Comfort from a Block of Ice

A History of Comfort Cooling Using Ice

The First Century of Air Conditioning

This is the third article in our special series to commemorate a century of innovation in the HVAC&R arts and sciences.

By Bernard Nagengast
Member ASHRAE

There is a basic human drive to be comfortable. I once had a rhyme (author unknown) on my college room bulletin board that put it whimsically:

"Man is a funny creature.
When it's hot he wants it cold.
When it's cold he wants it hot.
Always wanting what is not.
Man is a funny creature."

Funny or not, the quest for comfort probably is as old as the human race. We know that fire was used for warmth at least 100,000 years ago, and perhaps much longer than that. There are charred remains of ancient campfires to prove it. But what of comfort cooling? Melting ice or snow leaves no archeological record. Thus the beginning of the timeline of comfort cooling is buried in obscurity; we have to rely on written records for the history of cooling. Since there was no mechanical refrigeration before the 19th century, any attempts to artificially cool the air would have used ice, snow, cold water or evaporative cooling. This article will consider the history of comfort cooling in the United States using ice.

The Antecedents

One of the earliest written records, the Holy Bible[1], mentions "The coolness of snow in the heat of the harvest." There are other sporadic accounts of ancient peoples using ice or snow for cooling. For example, the Roman emperor Varius Avitus ordered that mountain snow be brought and formed in mounds in his garden so that the natural breezes might be cooled.[2]

Other examples, most unrecorded, are scattered across the centuries. However, apparently not much was done in the comfort cooling field until the 1800s.

Shortly after the turn of the 18th century, Frederic Tudor of Boston sent a shipload of ice to Martinique in the West Indies to relieve the Yellow Fever epidemic that raged there. Curiously, the beginnings of the commercial ice industry in the U.S. can be traced to this shipment, Tudor's first one. That shipment that, technically, was used for comfort cooling was the beginning of the ice trade in the U.S. At that time, physicians were already using ice in their efforts to reduce fever. In 1901 it was reported that prior to 1825, physicians in larger American cities already kept stores of ice for medical use.[3]

The Debut of Ice-Powered Systems

The aforementioned U.S. examples of ice use for cooling are not those that HVAC engineers envision. The doctors did provide comfort cooling, but it was done by direct application of

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the ice to the body. Engineers think of complete systems, but examples of ice cooled ventilating systems and equipment didn't materialize until the mid-18th. century. Their frequency increases as the 20th century approaches.

The earliest proposal for comfort cooling in the U.S. using ice was possibly that of George Knight of Cincinnati who, in 1864, proposed a hospital cooling system in *Scientific American.* It featured a ventilating system with an air washer to clean and cool the air. The water for the air washer was run through a cooling coil immersed in melting ice. Outside air was forced by a fan through the cold water spray to be distributed overhead through perforated outlets. Knight noted that "The device is intended especially for optional and discretionary use in the heat of summer..."[4]

Nathaniel Shaler of Newport, Ky. (across the Ohio River next to Cincinnati) who was the grantee of U.S. Patent 47,991 in 1865 for an "improved air cooling apparatus" envisioned another cooling system. The patent describes a heat exchanger made with "ice holders" placed in a "tortuous passage" through which room air is blown to cool it. Shaler also says that a desiccant can be placed in the airstream to dry it (see *Figure 1*).

After 1870, refrigeration and large building heating and ventilating systems began to be commercialized. For the first time, enterprises were organized with the express purpose of the engineering, manufacturing and sales of building infrastructure systems.

A demand was arising for central systems that would provide refrigeration for breweries, ice making and cold storage. Central heating and ventilating plants were needed for the various buildings being constructed. However, there was little demand for comfort cooling. At the time, mechanical refrigeration was too expensive to be used in this fashion. But ice was too!

In his 1873 article "On the various systems of cooling the air," A. Jouglet discussed using ice as a means of comfort cooling, but concludes: "In point of fact, this method of refrigeration must be considered as impracticable, while ice is not very cheap, and cold cannot be produced as inexpensively as heat."[5] It seems that

