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1 Applied Examples Case Study Buildings

Evidence of the methodology's successful application in the building industry is vital if the framework is to be adopted. As a result, two pilot applied examples were chosen as 'proof of concept'. This chapter introduces the two buildings that were chosen to pilot implementations of the BECs methodology. The first building is an art gallery open to the public. The second building is a campus building housing laboratory and office spaces. Both facilities belong to University College Cork and this research was facilitated with full access to the energy systems and energy consumption data.

It was vital that any applied examples should incorporate unique and demanding environmental designs in order to assess the robustness of the methodology. Both of these buildings presented challenges that highlight the strengths *and* weaknesses of monitoring and predicting the energy performance of buildings. As such, this chapter gives a brief overview of the example buildings' environmental design parameters that are deemed pertinent to undertaking a BECs assessment.

1.1 Glucksman Art Gallery

The Glucksman Art Gallery is a facility that houses art exhibition spaces which are open to the public. The building itself boasts seven split-level floors with four exhibition areas, multifunction rooms, lecture facilities, a café/restaurant and a basement gallery store. The building was procured and opened by University College Cork in late 2004 in order to showcase its own modern art collections as well as travelling and special exhibitions. Since opening, the building has received numerous awards including: RIBA Stirling Architectural 2005 Final 6; CIBSE Best Project Under £20m 2004; and winner of the Thermal Energy Category at the Irish Energy Awards.

1.1.1 An Ideal Test-bed

The building provides an ideal pilot case study for many reasons including (1) its 'green' principles; (2) its complexity of design (geometric and environmental); (3) strict internal environmental control and –most importantly- (4) the in situ BMS which regularly monitors the environmental conditions of the spaces and the temperatures within the HVAC plant itself.

The building is bordered by the river Lee and surrounded by many mature trees as it rises up from a floor plan no greater than the two tennis courts which it replaced. Due to the unique and visually pleasing setting, the client stipulated a building that nestled in with its surroundings with minimal visual and environmental impacts.

As a result of this guiding principle of sustainability, the design of the building was driven by a policy to mitigate the building's environmental impact while maintaining strict internal environmental conditions. This resulted in an innovative and sophisticated design. It immediately presented challenges for predicting energy performance (all of which will be presented in the following two chapters).

The unique geometry and layout incorporates 2,350 m^2 of building space (see Figure 4-1 for a view of the exterior of the structure). From the outside, the building - though dramatic - ultimately gives the impression that the top floors are floating in amongst the densely populated area of mature trees. The complexity of the structure is advanced within the building; the four interlocking exhibition spaces vary in size and are staggered over several split level floor spaces (see Figure 4-2). A building like this truly tests the capabilities of employing geometry translation software tool without the loss of information as discussed in section 3.5.3.1.1.

Figure 4-1 –Aspects of the Glucksman Art Gallery highlighting the dramatic nature and geometric complexity of the structure

Art galleries - by their very nature - demand a highly controlled internal environment for the safe keeping of the art collections. Anne Fahey, in her reference book titled Collections Management (Fahey 1994), presents detailed text to develop standards for collections management. It highlights the significance of building *type* and *condition* as vital discriminating factors. It pointed to the fact that poor conditions endanger collections housed within. As a result, it was vital that any HVAC solution would have a minimal environmental impact *yet* guarantee the safe provision of the internal environment.

Figure 4-2 – North-South section through the Art Gallery Building depicting the split level galleries on the second/third/fourth floors

The mechanical plant also introduces interesting challenges for simulation. After the detailed design stages, the building's environmental team expected the building to consume 75% less energy than a typical scheme (Kennett 2005). These kinds of claims may be well founded due to the presence of a chiller system which provides both cooling *and* heating water *simultaneously*. A more low-level view of the building's mechanical design is explored in section 4.1.2.2.

