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# Energy efficiency in industrial buildings

Industrial and storage buildings have been in the news recently because of high fuel bills, neglected maintenance and a spate of roofing failures. *Dr Stephen Wozniak* of BRE, formulating a research project in BRECSU, raises some of the issues and asks for feedback from building owners and users.

Industry as a whole consumes about 2600 PJ of primary energy annually. Of this, industrial buildings account for around 600 PJ for space and water heating and lighting, with space heating being by far the largest component.

The industrial buildings sector comprises about 230 million $m^2$ of industrial floorspace and 130 million $m^2$ of covered warehousing. The replacement cost would be some £90 000 million assuming an average new-build figure of £250/$m^2$.

The annual fuel cost of about £1500 million may not seem large by comparison, but many energy efficiency issues are strongly linked with concerns about the present general condition of building fabric: in comparison with the factories of Germany and Japan, our industrial buildings have been described as suffering from conspicuous neglect.

Lack of maintenance and little concern for energy efficiency have combined to give a backlog of fabric repairs, and energy bills that can be an uncomfortable fraction of net profits.

Curiously, this may now present a significant opportunity for energy efficiency because many measures may be undertaken most cost effectively as part of refurbishment or rehabilitation. New-build offers other opportunities for energy saving.

1·7 million $m^2$ of industrial floorspace and 3 million $m^2$ of covered warehousing is constructed each year in the UK, an annual renewal rate of about 1·3% overall or about 17% by the year 2000.

From information gathered to date there seem to be many promising areas:

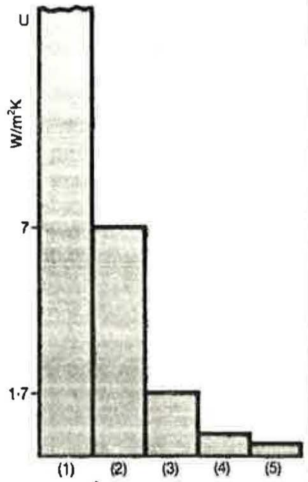
☐ better control of heating and lighting systems;
☐ roof insulation;
☐ control of ventilation heat losses;
☐ more appropriate design of heating and lighting systems;
☐ appreciation of the importance of energy efficiency among both management and the workforce.

Control of building services is often poor and no doubt there is much scope both for improved use of low-cost conventional heating controls, as well as optimisers and modern lighting controls. In larger buildings especially, or on a site having many small buildings, some type of energy management system may be worthwhile and guidance from ETSU projects is available.

## Roof insulation

Building services engineers need to be aware of developments in factory roof insulation since more than half the total heat loss of an industrial building can be through a badly insulated roof and, in extreme cases, as much as 70-80%. Any refurbishment or upgrading of insulation can therefore have profound consequences on the operation of a space heating system.

The current insulation standard (U = 0·7 for roofs and walls) was introduced in the 1978 Regulations. These required for the first time the use of insulation material within roofs and walls, as opposed to merely a double skin construction. Restrictions were also placed on the areas of rooflights and windows. Figure 1 shows improvements over the years, culminating in the 0·35 U-value achieved in the Welsh Low Energy Factories project[1].




*Above:* Figure 1.

Much of our present stock of industrial buildings was constructed before there was any substantial control over roof insulation. Around 30-40 million $m^2$ of industrial and covered warehouse floorspace has been constructed under the 1978 Regulations, approximately 10% of the 1984 total stock or around 360 million $m^2$. However, it is unknown how much single skin and double skin roofing, or what area of single glazed roof or northlights remains in use, all of which constitute a liability at least in heating energy terms. This information is sought by BRECSU as part of efforts to categorise the UK building stock by age, sector, subsector, ownership etc, so as to help identify the priorities for research and opportunities for demonstrations.

Substantial provision for daylighting has been a part of factory design for many years. Nowadays, high efficiency light sources with good colour rendering are available and there is more opportunity for a trade-off between natural and artificial lighting and roof heat losses. As an example, even if only 5% of double glazed rooflight is designed into a roof of 0·35 U-value, one third of the total roof heat loss is through the glazing.

There are indications that all is not well with the design and construction of many modern profiled metal factory roofs. The main problem is water ingress which can degrade insulation perfomance as well as inducing corrosion in both structural steelwork and sheeting.

