BARC0168: SENSE, SENSING AND CONTROLS

COURSEWORK 2 : Specifications and Evaluation of a Control System

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Candidate Code : WRGD1
Student Number : 20074993

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1. INTRODUCTION

This report discussed the specifications of a transformative ‘Art Gallery Space’ and evaluates a suitable control system designed for its requirements in order to maintain indoor comfort.

2. THE ZONE

The zone selected is an ‘Art Gallery’ space located on a beach in Great Yarmouth, Norfolk, UK. Additionally, the space acts as a transformative space wherein it is used as an ‘Artist Lounge’ for collaboration and networking at times when the gallery does not have a show for viewing. The gallery requires a climate-controlled environment to preserve the artwork while maintaining a comfortable environment for visitors, with temperature and humidity levels kept within specific ranges. Hence, the building controls in the gallery must be designed to achieve this goal efficiently and sustainably.

According to CIBSE Environmental Guide 3: "The Environment for Art” recommends monitoring temperature and humidity levels using sensors and controlling them using an appropriate heating, ventilation, and air conditioning (HVAC) system.

BSRIA suggests that using open protocols and standards can help ensure compatibility between different systems and components. This is especially important for the gallery, as it may need to integrate various systems such as HVAC, lighting, and security into a single control system. The control system should also be able to communicate with external systems such as weather monitoring systems to adjust temperature and humidity levels based on external conditions.

ZONE REQUIREMENTS	ART GALLERY	ARTIST LOUNGE
Total Area of Space (m^2)	350	
Maximum Occupancy	150	variable
Humidity (%)	40-60	40-60
Winter Comfort Range (°C)	18-21	20-24
Winter Activity (met)	1.2	1.0
Winter Clothing (clo)	1.0	0.9
Summer Comfort Range (°C)	23-26	23-27
Summer Activity (met)	1.2	1.0
Summer Clothing (clo)	0.5	0.5
Suggested Air Supply Rate (l/s/p)	8-12	10-15
Maintained Illuminance (lux)	200-300	200-500
Noise Ratings (NR)	NR25	NR30-40
Good Practice Electricity (kWh/m^2)	100-150	100-200

Table 1 General Comfort Conditions of the Zones

3. CONTROL REQUIREMENTS

3.1 SET-POINT/SET-BACK TEMPERATURES

	Occupied Set-Point Temps.	Occupied Set-Back Temps.	Unoccupied Set-Back Temps.
Heating System	20°C - 22°C.	15°C	18°C
Cooling System	22°C - 24°C.	24°C.	28°C

Table 2 Set-point and Set-backs

3.2 INDOOR AIR QUALITY (IAQ) REQUIREMENTS

Variable	Ideal Targets For Good IAQ
CO_2	1000 ppm
$PM_{2.5}$	5 – 15 μg/m^3
Fresh Air	10 l/s/p

Table 3 IAQ Requirements

3.3 APPROPRIATE SYSTEM

The most appropriate HVAC system for an art gallery would be a variable air volume (VAV) system. VAV systems are designed to maintain consistent temperature and humidity levels in different zones of a building while minimizing energy consumption.

In an art gallery, it is important to maintain stable temperature and humidity levels to protect the artwork from damage due to fluctuations in environmental conditions. VAV systems use multiple air handling units (AHUs) to supply conditioned air to different zones of a building based on their heating and cooling loads.

Each AHU would be equipped with a variable speed fan and a variable air volume box (VAV box) that controls the amount of airflow delivered to each zone based on its heating and cooling load. The VAV boxes are equipped with temperature and humidity sensors that provide feedback to the AHU controller, which adjusts the output of the AHU fan and heating/cooling systems to maintain desired setpoints. This allows for precise control over temperature and humidity levels in each zone.

Additionally, the AHUs can also be equipped with high-efficiency filters and other components to improve indoor air quality and protect artwork from dust, pollutants, and other contaminants.

In addition to the VAV system, an art gallery HVAC system may also include a dedicated outdoor air system (DOAS) that provides fresh air ventilation while minimizing energy consumption. The DOAS uses a separate AHU to supply fresh outdoor air to each zone of the building while exhausting stale indoor air. This helps to maintain optimal indoor air quality while minimizing energy consumption.

