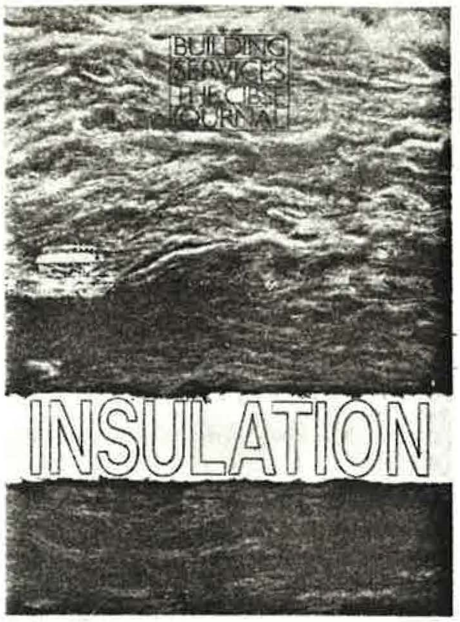
#2672 Cibse Jnl May 87

AIVC

ALUC 2245

2672



The challenge of super insulation

The impact of increasing levels of insulation spreads in many directions. Foremost among these is upon the heating installation. Two recent conferences have explored in depth the challenge to the building services engineer of high levels of fabric insulation. *Stephen Ashley* reports.

The amount of energy wasted by our buildings is not only a national scandal but a ridiculous waste of money according to David Hunt, the Parliamentary Under Secretary of State for Energy.

In opening this year's CICC Nottingham conference on the impact of high levels of insulation on building services, he said that he could understand a lack of foresight on behalf of the developers of buildings but he looked to the professional designers for a longer view in the provision of low energy use and in clawing back some of the £3·5bn of energy which is wasted in buildings each year in the UK.

The themes of building to higher levels of insulation have been spelt out by Roger Courtney, the deputy director of the Building Research Establishment. These are:

☐ The implications of high level of insulation for other aspects of building performance.

☐ The problems that may occur in the construction process.

☐ How the occupants will react and what heating and ventilating systems and controls will be needed to provide an acceptable internal environment at minimal cost.

He defined high insulation as something less than 0·35 W/m^2°C. This may not seem particularly high to Scandinavians and Canadians but it does represent a considerable change from current or even proposed standards of performance in the UK and brings with it considerable changes in the practice of design and of construction.

Courtney suggests that the main changes in design practice following on from high levels of insulation relates to the likelihood of rain penetration, the durability of the wall, the strength of the structure, the possibility of cold bridging, the provision of ventilation, the degradation of timber, and the performance in fire.

Whereas at current regulations one need only take account of exposure levels expressed in *DD93*, this will not be sufficient for high levels of insulation when the area, the site and the location of the individual house will all be of relevance.

If 100 mm of insulation is incorporated then the outer leaf will be colder than a similar uninsulated wall by 1·5°C. Although this may not produce a deleterious effect, the designer may well consider it worthwhile specifying a more durable brick. The insulation materials themselves and the steel straps etc will also be subject to more severe conditions.

The use of super lightweight blocks produces problems of bearings for lintels. Because of the higher insulation value larger temperature differences can occur across the block possibly leading in turn to damage caused by thermal movement.

Cold bridges become much more important. An example of an unforseen problem occurs when a brick cavity brick wall displays temperatures at 10°C on the inside corner of the room when the outside temperature is at 0°C and the general internal temperature is at 20°C. Treatment of the junctions of external and internal walls by designers also become more tricky.

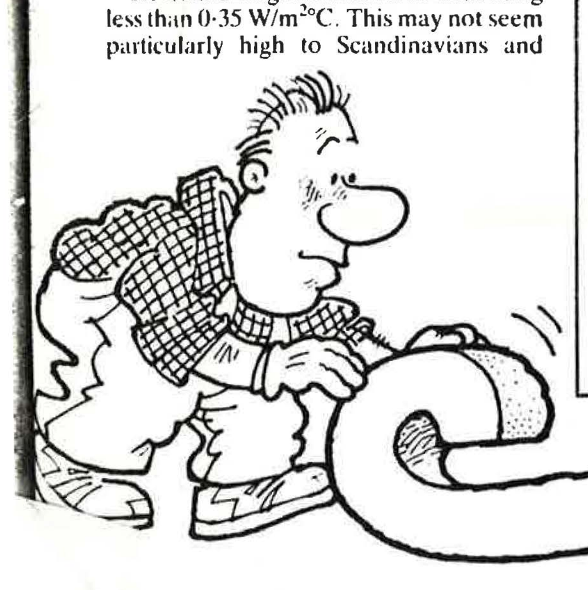
One of the problems of ventilation is that it is very difficult to predict what incidental air infiltration will be achieved in addition to that planned. This is particularly so on masonry construction when there is not the advantage of a polythene sheet stretching over the timber frame, unless of course the electrician has slit this in order to be able to feed his cables through!

