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ENVIRONMENTAL DESIGN OF ATRIUM BUILDINGS IN THE U.K.

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INTRODUCTION

Atrium buildings were first prominent in the U.K. in Victorian times when glazed features were incorporated into building designs to improve daylight quality while providing shelter. Many fine examples of this form of architecture still exist, the most popularly known types being shopping arcades and main line railway terminals.

U.K. developers and their architects, impressed with the success of atria in North America, have adopted this approach to U.K. developments and, since 1980, more than 200 examples of various types have been constructed. The approach to the servicing of these atria has been cautious, with little definitive design guidance in existence. Some early schemes followed the North American approach of heating, ventilating and, in some cases, air conditioning atria, while others adopted a pioneering approach seeking to embody passive solar principles.

This paper outlines these developments in design and gives examples of recently completed projects. The case is made for a passive solar approach that can be successful in the temperate climate of the U.K. in the majority of cases provided correct design principles are followed. The same approach is suited to those parts of Europe sharing similar climatic conditions to the U.K.

Historical Development of Atrium Buildings

Early architecture developed building forms that included enclosed courtyards. These provided attractive interior spaces which could be private to the users of the surrounding buildings, or open to the public as a thoroughfare and meeting space. The quadrangle formed by this approach ensured that each section of the surrounding buildings was narrow enough for daylight and natural ventilation to be effective and allowed aesthetic landscaping features to be included in the form of trees, shrubs, fountains, statues, and seating. This approach is still common and extremely effective in tropical countries, where a low-cost approach is required for construction and energy usage.

In Victorian England this style was taken a stage further by covering the courtyard with a glazed roof, providing an environment that captured the qualities of external space without the unpleasant effects of bad weather.

The innovative architects of this period were applying technology made available by the Industrial Revolution. Iron and glass could provide well lit, comfortable interiors. An early example is the gallery at Attingham Park, Shropshire, by John Nash in 1806. Many more examples followed in both the U.K. and North America, with perhaps the most ambitious project of the period being Paxton's Crystal Palace near London, erected in 1850 but sadly destroyed by fire shortly thereafter.

Despite the obvious success of these early atria, many of which still stand and are considered prestigious buildings, atria buildings lost favor with architects after 1900. This may have resulted from the development of electric light technology, which allowed architects to design buildings without seeking to achieve good daylighting. Deep plan buildings resulted, with opportunities for increasing densities on restricted sites.

Glass reappeared as a major architectural material in the 1960s, when offices with large proportions of glazed elevations became fashionable. The design concept was based on the belief that the high-tech era of air conditioning had arrived in which engineering services could be designed to cope with the excessive heating and cooling loads created by this design philosophy. The approach was generally disliked by building users and public alike. The energy crisis of the 1970s saw the introduction of building regulations that limited glazed areas on buildings (e.g., 35% maximum single-glazed area on offices).

U.K. architects began to rethink their approach to design. Priorities were changing, public awareness increasing, and technology developing in new directions. The atrium offered many advantages in dealing with these issues while providing a new, exciting approach.

Background to the Modern Atrium

At the present time, the atrium features strongly in building designs. Nearly all projects in which the author is currently involved have some semblance of an atrium, whether it be simply a glazed entrance feature, a conservatory link passage or, as is now commonly the case, a large central space providing a focus for the operation of the rest of the building. Yet the modern atrium is a relatively new concept and is still viewed by some as a fashion. Prior

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to 1980 an atrium feature in a new building was something remarkable. Some of the earlier examples were in fact added to existing buildings as a means of refurbishing and improving amenities while retaining the early character. Coutt's Bank in the Strand is one such example where an atrium now provides banking hall facilities in the former courtyard.

While atria have undoubtedly been acclaimed as extremely pleasant and welcome spaces by an appreciative public, their environmental aim is generally unclear. Should an atrium be regarded as part of the building, providing environmental facilities to match? Or should it be a free-running space acting as a buffer between the main part of the building and the outside climate in which environmental conditions vary from cold to hot according to the prevailing weather? Or is there some intermediate usage in which an atrium can provide an environment suited to the less critical functions carried out in buildings?

The re-emergence of atria in modern times against a background of increasing demands by developers for high rental returns by optimizing rentable space is testimony to their popularity in the commercial market. Their apparent extravagant usage of space is more than compensated for by their additional benefits, added prestige, and ability to attract higher rental returns, as is now the case in office developments.

Hotel developers and operators consider that the inclusion of an atrium to a project will raise its profile to a four- or five-star standard. There is an opinion that an atrium would be out of place on a two- or three-star scheme although in design terms they can undoubtedly be included within budget constraints.

Even at the smaller building end of the market, atria are finding favor with brewers and restaurant operators as a means of extending or improving premises to include attractive, prestige restaurant and bar spaces.

The Environmental Parameter of Atria Buildings

Environmental engineers are thwarted from the outset by lack of definitive design guidance on atria. The CIBSE codes, which represent the industry standards of accepted practice, do not contain direct reference to atria.

