NATURAL VENTILATION AND THE PSA ESTATE

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The wide variety of buildings that constitutes the Central Government estate pose many differing ventilation problems. Most buildings are naturally ventilated and the rates achieved in practice are unknown but in many instances are thought to be excessive and as such responsible for considerable energy waste.

The paper sets out recent PSA experience and findings in an attempt to obtain a better appreciation of the interacting problems associated with natural ventilation.

INTRODUCTION

Escalating fuel costs over the last decade, a trend likely to continue into the foreseeable future, has focussed attention on the use of energy, particularly that used for heating buildings. For new buildings this has resulted in improved thermal insulation standards and greater attention to energy requirements during the conceptual design stage. While, for existing buildings, it has resulted in improved plant operation and maintenance and the upgrading of building services and the thermal envelope. More recently attention is being directed towards natural ventilation in both new and existing buildings because of its increasing significance on energy requirements.

The Property Services Agency (PSA) forms part of the Department of the Environment (DOE) and provides, maintains and operates a wide range of accommodation and fixed installations for UK Government Departments. This wide range of accommodation poses many differing ventilation problems but it is not intended in this paper to examine these in detail but to relate recent PSA experience and findings to the endeavour of a better appreciation of the interacting problems associated with natural ventilation.

ENERGY USE

The energy conservation programme undertaken by PSA over the past seven years has primarily concentrated on existing buildings. This has resulted, through the selective application of highly cost effective measures such as the up-grading of heating controls, improved plant management and additional thermal insulation, in an annual energy saving for heating fuels in excess of 35% to date. However, while a significant reduction in overall consumption has been achieved and the mean consumption per unit floor area for heating reduced, it was of concern to find that the variation in consumption per unit floor area has remained relatively constant at about 4 to 1. Table 1 shows the results for the period 1972 to 1979 of a sample of buildings located in the Midlands.

TABLE 1 - Energy Consumption (GJ) per m^2 (Nett Floor Area) For Heating and Domestic Hot Water

YEAR	MEAN VALUE	95% POPULATION CONFIDENCE LIMITS LOWER	UPPER	RATIO OF LIMITS
1972/73	1.47	0.697	3.093	1:4.4
1975/76	1.21	0.635	2.33	1:3.66
1978/79	1.11	0.57	2.168	1:3.8

Figure A shows the typical frequency distribution of the energy consumption per square metre of floor area for a representative year. It is evident that there is a bias in the sample which indicates that there exists some lower limit, below which few existing buildings can operate and maintain comfort, while there appears to be less constraint on the maximum amount of energy consumed. In practice the installed capacity of the heating plant, which has been found to vary between 115 W/m^2 and 375 W/m^2, will limit energy consumption. Generally buildings with a high energy use per unit floor area were found to have a high installed plant capacity per unit floor area.

Plotting the annual energy consumption for each building over a period of five years confirmed, as expected, that some buildings remained consistently either above or below the average for all buildings. The average consumption line for all buildings was determined as the best fit line through the points for each year. Not all the points have been plotted in the interest of clarity but most buildings whether greater or less than the average had a reducing consumption. It seems not to have been possible to make extra large savings in most of the original relatively heavy energy users.

Clearly there was a need to survey the buildings, but as the high and low energy users were of prime interest, it was decided to survey those above or close to the upper 95% confidence limit and similarly those below or close to the lower 95% confidence limit.

It was not possible to measure the ventilation rates for the buildings but a common feature of buildings with a high energy consumption was that they were generally cold and draughty which suggests that ventilation rates were higher than need be. Similarly for the same group of buildings, the standard of plant operation and maintenance was not always what it should have been. The reasons for this are perhaps many, but it is suspected that often maintenance staff are driven to despair, through numerous complaints from the building occupants about low temperatures and draughts, consequently heating controls are overriden or incorrectly adjusted in an attempt to satisfy client requirements.

The relative significance of these problem areas could not be determined from the results of the surveys. The surveys did however suggest that buildings of an apparent high energy design did not necessarily demand excessive consumption in practice.

PREDICTED VARIATION

A common feature of the PSA energy conservation programme of work has been to compare empirical findings with theoretical predictions. This has generally led to a better understanding of problems.

In view of the large variation in consumption per unit floor area found in existing buildings and the limited findings of the surveys, a simple assessment of the theoretically predicted spread in consumption was undertaken. There were problems however.