The integrity of vapour checks is of course very important for the preservation of timber frames and the fire brigade has shown quite clearly that highly insulated houses do increase the severity of a fire; at least until the windows break and ventilate the fire.

Annual space heating consumption for typical semi-detached house

	1970		*1980*		*High insulation*	
	GJ	*%*	*GJ*	*%*	*GJ*	*%*
Fabric	46·9	75	35·5	71	17·4	60
Ventilation	15·6	25	14·5	29	11·6	40
Total	62·5	100	50	100	29	100

Notes:
1. 1970: U = 1·5 W/m^2°C for walls, 0·8 for roof, 0·6 for floor
2. 1980: U = 1·0 W/m^2°C for walls, U = 0·6 for roof and floor
3. High insulation: U = 0·3 W/m^2°C for walls, roof, and floor
4. Ventilation rate assumed to be 1·2 ach in all cases; the annual energy consumption consequent on ventilation losses falls as the heating season is reduced through increased insulation.



Buildability

The buildability of partially filled cavity walls came in for considerable criticism during discussion periods at Nottingham.

Some local authorities reported that they had given up partially filling cavities for the simple reason that it was proving so difficult to get a job that did not lead to problems. Blame was placed on fixings, damaged batts, mortar bridging and lack of supervision. Some councils were going for wider blocks and some were going to complete cavity fill. Courtney himself advised delegates to take a pessimistic view of site skills and to accentuate their importance in specifications.

It was clearly demonstrated that in highly insulated buildings occupants may simply not need the advanced programming that a conventional system provides. The cheaper, manually switched individual room heater may be just as effective. On the other hand there may well be a move, in buildings where central systems are obtained, to use air heating to a larger extent as it offers a rapid response and, with low heat loss rates, it would be compatible with mechanical ventilation. Being a low temperature heat distribution system it is also suited to high efficiency heat generators such as heat pumps and condensing appliances.

Many of these considerations are applicable whether the building is domestic or non-domestic but the impact on services design is likely to be particularly significant in non-domestic buildings. There are potentially large implications for the commissioning of heating systems.

High insulation offers the opportunity to centralise heating systems. It increases the risk of overheating in summer and it may well stimulate the development of "smart skins" where building envelope changes its thermal properties in accordance with the internal demand and the external environment.

Even here discussions constantly came back to the question of buildability and the need for quality control. Courtney found it significant that the major Canadian programme on highly insulated dwellings began as an energy initiative but rapidly developed a major quality theme. Responses from the floor also showed a number of occasions when energy conservation had been the trigger but with final decisions being made more on an improvement of the environment question.

Pilkington has done a lot of work on establishing the cost effectiveness, or otherwise, of higher levels of insulation and has shown quite clearly that savings in the capital costs of heating installations can outweigh the extra costs of the higher levels of insulation.

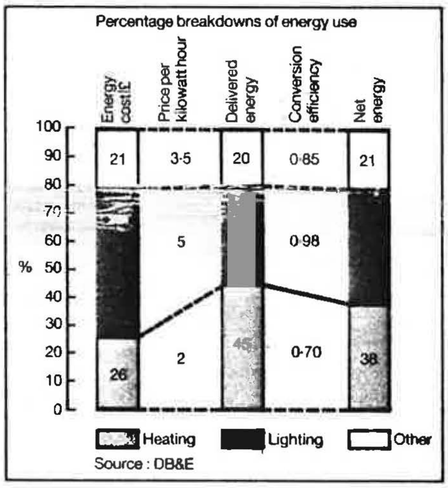
Ken Jackson of Pilkington argues that the cost benefits of high levels of insulation are so great that we should not be talking only of new buildings. Repercussions of upgrading the existing housing stock to even current levels of insulation would be measured in billions of pounds. He argues that this is not as pie-in-the-sky as it would seem as the UK does have experience in huge schemes of this nature affecting every home, such as the *Smoke Control Acts* of the 1950s and the switch to natural gas.

Cost targets

For office buildings there is a dearth of available data but some pointers are available.

Davis Bellfield and Everest have experience going back over a number of years in the collection of figures relating to the costs of providing extra levels of insulation and other energy conservation measures in building. They have managed to produce some rules of thumb.

