functional absorbers used in factories and sports halls) may be fixed above the open grid but in such a manner that convection currents are encouraged to expose the thermal mass to the mixed room air.

It is worth noting that the elimination or reduction of the void can have positive energy benefits by increasing window height or immediate economic benefits during construction by reduction of floor to floor heights.

NATURAL VENTILATION SYSTEMS

It was argued earlier that acoustic criteria will have to be interpreted with more flexibility and that insulating against road traffic noise and in some cases aircraft noise is likely to cause most problems for naturally ventilated buildings. High ventilation rates required to avoid summer overheating in commercial buildings are not compatible with good sound insulation. However it has been mentioned that certain systems can give some sound insulation in conjunction with moderate air change rates (2-5a.c.h.). Secondary glazed systems allowing a staggered 100 mm open gap on each pane have been shown to give a sound insulation of 27dBA-3OdBA depending on the type of noise.[9,10]

Recent work at the BRE[11] has looked at trickle ventilators and passive stack ventilators applicable to domestic buildings. Trickle ventilators are holes or slots. Holes generally provide better attenuation than equivalent slots and the actual transmission naturally depended on size. In general those tested provided no worse attenuation than closed single glazing below 630 Hz and below 315 Hz with secondary glazing. At the higher frequencies the performance was no worse than opening the windows. Passive stack ventilators performed similarly though better attenuation would be provided against traffic noise than aircraft noise because of the change in angle of incidence of the noise. The type of duct was important in the performance above 630 Hz. Rather interestingly a larger 155mm duct gave better attenuation than a 100mm duct. The nature of the termination and type of duct affected both the acoustic performance and ventilation rate generally in opposite directions. Attenuators may be necessary but they can become very large in commercial buildings. Solar chimneys have similar problems as they are designed to move the air quicker, thereby helping reduce overheating.
Essentially a part glazed vertical duct exposed to the sun, the air is warmed and the stack effect increased. They are not common in the UK but a study centre for the Centre for Alternative Technology, Machynlleth, Wales[12], proposes to use them to provide summer time ventilation for bedrooms located behind a glazed buffer space. Duct areas are large but in this case the problem is potentially cross-talk and can easily be solved by designing a separate chimney for each bedroom. In other cases where a chimney , solar wall or double skin type system may have to serve several vertically arranged spaces the solution is not so simple.

While the stack-ventilator or solar chimney itself may cause problems the air inlet needs to be considered. The proposed Energy faculty Building at Leicester Polytechnic[13] uses passive stack ventilation chimneys to ventilate a lecture theatre, the air being drawn through grilles under the seats from the outside via the plenum created by the builders work. The problem is obtaining sufficient sound attenuation with minimal flow resistance. Traffic noise is around 70 dBA in the street outside and very large attenuators have been provided. In addition the chimneys have been lined with acoustic absorber

ATRIA

Another concern in passive solar design is atria. Atria have the potential for improving the energy efficiency of a building if unheated or minimally heated. Mostly designed with hard finishes the reverberation times are often high and sometimes boasted about. The problems arising will depend on use of the surrounding spaces, the use of the atria and the size of the atria. Despite a long reverberation time the reverberant sound level in large spaces is low and it is likely to be the smaller atria where problems could arise. In some cases the acoustics of small atria such as the Cambridge Consultants building in Cambridge Science Park have benefited from acoustic treatment of the surface.
In a recent International Energy Agency Task Group XI report on Passive Solar and Hybrid Commercial Buildings,[14] three social surveys give an insight into the occupants' reaction to noise in atria. These were either retrofit atria or extensions to existing buildings and in two cases before and after studies could be done. The first dealt with was that of the Tegut Company, Fulda, Germany. Additional office space was created and then glazed over. The glazed area was heavily planted. With office workers moving from the air-conditioned spaces to the atrium pavilions there was a slight reduction in the perceived noisiness although they remained on the noisy side of neutral. The air-conditioning in the original offices had been causing noise problems.

In another development at the Norwegian Institute of Technology, the extension to the Department of Electrical Engineering and Computer Science, several new office and laboratory buildings were linked to each other and existing buildings by glazed spaces. The occupants found the building slightly noisy but a concluding remark was 'noise levels in the atria and noise disturbance from the atria to office spaces also gave rise to some complaints.' This apparently arose because groups of students congregate in the atria to drink coffee and make conversation.

Finally a development in Wasa City, Gaule, Sweden, involved glazing over an area linking dwellings, shops and offices. The social survey was designed for the residents, many of whom had lived in the dwellings before retrofit. Traffic noise in the area was very high but the report comments: 'Rooms badly affected by noise lie to the same extent facing the courtyard as facing the street. During the summer the ventilation shutters in the roof cause noise. In winter, snow on the roof makes noise as it slides down the glass in great chunks. Also the wooden duckboards in the open spaces in the atrium were mentioned as a source of noise. Noise is intensified in the atrium'.

While it would be unwise to draw any general conclusion from the surveys, they do tend to confirm current opinion. Noise problems created in offices by atria are less likely in large than small atria. Problems can arise if activities occur in the atria which create noise, Eg the congregation of a fairly large number of students at a coffee bar in the atrium or if a small orchestra or band is employed to play. The type of space surrounding the atrium is important. Dwellings and possibly teaching spaces are likely to be much more sensitive than offices.

REFERENCES

1. Comparison of health problems related to work and environmental measurements in office buildings with different ventilation systems, Robertson et Al, British Medical Journal, 291,