MODULE 151

HVAC&R SKILLS WORKSHOP

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CONTROLS AND HVAC

Controls and control systems are fundamental to how a building works and how individual building systems or services operate. Just as the IT revolution has changed all aspects of our personal and work lives, so the rapid development of digital controls has changed all aspects of how modern buildings and their systems work.

Building management and control systems are not items that can be taken out of a box and plugged into a building. Rather they are the brain of the building that must be connected to all of the senses (sensors and monitors) and all of the muscles (equipment, motors, actuators), before the building management control system (BMCS) is considered truly formed.

This Skills Workshop explains the HVAC system requirements for effective control, and offers checklists to assist with the strategy, implementation and the user interfaces of control devices.

Skills summary

What?

A guide to HVAC system requirements for effective control.

Who?

Relevant for anyone involved with developing, designing, procuring, installing, integrating and managing buildings and building control systems.

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HVAC system requirements for effective control

Effective control system performance requires careful design of the mechanical system and selection of components. Consideration needs to be given to the following by the mechanical system designer and the control engineer:

1. Design distribution system to deliver air to the space

- Extend ductwork to all parts of the space.
- Insulate ductwork if it runs through a space where the temperature is considerably different from that of the air within the duct, or if the space dew point is likely to be above the supply air temperature.
- Locate RA grilles where they will aid in distribution and eliminate short circuiting of the supply air.
- Make any necessary provision for transfer or relief air, e.g. transfer ducts, door grilles or door undercuts.

2. Select the correct type of diffusers for the space

- Do not have low ceiling diffusers blow directly downward.
- Use specialised diffusers for high-ceiling applications to prevent hot air stratification.
- Use several small diffusers rather than one large one for better air distribution/mixing.
- For variable air volume systems, prioritise selection of diffusers that provide high diffusion performance at low flow to maximise potential flow turndown.

3. Size and select the correct type of heating coils

- Size coils to meet their maximum loads. Avoid oversized coils for best control.
- Use multiple inline coils where the required temperature differential is high.
- Design preheat coils with a maximum temperature rise of 16 to 19 Kelvin.

4. Size and select the correct cooling and refrigeration equipment

- Consider dividing the cooling capacity among several coils. A low-load and a high-load coil can be used in series, and parallel coils can be considered where active dehumidification is required.
- Consider some form of reheat if dehumidification is required (refer to *DA20 – Humid Tropical Air Conditioning* for low energy reheat solutions).
- Prevent short cycling of PAC unit system compressors by selecting a system with:
  - Multiple, variable speed compressors
  - Variable speed supply air fans
  - Variable speed condenser fans
  - Sizing to match the load.

5. Consider separate mechanical systems for areas if their heating or cooling loads differ greatly from the other areas

Centralised heating and cooling systems are often constrained to run at very low load to serve small parasitic loads that have different profiles to the majority of system loads. The following points should be considered in system design in order to avoid these scenarios:

- Zones that are expected to have significantly different operating hours to the majority of the system should not be served by the centralised system.
- Zones that are not expected to have seasonal cooling load profiles should not be served by the centralised cooling system (i.e., computer server rooms, equipment rooms, meeting rooms or units without economy cycle).
- Zones with minimal internal load and high infiltration such as ground floor lobbies should ideally not be served by a centralised heating system.
- Slab heating systems should ideally not be served by the centralised heating system due to the long lead times these systems require to achieve temperature.
- The building fabric design should ensure that adequate insulation is installed on levels with boundaries shared with unconditioned space to avoid these levels driving heating and cooling systems when they would otherwise not be required (i.e., floors above carparks, above/below plant rooms).

6. Provide physical arrangement of system components to permit suitable location of sensing elements

- Furnish sufficient spacing between coils to permit installation of sensing elements.
- Provide ductwork downstream from a coil or other components to allow placement of the sensing element.

7. Install the sensing elements in the correct location

- Locate sensing elements where they will measure the variables they are intended to control.
- Locate space sensing elements on an interior wall where they can measure a condition representative of the whole space. Ensure zone temperature sensors are located:
  - Not exposed to direct sunlight
  - Not exposed to equipment
  - Not directly exposed to supply airflows
- Locate air pressure and flow pick-up elements away from immediate fan discharges and provide with capacity tanks where necessary to eliminate surges and pulsations.

- Locate humidifier leaving air humidity sensors no less than 2.5m and no more than 9m downstream of the humidifier.
- Locate CO_2 sensors in the conditioned space for ideal control.