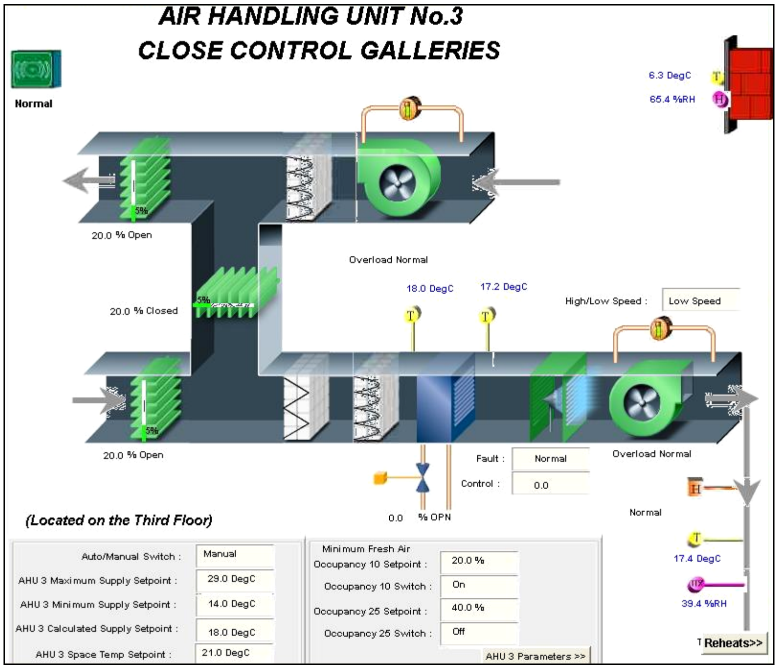

Figure 4-3 – A screenshot of the Glucksman Art Gallery's BMS User Interface

Most importantly –from this research's viewpoint– is the presence of a BMS system. Temperatures, humidity levels, fluid-flows and other values pertinent to the safe provision of an internal environment are all automatically controlled by the BMS system. The Glucksman Art Gallery's BMS is bundled with a Graphical User Interface (GUI) front end where facility managers may investigate process parameters (see Figure 4-3). The BMS's storage facility - containing temperatures and relative humidity levels – facilitates a full investigation of the HVAC system.

1.1.2 Environmental Design

Following the brief preliminary discussion related to HVAC design in the last section, the following subsections describe the details of the environmental HVAC design strategy that must be considered in order to carry out a BECs assessment of the Glucksman Art Gallery.

1.1.2.1 Geometry and Layout

The building is a twisting, turning, cantilevered structure anchored into the ground and has a gross area of 2,350 m^2. The plant rooms have an area of 300 m^2, the kitchens incorporate 105 m^2, the toilets occupy 65m^2 tand the dining area encapsulates 150 m^2. This leaves just over 1700m^2 for the gallery spaces and circulation routes open to the public.

Table 4-1 displays the specific functions of each floor which must be considered during the zoning process in a whole building simulation model.

Table 4-1 – Table outlining the functions of each floor in the Glucksman Art Gallery

Floor	Function(s)
Basement	Kitchen, Consumable Stores, Gallery Store, Toilets, Office, Plantroom
Ground	Dining Areas, Office, Finishing Kitchen
First	Lobby, Security Office
Second	Gallery Area, Toilets, Sales Area
Third	Close Control Galleries, Plantroom
Fourth	Storage Areas, Gallery Spaces
Fifth	Plantroom

1.1.2.1.1 Construction

The building uses cast in situ concrete for the basement floors right up to second floor. Above this floor, it reverts to a steel frame with composite walls. The building's exterior is clad in limestone and hardwood. The floors are cast concrete that vary in depth. Only the café has a significant area of glazing.

1.1.2.2 HVAC Design

The building is *mechanically* heated, cooled, humidity-controlled and ventilated. The following subsections outline details of the mechanical plants.

1.1.2.2.1 Exhibition Spaces Ventilation

The exhibition spaces are ventilated by a displacement ventilation strategy. Air is supplied at low levels through window floor boxes and other discrete inlets. Return air is taken out of the rooms through the shadow spaces at the gaps between the ceiling and walls. Supply air temperatures range from 19^{o}C in cooling mode to 29^{o}C in heating mode.

Typically within exhibition spaces, tight control of temperature and relative humidity (RH) is required. The air is provided by dedicated AHUs which provide 6 air changes per hour.

One of the important modes of operation frequently engaged during the summer months is dehumidification. The space setpoints are 50% RH and 21^{o}C. As a result, the AHUs must operate by employing the cooling coils (to strip out the moisture and reduce temperature) and the heating coils (to increase the supply temperature to the required level). The two dedicated AHUs are described below.

1.1.2.2.1.1 Wrap-Around Galleries (AHU2)

The spaces being supplied by this AHU are a mixture of double and single height spaces located on the 2nd and 4th floors. The AHU itself is the largest in the building and is composed of a mixing box, cooling coil, heating coil and supply fan. Several terminal reheat coils supplement the supply temperature. Temperatures are maintained at 21^{o}C year-round while the RH is maintained at 50% +/- 20%.

The unit itself was designed to accommodate design day climatic conditions but also a design load of 126 persons. However, despite the regular frequency of visitations by the public, the occupancy of these areas is rarely (if ever) at design conditions. Accordingly, part load performance of this AHU is extremely important given its large capacity.

1.1.2.2.1.2 Close Control Gallery (AHU3)

This AHU (termed AHU3) is composed of a mixing box, cooling coil, humidifier and supply fan. Two terminal reheat boxes are located before the supply inlets to the space. There is also an extract fan for drawing out return air. This AHU manages strict temperature (21^{0}C +/- 1^{0}C). This is the single most important AHU as the space houses the most prized exhibits. However, spaces-use varies with each exhibit. Alternate uses include:

- Small cinematic presentations. Short films are projected onto one wall and all the lighting is turned off;

- Closed off displays behind full height glazing. Priceless exhibits are displayed behind glass at the entry to the space and as a result, no persons may gain entry;
- Some exhibits require intensive lighting which adds to the internal cooling load and visitors are allowed to walk freely around the space.

1.1.2.2.2 Basement Ventilation

The lower levels of the Art Gallery contain numerous supply and extract fans. Three of the more significant fan/coil arrangements are discussed below. These zones may be considered as 'fully mixed' zones.

