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The architecture of the well-tempered environment

The Architectural Press, London/The University of Chicago Press

This book was prepared under a grant from the Graham Foundation of Chicago

The Architectural Press, London
The University of Chicago Press, Chicago 60637

Published 1969

Printed in the United States of America by
Kingsport Press

ISBN:
0 85139 074 9 (Architectural Press)
0-226-03696-0 (University of Chicago Press)
80 79 987654

1. Unwarranted apology

In a world more humanely disposed, and more conscious of where the prime human responsibilities of architects lie, the chapters that follow would need no apology, and probably would never need to be written. It would have been apparent long ago that the art and business of creating buildings is not divisible into two intellectually separate parts—*structures*, on the one hand, and on the other *mechanical services*. Even if industrial habit and contract law appear to impose such a division, it remains false.

If there is any division at all that can be tolerated in a humane consideration of architecture, it might be between those parts of structure that combine with certain mechanical services to provide the basic life support that makes a viable or valuable environment, and those parts of structure that combine with certain other mechanical services to facilitate circulation and communication—of persons, information and products.

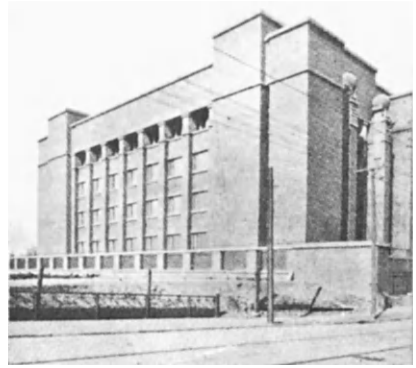
The fact that the outpourings of a radio may be understood as information or environmental background, that the flow of hot water through a pipe may be seen as contributing to the maintenance of an environmental condition or the transmission of a useful product, should warn us that the making of even the division proposed above is open to serious questioning, though the validity of this division for the purposes of the present book, which discusses the architecture of environment, should emerge as the argument proceeds.

Yet architectural history as it has been written up till the present time has seen no reason to apologise or explain away a division that makes no sense in terms of the way buildings are used and paid for by the human race, a division into structure, which is held to be valuable and discussible, and mechanical servicing, which has been almost entirely excluded from historical discussion to date. Yet however obvious it may appear, on the slightest reflection, that the history of architecture should cover the whole of the technological art of creating habitable environments, the fact remains that the history of architecture found in the books currently available still deals almost exclusively with the external forms of habitable volumes as revealed by the structures that enclose them.

The main topic of the present study has therefore only impinged upon the attention of architectural historians when it has incontrovertibly affected the external appearance of buildings, the most notable case being that of the Richards Memorial Laboratories in Philadelphia, by Louis Kahn. By giving monumental external bulk to the accommodations for mechanical services, Kahn forced architectural writers to attend to this topic in a way that no recent innovation in the history of servicing had done. No matter how profound the alterations wrought in architecture by the electric lamp, or the suspended ceiling (to cite two major instances of revolutionary inventions), the fact that these alterations were not visible in outward form has denied them, so far, a place in the history of architecture.

Yet what was visibly manifest in the Richards Laboratories, had been equally visible and manifest in Frank Lloyd Wright's Larkin Building in Buffalo, more than half a century earlier. Few architectural writers have made anything of those strong and monumental forms that Wright gave to the external expression of his pioneer system of mechanical servicing, however, except to cite them as the purely formal source of the external service-works of the Richards Laboratories.

So shallow an interest in so profound a building was both inevitable and predictable however; the art of writing and expounding the history of architecture has been allowed—by default and academic inertia—to become narrowed to the point where almost its only interest outside the derivation of styles is haggling over the primacy of inventions in the field of structures. Of these two alter-



Above: Larkin Administration Building, Buffalo, N.Y. 1906, by Frank Lloyd Wright.
Below: Richards Memorial Laboratories, Philadelphia, Pa., 1961, by Louis Kahn.

natives, the study of stylistic derivations now predominates to such an extent that the great bulk of so called historical research is little more than medieval disputation on the number of influences that can balance upon the point of a pinnacle.

As a result, a vast range of historical topics extremely relevant to the development of architecture is neither taught nor mentioned in many schools of architecture and departments of architectural history. Some are external to the buildings—patronage, legislation, professional organisation, etc.—others are internal—changes in use, changes in users' expectations, changes in the methods of servicing the users' needs. Of these last, the mechanical environmental controls are the most obviously and spectacularly important, both as a manifestation of changed expectations and as an irrevocable modification to the ancient primacy of structure, yet they are the least studied.

Thus, when the research for the present study was first put in hand, the intention was to write a purely architectural history; to consider what architects had taken to be the proper use and exploitation of mechanical environmental controls, and to show how this had manifested itself in the design of their buildings. To achieve this, some grounding in the purely technical history of these controls was obviously required, but I discovered that no comprehensive study of the topic could be found. The one work that was persistently recommended to me as having covered the ground or exhausted the topic, was Sigfried Giedion's *Mechanisation Takes Command*[1] of 1950. It proved, however, in no way to deserve such a reputation—a point to which this argument must return.

[1] London and Cambridge, Mass., 1950.

What needs to be said here and now is that although there can be no doubt that my view of the topic has been vastly enriched by my enforced studies of primary source material (trade catalogues, lectures to professional societies, specialist periodicals, etc.) the absence of any general and compendious body of study in the field leaves little chance of estimating how balanced and comprehensive is the view that I have derived from these readings.

The matter probably cuts deeper than this, because the absence of a body of studies means that the architectural, as well as the technical, aspects may be off balance. Thus, the average producer of a pinnacle-point type of doctoral dissertation on some such subject as 'The Influence of the Drawing Style of Mart Stam on the Aesthetics of *Elementäre Gestaltung*' is a scholastically secure man. He may be setting out to make drastic modifications in the balance of reputations of a group of architects working in a certain place at a certain time, but a known balance of reputations already exists for him to modify, because a continuing body of academic work keeps that balance under review in lecture, seminar and learned paper.

But step outside the security of that continuing body of work, and not only is there no balance of reputations, there are no reputations at all. Nobody knows who were the true masters and innovators, or who merely rode the coat-tails of genius. Ask a historian of modern architecture who invented the *piloti*, and he can tell you. Ask him who invented the (equally consequential) revolving door, and he cannot. Ask who were Baron von Welsbach, Samuel Cleland Davidson or what was first done on the façade of the *West-End* Cinema in Leicester Square, London, and the answer will come very haltingly if at all, and yet these are all matters deserving more than a footnote in any history of what has really happened in the rise of modern architecture.

In such conditions of ignorance and insecurity, and the sheer paucity and poverty of academic discourse on the topic, the reputation of *Mechanisation Takes Command* is perhaps understandable. Even James Marston Fitch, whose sagacious observations on environment and technology have been a constant inspiration to my studies, speaks of Giedion's book as 'a new and revealing study of American technology' despite the fact that his own published works constantly reveal the shallow and unconsidered nature of Giedion's observations.

The true fault of the book lay in its reception. Awed by the immense reputation of its author, the world of architecture received *Mechanisation Takes Command* as an authoritative and conclusive statement, not as a tentative beginning on a field of study that opened almost infinite opportunities for further research. In the ensuing twenty-odd years since its publication, it has been neither glossed, criticized, annotated, extended nor demolished. 'Giedion,' one is told 'hasn't left much to be said.'

This present book represents a tiny fraction of what Giedion left unsaid. This too is a tentative beginning, whose shortcomings, I have no doubt, will become manifest as research proceeds, especially since it suffers from at least one defect in common with Giedion's—the use of the concept of 'the typical.'

The chapters that follow are not exhaustive, therefore they are not definitive. In the light of partial knowledge one cannot specify with certainty, only typify with hope. That is, all one can really do is to indicate the sort of work that was done in a particular period of time, and select a particular building that seems to typify the kind of architecture done with that technique at that time. But in the absence of encyclopaedic knowledge or a going body of research and discussion, it is extremely difficult to be confident that one has picked the most typical building, or the best of a number of buildings exemplifying the same point. Matters of exact primacy in date, who thought of what first, are even harder to fix under these circumstances, but on this point, and in the context of this study, the use of the typical rather than the exactly definitive, can be defended.

While Patent-Office records, of the sort exploited by Giedion and his students in compiling *Mechanisation Takes Command*, make legal primacy of invention capable of being fixed with documentary certainty, such exact dates may be totally valueless in studying the history of architecture. In the practical arts like building, it is not the original brainwave that matters as much as the availability of workable hardware, capable of being ordered ex-catalogue, delivered to the site and installed in the structure. Thus the early patents for fluorescent lighting are almost inconsequential for the history of architecture, but the commercial availability of reliable tubes some thirty-six years later was to be of the utmost consequence. More confusingly, it is possible that one or two major buildings were being air-conditioned (in some senses) two or three years before the earliest air-conditioning patents, and before the phrase 'air-conditioning' had even been coined.[2]

[2] see chapter 9.

In conditions such as these, it may be unwise at present to try to establish absolute primacy of installation or exploitation, and pointless to lavish too much attention on primacy of invention. It has seemed better, in many cases, to settle for a building which appears to sum up forward thinking and progressive practice and let it stand as typical of the best or most interesting work being done at the time, but not to attribute to the concept of typicality those overtones of a platonic absolute implicit (and explicit) in Giedion's elevation of Linus Yale to the status of the very *type* of the Yankee inventor. The use of typicality in the chapters that follow is purely illustrative, the buildings singled out for mention tend less to be the first of their class, than 'among the first.'

This too seems just; this is less a book about *firsts* than about *mosts*. The invention and application of technological devices is not a static and ideal world of intellectual discourse; it is (or has been) impelled forward by the competitive interaction of under-achievers and over-achievers—who might even be one and the same person, for some breakthroughs in application were achieved without matching breakthroughs in invention. But nothing would have been broken through without some extremism of method, and extravagance of personality.

Le Corbusier might admonish in 1925 that 'an engineer should stay fixed and remain a calculator, for his particular justification is to remain within the confines of pure reason . . .'[3] but the fact remains that many of Le Corbusier's own buildings would have been unbuildable or uninhabitable had engineers ever heeded his advice, instead of pursuing their own eccentric and monomaniac

[3] *Urbanisme*, Paris, 1926, p 48.

goals without regard for professional demarcations and social conventions. The history of the mechanisation of environmental management is a history of extremists, otherwise most of it would never have happened. The fact that many of these extremists were not registered, or otherwise recognised as architects, in no way alters the magnitude of the contribution they have made to the architecture of our time. Perhaps finding such men a proper place in the *history* of architecture will be some help in resolving the vexed problems of finding their proper place in the *practice* of architecture.

3. A dark satanic century

An understanding of the way in which radical improvements in environmental technology came about requires a knowledge, not only of the mechanical opportunities and cultural advantages of the improvers and inventors, but also of the atmosphere in which they worked. The word 'atmosphere' is to be read literally. Whatever complaints may circulate today about air-pollution, as about traffic-congestion, we tend to forget that there is ample evidence that both were conspicuous evils of the nineteenth-century urban scene. Our common mid-twentieth-century habit of blaming both on the automobile, like the nineteenth-century habit of blaming them on the railways, the factory system, or other fashionable evils, ignores the fact that the root causes are simply the crowding of men together into restricted spaces. While it was necessary for men, in Aristotle's phrase, 'to come together in cities in order to lead the good life', those cities, by virtue of the coming together of men, would become places of pollution and congestion. The contribution of the industrialising nineteenth century was to bring even more people together at even higher concentrations, and to mark the gravity of the situation by means of new industrial wastes that gave unavoidable visible and olfactory form to the threat to health.

Phrased in the coolest possible terms, the working and living conditions of men in industrialised societies gave rise to environmental problems of the utmost urgency and baffling novelty. The sheer size and human density of settlements posed problems of waste disposal, and threat of epidemic (a threat tragically often fulfilled) that called for powerful legal action. The accumulation of large numbers of workers and mechanical plant in such places as factories and mines called for more than Factory Acts and similar legislation; sanitary and ventilating techniques had to be renovated and improved by radical inventions. The length of the working day required an unprecedented provision of artificial light (with its attendant fire-risks) even in structures above ground like shops and office-blocks. Furthermore, the pollution of the external atmosphere by the waste products of industry and primitive power-generation, and the matching pollution of the indoor atmosphere by human respiration and the inefficient combustion of illuminants, both served to aggravate problems that would have been almost intolerable without them.

However, the mere fact that the combustion of illuminants was inefficient and that most of the outdoor pollutants were wastes, gave an immediate and compelling motive for environmental improvement without waiting upon humanitarian legislation or political action by the victims of pollution. The inefficiency and waste represented lost profits to somebody, and the prospect of gain to any ingenious inventor who could reduce those losses. Below two dramatic panoramic photographs of Chicago wreathed in impenetrable palls of smoke, with the headline *Wastefulness*, the heating engineer M. C. Huyett declared in 1895

> While looking from a window on the fifteenth floor of the Monadnock building and observing smoking chimneys and escaping steam, the above headline (ie., Wastefulness) was suggested, because in it was expressed the economic condition presented to sight. Crossing the Chicago River and seeing hot water and steam from the sewer pipes of individual buildings emptying into the river, and when walking along the streets and seeing steam escaping from manholes, fixed in mind 'Wastefulness' and suggested the thought; 'What does the needless waste from these sources cost Chicago daily—$50,000–$100,000 ?'[1]

[1] *Mechanical Heating and Ventilating*, Chicago, 2nd ed., 1895, p 76.

Not only this, but there was obviously a matching wastefulness of human resources. However much, or little, nineteenth-century mill-owners and factory bosses may have regarded child-labour as an expendable commodity, that commodity was little use, even while fresh and unmaimed, if it could not see or breathe. One of Willis Carrier's earliest industrial air-conditioning installations was for the purpose of laying a fog of tobacco dust in a cigar factory, where conditions were so bad that the efficiency of workers was seriously affected. The foulness of the average nineteenth-century industrial environment is now almost beyond twentieth-century belief; its killer smogs and constant soot-fall little more than legends kept alive by the entertainment industry as picturesque effects in Sherlock Holmes stories. Yet the incidence of compulsive hand-washing in the early literature of psychoanalysis suggests that atmospheric pollutants may have corroded the minds, as well as the bodies, of those who had to endure these conditions.

If the elimination of profitless waste was one ever-present incentive to environmental improvement, the mere preservation of human life, and sufficient health for survival, was another, and ultimately more important one. As early as the eighteen-sixties, the difference in health of those working in controlled—even crudely controlled—environments and those in relatively uncontrolled ones, was a matter of public record. Ernest Jacob, in his posthumous *Ventilating and Warming*, cites Sir John Simon's report to the Privy Council

> In the year (1863) the deaths from consumption in country districts being taken as 100, the deaths in Manchester counted 263, and in Leeds 218. The greatest mortality took place among printers and tailors, classes who work largely by night, requiring a strong light, which necessitates the burning of much gas. On the other hand, contemporary statistics showed that the miners of Northumberland and Durham, where the pits were freely ventilated, formed an important exception to this rule . . .[2]

Since the safeguarding of health was so important an incentive to environmental study and reform, there should be no surprise at the important part played by medical men in these fields. What may occasion surprise nowadays is that their progressive activities involved direct action in the field of building. Their writings often reveal an intimate practical knowledge of the environmental performance of buildings, an expressed contempt for the architectural profession's apparent indifference to such matters, proposals for the improvement of building-design, and

[2] *Notes on the Ventilation and Warming . . . etc.* (SPCK Manuals of Health), London, 1894, pp 19*ff*. Professor Jacob, who taught at the Yorkshire College, Leeds, died shortly before his little book was published.

even the construction of reformed buildings by doctors themselves.

Thus Professor Jacob, who was quoted above, had no doubt at all that, as a pathologist, he was far better informed on such matters as heating and ventilating than were the architects whose work he had to visit, professionally or privately. The views of architects on environmental matters he regarded as little better than superstitious

> . . . in most cases architects are content to introduce an occasional air-brick or a patent device called a 'ventilator'. . .
>
> Real ventilation is so uncommon that . . . the architect usually thinks this object has been attained if some of the windows can be opened. Some think that the presence of 'ventilators', especially if they have long names and are secured by 'Her Majesty's letters patent', ensures the required end. We may as well supply a house with water by making a trap-door in the roof to admit rain.[3]

[3] op. cit., p 28.

This last point is of some importance in the context of the common state of architecture in the seond half of the nineteenth century. In the effective absence, from most buildings, of any system of ducted and force-fed ventilation (comparable with piped water under a sufficient head of pressure to make it go where it was needed) the movement of air was an almost uncontrollable function of the entire building structure, complete with its ancillary services and external weather conditions—the shade of a single tree, the closing of a door or the lighting of a fire in a spare bedroom might make the difference between tolerable and intolerable conditions. On the effect of innovations in ancillary services Jacob observes, for instance, that in concert halls

> Electric light being generally used, the heat from (gas operated) sun-burners—which were formerly used for lighting purposes—is not now available for ventilation . . .[4]

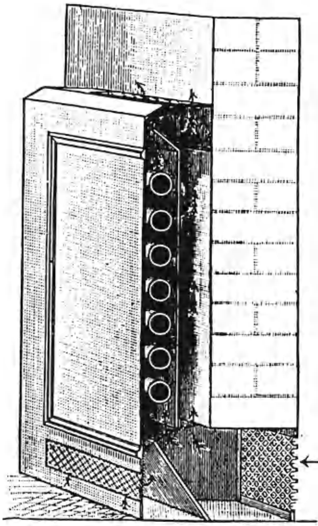
[4] ibid., p 94.

