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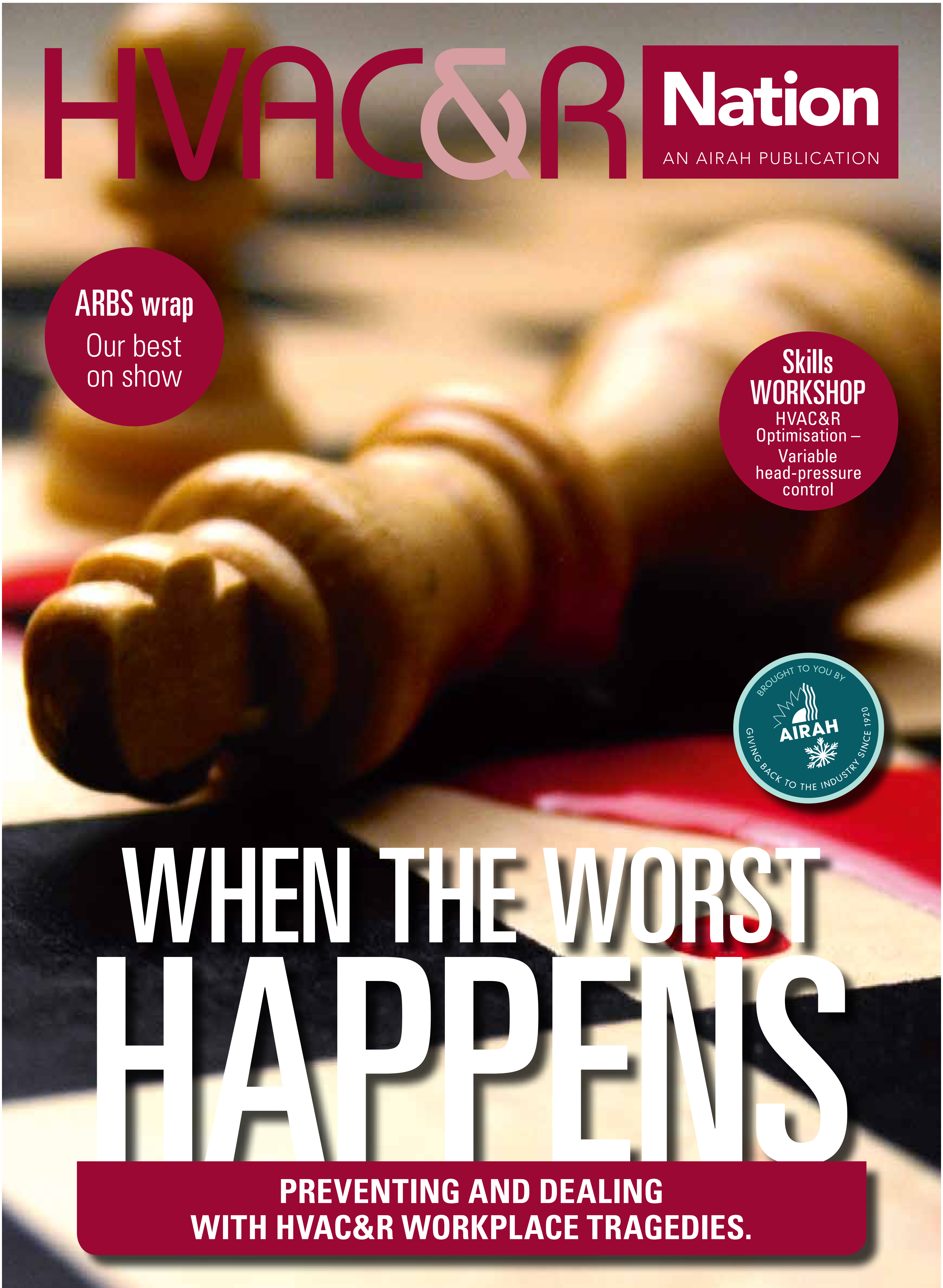

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HVAC&R Optimisation – Variable head-pressure control

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HVAC&R Skills Workshop

MODULE 93

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HVAC&R OPTIMISATION – VARIABLE HEAD-PRESSURE CONTROL FOR WATER-COOLED CONDENSERS

This month, we'll look into the optimisation strategy of applying variable speed drive (VSD) controllers to pumps for head pressure control of single water-cooled direct expansion (DX) units. By controlling the head pressure of water-cooled condensers, you are able to improve the energy efficiency of air conditioning systems in part-load conditions. When implemented correctly, this strategy could result in reduced energy consumption of CW pumps by 10–30 per cent, as well as improved control and reliability for AC systems during part-load conditions.

