Testing away the problem

The bay window design for the new offices at Bracken House posed a major problem for the design of a perimeter air distribution system. *Mike Holmes* explains how laboratory testing resulted in an optimal design solution.

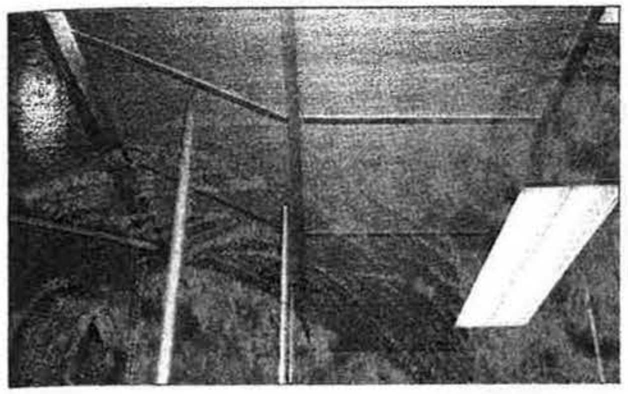


Figure 1: Air discharged over the window may flow along the ceiling into the room.

The air distribution in Bracken House is by means of a floor-mounted system, where conditioned air is supplied to internal zones by means of swirl diffusers. Ove Arup and Partners has a great deal of confidence in the application of this type of diffuser, and so the design for these areas was not considered to be of any great concern.

The perimeter zone, however, was a different matter. The swirl units were not considered to be a suitable means of handling the air quantities necessary to offset either a heat loss or solar gains.

For these reasons it was considered necessary to employ underfloor fan coils, to discharge air vertically over the window.

This would not normally have caused concern, and the grille would have been selected using a standard procedure[1]. However, in this case there were a number of complications, the most significant of which was the presence of a down stand (figure 1).

The obvious concern here is that air discharged up the window would initially flow along the ceiling and then be directed into the room with a subsequent undesirable effect on the comfort of the occupants. There is little general design guidance available to handle such a situation.

Other concerns were associated with the connection between the fan coil unit and the supply diffuser, the location of the extracts in the floor on either side of the bay, and whether or not the blind would rattle as air is blown over it.

The most important of these was the airflow, as the performance of a diffuser is related to the momentum flow it creates, which in turn is dependent on the velocity profile at the diffuser. Furthermore, the effect of a distorted velocity profile could be to bend the jet, either throwing it onto the blinds or away from the window and into the space, again with consequent implications for the comfort of the occupants.

These issues made it essential that some form of modelling should be done. There were two choices: applying computational fluid dynamics modelling[2], or building a test rig.

CFD modelling was thought unsuitable as it would be difficult to represent the inlet conditions caused by the bend and expansion following the fan coil unit. In addition, the open blind would interfere with the boundary condition, and blind rattling could only really be confirmed visually.

For these reasons a test rig was built at ABB Fläkt's laboratories in Sweden, which allowed Arup's to take full advantages of the most important feature of physical models – the instant feedback on the general effect of any modifications.

Figure 2 shows the main features of the model and instrumentation that was used. The effect of solar gain on the temperature of the glazing is simulated by using heated panels instead of glass. The impact of direct gain on the space is represented by electrical heating tape on the floor in the region of the bay.

Other heat sources are lights, occupants and equipment. Lighting is properly modelled using real fittings, while the grey tubes (each containing a 100 W lamp) represent the occupants. Office equipment is modelled in a similar way.

Air velocities and temperatures were measured by an array of instruments connected to a data logger which was used to produce a plot of space conditions. Of

