Evolution of Ice Rinks

By Ted Martin

By the time of The American Society of Refrigerating Engineers’ (ASRE) first meeting in 1905, the artificial ice rink industry had already established many of the basic design principles found in today’s multipurpose sports and entertainment facilities. By then, almost 30 years had passed since 1876, when the first mechanically refrigerated ice rink (The Glaciarium) was opened by Prof. John Gamgee at Chelsea in Charing Cross, London.

In the March 18, 1876, issue of All the Year Around, a weekly magazine founded by Charles Dickens, this first rink was described this way: “Copper pipes were laid down, and through these, a mixture of glycerine and water was circulated after having been chilled by ether.”

Visit any modern skating rink and you still will find a secondary refrigerant circulated through steel or plastic pipes embedded in the floor.

The Early Years

In 1564—more than 200 years before Professor Gamgee’s ice rink opened—the “Frost Fair” was held on the Thames in London. The event lasted from January to March each year that the Thames was frozen. The last “Frost Fair” was held in 1814. With the construction of a new London Bridge in 1823, the Thames now flows too fast to freeze over.

Dedicated natural ice rinks, both outdoors and indoors, were first developed by skating clubs. The first skating club was formed in Edinburgh, Scotland, in 1642. Many others followed. Skating clubs led inventors to try to produce an artificial ice surface. An 1843 issue of Punch magazine describes a visit to a rink near Baker Street in London where the ice was made “not of frozen water but of a slush of chemicals including hog’s lard and melted sulphur, which smelled abominably.” Another attempt in Manchester required patrons to skate on an uneven surface through an extremely thick mist.

The success of the 1876 Chelsea rink spawned many others. The much larger Southport Glaciarium, 164 ft by 64 ft,* opened in 1879 and operated for 10 years. Almost immediately, rinks sprang up in other countries, and many more opened in Britain.

The sudden popularity of ice hockey in the 1880s undoubtedly added to the public demand for construction of many skating rinks, but a certain amount of

* ft × 0.3047 = m
controversy exists on where the sport was invented. Hockey’s birthplace is given in various publications as Montreal, in 1875; Kingston, ON, Canada, in 1888; and Halifax-Dartmouth, NS, Canada, in the mid-1800s.

The first mechanically refrigerated ice rink constructed in the U.S. was built by Thomas L. Rankin. In 1879, Rankin installed and operated a 6,000 ft$^2$ ice rink in the Old Madison Square Garden in New York City. At a gala carnival held on the night of Feb. 12, 1879, hundreds of masked skaters, dressed in fantastic costumes, crowded the arena, along with thousands of spectators.

The first large sheet of artificial ice ever made by man and maintained in a temperature above freezing.

The lights from innumerable gas jets, hundreds of coloured lights, and the flashes of calcium lights of different colors aided the strains of music from Gilmore’s Serenade Band in making the scene unique. Over 100 members of the Empire and New York Skating Clubs filed a statement paying tribute to Mr. Rankin for creating this, the first permanent, multipurpose floor. Most facilities laid the pipes on wooden stringers on levelled ground and the pipes were covered with sand. Today, year-round ice rinks often still use sand-covered pipes rather than concrete floors due to the capital cost savings, plus the added accessibility to the refrigerated pipes.

After the Chicago arena was built in 1917 (see sidebar, “Grand Era for Ice Rinks”), it became apparent that if the rink floor was made of concrete, the ice would melt and the rink would remain water-filled. A new floor was required. Over 100 members of the Empire and New York Skating Clubs requested that the floor be of cast iron or brick. Steel was recommended, and the City of New York ordered a design for a floor made of 72,000 ft of 1 in.$^1$ extra-heavy wrought iron pipe, with a supply and return header at opposite ends of the rink. In 1912, this rink was rebuilt using Arctic compressors and renamed “The Duquesne Gardens.” This rink was renovated several times and remained in operation until 1956.

The History of Ice Skates

The oldest known pair of skates, found at the bottom of a lake in Switzerland, dates back to about 3,000 B.C. They were made from the leg bones of large animals. Holes were bored at each end of the bone, and leather straps were used to tie on the skates.

Around the 14th century, the Dutch started using wooden platform skates with flat, iron bottom runners. The skates were attached to the skater’s shoes with leather straps and poles were used to propel the skater. Around 1500, the Dutch added a narrow metal double-edged blade, eliminating the need for the poles, as the skater could now push and glide with his feet (called the “Dutch Roll”). By the late 1600s, the first all-metal skates with iron blades were developed in Russia.

