# PROBLEMS IN COMMERCIAL AND INDUSTRIAL VENTILATION

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The paper starts with a brief review of the factors to be taken into account in considering natural ventilation in such installations - the factors are, inter alia, its location and surrounding buildings, the activity within the building and the results required of the installation.

It continues with some notes about the problems and possible advantages of combining natural and fan powered systems and concludes with some examples in various installations, such as power stations, shopping malls, production areas etc.

## INTRODUCTION

It is trite but nevertheless true to say that the days of cheap energy are gone and it behoves us all therefore to seek ways of reducing energy consumption.

This has meant a return to earlier forms of energy generation and we are looking again at water power, solar power, wind power and rediscovering or advancing their potential.

And so it is with ventilation. Natural ventilation of buildings has been practised for more years than mechanical ventilation and so it is in keeping to turn to this also.

However, in the past many natural ventilation systems have been uncontrolled and if the system has provided too much ventilation for comfort in the winter it was easily made up by additional heating. This paper deals with buildings where a need does exist for ventilation for some, if not all, of the time.

## VENTILATION

Ventilation is the flow of air through a building, and to have fluid flow requires pressure difference - where there is no pressure difference - there is no air flow. These pressure differences are caused by :

1. The effect of the wind blowing over the building in question.
2. The effects of the wind on neighbouring buildings.
3. The effect of difference of temperature between the inside and outside of the building.
4. Any pressures, positive or negative, brought about by mechanical ventilation systems.

Because the flow depends upon the square root of the pressure difference, doubling the pressure difference does not double the flow, but gives only a 40% increase.

Thus when two or more forces are acting simultaneously, the individual pressures can be added to arrive at the combined flow, and not, as sometimes is done, add the individual flow rates to arrive at the combined flow.

## THE EFFECTS OF WIND

Considering items 1 and 2 on the aforementioned list (the effect of wind), if a ventilation system is designed, reliant upon the wind effect, then the ventilation result should be judged over the period of time from which the average design wind speed is taken. Thus, if the average wind speed over a year in some location is 9m/s., and this is taken as the design wind speed, the result of any calculation using this figure should not be judged in $m^3/s$ or even air changes per hour, but in air changes per year.

The point to make is that in commercial or industrial premises ventilating is for a purpose, usually connected with an industrial process.

When ventilating say, a glassworks, where the main problem is overheating, which will obviously be worse in June/July etc., it is not good thinking to design assuming the assistance of average annual winds which includes, apart from the summer calms, the February gales.

We must design taking into consideration the worst conditions, which is no wind, in the same way that the structural engineer must design allowing for the February gales and not the average wind speeds.

The source of data for wind speeds is worth examining. Data is often supplied from the local airport and, whilst this may be useful in assessing the highest wind speeds likely in the area, it may not be of much use in assessing the lowest wind speed in a city centre in the height of summer.

The effect of wind on buildings has been studied by various researchers (Baturin (1), Morgan and Marchant (2) ). The location of ventilators, particularly their location in the roof, is important.

Obviously it is desirable to avoid putting exhaust vents in high pressure areas and inlet vents in low pressure areas. The former can be more difficult to achieve.

Often useful research information is reported on solid block models. In fact, however, actual buildings are permeable and it is the pressure difference across the skin of the building that we are concerned with. The internal pressure within a building is usually slightly below atmospheric, which means suction effects are perhaps not as great as results from research on block models would suggest.

Even more important is the location of very large openings. Very large openings on the leeward side can cause increased suction within the building and those on the windward side of the building can cause enhanced pressure.

The increased suction effect was brought home to the writer many years ago following a complaint that, when the wind was in a certain direction, natural ventilators installed over an open bath intermittently down draughted.

Investigations were made at site and the multibay building with barrel vault roofs (Fig. 1) had ventilators mounted on the roof of the end bay and these worked effectively for the majority of the time. After many site visits it was found that the only occasion when the ventilators failed to exhaust was when :

1. The wind was roughly at right angles to the line of the barrel vaults.

2. The large loading bay doors (at B in Fig. 1) were fully open.

The opening of these doors caused a suction within the building which was greater than the normal suction over the roof. The pressure inside the building was thus lower than the outside causing air flow into the building through the roof ventilators.

To sum up, therefore, wind has an effect on ventilation. It is, however, a very uncertain ally. To be sure of his results the designer would be advised to ignore its favourable effects, which then come as an agreeable bonus and concentrate his design effort to ensure that the effect of wind is not adverse.

If a scheme has been designed assuming the assistance of the effects of wind and this does not materialise, then the scheme may have been under-designed.

There could well be occasions when the bonus referred to above is an embarrassment, but all properly designed ventilation systems, natural or otherwise, should have a proper control system so that the ventilation can be reduced or eliminated as required. In this respect it is interesting to see the progress made over the past few years in sealing closed ventilators against unwanted air leakage. (Fig. 2).