In order to undertake the assessment it was first necessary to decide over what range natural ventilation rates occur in existing buildings. It was generally felt that the average minimum rate was unlikely to be less than 0.5 air changes per hour but the maximum was more difficult to assess. One or two assessments of draughty buildings have indicated that the natural ventilation rate was about 3 air changes per hour. Another pointer to the likely maximum is that it is not uncommon practice for many Building Services Engineers to assume 2 air changes per hour in design calculations, as a result of adverse experience with lower values. Finally it was decided that 3 air changes per hour is likely to be representative of the maximum average value of natural ventilation found in existing buildings.

Using the air change values outlined a simple computer aided analysis was undertaken to establish the likely variation in annual energy demand for existing office buildings. The results are summarised in Figure C which indicates that the annual energy demand varies with a ratio of about 4 to 1. This correlates with that found in practice.

It is not possible to draw firm conclusions from the analysis but its correlation with empirical findings suggests there may be considerable energy savings through reducing excessive natural ventilation rates in existing buildings.

PERFORMANCE INDICATORS

To aid staff in the field, a simple method of assessing the energy performance of individual buildings has been developed which will enable bad performers to be quickly and easily identified. The method is based on a series of performance indicators deduced from the actual energy consumption characteristics of a random sample of existing office buildings, similar to those shown in the histogram in Figure A. It is not intended here to discuss the basis of the indicators, suffice to say that they are derived from established statistical techniques. The indicators are intended to be an approximate gauge against which to compare the energy performance of existing buildings. So far, indicators for naturally ventilated office buildings have been produced but it is intended to extend them to other types of Government buildings. The indicators for office buildings are shown in Table 2.

TABLE 2 - Performance Indicators for Existing Single Shift, Intermittently Operated, Naturally Ventilated Office Accommodation

RATING	PERFORMANCE INDICATOR
	Heating & Domestic Hot Water (GJ/m^2 (Gross Area)/annum)
GOOD	Up to 0.72
FAIR	0.72 - 0.84
POOR	0.84 - 1.16
VERY POOR	Over 1.16

The large variation in energy consumption per unit floor area for heating and domestic hot water services would seem to be inherent in the existing building stock due largely to variation in ventilation rates, though other factors do have an influence. This being so it follows that for buildings which compare poorly with performance indicators it is likely that their ventilation rates are excessive, subject to their heating systems being operated correctly. However more data and experience is required to fully validate this hypothesis but if it is verified the use of performance indicators will provide a valuable aid to the identification of buildings with excessive natural ventilation rates.

PRACTICAL CASE

To obtain an indication of the achievable savings through reducing the rate of natural ventilation in existing buildings, a field trial was recently undertaken on a London Office building.

The building chosen was located in an exposed position adjacent to the river Thames. It was erected post-war, and is constructed of 14" thick solid brick outside walls with metal windows on three sides, a flat roof, concrete ground floor, demountable internal partitions, and suspended ceilings. The metal frame casement windows give a glazing ratio on 3 faces of the building of about 50 percent, of which only half of the glazed area is openable. The building has 5 floors and a total gross floor area of 2230 square metres.

Over the years, the window frames have become twisted and no longer produce an effective seal, assuming they did in the first instance. A silicon rubber sealing mastic was applied to the frames so as to mate with the openable windows. This is a standard method of treating such windows and is widely employed. The cost of the work was about £2300 at 1980 prices and took about two months to complete. The initial reaction from the building occupants was favourable and comfort conditions were considered to be more acceptable.

Before proceeding further it is perhaps important to outline other reasons why this particular building was chosen for the trial. Firstly, as a result of previous trials for other purposes the fuel consumption and performance data for the building was well documented, secondly and perhaps more important, thermostatic radiator valves were fitted additional to the existing weather compensator control. The significance of these valves may not be obvious but without some form of internally sensed space temperature control, improvements to the envelope of a building in the form of better insulation or draught proofing, will rarely realize fuel savings without the readjustment of the controls which can be difficult and often is not carried out.

The preliminary results of the trial are summarised in Figure D which shows the performance of the heating system before and after sealing the windows. The annual fuel saving is estimated to be about 22 percent. The cost effectiveness of the measure based on the above fuel saving is as follows:-

Discount FACTOR / Life Span		5 years	10 years
4% TDR	IOP *	0.906	2.47
	PAYBACK PERIOD	2.4 Years	2.4 Years
7% TDR	IOP *	0.75	2.0
	PAYBACK PERIOD	2.7 Years	2.7 Years

*Index of Profitability

The remedial work was obviously cost effective and produced worthwhile savings. In addition a noticeable improvement in comfort was reported by the building occupants, though parts of the building are still draughty due to poor fitting window frames.