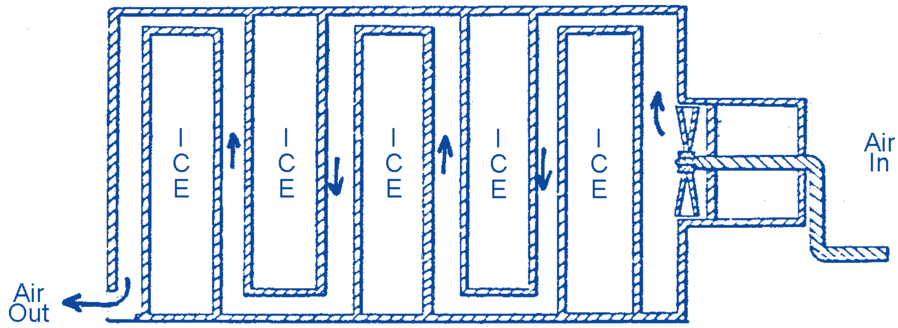

Figure 1: Shaler's patented cooler for ventilating air, 1865.

the few attempts at cooling at that time were perhaps done by the curious or by the entrepreneurs. One example was the ice cream vendor who was said to have cooled a Staten Island, N.Y., hotel dining room about 1880. He used a system that blew air through pipes imbedded in a mixture of ice and salt.[6] It was an isolated example, typical for a cooling era at the point of conception.

Engineered Systems

The Sanitary Engineer reported in 1880 that New York's Madison Square Theater was using about 4 tons (3630 kg) of ice to cool patrons at evening summer performances. Fresh air was filtered through a 40-ft (12 m) long cheesecloth bag, passing over wooden inclined racks, containing 2 tons (1815 kg) of ice, and into an 8-ft (2.5 m) diameter centrifugal fan. The fan discharge was directed over another 2 tons (1815 kg) of ice, into ductwork to various openings through which the cool air "...poured into the house to reduce the temperature and to furnish a supply for respiration."[7]

The Madison Square Theater installation was a new type of comfort cooling system. It was an engineered system, provided by B. F. Sturtevant Co., an engineering and manufacturing firm that soon became the foremost purveyor of air side heating and ventilating systems in the U.S. Engineered building systems would frequent the U.S. landscape in the coming decades. Companies like Sturtevant that offered to engineer, make and install H&V equipment were forming with frequency after 1880. The technical staffs at these companies were the newborn in a new profession, that of the heating and ventilating engineer. Their increasing numbers would soon show the need for a specialized engineering society, the result being the organization of the American Society of Heating and Ventilating Engineers in 1894.

This new era saw building systems designed to provide specified results. At first such results were often broadly defined. This was especially true for the few comfort cooling systems that were designed between 1880 and the early 1890s. And those few systems were ice type systems.

Possibly the most famous of them was the one that used ice to relieve the sufferings of U.S. President James Garfield who lay dying from an assassin's bullet in the summer of 1881. The system was described in a pamphlet "Reports of officers of the Navy on ventilating and cooling the executive mansion during the illness of President Garfield," published in 1882. It seems that the Naval engineers passed air through dozens of thin cotton screens onto which dripped the cold meltage from a salt-ice mixture contained in a tank above. The cooled air was ducted into the president's bedroom, resulting in as much as a 20°F (–11°C) temperature drop. The desired result—to cool down the president's room—was a broadly defined one. Any reasonable drop in temperature was acceptable.

Another cooling system was designed in 1889 for the Carnegie Music Hall by consulting engineer Alfred Wolff. Wolff was probably the first really successful heating and ventilating engineer, and he designed some of the most important comfort cooling systems around the turn of the nineteenth century. His first attempt used ice. The building's dedication records described the system:

"Fresh air, at any temperature desired, in large volume but at a low velocity, is introduced, and the vitiated air is exhausted. Generally, the fresh (warmed or cooled) air enters through perforations in or near the ceilings, and the exhaust is effected through registers or perforated risers in or near the floors and, passing through an elaborate system of ducts, worked into the construction of the building, is expelled above the roof."

"Through [the] heating surface, or at will through the ice racks, the air is drawn by four powerful blowers, each 12 ft [3.7 m] high, and forced through the system of fresh air ducts into the various parts of the building."

"The heating surface and other appliances are so subdivided that atmospheric changes can be immediately compensated for, and the temperature of the air introduced suited to the winter weather or the heat of summer."[8]

The cooling side of this system was not engineered to maintain a specified temperature and humidity. Wolff was happy with a result that simply lowered the room temperature. The effectiveness of the Carnegie Hall system is unknown-confirmations of its use seem to be absent.