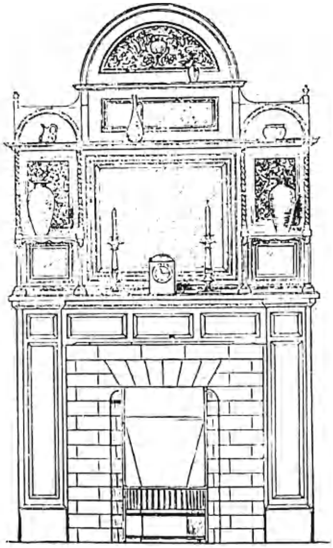
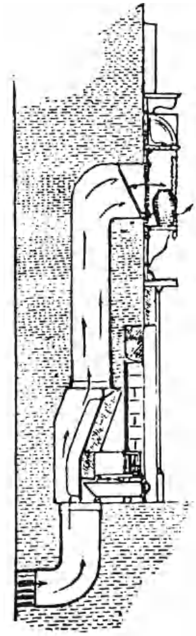
and, again, on the uses of external weather as an environmental aid

> A perfectly still day is the time when the greatest change of air is required, and the time when all wind-actuated schemes fail.[5]

[5] ibid., p 57.

The concept of the total involvement of the entire structure, its



Left: Professor Jacob's 'mixing valve coil-box for radiators'. Centre and right: Teale fireplace with warming chamber and concealed exits for warmed air in overmantel.

inhabitants and their activities, in the processes of ventilation and the distribution of heat, is what Professor Jacob's slim volume was all about. It was written primarily for the guidance of clergy, ecclesiastical building committees and church architects. The environmental insufficiencies of buildings for religious ritual and study always bring out his most caustic and characteristic blend of intellectual scorn and humane sympathy:

> The worst offenders against the laws of health are those responsible for the building of churches and other places of worship. The reason for this is not far to seek . . .[6]

[6] ibid., p 26.

Then follow some admirable examples of 'whole-building' environmental analysis:

> A church is built on a conventional plan, fixed in mediaeval times, when churches were less crowded, services shorter, and above all, at a time

when there was no lighting by gas . . . It is generally built in the form of a nave and side aisles, lighted by clerestorey windows. This gives, including the chancel, four ceilings of different heights, making it most difficult to extract the air at the level of the roof. The clerestorey windows chill the air as it rises, and send it down in the form of a cold douche on the heads of the congregation. The roof is lofty and dark, necessitating a large amount of light, and as a rule about twice as much gas is burned for lighting purposes as is necessary . . . Nonconformist chapels are generally worse, on account of the frequency of galleries and the consequent crowding. Worst of all are probably the numerous mission rooms which, through the energy of the clergy, are found in such large numbers in the poorer districts of our large towns. These are frequently improvised out of a couple of cottages. No architect is consulted on the subject, the alterations are made by a local builder, and sanitary conditions are absolutely unthought of. The strictest economy is observed, especially in the heating apparatus, which is generally a small stove, and every Sunday a large class of more or less unwashed children is succeeded by a crowd of totally unwashed adults, till the atmosphere can only be described as sickening.[7]

[7] loc. cit.

These last observations on the 'great unwashed' are not snobbery; Jacob clearly spoke sober truth based upon personal observation. Medical practitioners, in the course of their normal rounds and as visitors accompanying inspectors of mines and factories, had unrivalled opportunities for observing the varieties of environmental disaster the nineteenth century had bred, and would be exposed to conditions that rarely came to the notice of architects. The common contempt of medical men for the inhibitions of convention, and their rationalist belief in direct physical action are well enough known to leave no reason to be surprised that they frequently went beyond mere verbal protests at the conditions of the time. Not only did they often exert political leverage at the local and national level, but some also put up exemplary structures.

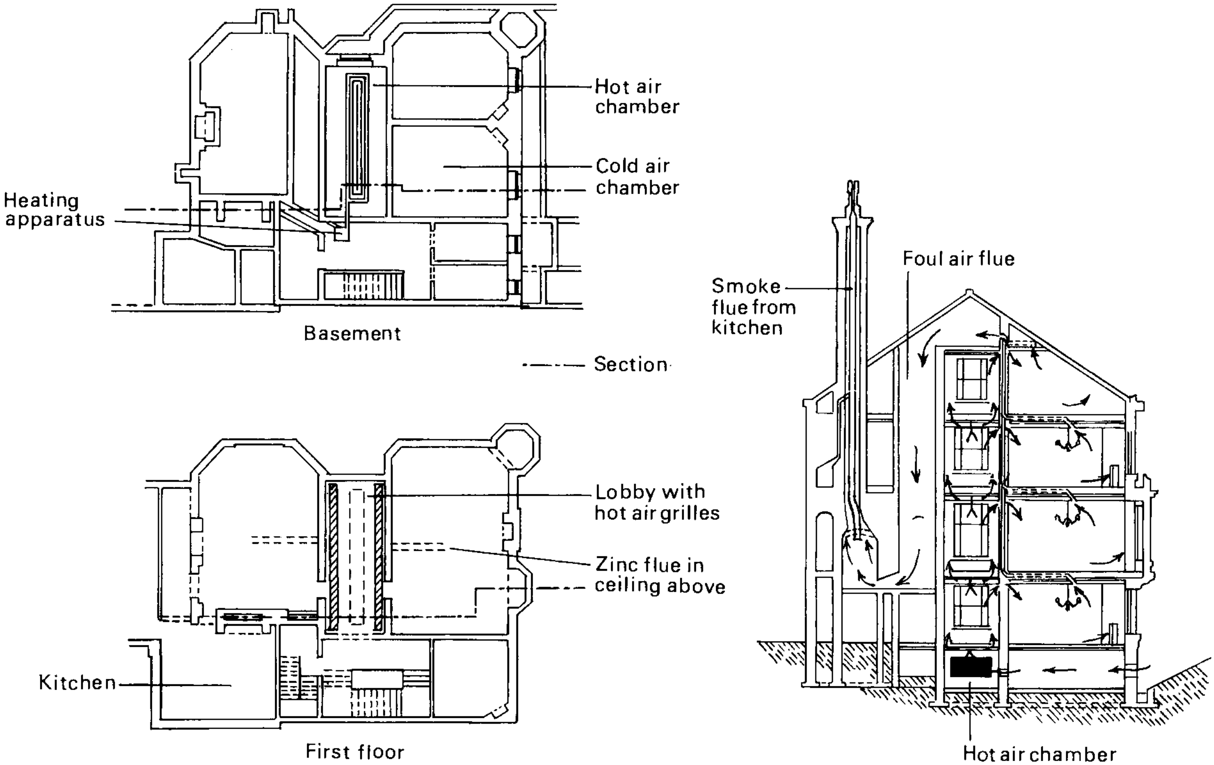
In the absence of any convenient source of directly applicable environmental power, they had to apply their medical knowledge and elementary principles of environmental physics in precisely the same holistic manner as is implicit in Jacob's critiques, designing the whole structure and use of the house anew, in order to achieve their environmental aims. In Liverpool, for instance, a Dr Drysdale, and a Dr Hayward, both built houses in the 1860's whose whole design turned around problems of ventilation and heating. J. J. Drysdale was the pioneer; his Sandbourne House of 1860 still stands. John Hayward's house, the Octagon in Grove Street, is a more complex and slightly more sophisticated affair, and was completed seven years later, and also survives, though in a very dilapidated condition. Both houses are well documented, as are their designer's intentions, because the two doctors collaborated on a text-book, *Health and Comfort in House-building* (1872) while Hayward read a paper on his Grove Street house to the Liverpool Architectural and Archaeological Society shortly after its completion.

His descriptions of the form and functioning of the Octagon in these two documents are so lucid and systematic, and give so good a picture of the environmental technology available and exploited in practice, that there is little left for later scholarship to add. All that need be said, in truth, is to draw attention to the way in which the whole plan, section and construction of the house, has been affected by his determination to control the ventilation, and the matching manner in which practically everything within the house, including the gas-lighting, is consciously set to work to assist the structure in realising that aim. A compact description of the house is given in *Health and Comfort*:

> The basement is devoted principally to the collection and warming of the fresh air. On the ground floor are the cellars (*scil.* cold stores) a ball-room, two professional rooms . . . The first floor is the living floor . . . The second consists of the family bed-rooms with breakfast room . . . and the third floor of the servants' bed-rooms with children's play-room, store room and two water-cistern rooms. And above, beneath the ridge of the roof, is the foul air chamber, into which all the vitiated air of all the rooms in the house is collected, and from which it is drawn by the kitchen fire, by means of a shaft passing down to the ground floor, and then ascending behind the kitchen fire, and up the kitchen chimney stack round the smoke flue.[8]

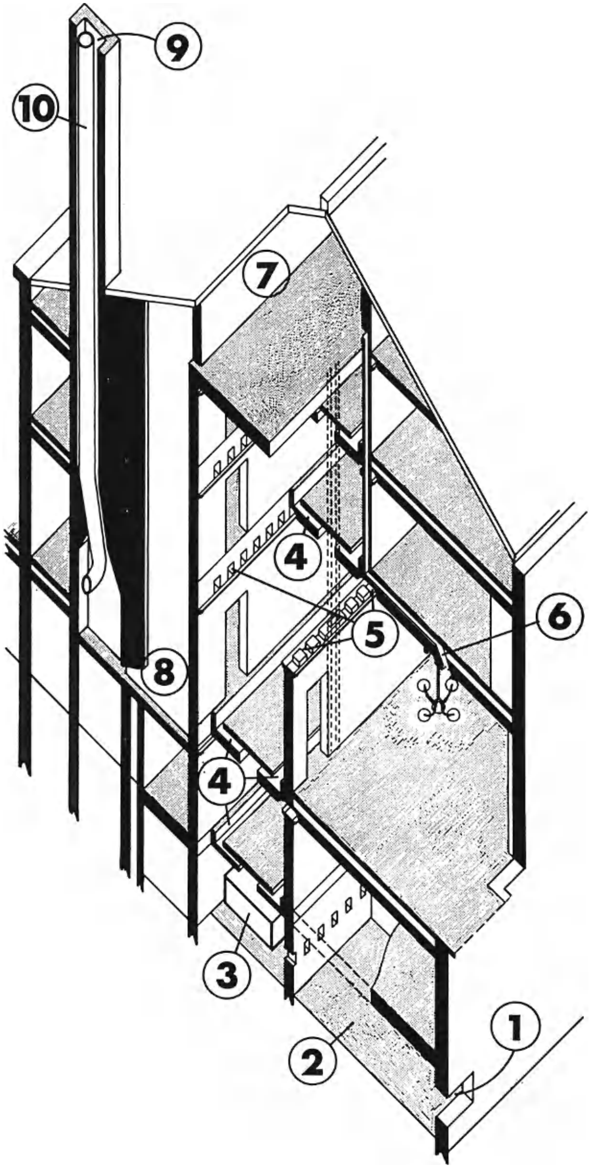
The use of an ascending/descending convection-duct of this sort,

[8] op. cit., p 68. All the available information on the Octagon, including survey drawings (which do not detail the duct-work, however) was brought together in a joint thesis report by J. I. Chambers, A. B. Shaw, R. J. Winter and R. N. Dent, which is now in the library of the School of Architecture, Liverpool University.



powered by waste heat (in this case, from the ever-burning kitchen range) was a pretty common form of air extract in the era before suitable fans were available. What is uncommon in the design of the Octagon is the way in which all the principal rooms open off closed lobbies, separated by doors from the hall and staircase. These lobbies, superimposed exactly in plan, form a vertical supply duct (called a 'corridor' by Hayward) delivering cleaned and warmed

Above: plans and section of the Octagon, Grove Street, Liverpool, built for his own occupation by Dr John Hayward, 1867.



Diagrammatic cut-away perspective of the Octagon, to show the circulation of the air.

1. Fresh air intake
2. Settling chamber in basement
3. Heating coils
4. Air passages in lobby floors
5. Air passages in cornice
6. Extract above gas lamp
7. Foul air chamber
8. Foul air down duct
9. Foul air chimney
10. Flue from kitchen range

air to the rooms, in a manner described as follows, to the Architectural and Archaeological Society:

> Along the centre of the ceiling of each storey of the central corridor is an ornamental lattice-work two feet wide, and along each side of the floor above is an iron grating one foot wide, these allow the warmed air to ascend from the lobby beneath to the lobby above, but check it for the supply of each floor, and prevent it rising directly to the top one.
>
> Along beneath the ceiling of the basement of this corridor run five coils of Perkins' one-inch diameter hot water pipes. Fresh air enters into the lower part of this basement and, rising, is heated by the heated pipes, and passes through into the lobby of the ground floor, and thence into the lobby of the first floor, and thence into the lobby of the second floor and thence into that of the third floor, so that the central corridor is filled from the ground floor to the attics with fresh warmed air.
>
> . . . Out of this central corridor all the principal apartments of the house open; and out of it, and out of it only, they receive their supply of fresh air.
>
> The cornice round the ceiling of the corridor, and of each of the rooms opening out of it, has a lattice enrichment seven inches deep, and the wall between these two cornices is perforated by as many seven-inch by five-inch openings as the joists will allow . . .
>
> Over the gasolier in the centre of each room is a perforated ornamental, covering a nine-inch square opening into a zinc tube nine inches by four-and-a-half inches . . . this zinc tube goes along between the joists of the ceiling into a nine-inch by four-and-a-half inch flue in the brickwork of the wall, between the corridor and the room above, where it is regulated by a valve. The flue rises up inside the wall and opens into the foul air chamber formed under the roof of the attic. The flue from each room *opens separately* into this chamber, and there is also a flue from the cloak room, the dressing room, the bath room, and the kitchen, and from all the water-closets, even the servants' in the basement; there are eighteen flues . . . Out of the north end of this chamber goes a brick flue or shaft, six feet by fourteen inches, taken from the back staircase . . . this outlet or shaft goes straight down to below the first floor, and then crosses eastward and rises up behind the kitchen fireplace, it is then collected in a square shaft . . . of at least *five square feet* surrounding the kitchen smoke flue, and these together form a large chimney stack, which is carried up to a greater height than any other chimney in the house, so as to secure a long siphon and a strong draught.[9]

[9] ibid., pp. 92–94.

It might appear from the above that the ventilation would be restricted, in practice, to a shallow zone below the ceiling, the air entering through the perforated cornice and leaving through the ornamental rose over the gas lamps. But this supply of warm air was not intended to heat the house—heat was provided in every room by a conventional fireplace, whose chimney would pull the fresh air down from the cornice and across the room. The function of the elaborate supply-system for fresh warmed air was the same as the reasoning behind the permanently sealed windows: to prevent cold draughts, which were the normal concomitant of any supply of fresh air in conventional structures of the period. The elaborateness of the provision that had to be made to achieve this, and the consequential effect upon the whole form and structure of the house will probably seem nowadays to be totally disproportionate to the benefit gained, but one must remember that 'the draught' was (and is) an obsessive enemy of thermal comfort in England. To have gained a draughtless air-supply, free from the common dusts and grits of the urban atmosphere (they had been allowed to settle out in the chambers of the basement) would have appeared a major gain in domestic environmental management at the time, especially when it is seen against a background of the going state of environmental knowledge and practice.

By the 1860's, the practice of heating had begun to stand less upon rule of thumb than upon a quantifiable body of knowledge of performance and control—at least the performance of boilers and radiators seems to have been within the scope of numerical expression and calculation. The progress of quantification, plus the solidification of custom, were to have a stultifying effect on speculative and humane thinking about the supply of heat, however, and by the end of the century the use of ordinary human imagination, if we are to judge by works like Baldwin's *Outline of Heating, Ventilating and Warming* (1899), had almost come to a stop. For Baldwin, it appears that questions of human comfort and physiological response to thermal stimuli either do not exist, or are not open to discussion. The aims and priorities of heating are set out in crisp phrases of crushingly mechanistic insensitivity, thus:

> BOILER: in warming by steam or water, the boiler is generally the first consideration.[10]
>
> It is usual to maintain a temperature of 70°F within a room.[11]
>
> It may be asked 'Why is the question of condensation the first consideration?' and in reply I will say that it furnishes us with the first item of data on which to base all our other calculations . . .[12]

[10] *Outline of Heating, Ventilating and Warming*, New York, 1899, p 22.

[11] ibid., p 34.

[12] ibid., p 32.

It may be objected that Baldwin can treat matters thus because there was a going consensus of opinion that rooms should be kept at 70°F and that no further human study was needed at the time. In fact, there was no such consensus, and never has been, though later 'environmentalists' have made equally procrustean propositions—eg., Le Corbusier's proposition to maintain a temperature of 18°C in buildings in all parts of the world irrespective of local need or preference. In any case, what makes Baldwin's approach to heating appear unattractive and mechanistic is that his observations on ventilating, which was not yet a quantifiable topic, are humane and direct. They are truly observations, based upon manifest personal experience, and they support a genuine discussion of the problems involved, without the short-hand dogmatism of his views on heating. He notes that:

> The early investigators depended largely on the sense of smell as a guide to the vitiation of rooms.[13]

[13] ibid., p 13.

and he, like his immediate predecessors and most of his distinguished contemporaries, was clearly a 'nose-man' and an experimentalist in the field.