While it is possible to infer by calculation the ventilation rate prior to and after sealing the building, the inherent inaccuracies of such a calculation render the results unreliable. A simple method of measuring the ventilation rate would be a considerable aid to validating improvements.

INTERNAL TEMPERATURE CONTROLS

Most office buildings are controlled by means of a weather compensator; a device that senses external air temperature only and infers internal temperature conditions. The main disadvantages of such devices are that they do not take account of the dynamic condition that occurs within buildings due to occupancy, lighting, other beneficial gains, and variations in natural ventilation rates.

The distinct advantage that internal temperature controls offer over the more traditional weather compensated control in minimising the energy losses associated with natural ventilation is not widely recognised.

Work undertaken during theoretical verification of energy savings associated with the installation of Internal Temperature Controls over and above weather compensator control, revealed that considerable energy savings are possible when natural ventilation rates are high. Figure E shows computer predicted percentage energy saving for rectangular buildings. Buildings of other shapes also produced similar savings but they cannot be represented in a graphical form. No extensive attempt has been made to test these theoretical findings in practice, but one closely monitored trial revealed savings of about 17% for a building with a glazing ratio of about 40 percent. The average seasonal natural ventilation rate was not known, however the building is that referred to earlier which is believed to have a relatively low natural ventilation rate of about 1-1½ air changes per hour.

Perhaps the most significant conclusion to be drawn from the theoretical analysis was that if the energy requirements for buildings are to be minimised, heating controls must be of a type that respond to beneficial heat gains and the dynamic changes that occur within a building, particularly in relation to a natural ventilation.

In addition it can be concluded that for existing buildings with a high natural ventilation rate, internal temperature controls are essential where it is not practical or economical to reduce the ventilation rates to more acceptable levels, if energy consumption is to be minimised.

CONTROL STRATEGY

The interaction of the many energy related variables is perhaps one of the most undervalued areas associated with building design. Much is assumed during the design process but more often not realised in practice.

For existing buildings, the situation is worse in that generally little attention has been afforded to obtaining a better understanding about their dynamic performance. Where there has, the tendency has been to treat particular problems in isolation with little regard to other interconnected variables and influences. As a consequence, optimum solutions are not necessarily evolved.

Reference has already been made to the close association of natural ventilation rates and internal temperature controls. The computer based analysis previously mentioned also revealed that as natural ventilation rates are reduced, the necessary running hours of heating plant is also reduced. The results are shown in Figure F. In practice, heating plant is generally running for well over 2000 hours for intermittently occupied buildings whereas theorectical predictions suggest that considerably less is required. To fully realise this additional benefit however requires a more comprehensive heating system control strategy than is generally applied to most buildings.

RETROFIT IMPROVEMENTS

Little work has been done to date by PSA to reduce excessive natural ventilation rates in buildings. This is not because it has been considered unimportant but because the limited effort available has been directed towards low risk proven measures. Work which has been undertaken however, generally falls into one of two categories; improvements to metal framed casement windows through the application of silicon rubber mastics, or alternatively, minimising the gaps around large sliding doors of hangars and workshops through the fitting of nylon brush seals.

Some of the first applications of silicon rubber mastics were undertaken four to five years ago, and have generally proven reliable in use, with the painter perhaps being its worst enemy. Most silicon rubber mastics are resistant to common gloss paints and will in fact repel them but it is not unknown for the painter to remove the mastic. For most practical purposes the life of the installation can be expected to be above five to ten years, which some suppliers will guarantee.

It has been a problem to maintain an acceptable working environment in buildings with large doors such as hangars and workshops and in one particular type of hangar it was found that infiltration gaps around the doors amounted to an equivalent area of about 158m^2 (170 sq ft), enough to drive a double-decker bus through. Nylon brush seals have proved to be an effective solution. Another but not disassociated problem was that the doors were often left open. To combat this problem, proximity switches were fitted to the hangar doors so as to turn off the heating system when they were opened. These adaptations were initially carried out on twelve such hangars and the effect on fuel consumption was as follows:-

Year	Condition	Actual Consumption (litres)	Consumption Degree day Corrected to a base year 77/78
1977/78	No Modification	481494	481494
1978/79	Modification fitted *	427545	390253
1979/80	Modification fitted *	246159	243269

*The modification involved the fitting of nylon brush seals to the hangar doors and proximity switches.

