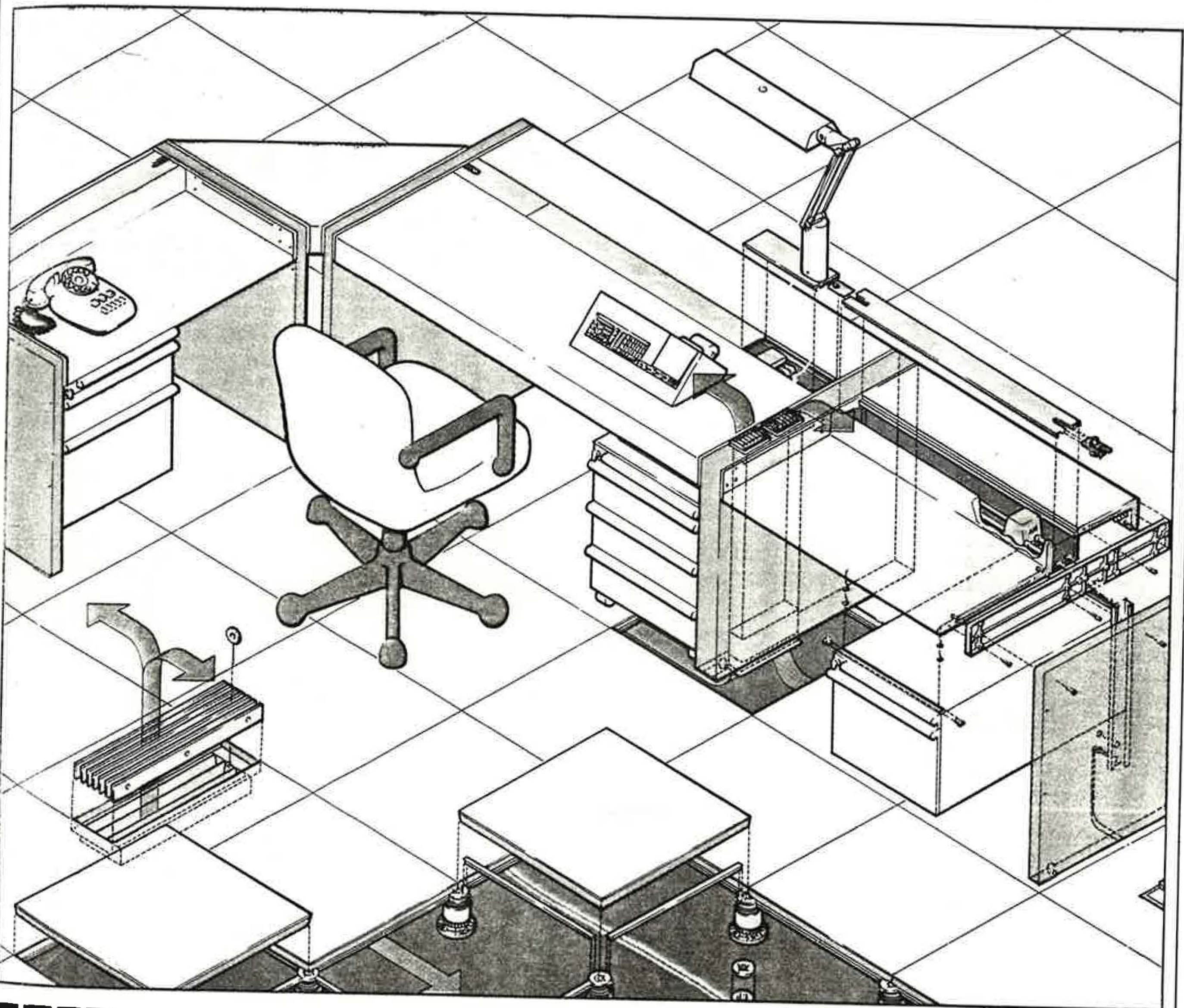
UNDER FLOOR AIRCONDITIONING

Building services has fashions like everything else, and the latest is to put the services underfloor. Fashions are always justified, by those who promote them, with convincing arguments. *Jonathan David* has been listening to the reasons being put forward as to why conditioned air really should come up from under.



Why underfloor airconditioning? Haven't we just about perfected the art of conditioning spaces via the ceiling void without causing draughts?