Such sealing is, of course, vital in any building which must be heated in winter.

## THE EFFECT OF TEMPERATURE DIFFERENCE

The effect of temperature difference between the inside and outside of the building is the main factor in design of natural ventilation systems for industrial and commercial buildings, and the designer's endeavours are usually to limit this to an acceptable level.

When calculating performance of natural ventilation standard formulae can be used for ventilator performance, relating height and temperature. There are several of these formulae of varying degrees of elaboration (ASHRAE (3), Hansen (4), Thomas et al (5), Hemeon (6)). The use of these formulae involves knowing the aerodynamic free area defined as follows :

"The rate of flow of gases through an orifice such as a vent is less than would be expected from energy considerations and the orifice behaves as though its area was less than that actually measured. This reduced area is known as the aerodynamic free area". (Thomas and Hinkley (7) ).

This can be established by wind tunnel tests. Using equations for ventilator performance and conservation of heat, it is possible to calculate the ventilation requirements for various temperatures and the position of neutral layer.

As mentioned earlier, pressure difference causes flow at inlets, the pressure outside the building is higher than the pressure inside, thus there is a flow of air into the building.

At the exhausts, the pressure inside is greater than the pressure outside, thus there is flow out from the building. Somewhere between the pressures inside and outside will be equal. This is the level of the neutral layer. This is important particularly in schemes which involve both natural and mechanical ventilators.

## POWERED VENTILATION

This is the fourth of those factors affecting the natural ventilation of a building: the pressures brought about by any mechanical ventilation system. These pressures can be relatively high and so in some locations difficulties may be found in opening doors, whilst rain can be drawn in through sheet laps because there is excessive exhaust and no provision for inlet with the result that air is drawn in through any opening at very high velocity.

In industrial and commercial buildings ventilation is provided for a purpose - usually to improve the working environment because otherwise it would be too hot or because there are excessive emissions of fume or noxious gases causing, to say the least, irritation and if consideration of fire is included, life hazard.

In many such applications results can be achieved by judicious application of some powered ventilation. One obvious case is overheating, where the additional air movement by fans can contribute additional cooling. Others could be where process extraction exhausts air from the building. Probably the most extreme case here is the boiler house in a power station where the air exhausted for the boilers is at the level of .46 kg/s per MW, and stations of 2000 MW capacity are not unknown.

In such buildings the level of neutral layer is important whether the ventilation is powered, natural or a combination of both.

Thus in a laundry, for example, with excessive moisture emission the level of the neutral layer must be above the top of the doorways to adjoining sections, otherwise moist and steamy air will flow out from one section to give condensation in another section. This can happen if there is larger installed inlet capacity than exhaust capacity.

Similar cases can occur in, say, a welding shop where the working level may be clear, but welding fume in the roof space above working level can spread into, say, adjacent fabrication shops through high level openings.

The reverse situation can of course occur. In the same laundry an excess of exhaust capacity such that the neutral layer was towards the top of the building could mean high level windows would allow cool air to meet warm, very humid air giving local fog, condensation, or perhaps even rain.

The same situation can occur in emergency heat and smoke exhaust systems when an excess of exhaust capacity over inlet capacity could mean openings in the building above the smoke layer acting as inlets, blowing smoke down to breathing zone. This could, of course, defeat the object of the exercise.

Having said something about the more basic considerations, it might be appropriate to consider some particular advantages of natural ventilation.

A natural ventilation system 1) uses no power

2) is silent in operation

3) gives results which (if the heat to be dissipated is under estimated) are closer to the design temperature difference than that achieved by a totally mechanical ventilation system

4) can impose less stress upon the building structure

5) can provide psychological relief to occupants

Advantages 1) and 2) are self evident, but advantage 3) needs enlargement by means of the following example :

Basic data; estimated heat load = 1 MW, ambient air temperature 293°K, and temperature of air leaving the building of 303°K, thus the ventilation rate must be $85.32 m^3/s$.

This can be provided by powered ventilation with fans capable of handling this capacity or by natural ventilators with an aerodynamic free area of $46.6m^2$ (assuming a stack height of 10m). However, it may be that the estimated and actual heat loads differ. Fig. 3 shows the results achieved if the estimate of the heat was too low. Applying a 1.5 MW heat load to the graph we see the temperature rise with natural ventilation would be 13.2°C and with a mechanical system it would be 15.4°C. If the heat output is doubled the respective figures are 20.9°C for the mechanical system and 16.1°C for natural ventilation.

The facility of flexibility is, of course, extremely useful if heat loads cannot accurately be determined, or if they are known to vary with process - and, of course, in fire situations.

The example shows only temperature differences liable to be encountered in ventilation of industrial properties. If the fire situation is considered, this facility needs to be even more carefully considered. Data for the heat output from a fire is not likely to be exact and most mechanical units do have an operating temperature limit. If this is exceeded the unit will stop running. A powered ventilation unit failing in a day to day ventilation system can be regarded as inconvenient, in a fire situation it could be regarded as catastrophic.