Selecting information to use from the codes is undoubtedly misleading. The temperature criterion for office spaces, stated as 19°C (winter), has been derived on the assumption that the space is of conventional shape and size, certainly not 20 meters in height and fully glazed. Heating such a space to 19°C evenly would not only be difficult and expensive, but would not achieve comfort conditions either.

Each atrium building has to be considered at the concept design stage on its own merits by the architect and engineer working in harmony. If previous experience is limited, then the involvement of a special energy and environmental design consultant is essential.

The environmental conditions achieved within the space will principally be determined by the design of the fabric and glazing system.

Environmental services should be designed to complement architectural design, not compensate for it. Heating, ventilating, and cooling of such large volumes is difficult to engineer in practice to achieve reasonable control tolerances and is made more difficult by the constraints imposed by the aesthetics of the interior space.

The size of atria and the perceived expectations of the building users represent a new challenge to architects and engineers. An incorrect approach will lead to overheating and temperature stratification in summer; condensation, cold drafts, and cold radiation effects in winter; a noisy environment; and high running costs leading to user complaints and difficulties in survival of plantings.

TABLE 1
Passive Solar Design Approach Checklist

1. Orientation	Select optimum orientation by matching solar heat gains with building's heat requirements and occupancy usage patterns.	Acknowledge physical limitations in positioning atrium on site.
2. Fabric	Wall and floor to be constructed of high-thermal-mass materials with hard, low-emissivity surfaces. Include insulation layer to prevent heat loss from other surfaces of these elements.	Typical external masonry wall ideal (solid brick or cavity brick and block work). Floor—tiled, concrete slab floating on insulation layer.
3. Glazing	Double-glazed, low-emissivity glass for high thermal insulation, ability to retain heat.	Argon-filled sealed units preferred. Tinted glazing generally not recommended.
4. Structure	Glazing structures to be insulated between inside and outside.	Wood and PVC structures are naturally insulated. Aluminum structures require a thermal break.
5. Ventilation	Design glazing system to include openable windows and rooflights that can be adjusted to vary air pattern and airflow rate.	Control from trickle ventilation to high (summer) ventilation.
6. Heating	Design glazing system to react to solar gains (when available) and internal gains from occupants.	Consider finned tubing perimeter heaters, which provide convective output and local air entrainment adjacent to glass.
	Output to prevent condensation on glazing. Background heating level required to prevent low temperatures in cold weather.	Consider heated floor for background heating with fan convectors for higher temperatures in occupied areas.
7. Stratification	Heat rises to high level, leaving cold air at foot level.	Install anti-stratification fans to promote air movement downward.
8. Shading	Direct sunlight falling onto occupants will cause nuisance overheating.	Install internal shading devices such as lightweight curtains, blinds, planting, and banners.
9. Daylight	Design interior to use daylight potential.	Light-colored surfaces reflect daylight to provide bright, attractive interiors.
10. Artificial Lighting	Some uplighting will complement daylight effect after dark by utilizing light-colored surfaces to reflect light and provide bright, attractive interiors.	Install metal halide (white) or high-pressure sodium (Son plus).

TABLE 2
Summary of Range Atrium Types Relative to Occupancy Comfort Criteria

Atrium Type	Performance Level	Applications	Comfort Criteria: Heating (Winter)	Comfort Criteria: Cooling (Summer)	Lighting
Canopy	Shelter, shade. No air containment.	Shopping precincts. Links between buildings, or alongside buildings.	Ambient air temperature. No heating.	Ambient air temperature. No cooling.	Daytime—Natural Nighttime—150 lux on floor.
Buffer	Winter air containment. Shelter, shade, summer natural ventilation.	Conservatory link. Covered courtyard. Covered shopping center.	No heating. Air temperature above ambient due to internal and solar gains by 5°C+.	No cooling. Natural ventilation used to remove excess heat. Peak air temperatures around 30° to 35°C.	Daytime—Natural Nighttime—150 lux on floor.
Tempered Buffer	Winter air containment. Shelter, shade, background heating. Summer natural ventilation.	Office entrance halls. Enclosed shopping centers.	Air temperature heated to 10°C in occupancy zone.	As above.	Daytime—Natural plus local feature lighting. Nighttime—150 lux on floor.
Partial Comfort	Winter air containment. Shelter, shade, heating. Summer natural and/or mechanical ventilation.	Office entrances and meeting halls. Enclosed shopping centers. Hotels. Restaurants, hospital. Glazed links.	Air temperature heated to 19°C in occupancy zone. Radiant heating to offset cold glazing.	As above.	As above.
Full Comfort	Winter air containment. Shelter, shade, heating ventilation and mechanical cooling.	Office space, banking halls. Enclosed shopping centers. Prestige hotels, restaurants.	Winter design 19°C minimum.	Summer design 25°C maximum. Mechanical cooling.	Daytime—Natural supplemented by local tack lighting. Nighttime lighting levels to 200 lux plus tack lights.
Passive Solar	Can be between buffer and full comfort according to design approach.	Any. Design approach seeks to optimize solar gains during winter and maximize natural ventilation effects in summer.	Winter design up to 19°C as designed. Heating to supplement solar gains.	No mechanical cooling. Thermal stack effects optimized to achieve high air changes. Peak temperatures around 27° to 30°C.	Daytime—Natural Nighttime—General background illumination with local feature lighting.