More ice-type cooling systems were installed in the next score of years. The Broadway Theater in New York used an ice cooled ventilating system for at least 10 years beginning in the early 1890s. The system forced outside air over ice blocks placed on wooden troughs, through ducts to registers in the theater. Keith's Theater in Philadelphia allegedly used a ton of ice per performance in 1903. That system was described as using natural induction, with hot air exiting through windows at the top of the auditorium. One engineer, a Mr. C. M. Stokes, commented: "... I have been in the auditorium in pretty warm weather. In fact I go there on a hot day to get cooled off. You can look down the floor register and see the ice in there."[9]

These systems had been mentioned in a technical session at the January 1903 meeting of the American Society of Heating and Ventilating Engineers. This was the first time the topic of comfort cooling using ice was presented to that Society. The subject obviously interested the H&V engineers—the discussion following the paper took up three times as much space as the paper did when it was published in the ASHVE Transactions.

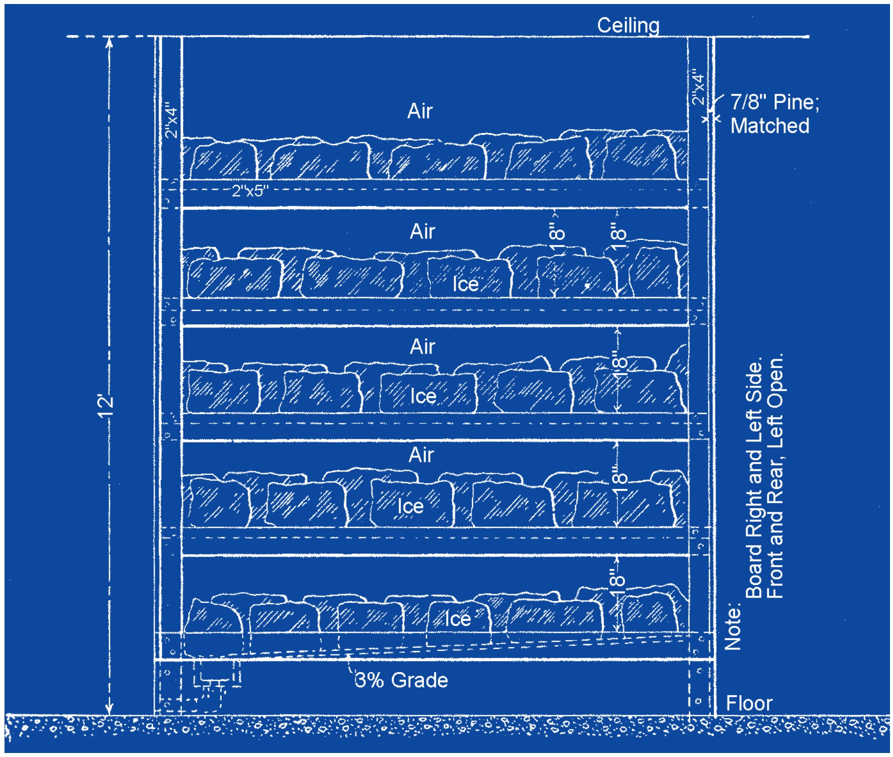

Figure 2: Ice refrigerator for high school.

The system that had fostered such interest was an ice type comfort cooling system used in Scranton, Pa., at the local high school. For at least three years, beginning in 1901, the auditorium was cooled at the time of the June graduation exercises. Comfort for as many as 1,400 persons was maintained by circulating 3 million ft^3 (85 million L) of air per hour over blocks of ice (see *Figure 2*). The air was discharged high up on the walls, exiting through aisle floor registers. About 6.5 tons (5900 kg) of ice were used for sensible cooling on a typical night to maintain an about 15°F temperature difference between outside and inside. Pans of calcium chloride were also placed in the airstream when necessary to lower the humidity. The amount of calcium chloride used was determined by deciding on a humidity level, then adding pans of the desiccant until a check of the air with a sling psychrometer indicated the desired result.[10]

Four years later, Theodore Weinshank, ASHVE member, described an Indianapolis theater cooling system that used ice before 1907:

"At the opening of one of their theaters the engineer undertook to cool the building. The outside temperature was 85°F (29°C). The outside air was taken into a fan through a large galvanized iron duct. Into this duct they placed a number of wire baskets... filled with crushed ice. The baskets were so arranged that the air entering the fan had to pass over or through the ice. The engineer succeeded in reducing the temperature of the auditorium to 70°F (21°C), but it kept four ice men hauling ice to the building as fast as they could go." Weinshank estimated that about 20 tons (1800 kg) of ice were used for the performance.[11]

Ice was being used, at least in some comfort cooling systems. Could it compete with mechanical refrigeration?

