transfer rate of the water cooler is considerably higher as a general rule than that of a direct expansion cooler for the same requirements. With direct expansion interchangers, it is almost impossible to keep the entire system flooded with liquid, whereas with brine interchangers the cooling medium completely fills the space of the interchanger and perfect contact is insured.

Ice may be used for chilling water or air for conditioning work. Its application is limited because of the cost of ice, and the difficulty of handling it. The word "water cooling" is used advisedly in that the direct cooling of air by ice is, while not impossible, rather impractical. It might be said that ice coolers are economical for systems requiring a maximum of 20 tons per 24 hours where the load fluctuates considerably, and where ice is introduced only as it is required to cool water. The most general method of cooling water with ice is to spray the water over the surface of the ice, insuring as much contact as possible and approximating the same performance as the Baudelot type of cooler. Because of the large fluctuations in load in the air conditioning system, the higher cost of refrigerating effect when ice is used is offset by the fact that there are no motor and condenser inefficiencies under partial load. Also, because the cost of the mechanical refrigeration equipment for the small system is so much higher per unit of effect, the fixed charges are small enough to overbalance the extra cost of the ice.

PROBLEMS IN PRACTICE

1 ● If, in a given air conditioning installation, fixed charges are estimated at 15 per cent per annum, what increased first cost would be justified for an auxiliary appliance on a refrigeration machine which could save $125.00 per year in operating cost?

\$125.00 capitalized at 15 per cent is, $\frac{\$125.00}{0.15}$ = \$834.00 increased first cost justified.

2 ● Electrically driven Freon condensing units are to be used in an air conditioning system, requiring 20 tons refrigerating capacity for conditions of maximum load. An overall analysis of the seasons operating conditions shows an average load factor of 62.5 per cent, and allowing for variable time intervals of operation of refrigeration units installed, three-quarters of the operating season, or 750 hours, would require operation of the equipment at one-half load, and one-quarter of the operating season or 250 hours full load capacity of the refrigeration equipment would be required.

The increased first cost of 2–10 hp, 10 ton condensing units over 1–20 hp, 20 ton condensing unit is, $830.00 installed price, to the customer.

The increased first cost of a 2-speed compressor motor of 20 hp size over a constant speed 20 hp size motor including increased starter cost is $210.00. The efficiency of the 2-speed motor above is 83 per cent at full load full speed, and 79 per cent for full load at ½ speed. At ½ speed, full load is ½ total bhp of full load full speed.

Discuss the considerations involved in making a decision as to whether a single unit with a 20 hp motor of the 2 speed type would be used in preference to 2–10 hp constant speed units.

The cost of 2–10 hp 10 ton units in excess of 1–20 hp, 20 ton unit with 2-speed motor, is \$830.00 − \$210.00 or \$620.00, increased first cost. At 15 per cent fixed charges, this represents an increased annual cost of \$93.00 for 2 compressors over one compressor.

The advantage of 2 compressors instead of one compressor on an installation of this type, is in the breakdown service provided in the event one compressor is shut down for repairs the system could be operated at one-half capacity utilizing the duplicate machine. The motor efficiency of the constant speed unit would be higher at full load than would be the efficiency of the 2-speed motor at low speed. Offsetting this latter advantage however, is the fact that the condenser on the condensing unit would provide a lower refrigerant condensing temperature for ½ load operation with the same final condensing water temperature than would be the case with duplicate units each furnished with its own compressor and condenser. Operation at a lower condensing temperature would provide for a power saving compensating for the lower efficiency of the 2-speed motor when operated at slow speeds. It is, in a case of this kind, purely a question as to whether or not the purchaser would deem an investment of \$620.00 more and an increased fixed charge of \$93.00 a year, advisable to get breakdown service thru the installation of duplicate units. In most cases, this increased first cost would not be warranted because of the fact that satisfactory indoor conditions could not be obtained at full load if only one-half the refrigeration capacity were available.

3 ● For an increased first cost of $210.00 for a 20 hp, 2-speed motor over a 20 hp constant speed motor to be used on a Freon automatic condensing unit for air conditioning duty, justify the increased investment based on a load factor of 62.5 per cent, on an operating basis of 1000 hours total of which ¾ of the operation of the refrigeration equipment would be at ½ load and ¼ of the operation season at full load. Motor efficiency 2 speed, 83 per cent, at full speed; and 79 per cent at half speed. Motor efficiency constant speed motor 83 per cent. City water is to be used for condensing purposes and is to be automatically controlled from the discharge pressure by means of automatic regulating valve. Compute increased first cost justifiable based on 15 per cent fixed charges and number of years required to pay off increased first cost.

At full load for 20 bhp load and 83 per cent efficiency, the kw input to the compressor motor would be 20 bhp times 0.746 kw per bhp divided by 83 per cent motor efficiency or 18.0 kw.

At ½ speed,

$$\frac{10\text{ bhp} \times 0.746\text{ kw per hp}}{0.79\text{ efficiency}} = 9.45\text{ kw input at } \tfrac{1}{2}\text{ speed.}$$

For a constant speed motor installation, 1000 hours operation at 18 kw load, requires 18,000 kwhr per season for operation.

With 2-speed motor 750 hours at ½ speed and 9.45 kw input = 7080 kwhr.

For full speed operation, 250 hours at 18 kw input = 4500 kwhr.

The total kwhr required with 2-speed motor = 7080 + 4500 = 11,580 kwhr.

From the above it is seen that the power consumption is reduced by the use of a 2-speed motor from 18,000 kwhr per year to 11,580 kwhr or approximately a power saving of 35 per cent annually.

For power at \$.02 per kwhr, 6400 kwhr saving per year would mean a saving of \$128.00 per year, which at 15 per cent would justify an increased first cost of \$853.00.

Further, the fixed charge added due to the increased first cost of a 2-speed motor would be 15 per cent of \$210.00, or \$31.50 per year, thus the net annual saving after correcting for fixed charged due to increased investment would be \$128.00 less \$31.50 fixed charge or a net annual saving of \$96.50 with a 2-speed motor based on a power cost of \$.02 per kwhr. Thus the increased first cost of \$210.00 would be returned to the purchaser in \$210.00 ÷ \$96.50 or 2.18 years.

Similarly a \$.03 power the gross saving exclusive of additional fixed charges to increased cost of 2-speed motor would be \$192.00; net saving per year \$160.50 and therefore, the 2-speed motor would pay for itself in 1.31 years.

For \$.04 power, the gross saving would be \$256.00; net saving, \$224.50 and the 2-speed motor would be paid for in 0.935 years.

It is safe to assume that any appurtenance which will pay for itself in less than 5 years, when computed on the above basis, will be accepted by practically all purchasers of air conditioning equipment, provided an analysis of the above type is properly presented.