They say that the recent report by the Audit Commission indicates that an appropriate annual performance target



for office buildings is between 200 and 400 kWh/m^2. These figures can be substantially beaten as evidenced by, for example, Gateway 2 at Basingstoke which has a reported delivered energy consumption of some 172 kWh/m^2/year, or the Building Research Establishment's low energy office at 143 kWh/m^2/year. Or, if one wanted to see just how low it is possible to go, and hang the expense, then one can get down to 46 kWh/m^2 as did the Ohbayashi-gumi building in Japan.

Typically, space heating and/or cooling can account for some 40-45% of delivered energy consumption in a commercial office building with lighting accounting for some 30-35% and the balance (20-30%) used for water heating, office equipment etc.

A similar breakdown on the basis of energy *cost* has to make an allowance for the disparity between the cost of fuel for space heating (typically gas) and fuel for lighting (electricity) and indicates that lighting can be the dominant cost energy item. Davis Bellfield and Everest indicate, through their studies, that as much as 65% of the annual artificial lighting energy consumption can be saved by the use of automatic lighting control strategies.

Annual energy costs for offices have been shown by the scope report to be between £5.5 and £34.9/m^2 but 75% of offices reported annual energy costs in the range of £5.5 to £16.2/m^2.

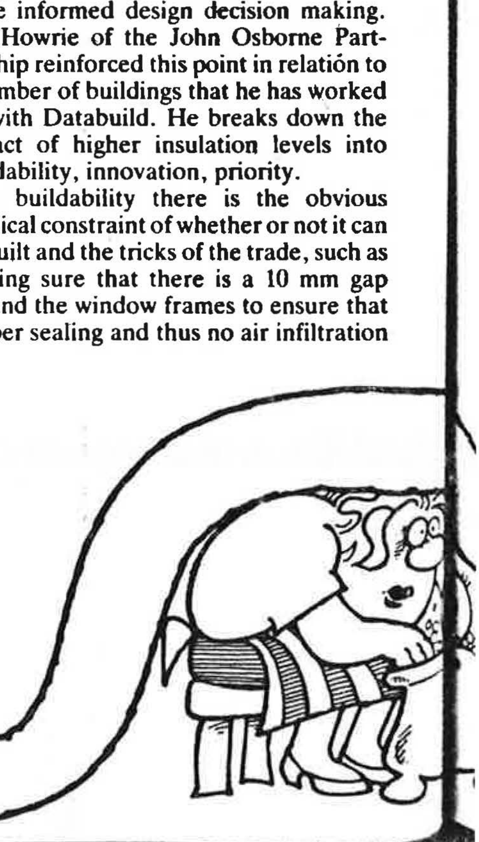
Geoff Brundrett of the Electricity Council demonstrated that the amount spent by households on energy is typically, just half of that spent on tobacco and alcohol.

Robert Smith of Davis Bellfield and Everest attempted to achieve some rules of thumb for how much could be spent on achieving energy conservation in office buildings. Take for example an office building of 1500 m^2 with an energy consumption of 100 kWh/m^2/year and a demand for 50% savings; with construction costs at £500 m^2, and given the most lenient case of full rate electricity plus a pay back period of 15 years, one could allow 8·25% of construction costs on achieving the 50% energy saving. On the other hand if one took the most stringent case of a building running on gas with a pay back period of five years then only 1% of construction was available.

Smith was quick to point out however that one can make considerable energy savings without spending any money at all; by getting the orientation right, by minimising the external building envelope and by organising the internal layout. The quantifying of the costs of higher energy efficiency are thus not easy to achieve.

Robert Smith made the point that it is important to realise that cost effectiveness assessments cannot necessarily cope with all aspects of design but can contribute to a more informed design decision making. Jim Howrie of the John Osborne Partnership reinforced this point in relation to a number of buildings that he has worked on with Databuild. He breaks down the impact of higher insulation levels into buildability, innovation, priority.

In buildability there is the obvious physical constraint of whether or not it can be built and the tricks of the trade, such as making sure that there is a 10 mm gap around the window frames to ensure that proper sealing and thus no air infiltration



takes place. On buildability, there is also however, the financial argument and the costs of extra administration and hassle in dealing with something that perhaps both client and builder are used to.

Innovation may be the very staff of life for architecture but just as we are in an era of defensive medicine we are now also in an era of defensive building design. Risk, cost of time and frustration, client attitudes, the fact that architects are really only interested in aesthetics and the lack of knowledge, all leads to pressure not to use high levels of insulation.

Then there is the degree of priority. What about the demands on available monies of other environmental factors, of the aesthetic and spatial parameters, of the difficulty of proving the cost benefit that you know is there? So often, in real life, the social and administrative problems outweigh the energy conservation benefits.