Ice Effectiveness Questioned

Although few in number, some of the cooling systems using ice did not achieve uniformly good results.

Leicester Allen, writing in Heating and Ventilation in 1893, commented:

"But there as yet exists one defect in this method of cooling. When warm air not previously dried by artificial means is made to pass over a cold surface, its humidity is made to approach the point of saturation as it is cooled; and, if not cooled to below the point of saturation so as to throw down some of its moisture its power to take up moisture is lessened by the cooling process... the air is not rendered thirsty for moisture until it is again reheated by the warmth of the room into which it flows. Simultaneous coolness and dryness are never attained by these processes."[12]

Ten years later, Professor William Kent observed:

"I know other attempts have been made to cool with ice and have failed on account of the excessive humidity. It seems that if you carry air that is normally near saturation into a chamber filled with ice, the escaping air will be thoroughly saturated. Then, if you bring that cold air into a hall which has warm air which is near the saturation point, you will make a fog, a mist, and deposit moisture on the walls."[13]

Both Allen and Kent blamed ice-type cooling systems for inadequacy. However, such blame actually was not warranted.

Today's engineers, studying early cooling systems, would note that many of these did not properly mix or distribute the air, nor did their design properly recognize the relationships of sensible and latent cooling. Such science and practice was in its infancy in the period between 1890 and 1910.

By the early 1900s, a science of comfort cooling had evolved. The effect of humidity on human comfort was understood, probably because it could be personally experienced. The relationship of humidity to temperature, the means of measuring it, and the control of it were the topics of study and discussion.

The debut of the scientific approach to air conditioning dates to the publication of German Professor Herman Rietschel's 1894 book: *Guide to Calculating and Design of Ventilating and Heating Installations* (see *Figure 3*). This book contained a chapter, "Cooling of Rooms," that discussed topics like humidity control, etc. It was the first time that engineers had a handbook for comfort cooling practice. Gershon Meckler described Rietschel's accomplishment in 1994: "What Rietschel did, in effect, was to use his scientific understanding to define the problem in engineering terms, i.e., to identify the variables and present a step-by-step design process. Because he put science into an engineering framework, making it more accessible to engineers, Rietschel was a pioneer of the engineering science of air conditioning."[14]

ASHVE charter member Herman Eisert presented Rietschel's science of air conditioning to the U.S. engineering profession in 1896.[15] Soon, the control of humidity became a primary goal. This was the objective of Alfred Wolff when he designed the HVAC system for the New York Stock Exchange in 1901, and of Willis Carrier in his design of the system for the Sackett-Wilhelms Lithographing Co. in 1902. Both used mechanical refrigeration to accomplish their goals. Why did Wolff abandon the ice approach he had used years earlier at Carnegie Hall? Why did Carrier choose not to consider ice for his systems?

Neither Wolff nor Carrier seem to have explained their preference for mechanical refrigeration in their cooling systems. We can speculate that there were several reasons.

The fact that more precise control of humidity was possible with mechanical refrigeration was no doubt one reason. Another was convenience. Mechanical refrigeration provides cooling on demand. Use of ice as a standby cooling medium is predicated upon the willingness to store it on site, or arrange for instant delivery when the weather demands comfort cooling. Still another reason could have been the growing public suspicion about the cleanliness of ice. At the turn of the last century many sources of harvested ice were becoming polluted. Contaminated ice might produce foul smells—bad for business in public halls! In some cases the reason was cost. Wolff's New York Stock Exchange system was a cogeneration system and the cooling was in effect free. The NYSE didn't have to pay for ice.

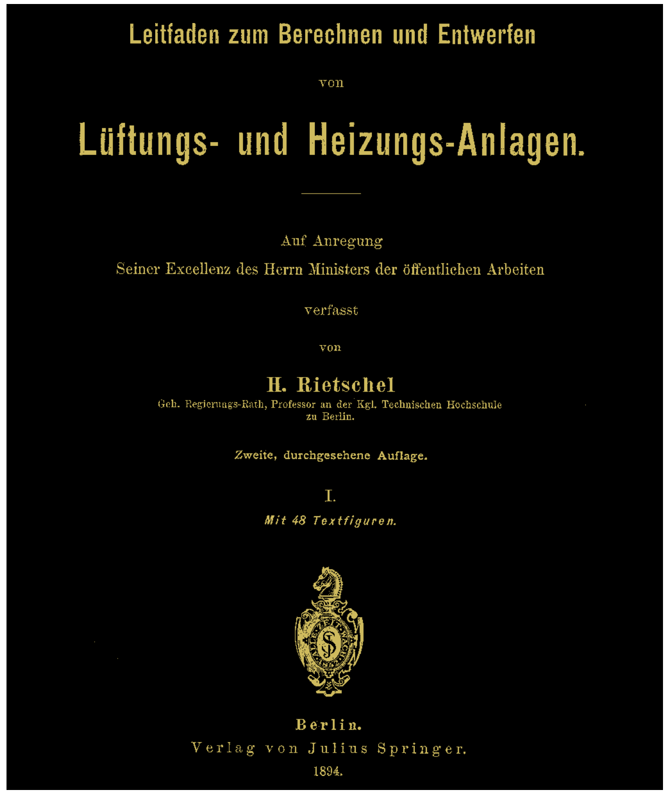
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***Figure 3:** Hermann Rietschel's textbook title page.*