The first year, despite a very hard winter, produced fuel savings of about 19 percent but for 1979/80 the saving was about 50 percent. This large saving occurred because during 1979/80 the doors were left open due to the mild weather but the proximity switches rendered the heating system off. However during the severe winter of 1978/79 the hangar doors were kept closed as much as possible in order to maintain comfort conditions. This is a simple but effective solution to many door problems, which demonstrates that it may be more acceptable to tolerate high rates of natural ventilation, at times, providing the heating is turned off.

BUILDING FAULTS

So far reference has been made to the particular problems associated with casement windows and large hangar doors, but there are other problem areas that lead to excessive ventilation rates. These generally fall into three categories:

(i) those resulting from poor design
(ii) those due to the poor fit of building components
(iii) those attributable to poor construction

Solutions to these particular problem areas are largely unexplored but if the wide disparity in energy consumption per unit floor area is to be reduced and energy savings achieved, a full range of remedial options must be developed, supported by sound evidence of their cost effectiveness.

BUILDING DESIGN

New buildings are generally designed with ventilation rates as recommended by the CIBS Guide, however it is not uncommon practice for higher rates to be assumed particularly when the recommendation is for relatively low rates. This practice has evolved as a direct result of higher than expected ventilation rates occurring in practice, which has led to underheating.

Closer attention is being given to assessing the natural ventilation rates of design options. One approach being adopted is based on obtaining a fair knowledge of the microclimate of the particular site together with a detailed knowledge of the window that has been selected for the proposed building. This data is subsequently processed by methods recommended by the BRE and the CIBS to derive a ventilation rate. This approach is thought to be a shade more exact than that of taking figures direct from the CIBS Guide, though as yet there are no measured results to confirm this.

The benefits of closer attention to natural ventilation rates in the design process will not necessarily be realised unless the fit of building components and construction standards are improved. These faults alone are responsible for excessive ventilation rates in many existing buildings.

CONCLUSIONS

1. Theoretical predictions suggest that excessive ventilation rates are a major contributory cause to the large disparity in consumption per unit floor area found in existing buildings.

2. Initial results of trials suggest that significant energy savings are achievable through reducing natural ventilation rates to more acceptable levels but further validation is required before extensive upgrading of existing buildings can be undertaken.

3. A simple method of measuring natural ventilation rates and assessing average yearly values would enable potential savings to be quantified so that investment decisions can be soundly based.

4. A greater understanding of natural ventilation within buildings needs to be developed, together with its interaction with other energy related variables, if the energy demands of buildings are to be minimised.

5. A full range of cost effective options for reducing excessive natural ventilation in existing buildings needs to be developed.

6. A sound heating system control strategy needs to be developed to take full account of the dynamic changes that occur within buildings.

7. A proven method of validating the natural ventilation rates of building design proposals must be developed to aid designers.

8. Building components fits and construction standards must be improved if the benefits of better designs are to be realised.

