or ice), or indirectly through a barrier wall (as cooling surface). When the latter method is used, and the surface temperature is held above the air dew-point, only cooling occurs without moisture interchange.

Evaporative Cooling involves the adiabatic exchange of heat between air and a water spray or wetted surface. The water assumes the wet-bulb temperature of the air, which remains constant during its traverse of the exchanger. No heat is added or abstracted from the medium (water), which is continually recirculated. Cooling of the air occurs due to the temperature and vapor pressure difference between entering air and water at the wet-bulb temperature. Humidification occurs as a result of the vapor pressure exerted by the water which is higher than that corresponding to the entering air dew-point. Since this is an adiabatic exchange, the enthalpy of the air remains constant, while the dew-point rises and the dry-bulb falls, and the loss of sensible heat exactly equals the gain in latent heat (neglecting radiation losses). The maximum available temperature reduction is the total difference between entering dry- and wet-bulbs (wet-bulb depression). Equipment delivering air at a dry-bulb temperature equal to the wet-bulb temperature is termed *completely* saturating or 100 per cent efficient, since the air leaves in a saturated state. Equipment delivering air at a dry-bulb temperature above the wet-bulb temperature is termed *partially* saturating.

Evaporative cooling is being used advantageously in many parts of the country. It is particularly applicable (1) in districts where the normal maximum wet-bulb temperature remains sufficiently low during the cooling season, and (2) in applications where the cooling load is principally sensible heat.

Dehumidification of air, in its broadest connotation, means simply the removal of moisture. Usage in the art has restricted the application of the term, so that the former broad meaning is now properly covered by the complementary names dehumidification and dehydration. *Dehumidification* usually refers to the *condensation* of water vapor from air due to its contact with a chilled medium (see Cooling). This type of heat exchange invariably includes temperature reduction due to removal of sensible heat. In practical applications dehumidification is generally the by-product of a sensible cooling operation. When moisture removal is the prime consideration it is frequently necessary to cool air to a greater extent than can be balanced by normal sensible heat gain in order to remove the required amount of water vapor by condensation. In this case it is necessary to restore sensible heat to the dehumidified air stream by re-heating.

Dehydration refers specifically to the removal of water vapor from air due to its contact with a dehydrating agent. The primary distinction between dehumidification and dehydration is the manner in which the required vapor pressure at the surface of the contacting medium is obtained. In the case of dehumidification, this surface vapor pressure is always the same as that which would be exerted by a body of water (or ice) at that same surface temperature. In the case of a dehydrating agent, the surface vapor pressure is always *lower* than that exerted by water at the same temperature, and the effectiveness of the medium as a dessicant is largely a function of the amount by which this vapor pressure can be lowered at the working temperature involved.

Thus it is evident that the primary function of a dehydrating agent is to maintain a vapor pressure lower than that of the water vapor in the air in order to secure a removal of moisture from the air. In its simplest form the process is essentially an adiabatic one in which the latent heat lost by the mixture is converted to sensible heat which raises the temperature of the air and medium by an equivalent amount. This process is therefore an energy exchange, similar to, but the reverse of, adiabatic saturation or evaporative cooling.

Combination Methods. It is evident that two or more of the above processes—cooling, evaporative cooling, dehumidification and dehydration—may be combined by the proper application of interchangers in sequence. Such combinations are dictated by the availability of prime sources and cost of energy as well as the requirements of the particular application in question.

This chapter discusses in detail the engineering and economic principles involved in the application of dehydration. For similar discussion of the other processes, refer to the following material: Cooling and dehumidification by the use of surface interchangers (cooling coils), see Chapter 26. Cooling, dehumidification and evaporative cooling with air washers, see Chapter 27. For sources of cooling involving city and well water and

cooling towers, see Chapter 27, while for mechanical refrigeration and ice, refer to Chapter 25. For the thermodynamics of evaporative cooling, see Chapter 1.

DEHYDRATING AGENTS

Dehydrating agents may be divided into two general classifications:

1. *Adsorbent*—A material which has the ability to condense water vapor on its internal surfaces without itself being changed physically or chemically. Certain solid materials, such as silica gel, activated alumina and activated carbon have this property.
2. *Absorbent*—A material which has the ability to take up water vapor but which changes physically, chemically, or both, during the cycle. Calcium chloride is an example of a solid material while liquid materials include solutions of lithium chloride, calcium chloride, lithium bromide and the ethylene glycols.

Adsorbents

These substances contain a vast number of sub-microscopic pores which afford a tremendous internal surface to which water adheres or is adsorbed. In spite of a porous structure these substances retain sufficient mechanical strength to resist the wear and handling to which they are subjected. To be suitable for dehydration purposes such substances must fulfill the following requirements:

1. Possess suitable vapor pressure characteristics.
2. Be available at a reasonable economical cost.
3. Adsorb sufficient moisture per pound of material to avoid excessive bed dimensions.
4. Be chemically stable, resisting contamination from impurities.
5. Be physically rugged to resist breakdown from handling, abrasion, etc.
6. Be able to withstand breakdown from indefinitely repeated reactivation cycles.
7. Be capable of reactivation at reasonable temperatures.

Aluminum Oxide (Alumina) in a porous, amrophous form is one of a series of solid absorbents derived from salts of aluminum and frequently called by the common name activated alumina. Commerical activated alumina commonly used for atmospheric dehydration contains about 92 per cent of Al_2O_3 combined with hydrated aluminum oxide and traces of soda and other metallic oxides. It is available in granules ranging from a fine powder to pieces approximately 1.5 in. in diameter. It has high adsorptive capacity per unit of weight and is non-toxic. It may be repeatedly re-activated after becoming saturated with adsorbed moisture without practical loss of its adsorptive ability. In the grade frequently used for air drying the re-activation may be accomplished at temperatures under 350 F. Specific gravity is 3.25 and the pores are reported to occupy 58 per cent of the volume of each particle. For most estimating purposes the volume-weight relation on a dry basis may be taken as 50 lb per cubic foot although in the smaller sizes the packed weight may be as much as 64 lb per cubic foot.

Silicon Dioxide (Silica), in a prepared form obtained by suitable mixing sulphuric acid with sodium silicate, is another solid adsorbent and is commonly called silica gel. Its capillary structure is exceedingly small, so small that its exact structure has to be deduced as it cannot be observed. It has high adsorptive capacity per unit of weight; it is non-toxic, and may be repeatedly re-activated at temperatures up to 600 F without practical