# BUILDING 2000

## Commission of the European Communities

- Magistrates' courthouse containing 10 courthouses, public waiting areas and other facilities
- Orientation allows high proportion of south-facing glazing
- Spread-out building form incorporating central courtyard allows much of the building to receive daylight and natural ventilation
- Provision of direct gain spaces two storeys high
- Preheating of ventilation air for courtroom by heat extracted from exhaust from direct gain spaces
- All courtrooms receive direct and/or borrowed daylight

# MAGISTRATES' COURTHOUSE

## ROTHERHAM/UNITED KINGDOM

**Building 2000** is a series of design studies illustrating passive solar architecture in buildings in the European Community.

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# PROJECT DESCRIPTION

## Building Type

This project concerns a new magistrates' courthouse for the Rotherham District in the County of South Yorkshire, UK. The building contains 10 courthouses plus public waiting areas and other public facilities, magistrates' facilities including retiring rooms, solicitors', police and press facilities, public counters for payment of fines and administration offices.

## Location

The building is being constructed on the edge of Rotherham town centre (latitude 53 ° 26 ' N) in the industrial valley of the River Don, much of which is now being redeveloped for commercial use (see Figure 1). The site is 25 m above sea level and is roughly triangular in shape, bounded by a canal, a railway line and the local police headquarters (see Figure 2). In winter, the latter causes overshadowing between 10.00 am and 1.00 pm.

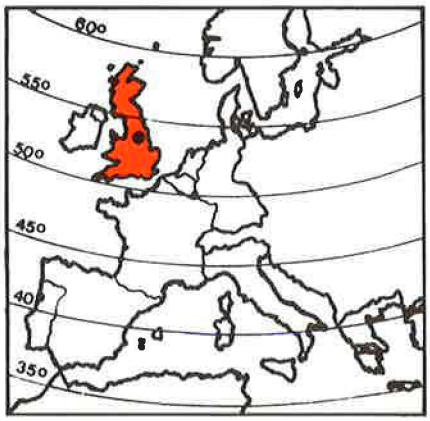


Figure 1. Location of Rotherham

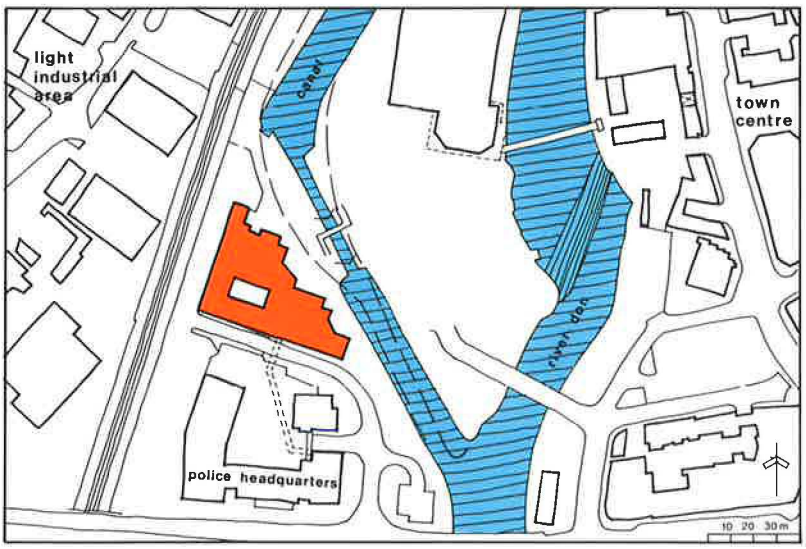


Figure 2. Site layout

## Site Microclimate

The climate is maritime in character with relatively mild winters and fairly cool summers. Passing frontal systems travelling east from the North Atlantic make the weather changeable and bring cloud and rain. Their effect is moderated by the presence of the Pennine hills to the west of Rotherham. The total annual rainfall is 808 mm. Winds are predominantly from the south-west but in winter there is the occasional severe east wind. Monthly mean solar irradiation, degree day, sunshine hour and temperature data are given in Table 1.

| Month | Solar irradiation on horizontal plane global | diffuse | Degree days base 18 ° C | Sunshine hours | Air temperature |
|---|---|---|---|---|---|
| | MJ/m$^2$ | MJ/m$^2$ | ° C days | hours | ° C |
| January | 144 | 70 | 447 | 38 | 3.4 |
| February | 248 | 99 | 411 | 54 | 3.5 |
| March | 483 | 166 | 390 | 92 | 5.5 |
| April | 637 | 220 | 307 | 129 | 8.3 |
| May | 816 | 237 | 215 | 162 | 11.3 |
| June | 851 | 207 | 125 | 183 | 14.5 |
| July | 829 | 246 | 88 | 160 | 16.0 |
| August | 712 | 233 | 89 | 142 | 15.7 |
| September | 510 | 187 | 137 | 111 | 13.9 |
| October | 347 | 128 | 237 | 84 | 10.7 |
| November | 181 | 73 | 347 | 43 | 6.6 |
| December | 104 | 46 | 421 | 35 | 4.6 |
| Total | 5863 | 1912 | 3214 | 1233 | |

Table 1. Solar irradiation, degree day, sunshine hour and temperature data

## Design and Construction Details

### Design Objectives

The design objectives were as follows:
- to reflect the authority of the courts;
- to reflect the open and public nature of the administration of justice;
- to segregate the circulation routes of the different categories of people using the building (magistrates, defendants, adults, juveniles);
- to provide a humane and comfortable internal environment for all buildings, relying as much as possible on natural ventilation and daylighting and exploiting the potential for passive solar heating;
- to make a positive contribution to the town centre, not only by creating an important public and civic building but also by providing well-designed outdoor spaces around and within the complex which relate to the canal and pedestrian approaches;
- to achieve a building with low running costs;
- to provide security and deter vandalism.