A natural ventilator will not be subject to this same operating temperature limit. Referring to Fig. 3 for example, doubling the heat load increases the temperature difference in a natural ventilation scheme by about 60% and in a mechanical scheme by 110%. Thus, designing for conditions where the heat load is likely to vary, generous safety factors are needed when using powered exhaust. There is too, a "domino" effect - if one powered exhaust fails there will be a reduction in volume, which will automatically raise the temperature causing quicker failure of the remaining units.

The fourth advantage is stress on the building. This is mainly a question of roof loading. Natural ventilators have been used to render a roof permeable and thus reduce the wind pressure effects. Natural ventilators, by virtue of their relatively light weight, can also impose less stress on a roof than powered ventilators of similar capacity.

Referring to the data given in the example for advantage 3), the rate of $85.32m^3/s$ could be provided by 14 individual powered exhaust units with an individual weight of about 110 kg spread over $1m^2$ giving a total weight of about 1500 kg.

The $46.6m^2$ of aerodynamic free area could be provided by 27 louvred natural vents with individual weight of about 40 kg, spread over an area of about 1.1m x 3m giving a total weight of about 1100 kg.

Psychological relief is illustrated by Figs. 4, 5 and 6, which show just how much natural daylighting and a clear view of the outside enhance the working environment.

CONCLUSIONS

To sum up, therefore, systems for ventilation of commercial or industrial buildings can be designed using natural ventilation and incorporating powered ventilation as appropriate.

Close control of both systems is possible.

Energy can be saved by reduction of running power and that same close control.

The system can reduce the loss in fire situations.

Figs. 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14 and 15 show some applications.

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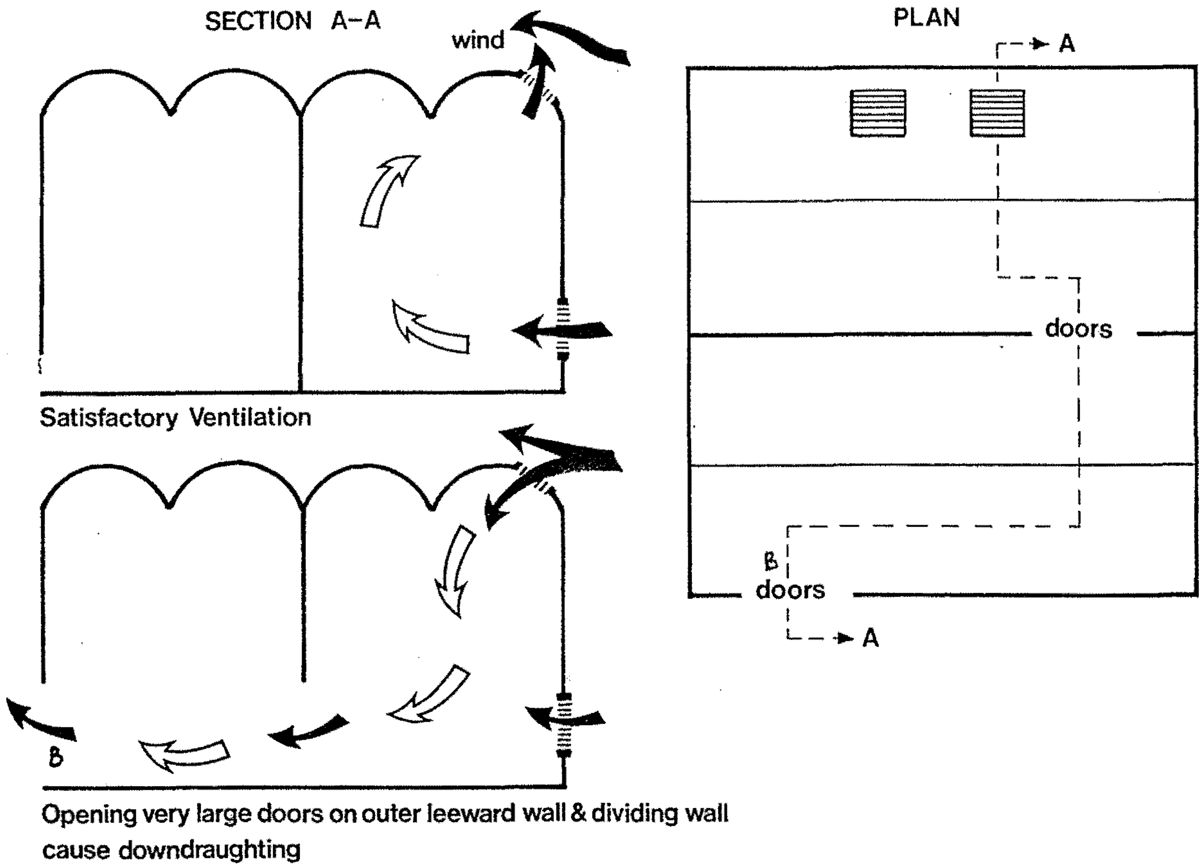
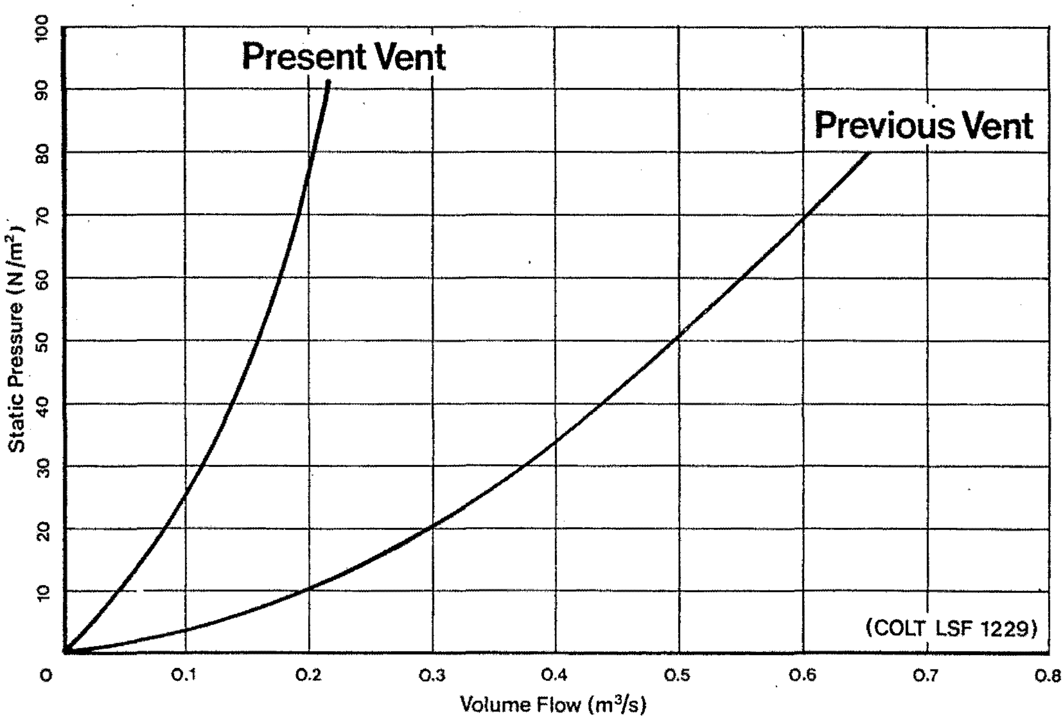