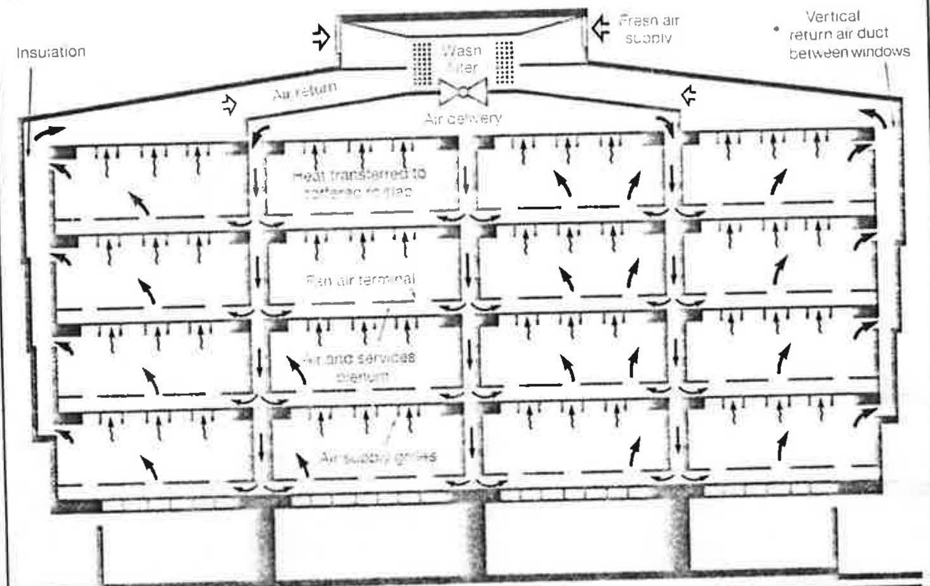
Going underfloor is not so much an attempt to provide better or more economical airconditioning as a response to new pressures now coming from other aspects of building services. The first culprit is the computer. As it invades offices it brings with it a trailing tangle of power and data cables to add to those of the uplighters, typewriters, dictating machines, calculators, word processors and other essential features of the modern office. Occupants are demanding ways of coping with this dangerous tangle, and the most straightforward way is often to install a raised floor and put everything underneath. But, says the building owner, why should I pay for a suspended ceiling, which I was told was intended to hide the services, *and* a raised floor? Can't I do away with the ceiling?

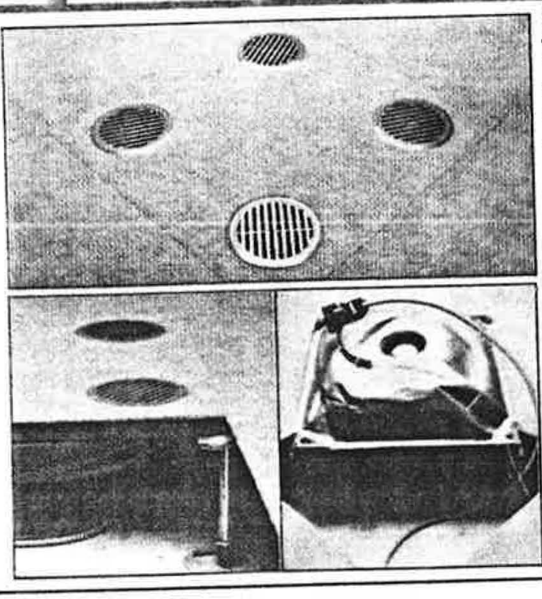
If he has already opted for uplighters there is no reason why he needs to attach anything to the soffit except the airconditioning supply and/or extract ducts. So where can they go? The obvious answer is to replace the ceiling plenum by a floor plenum, as is often done in computer rooms. This does not deal with extract but there are various ways of coping with this, of which more anon. And now this gives us the start of underfloor airconditioning.

The second pressure is a desire common to most people working in buildings to gain some control over their personal bit of space — their territory. Task lighting is a start, and usually seems to please; so why not task air conditioning? Put an air outlet on each desk and let the occupants decide on the appropriate temperature and air change rate for their personal domains. With a ceiling supply plenum this entails trailing flexible ducts which are not aesthetically acceptable in most offices. With a floor supply, nothing could be neater. There is in fact no need for the outlet to be on the desk. It can be in the floor adjacent to the desk. If the desk is moved, move the outlet too.

STANDARD BANK, JOHANNESBURG, SOUTH AFRICA

The Tate system developed from two installations in major bank buildings in Johannesburg, South Africa. The diagram illustrates the principle of using the structural mass of the building to store cool fresh air and the use of plena under a raised access floor to distribute air to work areas. The six storey Standard Bank contains over 37 000 m^2 of office space with all services in the underfloor plenum. The architects took advantage of the climate of cold nights and warm days, and the building's concrete structure is designed to maintain a relatively constant internal temperature. The underfloor plenum acts as a storage container holding cool air drawn in at night using off peak electricity. This air is distributed from the plenum into offices during the day by low voltage fan air terminals mounted in individual floor panels. Water cooled fan coil units located in the plenum provide additional cooling to "hot spots" such as conference rooms and control temperatures in perimeter areas. Air return to the primary hvac systems is via columns, corridors and atria. This air flow pattern is claimed to eliminate "forced" mixing of air.