Obviously, if water is found within a roof that was dry when constructed it can have come from only three sources:

☐ leaks of rainwater or snow through fixings, or driven through laps;
☐ condensation of water vapour generated within the building and transmitted through the inner skin;
☐ condensation of water vapour from outdoor air used to ventilate the roof cavity, and without vapour transfer from the building interior.

The first route is the easiest to understand and some authorities consider that many if not all problems are the result of poor detailing and site practices that leave the outer skin less weatherproof than its designer had intended.

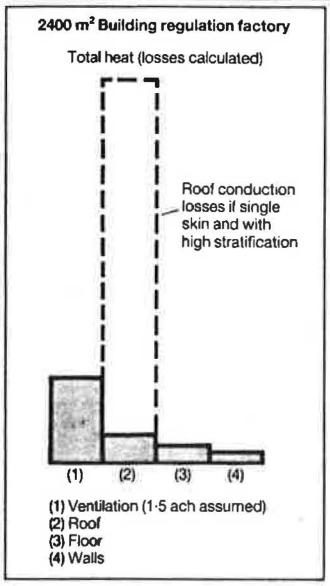
The second route represents traditional interstitial condensation and much BRE advice is available. This will be of more than passing interest to building services engineers because penetration of roof vapour barriers may often be done at their behest to fix heating equipment, pipework etc.

The third route is of current research interest. If it is confirmed that this mechanism is even partly responsible for some of the expensive profiled sheeting failures noted in recent years, then there may be implications for many more building owners[2]. Problems and energy efficient solutions are to be studied by BRECSU, following earlier BRS work[3]. Although very low pitch roofs were not studied, the findings imply that severe condensation problems are unlikely without moisture transfer from the building interior.

## Ventilation heat loss

Ventilation heat loss from naturally ventilated factories cannot yet be calculated accurately. Generally, ventilation may be between 0·5 and 2 ac/h, with much higher figures being possible if doors and windows are left open on several sides of the building.

Figure 2 shows the contributions to total heat loss for a 2400 $m^2$ factory constructed to the current Building Regulations. Building energy consumption may be predicted, but good agreement between calculated and measured fuel use may be merely the consequence of good judgement (all terms in the calculation being correct) or luck (errors being both positive and negative but cancelling out). If the




*Above:* Figure 2.

fuel consumption over past years is available then there is a temptation to adjust variables so as to align prediction and measurement. Of course, the wrong adjustments may be made and claims of high accuracy must be viewed with scepticism unless supported by measurements of at least the major parameters such as infiltration and ventilation.

For example, despite the claims made for energy savings from use of fast acting "rapid-roll" doors, a study undertaken for BRECSU by BSRIA has revealed uncertainty about the level of savings which can be confidently predicted. Further offers are welcome.

However, doorways can certainly be a major source of ventilation heat loss and discomfort, and results from the Welsh factories demonstration project show that much of the reduction in infiltration achieved in a low energy unit was due simply to the use of a loading bay door designed for low air leakage when shut. This was, in fact, the largest single factor in reducing the delivered energy use from a typical figure for a modern factory unit of 0·6 $GJ/m^2$/year to 0·4 $GJ/m^2$/year.

## Heating systems

The overall achieved efficiency of a space heating system is the product of the fuel conversion efficiency (appliance efficiency) and the efficiency with which heat is utilised within the building interior to provide comfort conditions within the occupied spaces. Since these spaces can be a small part of the total volume (figure 3) effort concentrated merely upon improving appliance efficiency by a few percentage points may not be significant.