If using return air sensing, ensure CO_2 sensors are located in a position where there will still be airflow when the system is operating in economy cycle mode.

- Consider the physical arrangement of humidity system components.
  - Locate humidifiers downstream from a source of heat.
  - Locate reheat coils downstream from cooling coils.
  - Provide unlined ductwork downstream of humidifiers, and straight for a minimum of 3m. Note that AS/NZS 3666 has additional compliance requirements.

8. Size and select the correct type of control valves

- Select mixing/diverting arrangements based on the type of control required.
- Select two-way and three-way control valves to maintain minimum distribution flow.
- Do not oversize modulating control valves.
- Select control valves that position properly on HVAC shutdown and on loss of motive force.

9. Allow air handling and control system design to provide energy conservation

The energy efficiency requirements of Section J of the *National Construction Code 2019* have been significantly enhanced in the 2019 version and should be referred to in system design as the starting point for energy efficiency consideration (as per statutory requirements but also as good practice).

- Use space sensors, rather than OA sensors, to determine reset schedules. For example, use the damper signal from space PI control loops to reset supply air temperature set-points.
- Do not permit air handlers to introduce OA to a building area which is unoccupied or during the warm-up period unless required for night purge or IAQ.
- Use PI control where elimination of control offset conserves energy or increases comfort.
- Avoid control strategies based purely on high-select or low-select (for example controlling a chilled water valve based on the highest zone temperature sensor reading). A failed sensor or erroneous reading can drive the system into overcooling (or overheating).

For a full list of HVAC control routines refer to Appendix B of AIRAH *DA28 Building Management and Control Systems* (BMCS) and the AIRAH/OEH *HVAC Optimisation Guide*.

10. Provide HVAC ventilation sequences that comply with current IAQ codes and standards

Refer to the NCC, AS 1668.2 ventilation standard, and ABCB / AIRAH publication *Indoor Air Quality Handbook*.

11. Ensure that control system designers fully understand the complete building HVAC system

Refer to HVAC system components manufacturers' recommendations for application requirements and guidelines.

12. Hard-wire safeties if on–off–auto switches are provided

- Hard-wire all temperature low limit, fire, and pressure safeties if the system can be easily operated manually. In cases where a BMCS operator monitoring station is provided, the safeties are also usually monitored by the local digital controller.
- If override switches are not provided, and system operation is always dependent upon the digital control system, safeties may be wired to the digital controller for control and monitoring, thus saving duplicate wiring.
- The real value of the safeties is achieved by proper mounting, testing, and maintenance of such devices.

13. Place control valves on the leaving side of water coils

- Control valves on the leaving side of water coils leaves pressure in the coil when the valve is closed. This helps removal of air through the air vent on the leaving side of the coil, and also prevents the possibility of air being induced into the system through the vent if the pump produces a negative pressure in the coil return line.

14. Consider the ability of the HVAC system operator to understand the system when designing graphics for the operator interface

- Ensure the Functional Description is kept up to date and stored in a readily accessible location.
- The Functional Description should contain:
  - Descriptions (in non-technical language) of the intended logic of each operational sequences and control strategy.
  - System schematics to show how all of the system components interact.
  - A points list outlining all physical and key virtual points and their defined purpose.
- Each BMCS graphics screen should display the values and status of key plant and control variables
  - For a list of recommended content for BMCS Graphics Screens refer to Appendix D of AIRAH *DA28 Building Management and Control Systems* (BMCS).

Controls for end-users

These checklists focus on the strategy, implementation and the user interfaces of control devices located in occupied spaces and operated by individual users. They are particularly concerned with achieving good results with minimum energy use, especially through good integration of natural and mechanical systems and in avoiding equipment running unnecessarily.

Where controls for end-users is a focus of design, the following items should be checked with the controls specification.

Checklist for building designers

- ❑ Does the controls specification require controls to be accessible to the building's users at the point of need?
- ❑ Has the specification for user controls been based on evidence from known occupant requirements, such as occupant satisfaction surveys?
- ❑ Does the design specification make clear the anticipated energy savings and occupant satisfaction that will accrue from well-designed, installed and fine-tuned user controls?
- ❑ Does the controls specification cover the effective, reliable, and economic operation of user controls?
- ❑ Is the controls specification written so that the context of use drives the controls solution, rather than by the thinking that controls technology by itself, will be sufficient?
- ❑ Does the specification require the controls to deliver a quick response to the user on what is happening? (Note: Some systems respond slowly, such as underfloor heating)
- ❑ Does the controls specification require the user controls to give instant, tangible feedback? (Such as a click followed up by visual indication of system status, such as a readout or light.)
- ❑ Does the controls specification require systems to revert to their lowest-energy mode when they are not required? (A general rule is manual on, manual and auto-off.)
- ❑ Does the controls specification issued to the controls subcontractor contain clauses covering clarity of purpose, intuitive switching, appropriate and clear labelling and annotation, ease of use, indication of system response, and appropriate fine degree of fine control?
- ❑ Does the controls specification require central controls to keep conditions to a specific setpoint?