Money or comfort?

House occupiers are not saving energy, they are taking higher levels of comfort.

Geoff Brundrett interprets this as meaning that householders view the energy question on what can be afforded. If they ca afford to heat their house to 23°C they will, but if they cannot then they will accept 15°C. In offices, on the other hand, if 23°C is what the workforce wants then that is what the workforce gets. Affordability thus becomes a lower priority than energy saving.

One interpretation of this philosophy is that Government should concentrate considerably more on reducing energy costs of commercial building rather than domestic.

Geoff Brundrett has reviewed much of the research work in providing high levels of insulation in houses and has gone on to assess customer satisfaction. Perhaps surprisingly, the customer satisfaction with low energy houses is very high. Brundrett's conclusions are that the priority is to heat the living room to a comfortable temperature and to make sure that landings are not warmer than bedrooms, that controls should be very simple, that manuals should be provided and that mechanical ventilation is used properly (ie windows are kept shut in winter).

He reports that low energy house users enjoy seeing the salt run freely without having to thump the bottom of the container and that there is an element of one-upmanship in that their windows remain free of condensation while their neighbours' are all steamed up! Also the lack of smells, the predictability of energy costs and the stability of the indoor environment use are all appreciated by the users.

A brief look was given at the conference to the Danish approach to low energy housing. Here U-values of 0·3 have been common for some time. The essential difference between Denmark and the UK appears to be that, in both private and public housing, the achievement of lower energy use is deemed a higher priority than the cost of the building. In the UK it is still perceived essential to provide buildings at the minimum possible cost.

It appears that in Denmark the drive behind the dominance of the regulations, instead of the financier, stems from the public desire for lower energy use which, in turn, probably stems from the country's need to import most of its energy combined with a decision not to go nuclear.

It is also clear that Denmark's builders have become quite used to the special techniques associated with high levels of insulation and the need for quality control. It was suggested that Denmark had the problems that we are now experiencing 10 to 15 years ago.

High levels of insulation however can cause their own problems, particularly if the ventilation is not adequate. Denmark has suffered complete building shutdowns because of this and Dr Strong of W S Atkins and Partners underlined the danger by relating his experience of what happens when things go wrong; the sick building syndrome.

He summed up the dangers as inadequate ventilation, rapid temperature fluctuations caused by solar gains or inadequacies of the control system, humidity, particularly very low humidity levels in winter, noise, static and negative/positive ion imbalances, air movement and draughts, overheating in summer and unnecessarily high energy consumption.

Somehow the line has to be drawn between wasting energy through excessive ventilation and not getting enough, leading to stuffy conditions etc. His advice is to concentrate on achieving an adequate building seal so that the design calculations for ventilation at least have a chance of being fulfilled. It is also important to vary the proportion of fresh air according to the outside temperature. Dr Strong is a very fervent supporter of thermal modelling through the use of computers as this allows one to make informed decisions between low thermal mass/fast response and high thermal mass/slow response for example.

One of Dr Strong's case studies concerned a highly insulated building where there was a high internal heat gain from machinery. Too late the client was asked whether he was happy to accept air conditioning and when he said "no", the only real alternative was to reduce the high levels of insulation.

Decentralised services

Once one has installed high levels of insulation a convincing case can be put forward for decentralising the building services.

Jim Leary of the Electricity Council has put together exhaustive calculations showing that this can reduce capital costs even in commercial buildings and that it has a number of spin-off benefits for users such as greater flexibility, easier maintenance, greater standby and much greater control leading to lower energy use.

Leary's conclusion is that capital cost is the dominating factor when it comes to evaluating the total cost in use. In addition, the modular layout of the heating or air conditioning system has the greatest influence on the capital cost. However, for the same modular layout the decentralised systems are more cost effective than the centralised systems.

He gives the essential features of a decentralised system as: local electric heating with individual room control; for air conditioning, localised single room fan units to distribute the conditioned air and individual room control to sequence cooling and electric heating without incurring mixing losses; local electric domestic hot water heating. He puts the minimum total cost in use as when a fully decentralised system is put at 4 or 5 m modules in a highly insulated building.

This all begins to sound like an organised, quality conscious approach to energy conservation in design. Such methods were consciously adopted in the design of the Bournemouth district general hospital which is now nearing completion. Energy checklists and decision points were built into the procedures right from the very beginning leading to close co-operation between architects and engineers and to a pleasing harmony between architectural and energy requirements.

