Water Cooled VRF Air Conditioning Systems

A New Low Noise, Low Space, Low Energy Opportunity for Apartment Buildings.

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SUMMARY

In Australia, air conditioning has now been almost universally adopted for new medium to high density residential developments and can account for a significant component of the electrical maximum demand of a building. Indeed, since about 2010, annual peak electrical network loads for Sydney now occur in Summer, rather than winter, due to the wide uptake of air conditioning in residential buildings.

This broad adoption of air conditioning presents special challenges to designers of such buildings. Subsequent to occupation, strata managers and the Owners Corporations who effectively manage and own the common property, including air conditioning systems and infrastructure can face many more challenges.

The use of a Water Cooled Variable Refrigerant Flow (WCVRF) System can address most, if not all, of the significant the issues that challenge the above stake holders. Moreover, the inherent improvements in performance of water cooled condensing when compared with air cooled, in conjunction with the heat recovery capabilities of VRF systems provide opportunities for significant energy savings, without significant cost imposts.

And by integrating the heat rejection system with indoor pool heating and domestic hot water systems, a significant "free-heating benefit" can also be achieved.

THE CHALLENGES OF HIGH DENSITY RESIDENTIAL AIR CONDITIONING

During design, the principal challenges on respect to air conditioning relate to:

1. Space requirements for condensing equipment;
2. The need for air cooled condensers to be located externally;
3. The noise generation of such equipment and the impact on neighbouring apartments;
4. Achieving safe and adequate service and maintenance access;
5. Providing adequate electrical infrastructure; and
6. Aesthetic requirements.

Once completed, the Owners Corporation and the Strata Managers must deal with on-going issues of maintenance and access, noise complaints from adjoining apartments and the cost of replacing equipment once it is at the end of its economic life.

For many occupants, the high cost of delivered energy will remain an ever-present issue, made more significant by escalating delivered energy prices (i.e. inclusive of network costs).

Of all these issues, the space requirements provide some of the greatest challenges. Air Cooled Air Conditioning Condensers, by their very nature, can provide an optimum structure for climbing by young children. Consequently, the must be located away from balustrades, further increasing the difficulties associated with locating these on balconies.

ORIGINAL WATER COOLED SYSTEMS

Until the mid-1990s, water cooled systems were a common option for apartment and hotel air conditioning. These systems were, on the whole, unobtrusive, with the equipment serving each apartment able to contained wholly within ceilings or air conditioning cupboards. Up to this period, air conditioning was not particularly common and only premium apartment buildings were being provided with air conditioning to every apartment.

These systems generally comprised a cooling tower at roof level and sometimes included a hot water generator within the condenser water circuit, allowing individual water-cooled air conditioning units to operate in reverse cycle.

The principal downside was that the indoor unit contained the complete refrigeration system, including the compressor. This resulted in equipment that was relatively large and noisy.

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VRF SYSTEMS

Variable Refrigerant Flow (VRF) Systems, also called Variable Refrigerant Volume (VRV) Systems, began to emerge in the mid 90's and revolutionised multi-zone air conditioning systems.

Conventional refrigerant systems were always difficult to control effectively at part-loads, but VRV technology permitted refrigerant flow to be throttled (controlled) much like a chilled water system. And, being a refrigerant system, provided the option of reverse cycle heating as well.

These then were akin to the popular and flexible Chilled Water/Heating Hot Water Systems that had transitionally been used in commercial systems for many decades.

A subsequent innovation, commonly known as the "Heat Recovery" or "3 Pipe System" further allowed VRF systems to simultaneously heat and cool with different terminal (indoor) units.

Limitations for such systems related to the use of relatively large, air cooled condensers, which needed to be located externally or in well ventilated plantrooms. Another limitation arose from the need for extremely long refrigerant lines, and whilst these limits have gradually expanded, the total refrigerant charge increased along with longer pipe runs, making such systems unsuitable for installations serving many small spaces, such as apartments and hotel rooms.

WATER COOLED VRF SYSTEMS (WCVRF)

By combining a VRF split system with a water-cooled heat pump arrangement, several benefits can be obtained. Key amongst these, from a designer/developer perspective are:

Single and Internal Condenser Location

A WCVRF System provides the flexibility of utilising one condenser to serve multiple apartments per floor (or where required more than one condenser) water cooled condensers, located within an *internal space* plantroom.

The advantages are significant. With typical mid-range apartments normally being fitted with a 7.5 kW_r air conditioning unit, a single condenser would be able to meet the requirements of up to four apartments[1].

And with typical condenser dimensions of 800 mm x 600 m in plan and 1000 mm high, several condensers can be located within a single, internal plantroom.

Indeed, a Condenser Plantroom / Cupboard, accessible from a Lobby corridor with dimensions of 3.8m wide by 1.2 m deep would be sufficient to serve up to 16 typical apartments.