The period leading up to World War I saw more H&V installations that featured comfort cooling systems. These were large systems installed in hotels, offices, restaurants, stores, hospitals and theaters. As a percentage of the total number of heating systems, the number installed were relatively small. However, most of these systems, as described in contemporary literature, used mechanical refrigeration to provide the cooling. It would seem that the ice type cooling systems were losing out to on-site refrigeration plants.

Ice Sees a Resurgence

By the 1920s, many American homes had refrigerators that used ice. However these so-called "ice boxes" slowly disappeared, replaced by electric or gas refrigerators. At first, the ice industry felt no threat from mechanical refrigeration applied to the home. Before the 1920s, it had been expensive and unreliable. This changed after 1925 as mechanical household refrigerators got better and less expensive. By the late 1920s, the mechanical units were seen as a serious threat to the commercial well-being of the ice industry, which soon searched for a means to replace its lost business. One possibility was to use ice, once again, for comfort cooling. The ice industry wondered: could its ice sales to homes and small businesses that had been superseded by mechanical refrigeration be replaced by sales of ice for comfort cooling to those same customers?

Beginning about 1929, numerous articles appeared that promoted comfort cooling using ice. By 1931, dozens had been published.[16] Even the U.S. Government got into the act. For instance, the possibility of cooling homes was discussed at President Herbert Hoover's Conference on Home Building in 1932. The conclusion: Mechanical equipment was still too expensive to make home comfort cooling feasible, but use of ice for the purpose offered the most likely solution, provided that the cost of ice could be reduced. For a house costing $10,000, the installation cost should not exceed $500 and its operating cost $100 per season.[17]

The ice industry recognized an opportunity. It was a fact that air cooling installations using ice would be cheaper than those using mechanical refrigeration. The ice industry was concluding that homes had not been cooled to any extent because equipment cost was high and there was little effort to sell the idea. "Whether or not ice is used for this purpose depends a great deal upon what the ice industry does about it." commented one writer.[18]

Doing something about this potential fell to the ice industry trade group: The National Association of Ice Industries. Fred McCandlish of the technical department of the NAII outlined the agenda of the ice industry:

"First: it is necessary that we interest air-conditioning and equipment manufacturers in the development of an apparatus suitable for ice refrigeration. Second: our own members, icemen, must be awakened to the possibilities of increased ice sales by the development of this market. Third: potential comfort cooling customers as well as the general public should be sold on the idea of comfort cooling so that they will be receptive to the development."[19]

The ice industry concluded that: "The potential market for comfort cooling is so vast that the saturation of a small part of it will require more than double the present production capacity of the ice industry." "Therefore, our sales program for the immediate future will have as its objective the obtaining of installations in locations where the advantages of comfort cooling can be seen, felt, and appreciated by the greatest number of potential users." "... we must sell an idea rather than merchandise."[20]

