DEVELOPMENT OF HVAC&R FOR LOW- AND HIGH-RISE BUILDINGS— One Engineer's Bird's Eye View

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ABSTRACT

The HVAC&R industry as we know it was virtually nonexistent before 1840. The heating of buildings was obtained almost exclusively by using fireplaces, kitchen stoves, or oil heaters, if there was any heating at all. This paper traces the general development of the major trends in HVAC&R, particularly as they apply to New York City, which was the first large-scale testing ground for many of the systems that evolved. The role of ASHRAE and its predecessor societies will be noted as appropriate.

Cave dwellers, the Greeks, the Romans, and American Indians, among others, have taught us a few things about the do's and don'ts of open-fire heating and ventilating. For one thing, it is not a good idea to build a fire in the back of a closed cave and then stand in front of it. The smoke may be harmful to your health, and you will not have a barrier between you and predatory animals looking for an easy meal. Through this kind of "trial by fire," our ancestors learned about the effects of combustion gas removal, the stack effect, convective airflow, and radiant heat. It was not until well into the Renaissance that the phlogiston theory of the development of fire was quenched. We now take these things for granted as part of our store of knowledge. In fact, we tend to forget, or ignore, too much of what the past has left as its legacy. The organized, quantitative, scientific basis for the HVAC&R field is not much more than 150 years old as applied to the building industry. Our 19th and early 20th century predecessors were real pioneers who did much experimentation before they achieved the results they desired. Much of this information has been documented.

In our quest to do things fast and economically, I fear that we do not always pay sufficient attention to what was learned in the past, though, of course, we have yet to consider and learn about futuristic problems, such as the effects of ionization on comfort and the need for full-building volume air conditioning. Many may consider that the solutions to such problems are pipe dreams, given the present state of our technological capabilities and knowledge of peoples' needs and how they function. Is it even possible to provide "healthful" comfort to more than 80% of the people within a given environment at any given time?

There is much to be said for the "good old days," when people had to accept the vagaries of environmental comfort as they were. They made do as best they could, and it was accepted because they were in tune with, and a part of, the natural order of the universe. Nowadays, we tend too often to expect perfection from others without giving it ourselves. Unrealistic expectations and finger-pointing do not bode well for our industry. Our buildings, and the solutions we conjure, are becoming too complex without achieving the trouble-free results we desire.

The development of HVAC&R for low- and high-rise buildings as we know it is less than 150 years old for heating, less than 100 years old for ventilating, and barely more than 50 years old for air conditioning (to be read "cooling" in the common vernacular, not the ASHRAE definition). It may appear that we have come a long way, but we still have a long way to go to meet the ASHRAE comfort criteria for buildings. It will probably take at least 200 more years, and I am not being pessimistic. Why, even our current technology still functions on a basis that was established more than 100 years ago. We need more original and creative thinking for the buildings of the future.

Let us start at the beginning as buildings were developed in the USA and in the New York City area in particular because New York City is where it all really began before slowly spreading throughout the land. In some respects, Chicago and, to a lesser extent St. Louis, were not far behind, and at times they were ahead in their thinking and deeds.

Prior to 1840, a bird's eye view of New York City would have revealed that virtually all buildings were either one or two stories. Four-story buildings, such as the First National City Bank Building built in 1842 at 55 Wall Street and William Street, were rare. The highest point of any building in populated areas was invariably the spire of a church, bringing it closer to the source of divine inspiration. Heating, if any, was generally provided by fireplaces, Franklin stoves, kitchen stoves, or animal oil heaters. Fuel was generally wood, coal, or anything available that burned. Midwestern prairie settlers often had little else available but brush, grass, and dried sod.

Wherever feasible, clustering of heating terminals to use common chimneys was employed for economy. Construction was usually wood, brick, or log with insulation a rarity.