Indeed, one of the great rewards of studying the environmental literature of the late nineteenth century is that while heating had been reduced to rule and formulae, ventilating had not been, but was still open to discussion, much of it sensitive, more of it speculative. As industrialised societies fought their way out of the soot, smog and grosser pollutants of their atmosphere, they came up against a situation which clearly baffled men of common sense accustomed to the practical mechanical solution. Whereas 'heat' or 'cold' could be satisfactorily measured with relatively simple instruments and their causes identified, the 'freshness' or 'stuffiness' of air could not, largely because their causes could not be identified. Even when the two worst offenders in the vitiation of air had been finally exposed—carbon dioxide and excess humidity—neither was as susceptible to easy measurement and constant monitoring as heat, and neither was as susceptible of direct personal observation without instruments because both, in the forms normally encountered, are invisible and odourless.

Thus, the two first impacts on the human senses were normally 'the smell' and 'the draught'. The smell was observed in all inhabited interiors, especially when they were crowded and heated, the draught seemed to arise whenever those interiors were aired sufficiently to remove the smell. Attempts to do away with the draught could be as complex as Dr Hayward's, or as self-frustrating as a case recorded by Baldwin:

> In well-built modern residences the construction is often so good that it will hold water . . . a grand New York residence was so air-tight that the air to supply the grate fires had to come down the register flues (and) the air had to come down the ventilating flue of the hood of the range in order to supply the range fire, until a window was opened.[14]

[14] ibid., p 53.

However, if the draught could be stopped at source, then the smell had to be stopped at source too, and this proved difficult while the ultimate causes of vitiation and stuffiness remained odourless and therefore undetected by a generation of engineers whose ultimate arbiter of ventilation was the human nose. Precise knowledge remained fragmentary and ill-diffused, surrounded by private suppositions verging on the superstitious.

For instance, the growth of scientific knowledge and speculation about the key vitiants was, in fact, as described by Dwight Kimball in 1929, who, after setting down the primacy of the great French chemist, Lavoisier

> who in 1777 began the study of oxygen and carbon dioxide

goes on to list the succession of true pioneers after him:

> Following this for about a hundred years the carbon dioxide theory

prevailed in ventilation. Then came the theory of Max von Pettenkofer (1862–3) who first established the conclusion that bad ventilation should be charged to other factors than carbon dioxide. The harmful effects of bad air and the beneficial effects of good air later led to the erroneous theory of hypothetical organic substances in the air. Then came the recognition of the work of Hermans (1883), Flügge (1905) and Hill (1913), proving that the thermal, rather than the chemical properties of air are of vital importance in connection with ventilation, insofar as normally occupied spaces are concerned.[15]

Not only had those 'thermal properties' (as measured by the wet and dry bulb thermometer) proven extremely elusive, but the pioneers had been misunderstood. Max von Pettenkofer, because he had proposed the measure of carbon dioxide as a workable guide to the level of all pollutants, was mistaken for a proponent of the carbon dioxide theory, which he manifestly was not. If a man of Pettenkofer's eminence and fame (he was the father of modern hygiene as we know it) could be misunderstood, the general confusion of knowledge should cause no surprise. Solid and responsible practical men stood upon their private experience (having nothing else to rely upon) even to combat their mistaken image of Pettenkofer, and in the process revealed the enormity and nausea of the olfactory problem. Thus Konrad Meier, a New York heating consultant, in his *Reflections on Heating and Ventilating Engineering* (1904) wrote:

Carbonic acid is not a poison in the ordinary sense of the word, and much larger quantities than generally assumed may be present without causing ill-effect . . . On the other hand, substances and impurities that cannot be estimated from the presence of carbonic acid, as for instance an excessive amount of vapour of water, sickly odours from respiratory organs, unclean teeth, perspiration, untidy clothing, the presence of microbes due to various conditions, stuffy air from dusty carpets and draperies, and many other factors that may combine, will in most cases cause greater discomfort and greater ill-health.[16]

What is striking about Meier's demonology of bad air is that it not only includes the real culprits, carbon dioxide (carbonic acid gas) and water vapour, but still retains nearly all the common Victorian villains, such as 'sickly odours' and makes provision for

[15] in *Heating, Piping and Air Conditioning*, June 1929, 'Air-conditioning, its future in the field of human comfort', p 93.

[16] *Reflections . . . etc.*, p 20. This document, found among the vast deposit of technical pamphlets that have come to rest in the New York Public Library (Bound Pamphlets, VEW, pv12, No. 1) appears from its format and content to have been some sort of annual address to the New York Branch of the American Society of Mechanical Engineers.

any demons he may have overlooked ('many other factors'). This was how he had observed the situation according to the evidence of his own nose. The pre-occupation with body odours may strike modern readers as a trifle obsessive and neurotic, but so general and emphatic was the apparent nasal evidence on this subject that the belief in an organic poison, mentioned by Kimball (above), is understandable—what else could have caused the unmistakable and ever-present 'stuffy smell' in occupied interiors, especially at a time when the knowledge of air-borne bacteria was beginning to diffuse among the general public?

But the point about 'the smell' in this sense is that it was not a gross industrial pollutant that caused it, but the mere presence of breathing human beings in a closed space. The better those spaces were closed by improved construction, the better lit by gas and the better heated, the worse the situation became, and it was not something that could be bettered by social legislation or moving out into the country. In other words it was not—like working in a mine or factory, or living in a tenement—a hazard that the educated and well-to-do could avoid by their usual methods. To the factors bearing upon environmental reform, the considerations of hygiene and efficiency, economy and profit, already cited, must be added the aesthetic distaste of wellbred persons for the stuffiness of their interiors and the consequent head-aches with which they woke so often in the morning (Professor Jacob also notes that clergymen had Monday head-aches after a full Sunday stint in crowded churches).

These people, in households that bred, or were presided over by, 'New Women' or their emancipated equivalents in non-Anglo-saxon countries, were the main support and proving ground for any environmental innovations that could be produced in domestic sized packages. The rise of electric lighting is inseparable from this milieu, its cleanliness and slightly mysterious quality seemed to chime in well with the interests of an intelligentsia that was turning away from the gross materialism and determinism that had characterised so many mid-century attitudes, in favour of a more mystical and aesthetic approach. The tenuous curves, pale walls and luminous decorations of Art Nouveau and Tiffany would be unthinkable without electric lighting, not only in the purely physical sense that effluents of gas lighting would have rotted delicate fabrics and darkened the decor, but also in the purely aesthetic sense that the quality and distribution of light that could be achieved is entirely apt to the style.

Insofar as Art Nouveau is the first of the new styles and not the last of the old, it is in its determination to repudiate the norms of nineteenth-century interior design, including its environmental standards. Art and technology combined to reject the dark, the coarse, the overstuffed and the stuffy. There had been previous attempts, before the 1890's, but they had been relatively inconsequential in the absence of a fundamental revolution in environmental technique. But if the sudden availability of electric lighting marks the turning point in that revolution, the ferment of improvement and innovation had been going on for most of the century. The evolution of the kit of parts needed to revolutionise the environment of men is a history in itself.

4. The kit of parts: heat and light

The preceding chapter will already have given some idea of the kind of technology of environment that was becoming available during the nineteenth century. The development of the art needs to be discussed in somewhat fuller detail, however, even though there is no intention of providing a complete technological history within the compass of the present work. Chiefly, it is important to establish the changes in the type of environmental power that could be delivered into an inhabited space. In the middle of the nineteenth century, the nature of that power was still essentially primitive, its basic characteristic was that fuel was burned more or less at the point where power had to be applied—coal or wood in grates and boilers, oil, gas or tallow in lamps and candles. In the absence of machinery of domestic scale most of this power had, of need, to be applied directly and crudely to the immediate environment, since water was the only substance commonly channelled through pipes or conduits.

However, the fact that water could be heated, and then circulated through pipes, afforded the prototype of most later forms of sophisticated environmental control—the combustion of the fuel at one convenient point, and the application of the energy thus generated at some other convenient or necessary point. The first proposals to use hot water in this way go back into the Renaissance, but their practical application belongs to the pioneer phases of steam technology in the late eighteenth century—James Watt had his own office heated by steam in 1784, and legend has it that the earliest building heated from the first by such methods was Matthew Murray's 'Steam Hall' in Leeds in the first years of the nineteenth century.

Given boilers of moderate efficiency, economically produced heat could be circulated by convection, without use of pumps, through fairly complex networks of piping to suitably placed radiators, and its comparative simplicity made it a practicable proposition for domestic installation. With the addition of pumped circulation and other refinements, the basic technology could be adapted to much larger installations, provided there was sufficient janitorial skill to operate them. By the 1860's, heating by steam or hot water could be looked for in most buildings, public or domestic, of any pretensions; considerable skill had accumulated in the design of the installations, both on paper and at the level of field decisions that had to be made by foremen and pipe-fitters. This was one of the great reservoirs of skills on which much of the environmental revolution was founded, though there is some evidence that the persistence of drawing office habits and fitters' folkways may have ballasted down the aspirations of innovators on occasions—Willis Carrier on one occasion had to correct the operating habits of an engineman before the cooling plant of one of his early air-conditioning installations would operate properly.

But piped steam heating is also, with the electric telegraph, the prototype of another—obvious and necessary—development in the use of environmental power. If heat could be distributed from a central boiler to different parts of the house, it could also be distributed to different houses

> It is doubtless true that in the early days of steam heating, various people have heated more than one building from a single source. However, just as Thomas A. Edison is looked upon as the father of the central lighting station, so in the heating industry there is one man generally named as the pioneer of central station heating, Mr Birdsill Holly, of Lockport, NY.
>
> In 1876, Mr Holly ran an underground line from a boiler in his residence to a barn at the rear of his property and later connected an adjoining house. In 1877 he constructed his first experimental plant at Lockport, in the state of New York, and a number of residences, stores and offices were successfully heated during the following winter.[1]

Although Holly was not really an innovator of the same order as Edison, there is some limited justice in the comparison. Both finally

[1] Bushnell and Orr, *District Heating*, New York, 1915, p 2.

went 'on stream' in downtown New York City in 1882–1883, supplying a basically similar service: clean environmental power from a central source. Whereas previous technologies had supplied the householder with raw or partly processed fuel (eg., coal gas) to be more or less inconveniently or messily burned in the room, Holly was supplying clean and directly usable heat that left no residue in the house to be cleaned up, and consumed none of the air available.

The elimination, in the process, of the open flame, is a development of some consequence, which will be discussed later. The next topic to concern us here is the application of heat, however supplied or generated, to the interior. In general, the technology of the mid-nineteenth century could offer little—at a domestic scale—beyond letting the heat find its own way into the environment by simple radiation and convection. However much the innumerable patented 'improvements' to stoves in the nineteenth century might have boosted their performance by better combustion or transference of heat to the ambient air, however much the design of steam and hot water radiators may have become sophisticated, the stove, grate or radiator stood at some point in the room dictated by custom, convenience or aesthetic preference and the warming of the space around it was at the mercy of draughts, open windows, local convection from lamps, obstruction due to furniture, etc. One can almost say that the only serious attempt to cope with this situation that achieved any widespread distribution is the inglenook, virtually a room within the room, around the fireplaces of rooms in large houses by Frank Lloyd Wright, C. F. A. Voysey and their contemporaries. These screened areas with built-in seats provided an area of reliable thermal performance, shielded from draughts. Though ultimately a revival of mediaeval usage, they could only be properly revived in a epoch that already disposed of piped central heating—the effect of trapping so much of the heat available in an area around the fire would have been to deprive the rest of the room thermally, were background heat not available.

However, the improvements in heat transfer to which reference has been made, were not negligible, and were based, in most cases, on the separation of the convecting warmed air from any smoke or fumes that must be disposed of. There seems little doubt who was the true father of this art.

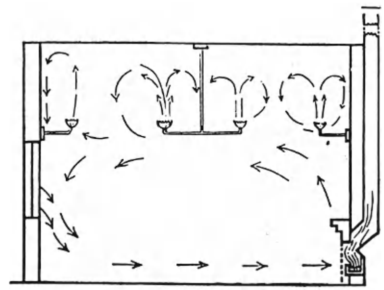
> The principle of heating a room with warm air was introduced by Benjamin Franklin in 1742. His stove of that date contained a chamber surrounded by iron plates and fed by a cold air box, openings for the escape of the air being in the sides or jambs at the top of the chamber.

wrote William Gage Snow in 1923, and added

> The warm air furnace of today is identical in principle but more elaborated.[2]

Other developments of the Franklin's—or the immediately succeeding—generation, included aids to more efficient combustion, such as Rumford's restricted throat grate. Many improved stoves and grates also called for a separated supply of combustion air, drawn from outside the space to be heated. This growing sophistication in the handling of air, carried further by such techniques as drawing it in from the outside only through grilles containing, or serving, radiators, was rendered necessary by the steady reduction of sources of accidental ventilation, due to the better sealing of windows, for instance, or the disappearance of the chimney in spaces where direct combustion was not the source of heat. As less was left to accident, more aspects of the thermal and ventilation performance of buildings had to be consciously controlled and investigated—Jacob, for instance, is able to show diagrams of air movement and heat distribution based upon controlled tests.

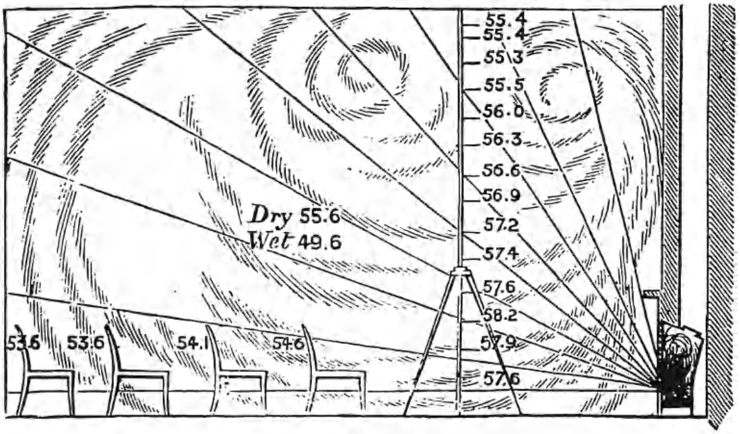
But, in all these improvements and innovations, the most consequential is perhaps the separation of the combustion gases (both input and output) from the air warming the room.[3] Once the heating air was on a different circuit to that serving and produced by combustion, that independence could be exploited. The circuit could include rooms other than that in which the stove was located, if suitable openings in walls, or ducts, were provided. Sooner or

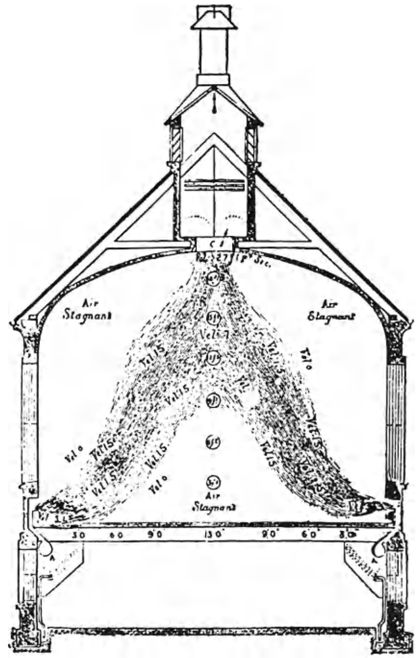


Air-circulation in a room heated by an open fire, and lit by gas.

[2] *Furnace Heating*, New York, 6th ed., 1923, p 213.

[3] Hot air heating is sometimes spoken of as senior to heating by hot water or steam, usually on the evidence of Roman hypocausts, and other primitive systems. Since such under-floor arrangements circulated the products of combustion promiscuously with the hot air, they clearly do not fall into the class of modern hot air systems, descended from the Franklin stove, discussed in this chapter, and their involvement with modern architecture since 1850 seems negligible.





Left: air movement, temperature distribution and humidity in a lecture-room, as measured by Campbell in 1857.
Above: currents of air in a 'model' hospital ward.
(both these diagrams reprinted by Professor Jacob from Galton's *Healthy Homes*, 1880.)