ACKNOWLEDGMENT

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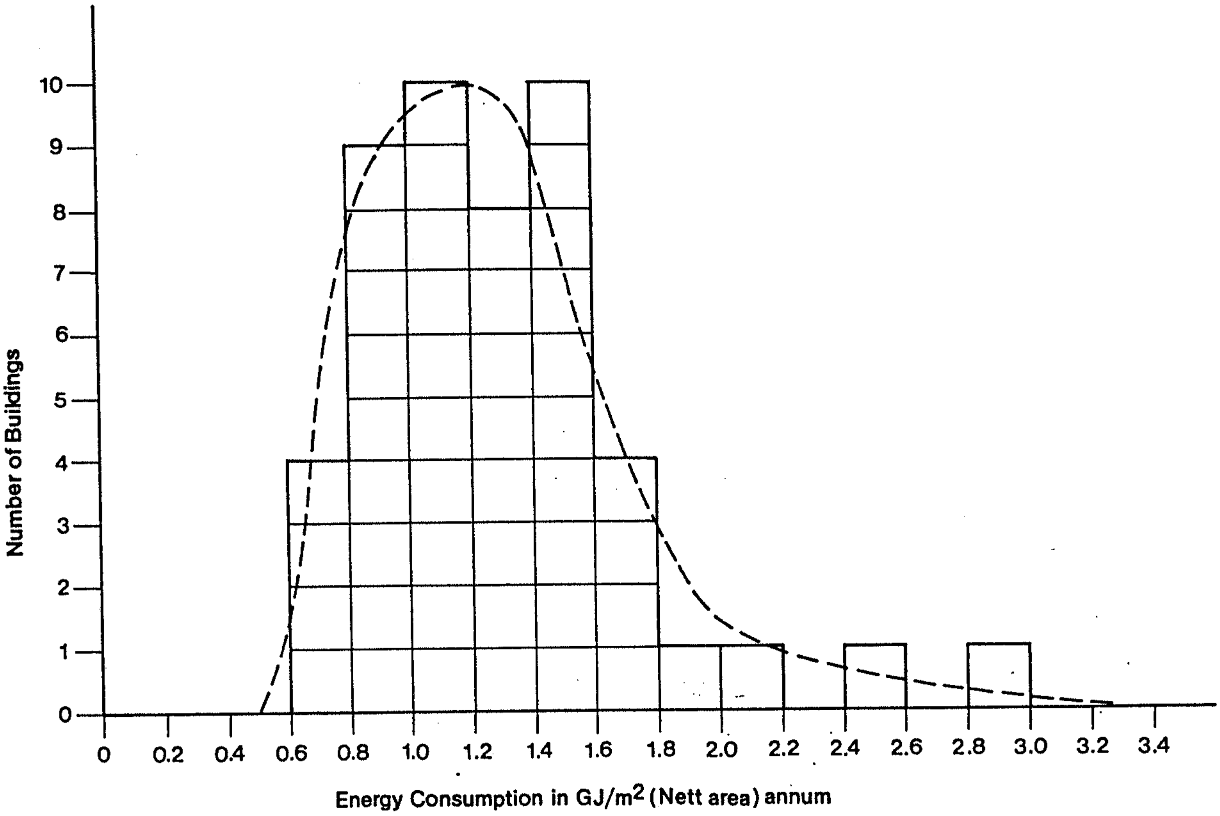

