AN OVERVIEW OF WATER-COOLED (TYPE 2) CONDENSERS

AIRAH has taken over responsibility for the Australian Refrigeration and Air-Conditioning (ARAC) Manuals Volumes 1 and 2, lauded since its original release in 1988 as the country’s primary resource for training the refrigeration and air conditioning industry. Authored by Graham Boyle, M.AIRAH, the ARAC Manual covers everything from the basic principles of refrigeration through to equipment, tools, principles, systems, testing, load estimating, installation, maintenance and commissioning. In this month’s Skills Workshop, we showcase an sample extract from the Manual – an overview of water-cooled condensers and their typical issues.

WATER-COOLED (TYPE 2) CONDENSERS

Water-cooled condensers offer considerable advantages, particularly for large machines. These include more compact condensers and lower head pressures, with subsequent increase in unit capacity with lower power requirement. However, because of widespread shortages of fresh water around the world, few countries can afford to run water to waste, particularly at the rate demanded by large air-conditioners. For example, one air-conditioner of the size required by a large office building could use 160 000 litres of water per hour in summer. For this reason, all water-cooled refrigeration and air-conditioning systems must recirculate the water using cooling towers to cool the water by evaporation. Evaporative condensers also recirculate water and will be considered later.

There are many varieties and sizes of water-cooled condensers. Water-cooled condensers owe their efficiency to the fact that:

- water is usually cooler than summer air and this reduces the condensing unit’s head pressure for higher volumetric efficiency
- heat transfer from a metal to a liquid is up to 50 times faster than from a metal to air, so the same condenser surface area could conduct up to 30 000 kilojoules of heat per hour to moving water, compared with only 600 kilojoules per hour to moving air.

Water-cooled condensers mainly use copper tubing to prevent corrosion and for maximum heat transfer and, on large units, integrally finned tubing is also used to advantage.

Commercial water-cooled condensers are of three basic types:

- shell-and-coil
- tube-within-a-tube, or double-tube
- shell-and-tube multi-pass.

Shell-and-coil condensers

The shell condenser, or shell-and-coil condenser as it is commonly called, is a tank made of steel with copper tubes inserted in the shell. Water circulates through the tubing and condenses hot gases into a liquid. The bottom of the shell serves as the liquid receiver. The advantages of this style of construction are compactness of design, the elimination of fans and a separate condenser.

A – refrigerant out
B – refrigerant in
C – water in
D – water out

Fig 3.18: A water-cooled condenser which also serves as the liquid receiver.
Also, it allows a very flexible type of assembly. Some companies produced this type of condenser with the difference that, instead of a coil of copper tubing being used for the water passages, the liquid receiver was given a double wall within which the cooling water circulated.

This type may be used on small units with water running to waste, in which case it is operated in conjunction with a water valve that operates either from head pressure or water temperature, to regulate the flow of water to the requirements of the load and day temperatures.

These valves are described later in this chapter (see Figure 3.27). However, most of these systems use remote cooling towers and have recirculated water pumped through them. Many such condensers can be connected to a single cooling tower, so such systems can still be economically viable.

These condensers are not normally used on plants exceeding 35kW of refrigeration capacity.

### Tube-within-a-tube (double-tube) condensers

The second type of water-cooled condenser, which is very popular because it can easily be made to fit the size of the unit to be cooled, is the double-tube type. One tube is put within another in such a way that water passing through the inside tube cools the refrigerant in the outside tubing. The outside tubing is also cooled by the air in the room, allowing very efficient operation.

This condenser may be constructed either in the cylindrical spiral style or in the rectangular style. Small condensers of this type may run water to waste and use water valves to regulate flow. However, these condensers are usually used in conjunction with a cooling tower and water is recirculated.

The water enters the condenser at the point where the refrigerant leaves the condenser to go into the liquid receiver, and the water leaves the condenser at the point where the compressor is connected to it. This is called contra-flow (or counter-flow) construction. The warmest water is adjacent to the warmest refrigerant and the coolest water adjacent to the coolest refrigerant (see Figure 3.19).

