One of the most common causes of poorly performing buildings is inadequate or deficient control systems. About 90% of controls for heating, ventilating and air conditioning (HVAC) systems are inadequate in some way, costing industry and commerce more than £500m a year in additional energy costs, according to the Carbon Trust (see Building Controls Technology Overview – CVT032, 2007). Controllability – or the lack of it – is a key issue when it comes to saving energy and cutting carbon emissions from buildings.

There are a number of definitions of controllability. For the purposes of this article, the term is used to mean the ability for the system to be controlled within acceptable limits for both occupancy comfort and energy efficiency/carbon emissions. Despite advances in control technology, poor control outcomes are still common. Controls can be inadequate or deficient for a number of reasons, but the most common are:

- Inadequately specified control systems/building management systems (BMS);
- Deficient commissioning and maintenance of control systems/BMS;
- Poorly understood, or ineffectual use of, control systems/BMS; and
- Poor controllability and un-controllable HVAC services.

All these factors are important, but the most misunderstood and difficult-to-resolve
The most misunderstood and difficult-to-resolve cause of poor control is the controllability of the HVAC services.

cause of poor control is the controllability of the HVAC services: no matter how good the control system or BMS is, lack of controllability means lack of effectiveness for all load conditions. A very simple example of an uncontrollable system is an oversized DX Cassette Unit with on/off control. This will never achieve a stable room temperature, and can result in cold draughts, dissatisfied occupants and poor efficiency of operation.

Changes to system design or plant selection may be required to achieve acceptable controllability – but such changes can be expensive and disruptive, and are avoidable by designing controllable systems. Alternative control strategies can sometimes be used, although not normally without some compromise of efficiency or operation.

Heating

Many controllability issues are associated with multiple boiler and chiller systems, which are normally less noticeable to the building user but are of increasing importance to reduce energy consumption and carbon emissions (and can be expensive and disruptive to rectify). CIBSE states that inadequate or incorrect application of boiler control can easily add 15% to 30% to fuel consumption, compared with a well-controlled system. Here are some of the most common heating-system controllability issues.

Poor header design (see Figure 1): Headers should be designed with flows at one end and returns at the other. If one circuit returns prior to the take-off for another circuit, the second circuit flow temperature will be affected – in this case the hot water supply (HWS) primary, which could affect HWS temperature. This should be obvious, but I’ve seen it on a major project within the last couple of years.

Split headers (see Figure 2): Individual flow and return headers will cause interaction between primary and secondary pumps, varying flows and potentially affecting stability of boiler control. It can be relatively easy to resolve by making the split header into a common header. A combined header/de-aerator/dirt separator can be very useful for this purpose.

Individual boiler pumps (see Figure 3): Individual boiler pumps and a common header are desirable to eliminate dilution of flow through off-line boilers, but can be the source of controllability issues. The most common issue is that boiler sequence cannot be controlled from return
differential temperatures, and consequently have lower flow rates. Whilst substitution of modern boilers with packaged pumps is normally successful at a domestic level, the effect on hydraulics must be considered for larger retrofit installations; reverse flows in common headers causing dilution of secondary flow temperatures is the most common problem.

**Boilers with variable flow pumps:** Pumps that vary boiler flow in unison with burner firing to maintain constant differential temperatures can cause significant hydraulic and controllability issues in multiple boiler applications, particularly where system differential temperatures have also not been carefully considered.

**HWS segregation:** Many systems combine heating and HWS heat sources to reduce capital costs. Segregation of HWS can often reduce standing losses in summer, and can permit far greater flexibility for boiler control, enabling more effective condensing operation.

**Two-stage burners:** These are very rarely correctly commissioned; only a few months ago I saw new boilers with both high and low burner stages set to the same temperature, working as single stage burners. Where controlled by the individual boiler thermostat, the second stage must be set to a lower temperature than the first stage; consequently, significant flow temperature variations will occur. Control can be integrated with sequence controls on multiple boilers to work effectively, but care must be taken to ensure compliance with HSE guidance note PM15.

There is little to justify two-stage burners as the theoretical gains over single stage burners are very rarely achieved. Modulating burners should always be used for good control and energy efficient operation.