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Institutional buildings might be built of load-bearing masonry with high-ceilinged floors. Ventilation was furnished through openable, single-glazed windows in each room. Not infrequently, the wood-fired kitchen stove provided the sole heating for the entire house. In the summer, people could keep cool by going down to the cellar, if there was one, or by sitting on the shady side of the building and fanning themselves. A few people, mainly farmers and some merchants, were able to get blocks of ice cut from frozen lakes or rivers and store them under piles of hay for future use—as long as they did not wait too long. The ice was used mainly to preserve foodstuffs. There was no electricity. Artificial light was obtained by candles and oil lamps. Power was obtained from the wind, running water, and animals. The steam engine was available for running locomotives and some industrial processes, but a boiler for making steam or hot water for heating a building had not yet been developed.

In the 1840s some people began to tinker with steam boilers that would be suitable for providing heat for buildings. They were cast iron, coal-fired devices that connected into wrought iron piping to bring the steam to cast iron radiator terminals. These terminal units were made up of many sections, causing more difficulties in developing these radiators than the boilers. It took a while to develop leakproof connections between the sections. Over the next 15 to 20 years, the relationships between air, steam, and condensate were studied (mostly on the job), and improved means for valving, air venting, and steam trapping were developed. As more building owners and developers saw the advantages of a central heating system, improved pipe and terminal unit sizing were devised. A central system enabled the construction of buildings up to seven floors high without multiple chimneys and no need for room occupants to make their own heat. The building height was limited due to the requirement that all walls had to be load-bearing to carry the upper structure. Also, it was difficult to get people to walk up four or five floors voluntarily.

HVAC&R consultants had not yet been invented, so it fell to a group of adventurous people to call themselves heating contractors (many of them were initially plumbers) and solicit to design and install heating systems in buildings. There is not much evidence to indicate that they were anxious for the resultant service contracts. The reputable contractors, probably in the minority, spent many unexpected hours at their installations to solve new problems, such as uneven heating, air binding, water hammer, and pipe leakage. These forays into the unknown generally involved the various manufacturers. As problems became resolved and understanding improved, the manufacturers and contractors got patents and reputations for good results. The trend toward steam heating systems during the balance of the 19th century caught on with the commercial, institutional, and multi-family residential markets. Single-family homeowners, except for some very wealthy owners of large, ostentatious mansions, did not indulge. They were not about to get involved with coal storage and banking and stoking regimens for the boiler.

By the mid-1800s, four- and five-story brownstone (soft, fine-grained sandstone) buildings were beginning to replace the red brick and farm houses that made up the landscape of New York City. Architects and others were fretting about the destruction of so many old buildings. It was during this period that the one-pipe steam distribution system came into vogue (to save contractors money, of course). Many contractors had to "leave town" because they skimped on the size of the piping and/or they did not understand steam systems well enough. By the early 1900s, most of the 850,000 land lots in Manhattan were taken, and, as one writer put it, "The landscape looked like a purple line of humble roofs with reddish brown cast of buildings." For some reason, he saw fit not to mention the dotting of the skyline with skyscrapers, which was taking place before the turn of the century. New York City was a merchants' city due in large part to its excellent port facilities, so any trend they tended to look upon favorably was encouraged. The really big growth in steam heating began in the last quarter of the 19th century. This growth was spurred by several important factors.

1. There was tremendous immigration from Europe.
2. Steam-powered elevated railroads along 3d and 6th Avenues in 1878 opened upper Manhattan and the Bronx, giving many newcomers to our country the opportunity to move out of the crowded lower Manhattan areas in which most of them lived. The 9th Avenue "El," built in 1890, opened up the west side of Manhattan. And we must not forget the tremendous impact that the Brooklyn Bridge had in opening up Brooklyn when it was put into service in 1883.
3. The development of safe elevators was suitably demonstrated in the 1870s and initiated the desire for vertical growth of buildings. The potential of the elevator began to blossom when George B. Post, an engineer by training but a prolific architect of commercial high-rise buildings in the late 19th century, designed the Equitable Life Assurance Building at 120 Broadway in 1870. Although it was only five floors high, it stood 130 feet tall, so elevators were installed. In 1875 his Western Union Telegraph Building at Broadway and Dey Streets (230 feet high) and Richard Morris Hunt's New York Tribune Building on Park Row opened.
4. Other factors that helped New York City to grow rapidly were the introduction of electricity by Thomas Edison in 1882, the opening of the first telephone exchange by Bell Telephone Company in 1876, and last, but not least, the completion of the Croton Aqueduct water system in 1890 across the Harlem River. The latter allowed for the increased growth of the population of Manhattan and the Bronx. By 1900, the area housed almost 2 million people.