ENVIRONMENTAL DESIGN—THE THERMAL ENVIRONMENT

Environmental Criteria

There are two aspects to be considered: occupancy requirements and planting requirements. The range of environmental criteria must be determined to suit each, with the most onerous requirement taking precedence.

Occupancy requirements will depend on the use of the space. Is it to be occupied for long periods, or used as an internal circulation space, external link corridor, or perhaps merely as a covering? Table 2 provides a summary of the range of types and their related environmental design criteria.

In many atria with transient occupancy there is a requirement for a receptionist, security guard, or similar person to provide a service for persons entering the building. In these cases it is necessary to provide a "local" environment suited to the needs of these persons, with the remaining environment pertaining to the general use of the space.

Planting requirements will depend on the range of species selected by the landscape architect and any special design features, such as fountains, water spheres, and waterfalls. Table 3 provides a summary of the range of plant species commonly used in atria, with their relevant environmental requirements.

Opportunities for Energy Efficiency

While there is undoubtedly great scope for improving energy efficiency in buildings by the inclusion of atria features, the main thrust in the U.K. toward energy-efficient design of atria has been to persuade developers and their architects that full heating and air-conditioning systems are unnecessary if passive design principles are adopted. The Energy Technology Support Unit (ETSU) of the Department of Energy's Energy Efficiency Office is currently managing a series of research and development projects to develop and demonstrate the potential for passive solar design and the means to its achievement. This work is extremely important if the passive design approach is to succeed. There is very little presently available to designers in the form of definitive guidance. The major design practices have developed their own ground rules based on empirical feedback from completed projects.

In his book "Atrium Buildings," Richard Saxon describes the buffer approach to energy economy in which the atrium achieves a buffering effect between the enclosed habitable space and the full force of the external climate. He notes:

> "The energy economy of buffer spaces is only fully achieved if no attempt is made to keep the spaces themselves comfortable all year round. They are lightly constructed and are colder in winter, hotter in summer than the comfort-conditioned spaces they protect. Uses in the buffer zone need therefore to be seasonally appropriate. In winter, for example, cafes would be for use by people dressed for outdoors; in summer, resort wear would be better. Buildings with expensively heated and cooled atria are, therefore, missing the energy point."

Table 1 includes a simple checklist approach to energy-efficient design of atria.

However, atria can offer further opportunities for improving the energy efficiency of the buildings in which they are included provided an integrated design approach is adopted. These include:

1. The atrium can act as a means of providing preheated air to mechanical air supply systems;

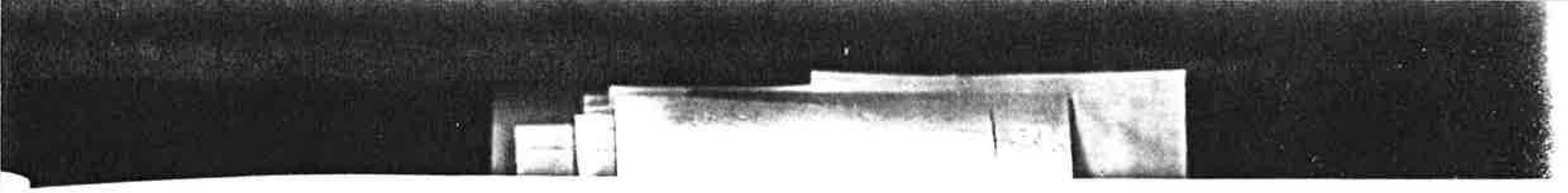


TABLE 3
Summary of Environmental Criteria for Atria Types Relative to Planting

Atrium Type	Environmental Performance Level	Planting Selection	Thermal Criteria Mechanical (Cooling Not Required)	Lighting
Canopy or Buffer	Shelter, shade. No heating. Natural ventilation.	External species.	Ambient conditions. Plants require a seasonal change winter to summer.	Daylight. Artificial lighting to 2000 lux may be required in shaded corners.
Tempered Buffer	Winter air containment. Background heating. Summer natural ventilation.	Semi-tropical species.	13°C minimum. High air temperatures tend to dry plant in summer and additional watering required to compensate.	Daylight. Artificial lighting to 2000 lux required in shaded corners and to compensate for short winter days.
Partial or Full Comfort	Heating. Mechanical ventilation. Mechanical cooling.	Semi-tropical or tropical.	13°C minimum. Air supply grilles to avoid air delivery onto plants. Air velocities 1 m/s maximum.	Daylight. Artificial lighting to 2000 lux or 3000 lux depending on species. Lighting to compensate for short winter days in U.K.

