readings observed at the workstation. Record calibration adjustments and settings;

b) 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;

c) Digital outputs shall be verified by witnessing the actual start/stop operation of the equipment under control;

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

e) Record all out-of-season or unverified points in the commissioning report as "non-commissioned."

f) 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;

g) 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 controlled devices (e.g., valves 1" or larger, dampers on major air handlers, etc.);

h) Provide confirmation that a series of test alarms has been successfully received at a designated remote monitoring workstation;

i) 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);

j) Provide testing of all LAN cabling to ensure that 100 Mbps bandwidth is supported;

k) 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;

l) The hardware commissioning report shall be signed and dated by the Contractor's technician performing the tests and participating Metrolinx trades staff;

m) At the completion of site commissioning, submit hardware commissioning report to Metrolinx;

n) The hardware commissioning report shall be signed and dated by the Contractor's technician performing the tests and participating Metrolinx trades staff; and

o) At the completion of site commissioning, submit four (4) copies of hardware commissioning report to Metrolinx.

3.6. SUBSTANTIAL COMPLETION INSPECTION

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

3.6.2. Provide written notification to Metrolinx that the site is ready for the Substantial Completion Inspection by the Consultant.

3.6.3. Issue a comprehensive site deficiency report to the Contractor for his immediate action.

3.6.4. Correct all items noted in the site deficiency report within ten (10) business days of receipt.

3.6.5. Provide written notification to Metrolinx that all items on the Consultant’s site deficiency report have been corrected.

END OF SECTION