PULLOUT

STRATEGY SUMMARY

Controlling the head pressure of water-cooled condensers improves the energy efficiency of air conditioning systems in part-load conditions. This optimisation strategy involves applying variable-speed drive (VSD) controllers to pumps for head pressure control of single water-cooled direct expansion (DX) units. It also involves applying condenser water (CW) modulating head pressure valves for head pressure control of multiple water-cooled, AC DX units supplied by CW from one CW pump.

> Implementation of this optimisation strategy could result in reduced energy consumption of CW pumps by 10–30 per cent and improved control and reliability of the operation of AC systems during part-load conditions.

PRINCIPLE AND EQUIPMENT

During lower ambient air temperatures, the AC load typically decreases while the capacity of condensers increases. Energy savings are therefore possible by reducing the condensing pressure of the refrigeration cycle. This reduced pressure can then be maintained by VSD-controlled pumps, which would save additional energy compared to a control scenario where the pump is running at fixed speed.

Appropriate head pressure or condensing pressure is important for the proper operation of AC and refrigeration systems with head pressure maintained in several ways. The most energy efficient way of maintaining condensing pressure (constant or, even better, floating set point) of water- cooled condensers is to adjust the amount of heat rejection in condensers:

- by VSD controllers for single AC units
- via CW-modulating head pressure valves (for multiple AC units, that are supplied CW from one CW pump).

Water-cooled condenser/chiller.

For multiple AC units that are supplied CW from a pump controlled by a VSD (such as supplementary tenant AC systems), it is also important to automatically shut off the water supply to the condenser when the AC unit is not operating. This will significantly reduce the energy consumption of the CW pump.

CAUTION

AC systems should maintain adequate condensing (or head) pressure in order to enable the proper operation of the vapour compression refrigeration cycle. Supplying more CW than required will extract more heat from the condenser, thereby causing over-cooling or over-condensing of an AC system.

Over-condensing reduces the condensing temperature and condensing pressure, compromising the performance of the vapour-compression refrigeration cycle of the system.

MINIMUM REQUIRED INFORMATION

The minimum required information for maintaining head pressure includes:

- head pressure set point
- control strategy for modulation of the amount of heat rejection
- type of refrigerant.

MINIMUM REQUIRED EQUIPMENT

The minimum required equipment includes:

- field sensors (temperature, pressure)
- controllers and data processors
- CW pump
- if the CW pump supplies CW to multiple DX AC units, a head pressure control is required
- VSD controllers.

CURRENT PRACTICE

Most water-cooled condensers employ one of the following common control strategies to maintain head pressure:

- constant CW flow as per manufacturer's requirement
- constant CW flow as per HVAC system designer's requirements.

Both control strategies ensure sufficient heat rejection during the hottest O/A conditions; however, they potentially compromise part-load performance of associated AC DX units due to the risk from over-condensing. The additional CW flow also results in wasted energy at the CW pump.

In many buildings, CW continues to circulate through the AC units even when they are not in operation, thereby wasting energy at the CW pump.

OPPORTUNITY FOR OPTIMISATION

The following control strategy and parameters are recommended in order to maximise the energy efficiency of refrigeration systems while not compromising their performance:

- Determine optimal head pressure or calculations for a floating head pressure.
- Maintain optimal head pressure:
  1. **for single AC units:** using VSD controllers to control the amount of heat rejection by controlling the speed of condenser pump
  2. **for multiple AC units fed by a single CW pump:** using CW modulating head pressure valves to control the amount of heat rejection by controlling the amount of CW entering the condenser.
- When AC units are not in operation, ensure that CW to these units is isolated through a two-port valve.

ENERGY-SAVING POTENTIAL, COSTS, BENEFITS AND RISKS

Variable head-pressure control is typically a cost-effective HVAC energy-efficiency improvement. It does require some investment in new drives, valves and controls; however, it can immediately reduce the energy consumption of the HVAC system by reducing system pump power.

This strategy can save up to 30 per cent of energy consumed by CW pumps.

Benefits arising from controlling the amount of heat rejection for water-cooled condensers include:

- more reliable operation of refrigeration systems
- reduced energy costs
- reduced GHG emissions
- reduced pump maintenance costs.

POTENTIAL RISKS INCLUDE:

- inadequate set-up of the head pressure control valves with units either over-condensing (unsatisfactory performance and energy wastage at CW pump) or under-condensing (unsatisfactory performance, energy wastage at AC unit and risk of units tripping on protection devices)
- in open circuit systems, if the CW flow is shut down when the AC unit is not in operation, this creates a dead le.g. with the associated risks of corrosion and microbial growth
- supplementary AC units are typically owned and installed by tenants. Failure to seek their cooperation before carrying out modifications (such as shutting down CW flow when AC units are not in operation) and failure to execute this measure satisfactorily can damage relationships.

APPLICATION NOTES

Maintenance of head pressure using VSD controllers to control the speed of the CW pump is applicable for any single water-cooled AC system that operates on a vapour compression refrigeration cycle principle.