2. Underfloor heating of atria can be served from a condensing boiler plant. Floor temperatures of 30°C, requiring flow temperatures of around 40° to 45°C, will help to reduce return temperatures to 35° to 40°C, achieving condensing boiler efficiencies of more than 90%;
3. Similarly, electrically driven air-to-water heat pumps can be utilized to deliver low-temperature heating water (40° to 45°C) to underfloor circuits, achieving unit coefficients of performance of more than 3:1, making their running costs below that of natural gas;
4. Since electrical supplies at night are at a reduced tariff, heat pumps can be used to deliver heat into the floor fabric to raise temperatures overnight for use during the day (a form of off-peak night thermal storage).

This will be the next phase of development of atria buildings, driven by the desire for improved energy efficiency and the opportunities for negotiating favorable fuel rates with the supply companies once the U.K. privatization of the electricity industry is completed.

Heating

Where an atrium requires a heating input, a design solution must be derived that takes account of design criteria (occupants, plants), interior design aesthetic, energy efficiency, and condensation risk.

Design Criteria The thermal component of human comfort can be measured by resultant temperature as follows:

$$t \text{ resultant} = 1/2\, t \text{ mean radiant} + 1/2\, t \text{ air}$$

In an atrium the mean radiant temperature is a derivative of the temperatures of the surrounding inside surfaces. In winter some of these will be low enough to create an uncomfortable cold radiant effect. Single-glazed vertical glass walling may have an inside temperature of 5°C with an outside ambient of −1°C. This cold effect is further noticeable by radiation interchange between the human body inside the atrium and the cold surfaces of buildings outside and the clear night sky. Another factor may be the patent glazing framework if a metal system is employed that does not incorporate a thermal break.

To raise the mean radiant temperature to acceptable levels the following should be adopted where possible:

Radiant Heating: Atrium surfaces are usually of "hard" solid materials such as stone, marble, and travertine. Radiant underfloor heating systems achieving surface temperatures of between 30° and 35°C will provide a warm radiant component close to occupants.

Glass Heating: Introduce heating at the foot of external glazing to provide a warm air curtain rising vertically across the glass. This will raise the inside surface temperature of the glass. (Note: also under "condensation.") Successful solutions have been based upon bare and finned tubes installed within a floor duct or pelmet across the foot of the glazing with floor grilles installed for aesthetic and functional purposes. Heating outputs from tubes can be selected according to the size of the tubes, spacing and size of fins and material of construction, with copper being favored, as it provides higher outputs per unit length than alternatives such as steel.

Specify patent glazing systems which incorporate a thermal break.

Specify double glazing with low-emissivity coating.

The air temperature of an atrium is likely to vary both vertically and horizontally and this variation may be large, depending on the height and volume of the space and relationship between external walls and interior space. In design terms, the air temperature of concern is that within the "occupied zone" which, in practice, is contained within the volume of air up to 3 meters above floor level.

Where perimeter heating and underfloor heating are employed, an air temperature in this zone can be achieved to provide satisfactory buffer space comfort conditions with certain areas away from the perimeter at higher comfort levels, if desired.

The problem becomes more complex when the atrium has more than one level used by occupants. In these cases it probably will be difficult to provide underfloor heating to upper levels if these are relatively narrow walkways or balconies. Some form of mechanical ventilation will be needed to provide local conditions to an acceptable level. Fan coils will suffice but ducted air systems can be used if the system can be integrated into the scheme. Air distribution must deal not only with warm air delivery but also achieve anti-stratification at these intermediate levels.

Building services design of all heating system components must take into account planting requirements. Table 4 summarizes the main points to be observed.

Atrium heating from adjacent spaces. Heat from adjacent spaces, i.e., offices and shop units, which are in a heat excess situation, can usefully be dumped into the atrium to provide "free" heating.

Ventilation

Ventilation of atria concerns the removal of hot air in summer to maintain reasonable comfort levels. Ventilation for air quality is not an issue since the large space volume

TABLE 4
Atrium Heating Planting Criteria

ITEM	DESCRIPTION	CRITERIA
Radiant Temperature	Radiant temperatures unlikely to affect plants if in normal comfort range.	None
Air Temperatures	Plant well-being related to air temperatures.	13°C minimum for most indoor species.
Air Distribution	Plants dry out if subjected to air at high velocities and/or high temperatures.	Air movement across plants below 1 m/s. (Do not position grilles/diffusers/fan coils to direct air onto plants.) Ensure air mixing reduces air temperature below 25°C before reaching plants.