**Biomass boilers:** These are increasingly used as a low carbon solution, but require a number of additional factors to be considered for successful operation. Purely adding a biomass boiler to an existing system without considering overall system integration – hydraulics and control – can be a recipe for problems. There are too many factors to consider here, but controllability is a major factor in successful biomass boiler system design.

**Component pressure loss:** Modern boilers can have significant pressure losses, which should be considered in their selection, as this will add to overall energy consumption. System components should also be...
KX6 VRF... applied

Curve Theatre, Leicester
Two auditoria with 1,200 seats, studios, rehearsal suites, dressing rooms and dining facilities all climate controlled simply, effectively, efficiently.

Ford Showroom, Swindon
600m² showroom, offices, meeting rooms and a 900m² service centre and canteen in need of cooling, but little plant space. Solution: KX6 micro single fan outdoor units.

Icon Hotel, Luton
43 guest bedrooms, reception, bars, restaurants and fitness suite zones simultaneously receive heating or cooling as required, with simplified guest controls for ultimate comfort.

amp air conditioning limited
Tel: 01707 378670 Fax: 01707 378699, sales@ampair.co.uk, www.ampair.co.uk

HRP Limited
Tel: 01359 270888 Fax: 01359 271132, headoffice@hrpltd.co.uk, www.hrnonline.co.uk

3D Air Sales
Tel: 01753 495720 Fax: 01753 495721, sales@3dair.co.uk, www.3dair.co.uk
Scotland Tel: 0141 777 5007, Ireland Tel: 00 353 (0) 1463 8604
carefully selected, and individual items with significantly higher pressure losses avoided, as these can dictate the maximum pump operating head. I have encountered systems where the majority of the loads had losses of 15 to 30 kPa, but a couple of loads were around 100 kPa.

To minimise energy use on variable flow systems, additional differential pressure sensors can be installed to control the individual parts of the circuits, to meet the required differential pressure only when these items of plant are operating. However, care needs to be taken to ensure stable operation of all items of plant when the system differential pressure changes. Selecting components with similar (low) pressure losses on each circuit is by far the most effective method for energy efficient controllable operation.

Chillers
One problem with chilled water (CHW) systems that I have identified on a couple of sites recently is parallel connection of a pair of chillers with a common pump-set (see Figure 4). In both cases the chillers were modern, large energy efficient chillers, but had flow temperature sequence control observed at low load, with one on-line chiller having an evaporator discharge temperature of 4.5°C, mixing with the flow through the offline chiller to achieve a mixed flow temperature of 6°C.

An evaporator flow temperature of 4.5°C will only satisfy a 23% load, assuming a constant flow system and 6°C to 12°C system temperatures. 3°C would be necessary for 50% load with only one chiller operating to provide a mixed temperature of 6°C, although chillers are typically set for a minimum control temperature of 4°C to avoid the possibility of freeze-up. Running a chiller at lower CHW temperatures will typically have a reduction in coefficient of performance (COP) of around 3% to 6% at 4.5°C instead of 6°C, and 6% to 12% at 3°C.

The overall reduction in seasonal efficiency could be significantly greater, dependent upon the selected chillers and load profiles, plus there will be additional pumping losses compared with individually pumped chillers. I understand in both cases the chiller manufacturers had recommended the hydraulic layout and control system!

It is normally more efficient to run modern multiple chillers together down to loads of around 20% to 25%, dependent upon chiller selection. However, individual chiller turn down is limited and stability of operation has to be considered at low loads. Significant energy savings and stable, reliable operation can normally be achieved with a controllable system design incorporating individual chiller primary pumps, a common header or buffer vessel, heat load control and variable flow secondary circuits. Reset of evaporator flow temperature at low loads can also save further energy in many applications.

Conclusion
The above is a selection of common controllability issues, most of which are easily avoided with suitable input to system design, resulting in controllable, energy-efficient operation. Robust control strategies are necessary to achieve optimum energy efficient, low carbon operation. Simple solutions are preferable, wherever possible, although modern plant with direct communication via BACnet, for example, offers further opportunities for more efficient operation.

www.birlingconsulting.co.uk www.cibse.org/bookshop