Going back a bit, in 1846 the spire of Trinity Church at the west end of Wall Street was, at 284 feet high, the highest structure in New York City. It lost its ranking to George B. Post's Pulitzer Building in 1890, which at 390 feet became the tallest building in the world. The Pulitzer Building lost that title the following year to several Chicago structures. As a historical note, it was in the Pulitzer Building in August 1894 that the first meeting was held to discuss the possibility of forming a heating engineers' society. Between 1880 and 1890, 8- to 10-story buildings were no longer a novelty that attracted sightseers. In fact, between 1890 and 1897 so many tall office buildings were erected that one writer stated, "the enterprise of business has surpassed the aspiration of religion."

Buildings taller than 10 stories did not appear until George B. Post designed and built the world's first building that combined a wrought iron and masonry structure, the Produce Exchange at Bowling Green in 1886. In 1889, architect Brad Gilbert built the 11-story Tower Building at 50 Broadway on a 21½-by-108-foot lot using the Chicago construction system, complete interior framing with metal and without masonry walls. As skyscrapers were developed and grew taller, they presented new and different problems for the H&V engineer. As with so many innovations, the concept of skyscrapers began in Europe, Paris to be precise. It was in this heady construction climate that the American Society of Heating and Ventilating Engineers (ASHVE) was founded on 10 September 1894 at the Broadway Central Hotel, a seven-story structure at Broadway and 3d Street. This hotel was built in 1870 and was originally called the Grand Central Hotel.

In all of the tall buildings, coal-fired boiler plants were installed. Many also included electric power generating plants that used steam to drive turbines. No two plants were alike. Since the contractors designed and installed the steam systems and their related heating and distribution requirements, there was often a conflict of interest dictating (a) what the owner got and (b) the quality of the systems installed. The end results varied greatly. ASHVE hoped to develop better design standards and criteria to eliminate many of these problems. Many building owners decided not to build their own steam plants and connected their buildings to the New York Steam Corporation central distribution underground piping network in lower Manhattan. NYSC had been in the business of selling steam since 1881.

Although buildings got taller, care was taken in their design to ensure that no occupied space was more than about 20 feet from an openable window that permitted outdoor air to enter. Ventilation air systems were almost the exclusive domain of theaters, large public buildings, and factories employing many people. At the turn of the century, ASHVE was instrumental in getting states to promulgate laws on minimum ventilation requirements for schools, factories, and other places of assembly. As the buildings got bigger, the use of two-pipe steam systems with gravity condensate return became common. In very large buildings, the use of vacuum condensate return systems was initiated to increase the system heating capacity and reduce the sizes of the condensate pipes.

When a building had interior spaces, ventilation could sometimes be provided by architectural features such as clerestories or skylights. More often, the early fresh air ventilation systems were designed to bring in outside air to the affected area. This fresh air was usually brought in from an exterior source several floors above ground level to make sure that the air was not contaminated by vehicular traffic. It was then filtered through sheets of mesh cloth and heated by an extended surface cast iron coil before being discharged into the space, usually at the floor, since hot air rises. The air traveled through building chases and sometimes through sheet metal ducts, propelled by large, slow-speed, vaned wheel fans driven by electric motors or steam-driven engines. Starting with the early part of the 20th century, air washers became more commonly used to clean the air and to provide some rudimentary cooling. The construction boom of the turn of the century slowed due to the impact of World War I and did not pick up again until the early 1920s due to a shortage of coal. It was during this period that the use of fuel oil for heating buildings began to be promoted. By the mid-1920s, gas for heating buildings was also being pushed. Gas for cooking was already commonplace. But coal was still king.