## FIG. 1 HOW DOWNDRAUGHTING MAY OCCUR




## FIG. 2 VOLUME FLOW THROUGH CLOSED VENTILATORS AT VARIOUS PRESSURES

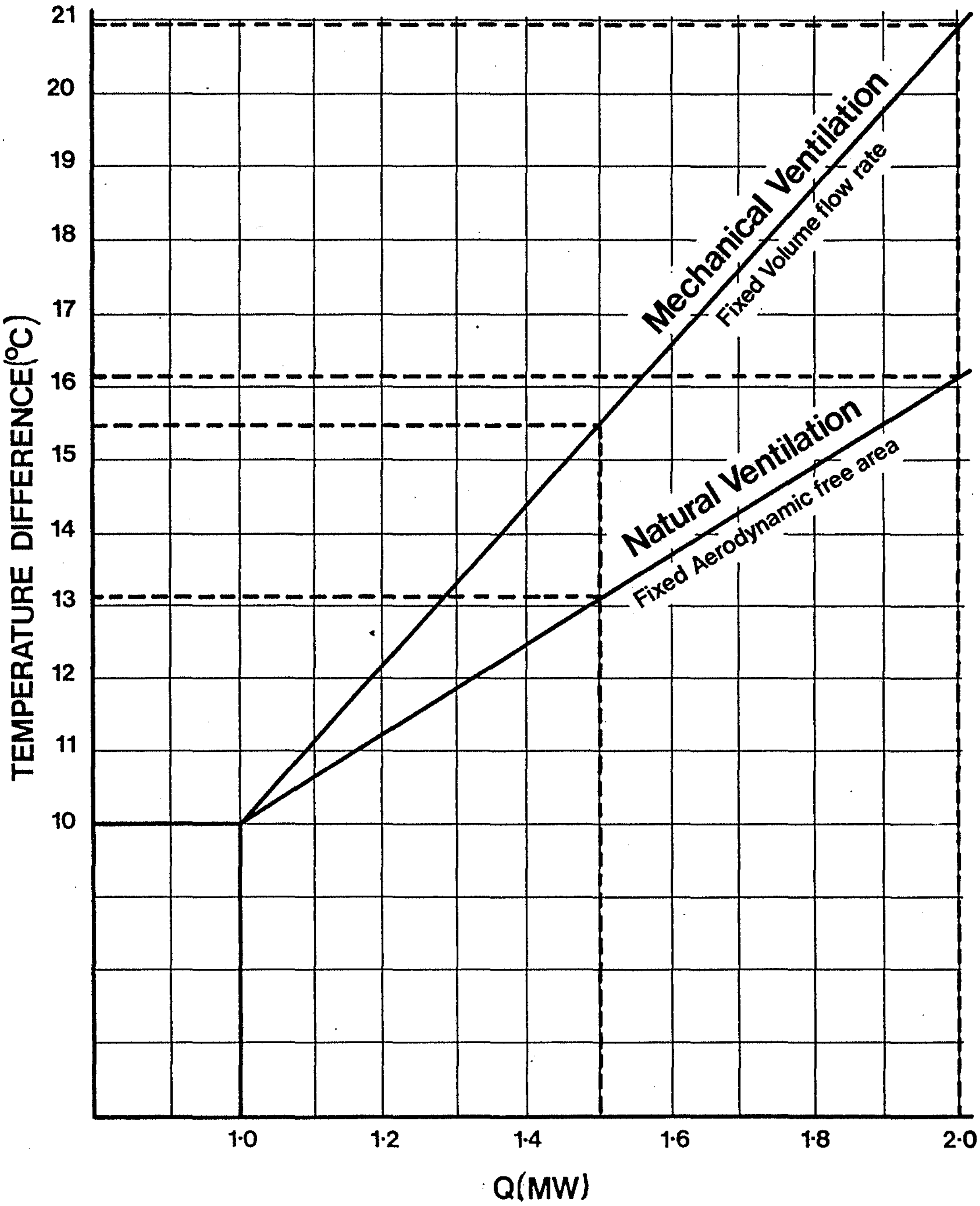



FIG. 3 SHOWING THE RESPECTIVE INCREASES IN TEMPERATURE WITH NATURAL & POWERED VENTILATION. IF DESIGN HEAT LOAD IS EXCEEDED.