Note that tight control of internal conditions is often wasteful and inappropriate and that reasonable limits might be more appropriate, particularly for control of space temperature.

- ❑ Does the controls specification require the controls supplier(s) and installer(s) to provide the facility and/or space on or beside the controller for explanatory labelling?
- ❑ Is the controls specification clear when the occupant controls are linked to, and communicating over, the building management system communications network?
- ❑ Does the controls specification make clear the degree to which the occupant controls can control the relevant items of plant in each particular specification?
- ❑ Does the controls specification make clear the conditions under which a field controller will override settings changed by users on their local control?
- ❑ Does the controls specification contain a clause requiring override facilities to control the operation of devices during out-of-hours occupation?
- ❑ Does the controls specification contain provision for requirements for reviewing and improving the performance of user controls and the systems they control, in the first 6-12 months of building occupation? (This would benefit from a fully-funded contract provision that covers whole building fine-tuning, outside of defects and liabilities period).

Checklist for controls manufacturers and suppliers

- ❑ Do you have a mechanism by which the design team can define a special (non-catalogue) user controller or labelling system that could be better tailored to specific devices in the building (such as lights and blinds)?
- ❑ Have you made the architect aware of the controls requirements, and are you aware of any specific controls requirements made by the architect? (To control windows and blinds, for example.)
- ❑ Does your guidance to the controls installer include specific advice on the importance of placing a controller in a position suitable for needs of the users, and for the effect of the controller on space conditions?

Check the following against the designer's controls specification:

- ❑ Are the proposed user control devices matched to the specific controls task?
- ❑ Do they possess clarity of purpose?
- ❑ Are the proposed controls simple to understand, use and maintain?

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- ❑ Will generic, off-the-shelf control devices have sufficient functionality, or will they need further attention if what they do in respect of the specific controls task is to be intuitively obvious?
- ❑ Do your proposed user controls provide enough fine or stepped control?
- ❑ Does the labelling and annotation provided on your controls possess sufficient detail to be understood by the average building user?
- ❑ Do your proposed user controls give clear and tangible feedback on system status and operation, such as an audible click and/or display of system status and operation

Check the following with the system installer

- ❑ Has the installer been informed and/or educated on the context-specific requirements where your controls will be used?
- ❑ Has the installer received guidance on the importance of having context-specific solutions (and avoiding off-the-shelf controls which do not have clear user information) for critical devices like HVAC units, blinds and windows?
- ❑ Has the installer been instructed to provide fine-tuning and user familiarisation during handover and the initial months of building occupation?
- ❑ When working directly for clients, can the system installer demonstrate that it has involved building users, facilities staff and maintenance staff in the selection of user controls?
- ❑ Is the installer prepared to provide additional labelling of user controls in the light of early end-user experience, and has this been included in the cost plan?
- ❑ Have you included provisions for initial training in the use of controls for the building occupants (such as computer-based training on controls operation)?

Checklist for controls installers

The following items should be checked with the controls manufacturer:

- ❑ Do the user controls possess a level of functionality appropriate to the specific task, as understood by the building's users rather than design specialists?
- ❑ Are the architects and site contractors aware of the need to locate the user controllers close to the devices they control or where the users want to access them?
- ❑ Have you provided the right annotation or enough labelling to ensure that users will know precisely how to operate the controls?

Checklist during commissioning:

- ❑ Do all user controls in the building have suitable annotations or labels?
- ❑ Is the facilities manager fully aware of the purpose of each controller?
- ❑ Do the operation and maintenance documents explain the purpose of the controls, and ways to adjust them within the limits set by the design?
- ❑ Do the user controls possess a level of functionality appropriate to the specific task, as understood by the building's users rather than design specialists?

