

perature difference between superheated vapor and air and the high heat transfer coefficient obtained with the relatively high vapor velocity. In this zone, the refrigerant vapor is cooled to the condensing temperature. For efficient heat transfer, counterflow between air and refrigerant is used; therefore, the desuperheating zone is preferably in the leaving air stream.

Condensing takes place in approximately 85 percent of the condenser area, at a substantially constant temperature. The indicated drop in condensing temperature is due to the friction loss through the condenser coil. The temperature rise of the cooling air, on the basis of customary cfm per ton ratios, is roughly 12 F deg.

Subcooling in an air-cooled condenser is usually limited because of the small temperature difference between air and refrigerant in this zone. The heat quantity transferred in the subcooling zone is relatively small (about 5 percent of the total heat transfer). In many designs, subcooling in the condenser is held to a minimum, and an integral subcooling coil is located in the air stream entering the condenser.

TYPES

Air-cooled condensers may be classified as, (1) the chassis-mounted condenser, which is always a component of a condensing unit, or (2) the remote condenser, an integral assembly remote from the compressor. Both are further subdivided into indoor and outdoor units of either the forced-air or gravity (free-convection) type.

Chassis-mounted (Indoor Type)

These condensers are usually mounted on a common base with the compressor, motor, and receiver. The condenser fan may be mounted on the shaft of the compressor motor. For small compressors up to $\frac{1}{2}$ hp, free-convection condensers which require no fan are sometimes used.

Most chassis-mounted condenser coils are made of steel tubes and steel fins, with the fins copper-brazed to the tubes. The use of all-copper coils is now limited to special applications because of their relatively high cost. Steel fins are usually 0.012 to 0.015 in. thick, spaced 6 to 8 per inch. Fin spacing closer than 10 per inch is seldom used in indoor condensers since they are often located where the finned surfaces are subjected to dirt clogging. The entire condenser is painted to provide protection from corrosion, and to improve appearance.

Approximately 100 to 150 sq ft of coil surface, and 500 to 700 cfm of air, per compressor horsepower are used. In most designs, air is drawn through the condenser coil and discharged over the compressor motor for additional cooling. The air velocity through the condenser depends on the relative positioning of the fan and coil.

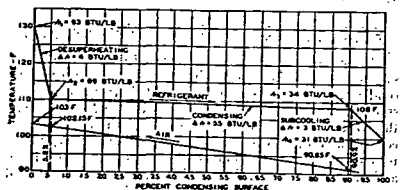


Fig. 14.... Temperature and Enthalpy Changes in an Air-cooled Condenser

In condensing units equipped with belt-driven compressors, the compressor motor drives both the compressor and the condenser fan. Therefore, the power available to drive the compressor is 20 to 30 percent less than in water-cooled condensing units of equal horsepower which require no condenser fan. In condensing units with hermetic or direct-driven compressors, the condenser fan is powered by a separate motor. Condenser coils for indoor air-cooled compressors are usually sized to operate at comparatively high head pressures. For this reason, rated capacities of factory assembled air-cooled condensing units are lower than those of water-cooled condensing units.

Chassis-mounted air-cooled condensers are seldom made for indoor condensing units over 5 hp because their length and height would exceed door opening dimensions.

The fans in indoor condensing units are usually of the propeller type and are assembled close to the coil. Due to the high speed of these fans (usually 1500 or 1750 rpm) and their proximity to the coil, their relatively high noise level often prevents the use of such air-cooled indoor condensing units in many locations.

Chassis-mounted (Outdoor Type)

Unlike the indoor condensing unit, the outdoor chassis-mounted condenser does not occupy valuable building space. Its dimensions are not limited by floor space or by door opening size. At the same time, the condenser has the advantage of an abundant supply of clean, cool air. Outdoor compressor units include separate condenser fans driven by their own motors, so that all compressor motor power is utilized to produce refrigeration. Air is drawn through the condenser coil and, in some designs, discharged over the compressor to provide supplemental cooling of the compressor motor. The entire assembly is enclosed in a casing which is removable for servicing. Built-in, automatic head-pressure control is available for units installed in cold climates.

