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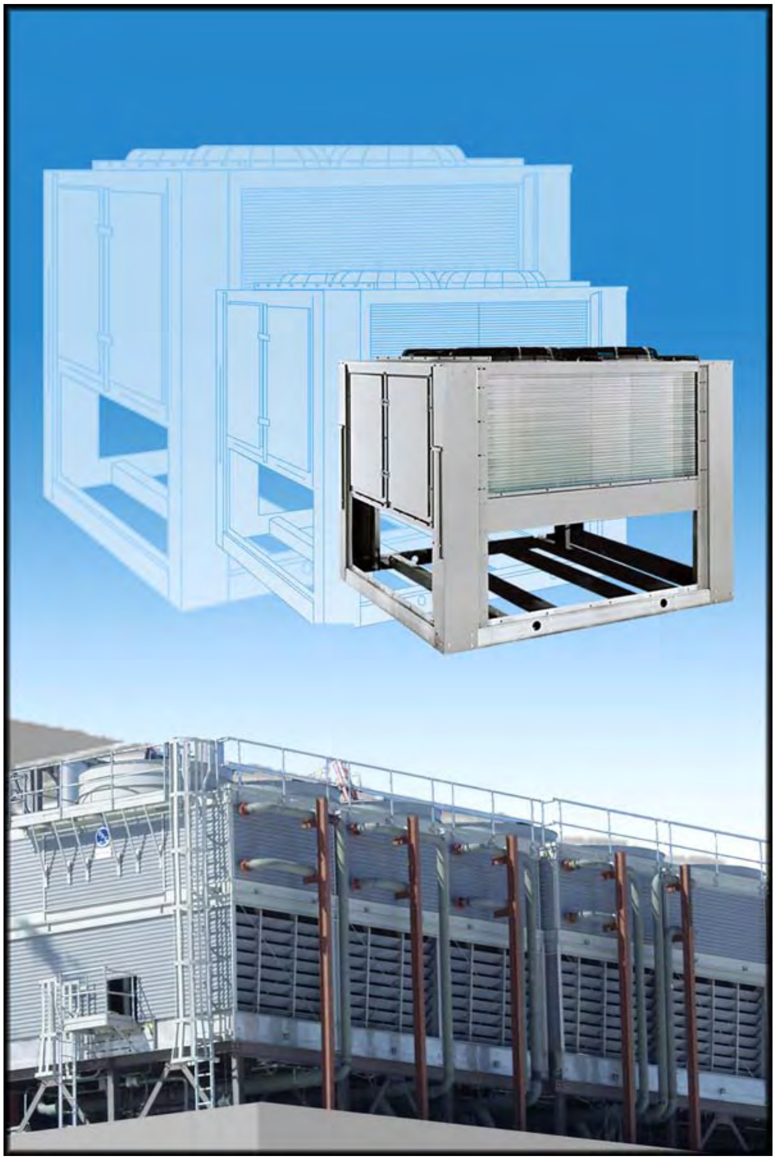
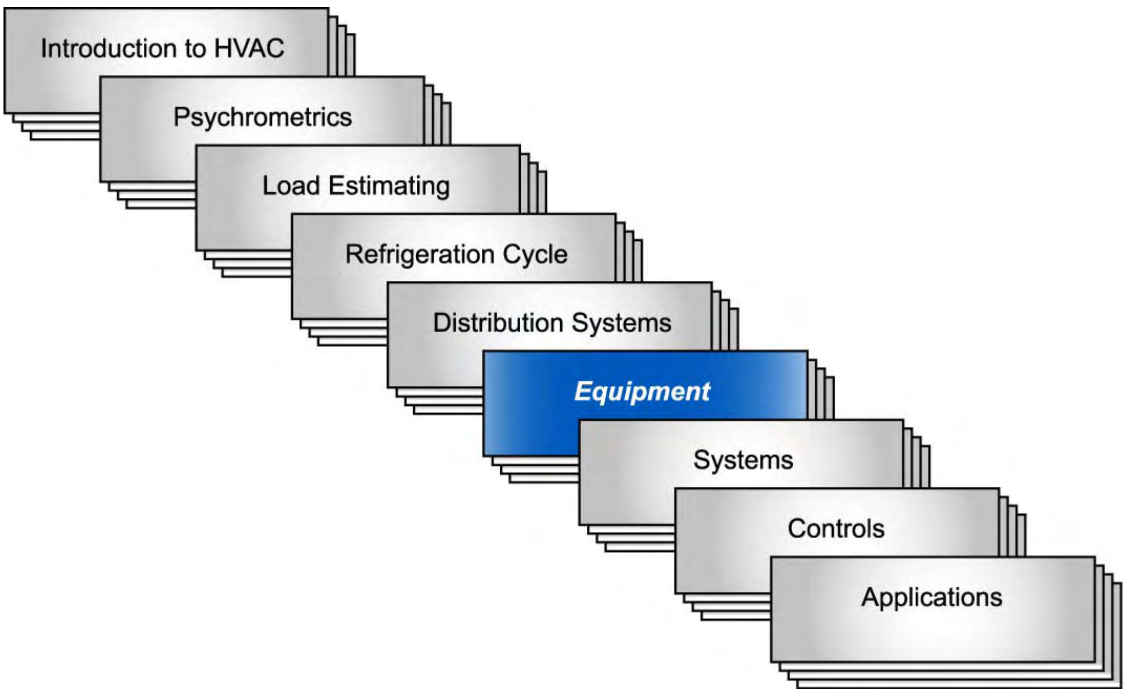