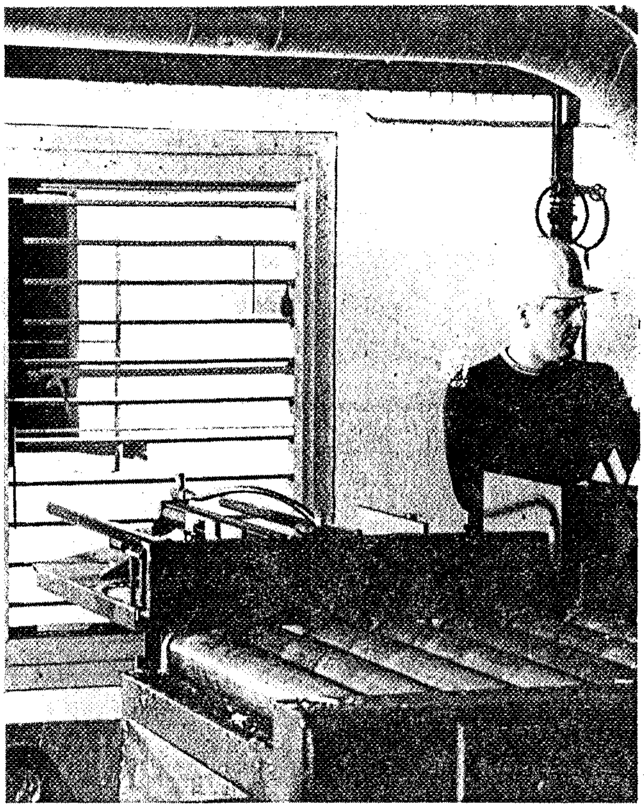


Fig. 4 - Aluminium Extruding Plant

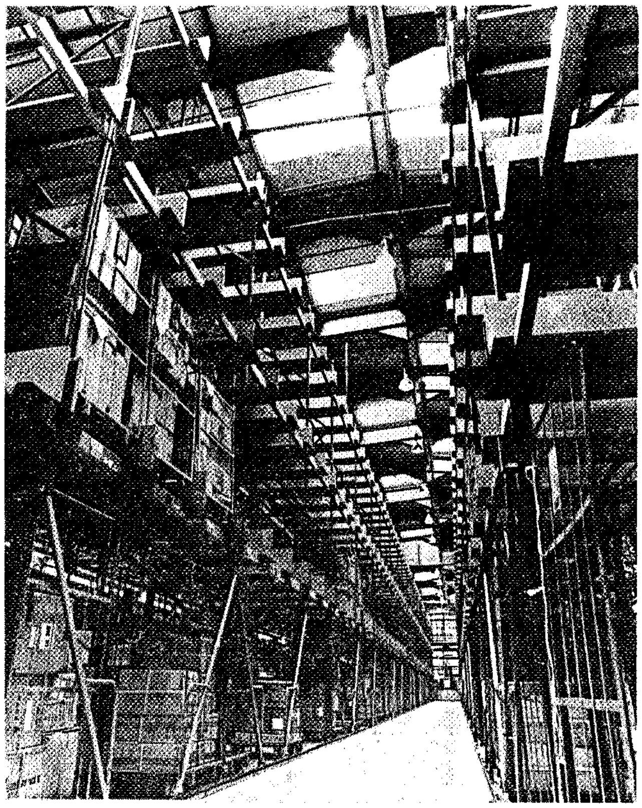


Fig. 5 - High Bay Warehouse

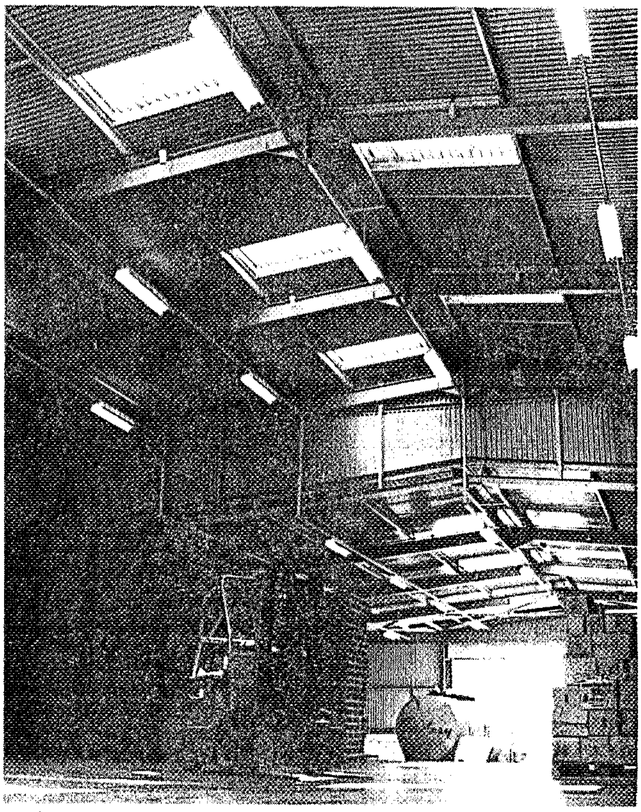