As important as heating was in the years leading to the 20th century, and no one questioned its necessity in the colder climates, many communities still did not have laws specifying minimum requirements for heating. The mentality of the fireplace era was still present in many locales. At the turn of the century, though, it was mainly a matter of design and installation criteria and the proper temperatures to be maintained. Some medical and public health authorities were quite convinced that an indoor temperature of 70°F was too high for optimum health. They pointed out that Europeans generally functioned well at temperatures 8 to 10 degrees lower. Ventilation aroused the greatest passions among engineers and medical and public health authorities. In fact, one of the first tasks tackled by ASHVE after its formation in 1894 was the development of ventilation standards for workers in factories. Ventilation standards for classrooms, auditoriums, and theaters were also studied. State standards began to be promulgated in the early part of the 20th century. The magic number always seemed to be 30 cfm of fresh air per person. You would be amazed at how many businesses and building owners claimed that having to install such ventilation systems would force them to go out of business!

The controversy over school ventilation for classrooms spanned a 30-year period and centered on whether gravity or mechanical ventilation was more effective and healthier for students. Detailed, long-term studies by acknowledged authorities in state-of-the-art laboratories in the 1910s "proved conclusively" that gravity supply air through the classroom windows and gravity exhaust through roof-wind-actuated ventilators produced substantially less student absenteeism and sickness than mechanical ventilation systems of the day. This created quite a stir among manufacturers, mechanical contractors, and the ASHVE community in general. The Newark and New York City Boards of Education, which were in the forefront of H&V activities in those days, studied the issues and decided in the 1920s to standardize on mechanical unit ventilator systems, which had been substantially improved since the turn of the century. One of the big improvements was the development of unit-type dry filters. Mechanical air systems were also being used in St. Louis schools.

In the early 1900s, when a large number of new hospitals were being built in New York City, ducted air-heating systems were installed in many of them for those areas requiring special ventilation, supplementing the standard cast iron radiation steam heating system. Cast iron radiation for hospital use was made to facilitate cleaning. In the 1910s, small refrigeration plants were installed in some hospitals' operating suites, as in Mt. Sinai Hospital. However, mechanical refrigeration was seldom used for commercial, institutional, or residential applications. Its prime areas of use were for the manufacture of ice, warehousing of foodstuff, and industrial applications such as printing plants. Ice was the prime medium for providing cooling. Theaters, in particular, used ice in large hoppers through which air was blown and then delivered to the seating areas to provide cooling. Up until the late 1930s, when General Motors invented the first of the halide refrigerants, most refrigerating systems used ammonia or carbon dioxide as the refrigerant.

The building boom of the 1920s ended with the Stock Market crash in 1929 and did not resume until several years after the end of World War II. Two notable edifices built after the crash in the early 1930s were the Chrysler and Empire State buildings. Starting in the 1910s, some engineers began designing gravity circulation hot water heating systems for all types of buildings, including high-rise structures. If properly designed, they seemed to work quite well. This design practice expanded with time. Pumped water heating systems were not common before World War II. Fully air-conditioned buildings were even less common before World War II. It is of interest that the first fully air-conditioned building that had fixed glazing in the U.S. was the Frank Lloyd Wright-designed Larkin Building in Buffalo, NY, in 1906. It had an ice bin in the basement, and air was blown over the ice and distributed throughout the six-story building, which had a full height interior atrium. The windows were all sealed because the location of the building was next to a railroad yard. The building had many unique features including steel folding chairs and furniture, wall-mounted water closets, fire safety features that would be the envy of many of today's buildings, plus much more. Wright knew what made buildings work better and convinced his clients to use his ideas.