Condensers and Cooling Towers

Technical Development Program

Technical Development Programs (TDP) are modules of technical training on HVAC theory, system design, equipment selection and application topics. They are targeted at engineers and designers who wish to develop their knowledge in this field to effectively design, specify, sell or apply HVAC equipment in commercial applications.

Although TDP topics have been developed as stand-alone modules, there are logical groupings of topics. The modules within each group begin at an introductory level and progress to advanced levels. The breadth of this offering allows for customization into a complete HVAC curriculum – from a complete HVAC design course at an introductory-level or to an advanced-level design course. Advanced-level modules assume prerequisite knowledge and do not review basic concepts.



This TDP module discusses the most common heat rejection equipment: condensers and cooling towers. Heat rejection is a process that is an integral part of the air conditioning cycle. The heat is rejected to the environment using air or water as the medium. In order to properly apply system concepts to a design, HVAC designers must be aware of the different heat rejection methods. Also presented is the concept of total heat of rejection, it's derivation, and how it applies to the process of air conditioning, as well as the controls that are used to regulate each type of heat rejection unit.

Printed in Syracuse, NY

CARRIER CORPORATION
Carrier Parkway
Syracuse, NY 13221, U.S.A.

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Introduction

Condensers and cooling towers are the most common kinds of heat rejection equipment. There are three types of condensers: water-cooled, air-cooled, and evaporative. Water-cooled and air-cooled condensers use a sensible-only cooling process to reject heat. Evaporative condensers use both sensible and latent heat principles to reject heat.

Cooling towers are similar to evaporative condensers because they also utilize latent cooling through the process of evaporation. We will discuss three kinds of cooling towers in this TDP: natural, mechanical, and closed-circuit.

We will discuss total heat of rejection, its derivation, and how it applies to the process of air conditioning. Applications for condensers and cooling towers, as well as the controls that may be used to maintain proper refrigerant and water temperatures will also be covered.

Figure 1

Three Types of Condensers
Photos: Water-cooled: Courtesy of Standard Refrigeration; Evaporative: Courtesy of Baltimore Aircoil Company

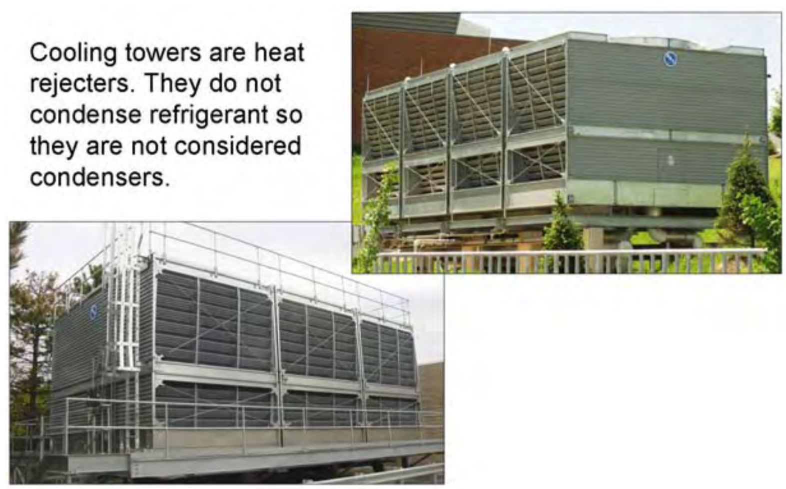

Figure 2

Cooling Towers
Photos reproduced with permission of Baltimore Aircoil Company

Condenser Total Heat of Rejection

The heat to be rejected by the condenser in condensing the refrigerant is equal to the sum of the refrigeration effect (RE) of the evaporator plus the heat equivalent of the work of the compression.