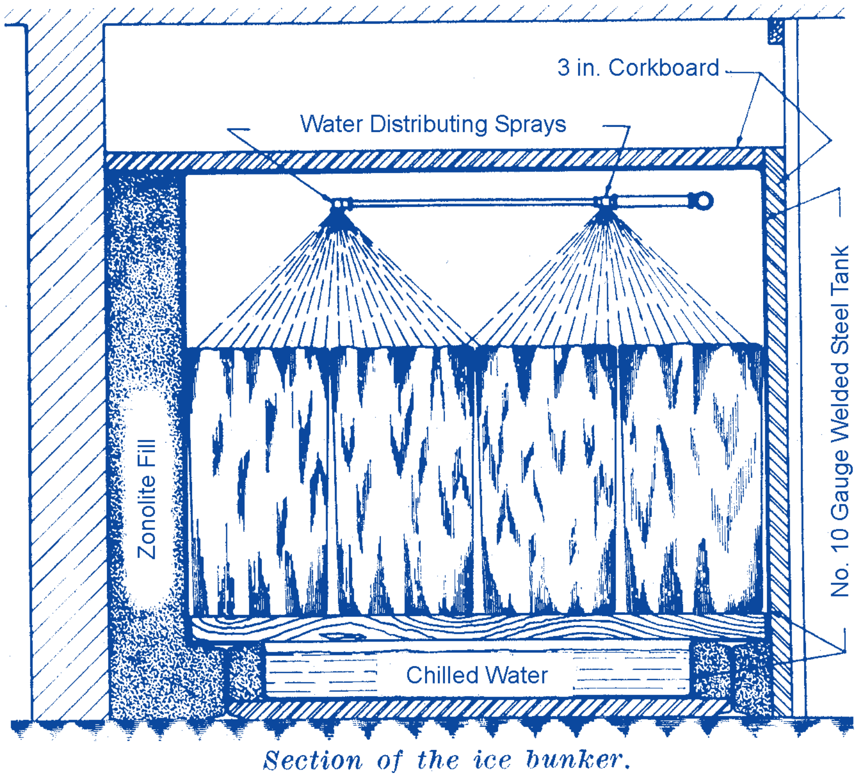

Figure 4: Diagram of Knickerbocker air cooler.

The focus of the ice industry was on selling a perishable product. This was different from the approach used in earlier comfort cooling installations. In those cases, the mechanical refrigeration industry and its engineers approached the market as one that used equipment that was sold once. The ice industry approached its market as a continuous consumer of its product, ice. "We are interested in equipment sales only as a means to an end-creating new markets and increasing the consumption of our product, ice."[21]

The National Association of Ice Industries supported its promotional efforts with manuals issued by its technical department. These included an engineering manual that prescribed methods of load calculation and system design.

The manual pointed out that comparisons of systems using ice and mechanical refrigeration should not be done using general cases because the calculations could be manipulated to show that ice type systems were more expensive.

Although the capital expense of an ice-type cooling system was much lower, the operating cost could be shown to be much higher when compared to a cooling system using mechanical refrigeration. This depended upon the assumptions used to calculate the seasonal load and the time allowed to depreciate the equipment. The manual included an example of a system in which the seasonal owning and operating cost varied. Using one set of calculations the cost was $1,000 more for ice; or it could be $260 less using different assumptions. The manual recommended that each job should be considered independently for comparison purposes.[22] No doubt, sales personnel on both sides of the issue took liberties with their assumptions to show that their own system was the least costly.

Typical Installations Using Ice

It seems that the efforts of the ice industry were successful. An article in *Ice and Refrigeration* reported that "Ice is now being successfully used to cool and condition many theaters throughout the country. We have learned of two in New York City, one in Philadelphia, one in Baltimore, two in Indianapolis, one in Cleveland and six in Chicago. Contracts have been made to install equipment in other theaters in Boston, Philadelphia, St. Louis, Chicago and Kansas City. No doubt there are many others..." It was reported that these installations typically used about 6 tons (5440 kg) of ice per day, costing about $250 in 1998 dollars. The article notes that the theaters were able to charge extra for the cooling, with admission prices of $6 to as much as $11 (expressed in 1998 dollars). "The neighborhood theaters, with their admission prices of 25, 35, 50 cent admissions have been unable to absorb such expense." (In 1998 dollars, these admissions would cost about $2.50 to $5.00.)

The article went on to report installations in restaurants and stores. "Many department stores are providing equipment for conditioning the ladies' alteration and fitting departments. This will eliminate their previous losses due to soiled dresses and gowns which has been quite an item."[23]

Although the ice industry did not directly manufacture or install air cooling equipment, there seemed to be no shortage of manufacturers or installers. For example, the Betz Unit Air Cooler Co. manufactured two kinds of coolers for ice. One used an air washer-type arrangement; the other melted ice in water, circulating it through a fan coil.[24]

A typical installation was that engineered for the offices of the Knickerbocker Ice Co. on the 21st floor of the Liggett Building in Detroit about 1937. The system, designed by the Typhoon Air Conditioning Co., was used by the ice company as a showcase installation to promote use of ice for air conditioning purposes. More than 8,000 ft^2 (743 m^2) of office space was cooled with 2,000 cfm (944 L/s) of outside air and 4,000 cfm (1888 L/s) of recirculated air. The air was passed over 1,100 ft^2 (102 m^2) of cooling surface cooled with chilled water. The water was cooled by spraying it over cakes of ice in an insulated bunker having a capacity of holding 6 tons (5443 kg) of ice (see *Figures 4* and *5*). Constant supply water temperature was maintained by use of a thermostatically controlled bypass valve at