Maintenance of head pressure using CW head pressure valves to control CW flow of multiple AC units fed from one CW pump is applicable for water-cooled AC systems, which operate on a vapour compression refrigeration cycle principle.

The installation of two-port valves to shut off CW supply to AC units when not in operation is best carried out during manufacturing when the unit is specified. When retrofitting, it is essential that the manufacturer's advice is sought to prevent nuisance tripping of the units or affecting the warranty of the units.

OTHER VARIABLE SPEED APPLICATIONS FOR HVAC

STRATEGY SUMMARY

Apart from the uses of VSDs for motors discussed so far, there are many other HVAC applications in which VSDs are employed. Some of these are applied to achieve energy savings, while the main role of other applications could be to serve as soft-starters i.e. as electrical devices to optimise the starting current of motors. As these applications are not essential for major energy savings in HVAC systems, but are still important, their basic characteristics are briefly explained below.

Appendix D outlines the relationship between flow rate, pressure and the energy consumed by a fan or pump. These affinity laws can be used to estimate energy savings.

PRINCIPLE AND EQUIPMENT

When retrofitting VSDs, motors should always be checked for their ability to run at reduced speeds. Older motors, typically more than 20 years old, may also have insulation that is brittle and the installation of VSDs could lead to premature failure. However, in most cases, the cost of a new motor will be small in comparison to the potential energy savings and other benefits.

The photo (previous page) shows two partially throttled valves that are being used to regulate the water flow through a CW system. The same water flow can be maintained by opening the valves and reducing the speed of the pump by using a VSD. This optimisation strategy will save system energy as reducing pump speeds reduces pump power consumption.

Throttled (choked) distribution system.

OPPORTUNITY FOR OPTIMISATION

Supply air fans (constant air volume applications) in air-handling units

During mild weather conditions, the amount of S/A can often be reduced without compromising comfort while saving up to 50 per cent of fan energy.

Typical settings would be:

- speed changes between 70–100 per cent corresponding to O/A temperatures from 23–27°C (adjustable)
- the VSD controllers would run the S/A fan at 100 per cent speed if the O/A is higher than 27°C
- the VSD controllers would run the S/A fan at 70 per cent if the O/A is below 23°C
- if the O/A temperature is between 23–27°C, the speed would be adjusted based on a linear function between the O/A temperature and the speed of the S/A fan
- an override function would be available to increase the speed of the fan if space temperature increases at lower O/A temperatures.

Alternatively, the indoor temperature can be used to control the fan speed.

Minimum O/A flows for ventilation should be sufficient at all times, in line with AS 1668.2 requirements.

A minimum fan speed/air flow is required to maintain the air diffusion from the S/A registers; motors should be checked for allowable speed turndown.

Primary chilled water pumps

The amount of CHW pumped to the field and the energy consumed by CHW pumps can be reduced in response to the reduced cooling load during part-load conditions of HVAC systems.

This potential energy saving is limited by the minimum CHW flow required for associated chillers. Primary CHW flow controlled with a VSD varies between a minimum and maximum flow rate and is based on the type of chiller. Minimal value is typically set as 10–15 kilopascals (kPa) above CHW pressure differential settings for a chiller's flow switch, to ensure proper operation of the chiller during low CHW flow conditions.

With the introduction of a secondary CHW loop, this potential greatly increases,.

Outdoor air fans (risers)

In many buildings, O/A is provided to AHUs and spaces via masonry or ducted shafts and risers. Typically, the O/A fan is controlled by the VSD controller, which maintains a certain static pressure in the shaft or a duct (100–200 Pa typically).

As AHUs have their own fans, very often, there is an opportunity to reduce the static pressure set point of the O/A fans and their energy consumption. This should be carefully considered on a case- by-case basis and investigation should include air flow testing.

At very low part-occupancy, i.e. after-hours operation, O/A and spill fans can be shut down completely in some circumstances.

Kitchen hood exhaust and make-up fans

VSD controllers can be used to adjust the air flow of exhaust and make-up air fans in kitchen exhaust systems and the like to reflect actual usage rates.

Return air fans

In VAV applications where S/A fans are typically fitted with VSD controllers, R/A fans, if they exist, should also be fitted with VSD controllers.

Numerous strategies exist for satisfactory operation and optimisation of R/A fans including plenum pressure control and tracking S/A fans. Significant performance and efficiency gains can be made with strategies to match the duty of the R/A fan to the S/A fan.

Bathroom exhaust fans

Bathroom exhaust fans can be fitted with VSD controllers if they serve multiple compartments, e.g. in multi-story residential apartment buildings, so that they can reduce air flow during periods of low system usage (e.g. from 11pm to 5am). ■

MORE INFORMATION

This month's Skills Workshop was adapted from the NSW Office of Environment and Heritage's HVAC Optimisation Guide.

For more information, visit www.environment.nsw.gov.au

Next month: **Gas measurement guide**