Fig. 6 - Food Warehouse Despatch Bay

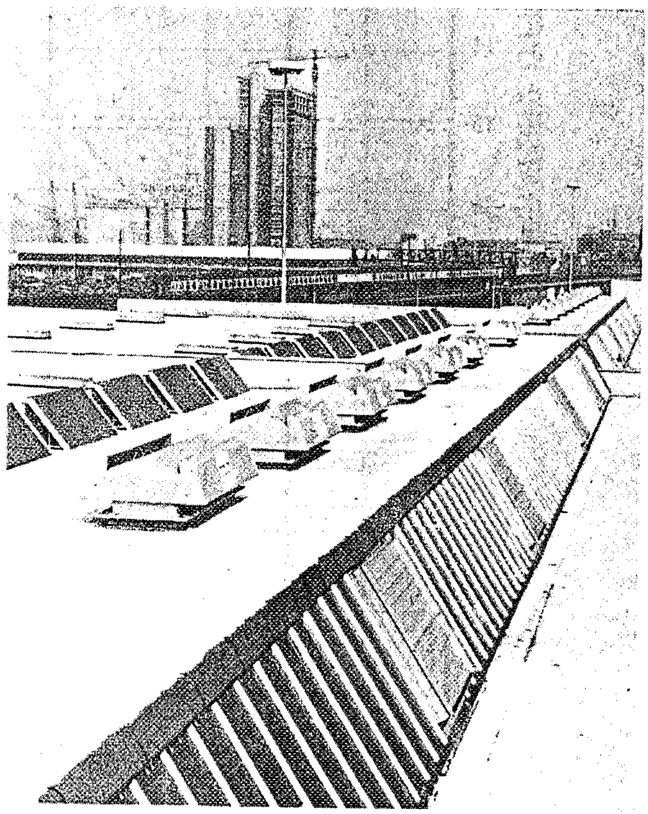


Fig. 7 - Fruit & Vegetable Market

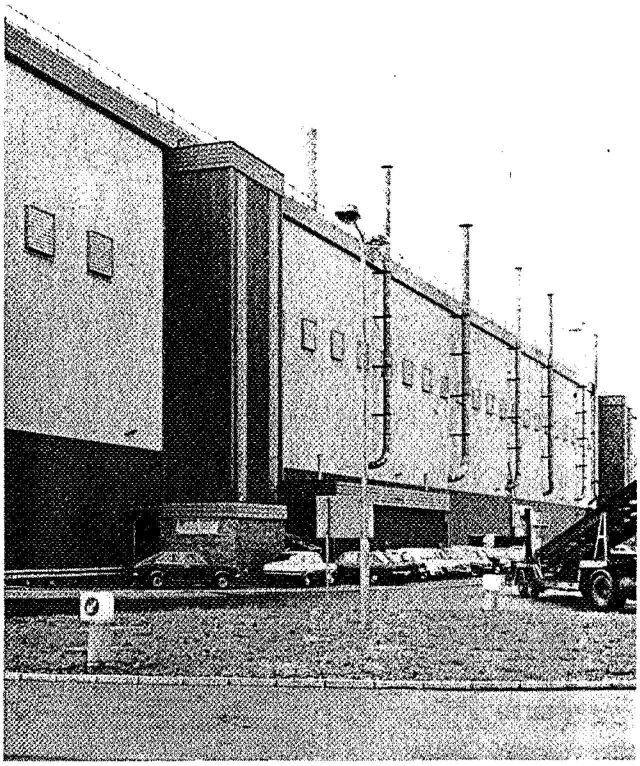


Fig. 8 - Manufacturing Plant