Figure A Histogram of Heating and Domestic Hot Water Consumption 1975/76

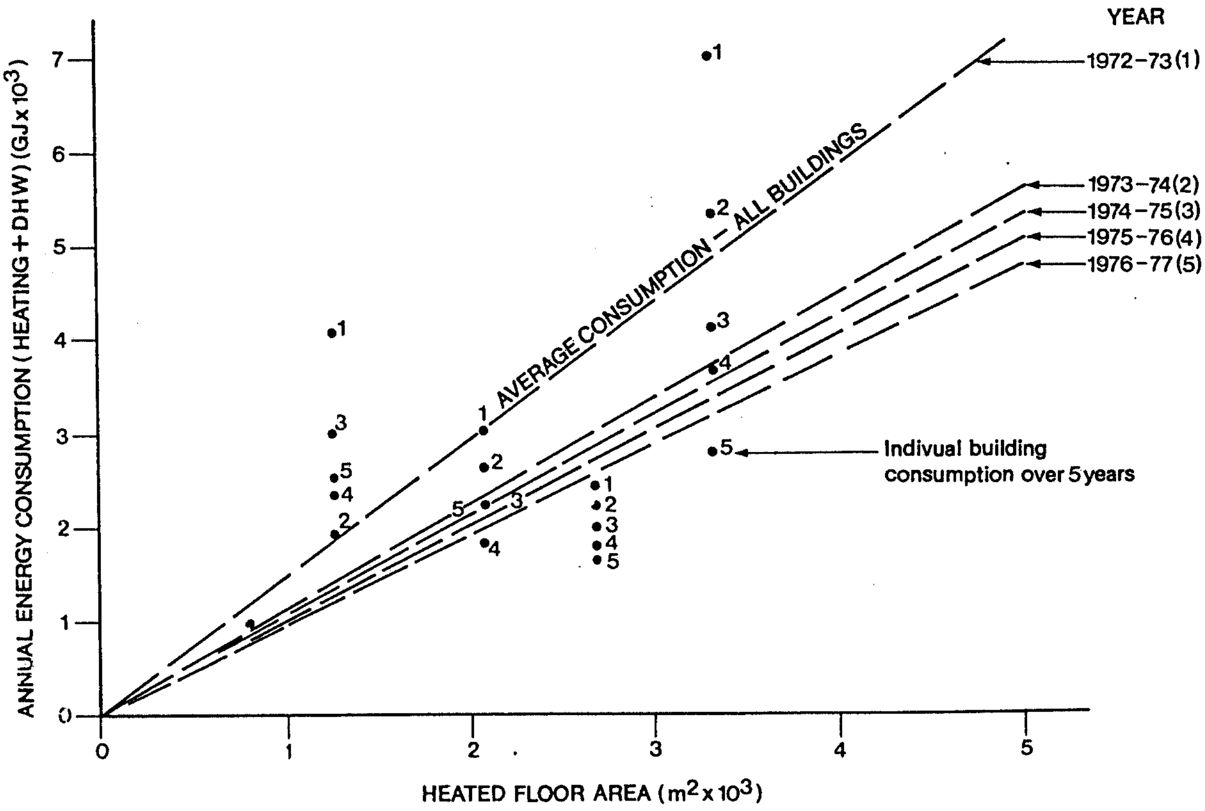

Figure B Assessment of Fuel consumed in 50 buildings