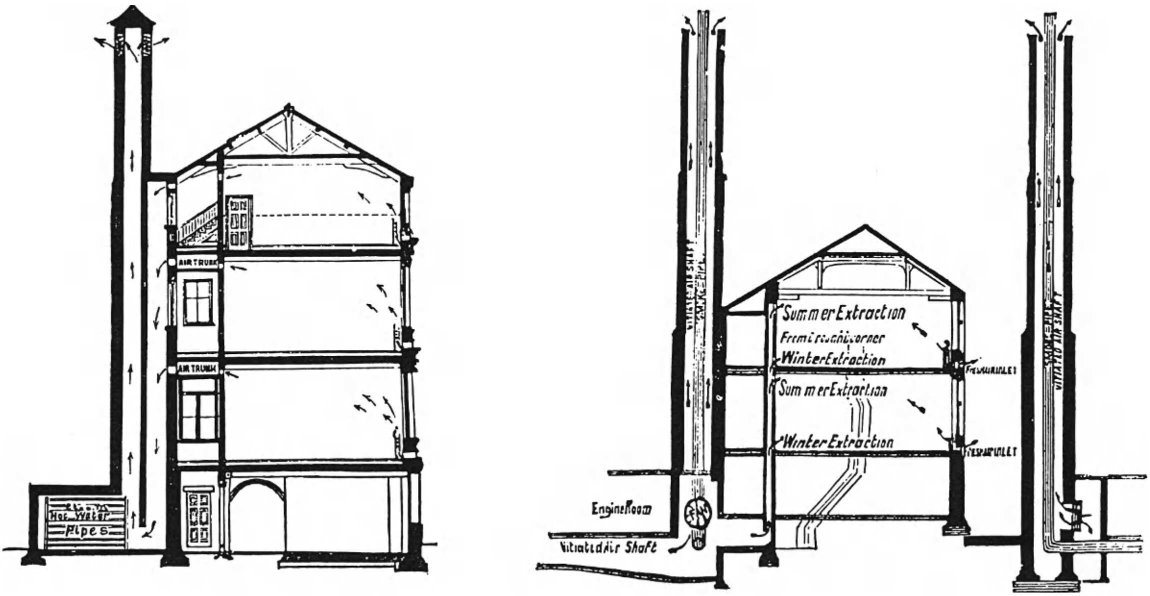
later someone had to dismiss the stove to the basement, tap the air output from its hot air box, and duct this heated air to the parts of the house where heat was needed.

Although this was to prove a portentous invention, since it established the basic heating method for most North American residences, its origins seem already to be lost even beyond the reach of legend. William Gage Snow quoted[4] the following from an unspecified issue of *The Metal Worker*:

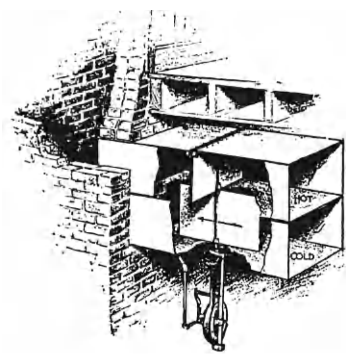
> . . . just who was the first to improvise this heating apparatus or when it was done, is difficult to learn. The date, while it cannot be fixed with certainty, was in all probability prior to 1836. There is an impression among many of the older hot air furnacemen that experiments in this line were numerous in the vicinity of Hartford, Conn., and that along about 1840 a number of hot air stoves are known to have come into existence.

It should be noted that the use of the hot air stove or furnace brought with it an added benefit over and above heating—since it delivered the heat by means of air, and only when that air moved, it was inseparable from ventilation. Either the movement of the hot air improved the ventilation, or the ventilation had to be improved to the point where the hot air could move. But this was not always easy to achieve in conventional architectural formats.

[4] loc. cit.



Heating and ventilating with thermal siphon extract, left, and with powered fan extract, right. Below: mixing valve with remote control for domestic hot air distribution, Sturtevant catalogue, 1906.



In complex multi-storey installations it was often difficult to find space for vertical riser ducts in conventional Victorian construction—though ingenious use of the furred spaces behind apsidal and polygonal room ends seems to have been made in the Boston area at least. But where ducted hot air finally came into its own was in the nearly-standardised single storey houses with basements that have spread from the middle-west to almost every part of North America. The basement provided not only room for the furnace but also freedom to distribute the ductwork efficiently and economically, and thus to deliver the warmed air to the places where it is needed most, around the perimeter of the house.

In the mid-nineteenth century, however, when the problems of warming and ventilation were being tackled together for the first time in terms of conscious design, the price of efficiency was usually the adaptation of the whole structure to the needs of convected air circulation—on a small scale, in the manner of the Octagon in Liverpool, discussed in the previous chapter, on a large scale in the

Sturtevant installation to provide warm air at the entrances and display-areas of a store in Boston, from the 1906 catalogue.

manner of giant brick ducts, often with their own source of heat to stimulate air-movement, which dragged air through institutional and civic buildings. Though considerable achievements were wrought with these techniques, at the expense of inconveniences in plan and section, the arts of both ventilation and heating really waited upon the development of effective blowing fans.

William Gage Snow records the 'embryo idea of a fan furnace' in a B. F. Sturtevant Company catalogue in 1860 (the year of that celebrated ventilating-company's foundation). But the idea goes back much further, of course. J. T. Desagulier invented the very term *ventilator* to describe the man who turned the crank of the centrifugal fans he was proposing, to supply air to the lower decks of naval vessels and the chamber of the English House of Commons in 1736. Nevertheless it was in the period after 1860 that fan-forced ventilation began to flourish. The pressing needs of mining and shipping, of industrial processing (such as the drying of tea, for which Davidson developed his *Sirocco* fans) and the increasing size and complexity of buildings all provided powerful stimuli to invention; the steam engine and, later, the slow running gas-engine drawing on the common town gas mains, provided the power. By 1870, the Sturtevant Company could patent a steam-coils-plus-centrifugal fan combination that was well out of any 'embryo' stage.[5]

[5] chronology in M. Ingels, *Willis Carrier, Father of Air-conditioning*, Garden City, 1952.

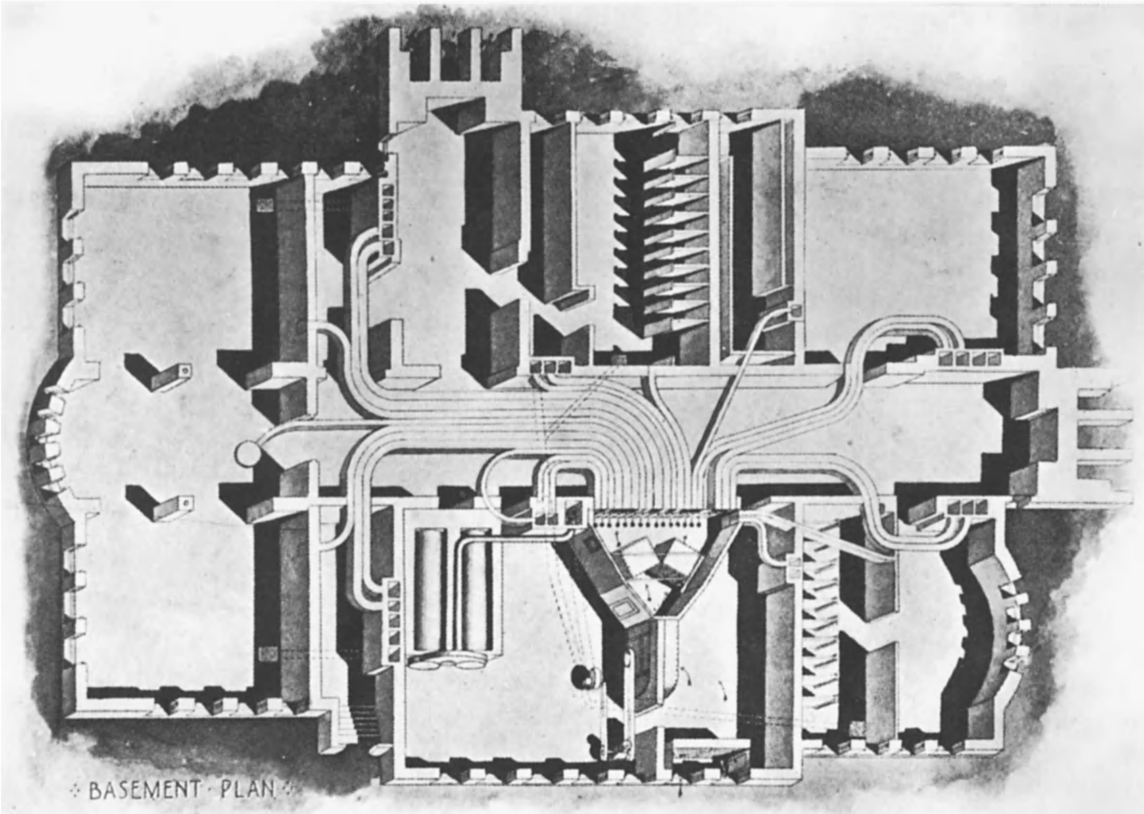
But the size and weight of such plant often made its location within the building-structure difficult, so that conservative ventilating experts could argue as late as 1882

> To attempt to draw down the foul air from the upper storeys of a building and to conduct it by an underground channel to an engine shaft, is generally a very roundabout and unscientific mode of ventilation . . . On the whole, it has been pronounced by competent men, that the heated shaft has more in its favour than the fan driven by a steam-engine . . .[6]

[6] *The Building News*, June 9, 1882, 'A Note on Hospital Ventilation', p 709.

The problem was to be resolved by finding other places than the conventional basement for the location of the fans and their attendant plant, or by making the plant less bulky and massive, or by using the fans in a different way, as in the Plenum system and its derivatives, in which force fans were used to keep the ventilated volumes under a slight pressure, so that foul air would find its own way out through accidental or designed exits (sanitary areas were a preferred outlet-route for systems of this sort, since the air-flow would carry the dreaded smell of 'drains' out of the building directly).

But the progressive application of fans was held back, until the last years of the century, by two major factors. One of these obstructions—lack of aerodynamic knowledge—was worn away slowly, by the accumulated practical experience of companies like Sturtevant and Sirocco; or by the design-work of men like Rateau in France and the theories of Joukovsky in Russia—the one



Ducting, boiler, fan and heating chamber in the basement of a school in Menominee, Mich., Sturtevant catalogue, 1906.

the inventor of the modern high-speed centrifugal fan, the other the intellectual parent of axial flow fans. The other obstruction to progress was the lack of a small power source adaptable to fans of domestic or personal scale, and here the breakthrough seems to have been more sudden, waiting upon the almost simultaneous development of domestic electrification and of Nikola Tesla's alternating-current motors. Both these basic developments belong to the 1880's, so do the first mentions of electric fans as room-coolers in downtown New York. The relative smallness of plant achieved and its presence in the actual room being ventilated, is probably less important than the range of descending sizes of electric power-unit and ventilator and the great handiness of their management and location. It was upon these bases that the growing sophistication of ventilating techniques in the twentieth century was to be built.

Until such time, however, ventilation-technology had to make do with, fundamentally, the same kit of parts as Dr Hayward had used, and since this normally involved the direct application of heat as a source of convecting power, its strong point was emphatically not summer cooling. Although something could be done by stacking ice in intake ducts, or (towards the end of the century) by the use of cooled coils supplied by a refrigerating plant to chill intake air, the mere dropping of the temperature did not necessarily promote comfort, since the process might raise the relative humidity. As late as 1906, the ingenious heating/cooling plant devised by A. M. Feldman for the Kuhn and Loeb bank in New York (its ingenuities were as much architectural as mechanical, and will be discussed in a later chapter) while it could pull the temperature in the banking hall down to a figure ten degrees lower than an external shade temperature of 91°F, did so at the cost of boosting the relative humidity from 53% to 63%.

For most of those locations (hot humid areas) where cooling was felt to be necessary, humidity control was equally necessary—what was needed was the sort of total environmental control that only full air-conditioning could supply. But there was probably little point in even attempting total control until the atmosphere had been cleansed *at source* of its worst and most persistent class of indoor pollutants, the waste products of combustion from illumination-fuels. Interactions between the controls of the luminous and atmospheric environments are almost inevitable if only because of the heat-load imposed by illumination-sources, as in the 1940's, when better air-conditioning and the reduced thermal output of fluorescent lamps gave new freedom in the design of office-blocks.

But, given the much greater heat load of flame light sources, and the atmospheric load of water-vapour, carbon oxides and pure carbon which they also generated, there would seem to have been little point in Carrier and Cramer even starting on air-conditioning until the filament electric lamp had abolished most of this atmospheric garbage at a single blow. The rise of air-conditioning can conveniently wait till chapter 9, but the revolution in illumination cannot, so fundamental is it to the attainment of the kind of environmental conditions thought proper to modern architecture.

The utilisation of artificial light rose sharply after the middle of the nineteenth century, and the increase is even more striking if measured in candle-power hours than in expenditure on fuel burned. Up till the mid-century, it is doubtful whether the illumination of the average household rose much above an almost mediaeval level: a single candle burned for an hour or two each evening, the life of the household tailored to make best possible use of the exiguous light available—that is, those with the greatest need, as in reading or sewing, closest to the lamp on the table, those with less need further away, almost a camp-fire situation, in which space was, for the moment, focused around the lamp as much as framed by the walls of the room. More efficient oil-burning lamps, such as the Argand, did not materially affect this situation, and it was the rising availability of coal gas from the mains after the middle of the century that really began the increase of fuel burned, light used, and number of lighting outlets employed. Where figures have been analysed, they can show as much as a twenty-fold increase in the actual amount of illumination employed in an average household in a city like Philadelphia, between 1855 and 1895.[7]

[7] figures given by Dr Walton Clark in *NELA Bulletin*, 1910, Vol. X (III, new series, No. 10).

The sheer amount of light available and used, in itself must constitute a major revolution in human life; the means of obtaining that light remained prehistoric, piped gas notwithstanding. All that increase noted above, barring the last five years or so to 1895, was obtained by means of open flames, inefficiently operated.

Inefficient they had to be, since the actual source of light was the incandescence of unburned carbon particles in the flame, whether that flame was fuelled by oil or gas, whether it burned in a fish-tail, bat's-wing or any other type of burner. Having served as the medium of incandescence, the carbon particles then ascended in a narrow column of soot and deposited themselves on the ceiling, as much as anywhere else. It was to deal with this encrustation of soot, which left the ceiling dark grey, or even black, above the gasolier and shading off to lighter greys at the cornice, that nineteenth-century house-keepers elaborated the ritual of spring cleaning. At the end of the soot-generating lighting season (autumn–winter) they took all soot-gathering fabrics, draperies, carpets and upholstery out of the room and at least beat the loose soot out of them, and at the same time the ceiling could be cleaned or even re-whitened. But such domestic upheavals grew less and less welcome even in households that were still accustomed to total disorganisation every Monday in order to accommodate the equally elaborate ritual of 'washday'. A clean light source could clearly do much to reduce the rigours of both rituals, and even the increasing amount of dirty light in use was increasingly revealing a matching increase in general domestic dirt and pollution.

Attempts to bring the existing illumination-products within bounds varied, but most were concentrated—understandably—on the area above the gasolier itself. The use of extract grilles above the light-fitting was not peculiar to the Octagon, Liverpool; in practice, it was a method both of disposing of sooty wastes and of exploiting the thermal waste to convect foul air out from the heavily polluted zone immediately under the ceiling. Such grilles were usually incorporated in an ornamental or rose—a sizable plate of foliate or architectural decoration in fairly heavy relief, surrounding the point of suspension of the light-fitting. The ripe decoration which characterised such objects may or may not have been there primarily at the behest of ripe Victorian tastes in decorative art, but the depth of its relief, its undercuttings and convolutions, also appear to have done much to trap sooty waste within the confines of the ornamentation, and discourage it from spreading right across the ceiling.

However, the worst of the problem was suddenly avoided by a major breakthrough in gas-lighting technology at the beginning of the 1880's, when the egregious Austrian inventor, Baron Auer von Welsbach produced a commercially viable gas mantle—that is, a bulb of fireproof fabric impregnated with oxides of rare earths which would incandesce in the heat of a gas flame. Since the mantle itself incandesced, there was no need for unburned carbon to do so, and the flame could burn efficiently on the principle of the Bunsen burner, with its correctly regulated flow of air. As a result, the output of sooty wastes was greatly reduced (though rarely eliminated under normal domestic conditions) even though the output of heat remained considerable.

This was an enormous step forward, especially when the neat and convenient inverted mantle was introduced, and everyone who has lived with domestic lighting by gas will know that it has much to recommend it—a warm, murmuring, friendly radiance, of quite a pleasant colour-spectrum when correctly trimmed. The gas mantle, together with its heating partner, the incandescent gas fire (models using asbestos string as the radiants were available from the early 1880's) might have had a great future, but for two things. The first was von Welsbach's attitude as primary patent holder, combining as it did an almost feudal conception of absolute property rights, a Levantine deviousness in financial methods, and a straightforward nineteenth-century determination to make as big a killing as possible, which all combined to leave him trying to hold the market to ransom at the very moment when deliverance was at hand in the shape of the second thing—the perfection of a workable system of domestic electric lighting. The Welsbach mantle appeared on the scene just too late to establish itself fully before the whole basis of gas illumination was swept away by the triumph of Edison and Swan.

Electric lighting offered in a single package, a double solution to the environmental problems posed by gas; it generated less heat, and made no soot. Further it needed dramatically less servicing and trimming than gas, and could be installed in many restricted spaces where gas with its heat and need for air would have been barely practicable. Given these advantages, electric lighting was irresistible, however much more expensive than gas in installation-cost and running consumption it might have been at first. So attractive was it, that hard headed and cost-conscious business men called for its installation in new buildings even before the supply of electric power was available. A justifiably famous case was that of the Montauk block in Chicago, designed by Burnham and Root. In a letter to their Chicago agent, Owen F. Alldis, dated February 5, 1881 (a clear twelve-month before public mains supply of electricity was available anywhere in the world) the proprietors suggested:

> The less plumbing the less trouble. It should be concentrated as much as possible, all pipes to show and be accessible, including gas-pipes. It might also be advisable to put in wires for future electric lights. It is not uncommon to do it in Boston now.[8]

[8] quoted in C. Condit, *The Chicago School of Architecture*, Chicago, 1964, p 53.