In the two decades before World War II, although only heating and ventilating were provided for most buildings and ventilation was mainly for toilet exhaust and a few other special areas, air washers with small refrigeration systems were installed in many buildings to cool special areas such as board rooms. However, the refrigerated warehouse field grew during this period, just as the ice manufacturing business was declining because many households were purchasing electric refrigerators, and unitary ice makers came to the marketplace for butchers, grocers, and fish markets. After World War II, the facades of many residential buildings as well as the pre-war office buildings became dotted with window air conditioners. There was a large call for packaged air conditioning for restaurants, bars, and all types of business establishments, plus the operating suites of hospitals, meeting rooms, theaters, and other places of assembly.

The real HVAC&R explosion in the air-conditioning industry began when it became apparent to the real estate industry that there was a need for much more commercial office space. The building boom started around 1950 and didn't really let up until the oil embargo of 1973. Aside from the frenzy of construction that was started before 1973, which left New York City looking like a ghost town with all of the empty office buildings visible in 1975, what made this high-rise construction unique was that most buildings were built with large amounts of interior space requiring year-round space conditioning. Often, this interior space had more floor area than the perimeter space, which meant that air conditioning had to be considered during the initial design phase of the building to a much more extensive degree than in the past. In addition, the exteriors of the buildings were no longer predominantly masonry. Less costly single glass and enamel panels were used to clad the exterior. To reduce the first cost even more, many owners opted for fixed glass on the premise that the interior air conditioning would provide greater comfort. Another important side effect of the oil embargo was that a large number of experienced HVAC&R engineers from the Northeast migrated to the South and Southwest to bolster the expertise available for the burgeoning building boom that was just getting under way.

The increased use of wall insulation, double glazing, and higher lighting and equipment loads generally reduced the winter heating requirements but increased the need for summer cooling on the perimeter areas. In some cases, the interior loads were so great that most of the winter heating load could be furnished by leaving the lighting on. The plethora of air-conditioning systems and equipment devised to serve these buildings, plus the multitude of existing buildings that were retrofitted to make them marketable, attests to our creativity and lack of standardization. Happy days were here again and almost everyone was making money and giving free vent to their design genius. However, a definite trend took place from the 1950s to the mid-1970s. Initially, most of the large buildings had central air conditioning, with as few air-handling systems as possible, split between perimeter and interior spaces. Some of these air-handling units provided more than 100,000 cfm each. Perimeter systems were often combination air/water induction systems with constant-volume interior air systems. Automatic control systems were mostly pneumatic with some electric systems being put in. Toward the end of the 1960s, as costs escalated, second-generation building owners started using air distribution systems such as dual-duct systems and hung ceiling return air plenums. This allowed lower floor-to-floor heights and cut down on non-usable floor areas. Owners saved on first costs, but tenants paid for the higher utility bills.

The residential market of the 1950s and 1960s took a different direction. Induction systems were installed in some of the high-rise buildings, but the vast majority of buildings had fan-coil system terminal units with a central refrigeration plant providing chilled water. In most cases, outside air was furnished through openings in the back of the fan-coil units directly through the outside wall. The same piping system was used to provide heating in the winter by means of hot water. Existing residential buildings generally had window or through-the-wall packaged units.

Creators of more speculative office buildings in the late 1960s began to design for fan-coil unit systems or packaged air-conditioning units on each floor. This unitary approach was developed to the point where tenants were required to provide and maintain their own air conditioning, which would be connected into the building's central chilled water, condenser water, or outside air system, depending on the specific building features.

During the post-World War II construction period, almost all refrigeration units initially were electrically driven until steam absorption machines came into the market. The economic analyses of the day seemed to favor absorption units over electric in the New York City area, especially in the areas served with underground steam. Owners of some of the larger and more sophisticated buildings installed steam turbine plants, some of which used exhaust steam to feed absorption units to improve plant efficiency.

To further reduce building first costs, owners of many buildings, in particular apartment houses, were induced to install all-electric heating and cooling plants. In less than 10 years, most tenants and many landlords began to see the folly of this approach as electric rates rose precipitously.