Remote Air-Cooled Condensers

Remote air-cooled condensers are now successfully used for refrigeration systems of all types, with capacities from one-half to 500 tons and larger. Remote air-cooled condensers are generally of the forced-air type (unit condenser). A gravity (free-convection) condenser is offered by one manufacturer.

Remote gravity condensers consist of a single row condensing coil of large face area, usually mounted on the roof at a 7 deg angle with the horizontal. Since air movement through the coil takes place due to gravity or wind, the condenser capacity is highly sensitive to wind velocity (Fig. 15). Selection of these condensers is made on the basis of minimum wind velocity, or by correlating wind velocity with simultaneous dry-bulb frequencies. These condensers are recommended where: (1) ample roof or floor surface is available for installation, (2) fan noise must be completely avoided, and (3) power cost is relatively high so that the saving in fan motor current becomes significant.

Gravity condensers are usually constructed of copper tubes with aluminum fins spaced 4 per inch. The face area, based on a rated temperature difference of 20 F deg between condensing and air temperature, varies from 17 to 22 sq ft per air conditioning ton, with single row coils.

Forced-air unit condensers consist of three main components: (1) a finned condensing coil, (2) a direct-driven or belt-driven fan with its motor, and (3) an aluminum or steel casing. In smaller condensers, the casing can be formed by extending the frame of the coil. The fan is usually of the free delivery multiblade propeller type. For indoor applications where ductwork is required, centrifugal fans are used.

Air may either be drawn through or blown through the coil by the fan and motor. In the draw-through unit, the fan and motor are located on the air discharge side of the coil. On a blow-through unit, the motor is located in the entering

Condensers

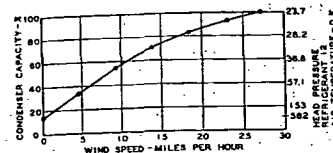


Fig. 15.... Effect of Wind Velocity on Heat Transfer in an Air-Cooled Condenser

air stream. In most designs, the motor is located inside the casing for protection from the weather.

Unit condensers are suitable for outdoor and roof installation where an ample supply of cooling air is available at a low temperature.

Condensing coils for remote unit condensers are installed either in the vertical plane for horizontal air flow or in a horizontal plane for vertical upward air flow. Certain designs for vertical upward air flow orient the coil face at a 45 deg angle from the vertical, to reduce the overall height of the unit condenser. The slanted coil is also favored by designers of heat pump systems because it facilitates drainage when the condenser serves as a heat source during the heating cycle. Coils are constructed of copper tubes and aluminum fins, although all-copper and all-aluminum coils are also available. Most coils are of the vertical serpentine type with parallel circuits and horizontal inlet and outlet headers. Tube sizes range from $\frac{1}{2}$ to 1 in. diameter, with fin spacing from 6 to 13 per in. The condensing coil surface for 20 F deg temperature difference between entering air and refrigerant, is from 170 to 200 sq ft per ton, while a coil designed for 30 F deg temperature difference requires 100 to 125 sq ft per ton. These figures vary widely, depending on the air quantity, air velocity, fin spacing, and the coil heat-transfer characteristics.

The coil of a unit condenser may have several separate condensing circuits for use with several compressors. The capacity and location of individual circuits is adapted to the combination of compressors used. Each circuit has its own inlet and outlet connection and uses a separate receiver.

Air and power requirements. For most refrigeration applications in the United States, remote unit condensers are selected for a temperature difference of 20 to 25 F deg between air and condensing refrigerant. For instance, with air at 90 F entering the condenser, the design condensing temperature is 110 to 115 F. For economical design, a temperature difference of 6 to 10 F deg should be maintained between the condensing refrigerant and the leaving air temperature. At 14,400 Btu/h per evaporator ton, 70 to 100 cfm of air per 1000 Btu/h of condenser heat rejection will be required. Free delivery propeller fans require approximately 0.1 motor horsepower per air-conditioning horsepower. Centrifugal fans require 0.15 to 0.25 hp per air-conditioning horsepower, depending on delivery resistance.