In 1850, steel blades were invented by E.W. Bushnell, an American. They clipped to the boot bottom, were stronger than the iron blades and much sharper. These blades allowed skaters to perform “tricks” (spins and jumps) without slipping.

Different Floor Types

From 1880 on, many ice rinks were built in Europe. In 1891, the Linde Ice Machine Co. built an ice rink in Frankfurt, Germany, using brine circulation in the floor pipes placed in a shallow tray filled with water that was then frozen. In November 1893, Thomas L. Rankin of Chicago was awarded a U.S. patent on the forerunner of today’s modern ice rinks, with cooling pipes embedded in a “composition of asphalt or other suitable cement and metallic filings or borings, etc., sufficient to constitute the floor a good conductor and bring the cold to the surface to produce a coating of ice thereon sprayed with water.”

Until about 1918, no rinks had a permanent, multipurpose floor. Most facilities laid the pipes on wooden stringers on levelled ground and the pipes were covered with sand. Today, year-round ice rinks often still use sand-covered pipes rather than concrete floors due to the capital cost savings, plus the added accessibility to the refrigerated pipes.

The History of Ice Rinks

The years from 1890 to 1920 saw the construction of a great many rinks throughout the world. Some highlights are:

- 1895—Schenley Park Casino, Pittsburgh. The rink was 70 × 225 ft and used a 160 ton$^1$ St. Clair Compound compressor manufactured by York Co. Direct expansion was used for the first time. The floor was built with 72,000 ft of 1 in,$^1$ extra-heavy wrought iron pipe, with a supply and return header at opposite ends of the rink. In 1912, this rink was rebuilt using Arctic compressors and renamed “The Duquesne Gardens.” This rink was renovated several times and remained in operation until 1956.

- 1895—The Niagara Hall Ice Rink, London. This 112 ft diameter rink was built on a wooden plank floor that formed the ceiling of a cold-storage space below. The floor was covered with 30,000 ft of 2 in. diameter pipe and 1/8 in. wall thickness. Valves controlled the flow of brine from the 12 in. diameter mains. The brine was cooled by three 12-ton De La Vergne compressors.

- 1896—Washington Convention Hall. The rink measured 155 × 205 ft., and was the largest of its kind in the world. This was another

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$^1$ ft$^2$ × 0.0929 = m$^2$; tons × 3.517 = kW; in. × 25.4 = mm; (°F – 32) ÷ 1.8 = °C
the facility could be used for many purposes throughout the year. The first experiments were made in 1917 to determine if it was possible to refrigerate a concrete floor so that ice could be formed on top of it. D.H. Scott conducted many experiments at the Elysium Ice Skating Rink in Cleveland. Scott was the inventor of the Scott Ice Control System, used by many of the rinks at that time. The system used electric resistance thermometers embedded in the floor. His concrete investigations continued the work of Edward Engelmann of Vienna, Austria, who had installed a permanent ice rink floor in that city around 1908. Engelmann delivered a paper on his installation in 1913 at the Third International Congress of Refrigeration in Washington, D.C., and Chicago, in which he emphasized the importance of a free-floating slab that could contract as the slab temperature was lowered.

After Scott completed his experiments, a concrete floor was poured at the Elysium rink in Cleveland, most likely the first permanent concrete ice rink floor poured in the United States. Other concrete floors followed in Philadelphia arena and Milwaukee. The Winter Garden, in Milwaukee, featured a terrazzo topping on the concrete slab. For the first time, a heat exchanger was installed to heat the brine to speed up the removal of the ice by warming the floor. Both of these floors developed problems with cracking because they were not constructed to withstand expansion and contraction.

The next concrete floor built was at Madison Square Garden, with steel shavings embedded and expansion joints about 60 in. apart. The floor was finished with terrazzo, and brass strips were laid at each expansion joint. Subsequent investigations of floor failures in the 1930s found the use of steel shavings did not enhance heat transfer, and also led to porosity in the concrete and the possibility of brass in the turnings, which increased the likelihood of corrosion of the steel pipes.

In 1929 a new type of floor was designed and patented by M.R. Carpenter, a charter member of ASRE. The floor was poured as a monolithic slab with no expansion joints. The first installation was an 80 ft × 208 ft floor in the Ice Casino at Playland Amusement Park in Rye, N.Y. This was a recirculated brine rink using two Frick compressors driven by synchronous motors. The ability to build a reliable, crack-free concrete floor led to the construction of thousands of arenas that could be used for multiple purposes. For example, since 1990, every new NBA facility has included an ice rink that can be covered with an insulated board system when basketball is played.

