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The Controlled Environment

W. L. McGrath

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The controlled environment

By W. L. McGrath
Carrier Corporation, Syracuse, New York, U.S.A.

In framing a prognosis for the 1980s with respect to our indoor environment, we could, like Orwell, select 1984 as a target date and this after all is only 13 years away. One way to cut fanciful prognoses down to size is to think back 13 years ago to 1958 and ask oneself, 'what have we really accomplished in the *last* 13 years?'. Well, there has been progress technically but the most impressive change has been the public acceptance and market development of the concept of indoor environment control. That is, all-season air conditioning.

In the 13 years since 1958, air conditioning has become a major industry in the United States currently amounting to an installed value of nearly $\$6 \times 10^9$ per year, and this is more than four times the level of 1958.

I offer some pertinent statistics:

(1) In the past 13 years annual installation of central residential air conditioning has multiplied 8.5 times to 1.2 million units per year and today one-third of all new single family detached houses built are air conditioned.

(2) Today more than 85 % of all multi-family buildings are air conditioned as built.

(3) Classroom buildings for colleges and universities are today nearly always air conditioned.

(4) Air conditioning is installed 50 % of the time in new primary and secondary schools as compared to less than 2 % 13 years ago.

(5) Practically 100 % of major office buildings that are built are air conditioned and have been so designed for the past 20 years.

One simply could not afford to build an office building in the manner in which they were built in the 1920s, when buildings were constructed in patterns resembling letters of the alphabet so that by open windows one could seek some heat alleviation.

Today we minimize the amount of outside exposure in relation to floor area as this creates a building which is more frugal in the use of valuable real estate, is cheaper to build, and costs less to maintain than the old alphabetical structures.

The evolution in office building design practice that took place during the 1940s and 1950s is a phenomenon that is being repeated today in the design of school buildings. It has been demonstrated repeatedly that the construction costs for completely air-conditioned schools will be lower than older extended structures employing separate heating and ventilation systems. Added economies are made possible by the potential of 11- or 12-month school years.

The net result of this growth is that the installed air conditioning in the U.S.A. over these last 13 years has gone from an energy demand of 30×10^6 kW in 1958 to over 200×10^6 kW in 1971.

Turning now to the technical accomplishments of the past 13 years, one cannot claim startling improvements but certainly we have at least seen some significant advances:

(1) The rapid growth of central refrigeration plants to distribute heating and cooling as utility operations and the development of very large refrigeration machines to serve this need.

In 1958 the largest refrigeration machine made was approximately 3000 tonnes – today it is 10000 tonnes.

(2) We have seen an explosive growth in the amount of air-cooled packaged air conditioning installed with most of this displacing field applied systems which would have used evaporative heat rejection methods.

(3) There has been a substantial decrease in the use of hot water or steam heating in the U.S.A. brought about primarily because of the recognition of the need for all season air conditioning in structures of all categories.

(4) Over the past 13 years we have seen a very rapid growth in the use of electricity for space heating. In 1958, the estimated connected space heating load was approximately 10×10^6 kW, and today this figure stands at almost 100×10^6 kW – a tenfold increase in 13 years.

As to the prognosis for the next 13 years, it is obvious then that the rate of growth of air conditioning will be simply the same rate as is represented by building construction for office buildings and buildings for higher education. However, in housing of all types for the rich and for the not so rich we expect geometrically increasing demand for complete environment control.

Technologically, we may be on the threshold of a period of change that could drastically alter the state of the art. The result of this change will be a better life for more of the people of year 1984 than we enjoy today.

The causes of the change are even now identifiable, and include these significant developments:

(1) Income and population trends suggest the rapid urbanization of great sections of our country and perhaps the world. In addition, we will see a rapidly improving status of all of the citizens of the world with respect to real income and their ability to enjoy the good things of life. In 1945 only 10 % of our families had incomes of $10000 or over while by 1958 this figure had risen to 20 %. Today the ratio is 50 %, and by 1984 we estimate that 80 to 90 % of the families will have incomes over $10000 per year. These income figures are expressed in constant 1969 dollars.

(2) We are experiencing a crisis in the availability of electrical energy at peak load demand. This crisis occurs on the hottest days of summer and therefore must be attributed in part to the presence of the growing air-conditioning load. This problem will not be quickly solved because it seems to be worsening faster than new capacity can even be planned.