If even such tough commercial minds could be captivated in this way by a service which was still no more than a promise, we can hardly be surprised that the advent of electricity as a source of lighting and environmental power was awaited with something like religious awe, as if men had been vouchsafed a vision of beneficent magic. In May of 1882, the *annus mirabilis* of the incandescent electric lamp, John Slater, a Fellow of the Royal Institute of British Architects, read a paper to the Institute on 'Recent Progress in the Electric Lighting of Buildings.' It was a major occasion; the room

> . . . was lighted by incandescent lamps of the Swan, Edison, Lane-Fox and Maxim types, supplied with power from an accumulator invented by Messrs Sellon and Voelkmar, and which stood in the room . . .[9]

[9] reported in *The Building News*, May 19, pp 600*ff*. The name of John Slater does not figure very large in the annals of British

and thus surrounded and illuminated by visible proofs of this seemingly miraculous light source, Slater observed that the

> . . . revolution was mainly due to the invention of incandescent lighting . . . a stable and unchanging point of light, in contradistinction to the arc-light, in which the glowing material was continually disintegrating and burning away.
>
> . . . the economic value of the new means of illumination had if anything, been underrated. The readiness with which the incandescent bulbs lent themselves to any scheme of decoration was one of their chief attractions. It would be undesirable to follow the lines of gas fittings, as the conditions were so completely altered, but points of light could be placed wherever they were required, and there was no fear of blackening ceilings, or of setting fire to the most easily ignited materials. The progress of this system of lighting had been so rapid that architects had as yet had no time to turn their attention to its decorative capabilities, but when they did so they would find it fulfil every requirement for perfect lighting.[10]

Slater's use of the word *decorative* in this passage need not be taken to mean anything merely superficial; it is clear from the rest of his text that he sensed a profound revolution in the nature and use of the built environment, even if he did not quite dispose of the vocabulary for discussing such matters that is available today. No doubt, it is this sense of a profound revolution that accounts for the almost religious solemnity of his concluding paragraph:

> The progress of electrical science is the most striking feature of the latter part of this nineteenth century, and the day is not far distant when we shall find a certain acquaintance with the subject of electrical science a necessity for us architects in our everyday work, unless we wish to be entirely in the hands of the men we employ. Science has captured the lightning it is true, but it is scarcely tamed yet; let us beware that we do not attempt to deal with this new servant ignorantly. Electricity is a new power given into our hands to work out, and it behoves us to study its nature and advantages and to guard against its risks and dangers, and learn to use it, with the older means at our disposal, in accordance with the maxim 'Usui civium, decori urbium.'[11]

The only point where one may find fault with Slater, given historical hindsight, is in his insistence on the crucial nature of the invention of the incandescent bulb. One must admit that direct

architecture, though the partnerships of his son (Slater and Moberley; Slater, Uren and Pike) played a respectable part in the twentieth century. Slater's electrical interests were not without their rewards; he rebuilt the first, temporary generating station of the Kensington network in 1895, and built other stations at Notting Hill and Wood Lane. He also built a house for Colonel Crompton, promoter of these schemes. Died, 1924.

[10] *Recent Progress* . . . etc., loc. cit.

[11] ibid.

personal acquaintance with the light sources then available would show so great a contrast between the flare of gas and the steady cool light of electricity, that the latter would be sure of having great impact—the author recalls with what vividness one of his school science teachers, then nearing retirement age, remembered as a boy seeing his first electric lamp, burning in the bottom of a tank of gold-fish in a shop window in Dublin! Nevertheless, hindsight and a suitable vocabulary now enable us to identify what we should call a triumph of systems engineering as the crucial invention. The lamp-bulb itself had been on the point of successful operation for some time—in England, Swan had a primitive paper-filament type of bulb as a laboratory toy as early as 1848, though difficulty in obtaining and securing a sufficiently good vacuum inside the bulb caused the filament to burn away too quickly for the lamp to be of any practical use. Then, towards 1877, the use of the Sprengle vacuum pump made the attainment of much harder vacuums possible, and the use of platinum (which has a coefficient of expansion very close to that of glass) for the leads through the bulb made those hard vacuums easier to seal in permanently. The carbon filaments of Swan and Edison were so nearly exactly contemporary that patent litigation between them ended in a drawn match, and they formed a joint company to exploit the British market. From 1878 onwards, a succession of patents relating to lamp bulbs and to metallic filaments in particular, appear almost annually.

But the unique achievement that makes Thomas Alva Edison the true father of electric lighting has less to do with the practicable lamp bulb (though he and his commercial backers would have been totally frustrated without one) than with his invention and assembly of the complete system to supply that lamp with commercially profitable electricity. The story of what happened between the formation of the Edison Company in 1878 and the opening of the first public mains supply in 1882 is too involved to be pursued here in detail. The outstanding point to be noticed, however, is that very few of the component parts of the system were totally original inventions. It was the conception of their total functioning together as a practicable kit for generating, controlling, measuring, distributing and utilizing power derived from a central generating station that is the great invention.

To achieve it, many detailed triumphs and felicities of technological ingenuity were required, sometimes combined with gratifying civic foresight, as when Edison, observing

> . . . you don't lift waterpipes and gas-pipes up on stilts.[12]

[12] cited in *Thirty Years of New York*, a promotional history published by the Edison Co., New York, 1913.

insisted on saddling himself with the task of inventing satisfactory and properly insulated underground conductors for his power, instead of imitating the overhead cables of telephone practice, which used the surrounding air as a cheap insulator.

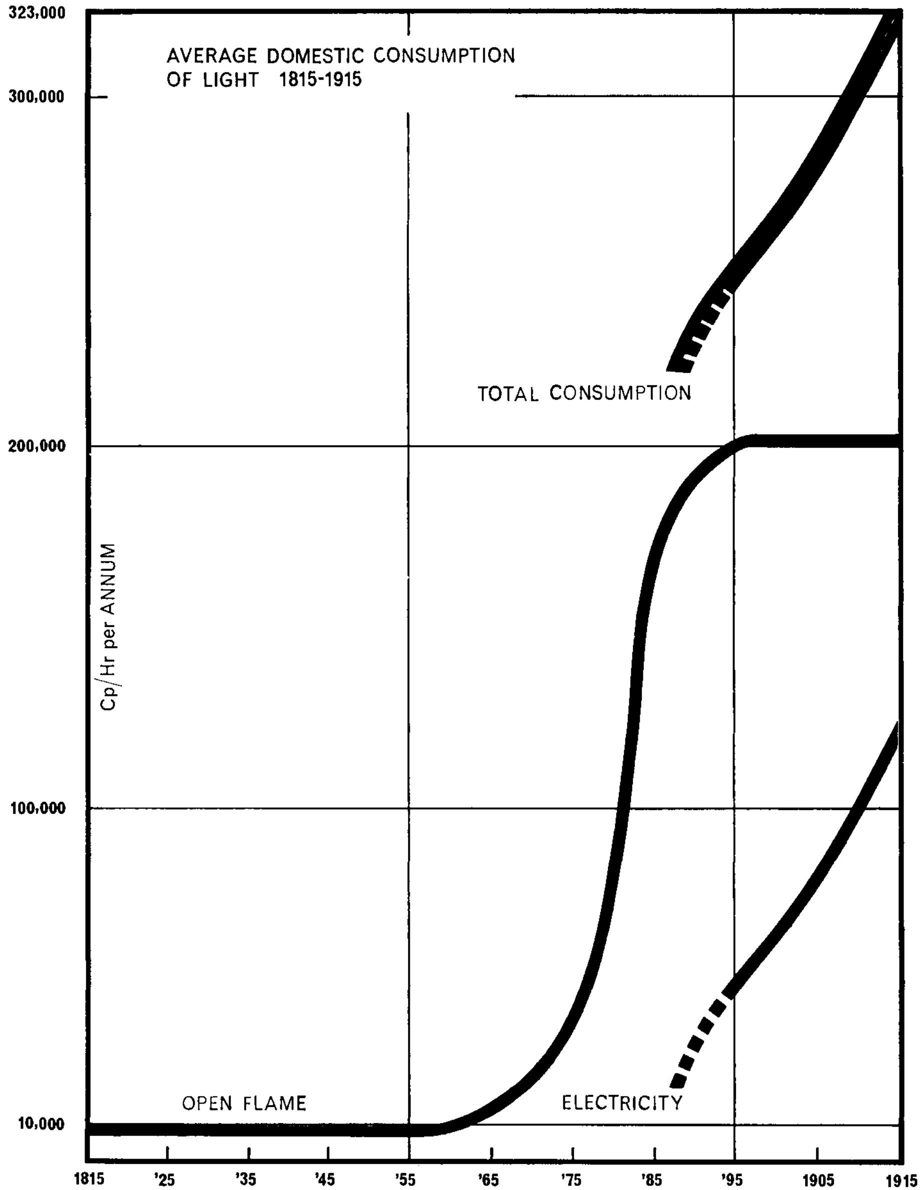
Nevertheless, telephone practice, in various ways, played a large part in Edison's triumph. For a start, much of the necessary electromechanical skill needed to make and operate his system could only come from the reservoir of trained talent that had accumulated in the telegraph system of the US since the 1840's, and in the telephone system since the late 1870's. But it was out of this pool of talent (including its most talented member, Edison himself) that there came the solution of the problem that was supposed to make the supply of varying amounts of electricity to independently-minded domestic consumers as good as impossible.

As late as 1879, evidence had been given before a select committee of the House of Commons

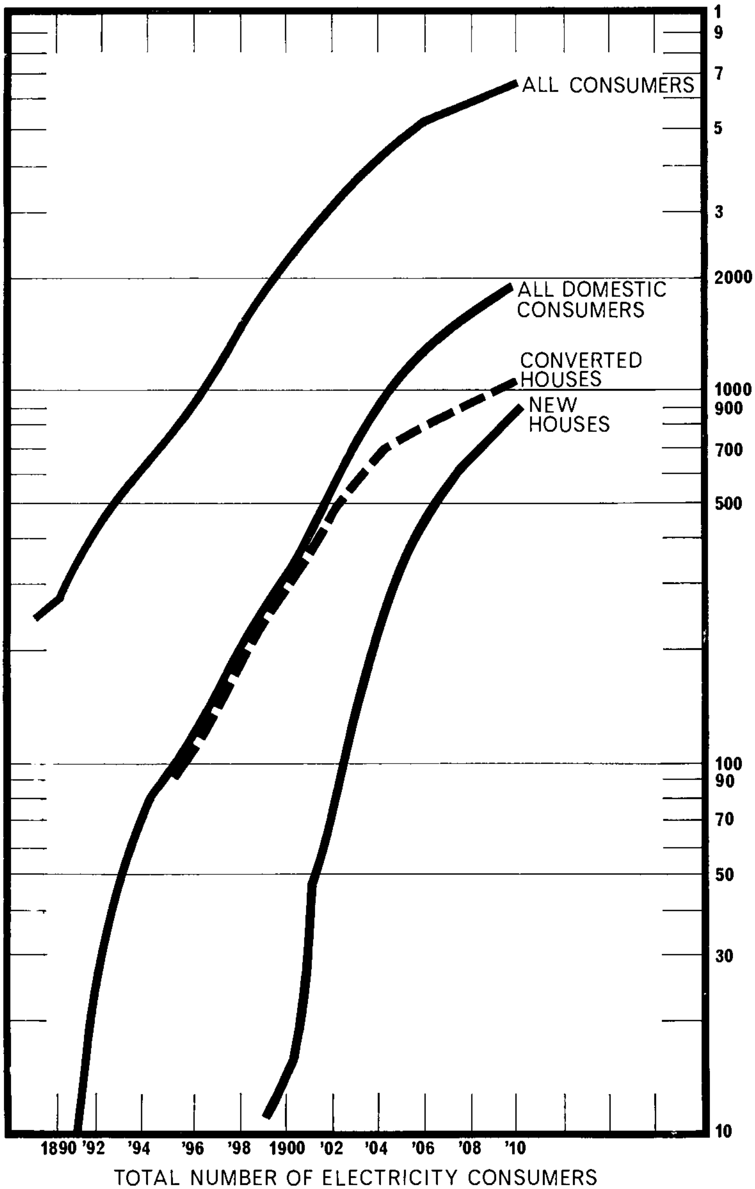
> by such scientists as Sir William Thompson and Professor Tyndall as to the impracticability of subdividing the electric light for domestic use . . .[13]

[13] Slater, loc. cit.

but Edison brought with him from his years as a telegraph operator, professional craft in the routing and re-routing of small electric currents through complex networks, by means of rule of thumb techniques such as 'borrowing current' or downright underhand ones such as stealing it. He seems to have known, on the basis of



Increasing domestic consumption of light, in candle-power-hours per annum, based on figures given by Dr Walton Clark in 1916.



Rate of installation of domestic electric lighting in part of Liverpool, 1890–1910, based on research by H. C. Morton.

this experience, that although an electrical distribution network could not have the storage capacity that enables a gas or water network to cope instantly with a tap turned on or off, there were still margins enough of tolerance in a complex electrical system for suitable equipment and control techniques to handle what was theoretically beyond control, and thus to achieve an effective subdivision of the electric light.

Given this, and a method for measuring the current consumed (originally by periodically weighing the plates of an electrolytic cell) a commercial supply from a central generating station could begin. In January 1882 an Edison combined street-lighting and domestic-mains system went into operation in the area of the newly-built Holborn Viaduct area of London, some months before any of his US plants were on stream. But more than months elapsed before any similar schemes appeared in other parts of London, for the gas industry's parliamentary lobby effectively blocked any enabling legislation for the supply of electricity through cables laid in trenches in the public street—Holborn Viaduct was a legal anomaly because it was largely made-up ground—until legislation was finally pushed through in 1887, and a domestic supply was established in Kensington.

Meanwhile, the first public supply areas in the US were established in August and September of 1882, including the famous Pearl Street district in the business area of New York, thus launching the long and stormy relationship between that city and the Edison, later Consolidated-Edison, Company. Also launched by these actions was the greatest environmental revolution in human history since the domestication of fire.

The dizzy rise of the consumption of light was resumed as steeply as ever, even though the market for gas lighting went into a gradual decline. The installation of electric wiring and lamps became a branch of the construction industry that flourished even through periodical slumps that affected the rest of the business badly, right up to the First World War, because of the backlog of existing buildings ripe for conversion to electric light.[14] And over and above the new clean light source, electrification also opened the way for a host of other environmental services and domestic conveniences.

The use of domestically scaled electric fans has already been noticed, above. By 1900, manufacturers' catalogues listed and illustrated most of the cooking vessels (kettles, skillets, etc.) with built-in heating elements that are with us today, albeit in rather primitive forms, also toasters, roasters, hot-plates and ovens, radiant-panel heaters, convecting heaters, coffee-grinders, immersion heaters, and such period hardware as electric cigar-lighters and curling-tong heaters. By the time of the General Electric catalogue of 1906, the most prized of all domestic electric equipment, the electric flat-iron, was well established, as was the electric coffee-percolator and the fore-runner of the electric blanket heater. The domestic refrigerator and the vacuum cleaner were to wait until after the War for their full domestication; versions of the vacuum cleaner existed from soon after 1900, but the first Kelvinator was not sold until 1918. But captivating or necessary as all these devices might appear, none had such overwhelming advantages as electrical lighting, and none posed quite such subtle and unexpected problems for the architect and interior designer—so subtle and unexpected that they deserve a sub-chapter of their own.

* * *

At first, the fascination of the new clean light was such that further thought seemed unnecessary. It was enough to let the beautiful bright light flood over the interior, often from the old gas fitting, hastily modified, and increase its sheer quantity year by year as the industry obligingly supplied bigger and better bulbs—a high rate of technical improvement continued into the nineteen-teens, and made bigger and bigger outputs possible. Furthermore, the

[14] as is made clear by H. C. Morton's account of electrical connections and installations in Liverpool in the last decade of the nineteenth century. (Unpublished Master's dissertation, *A Technical Study of Liverpool Housing 1760–1938*, submitted in 1967.)

continual improvement in prism-cut glass shades (originally developed for Welsbach gas-mantle sources) made it possible to direct more and more of the available light downwards where it was wanted, without wasting a single precious candle-power. And it was to be some time before the sense or desirability of these unthinking methods were effectively questioned.

Nevertheless, from Slater onwards, there were solitary voices raised against the mere flooding of interiors with unrestrained light. Not only did he envisage the distribution of small point sources around the room, but also the use of indirect lighting from behind baffles that were part of the permanent architecture of the room (chiefly as a way of taming the tremendous brilliance of arc-lamps). But the trade and, with it, common practice, seemed committed to the central ceiling fixture, clearly in view. Some arguments can obviously be advanced for this usage. In many cases the electric light inherited the location, ceiling rose and even the piping (now used as cable conduits) of a previous gas installation (which had had to be centred in the ceiling to reduce staining of the walls). Furthermore, in rooms of unspecific function, as so many domestic rooms had to be in real life, if not in architects' visions, a central location recommends itself as a painless compromise solution to the problem of where best to put the light-source.