Advances in ice rink engineering have been relatively slow since the 1930s. As previously stated, many similarities exist between modern rinks and that first rink in London built in 1876. The majority of skating rinks still circulate a calcium chloride brine solution through pipes in either a sand or concrete floor. In recent years, due to the phase-out of chromate as a corrosion inhibitor for brine, and changes in heat exchanger technology, inhibited ethylene or propylene glycols are becoming more common. New fluids have been introduced that promise minimal environmental impact in the event of a leak and reduced pumping horsepower; these include potassium formate, potassium acetate, and various proprietary compounds.

Direct expansion, or liquid recirculation floors, in which the refrigerant is circulated through the floor piping, have been popular at times due to the increased efficiency of the refrigeration plant. However, the floor piping becomes part of the refrigeration piping system and is subject to all ap-
plicable safety and environmental codes. Direct expansion ammonia rinks were quite common in Canada until the 1970s, when safety concerns limited their use to only outdoor rinks. Eventually, most if not all of these were converted to glycol or brine-circulated rinks.

Rinks also have been constructed using direct expansion R-22 in copper or steel piping embedded in concrete, but proper circuiting design was critical to their success, and the small diameter thin wall tubes proved susceptible to corrosion and leaks. With the move towards minimizing refrigerant charge in all refrigeration plants, little incentive exists to circulate refrigerant directly through the floor.

A more recent development, or perhaps a repeat of work from many years back, is the use of liquid carbon dioxide (CO$_2$) circulated as a volatile secondary fluid through the rink pipes. This has been successfully applied in a number of European installations, but requires floor piping systems that can operate at 450 psig.** These CO$_2$ floors operate with cascade ammonia refrigeration systems, resulting in an environment-friendly installation. Again, compliance with refrigeration codes and the added cost of high-pressure floor piping may limit the widespread use of this design.

** Piping and Coolant**

Piping systems in the typical rink have not varied greatly over the years. Pipes are typically 1 in. to 1¼ in. diameter, laid on 3½ in. to 4½ in. centers. Closer spacing is used on floors subject to higher heat loads, such as those found in National Hockey League facilities. Steel piping is still common in these rinks for providing enhanced heat transfer.

Perhaps the greatest change in floor systems was the introduction of polyethylene rink pipe in the 1950s. Clifford A. Meadows, a Toronto civil engineer, pioneered the use of plastic pipe for temporary “take-up” rinks and was issued both U.S. and Canadian patents on his invention in 1957.

The first plastic floor ice rink on record was built in Detroit’s Chandler Park in May of 1953. Four other Detroit outdoor rinks quickly followed.

The first indoor rink using plastic pipe was constructed at the Hamilton Arena in Ontario, Canada, in late 1953. An excerpt from Meadows in Canadian Plastics Magazine, November 1953, reads,

> Where it is impractical to lay down a concrete slab, for example, on a rugby field or a baseball diamond, or when the high cost of the concrete must be considered, the Meadows “take-up” rink provides a ready answer.

> The rink may be laid down in the fall, flooded and frozen for the winter, and taken up in the spring to be placed in storage until the next fall. Summer use of the area is, as a result of the rink’s portability, not interfered with. The “take-up” rink is adaptable to all types of playing fields, tennis courts, and may even be placed in a wading pool or a swimming tank.

Serious concerns existed about the heat-transfer characteristics and longevity of this material when it was introduced, but some of the first rinks with plastic piping are still operating 40 years later. Moving from welded steel piping to plastic piping reduced construction costs significantly, and the plastic was resistant to the corrosion that often ended the life of a steel pipe floor.

The drawback to plastic piping is the necessity of using pipe clamps for joints at the rink headers and return bends. Typically, the headers have been installed in a header trench at one end of the rink, so the joints remained accessible. Some rinks also incorporate a trench at the return bend end for the same reason. In recent years, headers are increasingly being buried in the floor slab because the clamped joints proved to need minimal maintenance. Elimination of the header trench saves construction, maintenance and eliminates the need for removable wood, steel or concrete trench covers.

Proprietary plastic floor piping systems also have been developed, which are constructed in mats that can be quickly rolled out and the integral headers can be joined to make a finished floor. These use small diameter (typically ¼ in. diameter) tubing on ¾ in. centers and have proven popular for smaller portable rinks.