To examine the system and its limitations, first the inputs, outputs and the variables that lead to the control and regulation of comfortable output conditions.

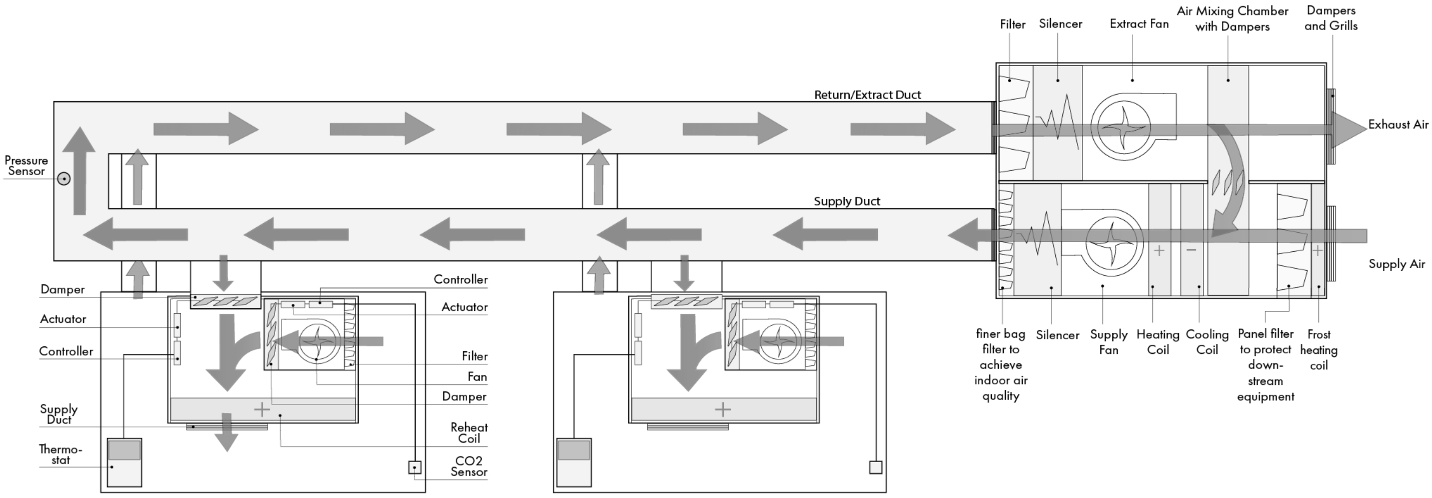

Figure 1 Basic HVAC system with VAV

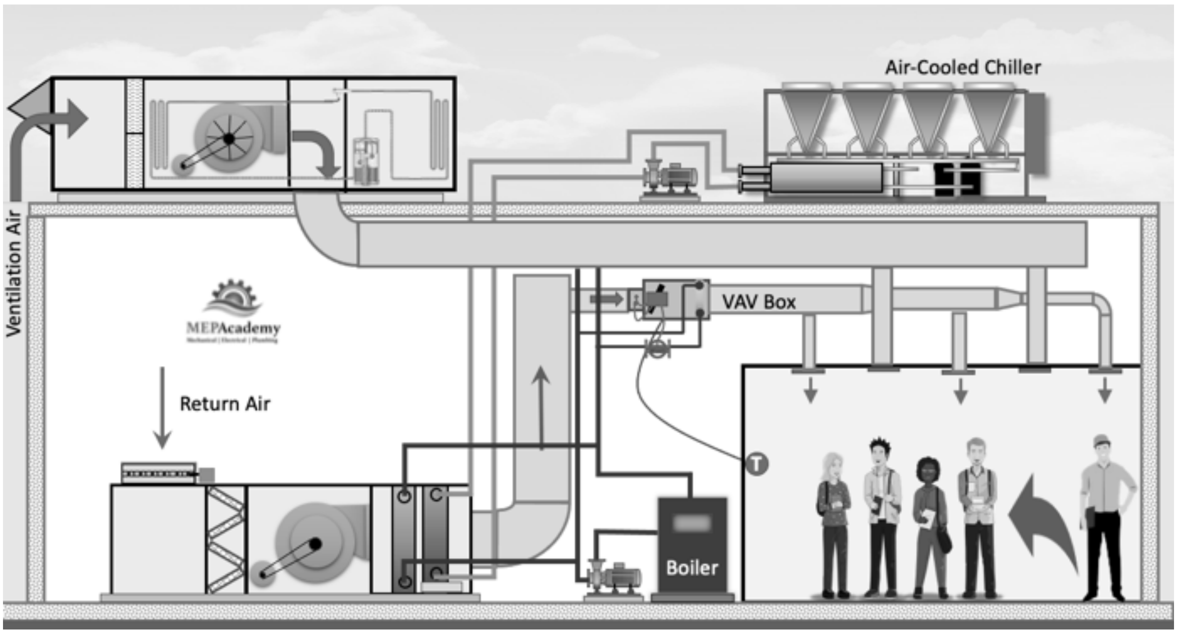

Figure 2 Example of an integrated dedicated outdoor system

CRITERION	INPUT	AUTOMATICALLY CONTROLLED INPUT VARIABLES (ACIVs)	UNCONTROLLED INPUT VARIABLES (UCIVs)	OUTPUT
Temperature + Humidity Control	-Temperature Sensor -Humidity Sensor	-Temperature -Humidity	-Solar Radiation -External Climate	-Setpoint -Control Signal
HVAC	-Temperature Sensors -Airflow Sensors -Pressure Sensors	-Temperature -Airflow -Pressure	-Building Envelope -Occupancy Patterns -Equipment Performance	-Setpoint -Control Signal
Lighting Control	-Occupancy Sensors -Light Sensors	-Occupancy -Ambient Light	-Daylight Availability -Room Reflectance -Lamp Lumen Depreciation	-On/Off Signals -Dimming Signals

Table 4 Basic Control Parameters

3.4 FEEDBACK LOOP

The system must incorporate feedback control loops in order to establish pleasant internal conditions and integrate control strategies. These parameters can be met over the long run thanks to the ongoing feedback.