The interests of the trade seemed to have been two-fold; firstly, the almost annual boost in power was already beginning to produce lamps so strong and so hot that they seemed safer in the middle of the ceiling—but also, a distributive solution meant smaller lamps, and therefore no incentive to produce a more powerful model next year, so that this was one of those self-sustaining vicious spirals to which the technologies of market economies are so often prone. And again, big central fixtures were more expensive to manufacture, and thus promised a bigger mark-up to the retailer who sold them. Again, they were often so heavy and complex that only a skilled professional could install them, thus offering further returns to the neighbourhood electrical store, whereas distributive

The Great Hall of Stokesay Court, by Thomas Harris, 1889, with lights still arranged according to the original design.

solutions were often effected with table-lamps, standard-lamps and 'art lamps' generally, which the householder could plug in to a wall outlet without skilled assistance. The retail trade continued to combat the portable lamp for many decades, and as late as 1925 an editorial in *Lighting-fixtures and Lighting* was demanding rhetorically 'Are lamps forcing out Fixtures ?'[15]

[15] *Lighting Fixtures and Lighting*, February 1925, p 24.

The same editorial also implied that the use of central fixtures was in the interest of the architect or interior designer, as well as the interest of the trade

> The public, ignorant on lighting . . . leans towards lamps which, in many instances, are entirely inadequate, besides throwing decorative scheme out of balance . . . Living room in a costly residence with thirteen lamps and without ceiling pieces or brackets, produces a frightful combination of colours—Yet some-one was to blame for the lighting scheme; was it architect, owner, or just indifference ?[16]

[16] loc. cit.

Whatever the situation may have become by 1925, it seems possible that at the beginning of domestic electrification, architects had interpreted the situation in Slater's terms, and preferred distributive solutions. Thomas 'Victorian' Harris's installation in the great hall of Stokesay Court, in Shropshire, uses low-power bulbs dangling on flex from simple wooden brackets attached to each of the columns that support the upper gallery. The date of the design is 1889 and this is almost certainly the first house in England specifically designed for electric lighting, since lighting-wires can be seen installed in their present positions even in pictures of the house taken immediately after completion (in the photographic album now at the RIBA Library).[17]

[17] information from correspondence with the present Sir Philip Magnus, and Lady Magnus-Alford.

The best general overview of the art of electric lighting in its early stages in undoubtedly that afforded by the writings of Dr Louis Bell, above all, his *Art of Illumination* whose first edition appeared in 1902. At one point in his argument, Bell makes an ingenious objection to the fixity of fixtures, and to the unquestioning acceptance of novelty:

> Professor Elihu Thompson once very shrewdly observed to the writer

> that if electric light had been in use for centuries and the candle had just been invented, it would be hailed as one of the great blessings of the century, on the ground that it is perfectly self-contained, always ready for use and perfectly mobile.
>
> Now, gas and incandescents, while possessing many virtues, lack that of mobility. They are practically fixed where the builder or contractor found it most convenient to install them, for while tubes or wires can be led from fixtures to any points desired, these straggling adjuncts are sometimes out of order, often in the way, and always unsightly.[18]

[18] *The Art of Illumination*, New York, 2nd ed., 1912, p 208.

However, the candle business is clearly only a debating point, and for the rest of his argument, Bell speaks directly to the problem:

> In domestic, as in other varieties of interior illumination, two courses are open to the designer. In the first place he can plan to have the whole space to be lighted brought uniformly, or with an approximation to uniformity, above a certain brilliancy, more or less approximating the effect of a room receiving daylight through its windows. Or, throwing aside any purpose to simulate daylight in intensity or distribution, he can put artificial light simply where it is needed, merely furnishing such a groundwork of general illumination as will serve the ends of art and convenience . . .
>
> In electric lighting the most strenuous efforts are constantly being made to improve the efficiency of the incandescent lamps by a few per cent, and an assured gain of even ten per cent would be hailed with such a fanfare of advertising as has not been heard since the early days of the art. Yet, in lighting generally, and domestic lighting in particular, a little skill and tact in using the lights we now have, can effect an economy far greater than all the material improvements of the last twenty years. The fundamental rule of putting light only where it is most useful and concentrating it only where it is most needed, is one too often forgotten or unknown. If borne in mind, it not only reduces the cost of illumination, but improves its effect.[19]

[19] op. cit., pp 208–209.

But if these constitute a set of ground rules for the functional deployment of 'the lights we have' as of 1902, there were also visual and aesthetic problems of electric lighting that can be regarded as almost specific to the architect as artist. The use of electric lights could alter the appearance of forms and volumes in a way that no other environmental aid ever could. For instance, by concealing tubular strip lights (which existed from quite an early stage of the art) above projecting cornices, with their illumination thrown upward onto a vault above, it was possible to reverse the fall of light and shade across its curved surface, to invert normal visual expectations and make a nonsense of the ancient art of sciagraphy.

The possibilities and problems inherent in such employments of light (now commonly duplicated in exterior situations where floodlighting is employed for publicity or *Son et Lumière*) have barely been understood or usefully discussed in the eighty-odd years that electric lighting has been with us, though there is often implicit evidence that architects were aware of them. Another, and equally intriguing problem that arose does seem to have had some public discussion: in 1917, Morgan Brooks in some observations on *The Relation of Lighting to Architectural Interiors* wrote:

> At first sight it appears surprising that an architect who has successfully produced a beautiful interior should relegate the lighting thereof to an uninspired subordinate, with results so inharmonious as to obscure his art. Doubtless, this is partly due to the fact that the architect did not visualise his illumination with his interior plan, and will not or cannot give it afterthought, and partly because he is not seriously disturbed by the incongruous lighting of an interior which appeals to him as beautiful with or without light, so powerful was his original idea.[20]

[20] *Scientific American Supplement* (Vol. LXXXIII) June 2, 1917, p 367 (reprint of a paper given to the Illuminating Engineering Society).

and the insight into the psychology of the architect, both as artist and professional, that he showed here does much to illuminate the whole problem of subsequent inabilities to grapple with the problem of lighting. Architects are at the mercy of their first sketches, and those sketches normally represent forms viewed in natural daylight, or some form of abstract universal light such as only exists in architectural sketches. What it never is, or only very rarely, is light emanating from inside the illuminated objects, and therefore, as Brooks also observed:

> It has been customary enough for architects to design their specially-built gas and electric fixtures, but it will be agreed that, as a rule, the harmoniousness of these fixtures is felt more by day than by night.[21]

[21] loc. cit.

This is not only shrewd and a truism, but it also cuts very deep into the problem. How can a man trained to model forms by external light and its cast shadows, to define architecture in Le Corbusier's terms as 'forms assembled in light', turn his art inside out and model his shapes by light emerging from within, and without shadows, to define his art as 'the magnificent, cunning and masterly play of light assembled in forms'?

Electric lighting thus put the challenge of environmental technology to architects in direct terms of the art of architecture, because the sheer abundance of light, in conjunction with large areas of transparent or translucent material effectively reversed all established visual habits by which buildings were seen. For the first time it was possible to conceive of buildings whose true nature could only be perceived after dark, when artificial light blazed out through their structure. And this possibility was realised and exploited without the support of any corpus of theory adapted to the new circumstances, or even of a workable vocabulary for describing these visual effects and their environmental consequences. No doubt this accounts for the numerous failures in this century to produce the effects and environments desired; equally doubtless it accounts for the periodic waves of revulsion against 'glass boxes' and fashionable returns to solid concrete and massive masonry, where visible form is still generated by external light and cast shadows, for which there is established theory and customary terminology.

We have been passing through such a period of revulsion and return in the last decade, and valid-sounding reasons can probably be advanced for it, such as the need to consolidate our knowledge and re-appraise our progress. But however it is excused, the fact remains that compared to the range of technological aids to environmental management currently available, the attitude of the architectural profession seems vastly less adventurous than that of the pace-setters of 1900–1914, and especially that of Frank Lloyd Wright who, by any standards, must be accounted the first master of the architecture of the well-tempered environment, and must therefore be the hero of the next two chapters.

9. Towards full control

As the progress of Le Corbusier's thinking shows, it would have been necessary to invent air-conditioning around 1930 had it not existed already. What makes the situation even more striking is that the development of the art of air-conditioning was itself reaching a point where its future growth seemed to demand a closer integration into the kind of building-design with which architects were normally concerned. For the history of air-conditioning is almost the classic example of a technology applied first in units of large capacity to industrial needs and to correct grossly deleterious atmospheric conditions, and then slowly sophisticated towards a condition where it could be subdivided and rendered subtle enough to handle domestic requirements.

The narrative of this process concerns, once again, the genial application of available scientific knowledge, or time-honoured rules of thumb, in piecemeal packets to piecemeal problems as they became apparent. But if this resembles the history of electric lighting in general outline, it is not dramatised by any single burst of concentrated systems-invention, such as Edison achieved, around 1880, nor is it ornamented by any personalities quite of Edison's quality. Willis Havilland Carrier has as good a right to be known as the father of his art, as Edison of his, but emerges from even the most eulogistic biographies as a man of more limited vision who, at least, began by evolving pragmatic solutions to *ad hoc* problems put in his way by other people. One might even, in an unsympathetic presentation, say that he did not recognise a problem until someone else offered him money to solve it. In his own words, 'I fish only for edible fish, and hunt only for edible game—even in the laboratory.'[1]

He seemed so content to solve problems as they were put to

[1] cited by Ingels, but already legendary.

him—often with startling ingenuity and depth of technical or intellectual resource—that one may doubt whether he had any general mental conception of the art he was founding until long after he had fathered it. The very words 'air-conditioning' are not his own, but were coined by his early competitor, Stuart W. Cramer, who used them more than once, in lectures and patent-documents, in 1904-1906. The Carrier Corporation, on the other hand, was still using phraseology like 'Man-made weather' as late as 1933, by which time the words 'air-conditioning' were general in the trade and were on the point of becoming part of common US usage—and had already appeared in the name of at least one of the numerous companies floated at various times around the personality and talents of Carrier himself.

Yet the phrase 'Man-made weather' is an admirable one, not only in describing the end product of the air-conditioning process, but because it also underlines the extent to which Carrier's mastery of the craft turned upon direct observation of the nature and performance of air as a component of outdoor weather. Thus his most crucial patent, dew-point control, for which application was filed in the *annus mirabilis* of this business, 1906, depended on a personal confrontation with the facts of fog, on a railroad station at Pittsburgh, late in 1902. According to Carrier's own account, recalled in old age, his response to air so laden with water droplets as to impede the sight, was:

> Here is air approximately 100% saturated with moisture. The temperature is low so, even though saturated, there is not much moisture. There could not be, at so low a temperature. Now, if I can saturate the air and control the temperature at saturation, I can get air with any amount of moisture I want in it.[2]

[2] Ingels, *Willis Carrier, Father of Air-Conditioning*, Garden City, 1952, p 15.

Such an observation cannot have failed to occur to others beside Carrier, once the mechanics of atmospheric humidity were understood, but by phrasing the matter in this way, he would almost automatically suggest a mechanism whereby that moisture could be controlled—to govern the absolute water vapour content of a body of air by holding it, in the presence of excess water, at the temperature at which the maximum of water vapour it could be made to hold was the same as the amount desired, and then to remove the excess water droplets and restore the air to the temperature at which it was required to be circulated. This, obviously, meant regulating the temperature of the air twice, once to achieve the correct dew-point conditions required to regulate the total water-content, and then once more, to restore (usually to a higher temperature) the correct thermal content for circulation. Where Carrier put his observations of the fog to the most crafty use was in devising a method of achieving the dew-point temperature that was so brilliant and so paradoxical that it occurred to none of his contemporaries (there seem to have been no competing patents) and is still incomprehensible to many people today. His account of the Pittsburgh vision continues:

> I can do it, too (*scil.*, 'get air with any amount of moisture I want.'), by drawing the air through a fine spray of water to create actual fog. By controlling the water temperature I can control the temperature at saturation. When very moist air is desired, I'll heat the water. When very dry air is desired, that is, air with a small amount of moisture, I'll use cold water to get low-temperature saturation. The cold-water spray will actually be the condensing surface. I certainly will get rid of the rusting difficulties that occur when using steel coils for condensing vapour in air. Water won't rust.[3]

[3] ibid.

A knowledge of normal high-school physics will confirm the propriety of Carrier's method, but common-sense still boggles at the realisation that, for most of the air-conditioning year in most of the climates where air-conditioning is necessary, Carrier was proposing to dry air by pumping it full of water—and this, not as a bench-top trick at a Christmas demonstration lecture, but as a commercial proposition, twenty-four hours a day. It did not become practical at once, however; some years of trial and error with types and dispositions of spray-nozzles, and with baffle-systems to remove unwanted air-borne droplets of water from the saturated air were required. But, in the end, by this technique and a variety of automatic controls (which were not all of Carrier invention) the human race was at last armed with a workably sophisticated device for controlling the most elusive of environmental discomforts—parched or humid air.

But one must emphasise that the human race possessed this long-awaited device only in very large packets, applicable for reasons of bulky plant and crude ducting chiefly to industrial needs. At the time that Carrier began his industrial career with the Buffalo Forge Company in 1902, the large body of experiment and innovating installation then proceeding in a largely unco-ordinated manner throughout the American (and, indeed, world) ventilating and heating industries was oriented almost entirely towards improvements in factory environments, because there alone were the problems big enough, and profitable enough, to bring the manufacturers of plant and its users together in situations where the economic advantage to both sides were clear enough. In other words, air-conditioning was a way of losing less, or making more, money. With one or two freakish exceptions concerning supreme legislative bodies (the British House of Commons in 1838) or chief executives (the dying President Garfield in 1881) who were deemed worthy of environmental aids beyond those awarded to ordinary mortals, industrial needs dominated: refrigeration and ventilation in ships, regulated hot air for drying tea, bulk cooling in breweries, dust-laying in tobacco factories, control of mould growth on celluloid, fibre-humidity in weaving, ventilation in mines. Ogden Doremus might rhetorically enquire, 'If they can cool dead hogs in Chicago, why not live bulls and bears on the New York Exchange?', but until it could be shown that profits on 'Change were sagging, no-one was going to consider the proposition.[4]

In many of the purely industrial applications, of course, human comfort was a lively consideration wherever profitability depended on the efficiency of the work-force—thus, the laying of tobacco dust made it possible for operatives of cigar rolling machines to

[4] in historical fact, Professor Doremus's rhetorical question was to be answered within a mere eleven years of its utterance, for Alfred Wolff installed some form of cooling plant in the Stock Exchange in 1904.

see what they were doing, and thus make fewer mistakes; the ventilation of mines made it possible for miners to stay alive by breathing in locations and situations where there was profitable coal to be worked, but natural ventilation could never reach. Even the Larkin Building would probably have shown less care for controlled ventilation had the external atmosphere been tolerable by the standards of the time—indeed, it has been argued that the avoidance of soiling of documents and fouling of office machinery by airborne smuts was the Larkin Company's main motive for accepting a sealed building. Even in the roughly air-conditioned Royal Victoria Hospital, Belfast, it was dire medical need, rather than thought for human comfort, that dictated the use of Plenum ventilation, and all that that entrained architecturally.

There were, in practice, few situations where simple human comfort offered a profit margin proportionally large enough to make investment worth while, and large enough in absolute terms too, to make investment possible, given the plant then available. Hotel dining-rooms and ball-rooms came within this class, as did Pullman cars and—above all—theatres. The concentration of large audiences in places of entertainment—where they will normally expect to be made comfortable as part of the service for which they have paid—has always posed extreme environmental problems. The form of the buildings commonly employed, where 'crowding due to the presence of galleries' had the same effect as Professor Jacob had observed in Non-conformist chapels, and the need to make them reasonably proof against external noise and other distractions, produced a situation of congestion and enclosure where the heat from the bodies of the audience was more than sufficient to maintain normal room temperatures. Thus it became the custom of the trade during the period 1920–1950 when cinemas were normally full (or nearly so) from around mid-day to late evening, to turn off the heating altogether about two hours after opening, except in very severe winters.

In warmer, Southern climates, the body heat load commonly became an embarrassment or even a hazard. The prevalence of fainting in the audiences certainly had more than purely dramatic causes, and the use of the fan was often as much an environmental necessity as an aid to flirtatious communication. With such a heat load, the chemical vitiation of the air became an even greater burden, but it would have been bad enough without the thermal hazard—some of the nineteenth-century's most spectacular concentrations of carbon dioxide were recorded in the pits of theatres. Nineteenth-century environmental engineers had made a start on these problems long before air-conditioning was even contemplated, of course—large public buildings with auditoria, like the Free Trade Hall, Manchester, or council chambers, as in Leeds Town Hall, were often provided with large thermal syphon extract ducts, powered by braziers or heating coils at their bottoms. In cases like Cuthbert Broderick's design at Leeds, these ducts could emerge above cornice level in bulk large enough to rival the intentional features of 'art architecture' and demand equally artistic detailing as a consequence.