The Task Air Module consists of a ConCore floor tile with four circular outlet grilles set into it. Under the tile, a low voltage electric fan is sealed within a flexible "bag". Each air outlet grille can be turned to control the direction of air delivery, and one grille in each tile incorporates speed adjustment by means of a knurled wheel. Thus the users can control both the volume and direction of the air entering the space, and each Task Air Module can serve up to four desks or work stations.

These two strands of argument lead logically to underfloor airconditioning, and in West Germany, South Africa, Italy, the USA and more recently the UK the idea has been developed to the stage of practical application. At least one installation in the UK is up and running (see p 33), there are several in South Africa and Italy, and in West Germany several major companies have taken to the idea. It is rapidly becoming the fashion for any out of the ordinary new office block — Lloyds of London and the Hong Kong & Shanghai Bank being just two examples. And standard products are appearing to enable the method to be used in more normal projects. So what does it entail?

There is a big difference between air conditioning a "traditional" computer room and air conditioning a high quality office space. Because of the high heat loads and the close control required, along with the small number of occupants, it has become accepted that high air velocities are required. "Computer floors" were first introduced as the only way of coping with the air flows involved. But comfort was a low priority and the noise was in any case masked by the noise of the computer machinery.

This approach is not acceptable for high quality office spaces; neither is computer flooring. Fortunately air volumes to be moved are much lower and velocities and thus noise are much reduced. But a whole new approach has been required to produce components giving satisfactory air supply and ensuring efficient circulation and mixing of conditioned air.

Only one system offers both air supply and return through the floor. Hiross, an Italian based airconditioning and raised floor company has several prestige projects to its credit using its INCAS (INfinite Conditioned Air System) system in which the underfloor void is partitioned into air supply and air extract zones, both linked back to the freestanding airconditioning unit.

In conjunction with Hiross, office furniture manufacturer Faram, also Italian, has developed the Superalfa range of desks etc incorporating air conditioning outlets at desk level. Air supply is via a hollow desk end which communicates directly with the supply plenum below. Air supply relies on a positive pressure within the plenum; adjustment is by damper. The desk end is designed so that one module can supply two adjacent desks with air while cable connections to equipment on the worktops is via other desk ends.

Obviously this form of air supply severely limits future options for moving desks as use of the space changes. All desk air supply ends must be positioned over areas of air supply plenum, so the layout of the air supply and return routes needs particular care.

The firm with the most underfloor air conditioning installations is probably Krantz of Aachen, West Germany. In that country the emphasis has been on personal space and most buildings with raised floors and Krantz systems seem to retain their suspended ceilings and use them for air extraction, often through the luminaires. Thus the Krantz system offers two ways of introducing air into the space under the control of the immediate occupant, but does not handle air extraction. Air supply from the central airconditioning unit is into the underfloor plenum, from where it passes into the occupied space either through floor outlets of several designs or up a flexible duct to a desk mounted adjustable outlet.

Tate Access Floors is an American company with subsidiaries in many developed countries including the UK and South Africa. It has also sought a way of providing individual control with a floor supply system. The Tate system is slightly different from that by Krantz in that the floor plenum is kept at "zero" pressure, and air supply into the space is controlled by a small fan in the floor outlet. The speed of this fan is then under the control of the occupant, along with the direction of discharge of the air through four small

circular grilles. It is claimed that it is easy to move the floor tiles containing the air outlets to suit new furniture layouts — a claim common to all approaches. At present Tate has only one building in the USA using this system, essentially a "guineapig" building though one which has been let commercially. But the origins of the system go back some years to a couple of large South African installations of a basically similar system.

A completely different approach is that of Temperature Ltd. The VersaTemp unit has traditionally been a floor standing, wall mounted or ceiling plenum design, but following a contract for perimeter areas of the Lloyds building temperature developed a standard underfloor version of the unit. Model VU 150 sits in the floor plenum, typically with air extract through a local grille and supply via ducting to further suitably placed floor grilles. The unit is sized to be accommodated within the usual 600 mm support centres of a raised floor. Because of its mounting position it is designed for automatic control. In a sense it is complementary to, rather than competing with, the three systems described above — and the Lloyds of London building uses both Temperature units and Krantz floor outlets.