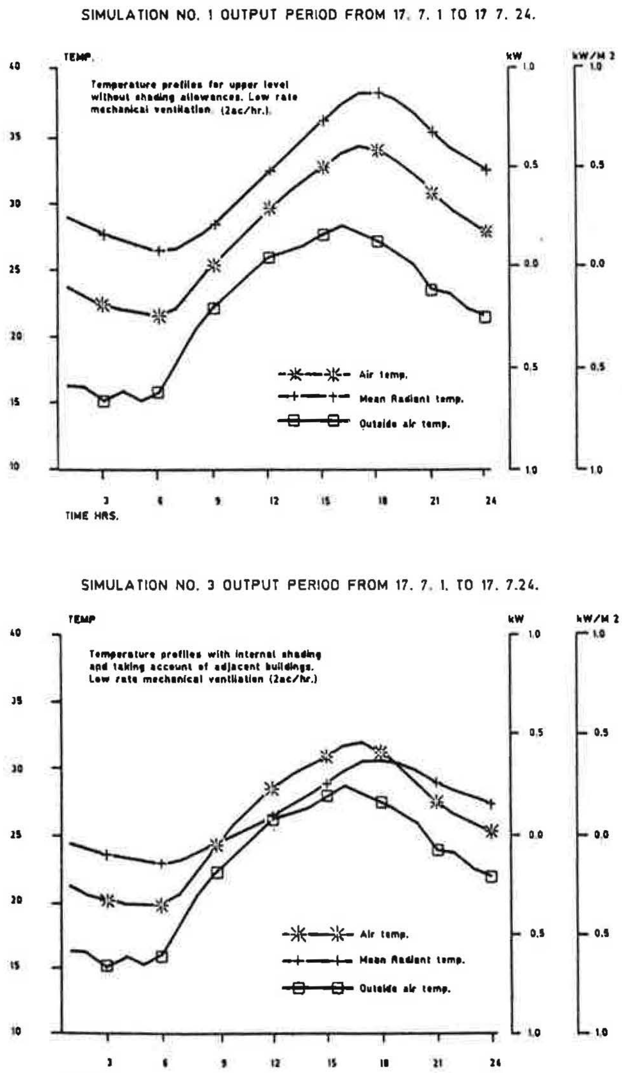


Figure 1 *Analysis of summer overheating in the proposed atrium entrance hall of a London banking headquarters.*

Simulations carried out on ESP program and based on low air change rate of 2ac/h.

and the likely adventitious fresh air openings mean that fresh air levels will always be satisfactory.

While many of the earlier U.K. atria of this decade include air conditioning, subsequent research and development have shown that this can be avoided in most cases, provided high air change rates can be achieved in occupancy zones. In this development period studies revealed that design results achieved using traditional calculation techniques, which had been derived for "conventional" spaces such as offices, hospitals, and the like, provided heating and cooling loads far higher than necessary to achieve comfort. More sophisticated calculation procedures have been developed which rely on computer simulation of the building's behavior. In my design work, I use the ESP thermal modeling program. This uses finite element analyses to simulate energy flows into and out of the building fabric.

This program models heat flow in three dimensions taking due allowance of the thermal properties of materials and the influence of heating and cooling regimes. Heat flow and storage into and out of fabric materials are closely predicted and their effect on internal space conditions and energy use is carefully analyzed. Figure 1 illustrates the results from an analysis carried out on a proposed atrium entrance hall to a new banking headquarters in London.

It has been found that the results from modeling programs such as ESP are closer to reality for atria spaces than traditional calculation methods and consequently designs are increasingly being based on dynamic modeling analyses. This trend has major implications for U.K. building designs, which may well have relevance in parts of North America:

a. The temperate climate of the U.K. means that "free cooling" by natural ventilation is a viable option even in summer, provided air inlets and outlets can be correctly sited and sized.
b. Peak summertime conditions in the U.K. occur for relatively short periods. The traditional summer design outside air temperature of 26°C is exceeded for 0.8% of the time in the three-month summer period (June to September) in the London area based on averaged historical weather dates. This equates to a total of 9.6 hours in this period which means that, on five or six days, air temperature will rise above 26°C for a period of two or three hours in the afternoons.
c. Peak air temperatures do not usually coincide with days of peak solar radiation or high humidity. It is rare for all these factors affecting thermal comfort to occur simultaneously.
d. Since the use of the majority of atria relates to transient space, high air temperatures can be accommodated without compromising comfort standards.

The passive solar design approach identifies ways of reducing the impact of these climatic peaks as follows:

- thermal mass in walls and the floor to absorb solar gains and reduce peak temperatures;
- use the stack effect to promote fresh air ventilation;
- use cross-flow wind effects to increase natural ventilation when available, and;
- incorporate natural shading devices to reduce the impact of direct solar gains.

The combination of thermal inertia and controllable fresh air rates results in an internal environment which is acceptable to users. Natural ventilation rates of atria can, in fact, be extremely high in some cases. For example, figures of 30 to 40 air changes per hour have been recorded in the glazed shopping street at the Skarholmens Center, Stockholm, in summer.

Air Conditioning

While the general design approach adopted is to avoid air conditioning of atrium spaces, there will be occasions in which such an approach is essential to the successful operation of the building. One such example is the Waverley Market shopping center in Edinburgh. This large specialty center occupies a central site in this historic city and planning requirements dictated that it had to be constructed into the ground to maintain sight lines from Princes Street through to the castle and buildings on the Royal Mile. The project architects were able to create an open daylight center by glazing across the roof and providing attractive landscape gardens within. However, natural ventilation could not be achieved since low-level inlets were limited. Instead, a ducted air-conditioning system serves the mall with heating and cooling delivered from central air-to-water reversible heat pumps. These also provide circuits to shop units and, when operating in the heat recovery mode, use waste heat from shop units to heat the atria and mall.