Fig. 9 - Improvement to older factory

Fig. 10 - Sports Stadium

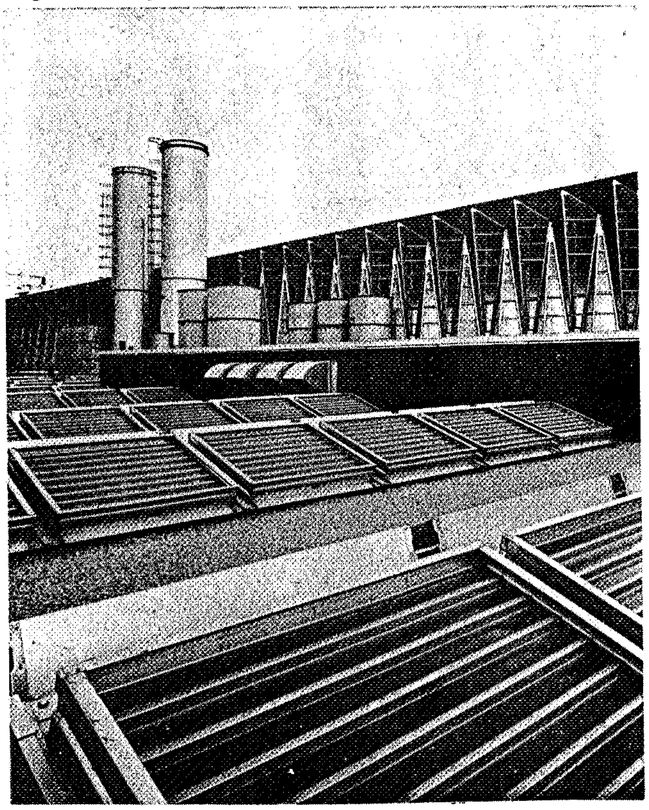


Fig. 11 - Power Station

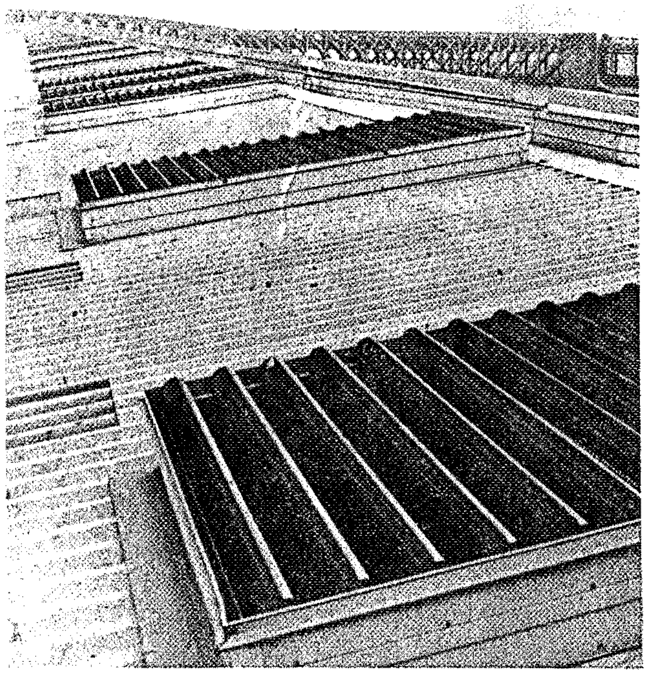


Fig. 12 - Shipbuilders