### Design Details

Plans, sections and elevations, etc., are shown in Figures 3-11 and design data are given in Table 2. The courtrooms are arranged in two staggered two-storey blocks separated by the main entrance. Together with the L- shaped administration block they enclose an open landscaped courtyard in the middle of the complex. One block contains juvenile courtrooms; the other contains formal and informal adult courtrooms. The large, high- security courtroom is on the lower ground floor next to a secure holding area for defendants in custody. Both courtroom blocks have a public waiting/circulation space, two storeys high, along the southern edge. In both blocks, vertical circulation for magistrates and defendants in custody are kept separate, the horizontal connections being made on the lower ground floor. A sidewalk between the building and the canal provides a pedestrian through route across the site and connects with a bridge across the canal which provides the major approach to the site from the town centre. At intervals the canal walk widens into larger public spaces. The three public entrances to the building open off these.

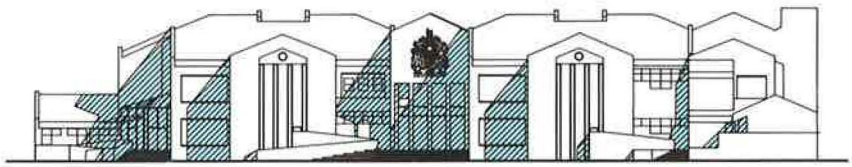

Figure 3. North elevation

### Construction Details

The building has a heavy structure for security reasons and to provide sound insulation. This takes the form of reinforced concrete framework and floor slabs with brick cavity-walling and dense concrete block internal partitions. The external walls have 100 mm brick outer leaf, a cavity filled with mineral fibre insulation and 140 mm dense concrete block inner leaf. The partly-buried external walls of the lower ground floor and all concrete floor slabs in contact with the ground or exposed to open air are also insulated with mineral fibre. The roof is a timber and steel structure insulated with mineral fibre quilt and clad with slate. There is double glazing throughout. In highly glazed walls the inner pane is of toughened glass - as is the outer pane in all glazing on the bottom floor. All materials and constructional detailing are robust to resist damage from vandals. U-values are given in Table 3.

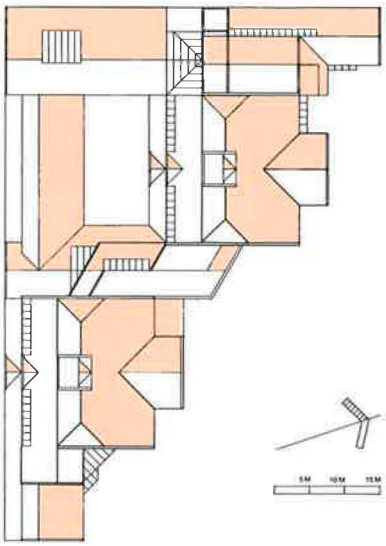

Figure 4. Roof plan

| | |
|---|---|
| Floor area | 4800 $m^2$ |
| Roof area | 2300 $m^2$ |
| External wall area (including all glazing) | 3650 $m^2$ |
| Glazing areas | |
| total | 750 $m^2$ |
| south facing | 400 $m^2$ |
| Budget cost (1989) £6,750,000 | |

Table 2. Design data

| | |
|---|---|
| Roof | 0.23 |
| Glazed roof | 3.20 |
| Floor | 0.33 |
| External walls | 0.36 |
| Double-glazed curtain walling | 3.20 |
| Windows | 3.20 |