Figure 5: Ice blocks inside air cooler.

the bunker that sensed the return water temperature. A second bypass valve was used to vary the amount of chilled water pumped to the cooling coil. The second valve was controlled by a variable differential temperature control that sensed the fresh air and the recirculated air temperatures (see *Figure 6)*. In effect, the outside air and the room air temperatures were sensed, and the thermostat operated in such a manner that at 75°F (24°C) there was no difference between inside and outside. As the outdoor temperature increased, the differential increased to a maximum of 12°F (–7°C) at 95°F (35°C). The ice was recharged when 80% to 90% of it had melted.

"With this system of controls, the ice-cooled equipment becomes entirely automatic and it is not necessary to vary the fan speed in order to prevent overcooling at low loads. This is advantageous, as it is virtually impossible to contrive a system of distribution that will function effectively through any considerable range of air volume variations."[25]

No doubt there are those who would maintain that this problem still has not been solved!

Mechanical Refrigeration Triumphs

The promotional efforts of the ice industry had the result that many of the comfort cooling systems installed in the 1930s did use ice. Those vigorous efforts by the ice industry did not achieve the potential originally envisioned, for mechanical refrigeration proved to be an equally vigorous competitor. In fact, the use of ice began to decline after World War II. Mechanical cooling equipment continually improved, and like the household refrigerator a couple decades earlier, the evolution of cooling equipment aimed for better reliability, smaller size and lower cost. Although there were many factors, one of the most important was the introduction of sealed refrigeration systems. By the 1950s, mechanical air-cooling equipment was affordable to many smaller businesses and homeowners. Ice type systems were rarely considered an option for comfort cooling.

It seemed that ice was doomed once again to be a relic of an earlier age. But the 1970s brought the energy crisis, and with it, a renewed interest in off-peak storage for comfort cooling. Some systems were designed and installed using ice banks. In these systems, ice was manufactured during the night, and that stored energy was then used during the day for cooling. In refrigeration systems with air-cooled condensers, evaporative condensers or cooling towers, use of cooler nighttime air resulted in energy savings.

Although storage systems are still being designed, raw ice is being replaced with different storage media with a greater energy capacity.

Ice—It's Still Here!

The saga of ice seems to have turned full circle. The article began by showing how ice was applied for on-the-spot comfort cooling by direct application in the first commercial venture. We saw that the principal use of ice in the early 1800s was in medicine.

Today, much ice is still used for comfort cooling in medicine. However, there is a new version of on-the-spot cooling, one not evident 200 years ago. In the U.S., no informal dine-out meal is complete without an iced drink. More ice is used for this direct application of comfort cooling than could have been dreamed of by the ice industry 70 years ago. Unfortunately for that industry, virtually all of this modern use of ice is satisfied by on site manu-

