

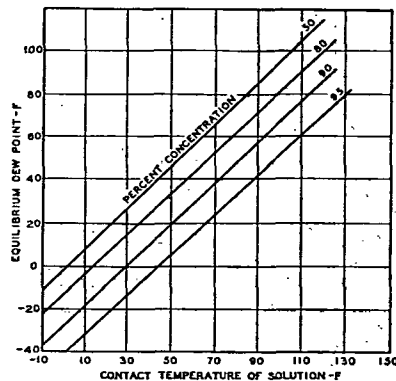


Fig. 3 Temperature-Equilibrium Dew-Point Characteristics for Typical Organic Absorbent

tained at the required temperature by adding heat in proportion to the water absorbed by the air from the solution. Water is automatically added to the solution to maintain the proper concentration.

SOLID ADSORBENTS

A solid adsorbent (desiccant) has the property of adsorbing moisture from, or adding moisture to, a gas, such as an air-water vapor mixture, depending on the vapor pressure difference between the water in the gas and the water in the adsorbent. Actually, all gases and vapors are adsorbed to some extent on an adsorbent surface. In the case of an air-water vapor mixture, the amount of air adsorbed is very small compared to the amount of water adsorbed, and, consequently, dehumidification of the air occurs. For some other gases containing moisture, the amount of the carrier gas adsorbed may be appreciable with a consequent decrease in water-adsorbing capacity of the desiccant. Although attempts have been made to correlate the amounts of specific components adsorbed on various desiccants, no completely reliable means of predicting these have been found. Polar compounds are usually more strongly adsorbed than non-polar. Within a given chemical family, higher molecular weight compounds are adsorbed easier than low molecular weight compounds. Correlations have also been made with boiling points and critical temperatures of adsorbates.

Adsorption takes place at the surface of the adsorbent where the gas and solid come in contact with each other, i.e., at the interface. Materials that are used commercially as solid adsorbents have a porous structure of submicroscopic dimensions, which gives them an extensive internal surface area. This area may be as large as 4,880,000 sq ft per lb (1000 square meters per gram) of adsorbent, and the internal pore radii only a few angstroms. The amount of material adsorbed under equilibrium conditions is proportional to the surface area of the desiccant if the pores are large enough to allow penetration of the adsorbate into the interior of the desiccant. Atoms or molecules of a solid are held together by various forces: electrostatic forces, van der Waals forces, valence forces, etc.¹ An atom in the interior of a solid is subjected to equal

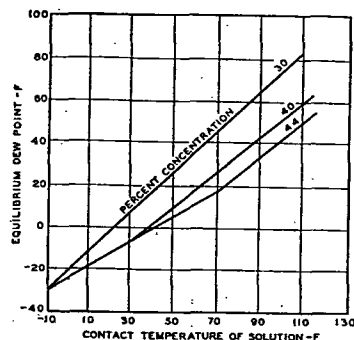


Fig. 4 Temperature-Equilibrium Dew-Point Characteristics for Typical Inorganic Absorbent

forces in all directions, whereas an atom on the surface of a solid is subjected to unbalanced forces, the inward pull being greater than the force outward. As a result of these unbalanced forces, the surface of a solid, just as that of a liquid, will tend to decrease and a surface tension will result. It is these unbalanced forces existing at the surface of a solid (internal and external) which cause the adsorbate to be attracted and held on the solid, i.e., for adsorption to take place.

When an active adsorbent is brought into contact with a gas of high humidity, there is a tendency for the vapor pressure of the water in the adsorbent to reach equilibrium with the partial pressure of the water in the surrounding gas, with the result that water is extracted from the gas by the adsorbent and the moisture content of the gas is decreased. Dehumidification of the gas stream has thus occurred. The weight of water a given adsorbent will extract is dependent almost entirely upon the relative humidity (ratio of the partial pressure in the gas to the saturation pressure at a given temperature) of the gas except at temperatures greater than approximately 180 F, where there is a slight effect of temperature. The adsorbent is said to be saturated for a given set of conditions when equilibrium is attained. The amount of