ENVIRONMENTAL DESIGN—OTHER FACTORS

Acoustics

The success of an atrium space in providing "comfort level" environmental conditions will depend not only on its thermal and visual qualities but also on its acoustic quality. Being large internal spaces with many of the qualities of external spaces, they represent a difficult design problem in this respect.

The following noise sources need to be taken into account:

Noise Source	Design Parameters
1 External noise from plant rooms, traffic, aircraft.	Siting and orientation. Location of glazed/fabric walls. Acoustic performance of glazing system.
2 Noise from adjacent spaces.	Acoustic performance of partition walls, separating doors. Noise absorption of finishes in adjacent spaces and in atrium. Architectural planning of spaces around atrium.
3 Noise from H&V systems.	Location of H&V plant and distribution systems. Selection of plant and terminal equipment, pipe and duct sizing. Selection of noise and vibration attenuators.
4 Noise generated within the space.	Acoustic properties of atrium materials and finishes. Internal shape of atrium volume. Internal design layout, position of acoustic obstructions (walkways, columns, desks, lifts, etc.). Inclusion of space sound absorbers (banners, draperies, flags, planting, trees, and umbrellas).

Atrium Acoustic Properties

Glazing The dominant feature of any atrium is the glazing system. Depending on the type of atrium, this will cover some or all of the wall surfaces and the roof. Glass panels act as low-frequency absorbers. By filtering out low-frequency noise and leaving behind medium- to high-frequency noise, glazing promotes a "shrill" acoustic character. One result of this is that speech and footsteps, which are mid-frequency-band noises, are retained and reflected around the space.

Floors and Walls Atrium floors tend to be finished in hard materials such as travertine quarry tiles which, in turn, overlay a concrete screed and/or slab. Atrium walls also tend to be finished in hard materials such as travertine, or concrete blocks and painted plaster, which are attached to brickwork or blockwork walls. These materials tend to create extremely resonant "ecclesiastical acoustics."

Functional and aesthetic requirements of the atrium usually dictate these hard finishes. However, there is scope for the inclusion of absorptive panels at strategic locations in the wall cladding. It is not necessary to treat all wall surfaces in this way. A 25% to 30% coverage applied in discrete sections at carefully chosen positions will have a dramatic effect.

It should be noted that to act as a passive solar collector the atrium requires internal surfaces that will absorb and store solar gain. Acoustic paneling will reduce the available area for solar absorption.

Shape Most atria are rectangular or square and are designed with attractively styled flush internal surfaces. This layout promotes cross reflections between walls, which will reinforce certain frequencies and cause an uneven distribution of sound. Internal modeling should be encouraged. A layout that serves to break up reflected noise will reduce reverberation time and lower the overall noise levels.

Sound Absorbers

At early design stages the designer is likely to design the atrium form interior without developing the detail. However, a range of features can be established to assist acoustic design. It is not necessary to determine the details to gauge their effect on the acoustic environment. Instead, a design discussion that establishes the type, extent, and approximate positions will yield useful data from which acoustic judgments can be made.

Feature	Acoustic Property
Trees	Large trees act to break up noise paths through the space, reducing reverberation. Effect depends on size and thickness of foliage.
Bushes, shrubs	Dense shrubs at low levels in planting boxes act as local acoustic absorbers. Help to shield speech noises, break up low-level noise paths.
Banners, draperies, flags	Usually mounted at high to medium level, these features break up acoustic paths to glazing panels, reducing the "shrill" effect. Effectiveness will depend on size and thickness of cloth.
Umbrellas, kiosk roofs	Usually located around a reception desk, meeting area, etc. Act to provide local acoustic shading, reducing speech transmission to rest of atrium. Also shields these areas from noise elsewhere.
Desks, furniture	Dependent on materials of construction, finishes, and location relative to surroundings. In general, furniture will act to break up sound paths and provide some degree of absorption.

Lighting

To satisfy landscaping requirements it is necessary to design a lighting scheme that delivers the required levels to plants when daylight is not available. In the U.K. the short winter days of five to six hours daylight mean that semi-tropical and tropical species will require artificial lighting to make up the eight, nine or, in some cases, ten hours of light they require. However, when daylight is available, artificial illumination should be switched off.

Atria offer benefits in terms of daylight to adjacent spaces including:

- their thermal performance allows windows to adjacent spaces to be enlarged to compensate for light loss due to obstruction due to the conservatory or atrium itself.
- the amount of daylight that reaches the lower levels of an atrium and is available for daylighting of adjacent spaces depends on the proportion of the atrium (the room index) and the reflectivity of the inner surfaces. Wall surfaces should be light in color.
- as light availability diminishes at lower levels in a four-sided atrium, windows should increase in size, leaving the greatest area of reflecting wall at the upper levels.
- to gain any advantage from daylight, the artificial lighting control must be able to respond to it. Dimming controlled by photocells is a normal provision, although manual switching may be more cost-effective in some situations.