(3) Another energy crisis is a shortage of non-polluting grades of fossil fuel such as natural gas and sulphur-free oil. World-wide we are consuming energy at a reckless rate.

(4) Another difficulty has to do with the lack of sensible utilization of land resources and the more general problem of defective urban ecology.

(5) We have a solid waste disposal problem of enormous dimensions in our country which is also starting to affect the rest of the world.

(6) Air pollution remains a growing and largely unsolved problem area for which our technology can offer solutions.

(7) Water pollution is a spreading cancer that is starting to infect our oceans as well as our lakes and streams.

(8) It seems that we may have a problem in fire control in tall buildings and this could have an influence on this technology.

(9) It is becoming apparent that there is a synergetic connexion between the concept of

complete environment control and the ability to build buildings of lower cost and better quality.

These then represent important considerations that will affect our technology and the other building technologies which are interdependent with us.

I would like now to put our prognosis in a nutshell: It is my belief that by 1984 our technology will have been forced to embrace a much broader concept of environmental control than would be implied by the terms 'heating', 'ventilating' or 'air conditioning'. Basic to the future of the building industry will be the necessity of acquiring a new respect for the value of energy and the development of technology and design practices to conform with that appreciation. The effect of our actions as architects and engineers on the quality of our environment must be understood and appreciated and we will surely find ways to control better the cost and manpower resources for our buildings. Finally, by that year we will have reversed many profligate practices through which we have been wasting our scarce land resources and compounding ecological bedlam.

The role of prophet is a precarious vocation not always honoured abroad or at home. Nevertheless, I will boldly make some predictions for our target year – 1984:

(1) In 1984, our architects and engineers will undoubtedly design buildings to conserve rather than dissipate energy. Peak energy demand will be reduced. We will come to appreciate the value of proper insulation, the impact of large glass exposures on energy requirements, the virtues of double glazed glass panels and reflective surfaces, and finally I hope we may expect to see better management of energy in our lighting systems.

(2) In 1984, our air-conditioning systems may well demand less than half of the electrical supply capability required by much of today's air conditioning. By employing advanced but practical techniques, we could theoretically reduce demand of our refrigeration serving air conditioning to as little as 0.75 or 0.8 kW/tonne whereas as much as 2.5 kW/tonne is required today with air-condensed packaged air conditioning. This power demand can be accomplished through evaporative heat rejection, power limiting control and by the use of refrigerant sub-cooling and other advantageous heat exchange opportunities in the cycle. Admittedly, the simplicity and convenience of packaged air conditioning using dry air for heat rejection will be a powerful counter influence, but the underlying economies of energy delivery must finally start to prevail. We may find that by 1984 there will be a reassessment of the rate structures generally used for electrical consumption. Electricity tends to be sold by the kilowatt hour like so many pounds of potatoes and this of course does not jibe with the true economics of the situation.

(3) In 1984, we will enjoy complete environmental control at home and at work with the control of temperature in each space and the maintenance of comfortable and healthful relative humidity summer and winter. The effects of air pollution, offensive odours, fumes, dust, air-borne spores, viruses and bacteria will be negated by the control of indoor air quality. With the cooperation of our architects, since building construction is also involved, we will enjoy proper control of summer humidity and in colder climates winter time humidity will be controlled at a proper level such as will eliminate static electricity and the physiological discomfort associated with very dry air. Better temperature control will eliminate compromises whereby one control centre is expected to do the impossible for many spaces.

(4) In 1984, most of our environmental systems will capture the heating and cooling now wasted in our buildings in order to reduce the total energy consumed. Heat-exchange cycles employing heat pumps, regenerators or other heat exchangers will salvage the heating or cooling

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from exhaust air to help condition incoming ventilation air. Heat pumps and other exchangers will also salvage the waste heat from lighting.

(5) In 1984, a large portion of our systems will employ a modulated air volume mode of control-reducing energy requirements as much as 24 to 50% while providing greatly improved control. In the past, the air volume was maintained essentially constant with the temperature adjusted or cycled to provide local control. In many applications the air has been reheated to cancel refrigeration for control purposes and this practice can, of course, be very wasteful of energy.