Rinks using glycol or brine require a heat exchanger to cool the fluid. Early rinks often used piping immersed in a brine tank (sometimes referred to as a high-efficiency coil); these systems remained popular into the 1950s in some areas, even though shell-and-tube chillers were used in rinks in the 1920s. The Olympia Skating Arena, built in Detroit in 1928, used two 42 in. diameter × 18 ft long flooded ammonia chillers, each having 10 brine passes. A 20 × 14 × 10 ft brine storage tank was located under the seats in the arena to assist the chillers under heavy load. Brine tanks were quite common to supplement the chiller capacity by prechilling brine to a lower than

** psig × 6.895 = kPa
normal temperature prior to an event. As refrigeration plant capacity increased, and chillers reliably delivered their rated capacities, brine tanks began to disappear. Shell-and-tube chillers became physically smaller as the designs progressed from 1¾ in. outside diameter 13-gauge tubing, to today’s common ¾ in. outside diameter 16-gauge tube chiller. Enhanced surface tubing also is being applied to reduce chiller size even further.

More Recent Developments

The introduction of welded and semi-welded plate-and-frame chillers for refrigeration service in the 1990s has led to their use in skating rinks. These chillers have the advantages of low refrigerant charge and expandability. Also, they can be disassembled for cleaning and are significantly smaller than equivalent capacity shell-and-tube designs. When applied to brine systems, titanium plates must be used at a higher cost; therefore, most new facilities using these chillers use glycol as the secondary refrigerant and stainless steel plates for lower overall cost.

Compressor technology for skating rinks kept pace with the available products. Large bore and stroke, low rpm horizontal or vertical compressors were replaced by increasingly smaller, higher rpm reciprocating compressors in the 1960s. In recent years, with the move towards large multipurpose facilities with four or more ice surfaces operating year-round, the refrigeration capacity is sufficient to use larger screw compressor systems. As higher-efficiency smaller screw compressors (30 hp and up) have been released to the market, these also are used in arena engine rooms. Designers must be cautious to ensure that the compressors are selected to match the widely varying loads in both winter and summer.

Ice rink control systems have undergone profound changes in the past 20 years. In the October 1927 issue of Ice and Refrigeration, M.R. Carpenter wrote at length on the challenges facing operating engineers in trying to match the refrigeration plant to the load that varied depending on issues “such as opening or closing doors, change in direction of the wind, variation of outside temperature, change in relative humidity, and, one of the most positive in its action, the skaters themselves. This action is in a degree modified by the number of skaters and quite particularly by the sex; though this latter cause is not as pronounced since the short skirts have come into vogue.”

Although the Scott Ice Control System allegedly provided the operator with all the information needed to manually adjust the plant, the most common control until the 1980s was a thermostat, sensing either the brine return temperature or the floor temperature. The introduction of PLC, DDC and computer controls automated the refrigeration plant at a relatively low cost, usually with a substantial payback in reduced energy consumption. Precise ice temperature control now can be achieved by measuring the ice surface temperature with infrared cameras mounted over the ice.

Conclusions

Today, small single-purpose community arenas operating only during the winter months still are being built, but communities increasingly are building large, multipurpose facilities that use two or more ice surfaces, gymnasiuems, swimming pools, meeting rooms, and so on. These facilities lend themselves to the integration of the refrigeration plant into the building mechanical system for recycling heat generated by the ice-making equipment.

In some cases the building air conditioning is being handled by off-peak ice building by the ice rink refrigeration compressors; in others, the refrigeration heat is rejected into building heat pump loops. A master control system overseeing the total facility’s heating, cooling and refrigeration needs, and adds or sheds loads according to usage and hour-by-hour energy cost information.

Another recent trend, at least in colder climates, is the construction of refrigerated skating paths for pleasure skating in a natural setting. There have been a number of these built in Canada and Europe, many as part of a larger facility so they can share the refrigeration capacity during the winter.

The basics of ice rink refrigeration were laid down almost 130 years ago. Today, ice rinks can be found in shopping malls, cruise ships and high-rise buildings. Progress in ice rink design has been steady, resulting in today’s low cost, energy-efficient facilities that attract millions of participants and spectators yearly.

Bibliography

2. Excerpts from De La Verne Refrigerating Machine Co. catalogue, 1897.

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†† hp × 0.746 = kW