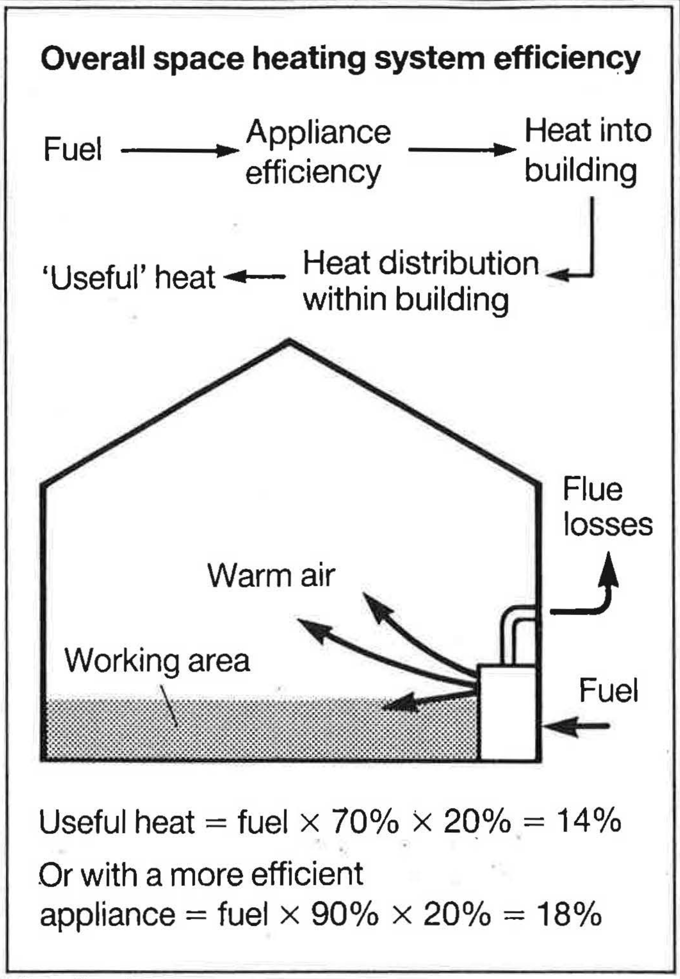
This product of two efficiencies is a concept relevant in principle to all building types, but is most important in large open plan areas where heat losses may be high, radiation temperatures low, (owing to very poor insulation standards) and occupants far removed from the source of heat.

Flued gas warm air unit heaters may be 70% efficient in converting input energy into warm air, and the best modern designs may achieve 80% or greater. This may be little consolation to building occupants if some are situated in areas below the output steam and others on a mezzanine floor where temperatures reach intolerably high levels. Destratification and greater air mixing within buildings has been known to effect a cure, but the points at issue are that the basic heating equipment as installed may not be suited to the task of providing reasonable comfort conditions for all the workforce and that quoted efficiency figures may not tell the whole story.

In low energy factories, where steady state losses are much lower than usual, a warm air system could operate with a much reduced output temperature (and perhaps with some reduction in fan speed) following the pre-heat period, and thereby achieve acceptable conditions without the need for destratification or other supplementary air mixing.

Direct gas-fired tubular radiant heaters have achieved a reputation in the UK for much lower fuel costs and more satisfactory comfort levels (however defined) than the old warm air heaters they often replace. There is some confusion at present over the efficiency of these systems, but claims of 65% or more of gas input energy being converted to downward directed infra-red may be optimistic given the tube temperatures involved.

A benefit of all types of radiant heaters is that, in a high building at least, a noticeable (if not easily measured) fraction of input energy does reach the workforce at near floor level. However, the air temperatures at roof level in buildings served by radiant heaters may be 30°C or greater, a consequence of high convective losses.




*Above:* Figure 3.

This will significantly increase the roof heat loss, but in well insulated buildings having low air leakage at high level the internal roof surface may rise in temperature sufficiently to give a useful degree of ceiling heating, and roof losses in absolute terms may still be acceptably low. They may nevertheless be greater than with various types of much maligned air heaters that induce a broadly uniform temperature gradient from floor to apex.

The energy saving potential of destratification systems will be reduced in well insulated buildings and needs to be taken into account in system selection. In fact, destratification is a good example of a technology that has been proven in service, but further application may be hampered by lack of confidence resulting from case histories in which the designer didn't quite get it right: successful systems destratify effectively and without excessive noise, draughts or energy consumption.

A general problem that manufacturers and specifiers of all types of industrial building heating equipment need to address is the high turn down ratio that will be needed in equipment used in low-energy buildings where the steady-state losses will be small.

In conclusion, what is lacking is a sufficient quantity of measured performance data and validated methods of prediction that could be combined into authoritative design guidance. This is especially relevant for promising new technologies where demonstrations or case studies could enhance the confidence of specifiers and building owners.

Dr Stephen Wozniak is head of the Energy Efficiency in Industrial Buildings Section of BRECSU. He would be pleased to know of schemes that might be suitable for inclusion in the r&d programme. He invites readers' comments on this article (in confidence if appropriate) in the light of their own experiences.

**References**

[1] Energy Efficiency Office, Energy Efficiency Demonstration Scheme, Project Profile 173: Low energy factory development.

[2] Falconer P Metal industrial roofs: moisture problems: *Architects' Journal*, 7 May 1986 p53-55.

[3] Pratt A W. Condensation in sheeted roofs. *NBS Research paper 23, HMSO, 1958.*