Around the time of the embargo, the post-World War II construction bubble for the Northeast had burst, energy and other costs had risen substantially, and the need for more office space was diminishing. It was time to take stock of where we were and where we should be heading. The various governmental authorities were in the process of giving us their valuable guidance through DOE and other agencies. Remember, there were a lot of private sector HVAC&R experts who lost their jobs during this transitory period and had to find employment somewhere. The government arena filled the gap for many. The concepts of energy conservation and management, though not new, were slowly being reconsidered. It took government edicts, fuel shortages, rising prices, the birth of a professional society dedicated solely to energy and environmental issues, among other events over a 10-year period, to make us collectively realize that energy use had to be considered side by side with design loads and equipment and system selection. Some consideration was even given to using the natural elements, such as the wind, sun, ocean currents and tides, and geothermal sources to provide our heating and cooling needs, but too many felt that the long-term benefits did not outweigh the shorter-term lower fossil fuel costs nor the inertia to consider new design and manufacturing technologies.

The task of considering the energy utilization characteristics of buildings is undoubtedly more time-consuming than just calculating a building's heating and cooling load. Fortunately, this task has been considerably simplified with the advent of computers. The job of controlling a building's energy use has also been made easier by the coming of age of direct digital control systems. However, in the 20 years since the embargo, it is doubtful that even 25% of building managers are actually aware that building energy issues could be treated as an independent profit center and should be a matter of continuous top management interest and participation. Building owners who have adopted this approach have generally reaped large benefits and profits. Also in this time period, it is doubtful that anything substantial has been done in more than 25% of all buildings to permanently improve their energy utilization. Many buildings owners who did things initially because "it seemed to be the right thing to do" have since regressed and are back to their old ways of operating buildings and having even higher utility bills. It continues to amaze me how little thought is given to the design of optimized solutions for new buildings. Still, the shift of change is in the air, albeit mostly verbally.

The past 20 years have brought many changes to the HVAC&R field. Some of the important ones, in my opinion, are the following.

1. No longer is it acceptable to arbitrarily tear down buildings without first considering rehabilitation.
2. In many instances, "smaller is better" (but not too small) when it comes to sizing HVAC&R equipment.
3. Engineers are more often being held accountable for the energy operating costs of the systems they design. Considering the reduced role that owners often mandate for consulting engineers during the construction process and the almost complete lack of engineer involvement during the operating phase, resolution of this accountability has yet to be adequately addressed.
4. HVAC&R equipment available in the marketplace is substantially more energy efficient. The larger manufacturers are now beginning to make such equipment more commonly available. Utilities are often offering rebates (paid for by their customers) for the use of energy-effi-

cient equipment to forestall the need for building new power plants.

5. More equipment, such as air-handling units and water pumping stations, are being factory fabricated instead of fie]d fabricated.
6. Public education is encouraged to promote an awareness of and the purchase of more energy-efficient equipment.
7. Buildings are being designed and/or retrofitted to be inherently more energy efficient by means of passive measures such as insulation, better glazing, building orientation, building shape and mass volume characteristics, lighting, and so on. The advances in glazing technology may be one of the major contributions of our times to improved building operations, if it becomes more widely accepted.
8. Improved HVAC&R control technology permits improved understanding and operation of the building to optimize energy and maintenance costs.
9. Ventilation standards have been increased to the pre-1973 level with improved technology, at reasonable cost, to help measure the components of indoor air quality (IAQ). The latter term requires much more understanding before it takes on the legal and governmental impact it appears to be generating.
10. ASHRAE standards exist to improve primarily new building design. Some attention is being given to improving existing building energy characteristics. The litigious attention being given to HVAC&R issues that may affect the ±20% who are not sufficiently benefitted by our standards is alarming and must be diverted or stopped.