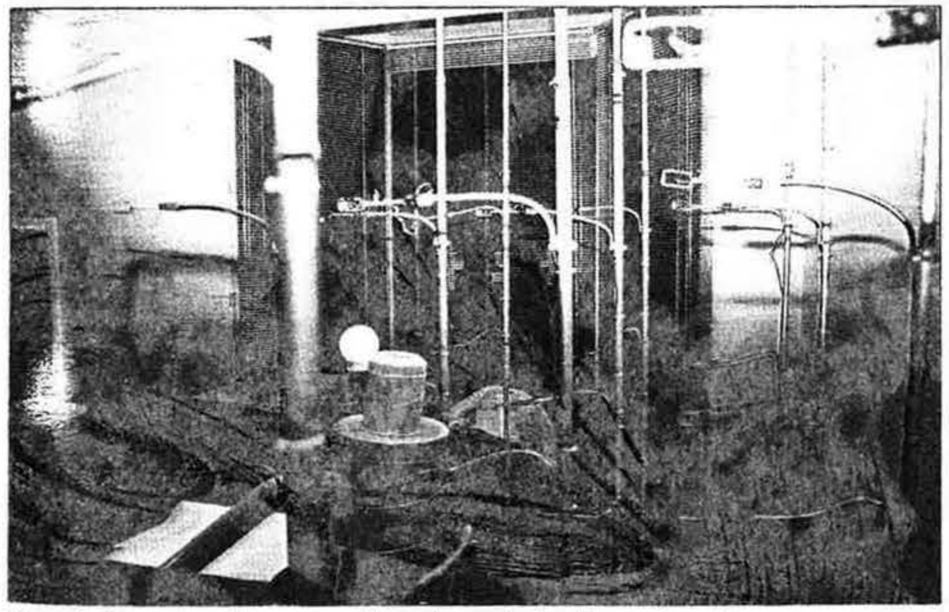


Figure 2: Arrangement of the mock-up. Heat gains are simulated by panels and tape.

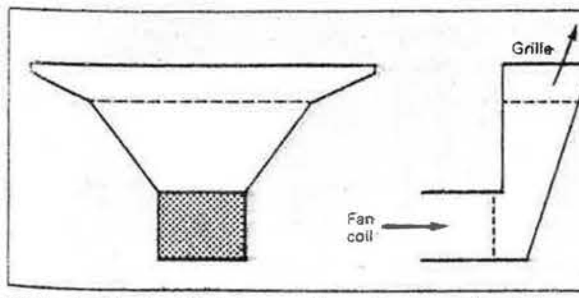


Figure 3: Sketch of the inlet transition with the position of the perforated plate shown as the dotted line.

greater importance in assessing the performance of the system was the availability of smoke for flow visualisation.

It is important not only that velocities in the space are within acceptable comfort bounds (for example no greater than 0·25 m/s), but that a stable air flow pattern is established. The latter can only be properly checked by using some form of flow visualisation.

So what happened and what did we find out?

Testing results

The first test carried out was at a flow rate of 280 litres/s corresponding to an air change rate of 14 ac/h and a heat load of 1·9 kW. The air flow pattern was totally unacceptable, with the blinds rattling and flow separation from the ceiling at the downstand. Measurement of the velocity profile at the slot indicated severe non uniformity.

On investigation, it was found that, due to a misunderstanding, nothing had been done to smooth the flow in the transition piece between the fan coil and the supply grille. The restricted space available made this a complex piece of ductwork, involving a right angle bend followed by an expansion (see figure 3).

The advantage of being present at the tests was now apparent in that we were able to discuss and experiment to find the best way to ensure a uniform air stream at the diffuser without causing a noise problem.

This was done in several stages. First, a vertical perforated plate was introduced just before the bend and expansion (figure 3). A quick check indicated that the supply air was moving sideways, somewhat following the line of the diffuser, and probably short circuiting directly into the two extract ducts at either side of the bay (see figure 4).

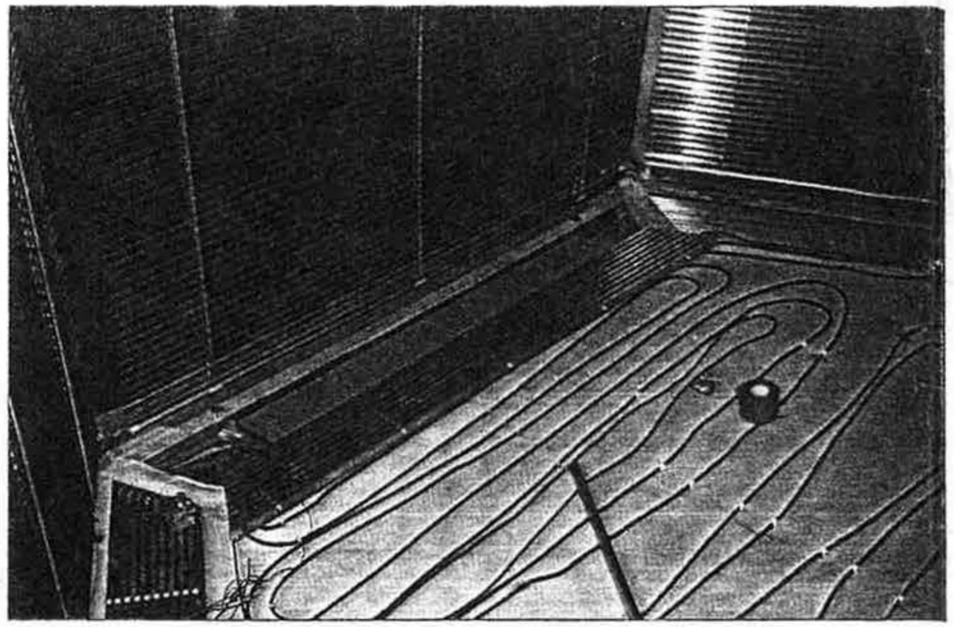


Figure 4: Supply air was moving sideways, closely following the line of the diffuser and probably short-circuiting directly into the extract ducts at the side of the bay.