Table 3. U-values in $W/m^2 K$

# DESCRIPTION OF PASSIVE SOLAR FEATURES/COMPONENTS

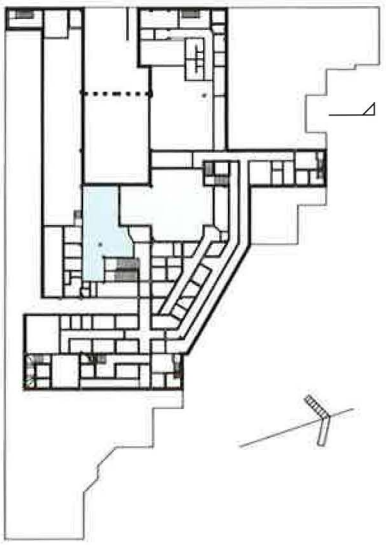

Figure 5. Lower ground floor plan

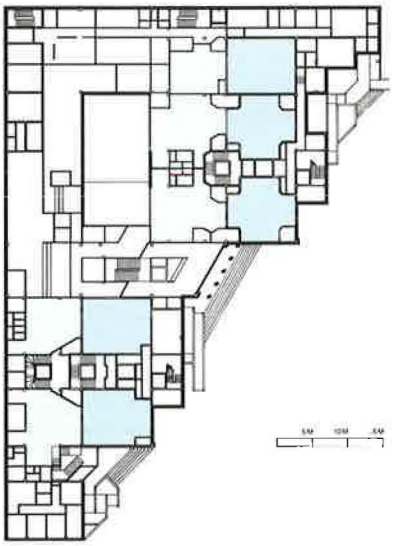

Figure 6. Ground floor plan

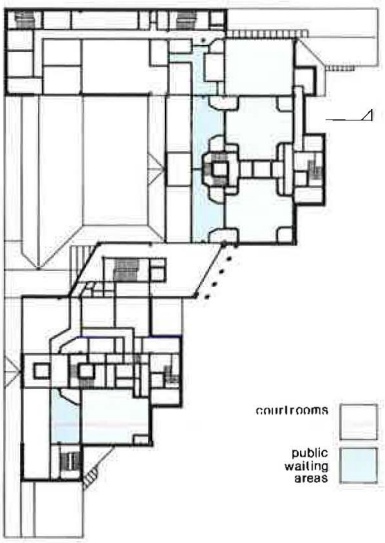


Figure 7. First floor plan

## Introduction

When the brief was formulated, the magistrates expressed a strong desire for daylighting and natural ventilation (as opposed to artificial lighting and air conditioning) to be used as much as possible in the new building. This is in line with current UK trends away from deep-plan air conditioned buildings. Since running costs are important in this project, it was decided to follow up the magistrates' preferences and explore the use of design features which allow natural light and air to penetrate the building and permit passive solar energy to contribute to its heating requirements.

## Passive Solar Features

### Orientation

The building has been oriented north-south to enable a high proportion of glazing to be located on south-facing walls. The north, east and west glazing has been minimized.

### Building Form

The building has been spread out over the whole site and arranged around an open courtyard, rather than made compact and monolithic in form. This allows more rooms to be located on external walls and, therefore, to be daylit and naturally ventilated. It also increases the proportion of south- facing glazing. The part of the building to the south of the courtyard has been kept low to minimize overshadowing of the courtyard.

### Direct Solar Gain

Early in the design development it was recognized that the public waiting/circulation areas, especially, had the potential to use direct solar gains to offset heating costs. Accordingly, it was decided to locate these spaces on the south side of the courtrooms and give them large amounts of glazing. Subsequent decisions resulted in these spaces becoming two storeys high. Solar heated air will be extracted at high level from these spaces and redistributed or used to pre-heat ventilation air for the courtrooms. Locating the waiting areas on the south side has the added advantage of making them bright and sunny spaces - which could help to relieve stress and tension in those waiting for court hearings. The large amount of glazing will also make it easier to supervise these areas.

### Insulation

Although the spread-out design increases the potential for daylighting, natural ventilation and solar gain, it also increases the possibility of heat loss. This is offset by incorporating more insulation into the building envelope than that required by the new UK Building Regulations.

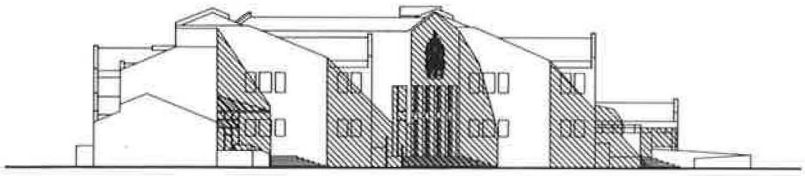

Figure 8. East elevation

Figure 9. South elevation

Figure 10. View from south

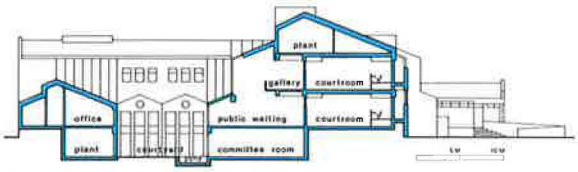


Figure 11. Section

### Thermal Mass

The heavy structure required for security and sound insulation reasons will also provide sufficient thermal mass for heat storage and enough thermal inertia to help prevent summer overheating.

### Ventilation/Cooling

Wherever possible, ventilation is provided by natural means (i.e. opening windows) and controlled by building occupants. Where greater environmental control is required, such as in the courtrooms, a system is installed to supply fresh air mechanically. The input air will be pre-heated, if necessary, in the direct gain spaces. In the six courtrooms with direct daylight the magistrates will be able to switch off the mechanical air system and open the windows if they wish.

In summer, the air flows generated by temperature stratification and natural ventilation will keep the public waiting areas cool and ameliorate the effect of overheating in these highly-glazed spaces.

### Shading

Automatically-controlled retractable blinds will be installed on all south- facing roof glazing and some vertical glazing.

### Control

Although occupants will be able to control their own environment in much of the building, a building management system will be installed to control and record all aspects of the building's energy consumption and use.

## Daylighting Features

The spread-out design permits daylight penetration into a greater proportion of the internal spaces.

The central courtyard allows much of the lower ground floor to be daylit.

Usually, courtrooms are located in the interior of buildings. In this project, six out of the ten courtrooms have been placed on an external wall and thus receive direct natural light. In addition, borrowed daylight has been introduced into nine out of the ten courtrooms via the highly-glazed two-storey public waiting/public circulation spaces.

Stairwells allow daylight to penetrate the lower reaches of the building.