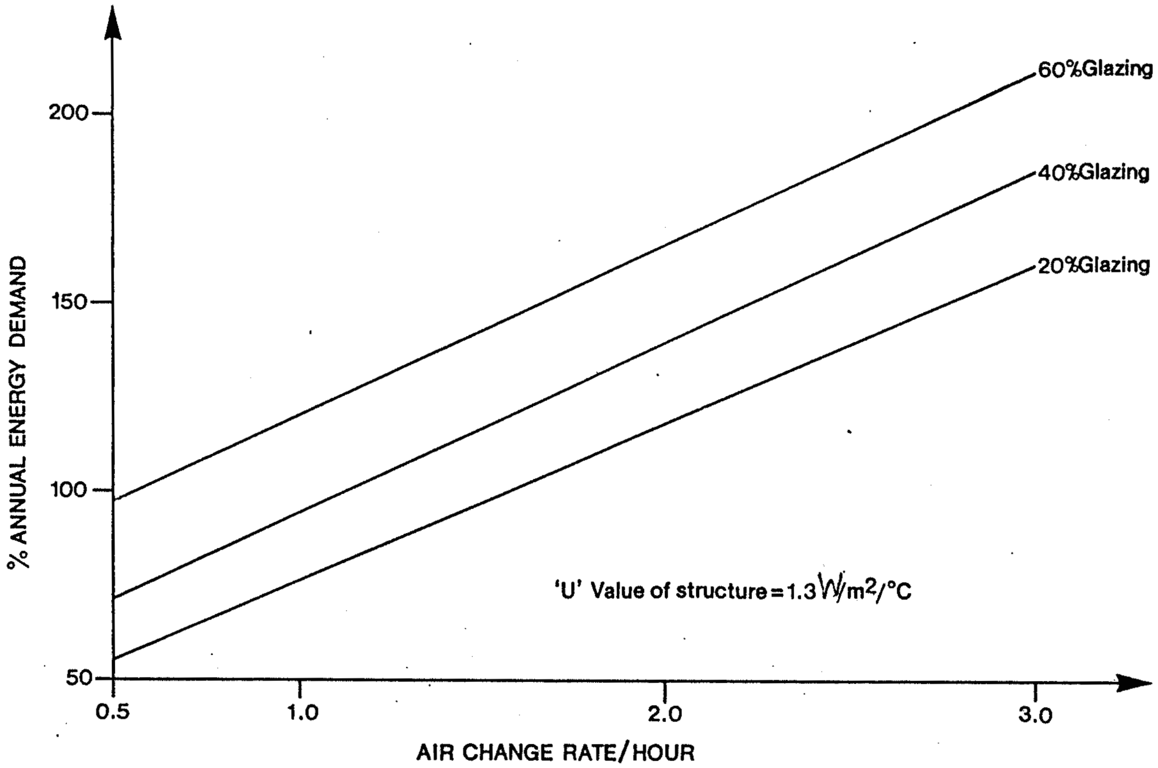

Figure C Annaul Energy Demand in relation to Glazing and Air Change Rates

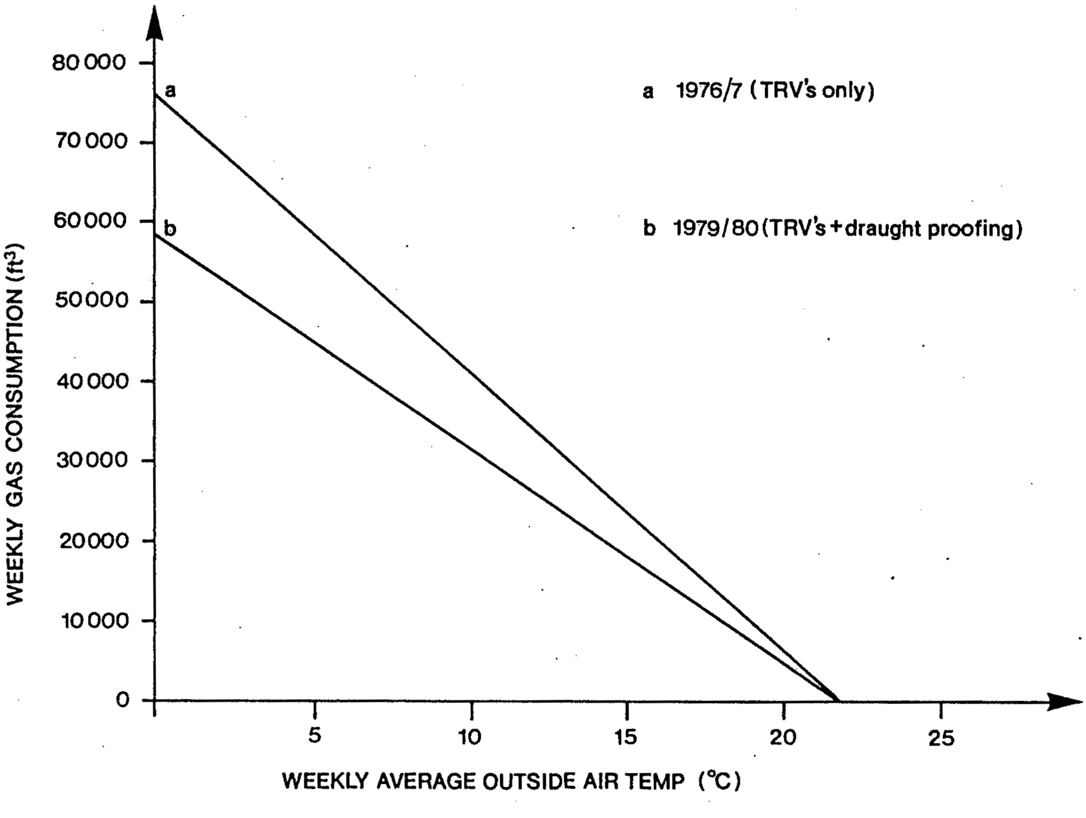

Figure D Heating System Performance

