Subfloor Heating for Freeze Protection

Ice rinks built on grade slab with air duct heating systems prove to be reliable.

by Claude Dumas

The city of Montreal operates 25 indoor skating rinks and uses four different technologies for subfloor heating. Nine of the rinks are not heated and seven rinks were heated with low voltage electricity applied to buried steel wire mesh systems. Four of the rinks are heated with buried mineral insulated electric heating cable system. Three skating rinks were built on insulated structural concrete floors with a ventilated crawl space under the floor. Two rinks are heated with air duct systems.

AIR DUCT SYSTEMS

The first air duct system, at the Sylvio-Mantha Arena, was built by Montreal in 1982 as part of the original construction. The second system, at the Clement-Jette Arena, was built in 1988 during the replacement of a slab that was damaged by frost heave. It is identical to the Sylvio-Mantha arena air duct subfloor heating system. Both have been found to be effective and have not shown any sign of deterioration.

SYSTEM DESIGN

With the heat exchanger system, warm air is supplied in the ground located under the ice rink slab system via a series of PVC pipes, as shown in *Figure 1*. The underside of the skating rink slab system is insulated with two layers of two inch polystyrene foam boards, laid with overlapped joints and wrapped in a polyethylene vapour barrier.

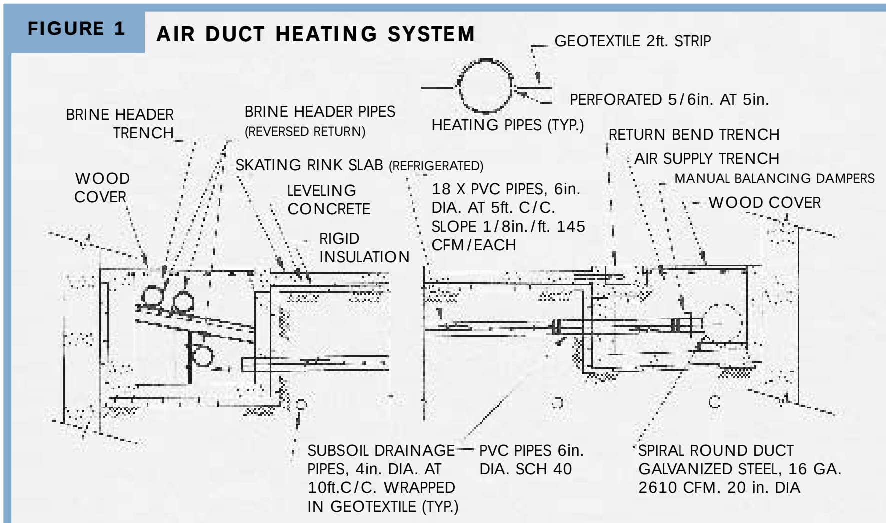
Six inch diameter heating pipes are perforated and installed under a cover of geotextile membrane with a slope of 1/8"/ft. The air supply duct, which is a 20" diameter, galvanized steel spiral duct, is located in the air supply trench. The heating pipes are placed at five foot centres and fed from a series of tees and manual balancing dampers located on the air supply duct There are 18 heating pipes supplying warm air at a rate of 145 cfm each. The return air is discharged directly into the brine header trench that is used as a return plenum, feeding a return air duct and return fan.

"THE VENTILATION/HEATING SYSTEM COULD BE BUILT IN A SINGLE MECHANICAL ROOM WITH MOST OF THE SUPPLY AND RETURN DUCT LOCATED OVERHEAD IN THE ARENA."

SUBSOIL DRAINAGE

The subsoil drainage system, also shown in *Figure 1*, is a series of perforated four inch diameter PVC drainage pipes, wrapped in geotextile membrane and placed at a spacing of 10' centres. Its function is to minimize water flow into the air duct distribution system and the trench.