A pond in the open courtyard enlivens the daylighting in the Magistrates' Committee Room on the lower ground floor.

## Operation of Passive Solar Systems

### Basic Principles

The public waiting areas are used as direct gain sunspaces. As these areas are occupied by members of the public wearing outdoor clothes, the temperature in these spaces is allowed to float. It is felt that a minimum temperature of 16 ° C is acceptable in winter and a maximum of 26 ° C in summer. The predicted temperatures reached in these areas in the different seasons are given in Figures 12-14.

Conditions in the courtrooms are more critical and will be controlled when required to 19-21 ° C. When the temperature in the waiting areas is above the minimum set point in winter, warm air is extracted at a high level and passed through a heat exchanger to preheat the fresh air input to the courtrooms. The preheating takes place in recuperators built within the main air handling plant.

Blinds are fitted to all glazing in the public waiting area to limit solar gains in summer. To reduce any overheating which does occur, low and high vents are opened to allow outdoor air to pass through these spaces by the stack effect.

The courtrooms are also ventilated using a displacement air system. Fresh air is introduced at a low level and at a temperature slightly lower than the temperature required in the space. The system provides pleasant and healthy air because it avoids the mixing of stale and fresh air and the recirculation of used air. However, because 100% fresh air is used, heat recovery has to be incorporated into the plant.

### Auxiliary Heating

Auxiliary heating in the courtrooms and public waiting areas is by low-pressure hot water radiators or perimeter heating convectors.