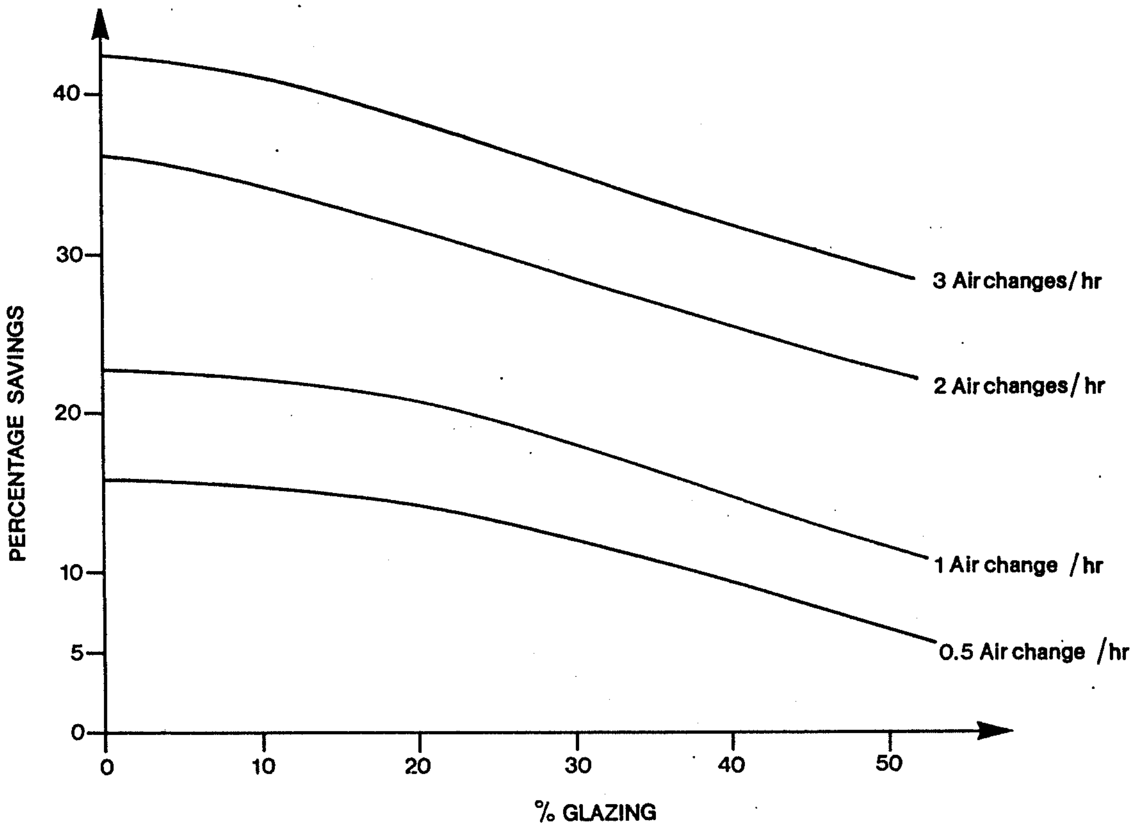

Figure E Potential Energy Savings due to internal Temperature Controls

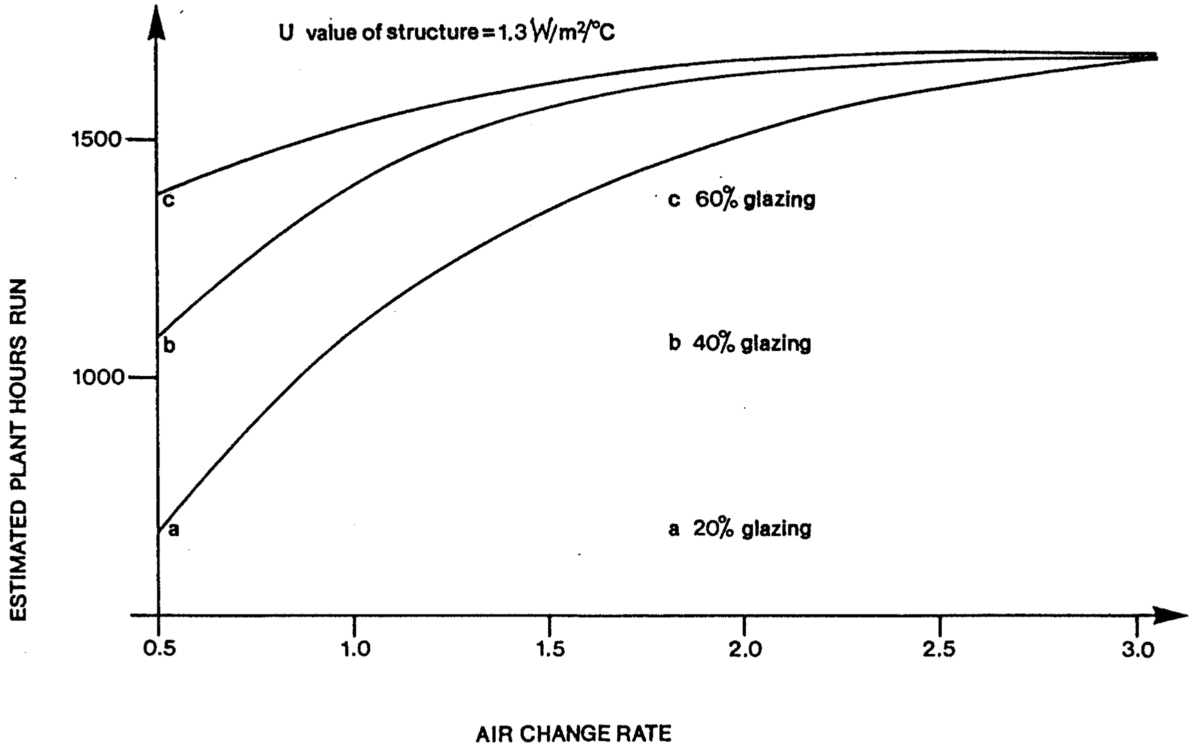

Figure F Estimated Plant running hours