1.1.2.2.2.1 Kitchen

The kitchen area contains many units, including large industry refrigerators, cooking hobs, deep fat fryers, etc, which transfer a large amount of heat to the space. The area itself is ventilated by a supply fan and a heating coil. Air is exhausted from the space via extract fan. There is a large flow rate through this unit in order to adequately ventilate the space.

1.1.2.2.2.2 Security Room

This room contains several computers and also the comms server for the building. As a result, there is a large variance in the heating and cooling loads (depending on the external climatic conditions). Due to the fact that this room may be occupied on a 24 hour basis, it contains its own dedicated AHU which is composed of a mixing box, cooling coil, heating coil and supply fan. Air is exhausted by a dedicated extract fan.

1.1.2.2.2.3 Gallery Store

This area has a dedicated AHU for maintaining *strict* temperature and RH control. This is vital in order to secure a safe internal environment for the art works contained within. The AHU is comprised of a mixing box, cooling coil, heating coil and supply fan which provides 100 litre/s. Air is exhausted from the space through a seperate extract fan.

1.1.2.2.3 Water Services

In order to provide the ventilation units with sustainable sources of hot and chilled water, an innovative chiller unit and design was employed. Well tests confirmed the availability of a clean, thermally stable water source (with a steady temperature of 11^{o}C) located in the alluvial gravel deposits to be found deep down in the River Lee's basin. The chiller unit, termed a Ground Energy Thermal Transfer System (GETTS), minimises energy consumption for the building by providing both heating and cooling water simultaneously. The plant minimises the reliance on non-renewable sources of energy by exploiting the water in alluvial gravel deposits beneath the site. In doing so, energy consumption has been reduced to 25% of the levels expected from conventional chiller and boiler heating systems.

The building operates through two water cooled chillers. They simultaneously generate chilled water at 6^{o}C and heating water (referred to as low grade hot water (LGHW)) at 45^{o}C (30^{o}C when providing cooling only). Any excess heat or coolth is transferred to ground water through plate heat exchangers. The ground water itself is sourced from two 12 metre deep wells. Excess water is discharged directly to the river. When the groundwater is cooled, it is acting as a heat source in the winter months and the rejected water temperature would be approximately 6-7^{o}C. When the groundwater is heated, it is acting as a heat dump in the summer months and the rejected water temperature would be approximately 19-20^{o}C.

At capacity, the GETTS has a capacity of 170kW cooling and 200 kW heating. This system can provide of CoP of 8 (1 kW of electrical power in the chillers can provide 8 kW of heating and cooling energy).

Two gas-fired boilers provide back-up to the GETTS and also provide high temperature water for the building (referred to as low temperature hot water (LTHW)). This high temperature water is utilised by the trench heating, radiant panels and radiators.

1.1.3 Internal Environment

The Glucksman Art Gallery houses many areas with disparate functions. As a result, the internal conditions that must be controlled differ somewhat. A generic overview of the internal conditions can be seen in Table 4-2.

Table 4-2 – Table highlighting the environmental conditions in the Glucksman Art Gallery

Area	Max Ventilation (m^3/s)	Summer Temp (^oC)	Winter Temp (^oC)	Relative Humidity (%)	Outside Air ($l/_s$/person)
Foyer, Second & Fourth Floor Galleries	4.0	19	24	50 +/- 30	12
Close Control & Multi-Media Rooms	0.86	19	22	50 +/- 5	12
Café	2.0	25	20	50	15
Private Dining	1.0	25	20	50	15
Gallery Store	0.1	19	19	50 +/- 5	10

The numbers of persons used as input for design parameters (during the detailed design stages) are absolute maximum figures. These figures drive the design conditions used to find the maximum loads on the HVAC system. However, they do not reflect the frequency or distribution of people visiting the public building in a real life scenario. As a result, when attempting to undertake as assessment of part-load operation, it is vital to determine a more accurate assessment of visitors to the gallery. This is carried out to reflect occupancy in the café (maximum occupancy occurring during mid-day lunch) and in the gallery as a whole which are subject to random events such as school tours (during the mid-afternoon) and a higher density of visitors during the weekends.

The building is considered to be a closed envelope (it is not designed to allow natural ventilation flow through the building; all rates of ventilation air are assumed to be mechanically moderated). However the private dining and the café *may* be naturally ventilated (by opening large glazed full height window areas) during the summer months to avoid over-heating. This is at the building manager's discretion.

The building envelope is considered to have been design and constructed to best practice. As a result, the design team consider that all infiltration rates (the unsolicited flow of outside air through the building) can be taken at 66% of suggested values found in building guidelines such as the CIBSE Environmental Design Guildlines ((CIBSE 1999)).

The density of electrical equipment is extremely low. Only the security room and a small office on the second floor contain computer terminals and other small electrical equipment. Beyond this, there is a very low distribution of electrical devices within the building.

1.1.4 Design Expectations

The design team expect energy consumption to be 400,000 kWhr, or 175 kWhr/m^2/annum (Kennett 2005) for the assumed hours of occupation.