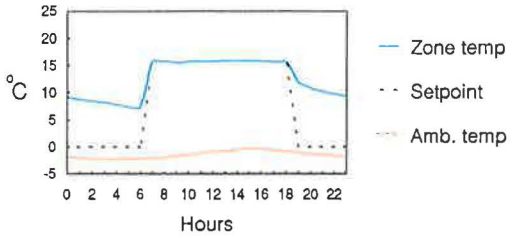


Figure 12. Temperatures in public waiting area on a winter day

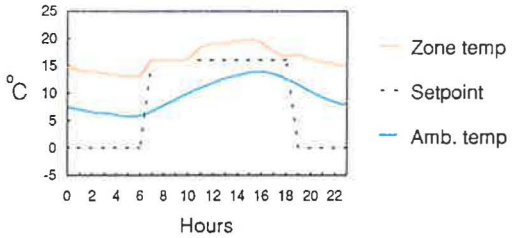


Figure 13. Temperatures in public waiting area on a spring day

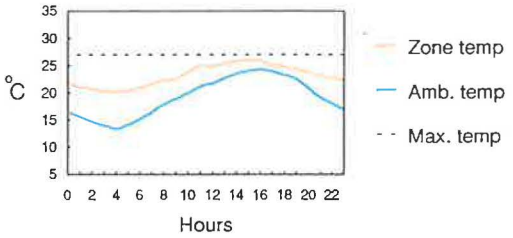


Figure 14. Temperatures in public waiting area on a summer day

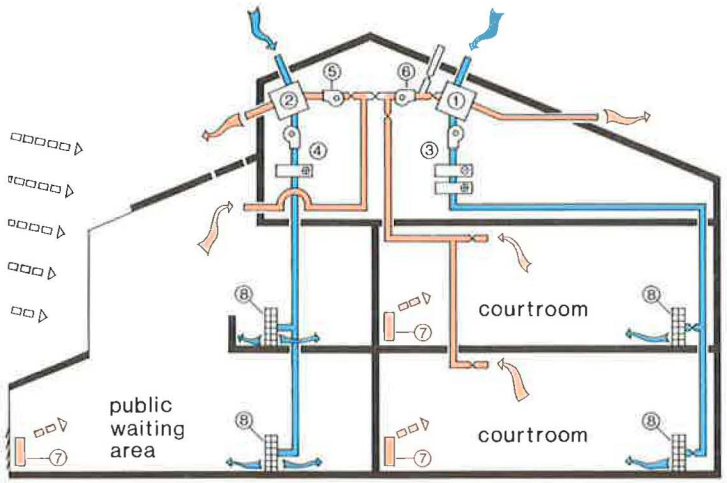


Figure 15. Mode of operation in winter

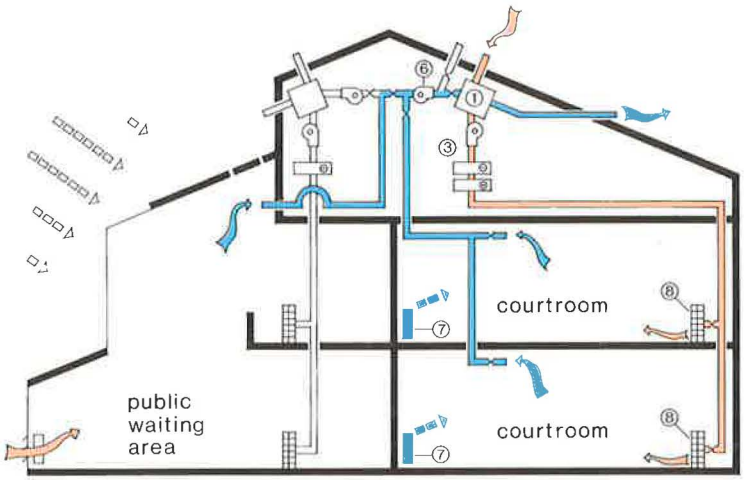


Figure 16. Mode of operation in spring/autumn

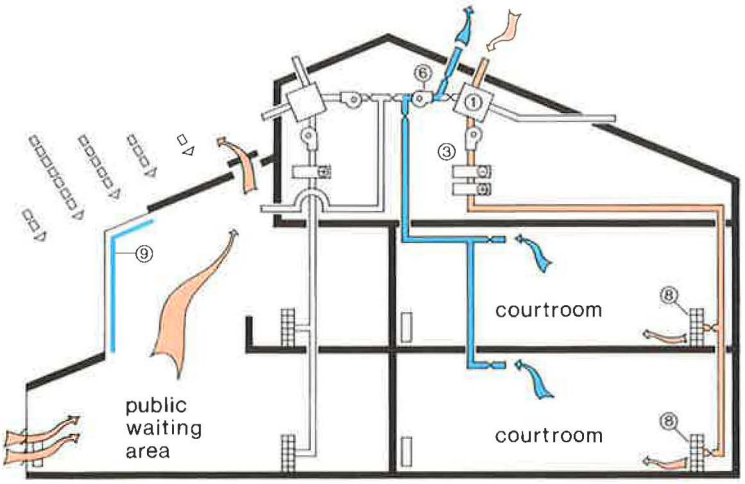


Figure 17. Mode of operation in summer

Key to Figures 15-17:

1. courtroom supply recuperator
2. public waiting area supply recuperator
3. courtroomplant
4. public waiting area plant
5. public waiting area extract
6. courtroom extract
7. heating system
8. displacement ventilation input units
9. blinds

## Modes of Operation

### Winter

In the public waiting areas, the auxiliary heating is on when required to maintain a minimum temperature of 16 ° C. The ventilation system gives a minimum air change rate. The vents are closed. Used air passes to the public waiting area recuperator.

In the courtrooms, the auxiliary heating is on, maintaining a temperature of 19 ° C. The ventilation system is on - or windows are opened if desired. Used air passes to the courtroom recuperator.

### Spring/Autumn (Bright, Cold Days)

In the public waiting areas, there are solar gains and the heating is on when required to maintain a temperature of 16-25 ° C. The ventilation system is off. The low level vents are regulated to provide fresh air input while maintaining the minimum temperature. Used air passes to the courtroom recuperator to preheat fresh air.

In the courtrooms, the heating is on if required. The ventilation system is on or the windows opened. The fresh air input is preheated by extract from the public waiting areas and courtrooms.

### Summer (Hot Days)

In the public waiting areas, the heating and mechanical ventilation systems are off. The low level and high level vents are open and the blinds closed.

In the courtrooms, the heating is off. The mechanical ventilation system is on - or windows opened. Used air from the courtrooms goes direct to waste, not via the recuperator. In really hot weather the cooling plant is run to reduce the fresh air input temperature. If the extract air from the courtrooms is at a lower temperature than the fresh air then the recuperator is brought into use to restore cool conditions.

# ENERGY CALCULATIONS PERFORMED AND DESIGN TOOLS USED

## Introduction

The passive solar and daylighting systems were designed using various design tools. The SERI-RES computer model was used to determine the thermal performance in the public waiting areas and courtrooms. GNOME, a program developed in the School of Architecture of Humberside College of Higher Education, UK, was used to assess whether glare would be a problem in the courtrooms.

## Results of Thermal Performance Studies

### Design of Glazing in Public Waiting Rooms

The preliminary design for the public waiting areas incorporated fully-glazed roof areas in an attempt to maximize both daylight and solar gain. The thermal performance evaluations, however, showed that, if this was done, temperatures in the public waiting areas could rise to 28 ° C. To limit the excess heat gains to an amount which could be used to preheat the input air for the courtrooms and to reduce overheating in the public waiting areas, the roof glazing was reduced to the minimum which would allow daylight to reach the courtroom via the window in the partition wall between the waiting area and courtroom. By doing this, the maximum temperatures predicted were reduced to 25-26 ° C (see Figure 18).

### Savings Made by Using Solar Gains to Preheat Ventilation Air

Using direct gains in the public waiting areas to preheat ventilation air for the courtrooms typically saved 90 kWh/day for a spring/autumn day and 60 kWh/day for a winter day. This gave annual savings of 23,000 kWh for the whole building. Very little additional plant is required for this recovery technique. The recuperators need to be slightly larger to enable them to cope with additional air volume from the waiting areas and more ductwork and dampers have to be installed to complete the air circuit.

The above savings represent the difference between using spare heat from the waiting areas and a similar system operating on full fresh air, controlled using the existing energy management facility. Savings in capital plant and running costs due to incorporation of heavy mass and insulation into the building and glazing optimization are additional to this. Compared to a conventional air-conditioned building with air conditioning, the overall capital and operational costs of this building are low.

