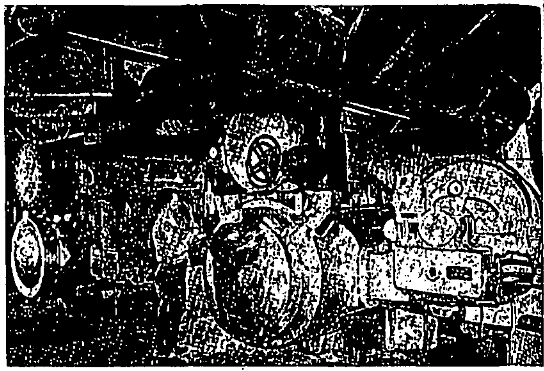
Here are seven easy-to-use formulas to find capacity of your system, be it direct or indirect type. Study the problems solved for you so you'll be ready for some fast checks

By D K CHAPMAN
Service Engineer, Worthington Corp



CENTRIFUGAL COMPRESSORS serving large refrigeration load in a hotel. There are many useful checks you can make on system performance by using hints given here

Easy Figuring Helps You Check Out Refrigeration for Air Conditioning

► TWO TYPES of refrigeration systems may be used with air-conditioning units—direct and indirect expansion. *Direct* has evaporator coils in air stream. Expansion valve in coil regulates refrigerant flow. *Indirect* has evaporator coils that cool water or other liquid pumped through the air-conditioning unit.

Spot Checks. You can check refrigerating-machine performance in several ways. With each you must use some simple arithmetic—but don't let that scare you. Just follow the formulas and steps we give below. They're accurate enough for all ordinary jobs. You can figure some results closer, but the extra work needed really isn't necessary unless you're designing a plant.

System Capacity. On trouble shooting and other jobs you often benefit from knowing actual capacity of a system that cools chilled water for air conditioning. Most systems like this have a water chiller in which refrigerant expands in a coil. Water passes through chiller shell. But you can use same method for a flooded-type chiller, too.

Figure the capacity from $C = 0.042$ gpm $\times t_a$, where C = tons refrigeration; gpm = gallons of chilled water circulated per minute; t_a = temperature difference between water entering and leaving the system's chiller, F.

If you don't have a flowmeter to measure chilled-water flow, multiply difference between suction and discharge pressure-gage readings of circulating pump by 2.31. This gives pump head in feet. Refer to characteristic curve for pump, read gpm corresponding to that head. Diagram, right, is a typical characteristic curve for a centrifugal pump.

To estimate gpm from curve you must know both the head and horsepower of pump. Easiest way to find pump hp is to use a clamp-on wattmeter to measure input watts. Divide reading by 746, and multiply result by 0.80 and pump efficiency, read from the characteristic curve. (The value 0.80 is the assumed motor efficiency, 80%, expressed as a decimal.)

Remember, you must use the characteristic curve for the pump in your system. Diagram is only an example of a typical centrifugal-pump curve.

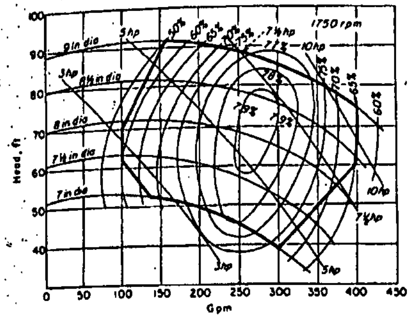
Direct-expansion systems may be figured in three ways if you wish to check over-all capacity of system. These are: (1) measuring total heat removed from air passing through coil (2) measuring heat rejected to condensing water (3) separately measuring sensible and latent heat removed from air.

Sensible-heat removal results in a change of air temperature while latent heat comes from moisture that condenses out of the air. Method 2 is equally good for direct and indirect systems.

Total Heat. To figure total heat removed from air passing over a coil use this equation: $H = 4.5 \times$ cfm $\times h_a$, where H = total heat removed from air, Btu per hr; cfm = cubic feet of air passing over the coil per minute; h_a = enthalpy difference between entering and leaving air, Btu per lb.

Obtain air enthalpy from a psychrometric chart or the table, right. Read enthalpy at the air's wet-bulb temperature, not the dry-bulb. Once you've figured total heat removed by refrigerant, convert this to tons refrigeration by dividing by 12,000 Btu per hr per ton. If wet-bulb temperatures you're working with are above or below those in table, see a standard reference book such as ASH&VE *Guide*.