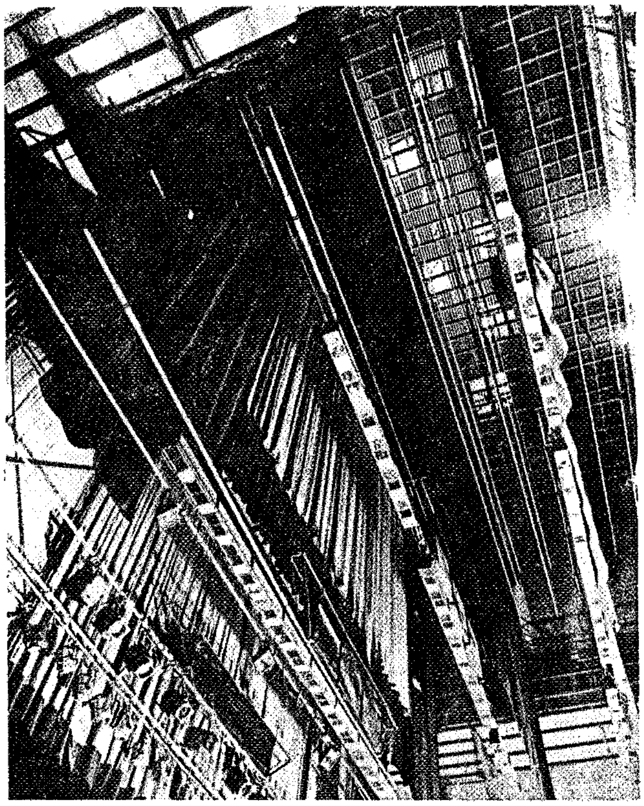


Fig. 13 - Theatre stage area

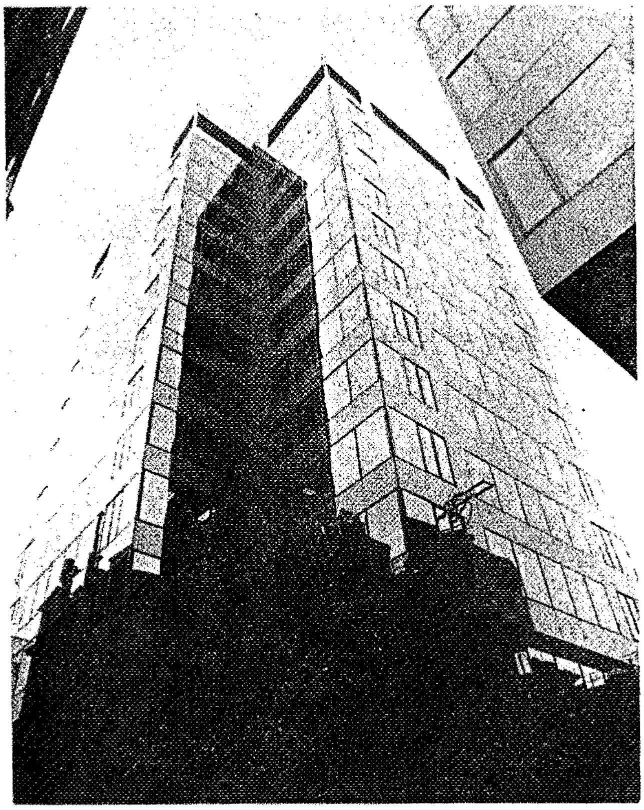


Fig. 14 - Rooftop Plant Room

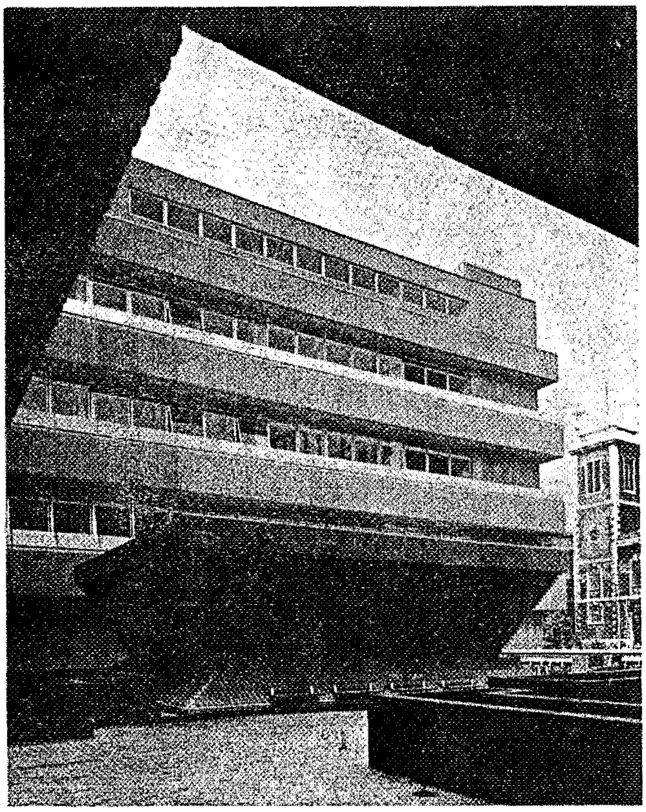


Fig. 15 - Underground Car Park