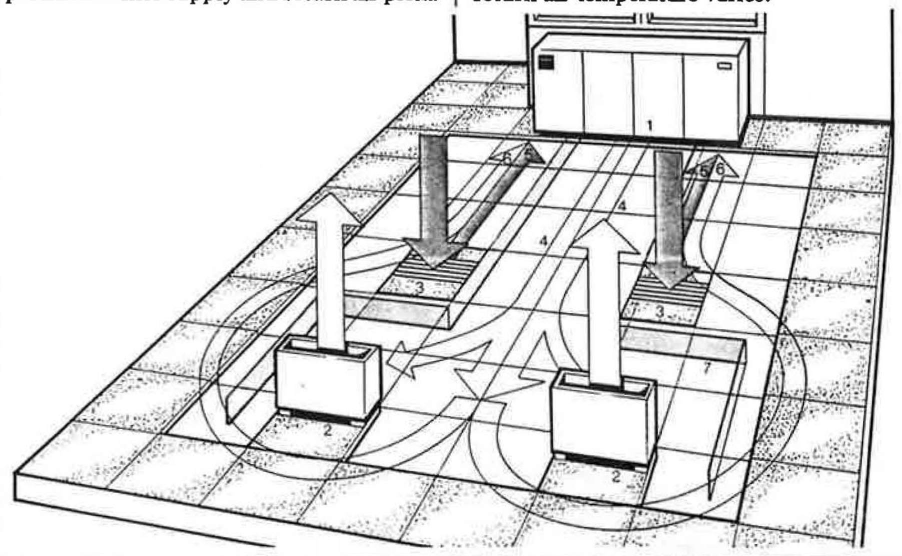
Underfloor air conditioning is not going to become a major fashion. It will be used in offices where the owners know that they will be placing great demands on the services distribution systems. It is, like uplighting, really suitable only for prestige areas with fairly generous space between work stations for positioning of the air outlets or return grilles. One suspects that as the computer/communications industry gets its act together and replaces all the present electronic office machines and communication systems with integrated hardware connected to local area networks, and the amount of cabling is drastically reduced, the case for access floors will be weakened. In the UK as a whole a large part of office development is now refurbishment. Adding a raised floor can cause problems unless the refurbishment also allows for rebuilding staircases and remodelling lift landings—though there are ways of accommodating a raised floor without, by using steps or ramps.

There is really only one major question unanswered. Can satisfactory air circulation patterns be guaranteed, given the ability of the occupants to move outlets and the low air velocities normally involved?

Short circuiting, draughts and stagnant areas are all possible. It is sometimes claimed that temperatures above head level can be allowed to rise above comfort levels with low level air supply and high level extract. This is a risky approach indeed, and many designers will be unhappy about following it. Answers to these questions will come with experience of the installations now going in, but there is a great deal of difference between an installation designed with loving care by an expert services engineer and a method that can be used as a run-of-the-mill design approach by any engineer who decides to be in fashion.

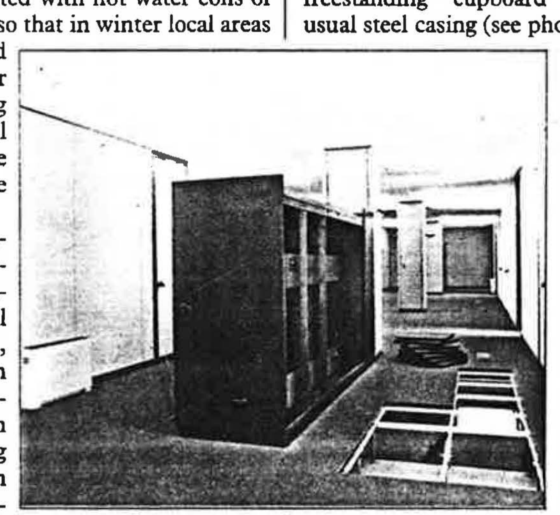
THE INCAS SYSTEM

Hiross's INCAS system consists of three components: a central downflow air conditioning unit with return ducted from the floor plenum to the top of the unit (1); fan air terminals to control the flow of conditioned air into the space (2); and the raised floor system which acts as a supply and return plenum and contains return air grilles strategically placed. The raised floor system is based on the existing Hiross Floor using steel faced panels which can be covered in just about any flooring material desired. Each return air grille replaces part of one panel (3). Under the floor the space is partitioned into supply and return air plena by means of dividers (7) which need not be along the floor module. Delivered conditioned air is moving at low velocity (4) around the circuit. Part passes into the conditioned space via the fan air terminals, but except at times of peak demand some will be recirculated (6), joining the return spent air (5). Unlike a standard air conditioning system, the INCAS system runs with the air conditioning plant at constant volume but the supply of air to the space at variable volume. Therefore, rather than return air temperature, the system is controlled on supply temperature and the return air temperature varies.



The fan air terminal consists essentially of a small painted sheet steel cabinet in which air is drawn from below using a three speed fan under the occupants' control. The unit draws the air either from underfloor or from the conditioned space depending on the position of a motorised damper. Units can be fitted with hot water coils of electric heaters so that in winter local areas can be heated while the air conditioning system is still running in the rest of the building.