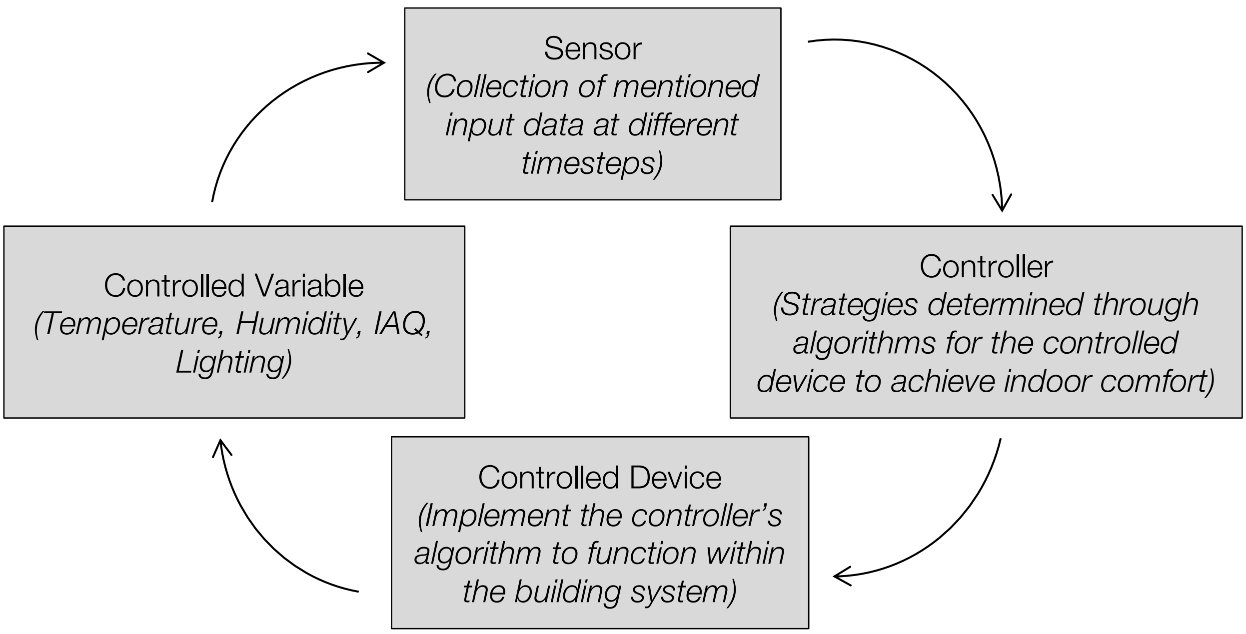

Figure 3 Feedback Loop

Control Strategy	Controlled Variable	Sensor	Controller + Control Algorithm Rules	Controlled Device (CD)	Resultant Load
Heating	Temperature	Thermostat	If zone temp. is under set point, CD to turn on heating coil	Reheat coil in the VAV terminal	Increase in heating load
Cooling	Temperature	Thermostat	If zone temp. is over set point, CD to open damper	Actuator that controls the damper in the VAV Terminal	Increase in cooling load
Humidity	Humidity	Humidity sensor	If zone RH is over/under CD to close/open damper	Actuator that controls the damper in the VAV Terminal	Increase heating/cooling load
IAQ	CO_2 (int), $PM_{2.5}$ (ext)	CO_2 + $PM_{2.5}$ sensors	If IAQ is above comfort CD to open damper	Actuator that controls the damper in the VAV Terminal	Increase heating/cooling load
Pressure	Duct Pressure	Pressure sensor in return duct	If low pressure, CD increase fan speed and vice-versa	Fan in AHU	Increase energy consumption
Lighting	Occupancy, Daylighting	PIR Occupancy Sensor + LUX sensor	If space is occupied/lux levels are under comfort, CD to turn on lighting	On/Off Switch in lighting circuit	Increase energy consumption

Table 5 Implementation of the Feedback Loop

3.5 ADDITIONAL STRATEGIES

In addition to the following parameters to be controlled, other potential control strategies could be implemented.

- Frost Protection:

When the external temperature reaches the set minimum 3°C, the frost heating coil is switched on to protect downstream equipment/

- Fire Protection:

Smoke detectors should connect to the BMS to start additional alarms systems(sprinklers). In case of an alarm, all the fans should turn off immediately.

- Alarm Requirements:

High Priority is fire alarm, power failure, larger failure of the building system, AHU smoke alarm etc. General Priority is AHU airflow failure, frost thermostat operation, mechanical ventilation fault alarms. There should be LEDs to indicate whether there is a fault.

4. ENERGY SAVING

There are several aspects of the installed system that can create the risk of unsatisfactory environmental control or higher than expected energy usage.