Wind Effects

Designers have become aware of the need to identify the effects of wind on atria to avoid problems such as strong winds causing problems to building users; malls and entrances becoming "wind tunnels"; high winds leading to excessive air change rates and heat losses; winds blowing exhaust fumes back into occupied areas; and, in the event of fire, winds blowing smoke back into the building, defeating the thermal stack effect of the atrium and causing smoke dumping into occupied areas.

Predicting the effect of wind influences on buildings requires a special knowledge of the behavior of wind in built-up areas. Besides information on prevailing wind strength and direction, an analysis of the effect of the local land topography and adjacent buildings is required. The micro-climate created around a site can often be quite different from the general conditions of the area. I have found that a successful approach has been achieved by involving the aeronautical department of a local university to carry out studies to identify possible problems.

The combination of specialist knowledge of aerodynamics and environmental design provides the basis for sound solutions that are acceptable to the design team, the client, and building users. A recent example of this approach is the new shopping center being integrated into the historic city of Lancaster (England). Planning requirements mean that an existing open square would be retained along with certain fine quality buildings. However, it was predicted that prevailing winds in winter would descend into the large open square and funnel toward the entrance to the shopping mall, creating a nuisance and blowing in dust and litter. The solution, which overcomes this problem and satisfies aesthetic requirements, is a large sculpture, positioned and shaped to deflect wind upward over rooftops.

Of course in this instance canopies, kiosks, and the like would not have been allowed under the strict planning controls in force and few would argue that this solution is not, in fact, the most appropriate.

On some projects, wind effects are difficult to assess by analytical methods and it is then necessary to carry out wind tunnel tests to allow measurements to be made on scale models of the scheme, by which various options can be evaluated.

Fire and Smoke Control

Design requirements for the control of fire and smoke are still in the development stage in the U.K. For the purposes of this paper the following brief notes are provided as an update.

Background Atrium buildings in their present form are relatively new in this country and many of the problems of fire in them are unique to this building type. Experience of real fires often initiates new design thinking, but world-wide experience of atria fires is very limited. As a result, the legislation and design methods relating specifically to atria are sparse and often reflect the uncertainties involved.

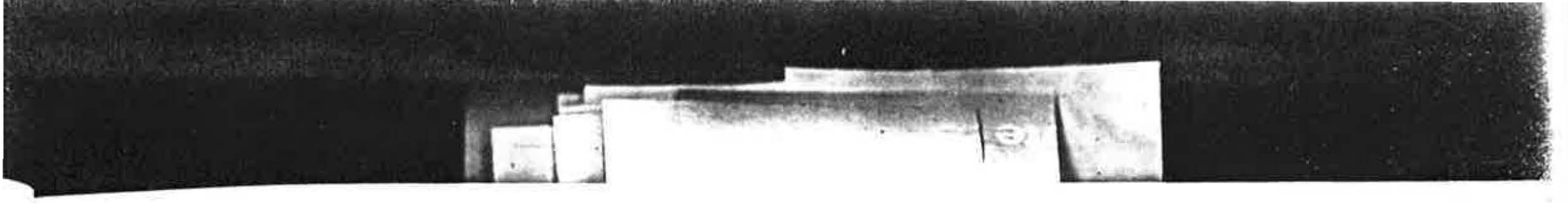
Fires in both the atrium space itself and in adjacent spaces (which are normally open or have glazing into the atrium) must be considered. This is because a fire in an adjacent space may break the intermediate boundary so that flames and smoke can enter the atrium itself. The problem is then to limit the spread of fire and remove smoke from the atrium.

Legislation on Fire Safety Statutory legislation on fire safety is very general, with most project-specific decisions left to the local fire officer, who issues a fire certificate. Local authorities (particularly those in large cities) often have their own legislation which may be adopted by other areas.

Good summaries of general legislation are given in "Fire and the Architect" (Fire Prevention Information Publications Centre), Section 1 and the CIBSE Guide, Volume B. A more detailed description is in the NJCC Guidance Note 3: "Fire Officer Recommendations," and the CIBSE Technical Memorandum TM2: "Notes on Legislation Relating to Fire and Services in Buildings," 1979.

There are many non-statutory codes and standards, some of which may be stipulated for insurance purposes or by fire officers, according to the individual case; a detailed description is given in CIBSE Technical Memorandum 9. The most important of these are the British Standards, in particular BS 5588: "Fire Precautions in the Design and Construction of Buildings," with different parts relating to different building types; 1985 Building Regulations and other British Standards on materials, fire alarm systems, etc. The BS 5588, Part 10, on shopping malls (in draft form only) is to be revised shortly and a new Part 7 on atrium buildings is currently in preparation and due for publication later this year.

Legislation specific to atria is very limited. Some is described in "Fire and the Atrium" by Ferguson (1985), which makes several references to the Technical Information note produced by the now-defunct GLC in 1985, "Fire Safety for the Atrium." This had detailed regulations on all aspects of fire safety for atria, and had legal status in London. A replacement document, "Fire Safety in Atrium Buildings," has been published by the London District



Surveyor's Association. This document has a general section, Part 1, and subsequent sections specific to different building types. Responsibility for ensuring fire safety in London has passed to the District Surveyor and the fire service.