But the availability of large-capacity fans toward the end of the century brought these hazards in sight of solution. Professor Jacob, as usual, gives a reliable survey of the state of the art at the time of his writing, and draws particular attention to two cases:

> The arrangements for the heating and ventilation of the Vienna Opera House are singularly complete. They were designed by Dr Bohm, the medical director of the Hospital Rudolfstiftung. There are two fans, one for propulsion, the other for exhaust. The air is heated by steam coils, and is admitted by the floor and through the risers of the seats. Each gallery and compartment, including the stage, has its own independent supply and means of heating . . . Air is admitted to a basement chamber, into which, in summer, sprays of water are introduced; it is then driven over the steam piping and on into a mixing chamber . . .
>
> Very similar arrangements are found in the Metropolitan Opera House, New York; but there is but one fan, and that is used on the 'plenum' system . . . to avoid draughts from the doors, which are so usual in theatres ventilated on the exhaust principle.[5]

[5] Jacob, *Notes* . . . etc., p 93.

Jacob also cites the case of the Madison Square Theatre in New York, as do other writers, because its Sturtevant fan-system, from 1880 onwards, had provision for blocks of ice to be stood in the intakes to cool the air, and could consume up to four tons of ice per night in summer.

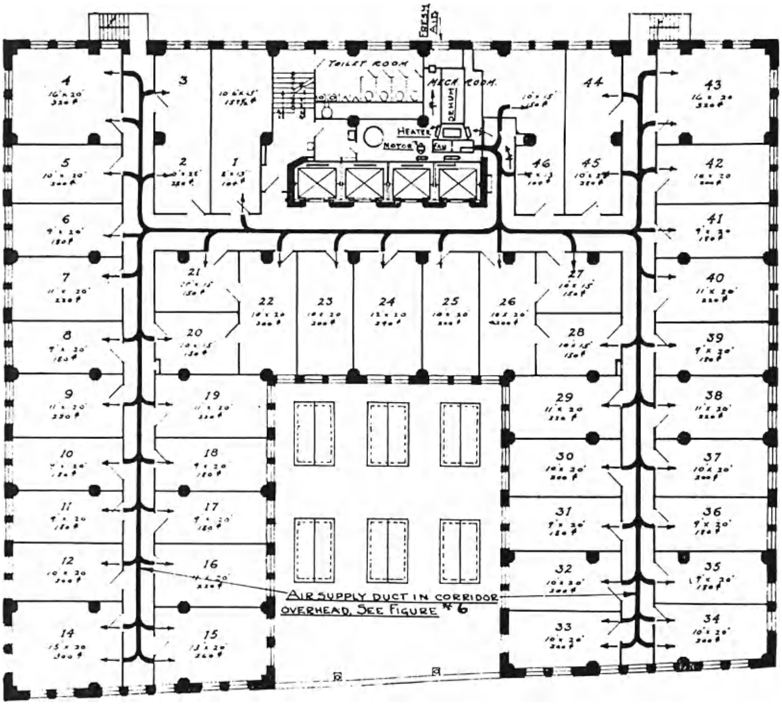
Such cooling techniques could be capricious, of course; according to ambient circumstances, the input air might pick up moisture from the ice by evaporation, or lose it by condensation on the ice surface. Though the probability would normally be that these effects would have the right tendency—that hot dry air would pick up humidity, and hot humid air would, with luck, shed some—the system was not reliable enough to compensate for its cumbersome bulk, messy operation, impossibility of automatic control and constant demand for labour. Air-conditioning looked a more attractive proposition on all of these counts, and was bound to come in as soon as it was mechanically practicable. There appears to be some room for argument about which was the first of such 'theatre comfort jobs' but Margaret Ingels in her life of Carrier, awards the palm to Graumann's Metropolitan in Los Angeles, a Carrier installation with Carbondale refrigerating plant, of 1922.

The Graumann's installation, and the numerous other theatre and cinema comfort jobs which followed, all effectively reversed the ventilating proposition discussed in the quotation from Jacob, above. Whereas schemes such as Bohm's at the Vienna Opera had tended to use the space under the ramped seating as a distribution volume for the input air, which entered the auditorium under the seats, the new comfort jobs reversed the flow, bringing air in through diffusers overhead at low velocity, whence it settled in a cooled blanket gently over the whole auditorium, to be extracted through grilles in the risers under the seats. Given the fact that in most auditoria, cooling is a far greater problem than heating, and that this arrangement gives the preferred 'cool-head/warm feet' stratification, overhead input and under-seat extract is now almost a world standard. Most commercial theatres also developed, at an early date, the habit of deliberately spilling some of their conditioned air out of the foyer on to the side-walk, thus offering tangible proof that it was, indeed, 'cooler inside.'

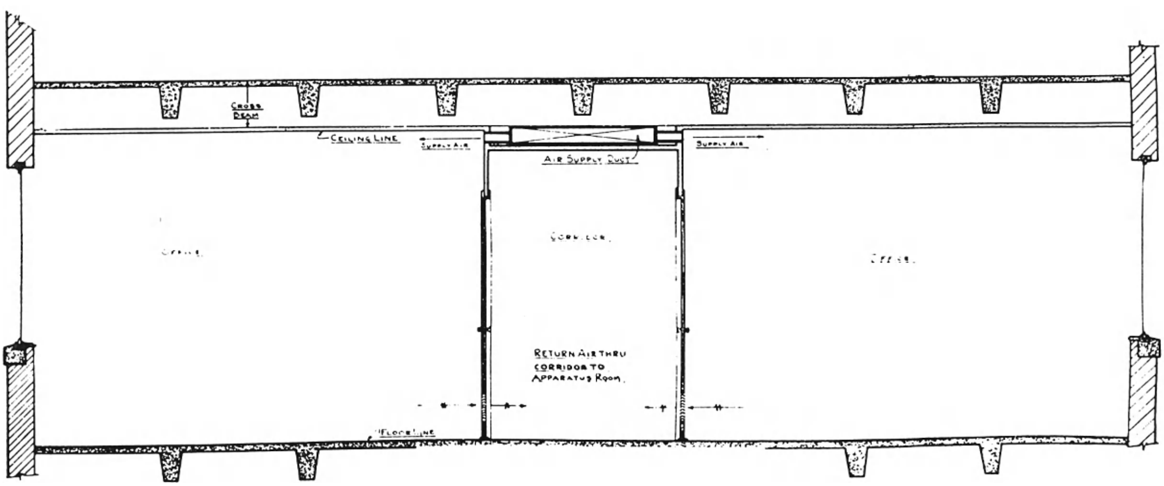
The movie industry thus introduced the general public to the improved atmospheric environment, as well as the improved luminous environment which will be discussed in the next chapter. But could any members of that public enjoy that same improved environment at home, or even at work? Well before the end of the twenties it was clear that anyone who could reduce air-conditioning to an office-block scale, let alone a domestic one, had a bright commercial future. Traditionally, the earliest fully air-conditioned office block is taken to be the Milam Building in San Antonio, Texas, of 1928; architect, George Willis, and engineer, M. L. Diver. In spite of its uninspiring exterior, it was an innovating building on many counts—for instance it was among the first concrete-framed skyscrapers and, at twenty-one storeys, the tallest multi-storey concrete framed structure in the world at the time.

Its air-conditioning method was simple in general conception, though complex in application.[6] A common refrigerating source in the basement supplied, firstly, an air conditioning plant for the main public rooms on the lower floors, and secondly, a set of standardised smaller plants for the standardised office floors. These sets of machinery were distributed at the rate of one to every two floors, near enough, throughout the height of the block, and were located between the toilets and elevators at the back of the floor-plan: each set supplied conditioned air to two floors through ductwork in the furred spaces above the ceilings of the central corridors, and the corridors themselves served as the return ducts, exit grilles from the rooms being provided in the doors. This effected a reasonable and economic compromise between the unavoidable necessity of working with fairly large units of plant, and subdivision of their output without consuming too much rentable floor space with large vertical ductwork.

[6] there is a useful description of the building in *Heating, Piping and Air-Conditioning*, July 1927, pp 173*ff*.



Milam Building, San Antonio, Texas, 1928, by George Willis; facing page: exterior view; left: plan of typical floor and below, section of standard duct and corridor arrangement.



In such situations where commercial practicability was both the initial motivation and the ultimate veto, the consumption of floor-space by duct-work was a life-or-death consideration, since even the comforts of air-conditioning were rarely attractive enough for the rental to be elevated to the point where the loss of square-footage was offset. Carrier's solution—and ultimately everybody else's—was to distribute filtered and moisture-controlled air at high velocity through small diameter ducts, and heat it or cool it at the point of delivery under the windows of the offices by means of pipe-coils warmed or chilled by water supplied on a separate network. Also at the point of delivery, the unwelcome side-effects (noise, draught, etc.) of high-velocity distribution were tamed by using injector nozzle systems to make the conditioned air draw considerably more than its own bulk of room air through the casing of the unit, the mixture of new and locally recirculating air emerging quietly and at unobjectionable speed as a curtain in front of the window glass.

The embryo of this concept, and some of its essential parts, already existed in the board-room installation at the Lyle Corporation offices in 1929, to which reference was made in the last chapter, but it was not yet a sufficiently workable proposition to be used by Carrier in the Philadelphia Savings Fund building of 1932 (see next chapter). The full 'Conduit Weathermaster' installation as a standard kit did not exist until 1937, but something very like it can already be seen in the illustrations to an article, *Preliminary Planning for Air-Conditioning in the Design of Modern Buildings*, by two Carrier employees, Realto Cherne and Chester Nelson, which appeared in *Architectural Record* in 1934. But the importance of the article as an historical marker goes well beyond this point: the illustration shows, unmistakably, an office block divided up into small room-units, not a large single industrial or theatrical volume; the text says, 'This discussion will be limited to air-conditioning for comfort . . .',[7] and the whole represents the earliest ascertainable occasion on which air-conditioning appears

[7] *Architectural Record*, June 1934, pp 538*ff*.

to have been discussed at the level of the kind of conventional professional wisdom that is embodied in architectural check-lists.

The emphasis in air-conditioning had clearly changed; but for the tide of recession and economic collapse that swept North America, the use of air-conditioning in large, multi-celled buildings would probably have become established before the thirties were over. As it turned out, however, the rate of progress was slow, and the expensive installations at Radio City that so impressed Le Corbusier were without significant rivals after 1932. In some ways, it may be argued, this delay may have benefited both architecture and air-conditioning. With the Second World War following even before economic activity was fully recovered from the Slump, a total of more than a decade was amputated from the expected growth of air-conditioning. Real progress was not fully resumed until after the end of the forties, by which time the mechanical possibilities for office-block air-conditioning had been reinforced by a new technical aid in the field of lighting, and a new set of aesthetic preferences in the design of building envelopes.

The innovation in lighting was the fluorescent tube, which, with its relation the gas-discharge tube, had existed as a potentiality since the beginning of the century. Claude, in France, and Moore, in England, had produced workable discharge tubes at an early date—Moore tubes had been used to outline the façade of the West-End Cinema in London in 1913, and Claude's favoured discharge-gas—Neon—had added a new word to the language before 1930. But it took from Edison's 1896 experiments with fluorescent bulbs until the simultaneous announcement by Westinghouse and GEC of their 'Lumiline' tube in the summer of 1938, to get the fluorescent tube into the catalogue and onto the market.

To the world at large, and in the minds of architects, the fluorescent tube was essentially a post-War innovation, and was prized primarily for its economy of current and its lack of concentrated glare. But even in the first Lumiline announcement, the relevance of the fluorescent tube's diminished heat output to problems of air-conditioning was mentioned. And in any case, the use of fluorescent lighting was soon to generate new glare problems when it was employed in even and continuous grids over office ceilings as a source of PSALI in areas too remote from the perimeter windows of the block to receive much usable daylight. But such use of PSALI (Permanent Supplementary Artificial Lighting of Interiors) at the core of very deep floor-plans could never have come about without the neat confluence of the potentials of air-conditioning and fluorescent light. The heat output of enough incandescents to give a tolerable level of illumination for paper-work would have been more than any ventilating system could economically have swept out. But with a diminished heat output, air-conditioning could cope economically, and once this was possible it also became possible to make a long overdue rationalisation of the standard US office tower's plan-form.

Traditionally, it had always exhibited a notch or re-entrant in the back (Europeans will probably know it best from the plan of Holabird and Roche's Marquette building which is so often illustrated in accounts of the Chicago School) and this re-entrant served to bring light (and ventilating air) to the centre of the block, including its ancillaries, such as toilets and elevator shafts, as well as rentable office areas. But a plan bitten into in this way was more difficult to subdivide and contained more awkward corners that were difficult to let, than would the plain rectangle of what was to be called the 'full-floor' type of plan, with its ancillaries islanded in the centre—a possibility that existed, profitably, only with air-conditioning and low-heat lighting. Given these, however, it was calculated by a Chicago real-estate man, George R. Bailey, that

> Full-floor development can be produced, complete with air-conditioning, fluorescent lighting and acoustic ceilings, for only about 8% more than a standard floor (i.e., with notchback) without air-conditioning and with only ordinary lighting.[8]

His calculus was timely—not only was the clear, well-serviced rectangular floor plan attractive enough for its rents to absorb that

[8] *Heating, Piping* . . . etc., September 1949, p 72.

extra eight per cent, but architects had by now more or less unanimously decided that their post-War skyscraper dreams were going to be realised in a starkly rectangular aesthetic. Both the United Nations building and Lever House were in design and construction at the time Bailey's results were published, and though both were prestige buildings which, for differing reasons, could support 'uneconomical' standards of servicing, the innumerable rectangular glass slabs which appeared in their imitation soon showed that such a format, and its necessary standard of servicing was not at all uneconomic—or, at any rate, not unprofitable. Le Corbusier's vision of the Cartesian glass prism of the slab skyscraper, and Carrier's practical technology for solving any environmental problem that offered an honest dollar had met, literally, in the UN building, and the face of the urban world has been altered.

But, even at that date, the interior of the domestic dwelling was still virtually unmarked by these upheavals of environmental technology—air conditioning was just beginning to find its way into the home in 1950. The story of its arrival had been a long and—for the trade—frustrating one. The ultimate historical reasons probably lie in the peculiarity of the industry itself, and the kind of men who led it. Men like Carrier, even when employed by commercial concerns, usually worked for companies that produced only part of the total kit needed for air-conditioning—the fans, or the refrigerating plant—and saw air-conditioning primarily as a means of promoting the parent company's sales. Almost like independent consultants, they assembled the total plant from the wares of several manufacturers, often by separate competitive tenderings. Nobody in the earlier stages appears to have manufactured, or even offered to sell, a complete installation as a pre-assembled package. The elements of the kit were distributed, according to private lores and mysteries of consultancy and subcontracting, within the interstices of the building-structure, and the layman therefore had difficulty in identifying air-conditioning plant as a commodity or recognisable service such as he might be able to install in some convenient space in his own home.

What made this situation the more frustrating for the trade's visionaries and opinion-makers was that such convenient spaces existed almost universally throughout North America, in the common house-basement, and that those spaces already contained testimony of the wide-distribution of the skills needed to install air-conditioning, in the shape of the ductwork taking hot air from the furnace to the various rooms—indeed, these ducts would often have served well enough for conditioned air as they stood. Even a small opening into this promising market could, like office-block installations, have helped the industry round the awkward corners of the Slump. A rousing editorial in the Chicago magazine, *The Aerologist* during the summer of 1931 coined the splendid slogan: *Wanted, an Air-Conditioning Flivver!*, and called for

> . . . an air-conditioning unit for the home, efficient, moderately priced and relatively fool-proof . . .
>
> Its production on a quantity basis by modern manufacturing methods would soon make air-conditioning more of a necessity than the radio or even the automobile, and its acceptance in the home would soon force its general adoption on a grander scale in practically every other building and conveyance used by man.[9]

Effectively, history was to run in the opposite direction—effectively 'every other building and conveyance' would be air-conditioned before there would emerge a domestic air-conditioner as ubiquitous as the family flivver, and the process was ultimately to take almost two full decades from the publication of the *Aerologist* editorial. In the mean time, there were to be isolated and expensive installations in luxury homes, some, indeed before 1930, such as those in the Chicago area by the redoubtable Samuel R. Lewis. The General Electric Company installed an experimental room cooler for evaluation in Carrier's own house in 1929. There followed a flurry of interest in room cooler units, though most of them, unlike the example just cited, were not self-contained but serviced by a refrigeration plant somewhere else, usually in the basement.

[9] *Aerologist*, August 1931, front-cover editorial. Published in Chicago in the twenties and thirties, *Aerologist* was one of the few publications concerned with the general atmospheric good of the human race, not with narrowly technical or hygienic aspects of the topic.

Carrier, by now involved willy-nilly in manufacturing, *via* his Standard Products division, had an 'Atmospheric Cabinet' room cooler on the market by 1932, but this was still too bulky a block of equipment to recommend itself as domestic furniture. Most of the central-station units intended to service the house through ductwork from the basement were even more cumbersome. Even in the flattering light of carefully air-brushed advertisements of the mid-thirties, they are seen still to be *ad hoc* assemblies of the needed units, mounted—sometimes—on a common base and grudgingly wrapped in characteristic examples of industrial stylists' case-work of the period—though the Trane Company appear to have despised even this minimal concession to domesticity and continued to glory in a Boilermakers' Aesthetic of pipe-elbows and exposed valves. And they were bulky, commonly occupying a near cube of about six feet by six feet by six feet, heavy to match and costing more than $2000 in some cases. These figures alone would have made them an unattractive domestic proposition for the mass market, even had they been more fool-proof and more nearly self-regulating than they were. Ten years after the *Aerologist* had formulated the need, the Flivver had still to materialise, and the US went to war without any domestic air-conditioning to return to[10].