I feel that we are on the right road to improving the design and operating characteristics of HVAC&R systems in new and existing buildings. However, it takes a long time for real estate interests and building owners, in general, to initiate measures in a timely fashion, especially when the excess costs of running a building are passed along to the tenants, who are usually not aware that they are paying too much for the energy costs. Other factors that prevent us from achieving optimum building energy utilization are:

a. The fact that most buildings are kept at too high a temperature in the winter and too low a temperature in the summer. In the USA it appears that most buildings are kept at 74°F year-round when the buildings are occupied.
b. The continued reliance on initial lowest first cost of construction, as compared to total owning and operating costs over a reasonably based economic life for the building. Most buildings are used for a period of well over 50 years. The demand by management for paybacks of three years or less for contemplated building improvements in relation to the life of the building is usually very short sighted.
c. The lack of specific management oversight and responsibility for optimizing building operations and maintenance, including appropriate incentives for operating personnel to maintain high standards.
d. Insufficient training of building operating personnel.
e. The lack of establishment of energy conservation and management as an independent profit center to help monitor and optimize performance and help pay for future energy optimization measures.
f. The fact that, in my opinion, we have yet to address the question of whether ASHRAE is to direct its considerable talents to the current "hot topics," which may provoke litigious activities by others, or should direct more attention to improved and expanded efforts to educate people on what HVAC&R is all about. We need to let everyone know about the inherent limitations of the uses of HVAC&R equipment and systems and the multitude of uncontrolled, and uncontrollable, variables that affect the final results of our efforts and clarify the responsibilities and expectations of the users and occupants of air-conditioned spaces. ASHRAE must continually emphasize that the state of the art is still such that at any given time the chances are that only about 80% of the people in any given set of conditions within a building will be comfortable. Our efforts can be better directed toward better understanding of the factors that affect comfort, how to improve and achieve comfort, and how to upgrade that 80% figure. Hopelessly pandering to the notion of universal satisfaction with environmental conditions under all circumstances for all occupants is a futile quest. When was the last time that ASHRAE gave even a B+ to the air conditioning of any location where we have held our conventions?
g. Building developers and architects still have a long way to go to catch up to ASHRAE on the issues of energy optimization and comfort over the life of a building. More education and cooperative efforts are the answers. ASHRAE could also do more to attract the attention of building operating and management personnel by inviting them to participate in our activities—and we in theirs.
h. There is nothing wrong with manufacturers making equipment that was formerly field fabricated, but the equipment must do more than just look like what it represents. First cost is not the only criterion. Suitability for the function, capability of maintenance, ease of operation, and low energy costs are some of the factors that must be addressed. The entire burden of suitability should not be thrust on contractors, owners, and engineers to make detailed evaluations of what is being offered.
i. HVAC&R engineering consultants have to be better trained, more forthright and articulate in their conceptual design presentations, and ready and willing to carry their responsibilities through to the operating and moni-

toring phases of a building's activities. Owners must be convinced that this is the best way to achieve optimum building operating results. Our field is too fragmented, and the many interests present are often blatantly antithetical to each other. Everyone must be induced to work more closely together for the common good.

Now for the fun part of this paper. Where are we headed as an industry? What does the future portend? Do we head back to the caves, or will we be designing for the atmospheres of Mars and Uranus? Whichever direction we take, progress will be ever so slow. The construction industry is ever so conservative. Frank Lloyd Wrights do not come along frequently. Besides, the construction industry's activities are measured by the volume of work currently being performed, not its quality, and this rarely amounts to more than a few percent of the total building stock in the country. Now if the government mandated that all buildings that use domestic hot water must install solar panels for such use, that would almost guarantee a 10% reduction in annual energy use. That would positively generate new manufacturing industries and new contracting and service industries, provide new directions for architects, engineers, energy producers, and utilities, and save money for consumers. THAT would be a beneficial new direction, but, alas, it will be maintained by many, usually less than disinterested, sources that it is not "politically or economically viable," and lawyers would have a field day under our present system of resolving differences of opinion.

I'll venture that the median age of New York City's buildings is at least 70 years and that precious little has been done to upgrade their thermal environment other than what had to be done to keep them functional. The same undoubtedly holds true for many communities throughout the USA. It would be interesting to determine what proportion of the national debt could be recovered if at least 60% of all our buildings optimized their energy use—at least on a passive basis. Certainly within the next 50 years, large segments of New York City's housing stock will have to be replaced. Will that be done with 100-year-old HVAC&R technology or can we start to develop an approach that will ensure the buildings' survival into the 22d century?