Some of the rules in these London documents are somewhat arbitrary or untested (such as the use of drencher systems on glazing), but they appear to be the most comprehensive and detailed guidance currently available. The GLC/LDSA documents do not apply elsewhere in legislation, but may be used as a guide outside London in the absence of other standards.

CONCLUSIONS

Developers and their architects now desire to include atria and similar glazed spaces in their buildings. Such features are seen to be attractive by users of these buildings and provide additional beneficial indoor space. Both new and refurbished buildings can be treated in this way and the glazed spaces created are often designed as major features in anticipation of the pleasant environment created.

While these atria are often included as a means of energy efficiency, usually with a package of energy conservation measures, their principal purpose is aesthetic. Such is the desire to create a comfortable, visually pleasant environment that developers often choose to heat and air condition such spaces fully and to ignore passive solar benefits. Furthermore, time and financial constraints prevent a proper analysis of the design proposal and measures adopted so that no clear guidance is available to the designers.

Leading U.K. practices are discovering that a passive solar design approach can achieve acceptable environmental conditions with minimal energy input and low-tech engineering can save on plant capital and running costs. This also adds to the aesthetic of the interior by reducing the need for air ducts, grilles, etc.

Various research bodies are pursuing this design philosophy in order to develop the basic design rules which designers must follow if a scheme is to be successful. Failure to embody passive design principles will lead to overheating in summer, underheating in winter, and render the atrium unsuitable for use. Expensive landscaping schemes may be destroyed.

The Building Services Research and Information Association (BSRIA) has proposed the creation of an atria club through which members could share in research and development of the environmental design of atria.

The Department of Energy's passive solar research and development program has included a series of building studies with the aim of providing information that can be used by designers in future projects. These studies will assist in developing the design techniques to be used when considering atria schemes and the ways in which they contribute to energy efficiency.

Two sets of passive solar design studies have now been completed, one involving dwellings, the other non-domestic buildings. A second series of design studies is now under way and the present project concerns atria and conservatories in non-domestic buildings. Simultaneous design studies are being undertaken by the Department of Energy on "direct gain" in non-domestic buildings and on a further series of dwellings.

The structure of the current series of 12 studies has been developed from the success of the previous series, taking account of important lessons learned. Each study will involve a design team developing a building project to the sketch design stage based on a realistic brief prepared in consultation with a quasi-client. The design team will have access to special design advice to aid in the selection of suitable passive solar elements. As the design progresses, cost- and energy-related performance assessments will be undertaken and the information fed back to assist in refinement of design. The beneficial aspects of the atria features will also be assessed in discussion with the building client.

The selected case study projects will be based on existing completed schemes with a number of years of operation. These will be identified as those showing the most potential for benefit by inclusion of passive solar features.

These studies will generate exemplary building designs which will relate to future building designs. Through the studies the applicability, performance, and cost of passive solar and energy conservation measures will be analyzed.

Atrium buildings offer great benefits in terms of energy efficiency as well as building use provided the correct environmental design rules are followed. Building Services engineers in the U.K. must respond to the challenge of these new building types by understanding and applying these design rules to ensure that solutions are ultimately successful.

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DISCUSSION

B. Sun, M.E., Flack & Kurtz Engineers, San Francisco, CA: What are the current code(s) requirements for fire/smoke control in an atrium building in the U.K.?

F.A. Mills: The current situation regarding fire and smoke control in an atrium building is that there is no nationally accepted code suitable for covering the problems these buildings pose to designers. Of course, in the UK, the design and construction of buildings in general terms are covered by our building regulations. These were essentially introduced from a life safety and health point of view but have recently been extended to cover items such as energy efficiency. Separate sets of regulations exist for England, Wales, Scotland, and northern Ireland. The England and Wales regulations, which cover the majority of UK building work, include Part B on "Fire Spread" to deal with fire and smoke control.

However, in practice, an atrium cannot comply because it exceeds the maximum fire compartment size defined (allowed) in the regulations. A designer must, therefore, meet with the local building control authority and local fire officer (local to the area where the project is being constructed) to discuss—and agree to—ways in which an oversized compartment, such as an atrium, can be accommodated. A number of alternative codes, which are referred to in my paper, do exist which can be offered as the basis of a design approach.

The situation should be resolved later this year with the production of a new British standard (BS) that will be Part 7 to the existing BS5588, "Fire Safety in Buildings," and will deal with "Fire Safety in Atrium Buildings." I am a member of the team producing this BS and can report that work is at an advanced stage and a draft should be ready for consideration by the BS Committee by summer, 1990. Once the BS is agreed upon and published, it will be accepted as a national design code and will be adopted immediately by local authority and fire officers and, of course, eventually included as a reference within the building regulations. I can report that in producing the BS we have taken note of all relevant codes worldwide, including, of course, North America.

Please note that while a British standard does not carry any legal status of its own accord, it can be adopted as a legal requirement by the authorities as described above. It can also be adopted in the absence of other standards or a European standard, this being agreed to by the relevant CENTEC Committee. At present, there are specific European standards covering this subject.