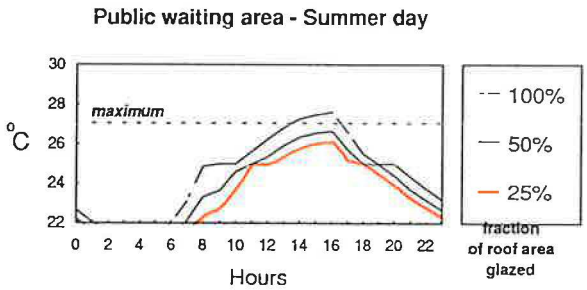


Figure 18. Temperatures reached in a public waiting area on a summer day for different amounts of roof glazing

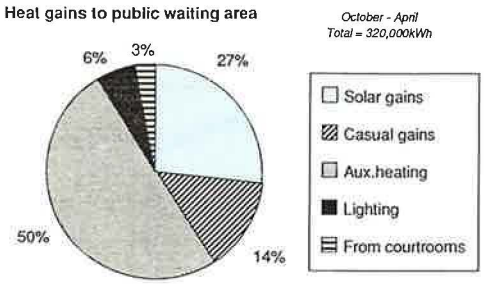


Figure 19. Breakdown of heat supply to public waiting area from October to April. (Total usage, October to April, is 320,000 kWh.)

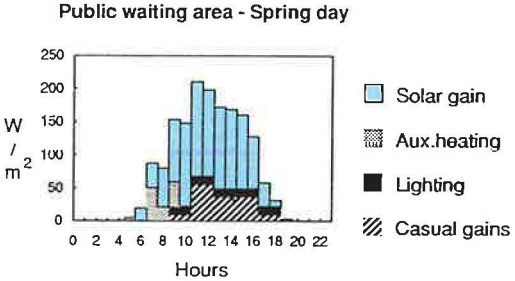


Figure 20. Supply of heat in public waiting area over a spring day

## Results of Courtroom Daylighting and Solar Glare Studies

### Introduction

The building has been planned so that every courtroom receives daylight, direct and/or borrowed. The borrowed daylight is introduced to nine of the ten courtrooms from their highly-glazed public waiting areas. The partition wall between the courtroom and the waiting area has a long high-level window fitted with acoustic double glazing. This provides a noticeable level of borrowed daylight in the courtroom and some contact with the outside world - especially important in those courtrooms which have no direct daylight.

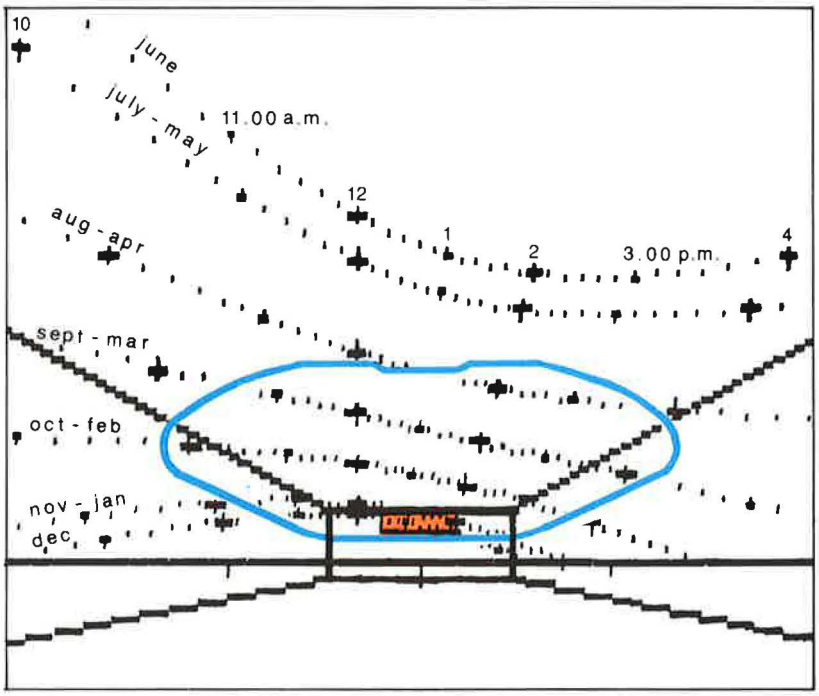


Figure 21. Plot of sunpath perspective as seen from magistrates' bench produced by GNOME computer program

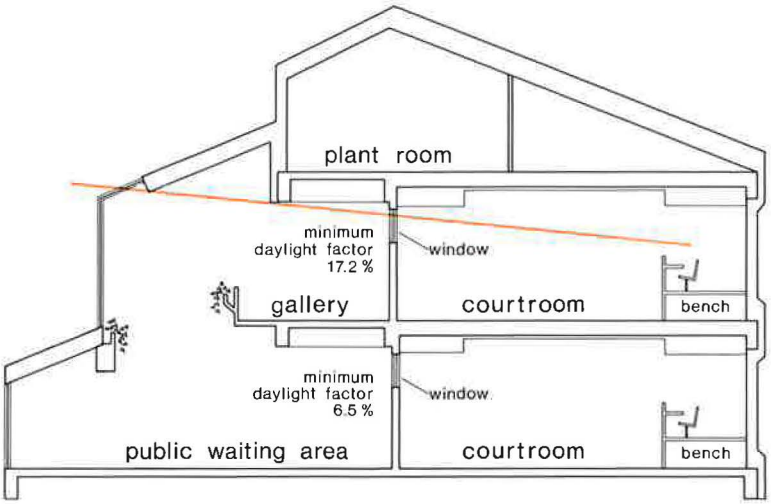


Figure 22. Section showing point where solid roof in waiting area should end if daylighting in courtroom is not to be impaired

### Glare Studies

The windows in the partition wall are oriented 18 ° west of south and are directly opposite the magistrates' bench. To assess whether there could be a problem of glare for the magistrates, the GNOME computer program was used to produce a wide-angle interior perspective showing the window and a plot of the monthly sunpath perspectives at 10 minute intervals (see Figure 21). The sun will be visible from the chosen viewpoint when it is within the window outline. The direction within which complaints of solar glare can be expected is also outlined and so the season and duration of complaints can be estimated.