As with air-cooled condensers and evaporators, the flow of cooling water in water-cooled condensers should be in the opposite direction, or counter, to the refrigerant flow, to ensure that the coldest water comes in contact with the coldest refrigerant. This provides the greatest mean temperature differential and the highest rate of heat transfer.

Water-cooled compressors are sometimes used with water-cooled condensers. The water flow, with few exceptions, is through the condenser first, then through the cylinder head and finally out into the drain. The water flow through these condensers is regulated by means of an automatic water valve, similar to that used on the previous type.

### Shell-and-tube condensers

Shell-and-tube condensers are available in capacities ranging from 7kW of refrigeration up to 3500kW or more. Shell diameters range from approximately 100 mm up to two metres; tube length varies from approximately one to six metres. The number and the diameter of the tubes depend on the diameter of the shell. Tube diameters of 15mm to 50mm are common, while the number of tubes in the condenser varies from as few as six or eight to as many as one thousand or more.

The end-plates of the condenser are removable to permit mechanical cleaning of the water tubes.

### Service problems with water-cooled condensers

#### Water corrosion

Properly designed and sized condensers present very few problems from the refrigerant side. However, the cooling water and its accessories require regular maintenance and frequent replacement due to the corrosive nature of the supply waters with their dissolved salts and the effects of electrolytic corrosion between dissimilar metals.

Water corrosion is a serious problem in Australia for two main reasons:

- Water cannot be run to waste, but must mostly be recirculated, requiring the use of cooling towers which cool the condenser water by evaporation of some of the water. This leads to a concentration of the corrosive salts and scale-producing carbonates.

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**NOTE** The increasing need to conserve fresh water means that it is now unusual to find a system that runs ‘fresh’ water to waste.
• In some areas, an increasing use of underground water with higher concentrations of solids has made chemical treatment of the water much more costly and difficult to control as concentrations can vary from day to day. The water treatments recommended by chemical suppliers are usually potent corrosives themselves and designed to neutralise the water’s salts, to hold scale-forming carbonates in suspension and prevent fungal and bacterial growth in the water. Unless checked daily or weekly, the balance can be lost and the water can become highly corrosive.

**Heat**

As with all parts of a refrigeration system, excessive heat is a major enemy. High condensing temperatures resulting from insufficient water flow, high water temperatures, air in the system and overloading all increase the rate at which scale forms on the surfaces of the condenser. Scale acts as an insulating blanket, reducing heat transfer and further raising temperatures. It sets rock hard and sometimes cannot be removed, even with physical scraping or raw acid dosing.

**Cleaning condensers**

Only shell-and-tube condensers can be physically cleaned and inspected, because the tubes can be scraped using rods with nylon brushes attached when the end shields are removed. Shell-and-coil and tube-in-tube condensers are cleaned by circulating an approved chemical through the water tubes. Very often, shell-and-coil condensers are considered to be ‘throw away’ components, replaceable at less than the cost of repairs.

**Self-cleaning condensers**

The latest shell-and-tube condensers have self-cleaning brushes fitted into the tubes. Small nylon brushes in brass casings are fitted into each tube. When the plant is in normal operation, the brushes are at one end of the condenser tubes. At the end of each day’s operation, the direction of water flow through the condenser is reversed by a set of valves and the brushes move through the tubes to the other end, scraping off the day’s accumulation of scale. The flow is then reversed to normal and a second cleaning ‘pass’ results.

It is claimed that the ‘scaling factor’ will be reduced from 0.001 to 0.0005, effectively increasing the condenser capacity by over 25 per cent. If successful, condenser capacity should remain constant and not suffer a slow decline between overhauls, as scale build-up is eliminated.

**Evaporative (Type 3) condensers**

Evaporative condensers utilise both air and water to achieve heat rejection. The refrigerant flows into a condenser located in an enclosure, water is sprayed over the condenser to promote cooling of the refrigerant and air flows over the condenser to promote evaporation of the water and removal of heat energy. The water cycle is all in the condenser cabinet in this system. Longer refrigerant runs are usually needed to carry refrigerant to the evaporative condensers. Usually the evaporative condenser is mounted out of doors; however, it is possible to locate an evaporative condenser indoors by providing air ducts linking the condenser to the outside.