Interestingly, the team believes that, of the 27% energy savings identified during the process, 22% came about within the first three months of the conceptual thinking. Much of this saving came from intelligent orientation and façade treatment plus separating high energy using needs from low.

Authorities such as Manchester and Milton Keynes have realigned whole housing design policies to high insulation levels as a result of their experience.

Manchester in particular has moved on from "merely" insulating houses to higher levels and to getting energy conscious detailing, to reducing heating appliances in houses to the bare minimum. One demonstration project currently underway uses just two small individual gas room heaters to provide space and water heating for the whole house.

The message from the Nottingham conference could well be stated as a concern that, although high levels of insulation provide no difficulty in theory, in practice they provide a considerable challenge on quality control and require a more intelligent and detailed consideration of the remaining building services installations. When it goes right the results can be spectacular. When it goes wrong the results can also be spectacular.

Superinsulation

The Superinsulation conference held by the UK section of the International Solar Energy Society was far more direct in its allegiance to low U-values.

To even begin to be regarded as highly insulated 0·25 W/m^2°C had to be achieved while delegates and speakers happily talked of the one hundred and fifty thousand plus houses in the northern hemisphere which achieve a specific heat loss below 80 W/K for a 100 m^2 detached house — less than the hot water costs.

The UK stands out particularly for its lax, in comparison, building regulations on energy and even the new proposed U-values of 0·45 were regarded by speakers as rather a joke. Speaker after speaker referred to the need to go abroad in order to purchase components that were of sufficient quality for use in low energy housing and many saw no short term solution to the problem of low standards in UK building work.

Some speakers saw the whole area of low energy building remaining the province of the one-off building and of the small builder who sells on quality rather than on high powered marketing.

About one quarter of the conference was spent reviewing international experience to date. The inevitable conclusion was that superinsulation is not a free market phenomenon. The development of techniques, the forcing of the market and of general patronage through legislation, pr etc has to be backed by government, state of local authority effort. Seen in the wider context, the UK is not alone in being patchy over such support. Only in Scandinavia are superinsulated houses universal in application while, even in parts of the USA and Canada where average winter conditions are worse than the inside of our domestic freezers, superinsulated housing is still not approaching market dominance.

However, international effort seems to have moved on from the establishment of superinsulating techniques to the problems of refurbishment of buildings to superinsulated standards and to the improvement of mechanical ventilation/heat recovery techniques.

One long running myth destroyed by the conference was that of superinsulation being a phenomenon of cold, dry climates only. Very many superinsulated houses have been built in maritime climates and in areas with similar degree-days to the UK.

Two crucial areas of technology permeate the superinsulation market: condensation and ventilation. Both were given time at the conference.

The Timber Research and Development Association has carried out a wide ranging series of investigations into the effects on timber members of various thicknesses of insulation and varying placement of the vapour control. The one surprising conclusion is that one has to be particularly nasty to the vapour barrier before deleterious effects are seen, even in severe conditions. Part of the reason for this is that timber and glass fibre/Rockwool materials can absorb moisture over a short period without damage. It is only when warm moist conditions are held over an extended period, or exacerbated by the use of, say, non-absorbent polystyrene insulant that troubles seem to arise.

A selection of wall panels, based on a nominal thickness of 100 mm, were constructed for tests in a hygrothermal rig. Quite severe conditions were built into the rig as follows: the warm side was kept to 25°C and 65% rh giving a vapour pressure of 2082 Pa. The cold side was kept at 5°C and 19% rh, giving a vapour pressure of 785 Pa. Resultant temperature differential was 20°C and vapour pressure difference was 1297 Pa. Such conditions are likely to persist only for short lengths of time in practice and therefore extended exposure to such conditions constituted a severe test.

Test panels 2·4 m high and 1·2 m wide, most with an electrical socket box 900 mm up, were fabricated and installed in the rig in pairs, some with faults, such as panel high rips in the vapour barrier, built in.

In simple panels using rigid polystyrene boards between deep studs as the insulation and with a polyethylene vapour barrier immediately beneath the plaster board, unexpected and severe condensation occurred on the sheathing weather the boards were carefully fitted or not. The performance of such panels was unpredictable and use of rigid plastics insulent between studs is thus not recommended by TRADA.

Simple panels with mineral fibre insulation between deep studs but with metalised polymer vapour checks showed condensation on sheathing adjacent to "discontinuities" in the vapour check. Use of filled polymeric emulsion as an additional vapour check reduced the extent of condensation. Jointing details and service details thus need particular care with such plaster board.