The study showed that there would be a problem of glare at the magistrates' bench in the early afternoon in winter. It was decided to install movable blinds or curtains for control by the courtroom ushers.

### Design of Roof Glazing in Waiting Areas

As indicated above, to optimize the thermal performance of the public waiting areas, it was decided to reduce the roof glazing in the latter as much as possible without affecting the borrowed daylight in the courtrooms. A line was therefore drawn on section from eye level at the magistrates' bench on the first floor through the head of the internal window (see Figure 22). The point at which this line intersects the waiting area roof is the point below which solid roofing would restrict the view of the sky from the magistrates' bench, thus indicating the optimum proportion of solid to glazed roofing.

## Design of the Public Waiting Areas

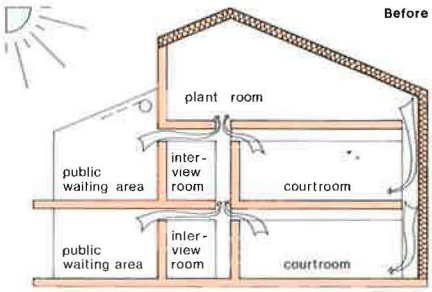


Figure 23. Preliminary design of public waiting area

In the preliminary designs (see Figure 23), the public waiting areas were simple single-storey conservatories/sunspaces separated from the courtrooms by a row of ancillary rooms. The idea was to take air warmed by solar gains from them to the plant room where it could be used to preheat the ventilation air for the courtrooms. However, after discussing these proposals with one of the Building 2000 consultants, it was realized that, if the public waiting areas were designed in this way, they would be too hot in summer and too cold in winter. It was further recognized that rigid environmental control was not required in these spaces because they are used by people wearing outdoor clothing. They will, however, be occupied all the year round and by people who might be there for considerable lengths of time. They were, therefore, redesigned as well-insulated direct gain spaces which provide a greater degree of protection from outside conditions than a sunspace but allow a greater degree of temperature fluctuation than is normal for a completely internal environment. The new design is shown in Figure 24.

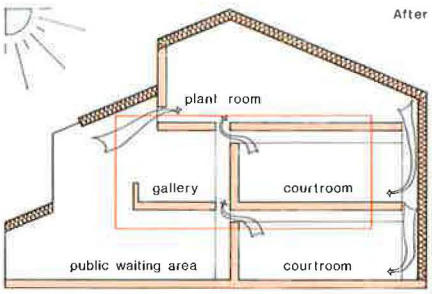


Figure 24. Final design of public waiting area

The major changes are as follows:

- increase in the height of the spaces to two storeys. This increases the potential for natural ventilation due to the stack effect (particularly useful in summer to prevent overheating) and provides more spacious and attractive spaces.

- provision of a gallery waiting area at first floor level. This provides a shaded area where people may escape from direct sunlight if they wish.

- reduction in the area of roof glazing. The roof glazing does not contribute much to the direct gains. In the winter, with the sun low in the sky, the vertical glazing is far more important; the roof glazing is mainly a source of heat loss. In the summer, with the sun high in the sky, the roof glazing allows solar gain when it is least required. It is an important source of daylight and can be a key design feature. The roof glazing was, therefore, reduced to the minimum compatible with achievement of good daylighting.

- relocation of some of the ancillary accommodation away from the courtrooms to the outer edge of the ground floor waiting area. This allows the direct gain spaces (the public waiting areas) to abut the courtrooms, enabling daylight to penetrate to the courtrooms themselves. In addition, the courtrooms benefit thermally from being adjacent to the direct gain spaces by the storage and passage of heat through the partition wall.

- allowing one of the waiting areas to open onto the external courtyard, providing a continuation of internal into external space, especially in summer. This has a psychological advantage in that the internal space becomes semi-external and people will tolerate greater extremes of temperature, as they do outside.

- provision of a variety of space types in the waiting areas , as indicated above. This gives people the choice of moving to the types of space they find most comfortable.

# GENERAL DESIGN GUIDELINES AND POINTS OF INTEREST RESULTING FROM THIS PROJECT

## General Principles of Passive Solar Heating in a Courtroom

The study described in this brochure showed that:
- Only spaces in which temperatures can be allowed to float between much wider limits than is normally acceptable should be designed as sunspaces. If the sunspace is allowed to reach higher temperatures in spring/autumn, more useful heat can be recovered. Acceptance of lower temperatures in winter reduces the required heating load.

- Roof glazing tends to cause overheating in the spaces below because it allows the rays of the summer sun to enter the building. Vertical glazing is more useful because it admits the low winter sun but does not allow entry of the overhead summer sun.

- Use of a displacement ventilation system means that higher supply temperatures can be used even when there is a net cooling load, thus making maximum use of fresh air preheated by the extract air from the sunspaces.