A classic example of refurbishment is International Office Service, Turin. Here an extensive renovation of an old building with very high ceilings, difficulty in locating heating plant and a need to provide extra parking places has produced an interesting building designed specifically for flexibility. IOS provides office space on a short or long term basis for small companies, so the use of individual spaces changes frequently. In practice some areas have had to cope with even greater upheaval as Fiat took part of the space as a short term home for a computer centre. The concept coped even with the requirements even of this demanding client. The building uses the Hiross INCAS system throughout, with individual tenants able to move the fan air terminals and return grilles to suit their needs. Each zone is served by a central air conditioning unit housed in a timber freestanding "cupboard" rather than the usual steel casing (see photo).



Nordwall is part of the same group of companies as Hiross, but manufactures partitioning. Its new building uses Hiross INCAS air conditioning throughout, and is set up as a showpiece with glass panels in the floor lit from underneath, and further panels around the staircase to allow sight of the floor interior.

Additional features are free standing steel pillars adjacent to doorways carrying light switches to free partitions of all wiring, and floor standing but desk oriented task lighting.

An odd feature is that partitioning carries through the false ceiling to the soffit so that the ceiling would have to be dismantled to allow partitions to be moved.

LLOYD'S OF LONDON

Lloyd's of London looks like being the first big London building to have underfloor airconditioning, but it is by no means a standard approach to the problems.

Two separate air conditioning systems are being installed in the 12 storey office building recently topped out by the Queen Mother for Lloyd's of London. Both make use of the floor plena of the 53 000 m^2 of offices for air distribution and there are several other innovative features to the hvac systems. The "Room" on the ground floor is supplemented by four galleries opening onto a central atrium. The next six floors are designated for tenanted office areas while floors 11 and 12 will contain committee suites for Lloyds executives. The architects, Richard Rogers Partners Ltd, have designed a building with external concrete columns, suspended concrete floors and triple glazed curtain walls. The essential building services are provided through six external satellite towers.

Early heat load studies by Ove Arup & Partners indicated that conventional overhead air conditioning systems were not compatible with the overall project. As the building was designed with raised floors to enable the office services and supplies to the electronic equipment to be installed more easily, Ove Arup recommended a floor fed air conditioning system with the terminal equipment under the control of the user.

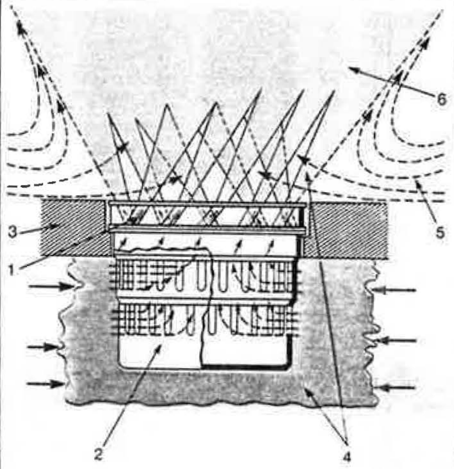
The central areas of each office floor are air conditioned by a high velocity ducted system discharging air beneath the raised floor. Fan air terminals located under the floor mix this air with a proportion of recirculated room air and discharge it into the room through Krantz floor mounted grilles and desk mounted outlets (see diagram). Air is extracted through the luminaires from where it is directed between the inner glass skin and the external double glazing to prevent cold radiation through the glass. Excess heat in the extract air is reclaimed and upgraded in double bundle condensers at the central refrigeration plant for direct re-use in air heater batteries, or held in thermal storage tanks. To control the environment in the perimeter zones on each floor, to offset the effects of solar gain and to bring the building to design temperature each morning, the consultants recommended a VersaTemp reverse cycle heat pump air conditioning system, to be installed underfloor. Temperature then had to work out how to design a unit with the cooling/heating capacity needed (1·5 kW heating, 1·3 kW cooling) to fit into the floor void less than 300 mm deep, within the raised floor module of 600 mm and meeting the noise requirements of the c onsultants (NR40 in open plan offices, NR35 in staff offices and NR30 in executive offices). Temperature developed the VersaTemp VU150 for the task and supplied 840 units (70 per floor plus 20 spare for maintenance). To match the noise criteria, the units have all moving parts on anti-vibration mountings and the compressor totally enclosed in an acoustic box. Each unit is connected by ducting to floor slot diffusers close to the glazing. A short length of duct connects directly from the diffuser to the inlet side of the unit and a longer acoustically lined duct links the discharge side of the unit with the discharge diffuser.