The addition of vertical blanking plates at the top of the transition piece rectified this. The resulting airflow pattern was as required, that is to say up the window, around the downstand and down the rear wall. However the blinds were moving.

Further investigation of the airflow pattern at the diffuser showed that the flow was being directed towards the blinds, again due to non-uniformities.

The introduction of a horizontal perforated plate (also shown in figure 4) rectified the situation, and a satisfactory air flow pattern was achieved with stationary blinds, but high velocities in the space. We now had to find a way to reduce the velocities in the room.

After some discussions and pooling our experience with that of the laboratory staff, we concluded that the heat gains used in the original test set-up were too high (a boost condition had been set) and so the air flow rate could be reduced, but even so it was likely that the grille should be changed. This was done, and after a little experimentation we were able to specify a grille on the basis of maximum discharge velocity.

The tests had confirmed that the design would work and relieved our worries that the jet might detach from the ceiling at the downstand (figure 5).

The value of attending such tests and participating in the experimental work was demonstrated further when we decided to see what happened if we altered the blind angle (something not in the specification). At a certain angle the jet's upward travel was halted. We decided that we would need something to prevent this happening, a mechanical stop was one possibility.

Mike Holmes is an associate director with Ove Arup and Partners

References
[1] Jackman PJ, "Air movement in rooms with sill-mounted grilles – a design procedure", *HVRA Laboratory Report No. 71*, 1971.
[2] Whittle GE, "Flow field modelling in buildings", *Building Services*, May 1991.

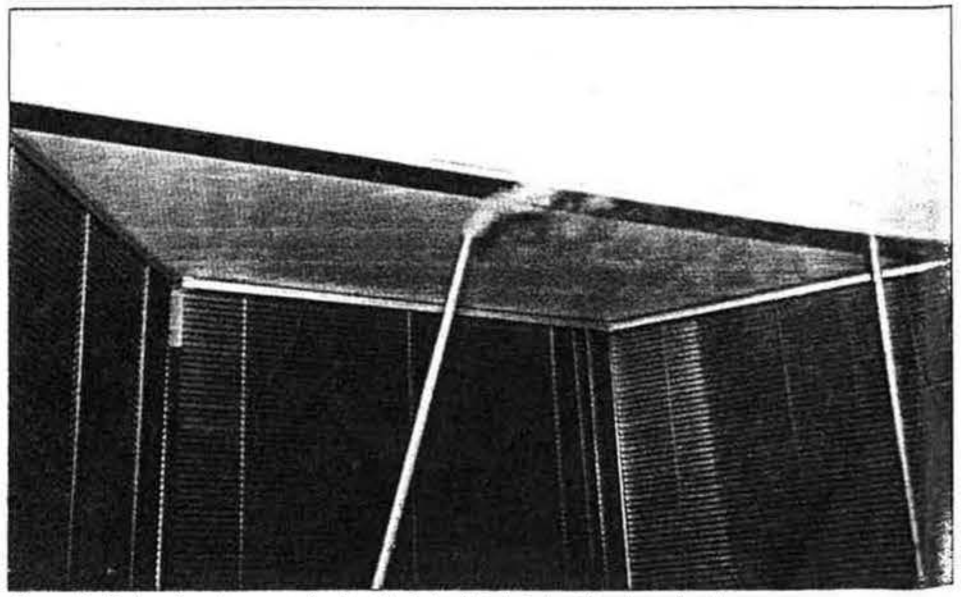
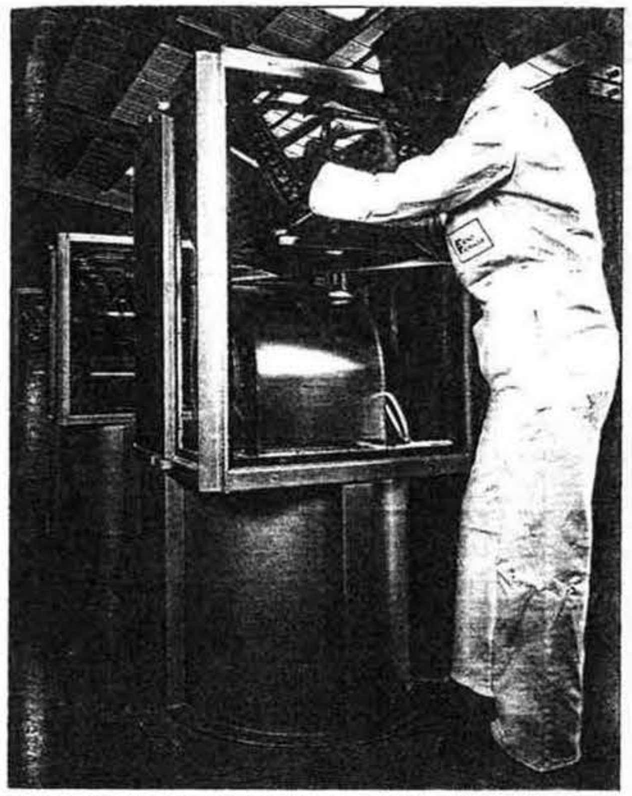


Figure 5: Tests relieved any worries that the jet might detach at the downstand.