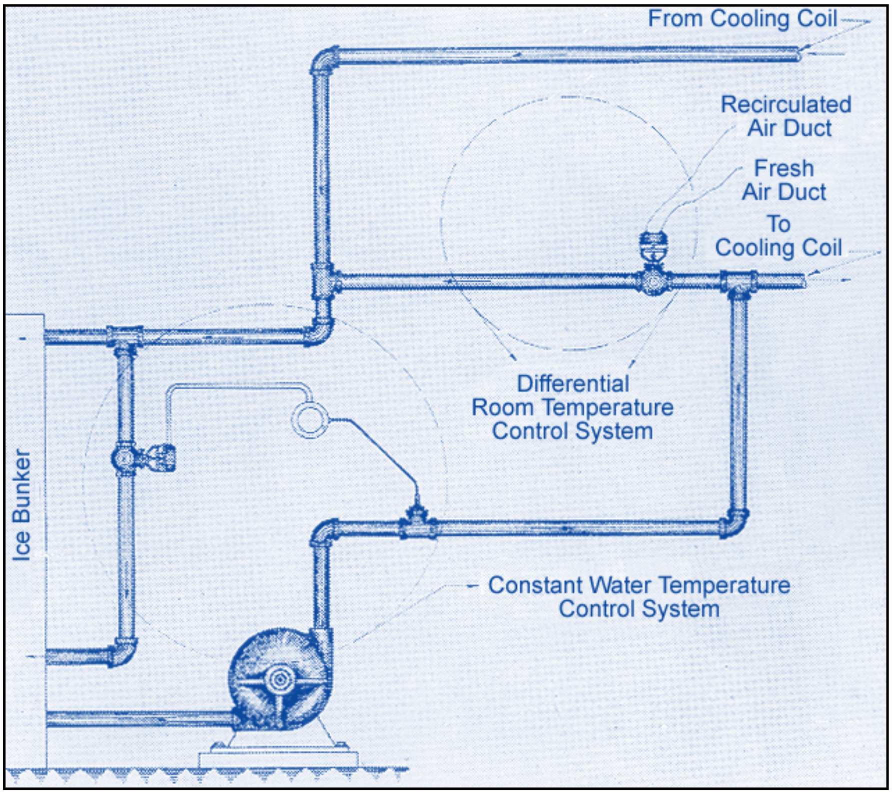

Figure 6: Piping and controls for Knickerbocker system.

facture using icemakers. It seems that the ice industry's nemesis—mechanical refrigeration—has succeeded in replacing the ice man in virtually every application.

Thus the ice man and the ice industry has withered. Cooling systems using ice instead of mechanical refrigeration have all but disappeared. But ice itself has survived and even prevailed in its own modern comfort cooling niche.

Every time we use an ice pack on our feverish head; every time we take a sip from an iced tea on a hot summer day, breathing a sigh of relief as we swallow; we are experiencing the uniqueness of ice for cooling. The art and science of air conditioning has progressed mightily, but we still take comfort from a block of ice!

References

1. Proverbs 25:13

2. Oldham, B. 1965. "The history of refrigeration." *The Journal of Refrigeration* 8(May):147–149.

3. Anonymous. 1901. "The tenth anniversary of Ice and Refrigeration." *Ice and Refrigeration* 21(July):7,8.

4. Anonymous. 1921. "Cooling of hospitals." *Journal of the A.S.H.V.E.* 27(October):763–764.

5. Jouglet, A. 1873. "On the various systems of cooling the air; and their application in factories, public buildings, and private houses." *The Practical Engineer* 1(6):450–463.

6. Ohmes, G. and A. Ohmes. 1936. "Early comfort cooling plants." *Heating, Piping and Air Conditioning* 8(June):310–312.

7. Billings, J. 1893. *Ventilation and Heating* 391–392. New York: The Engineering Record.

8. Ohmes and Ohmes, 1936.

9. Harris, J. 1903 "Cooling an auditorium by the use of ice." *ASHVE Transactions* 9:179–187.

10. ibid.

11. Anonymous. 1907. "Topical Discussions" Topic no. 4 "Air washers and air cooling." *ASHVE Transactions* 13:287.

12. Allen, L. 1893. "Summer ventilation and cooling." *Heating and Ventilation* 13(March):6.

13. Harris, 1903, p. 182.

14. Meckler, G. 1994. "The scientific roots of HVAC&R," p. xxiii, published in: Donaldson, B. and Nagengast, B. 1994. *Heat & Cold: Mastering the Great Indoors*. Atlanta: ASHRAE.

15. Eisert, H. "The cooling of closed rooms." *ASHVE Transactions* 2: 172–195.

16. McCandlish, F. 1932. "Bibliography of articles on use of ice for air conditioning." *Ice and Refrigeration* 82(February): 120–122.

17. Anonymous. 1932. "Comfort cooling for the home." *Ice and Refrigeration* 82 (February):142–143.

18. Bullard, J. 1931. "Automatic house cooling." *Ice and Refrigeration* 81 (July):1,2.

19. McCandlish, F. 1931. "Recent developments in comfort cooling with ice." *Ice and Refrigeration* 81(August):97.

20. Brandt, E. and L. Currey. 1932. Comfort Cooling Sales Manual, section III: "Increasing ice sales with comfort cooling." p.4. Chicago: National Association of Ice Industries.

21. ibid.

22. Brandt, E. and L. Currey. 1932. The Engineers Manual, section VII: "Increasing ice sales with comfort cooling." Chicago: National Association of Ice Industries.

23. McCandlish, F. 1931. "Recent developments in comfort cooling with ice." *Ice and Refrigeration* 81(August):98.

24. Anonymous. 1931. "Air cooling with ice." *Ice and Refrigeration* 81(October):207–211.

25. Holske, C. 1937. "A study of office air conditioning using ice." *Heating & Ventilating* November:31–34.

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