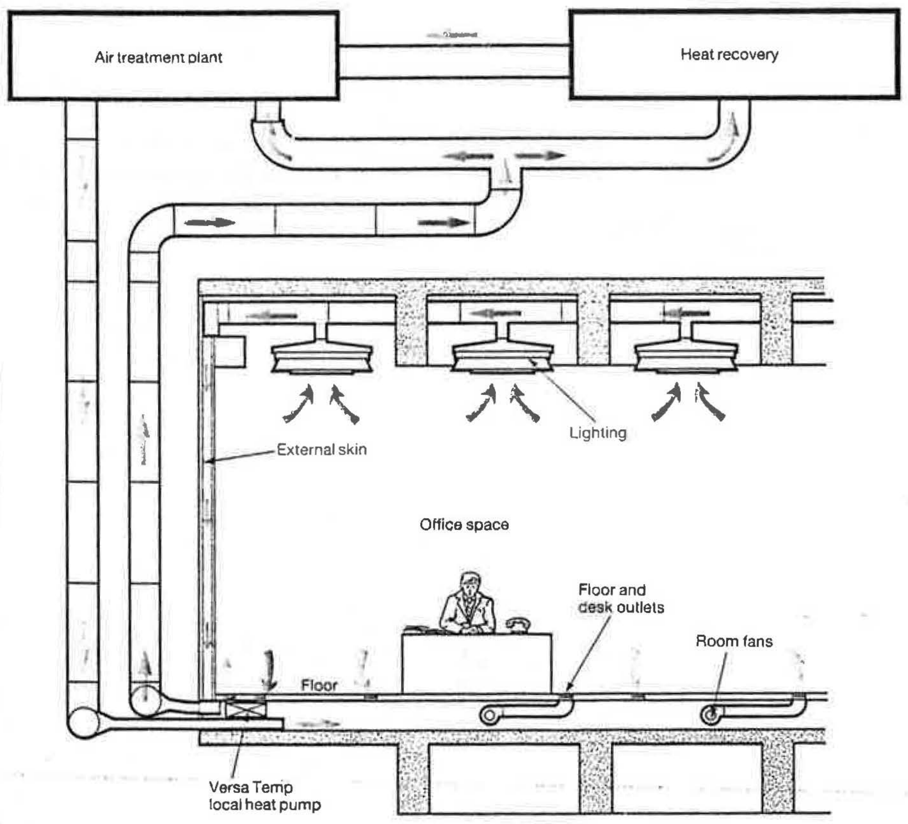
Those units in the Lloyd's occupied part of the building will function from a thermostat in the return air stream while in the tenanted offices separate remote controls are provided for each unit.

THE KRANTZ SYSTEM

As befits the company which has been in the field longest, Krantz has a wide range of desk and floor air outlets. The basic principle of the floor outlets is to add a "twist" to the air to ensure successful entrainment (1). This means that a higher air velocity can be accommodated without producing draughts as their air velocity decreases quickly as distance from the terminal increases. The outlet also incorporates a dirt collecting basket (2). The air enters from the plenum (4), passes through the floor plate (3) and mixes with the secondary air (5) in the conical mixing zone (6).

Krantz, one of Germany's oldest and largest air conditioning companies, pioneered the concept of floor outlets originally for industrial use, in factories with high heat loads such as glassworks, breweries, dyeworks etc. The concept was then modified for use in computer suites and finally adopted, adapted and developed for offices. The company sees the advantages of floor to ceiling air distribution over other systems as being numerous.





Schematic of the Lloyd's of London scheme.

THE ARUP APPROACH

At Farnborough can be found the first project in the UK designed by Arup Associates to use underfloor airconditioning. *Stephen Ashley* reports.

By using an underfloor air conditioning supply, Arup Associates the designers were able to produce a system with no terminal unit controls, which uses the exposed ceiling structure as a thermal flywheel, and which has only about half of the load of a conventional ceiling based air conditioning system.

Briarcliffe House occupies a small site left over between a major roundabout and a shopping centre in Farnborough, Hampshire. It is a fully glazed U-shaped structure of 9500 m^2 on three floors. It has a double skin on the longer elevation facing east, south and west, to combat solar gain and noise from road and air traffic. The 1·2 m space between the two skins contains the supply duct distribution and is used to prewarm ventilation air when the weather becomes colder. Exposed ribbed concrete ceilings span into columns located inside the building envelope.

Raised floors became a requirement because of the extensive cabling for computer terminals, power etc, and the need to be able to easily alter the position of outlets as occupancy patterns and office technology change.

The air conditioning system was designed for an adaptable open plan office, without a false ceiling, which did not require major modifications to respond to rearrangements of rooms and internal heat sources.

During the design a sophisticated computer program was developed to analyse the room thermal-dynamics taking into account the availability of a ceiling which has a high thermal capacity.

The ribbed concrete ceilings spanning each floor not only have a high thermal capacity but also present a large surface areas to the offices.

As the heat gain to the office space reaches a peak during the dry, the day resultant temperature swing is limited by heat transfer to the cooler concrete. This reduces the cooling system capacity required. This heat is later rejected back, as the temperature in the office falls at night and in the early morning.