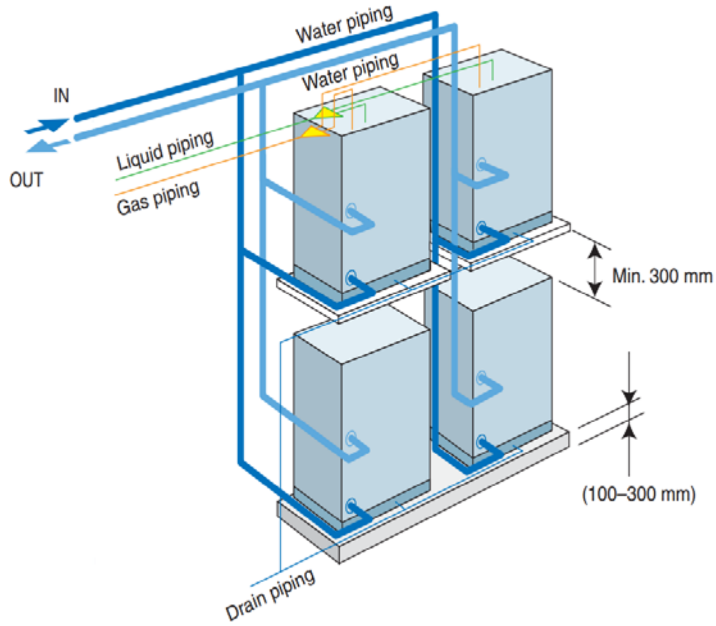

Figure 1: 4 Condenser Arrangement (Serves approx. 16 typical apartments. Dimensions 3.8m x 1.2m))

Significantly, the condenser space needs only minimal ventilation, generates relatively little noise and does not require access to an external wall.

Low Noise

Whilst water cooled condensers are by no means silent, the absence of a high-speed condenser fan greatly removes noise generation.

Moreover, as very little ventilation is required within the condenser space, it is easy to attenuate through conventional measures generally employed in residential building construction.

Improved Aesthetics

The complete removal of external air conditioning equipment from balconies and façades removes a further concern that has become significant for architects and the community in general.

REDUCED ENERGY CONSUMPTION: REFRIGERATION SYSTEM

The proposed WVRF System reduces energy consumption in several ways:

[1] Subject to limiting total refrigerant charge in compliance with AS1677.

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Higher COP from Water Cooled Condenser

The WCVRF system rejects the high temperature heat of refrigeration to a water-cooled condenser. For standard design conditions, this temperature will be 29.5^{O}C.

Energy savings are achieved through a higher Coefficient of Performance or COP[2], since, by rejecting heat at a lower temperature, less electrical energy is required. By comparison, an air cooled condenser is required to reject heat to the ambient air, which will generally be higher (and sometimes significantly so) than the water temperature.

This measure alone, even after considering the energy consumption of the central water cooling plant, results in an energy reduction of about 35%.

Energy Recovery from Simultaneous Heating and Cooling Requirements

One unique feature of a 3-Pipe VRF System is that whilst multiple fan coil units are connected to a single condenser, each fan coil unit can independently operate in cooling mode or in reverse cycle heating.

This feature can be applied to an Apartment building by utilising one condenser to serve apartments with different orientations.

Thus, if a single VRF condenser serves apartments on the North and South side of a building, there *may* be times when the northern facing spaces will operate on cooling, rejecting heat to the refrigerant circuit, whilst the south-facing apartments will absorb heat from the refrigerant circuit has they operate in reverse cycle heating mode.

However, this is not generally likely to be a major source of actual energy savings, since apartment air conditioning is operated at a lesser frequency than commercial systems.