Checklist during ongoing occupation (some of the following may require extra contract provisions):

- ❑ Will you solicit feedback from building users on usability, and propose any remedial actions to improve the as-installed controls?
- ❑ Will you check whether any user controls need fine-tuning, particularly to match changes in main plant operation? (This should be separate from defects and liability remediation)
- ❑ Will you check whether any user control pre-sets need resetting to balance user satisfaction and energy efficiency objectives/targets?
- ❑ Will you check to ensure that user controls are not defaulting systems to on, wasting energy and annoying the occupants?
- ❑ Will you check to ensure that user controls are not being unnecessarily overridden by central controls in a way that conflicts with the original design intent and controls specification?
- ❑ Are the setpoints in user controls suitably flexible to allow users to change their comfort conditions without causing disruption to central controls or wasting energy?
- ❑ Can building occupants use their local controls to achieve timely, effective, and lasting changes to their comfort conditions? (Note: systems must be commissioned to operate within their design parameters).
- ❑ The usability and performance of user controls can be improved by adopting a long term (12 months) separately funded controls fine-tuning agreement with the building owner. This would not necessarily include maintenance but would include staff training and additional explanatory labelling for user controls.

Source: *Controls for end users – a guide for good design and implementation*, Building Control Industry Association, UK/BSRIA / Usable Buildings Trust, 2007, www.usablebuildings.co.uk

Lessons from building occupant studies

Buildings can be improved through better understanding of their performance in use, and more attention to detail with their design, construction and management. Independent post-occupancy studies and management of feedback are a valuable method of closing the loop in the building delivery process.

From over 300 studies conducted worldwide, including over 50 in Australia, the main considerations for designers, builders and building managers are:

Designers

- Keep things simple
- Do things well
- Think about performance over time as well as the physical form of the space.
- Keep controls for users as close to the point of need as possible.
- Remember that user needs vary widely.
- Do not design for a norm.

Maintenance of controls

Builders

- Lack of air tightness is increasingly critical, especially in green buildings.
- Integrate trades packages properly.
- Get feedback on performance of building.

Building managers

- Treat building users with respect. Don't patronise or ignore them.
- Respond rapidly to complaints, however seemingly trivial.
- Insist that designers think about usability and manageability for the long term.

Controls and maintenance

The fundamental purpose of controls is to regulate the performance of plant to meet system operational requirements. Control systems act to achieve and then maintain a set condition. Controls play a key role in energy-efficient operation and sustainability. Control irregularities can be a significant cause of inefficient operation and excessive energy consumption in HVAC&R systems.

Control systems can fail or perform poorly for the following reasons:

- Poor design
- Poor location or installation of sensors
- Low-quality sensors
- Oversized dampers and valves
- Incorrect commissioning
- Inadequate maintenance or system tuning.

The most important aspect of control systems is that the operator and maintainer of the system understand the control logic and design intent. Controls need to be well managed and maintained and if the logic and intent of control systems cannot be readily understood the system will need to be simplified or training provided.

Control systems can be relatively simple or highly complex. As the capability of the control system rises, the costs and complexity also tend to rise, leading to an increasing level of operating knowledge and maintenance expertise required, see Figure 1.

The effective functioning of any control system will depend on the correct location, positioning and calibration of each control sensor.

Recalibration of controls and sensors is a critical factor in the ongoing maintenance and system tuning regime. Constant recalibration of sensors can be time consuming and selection of high-quality control components at design stage can significantly reduce recalibration requirements and set-point drift.

Where occupants are provided with individual or general control interfaces, training or documentation should be provided to ensure that they appreciate the mode of operation that will produce the optimum results.

For centralised control systems, access should be restricted to authorised personnel only.

Intelligent controls can be arranged for self-monitoring, which can assist in maintenance management and delivery.

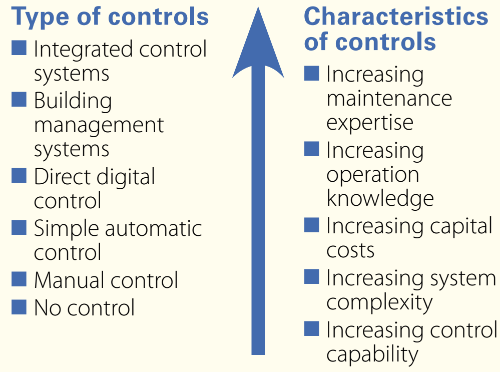

Figure 1 – Control system capabilities

This skills workshop is taken from the ***AIRAH Technical Handbook*** – available to all AIRAH members. For more information go to ***www.airah.org.au/Technical_Handbook/***

Next month: Fundamentals of water flow