The program predicted a constant supply air temperature of 18·5°C with a constant supply air volume of six air changes in the worst zone would maintain a maximum dry resultant temperature of 22°C at 1·5 m above floor level. It also predicted that temperatures would not drop below comfort levels with the same supply temperature and volume start up and low heat gain periods.

A maximum temperature in the return air duct of 28°C was anticipated. Subsequent monitoring of the building's environment has substantiated the program temperature predictions.

The consultants have done away with the false ceiling and return air is carried in ducts above the luminaires.

The air conditioning system therefore requires no room terminal controls limiting the changes required to respond to changes in layout or function to repositioning of the floor air outlets to cater for the new load pattern.

From outside, the building looks as though it has another inside.

A sophisticated control system is provided to the central air handling plant to utilise outside air and evaporate cooling whenever possible.

The perimeter area heat loss is offset by finned convector/radiators fed from the compensated temperature heating system. The convector/radiators are controlled by thermostatic valves to obtain maximum benefit in winter from solar and internal heat gains.

The perimeter areas are protected from excessive heat gains by motorised solar control blinds. The motorised blinds are activated by solar cells and may be retracted when not required to allow useful winter heat gains. The blinds are lowered at night and at weekends in winter to reduce heat losses from the offices through the windows in winter. They are perforated to about 20% of their area and so appear semi-translucent rather than opaque. This also allows a substantial amount of daylight to penetrate without a major heat gain problem.

Air handling plant for the offices is located at roof level and is divided into four systems. Each of these systems serves approximately one quarter of the requirements of the offices on three floors.

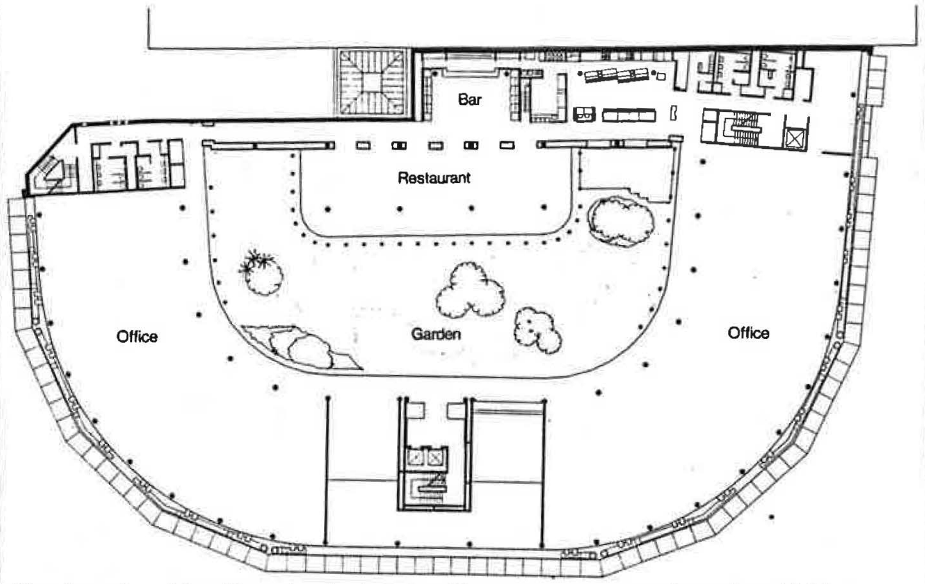
The supply air is delivered to the raised floor plenum by insulated ducts in the southern perimeter glazed void. The use of floor air supply and the reduced room heat gains allows a higher than normal supply air temperature of 18·5°C to be used. This allows the extensive use of evaporative spray cooling with efficient refrigeration plant, operating at high chilled water temperatures, only being required to handle peak summer conditions.

The evaporative sprays also allow the humidity in the offices to be raised in winter to a level which does not cause condensation to occur on the single glazing of the north facing courtyard elevation.

Air is extracted through ducts integrated into the luminaires and passed to header ducts located within the raised floor void above them. Extract air is recirculated or exhausted in varying proportions at the dictate of the control system. The recirculated air is either mixed directly with outside air or bypasses the evaporative cooler to achieve the required supply air condition.

The outside ventilation air for the offices is introduced into the air handling units at roof level. The air is normally taken from louvres in the plant room walls. In the winter when solar gains and office heat losses warm the air in the double glazed void the offices outside air is taken from the space to reduce the air handling plant heat loads.

In the summer when solar heating of the



First floor plan of the offices showing how the office space wraps around a garden which in turn contains the restaurant.

air in the double glazed void increases the heat gains to the office space, the void may be vented at roof level by louvres in the plant room walls. This encourages air to rise through the glazed void by "stack effect" reducing the heat gains to the offices.