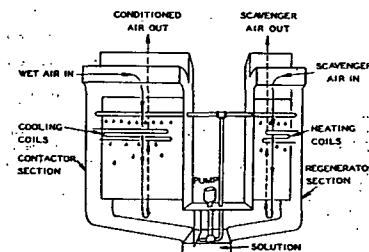


Fig. 5 Flow Diagram for Typical Liquid-Absorbent Dehumidifier

Dehumidification By Sorbent Materials

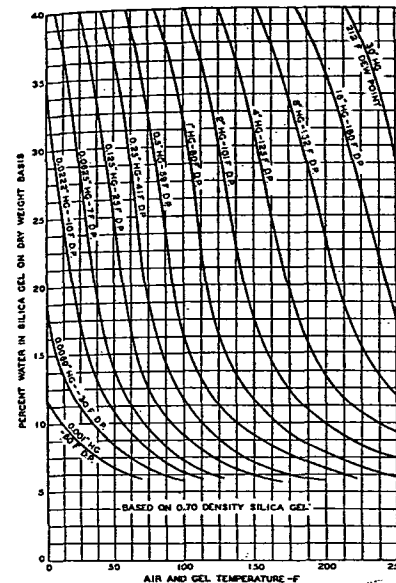


Fig. 6 Silica Gel-Water-Vapor Equilibrium Curves

water adsorbed on the desiccant at this point is known as equilibrium capacity.

The rate of water sorption is extremely rapid when the difference in vapor pressures between the water in the gas and in the desiccant is large. As this difference becomes small, however, the rate of adsorption usually decreases and many hours may be required to reach the equilibrium capacity. This equilibrium capacity will be identical whether determined under static or dynamic operating conditions, but many more hours will be required under static conditions because the forces of convection and diffusion must carry the water vapor in the air to the surface of the adsorbent.

Equilibrium capacities of a given desiccant for water can be represented in a number of ways. Basically, the three variables involved are temperature and moisture content of the air, and percent water adsorbed on the desiccant. It will be assumed that the temperature of the air and of the desiccant are the same at equilibrium conditions. Isotherms, or lines of constant temperature, result if the amount of water adsorbed on the desiccant is plotted versus the vapor pressure of the water at equilibrium. An infinite number of such curves can be drawn as parameters. Isotherms always show that the amount of vapor adsorbed increases with increasing vapor pressure. If the amount of water adsorbed on the desiccant is plotted versus temperature, an infinite number of curves called either isobars (constant pressure) or isopiestic (constant vapor pressure) can be drawn. These curves always show that when true equilibrium is reached, the volume adsorbed decreases with increasing temperature. Fig. 6 shows

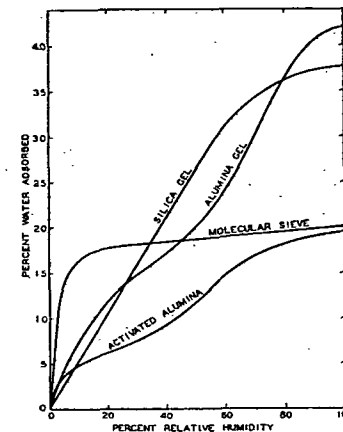


Fig. 7 Water Vapor Equilibrium Curves

isopiestic data for the silica gel-water system at equilibrium conditions. In this set of curves, silica gel and air temperatures versus percent water in silica gel (dry weight basis) form the abscissa and ordinate, and air dew-point temperatures (with the corresponding vapor pressures) are the parameters. Several important characteristics of the adsorbent are brought out by these curves. For example, note that each of the curves becomes asymptotic to the X-axis somewhere between 5 and 6 percent moisture content. This is so because, under normal reactivation temperatures, this amount of water, known as residual moisture, is always present in the gel. Any attempt to remove it results in a physical change in the desiccant as well as a reduced adsorptive capacity. The term *useful concentration* is used to designate the percent moisture in the gel above the residual moisture content. The variation in this useful concentration during a test measures the magnitude of adsorption or desorption since the residual amount theoretically remains unchanged, assuming no excessive activation temperatures. It will be noted that at constant air and silica gel temperature the amount of moisture adsorption varies directly with the air dew-point temperature, i.e., as the air approaches a saturated condition (dry-bulb temperature equal to dew-point temperature), the equilibrium moisture content of the silica gel increases. If useful concentration or actual percent water adsorbed on the silica gel were the ordinate in Fig. 6, all vapor pressure curves would be displaced downward by approximately 5.5 percent.

A plot of the variation of the equilibrium pressure with temperature corresponding to a constant amount of gas adsorbed is called an *isotherm*. Isotherms resemble the vapor pressure curves of liquids. For a given quantity of gas adsorbed the pressure increases slowly at first, then rapidly with temperature. Isotherms are seldom used in practice.

A convenient way of expressing equilibrium data is to plot the amount of water adsorbed on the desiccant versus relative humidity. By combining the variables of temperature and vapor pressure into relative humidity, a single curve can be plotted to cover a wide range of conditions from 0 to 100