FIGURE 1 AIR DUCT HEATING SYSTEM



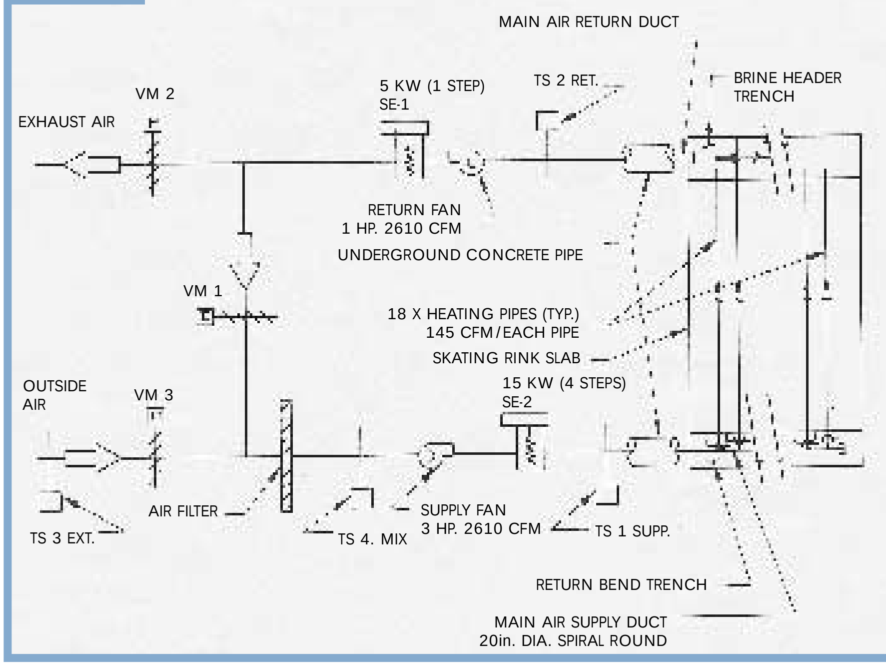
HEATING/VENTILATING SYSTEM

The heating/ventilating system, shown in *Figure 2*, is an H-type capable of handling 2,610 cfm. It fully modulates the flow of return and outside air. The return fan is located in the first mechanical room along with an electric heating coil. The coil was designed to prevent the freezing of the ground located around the 20" diameter underground concrete pipe connecting both mechanical rooms. A supply fan is located in the second mechanical room along with electric heating coil, the filters and the economizer system. The coil function is to heat the air distributed under the ice rink and prevent ground freezing.

CONTROLS AND SEQUENCE

One of two temperature sensors is located in the return air duct with a set point of 35F. A second sensor can be found inserted in the air supply duct, ahead of the first tee as shown in *Figure 2*. In the spring, summer and fall seasons, when the outside air temperature is above 40F, the return air is exhausted and

FIGURE 2 SUBFLOOR HEATING/VENTILATING SYSTEM



new air is introduced. The heating coil is closed and the economizer/fan system is used to bring in the required flow of outside air and to obtain an air mixture having the proper temperature to heat the subfloor. In winter when the outside air temperature is 40F and below, the economizer system is closed to outside air and the heating coils are cycled in step to heat the air and the subfloor. The original control system was an electronic model built in 1988 and was upgraded to direct digital control (DDC) in 1996.

ENERGY CONSUMPTION

The DDC control system recorded the run time of each system component which allowed operators to measure energy consumption and estimate the average power input of the Clement-Jette Arena subfloor heating system. A series of software elapsed time meters within the DDC system recorded one set of elapsed time monthly for 12 months. The amperage reading for five heating steps and the two fan motors was measured with a clamp-on ampere meter. The fan motors run continuously when there is ice in the arena.

"TWO MONTREAL RINKS HEATED WITH AIR DUCT SYSTEMS COMPRISE 32 YEARS OF OPERATING EXPERIENCE AND HAVE NOT SHOWN ANY SIGN OF DETERIORATION TO DATE."

Average heating coil power input is 4.9 kW. This is a supplement to fan heat. Some heating energy is wasted due to the brine headers trench being used as a plenum. The fan motors average power input is 3.3 kW and remains constant throughout the working season. Their location, out of the air stream, means that effective fan heat is only 2.6 kW when motor and drive inefficiencies are accounted for.