RE + Compressor work = THR (Total Heat Rejection)

Heat rejection in the condenser may be illustrated on the P-H (pressure-enthalpy) diagram. A pressure-enthalpy diagram is used because condensing takes place at constant pressure, or nearly constant pressure when blended refrigerants are used, (line F-G). This diagram may also be used to show the pressure rise of the condensing medium as it absorbs heat from the refrigerant (curved line).

The THR of the condenser is defined by line E-H, which is the sum of the refrigeration effect (line A-B) and the heat of compression (line C-D). As the ratio between compressor discharge and suction pressures increase, the refrigeration effect decreases and the heat of compression increases. This is because the work done by the compressor has increased.

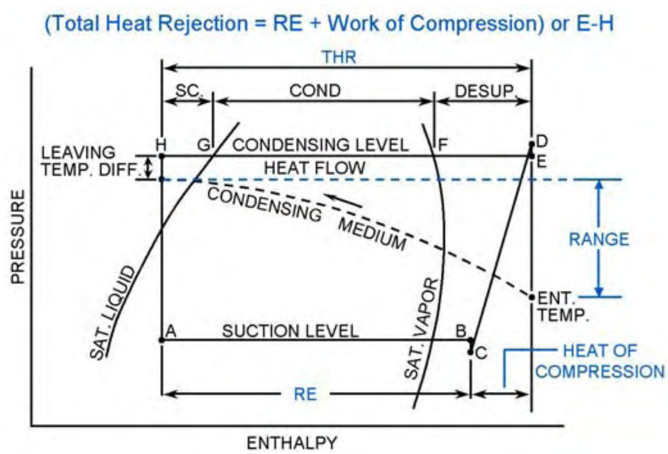

Figure 3

Condenser Total Heat of Rejection (shown on p-h diagram)

These are the equations to calculate the THR in units of Btuh:

In cases where the brake horsepower (bhp) of the compressor(s) is known:

$$THR = RE + (bhp * 2545)$$

2545 is a constant; it is the Btuh equivalent of one bhp. Brake horsepower is the application rating for the compressor.

In cases where the compressor kW is known:

$$THR = RE + (kW * 3414)$$

3414 Btuh is equivalent to one kW.

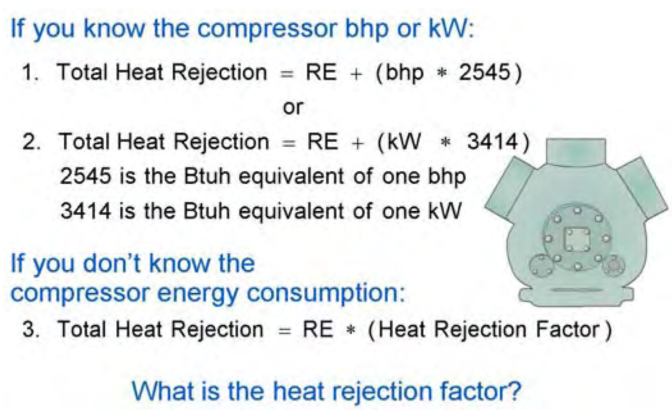

Figure 4

Total Heat of Rejection Formulas

Kilowatts

(1000 watts) is the term used to describe compressor power. The kW unit is used more often than brake horsepower because most manufacturers' product ratings are now expressed in kW.

THR reflects the work done by the compressor as well as the evaporator. THR can be expressed in Btuh tons, or MBtuh. One MBtuh is equal to 1000 Btuh. Where refrigerant is used to cool the motor, such as in a hermetic-type compressor design, added heat (the heat from the motor losses) also becomes part of the THR in the condenser.

Heat Rejection Factors

Heat rejection factor is a multiplier applied to the cooling capacity to find the condenser total heat of rejection.

When a chiller

is said to have a 100-ton capacity we are referring to the refrigeration effect. The condenser, however, should be represented in terms of THR tons. In the case of an air-cooled chiller, for example, the THR would be approximately 1.25 ∗ 100 = 125 tons.

The amount of heat added to the cooling capacity to arrive at the THR for any given application is a function of the compressor efficiency and the condenser cooling method (air, water, or evaporative) cooled. As an example, compressors used in HVAC equipment typically have a full load heat rejection factor in the range of 1.15 to 1.25.

Water-cooled screw and centrifugal compressors are very efficient, so they tend to have heat rejection factors between 1.15 and 1.18. Compressors used in air-cooled applications typically have heat rejection factors closer to 1.25. This efficiency is a function of the saturated condensing temperature, which is lower for water-cooled chiller compressors.