The question of where we are headed has two facets, namely, the structure and direction of our industry (including ASHRAE) and the development of our society. Since industry arguably exists to serve the needs of our society, I'll discuss the latter first.

Commerce, service, and light manufacturing industries have served to draw people into very small land areas. This has created congestion and the development of very high-rise structures to accommodate this mass of people for both living and working requirements. This has substantially increased the costs of construction, transportation, support, and governmental facilities and services compared to suburban and rural standards. In my opinion, the computerization of our society through the so-called "information highway" could act as a catalyst, be it ever so slowly, to spread the large city outward into smaller, multiple, self-sufficient communities interconnected by efficient mass transit facilities. In my mind, this means more but smaller buildings, permitting less complexity, greater standardization, and better quality control. This does not mean uniformity or monotony, but the uncontrolled "creativity" of the past would be more effectively channeled. Much more properly designed and controlled prefabricated construction will be available. The use of passive solar design features in building construction will become commonplace to inherently save on the size of the heating and cooling plants and the annual energy costs. The use of solar heating and cooling will become more widely demanded, as will the use of wind power, geothermal energy, and water power. Of course, this panoramic vision will not become noticeable until after the year 2345. A new market will be developed for personalized air-conditioned clothing, which will be both comfortable to wear and fashionable, not like the current space suits worn by our astronauts. This trend will also reduce the need to fully air condition or climatize all areas of our future buildings. Naturally, this new clothing will be solar powered.

Consider that there have been virtually no major breakthroughs in HVAC&R technology since at least the 1950s, except for the development of DDC systems. There must be other and better ways of transporting heat than by sheet metal ducts and pipes and the fans and pumps used to push air and water throughout a building by means of brute force. Why don't I read or hear about using photo-voltaic technology to provide arrays in the skins of our buildings to transfer solar energy from one side of a building to the others for heating and cooling or to provide the energy to furnish outside air locally to spaces on an as-needed basis? Why is fiber-optics talked about only by communication companies? Why can't this technology be used to bring in outdoor light to building interior spaces? Let the skin of the building act more like the skin of our body. I do not believe that it is that farfetched. If there is any real long-term truth to the ozone and greenhouse effects, then we may be going back to CO_2 and NH_3 refrigerants instead of the expensive substitutes being pushed on us. Can we rely on manufacturers to honestly produce benign refrigerants that will have no long-term deleterious effects? That has not been the case so far. Not that they have lied to us; they have just not known what the long-term effects would be. After all, CFCs have been around for little more than 50 years—that's less than a human lifetime.

The above is just a smattering of what goes through my mind when I think of the future of our industry. We have done fine so far, and we will probably continue to do even more and better. However, the complexity and multi-disciplinary nature of the issues we increasingly encounter makes me reflect on whether it would be a good idea to resurrect the ASHRAE Research Laboratory to study, organize, coordinate, and monitor our future research activities. Perhaps we should consider the idea of having our own research building to study and develop HVAC&R subjects, which are too broad for most manufacturers. This could truly be a multi-disciplinary effort in much the same way that government performs such functions at the request of industry and with its cooperation. I believe that this is the only way that we will make real progress in our industry and be ready when the large stock of existing buildings has to be replaced.

My personal vision is not too grand for the short term, and we will have to think and work very hard and in a very concerted manner to achieve reasonable long-term goals over the next 200 years. Unfortunately, there will be a great deal of opposition to any effective long-range plans we develop, but we must set a precise, realistic, and flexible direction. I hope that our Bicentennial Plaque can positively reflect even a fraction of my dreams for our industry and the role that ASHRAE should play. Of course, there are other visions for our future that are possible and perhaps also reasonable. I would hope that this paper results in a widespread and concerted dialogue to plan for that future. The sooner the better!