Measure air velocity with a velometer, if possible. This gives velocity readings directly. Convert to cfm by multiplying average velocity, obtained from 10 or 12 readings across the duct, by duct area in square feet. You can also use a pitot tube to obtain air



TYPICAL characteristic curve for a centrifugal pump in an air-conditioning system. Don't use this chart for figuring

Quick Check List for Air-Conditioning Refrigeration Systems

Item	*Range*
Condensing-water inlet temp, F	60-95
Condensing-water outlet temp, F	85-115
Water-temp rise in condenser, F	15-25
Freon-12 head pressure, psig	100-150
Freon-12 suction pressure, psig	25-50
Temp air enters cooling coil, F	75-90
Temp drop through cooling coil, F	12-25
Temp air leaves cooling coil, F	50-70
Air circulated per ton refrigeration, cfm	300-600
Room temp for comfort cooling, F	70-86
Condensing water, gpm per ton	3-5
Temp chilled-water enters coolers, F	50-65
Temp chilled-water leaves coolers, F	40-50

velocity. It's often handy when a duct opening isn't accessible. Be sure to follow instructions provided with these instruments when taking measurements.

Heat rejected to condensing water is figured from $h = 500 \times$ gpm $\times t_a$, where h = heat to condenser water, Btu per hr; gpm = gallons of water passing through condenser per minute; t_a = temperature rise of water through condenser, F. Deduct 10% of the figured heat to get actual heat rejected because this much heat in condenser water comes from what's called "heat of compression." This is heat from work that compressor must do to raise the pressure of the vapor. Divide result by 12,000 to convert to tons refrigeration.

Don't forget that if compressor is hermetic type, having motor winding cooled by suction gas, this heat is also rejected to the condenser water. So we must deduct the Btu equivalent of motor heat, or motor hp $\times$ 2544, from heat load on condenser. Treat fan motors in the cool air stream the same way.

This figuring is good for all shell-and-tube condensers. Use a flowmeter or measuring barrel to find water flow in gpm. On large jobs where it's tough to measure flow accurately with a barrel, install pressure gages on inlet and outlet of condenser water pump. Multiply difference in readings by 2.31 to find total head in feet. Read gpm from pump characteristic curve, after figuring motor hp as shown above.

Evaporative condensers are figured by method 1 above, except that we're dealing with an air-temperature rise instead of a drop. Also, we must subtract heat of compression (10%) and electrical heat, if any.

Enthalpy of Moist Air

Wet-bulb temp, F	*Enthalpy, Btu per lb*
68	31.92
69	32.71
70	33.51
71	34.33
72	35.17
73	36.03
74	36.91
75	37.81
76	38.73
77	39.67
78	40.64
79	41.63
80	42.64
81	43.67
82	44.72
83	45.80
84	46.91
85	48.04

Total sensible heat is found from $h_s = 1.1 \times$ cfm $\times t_a$, where h_s = total sensible heat removed from air, Btu per hr; cfm = cubic feet of air cooled per minute by refrigerant; t_a = temperature difference between air entering and leaving coil, F.

Figure total latent heat from $h_l = 8750 \times$ gph, where h_l = total latent heat removed from air, Btu per hr; gph = gallons of moisture condensed from air per hour. Add total sensible and latent heat to find amount of heat the coil removes from air.

You have enough methods here to make a good spot check on most jobs you run across. But since they are all subject to a little inaccuracy, depending on conditions, your best bet is to figure the job in several ways and take the average of your results.

For quick checks of refrigeration systems use the list shown above. Ranges given are typical, and you'll find them valid for most jobs you're called on to trouble-shoot.

Examples. Here are several typical problems showing how to use the equations above.

Example: A compressor chills 100 gpm of water through a temperature range of 20 F. What is compressor capacity at this load?

Solution: Use first equation; $C = 0.024 \times 100 \times 20 = 48$ tons.

Example: Air enters a coil at a wet-bulb temperature of 80 F, leaves at 70 F. What is compressor tonnage when 1000 cfm flow through coil?

Solution: Difference in total heat, using values from table, is $42.64 - 33.51 = 9.13$ Btu per lb. Put this in equation to find total heat removed as $H = 4.5 \times 1000 \times 9.13 = 41{,}085$ Btu per hr. This is $41{,}085/12{,}000 = 3.43$ tons of refrigeration.

Example: What is the capacity of a refrigeration unit using 30 gpm of condensing water when temperature rise through condenser is 20 F?

Solution: Using method 2, $h = 500 \times 30 \times 20 = 300{,}000$ Btu per hr. Subtracting 10% for heat of compression, quantity of heat rejected to cooling water is 270,000 Btu per hr and tonnage is $270{,}000/12{,}000 = 22.5$ tons.