Using a value of 1.17 as an example for a water-cooled chiller, for every ton (12,000 Btuh) refrigeration effect, the load on the water-cooled condenser would be:

12,000 ∗ 1.17 = 14,040 Btuh heat rejection for each ton of cooling capacity

A heat rejection factor of 1.25 results in 15,000 Btuh heat rejection per ton of cooling. (12,000 ∗ 1.25 = 15,000). Consequently, 15,000 Btuh per cooling ton was used for many years as representative of all chillers. For modern water-cooled chillers, however, this value is no longer accurate due to efficiency improvements.

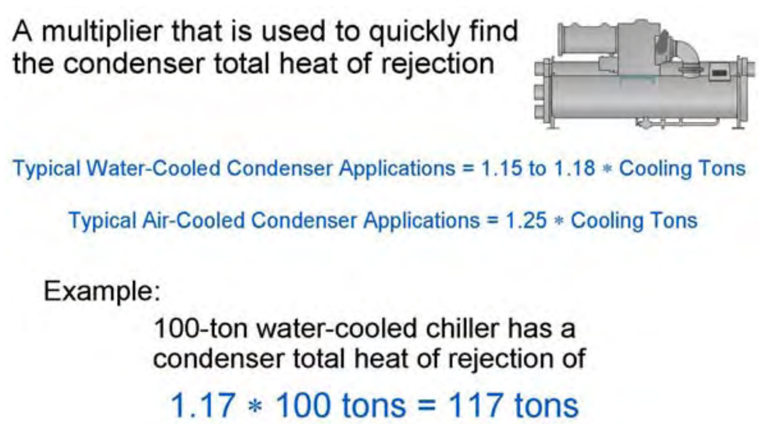

Figure 5

Typical Heat Rejection Factors

Condensers

Condensers remove heat from the refrigeration system. Like the evaporator, the condenser is a heat transfer device. Heat from the high-temperature, high-pressure refrigerant vapor is transferred to a heat-absorbing medium (air or water) that passes over or through the condenser. Condensers do three things: desuperheat the refrigerant gas, condense the hot refrigerant gas into a liquid, and subcool the liquid refrigerant.

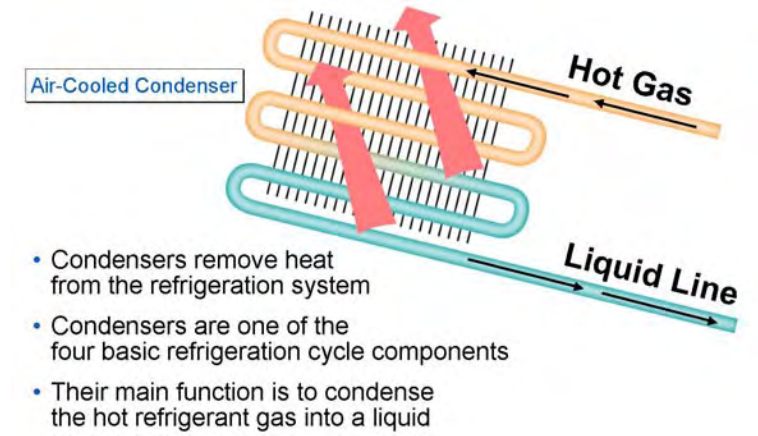

Figure 6

Condenser Definition

Condensers are one of the four basic refrigeration components. The other three are the evaporator, compressor, and metering device. The metering device shown in Figure 7 is a thermostatic expansion valve.

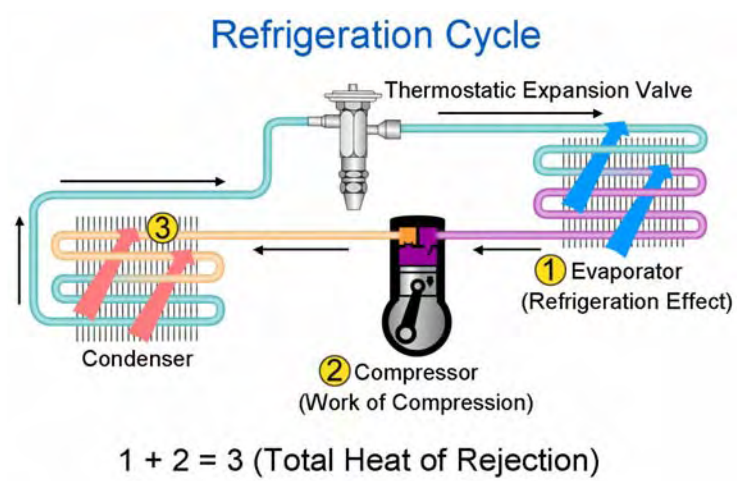

Figure 7

Condensers reject the heat from the evaporator and the compressor.