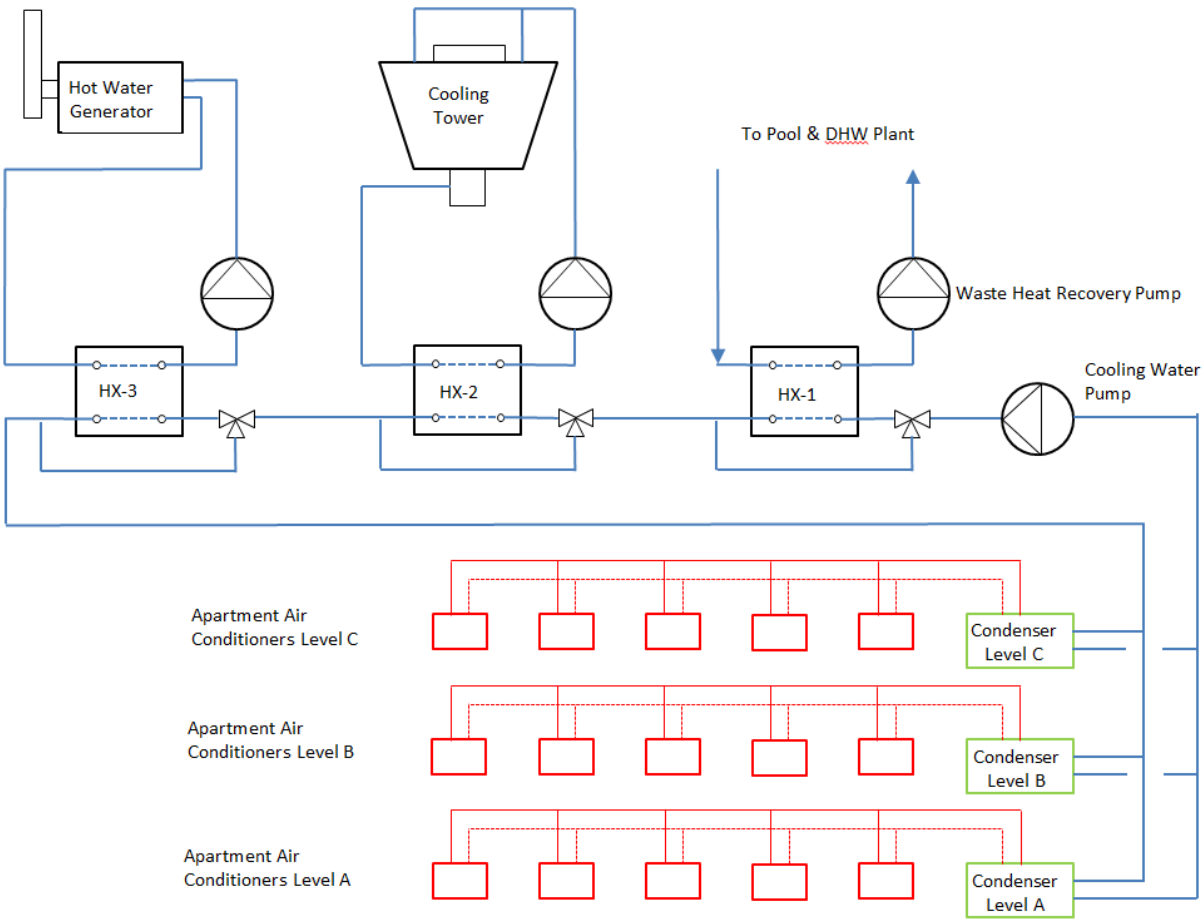

Figure 2: WCVRF Air Conditioning System Integration with DHW and Pool Heating

[2] COP is the ratio of heat removed by the refrigeration process and the input electrical power required to remove the heat)

INTEGRATION WITH DOMESTIC HOT WATER AND POOL HEATING

One substantial advantage of the WCVRF system is that it centralises all heat rejection, making recovery of waste heat practical and economic.

A water-cooled system will typically reject heat at 35°C and whilst this is significantly lower than temperatures achievable through heat recovery of de-superheating, it is far simpler to implement.

Intelligent design can utilise the waste heat stream in several potential ways. Two of the simplest ones are described below.

Pre-heating of DHW Cold Water Makeup

With cold water services typically at around 20°C and central Domestic Hot Water (DHW) Systems operating at a pasteurisation temperature of 62°C, DHW systems can require significant energy when hot water is being used.

Significantly, the waste heat energy stream from the WCVRF system, being at 35°C, is well above the cold water make-up temperature, even in Summer. This then provides a simple and low cost method of transferring the heat being rejected by the air conditioning systems to a useful end(see Figure 2).

Pool Heating

Heated pools require heating even in summer. The reason for this is that as pool water is heated, evaporation increases, which cools the body of water. Evaporation is increased by air movements and low ambient relative humidity and is generally higher in summer.

A 35°C waste heat stream can be utilised to completely heat a swimming pool and if required, the pool hall as well[3]. The use of such low-grade heat requires a customised approach to the design. However, the cost impost is minimal and the benefits can be significant.

DISADVANTAGES OF WCVRF

Whilst the WCVRF offers many benefits over conventional, single-unit air cooled split systems, there are some disadvantages that need to be considered by designers.

The primary disadvantage is the need for a central Cooling Tower, Hot Water Generator, associated pumps, heat exchangers and associated plant.

At a practical level, these are simple challenges, easily addressed and resolved. However, they do require a more considerate engineering approach than is often provides for relatively simple residential buildings.

Such central plant will also require maintenance and serving on a regular basis. However, previous work has shown that such costs are more than compensated for by the savings in energy expenditure by individual apartments.

CONCLUSIONS

Water Cooled Variable Refrigerant Flow systems offer several significant advantages for apartment projects over the currently popular stand-alone split air conditioning systems.

WCVRF Systems:

1. Require minimal space for condensers and completely avoid the need for locating condensers on balconies and other external spaces, thus greatly simplifying the design of the building and avoiding aesthetic compromises;
2. Result in greatly reduced noise generation and remove noise ingress into neighbouring apartments. What noise is generated can be easily attenuated through conventional building methods and materials;
3. Are simpler to achieve safe and adequate service and maintenance access;
4. Result in reduced electrical demand; and
5. Will achieve significant energy reduction, with potential enhancements if waste heat is recovered for use in Domestic Hot Water pre-heating and, where applicable, pool heating.

Like any alternative solution, a WCVRF System presents its own peculiar challenges. However, these are of a minor nature and easily addressed by competent, experienced engineers, making the benefits far greater than the disadvantages.

[3] Such a system is in use at the Macquarie University Aquatic Centre, designed by the author in 2007.