But there was not long to wait after the War. As usual, hostilities had stimulated the rate of invention and technological development, to the point of precipitating some minor technical revolutions, not all of which had any relevance to air-conditioning as they stood, but all tending to point the way towards a radical miniaturisation of the equipment involved. The cumulative effect of miniaturisation and other improvements was to be suddenly sensational around 1950. Writing with the slightly dazed air of someone who cannot quite believe his eyes, Arthur Carson observed in 1954:

> Research that started in 1946 hit the production line with its discoveries in 1951, when mass-produced home air-conditioning units appeared on

[10] Professor Condit has suggested to me that the slowdown of the progress (and miniaturisation) of air-conditioning in the 1930's may not have been as total as I have suggested, because of the continuing installation and improvement of railway air-conditioning in the US. By 1936 all lounge, dining and sleeping cars on major long distance trains in the US were air-conditioned.

McQuay Company, packaged air conditioners, 1948.

> the market in every shape and form. In 1952 dealers sold out $250,000,000 worth of equipment and had to turn away 100,000 customers. That year there were only 20 companies in the field; now there are more than 70, with the original 20 multiplying their 1952 output by 400–500%.[11]

Carson perhaps may be faulted on his starting dates, since some of this research appears to have hit the production line earlier than he suggests—both the McQuay Company, and General Electric, seem to have had the kind of air-conditioning pack he is describing in their catalogues in 1948, and there are some doubtful cases as early as 1946. One says 'doubtful cases' because the kind of air-conditioning unit that Carson is discussing is quite specific but not at all what the editorial in the *Aerologist* had anticipated. What had finally wrought the revolution and brought in the air conditioning Flivver was not a central station system servicing the house through ducts, it was not a room-cooler with a remote refrigeration plant, it was not a compound unit like Carrier's Weathermasters. It was a simple, self-contained box, needing connection only to an electrical outlet; it could usually be lifted by one man, or two if

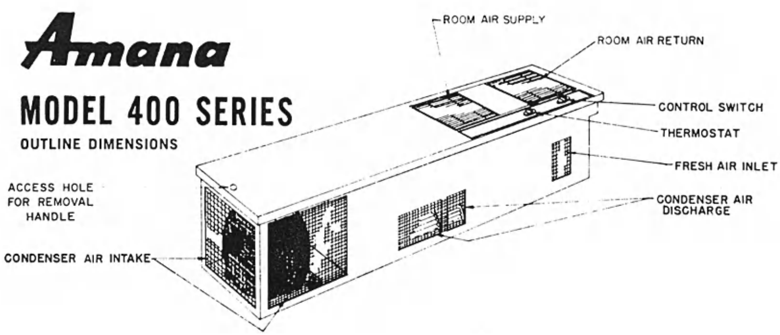
[11] Carson, *How to Keep Cool*, New York, 1954, p 56.

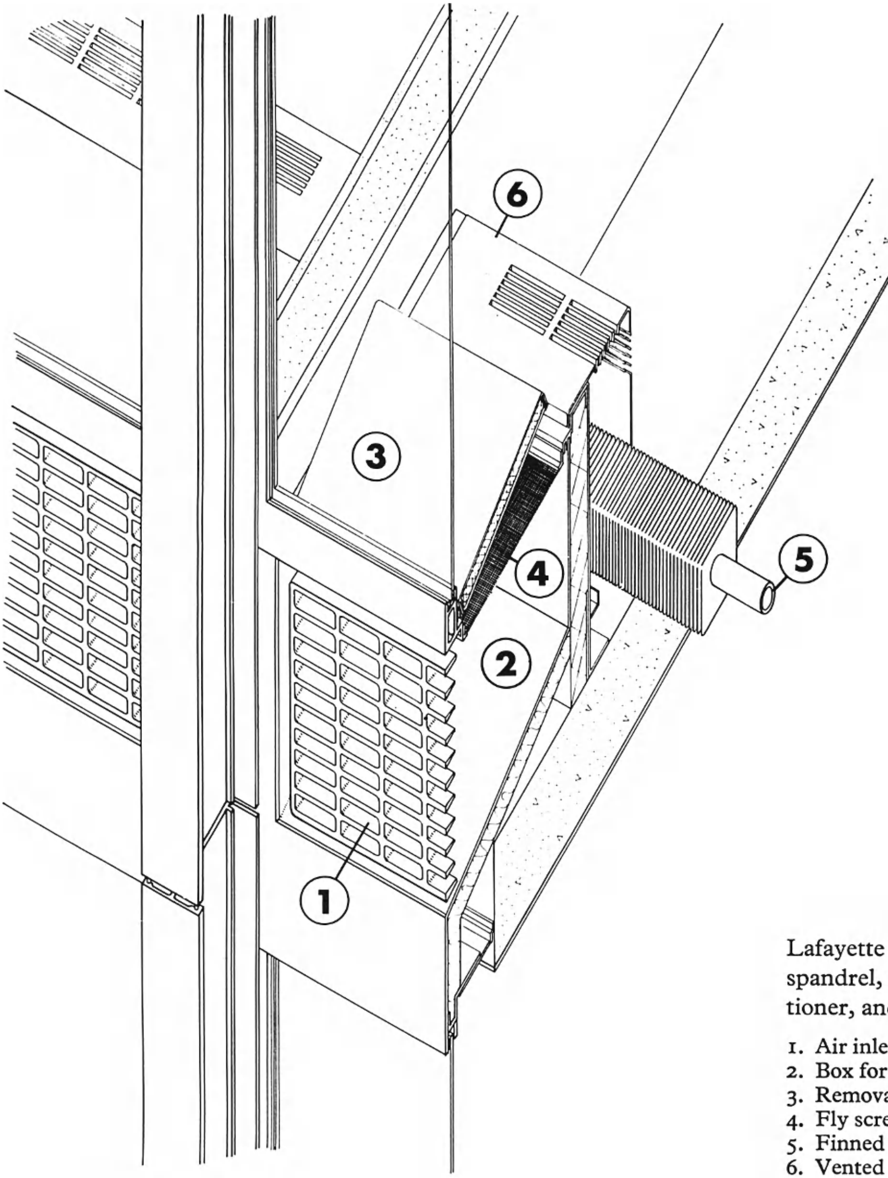
unusually large; its bulk might not be more than two or three cubic feet; and it provided full and complete air conditioning, with the possible exception of winter humidifying which is rarely needed anyhow. What makes some of the early units 'doubtful cases' is that it is not now certain how full a conditioning service they offered, but what Carson is talking about is a self-contained unit that can be installed in a hole in the wall or an opened window, plugged in to the electrical main, and can deliver genuine air-conditioning.

That is all the installation it gets in many cases, rested on a window-sill and the sash closed on top of it—many models nowadays come ready with flaps or fitted plates to block off the residual width of the window opening. Although domestic air-conditioning of the sort Carrier had envisaged, from a central station using ductwork in common with the winter heating, has also proliferated, it has done so in the wake of the self-contained window unit, which has finally made air-conditioning comprehensible as domestic equipment comparable with the cooker, the refrigerator and the television set—a neat box with control knobs and a mains connection. However one regards this device, it is a portent in the history of architecture.

Firstly, by providing almost total control of the atmospheric variables of temperature, humidity and purity, it has demolished almost all the environmental constraints on design that have survived the other great breakthrough, electric lighting. For anyone who is prepared to foot the consequent bill for power consumed, it is now possible to live in almost any type or form of house one likes to name in any region of the world that takes the fancy. Given this convenient climatic package one may live under low ceilings in the humid tropics, behind thin walls in the arctic and under uninsulated roofs in the desert. All precepts for climatic compensation through structure and form are rendered obsolete—though as James Marston Fitch (and others) have hastened to point out, any consideration of economy in the use of air-conditioning brings the

Lafayette Park apartments, Detroit, Mich., 1961, by Mies van der Rohe; left: exterior of blocks; below: specially developed air-conditioner package to fit under window.





Lafayette Park: cut-away of spandrel, box for air-conditioner, and heating pipes.

1. Air inlet grille
2. Box for optional air conditioner
3. Removable lid
4. Fly screen
5. Finned heating pipe
6. Vented heater casing

time-honoured usages of local tradition back with even greater force.

Nevertheless, the possibility of absolute variety and infinite choice of building form is now with us—and as so often happens with infinite choices, has led to almost perfect homogenisation of what is chosen. In the United States, air-conditioning has now made the established lightweight tract-developers' house habitable throughout the nation, and since this is the house that the US building industry is geared to produce above all others, it is now endemic from Maine to California, Seattle to Miami, from the Rockies to the bayous. Not without reason; the normative American house that Catherine Beecher saw evolving out of the normative US way of life that grew from the increasingly mechanised farming of the middle-west, probably answers to the understood aims and usages of the people who inhabit it quite as well as any localised vernacular house of the Old World suits its tradition-bound inhabitants. The house type was already widespread and still spreading long before air conditioning came along to wipe out its surviving deficiencies, and much of its adaptation to increasingly specialised climatic conditions was the work of tenants and owner-occupiers who fitted packaged air-conditioning to their own homes with their own hands in their spare time.

For this, secondly, may prove to be the most portentous aspect of air-conditioning, that, in the domestic package, it offers the most sophisticated device for environmental management that mankind has ever possessed, in a form that needs little skill to install, and even less to operate. Any normally intelligent householder can install one with normal household tools and many have done so. As far as the little houses of suburbia are concerned, this poses no great visual or architectural problems—the evergreens have already grown up in front of the units, and they are not seen. But in the apartment blocks of cities, such installations can bring the environmental improvements of the householder into direct conflict with the visual intentions of the architect. For every act of

intelligently permissive vision, like that of Mies van der Rohe at the Lafayette Park apartments in Detroit, where a characteristically well-detailed under-window box offers the householder choice between controlled natural ventilation and the installation of an optional air-conditioner purpose-designed to drop into the box, there are too many designs where conflict seems inevitable.

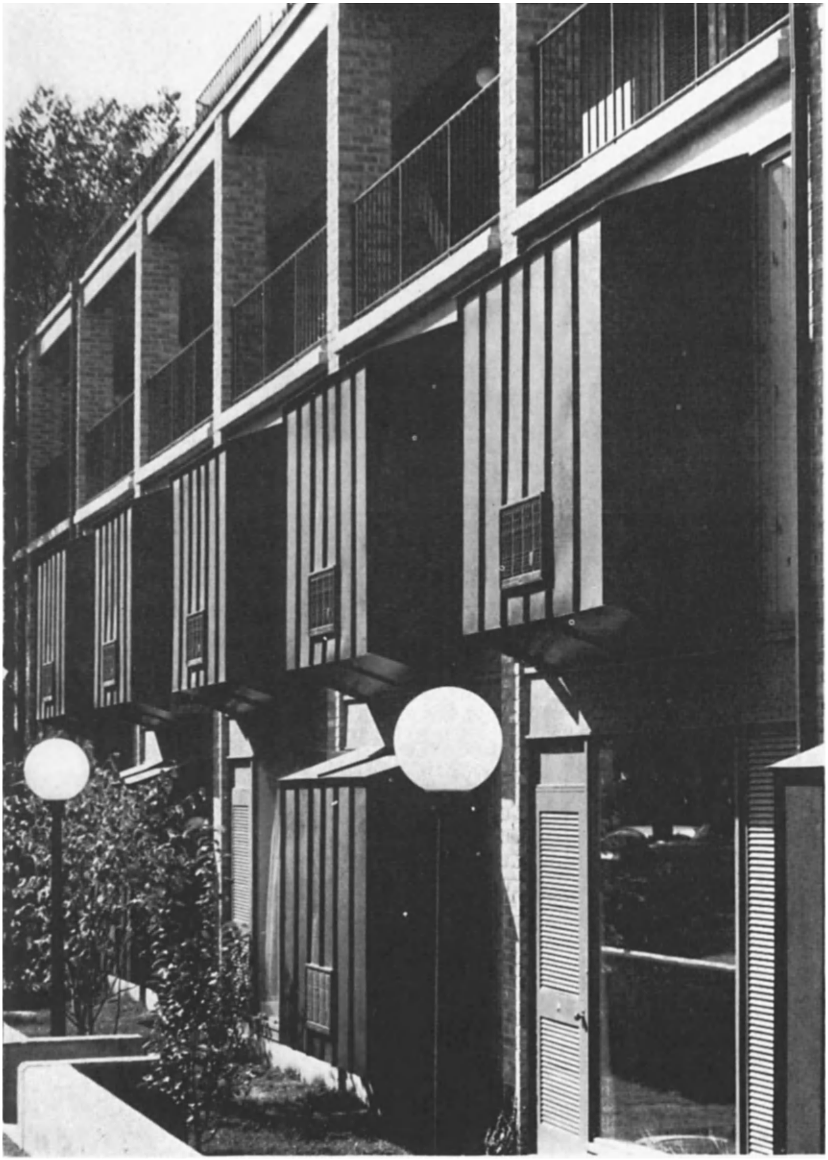
Kips Bay Apartments, New York, 1961, by I. M. Pei Associates; southern façade showing privately installed air-conditioners.

A conspicuous case is that of the Kips Bay Apartments in New York, designed by I. M. Pei and Associates. Since this is a scheme of 1959–61 the absence of provision for air-conditioning is not altogether easy to understand, though the determination of the tenants to fit it, especially to rooms on the south faces of the blocks, is entirely comprehensible. In order to preserve Pei's façade patterns, the managing company is reputed to have insisted that

Row-houses, Eugenie Lane, Chicago, Ill., 1963, by Harry Weese; above and facing page: rear elevation showing air-conditioners in projecting cupboard units.

tenants should install their conditioner packages, not in the spandrels under the windows, but back inside the room and connect them to the outside air with a flexible duct. Since, however, the environmental performance of almost every domestic air-conditioner depends on its being able to dump its surplus heat and moisture directly into the outside atmosphere (as any one will know who has been wept on by air-conditioners in the streets of New York) this hopeful proposition has not proven successful, and most of the tenants have their units back in the spandrels under the window—in a random pattern all over the façade that is not unattractive.

Although many architect-designed buildings are now beginning to make their peace with the seemingly inevitable eruption of room-conditioners on their façades, few have set out to exploit the neat visual detailing of their intake grilles, nor the convenience for interchangeability of their easy installation and removal. A rightly-noticed exception to this indifference is seen in the terrace of row-houses in the Old Town area of Chicago, designed by Harry Weese in 1963. There, the conditioner grilles form rather delicate visual accents on the outer faces of projecting cupboard units that occupy several bays of the frame on the back of the terrace, while the non-structural nature of these projecting cupboard-backs



should make them—as the *Architectural Review*[12] observed—'relatively simple to alter when the air-conditioners have been overtaken by the normal processes of technological obsolescence.'

Unfortunately, this terrace on Eugenie Lane is notable chiefly because it is an exception to the general failure of architects to make provision for this piece of equipment which is rapidly becoming as normal as the kitchen sink. And unfortunately again, this failure of provision does not, in residential work, produce even the accidentally picturesque disorder that often arises from the air-conditioning of standard US single-storey commercial structures, where below eaves level, one is confronted with an orgy of eclectic modernistic details often reaching extremes of uninhibited fantasy and above the eaves the air-conditioning plant is a free composition of geometrical solids of the sort that used to be the common stock in trade of the Purists and Functionalists of the twenties. One seems to see ghosts of the restrained and abstract International Style hovering above the exuberance of the current pop-art version of the American high-life which Oud discovered in the work of Frank Lloyd Wright. Except that what is above the eaves does not represent a conscious attempt at an idealised Machine Aesthetic, but is the outward form of the kit environmentally needed to make the high-life of supermarket-America possible.

[12] *Architectural Review*, May 1964, p 311.

Readings in environmental technology

As far as possible, all works consulted and sources of information have been acknowledged in the text or its footnotes, and any reader who wishes to pursue the topic further (and I hope that many will) should go to these sources. For those who simply wish to reinforce their understanding with background reading, the situation is less fortunate, because of the dearth of general works on the subject, about which complaint is made in chapter 1. However, the following works may prove helpful:

A Short History of Technology, by Derry and Williams, Oxford, 1960; especially chapters 14, 17 and 22, which give some account of water-supply, drainage, coal gas and electricity.
Home Fires Burning, by Lawrence Wright, London, 1964, which (together with his earlier *Clean and Decent*) gives an intelligent popularising overview of aspects of environmental history. Nor can one ignore
Mechanisation Takes Command, by Sigfried Giedion, London and Cambridge, Mass., 1950, which—in spite of such spectacular shortcomings as a total failure to attack the history of electric lighting—still contains a mass of useful if ill-ordered information.

And, finally, a work intended for a general readership but now hard to find,

Willis Carrier, Father of Air Conditioning, by Margaret Ingels, Garden City, 1952, which contains an invaluable tabulated chronology of inventions and developments in ventilation and refrigeration from the Renaissance to 1950, to which the present study is deeply indebted.