Some of the key factors to consider include sensor performance, installation and commissioning, long-term operation performance, and occupant behaviour.

Sensor performance is critical for the accurate measurement of temperature and humidity levels. Poor sensor placement or calibration can lead to inaccurate readings, resulting in inefficient energy usage and environmental discomfort. Therefore, it is important to ensure that sensors are placed correctly, calibrated accurately, and checked regularly to ensure optimal performance.

Installation and commissioning of the control system is also crucial. Poor installation or commissioning can lead to inefficient operation, which can increase energy usage and reduce environmental control. It is important to follow best practices during installation and commissioning, including ensuring that the system is properly configured, tested, and optimized.

Long-term operation performance is another key factor to consider. Over time, systems can degrade or become less efficient, resulting in increased energy usage and reduced environmental control. Regular maintenance, upgrades, and monitoring can help mitigate these risks and ensure optimal system performance over the long term.

Finally, occupant behaviour can also impact system performance. For example, if occupants frequently leave windows or doors open, this can result in energy waste and reduced environmental control. Education and communication with occupants about the importance of energy efficiency and proper use of the control system can help address these issues.

To mitigate the risks associated with these factors, it is important to develop and implement a comprehensive maintenance and monitoring plan for the control system. This plan should include regular sensor calibration, system testing and optimization, and ongoing performance monitoring to identify and address issues before they become significant problems. Additionally, providing education and training to occupants about the proper use of the control system can help promote more efficient and effective operation.

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