As has been demonstrated with some of the newer systems developed for office building structures and school buildings, this modulated air volume method of control can reduce energy costs because of reduced fan power and may reduce refrigeration energy consumption as well. In a given system of ducts and fans, the power requirements will vary as the third power of the air volume, so that a small reduction in volume offers a large power saving which is also magnified by the long hours of operation typical of fan systems.

In addition to saving energy, modulated air volume control can provide improved air conditioning by reason of graduated control of temperature and better dehumidification during the cooling season.

(6) In 1984, our piping systems which furnish chilled or heated water for environmental control will undoubtedly employ variable speed pumps again to save energy. Varying speed or capacity of pumps will consume less energy at all times excepting when required to meet peak demand. The power saving available for this cause could amount to 25 or 30% of the total annual pumping energy requirement.

Piping systems that allow the mixing of heated and cooled water for control purposes will certainly be obsolete by 1984, since they are energy wasters.

(7) In 1984, it is likely that the majority of our very large air-conditioning systems will employ heat-operated refrigeration cycles such as absorption refrigeration, a field in which new developments will give us thermodynamic cycles that may use perhaps half as much energy as is common today. The need for absorption refrigeration machines in large central plants will dictate the development of much larger sizes than are currently available, perhaps as much as 5000 tonnes in one machine.

(8) In 1984, our air-conditioning systems, particularly in tall buildings, may be designed and controlled to contribute to fire fighting efforts through the controlled ejection of smoke in emergencies. There are enough fan systems in a typical air-conditioned building that if properly utilized could change the volume of air in the building in as little as five minutes.

(9) In 1984, boilers will be available that employ pollution-free combustion processes for ordinary fuels that essentially will discharge only pure water vapour and CO_2 to the atmosphere. These combustion processes may also permit the use of lower grade fuels such as sulphur bearing coal and oil for the generation of power to serve our buildings and for the generation of heat to heat them or cool them. Sulphur and other contaminants will be absorbed and removed.

(10) In 1984, high energy pipe-line gas will be manufactured and distributed from minehead plants located in our coal fields. Thus the commercial utilization of practical coal gasification processes will provide a direct substitute for the natural gas now widely used and which is becoming depleted.

Another probable development is that coal gasification at such remote sites will furnish gas to dispersed central energy plants for the generation of electricity.

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(11) In 1984, the solid waste which is presently inundating us will be sorted, with useful non-combustible materials salvaged for reuse and the remaining waste may be used in pollution-free boilers or convertors for the generation of electricity and for the utility-like distribution of heating and cooling. New techniques in pollution-free oxidation of solid waste will make this possible. Even today prototype heat recovery incineration plants are already operating or are in the design stage. It is also likely that by 1984 we will see practical processes for converting combustible solid waste and even sewage sludge into combustible oil or gas that may be then used in our energy plants. In the U.S.A. we can predict that by 1984, almost 400 million tonnes of solid waste will be created each year, up to 75 % of which is combustible. Incentives will certainly be created to encourage the rough sorting of such waste at the source, with metals and glass being salvaged for reuse.

(12) In 1984, much of the heating and cooling of our buildings will be accomplished with zero energy consumption. By then we will heat and cool many of our buildings by central plants which act as utilities for distributing heated or chilled water. We can do this with essentially zero energy by usefully employing the presently wasted heat which is rejected from the power cycle used to generate electricity. It has been estimated that hot water from such a source can be pumped economically as far as 16 km from the central power plants. On the other hand, much of the power generated will be used for the lighting of these buildings and while we expect substantial advances in lighting technology, it is probable that the lighting may still dissipate enough energy to heat the new buildings of 1984 without requiring supplementary heat. Nevertheless, the heat rejection from electric power generation can surely be used to chill water by means of absorption refrigeration machines for distribution to buildings of the community thus converting a thermal pollution problem into a economic benefit.