For air conditioning applications, economic and dimensional considerations have led to use of remote condensers which operate at 30 F deg and higher difference between air and condensing temperature. Such condensers deliver 50 to 75 cfm of air per 1000 Btu/h heat rejection and require from 0.1 to 0.2 hp per ton. The elevated condensing pressures produced by such condensers at occasional high ambient temperatures can be tolerated by most present-day compressors at the expense of greater power consumption at a relatively small capacity loss. Thus, while initial cost savings are made possible by reduced size condensers, operating costs may be greater, depending on the geographic location, due to the greater power demand of the compressor, particularly if frequent operation at elevated head pressures is required.

APPLICATION AND RATING OF REMOTE UNIT CONDENSERS

It is current practice to rate remote unit condensers in terms of Gross Heat Rejection (GHR), which is the total heat removed in desuperheating, condensing, and subcooling of the refrigerant. This value is the product of the weight rate of

refrigerant flow and the difference in enthalpy of the entering refrigerant vapor and the enthalpy of the leaving refrigerant liquid, expressed in Btu/h.

A unit condenser may also be rated in terms of Net Refrigeration Effect (NRE), which is the total heat rejection less the heat added to the refrigerant in the compressor by the heat of compression. The Net Refrigeration Effect is a practical expression of the capacity of a refrigeration system of which the unit condenser is a component part.

Some manufacturers have incorporated in the design of the air-cooled condenser a liquid subcooling coil. The addition of a liquid subcooling coil results in an increase in compressor capacity of approximately 0.5 percent for each degree of subcooling. Subcooling coils are generally sized to give from 10 to 15 degrees of subcooling or 5 to 7 percent increase in system capacity. Since subcooling increases the refrigeration effect per pound of refrigerant, a smaller compressor may be used for a given refrigeration load and will operate at a higher Btu per KW input. Subcooling also permits greater liquid lift in vertical risers without flashing of the liquid and permits use of smaller pipe sizes.

The Total Heat Rejection of an air-cooled condenser is proportional to the difference between entering dry-bulb temperature and saturated condensing temperature. For instance, a condenser with a 30 F deg temperature difference will have a condensing temperature of 125 F, with an entering dry-bulb temperature of 95 F, or 120 F with an entering dry-bulb temperature of 90 F. The Gross Heat Rejection at 30 F deg temperature difference is 50 percent greater than the same condenser selected for 20 F deg temperature difference.

It is accepted practice to publish ratings in terms of Gross Heat Rejection. The ratings are based on temperature difference between condensing temperature and entering air dry-bulb temperature. Most compressor ratings include Total Heat Rejection as well as Net Refrigeration Effect and KW Input. This eliminates the need for converting Net Refrigeration Effect to Gross Heat Rejection by applying factors based on section and condensing temperature.

A standard method⁹ of testing for rating remote air-cooled condensers has been prepared by ASHRAE. Many manufacturers publish ratings in terms of Net Refrigeration Effect at 40 F evaporating temperature and 90 F air temperature entering the condenser and 120 F condensing temperature (30 F deg temperature difference), in order to obviate Gross Heat Rejection from the selection procedure. No attempt is made to correct such ratings for open versus hermetic compressors.

Condenser capacities published in such terms as basic rating can be converted to other than basic rating conditions by using the factors in Table 3. These factors can be applied with sufficient precision for Refrigerants 12, 22, 500, and 717, when used with belt-driven or direct-driven compressors, for most applications. Condenser selections for hermetic compressors are best made on the basis of gross heat rejection ratings, if published by the compressor manufacturer, and the gross heat rejection effect of the air-cooled condenser.

In the absence of published compressor heat rejection ratings for hermetic compressors, an approximate condenser selection can be made by using basic ratings and the factors in Table 3. This is because the additional heat of the motor in a hermetic compressor is dissipated in the desuperheating zone (Fig. 14), where high temperature differentials are available. The result is only a small possible error in the ultimate selection.

More precise selection of unit condensers is possible by cross-plotting Gross Heat Rejection of the condenser against Gross Heat Rejection of the compressor as shown in Fig. 16.