When secondary internal insulation using composite boards with an integral vapour check behind the plaster board was used using either mineral fibre or expanded polystyrene insulation bonded to the board, condensation occurred behind socket outlets which were left unsealed due to the integral nature of the vapour check. Again careful consideration therefore needs to be given to the use of such details.

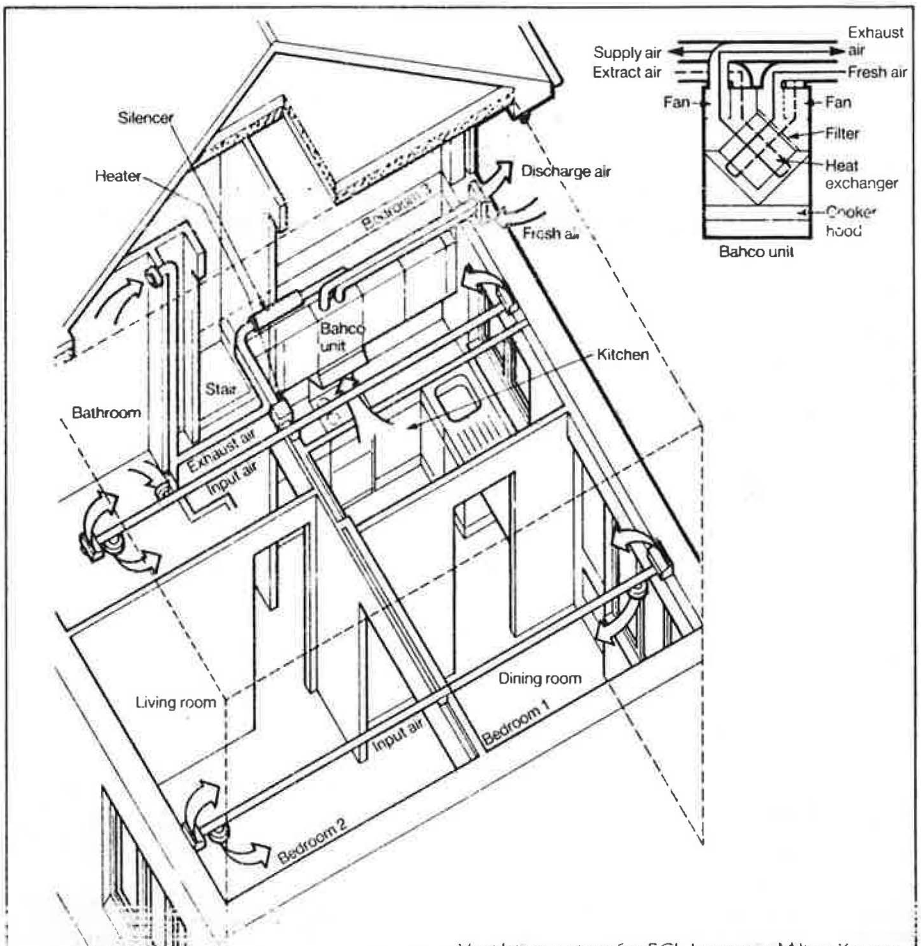
For secondary internal insulation using a mineral fibre composite board without an integral vapour check but with a vapour barrier placed at the board/panel interface, ie at approximately one third the insulation depth, no condensation was observed on the sheathing but some occurred on the vapour barrier. A position at one quarter the insulation depth may therefore be preferable to reduce the risk of this occurring.

For secondary internal insulation of rigid extruded polystyrene of high vapour resistance and with no vapour barrier, moisture problems were associated with the socket outlets. Careful consideration should therefore be given to service details.

For secondary external insulation, either mineral fibre or extruded polystyrene, both with polyethylene vapour barrier behind the plaster board internal lining, no problems were observed.

However the best performers were simple panels with mineral fibre insulation between deep studs protected by a polyethylene vapour barrier. These have a high degree of tolerance to damage and to inadequate sealing of electrical socket outlets or service pipes.

The conclusion for TRADA was that there is no real problem in moving to 150 mm timber walls giving U-values of approximately 0·26 W/m^2°C provided that already established design guidance on the provision and positioning of vapour



Ventilation system for PCL houses in Milton Keynes.

barriers is followed and good site practice ensures that damage is repaired and that service holes are adequately sealed.

Ventilation

Ventilation comes in two parts; Firstly, keeping air out of the building and, second, controlling air brought inside.

Firstly, as the proportion of heat loss due to uncontrolled ventilation gets higher, the importance of obtaining a 'tight" building increases. Second, as the building gets tighter, the need for mechanical ventilation gets higher.

Achieving a tight house is no easy matter, particularly given the poor and sometimes quite logic-defying practices of the average British builder.