END RESULT

The subfloor average heating load is: 4.9 kW + 2.6 kW = 7.5 kW; average power input for the system is 8.2 kW; energy consumption is 31,521 kW.h/year; and the annual energy cost is approximately $2400. Fan heat is 2.6 kW and provides 33 per cent of the subfloor heating capacity.

The installed heating coil capacity for Clement-Jette arena is 20 kW. This is oversized by 10-12 kW if compared to Sylvio-Mantha arena where the heating coil capacity is eight kW and obviously sufficient since it has been operating since 1982 without freezing of the subsoil. A five kW heating coil was installed to provide heating in the duct connecting both mechanical rooms.

There could be considerable construction cost savings if the system design is modified next time. The ventilation/heating system could be built in a single mechanical room with most of the supply and return duct located overhead in the arena. One mechanical room, one heating coil and some controls would be saved and the heating coil would be of a smaller capacity. The number of heating pipes would be increased from 18 to 19 and take over the heating duty of the 20" diameter concrete pipe connecting both mechanical rooms. The system air flow of 2610 cfm would be distributed into the heating pipes and would supply 137 cfm per circuit. Duct insulation area would increase accordingly as there would be more 20" duct located in the ceiling.

SYSTEM IMPROVEMENTS

At Clement-Jette arena the following air duct heating system improvements have been identified:

- Disconnect excess heating coil capacity in order to reduce the electrical demand by 10 to 12 kW. Shut down the five kW heating coil permanently since the return air temperature is 35F, which is warm enough to heat the underground return pipe.
- Modify the controls sequence to save on energy consumption In the spring, summer and fall seasons, when the outside air temperature is above 36F, the return air should be exhausted and new air introduced. When the outside temperature is above 42F, the heating coil should be closed and the economizer/fan system used to bring in the required flow of outside air to produce an air mixture having the proper temperature to heat the subfloor. In winter when the outside air temperature is 36F and lower, the economizer system should be closed to outside air and the heating coils cycled in step to heat the air and subfloor.

At both Clement-Jette arena and Sylvio-Mantha arena the following design improvements were identified:

- The 18 heating pipes outlet should be connected to a duct because the brine header should never be heated, as this is a waste of energy. Firstly, for the subfloor heating system, secondly, for the refrigeration system.

■ The fan motors and drives should be placed in the air stream in order to recover 100 per cent of the energy input as heat.

In new construction the following design enhancements have been noted:

■ Add a supplementary heating pipe to the design for a total of 19 at a supply rate of 137 CFM per heating pipe and use only one mechanical room.

■ Connect all nineteen heating pipe outlets to a return duct.

■ Locate the greatest part of the return and supply duct in the ceiling space of the arena and insulate it.

■ Select fans with the motors and drives located into the air stream.

■ Implement the proper controls sequence.

CONCLUSION

Montreal's experience with subfloor heating systems leads to the following conclusions:

■ Ice rinks built on structural slab are the best and the reliability is excellent. However, they are very expensive to build.

■ Ice rinks built on grade slab with electrical wire mesh as the heating system should be avoided. They have been found to be unreliable due to corrosion of the wire mesh, early failure and cannot be fixed.

■ Ice rinks built on grade slab with mineral insulated electrical cables as the heating system should be avoided because it is very difficult to install the cable system without damaging them. When damage is discovered it is usually too late in the construction process to easily repair it and it is impossible to repair after completion.

■ Ice rinks built on grade slab using air duct supply as the heating system are less expensive to build than those on structural slab. They are very reliable and can be repaired easily.

■ Avoid all systems using electrical resistors buried under the skating rink slab and pick a system where you can repair and access the components.

How reliable is the air duct technology? The two Montreal rinks heated with air duct systems comprise 32 years of operating experience and have not shown any sign of deterioration to date. The air duct subfloor heating system is a sound design with the improvements outlined.

■ *Claude Dumas, ing., is energy project engineer – building services, building operations division with the City of Montreal. He can be reached at 514-872-3825 or e-mail cdumas@ville.montreal.qc.ca.*