In winter the louvres should be raised to take advantage of the solar gains to reduce the office heating loads. The louvres are also opened to vent smoke if it is detected in the glazed void.

The office's supply and extract air volumes can be reduced to approximately 50% of their maximum by operating the manually variable inlet guide vanes fitted to the supply extract centrifugal fans. This clearly reduces the electrical and heating operating costs.

The exposed concrete ceiling ribs are at 1·8 m crs (in some cases tapering to 900 mm crs) and form the ceiling of the office space. The continuous air handling luminaires are located between the ribs and span the width of the building. The consultants designed the luminaires to: provide an average 600 lux at working plane, in a glare free manner by using cross blade white louvres and the deep rib cut-offs; evenly light the ribbed soffit from all viewing angles; extract air in a varying amount along the length of each luminaire; provide acoustic absorption in the office space; include emergency lighting 300/8W lamps, inverters and control gear; include segregated mains and emergency through-wiring facilities and include future provision for subswitching.

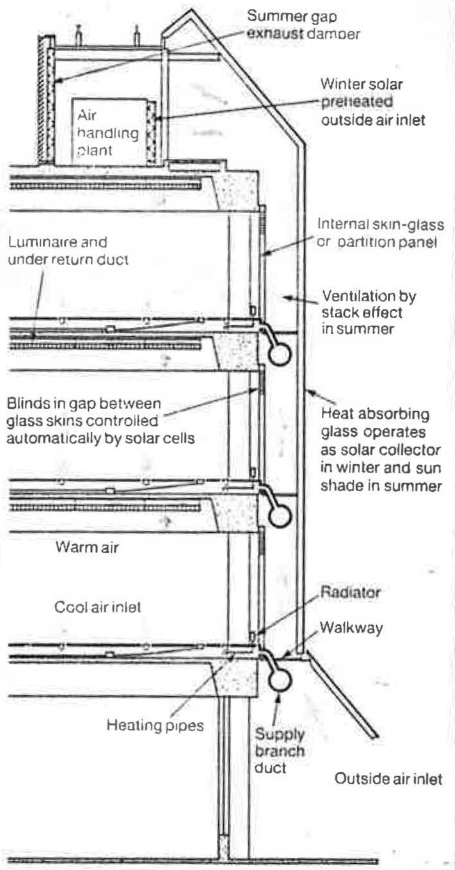
The lamps used were T8/Pluslux "warm-White" and the installed average lighting load (including losses) was 3·67w/m2/100 lux.

Circulation lighting is by purpose made indirect continuous tubelight with swept radiused corners to match the building curve with integral emergency lights and low voltage dichroic spots highlighting columns.

Computer suite circulation spaces utilise pl lamps in downlights and the high entrance/reception area has 250W tungsten halogen downlights and wall washers.

About 50% of the office floor area has been partitioned into cellular offices. These were designed to be placed on the double-glazed, long elevation and have not proved to interfere with the air conditioning, lighting or comfort interior of the building or to need any local control.

Because there are no hard surfaces and false ceilings, special consideration had to be given to sound absorption in the office space. Continuous sound absorbent panels are provided on each side of the luminaires and good quality carpet tiles were used throughout.



Schematic of the air circulation within the building showing how use is made of the space between inner and outer glazing as an air path.

The floor consists of proprietary chipboard panels on supporting pedestals at 0·6 m centres. Obtaining air tightness with this system proved to be more difficult than anticipated and, to be maintained means that alterations need to be carried out with care. The extra cost of a computer room style floor (or a metal channel edged floor panels) for underfloor air conditioning systems appears now to be worthy of probably more serious consideration.

A lot of effort was put into making the whole building air tight.

Originally, desk top air outlets and task lighting were considered in the design but during the design process, the client became part of a larger financial group which dictated that the building had to be capable of subletting to small, local firms. This decision implied a minimum of constraints on the type of furniture such a tenant could use and the consideration of task ventilation or task lighting was, in this respect, abandoned.

The building is being monitored and is working well. The cost of the building as a speculative office development was, at today's prices, around £7·3 million with the building services costing £1·95 million. As a guide to energy use the building has a gross office area of 8250 m^2, a boiler output of 700 kW and chiller capacity in the region of 400 kW and a maximum electrical demand of 500 kVA.

Main suppliers for the air conditioning related work were:
Air handling plant, Matthews & Yates; Chiller, Weathermaker; Floor air diffusers, Designed for Sound; Luminaires, Moorlite, Thorn EMI Lighting; External blinds, Colt Solar Control; Raised floor, H H Robertson. The management contractor was Laing Management Contracting, the pipework was by Brightsides M & E Services, the electrical services by Gratte Brothers and the ductwork by Henry Hargreaves & Sons. The client was Imperial Group Pension Trust Ltd but the building was built for Leslie & Godwin, who is the current tenant.