## Daylight in Courtrooms

Although, in order to achieve a more comfortable and pleasant internal environment, some daylight should be introduced into courtrooms, it is not practical to try to achieve workable levels of light from natural lighting alone. The courtrooms are the key spaces in a courthouse and it is essential that they function satisfactorily in every respect. The courtroom's environment must, therefore, be strictly controlled and certain standards, including lighting standards, must be attained. Ideally, courtroom lighting should be unobstrusive, providing a subtle hierarchy of illuminances to signify the importance of different parts of the courtroom. This can be achieved most consistently by artificial lighting but a measure of daylighting should be introduced to provide a very necessary and psychologically important contact with the outside.

Introducing daylight into courtrooms can be difficult because they tend to be surrounded on at least three sides by circulation areas for the public, the magistrates and defendants in police custody. This leaves only one side free which could be on an external wall and have windows. The building must, therefore, be planned from the outset to allow daylight into the courtrooms, if this is required.

In this project, the plan has been arranged and the circulation organized so that six of the ten courtrooms have an external wall with windows. These walls have been oriented so that dazzle and glare from direct sunlight will not occur during court hours.

Top lighting through roof glazing over the courtrooms can be an option if the building is planned to allow it. However, daylighting of this sort is not entirely suitable for courtrooms, especially over the magistrates' bench, and the problem of down draughts has to be dealt with.

Care must be taken over placement of windows in a courtroom. It is especially important that there are no windows in the wall behind the magistrates' bench. If there were, the magistrates would be seen in silhouette by the courtroom occupants. Ideally, the wall behind the magistrates' bench should be of intermediate brightness and colour to provide a visually comfortable background to the magistrates.

## A Note on Reflecting Ponds

Water reflects only 4% of the light shining on it and so a reflecting pond cannot really be regarded as a daylighting feature, although the percentage reflection can be increased if light coloured surfaces are used to line the pond. Perhaps the main daylighting effect of a reflecting pond is to affect the nature of the daylight in adjacent spaces by producing a pleasant ripple effect on the ceiling. However, the problem of glare from upward reflected light must be considered.

# BUILDING 2000

Building 2000 brochures are published by Directorate General XII of the Commission of the European Communities to show how design studies can help architects and other building designers use passive solar principles to the best effect to produce attractive energy-efficient buildings. Each brochure describes studies carried out with the support of the Commission during the design phase of one of thirty-six non-domestic buildings in the EC Member States. The studies were on such topics as daylighting, heating, cooling, ventilation, comfort, control systems and urban design. They were carried out with the help of acknowledged European experts in these fields and drew heavily on lessons learned and techniques developed through the Commision's research and development programme on solar energy applications to buildings.

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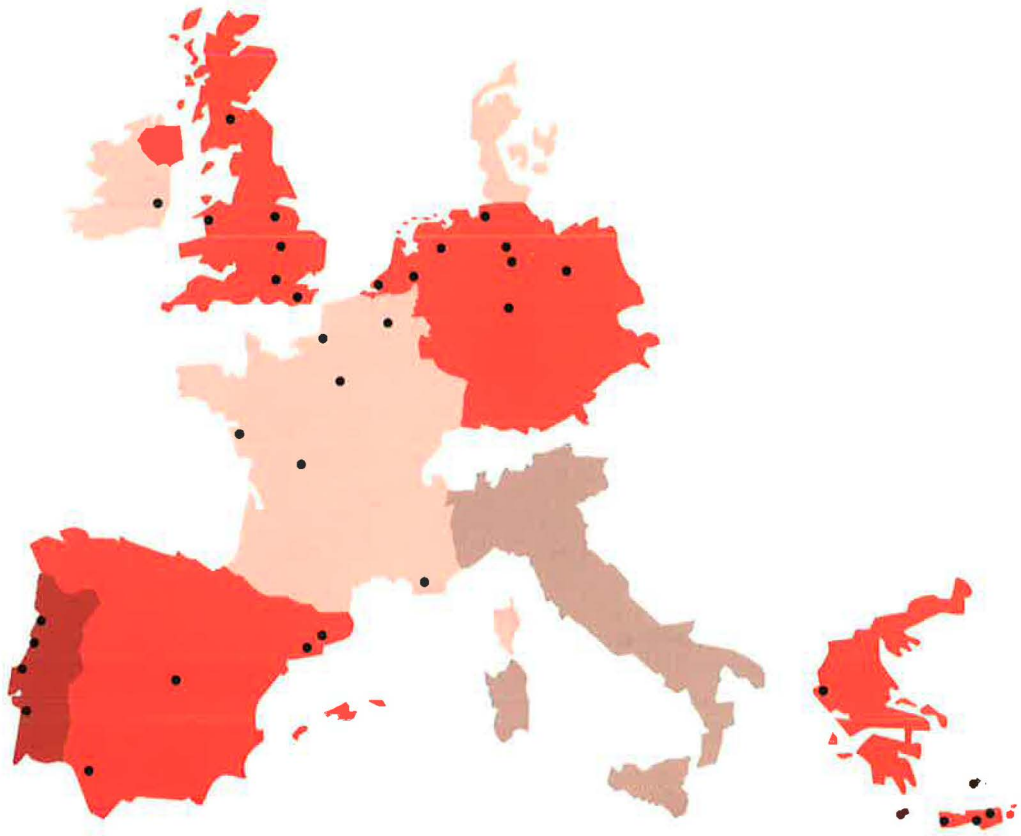

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