(13) In 1984, the thermal pollution which is credited to the thermodynamic cycles used for power generation and refrigeration may also be usefully employed to create food through thermally supplemented aquaculture and agriculture and such heat may even contribute to the generation of fresh water from sewage. Agricultural applications might provide a long growing season and accelerated growth rates for many types of vegetables. Employed in aquaculture this heat in its simplest application could provide for enormous growths of algae which can be harvested for animal feed. On the other hand, it can also be employed to cause accelerated growth and large harvests of shellfish as well as the nutrients upon which they thrive and certain types of vertebrate fish such as *Ictalurus punctatus*, an American citizen more commonly known as the catfish, which is very happy in water at 27 °C or more. This power plant heat is today wasted and indeed is berated as a major cause of thermal pollution in streams and rivers.

(14) In 1984, the concept of complete environmental control would well have spawned a new concept in housing design and community ecology, permitting the efficient utilization of land resources through high density dispersal yet providing each family privacy, security, green space and the opportunity for a good life. Architectural designers will discover that complete air conditioning for this housing of the future is the key that will give them a new degree of freedom in housing design. Since architectural provisions for natural ventilation may be eliminated, one can reduce the ratio of outside wall to floor area for our living centres and thus obtain many collateral benefits, including lower first costs and lesser costs for maintenance, repair and vandalism.

Of many sociological benefits, the most important is the fact that the family unit will be

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comfortable and encouraged to stay in its own domicile rather than dispersing into the street. Of all the problems attendant to high density housing, the lack of family unity and development looms largest. Improved learning ability will also result from the elimination of heat stress. This may be an important contribution to what by 1984 will be an 11 or 12-month school year to take the place of the present practice of turning children loose in the streets for a summer of idleness and mischief. Distraction of street noises and noises from other apartment units can be devastating in high density housing areas. Air-conditioned family units of the future can be accoustically isolated and windows will be closed shutting out distracting noise.

All of this could lead to an entirely new approach to housing design perhaps involving introspective housing concepts that, while providing substantial population density, could give each family needed privacy through the use of semi-private sun bathed courts. The roofs of such buildings should ideally contain parks and gardens designed and protected for the security of the residents.

By achieving high population density yet family privacy in such living centres, more of the land resources can be devoted to parks and playing fields. By planning the community ecology in total, efficient transportation systems may be devised, communicating with industrial and commercial work centres as well as shopping and recreational areas.

We have only to look around us to realize that our practices in these matters are so generally inefficient, that this better life for all can be assured if we so resolve.

Lest you think that Pollyanna helped me write this last prediction, I hasten to concede that bricks and mortar and green parks will not by themselves cure all the ills that infect the cities of my country. We must look to our contemporaries in the less tangible sciences of sociology, psychology, education, and religion to come up with essential counterpart developments. Nevertheless, we as planners and builders have the resources and capabilities within our grasp to provide in 1984 the assurance of a good life to all who will bring with them the desire to live in peace and harmony with their neighbours.

Perhaps the total concept which I have finally reached through this series of predictions, based upon my own perception of the outcome of our emerging problems, could cause some understandable scepticism. Thus, the vision suggested of huge housing centres may cause some of us to flinch as we think of that home in the country with cows, horses and the associated country fragrances. And some of us may be uneasy as we think of the total dependence of such planned neighbourhoods on the suggested central utility plants for heating, cooling, lighting, waste disposal, and perhaps even transportation. Then too, the concept of every modest dwelling enjoying summer cooling as part of complete air conditioning could inspire disbelief among contemporaries of the European scene where until recently even central heating may have been considered a surrender to opulence and somehow unmanly.

There simply is not enough land in this world to give everyone a country house and ten acres. And even if we tried to utilize what land we have in this manner some of us would find ourselves in the middle of the Sahara desert or on the Siberian tundra and commuting to the City would become several degrees more difficult. As to dependence upon utility centres and the concomitant fear of war or sabotage, we are already completely dependent upon central energy sources and the concept to which I allude would really represent an improvement since what is suggested is a multiplicity of energy centres rather than the centralization now employed.

In closing this discussion, I must express the conviction that our building industry is facing

a unique opportunity to contribute importantly to the elimination of many of the ills of our society. Certainly by 1984, our industry will have been able to develop techniques of housing and indeed community design that will arrest our problems of air, water, and waste pollution; that will replace chaos with effectiveness in the utilization of our land resources and that will provide for the sensible conservation of our energy supplies. The better life for all that is in our power to create will only come to pass, however, if we, as engineers, architects and builders, resolve that our actions individually in our chosen fields will be consistent with the pursuit of these goals.

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