$$B = 0.060\, a\, T\, H_e\, C \tag{4}$$

where

B = Cost of water for refrigeration during period, dollars.
a = Average gallons per minute (ton).
T = Tons of refrigeration at maximum design load.
H_e = equivalent full load refrigeration operating hours (Table 8).
C = Water cost, dollars per 1000 gal.

The average gpm per ton must take into account the variable water temperature. When well water is used as a source, and entering and leaving temperatures are considered constant, the average gpm per ton obviously is equal to the design gpm per ton. However, when the source is river or lake water, its maximum seasonal temperature will generally be reached at the same time that the refrigeration load factor is highest.

Table 9. Representative Tons per Square Foot for Various Applications

	Low	Avg	High
Department Store (Main Floor)	0.0050	0.0058	0.0067
Department Store (Upper Floors)	0.0029	0.0046	0.0054
Dress Shop	0.0029	0.0050	0.0071
Drug Store	0.0033	0.0054	0.0083
Lunch Room	0.0083	0.0108	0.0133
Office Bldg.	0.0021	0.0025	0.0038
Restaurant	0.0058	0.0075	0.0100
Shoe Shop	0.0029	0.0042	0.0063
Theater	0.064[a]	0.078[a]	0.093[a]

[a]Tons per Seat.

The average gpm per ton should be calculated from known or estimated water temperatures because they vary through the season. Maximum water main temperatures are given in Chapter 15. In lieu of this tedious work, the average gpm per ton may be taken as 80 per cent of design gpm per ton with reasonable accuracy, for the condition of variable temperature of entering water obtained from rivers and lakes.

When cooling towers or evaporative condensers are used, the windage and evaporation losses are usually between 3 per cent and 5 per cent of the water circulated.

Heating

The method of estimating fuel consumption to balance the building heat loss is given in Chapter 20. It is important to include the fuel required to heat ventilation air as used in ventilating and air conditioning systems. In estimating fuel consumption for ventilation air, the tendency of the conventional control systems to use less than the estimated quantity of outside air in cold weather should be considered in its effect in lowering fuel consumption. In addition, the heat required to accomplish winter humidifying must not be neglected, when this feature is included in the equipment.

BIBLIOGRAPHY

Modern Air Conditioning, Heating and Ventilating, by W. H. Carrier, R. E. Cherne, and W. A. Grant—Chapter IV (Pitman Publishing Corp., 1940).

Predicting Operating Hours of Refrigeration Equipment Used in Air Conditioning, by W. A. Grant (*Refrigerating Engineering*, July, 1941).

Cost of Operation of Refrigeration Used for Air Conditioning, by R. E. Cherne (*Refrigerating Engineering*, December, 1943).

CHAPTER 45

Industrial Air Conditioning

Atmospheric Conditions Required, General Requirements, Classification of Problems, Control of Regain, Moisture Content and Regain, Conditioning and Drying, Control of Rate of Chemical Reaction, Control of Rate of Biochemical Reactions, Control Rate of Crystallization, Elimination of Static Electricity

INDUSTRIAL air conditioning is primarily concerned with the atmospheric conditions required for the manufacture, processing, and preservation of material, equipment and commodities. The fundamental factors, one or more of which may govern these conditions are: humidity, temperature, air motion and air purity. The term air purity may have reference to the quantity of dust, bacteria, odors, or toxic gases present.

The optimum atmospheric conditions have been established for a large variety of industrial processes, but when the requirements are unknown it may be necessary to determine them by laboratory tests or by research. When the requirements are not definitely specified it is advisable to design the equipment to be flexible and to provide for future increase of facilities and capacity. Air conditioning requirements for human comfort are defined in Chapter 12. If the atmospheric conditions required for the process are not within the range of human comfort, separate consideration must be given to the maintenance of conditions which will not have a detrimental effect upon the health of the occupants.

ATMOSPHERIC CONDITIONS REQUIRED

The most desirable relative humidity for processing depends upon the product and the nature of the process. As far as the behavior of the material and its desired final condition are concerned, each material and process presents a different problem. The desirable relative humidity may range from a low of 5 per cent, as in certain industrial applications, such as insulation winding processes, up to a condition approaching saturation, as in processes relating to textiles, tobacco and baking industries.

Similarly, the most favorable temperature will vary according to the specific material and particular process. Frequently a compromise between the known optimum condition for processing and that required for reasonable worker comfort is desirable. This is particularly true where unconfined processes are required in departments where people are working and their health, comfort and productive efficiency must be considered.

It is generally recognized that relative humidities of 50 per cent or less are on the dry side. Such conditions are conducive to low regains in hygroscopic materials, drying out, increased brittleness of fibrous materials, prevalence of increased static electricity and tendencies toward increased dust liberation from the product. Relative humidities higher than 50 per cent are considered to be on the damp side. These conditions are conducive to high regain, promote softness and pliability in materials, decrease static electricity and tendencies toward reduced generation of product dust which represents a loss in weight of the material in process.