A bespoke solution

The dealing rooms at Bracken House were estimated to have a cooling load of 100 W/m^2. Energy Technique was contracted by Ove Arup and Partners to supply special on-floor cooling units. *Nick Wells* looks at the results.



The bespoke ahus designed for the Bracken House dealing floor.

With Bracken House being the new London base of the Industrial Bank of Japan, consulting engineer Ove Arup and Partners was required to design the services for a dealing floor, usually a high-tech environment with a heavy cooling load.

Bracken House was no exception to the norm. With a design cooling load of around 100 W/m^2, the cooling system supplying the remainder of the building obviously required enhancement to cope with the equipment heat gains.

The solution was to supplement the chilled water system with on-floor units combining a fan, cooling coil, filters, attenuation and the necessary control devices.

The subsequent packaged units, which stand from floor to ceiling, augment the central cooling system by replacing a number of the central system fan powered boxes under the floor. The floor supply duct is connected instead to the supplementary cooling unit, which in turn is connected to the ceiling plenum.

Floor barriers separate the pressurised floor from the areas supplied in the normal way from the remaining fan assisted terminals.

The air handling units (ahus) were very much a bespoke design, with particular aesthetic, quality and durability requirements. For these reasons, the consulting engineer created a product design team involving the the manufacturer (Energy Technique), the consulting engineer, architect, contractor and acoustic specialist.

The team decided that such a bespoke design would require a prototype to be built which could then be used for a variety of performance and acoustic tests, and also to determine the aesthetics of the unit and the durability of finishes.

Architectural considerations dictated that each unit's physical dimensions were critical, the footprint should be minimal and the styling of the external casing should integrate with the style of the building.

The units also had to be 'dealer-proof', resistant to scratches and small physical shocks. Vibration and break-out noise were reduced by making the unit from heavy gauge steel panels with a fully welded framework.

The panels were fabricated from 1·6 mm thick outer skin and 1·2 mm perforated inner skin. The acoustic insulation is composed of two layers of high density, class 'O' rated foam, sandwiching a 10 kg/m^2 sheet of lead.

In order to use the fan and coil face areas to their maximum efficiency, and thus meet the duty stated, the central fan coil section had to be rectangular.

The fan selected was of the forward-curved, double inlet centrifugal variety, with an external rotor/motor as the direct drive. The Ziehl-EBM motor, which is coupled to a variable speed drive, was used for commissioning purposes only, with the fan speed being fixed for normal operation.

The cooling coils were optimised according to air-side and waterside pressure drops, face velocities and dimensional constraints. This led to a vee-coil arrangement to optimise the height restriction and internal air flows created by the double inlet fan. The ahu was also designed to allow the filters to be removed from two sides of the unit.

An underfloor basket houses the controller, electrical connections and fresh air connection. Pipework passes up through the basket and through the discharge attenuator.

Energy Technique did not skimp on finishes. The metallic grey paint, developed by ICI, is the same paint that is applied to the underside of the Airbus aircraft. It was considered ideal for this application because of its durability and low baking temperature, which was required for the attenuator sections and the double-skinned panels.

A prototype unit was built and tested both acoustically and thermally. Performance testing was carried out by the Building Services Research and Information Association (BSRIA), with acoustic tests being undertaken by Hann Tucker Associates.

BSRIA used the *BS 848* test rig for the performance testing, which demonstrated that the airflows were comfortably achievable and that the duty was achieved to within 2% of design criteria. The tests showed that the flow and return pipework needed to be slightly larger to keep the pressure drop to a minimum.

For the acoustic tests on both the discharge and intake side, the ahu was attached to an acoustically calibrated reverberant chamber, and the sound power levels measured.

Typically the maximum noise break-out levels were around 3 db lower than design calculations, being within the frequency band 63 Hz-8 kHz, with a maximum noise break-out of 53 db at 63 Hz. Intake and discharge noise break-out was also lower than anticipated, with maximum sound power levels at 63 Hz of 69db and 70 db respectively.

The noise break-out actually conformed to NR 33 rather than the target of NR 35. In-duct noise was actually on the limit when it was designed to be 3-4 db on the safe side. These results prove how important it is to err on the side of caution when developing such bespoke packages.

Now that the equipment is commissioned, the greatest compliment that can be given is that the client is unaware that the units are running, let alone moving nearly 1 m^3/s of air.

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