Work by the BRE has shown that one is ventilating mainly to evacuate water vapour, carbon monoxide from combustion apparatus, and for tobacco smoke. Other pollutants such as formaldehyde and radon are not usually important unless special circumstances prevail. Neither do they suit being ventilated very well; prevention at source being considered to be the better solution by the BRE who do not appear to be too enamoured by the use of air blocks or trickle ventilators for they are subject to the weather and to users blocking them.

Likewise, passive, stack effect ventilation appears too subject to the weather and, in tight houses needs holes in the structure to let air in — thus negating the tightness.

Mechanical ventilation appears to be the answer but it costs money and has a maintenance penalty. This cost and maintenance penalty rises considerably if heat recovery is added.

Tips on mechanical ventilation from the BRE include: do not put the fans above bedroom ceilings unless you have to because the noise and vibration and difficulty of access; deliver warm air close to room temperature; beware of stagnant places such as cupboards. TRADA has also worked on ventilation and, in particular, on gaining air tightness in dwellings.

There are a number of positions where air leakage can occur. These can be summarised as joints between components or elements, penetrations of the external fabric for building services and openings made for access or ventilation.

These have all been tested by TRADA and some quite frightening results have been found. Measurement at 50 Pa of a developer's house on an estate that was considered to be built well showed an air change rate of 8 per hour. Of this 77% of the total came from leakage through joints. When these joints were sealed the overall background ventilation was reduced to 2·5 air changes per hour. This equates to a move from UK standards to within the range of airtightness accepted in Canada and Scandinavia.

TRADA is keen to promote the use of simple sealing methods. Foremost among these is the approved lapping of vapour barriers, which requires no additional material cost; only time and care in installation. Use of sealants requires additional material and labour costs and introduces a new operation into the building sequence. It does, however, provide a separate operation which could be checked and which is suitable for taking up large tolerances or errors in workmanship.

Use of gaskets requires both material and labour cost. Installation requires a new operation either in the factory or on site. Again, the presence of an appropriate gasket can be checked. Successful use of gaskets requires adequate control of the appropriate mating surfaces as most gaskets require a degree of compression.

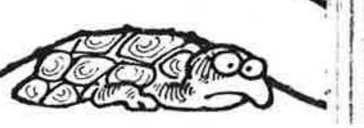
One of the most successful reductions in joint leakage was achieved when a gasket was placed under the bottom rail of the timber frame directly onto the concrete slab below.

At the Energy World Exhibition in Milton Keynes TRADA tried to achieve a 1·5 air change per hour rate at a test pressure of 50 Pa. This proved exceedingly difficult and was barely achieved after much work. The conclusion is that it is probably not cost effective to try for this level in the UK. However, it has to be said that at normal conditions of pressure this represents 0·1 of an air change per hour of natural infiltration as opposed to the 10 to 15 air changes per hour which is more usually achieved. The Canadian standard, for example, is 1·5 air changes per hour at normal pressure conditions.

Two examples of problems on site illustrate the problem. The intermediate floor and wall panels were craned off the lorry and moved on to site and all had their air/vapour barrier laps taped down. During the installation of the panels they were installed incorrectly by the erectors in such a way that laps could not join!

All the first floor lighting was designed to be wall mounted to obviate problems of penetration of the ceiling air/vapour barrier. The electrician was not informed as to why the lighting was all wall mounted and, in the conventional British manner, went up into the loft, proceeded to bodge holes through the ceiling, brought the wires up through the vapour barrier across the loft and then back down through more holes bodged through the vapour barrier and the ceiling to the wall points. On mature reflection, the blame was placed onto the lack of explanation and site training rather than onto the electrician.

In the end the major source of air leakage through the building was through the porous brickwork of the fireplace.



Practical results

By far the most detailed case study at the conference concerned some houses built in Milton Keynes under the control of the Polytechnic of Central London.

Here mechanical ventilation was used together with heat recovery and a heating coil and the results were impressive.

The temperature efficiency of the heat exchanger, which was a Bahco unit on the kitchen wall, was shown to be in the range of 70-80% and the co-efficient of performance was always greater than 3. In this insulation at a cop of 2·5 and above, the system is more cost effective than introducing the same volume of air and heating it by, for example, a gas boiler at an efficiency of 75%.

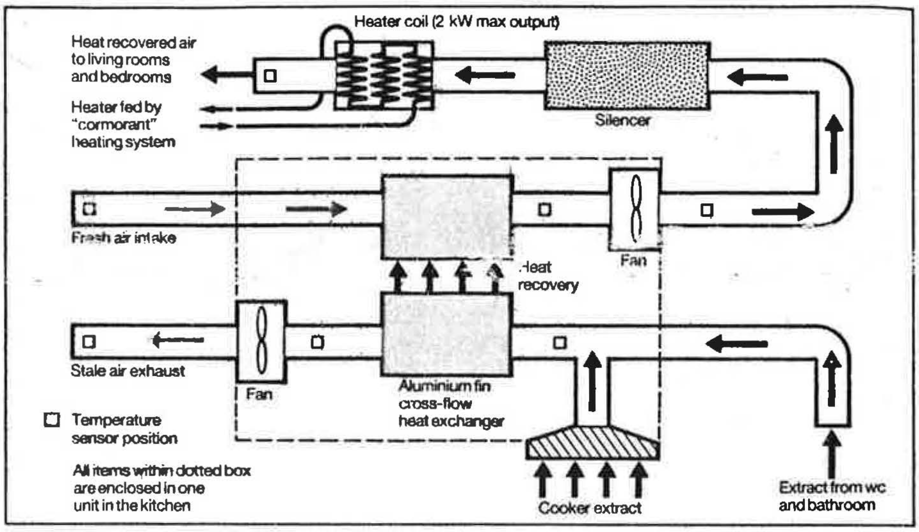
The houses were very well sealed, helped enormously by the large panel design and method of erection, and had U-values of 0·24 W/m^{2}°C for the walls.

There was a high level of satisfaction among the house owners, although some appeared to use the system more discerningly than others.

The use of the ventilation system to distribute the heat from the water-to-air heat exchanger is not entirely successful however. The heater coil is as large as it practically might be, but the system is often found to be lacking capacity according to the Polytechnic. The only method available of increasing heat output is to boost the air flow rate.

The fresh air is taken from outside, through the heat exchanger, through a silencer, through the heater coil and then delivered to living rooms and bedrooms. Heat is extracted from the wc and the bathroom and through the cooker extract, which is part of the Bahco unit. It is then passed through the heat exchanger and exhausted to out side.

Ducts are thin gauge, spiral wound and positioned within the floor void space, apart from one particular duct which crosses the joists on the top of a partition going the whole house width.



Ventilation system for the PCL houses in Milton Keynes.

Space heating and gas use ranged between 282 kWh and £6 worth of gas during the year for a couple with two children to the most expensive use of 818 kWh of electricity and £20 of gas for a couple with three children. In the control houses, without the superinsulation, but still highly insulated compared with UK standards, the range of energy use was from 2268 kWh and £48 of gas through to 3654 kWh and £83 of gas.

The houses are Finnish in design and construction, using large panel techniques, and cost an extra £2000 to build in the superinsulated form. The combined heat loss rate was 75 W/K.

A further innovation in the houses was the use of a Cormorant gas water heating system. The principle of the Cormorant is the insertion of a large thermal store between the heat generator and the heat/hot water distribution system. The thermal store is kept at a constant 17-18°C. The main advantage of the system is that the heat generator size can be significantly reduced as it does not have to cope with big demands. Being a mains hot water system, it also allows the designers to dispense with the cold water storage tank in the loft space so there are, most importantly, no service connections through the vapour barrier in the ceiling.

Although the system has won much praise from the Polytechnic of Central London, in this superinsulated house application it is said that, an average of 38% of the total gas consumed is lost into the house uncontrollably and this represents a ventilation load in order to keep the houses at design temperature. British Gas and the Polytechnic do not agree with each other on the cause or effect.

And finally, the crunch for these three bedroom semi-detached, 75 m^2 houses, was the total cost of energy over a year. It varied from £203 for a house with just one person living in it to £286 for the couple with three children and £293 for the couple with two children.

For over 20 years in Germany and Switzerland low energy houses have been built by the use of polystyrene formers interlocked, Lego style and filled with concrete. The first use of this material in the UK, was in a house at Energy World in Milton Keynes.

This particular house was built to demonstrate German techniques and not only used the Multitherm external wall construction but also lightweight steel and expanded polystyrene intermediate floor construction, foamed polyurethene roof insulation and tiling batten system for the roof. The systems all worked with commendable efficiency and were easily transferred to the abilities of the British builder. U-values of around 0·24 were achieved with just 0·17 for the roof. A particular lament of the architect for this house, David Sim, was that he could obtain very high specification windows to any size he required on three week delivery from Germany at a cost very comparable to much poorer and restricted products in the UK. Many said that, for superinsulated houses, one has to think of quality and inevitably found better products, at a compatible price abroad.

As for the future? For those already convinced the band wagon moves excruciatingly slowly.