

MOISTURE CONTENT OF AIR AT ONE ATMOSPHERE						
DEW POINT F	MOISTURE			PPM*	PERCENT PER DRY AIR	VOLUME PER DRY AIR
	GRAINS PER LB DRY AIR	POUNDS PER LB DRY AIR	GRAINS PER CU FT DRY AIR			
110	400	0.0600	25	60,000	9	
100	300	0.0500	20	50,000	8	
90	200	0.0400	15	40,000	7	
80	150	0.0300	10	30,000	6	
70	100	0.0200	7	20,000	5	
60	80	0.0150	6	15,000	4	
50	60	0.0100	5	10,000	3	
40	50	0.0090	4	8,000	2.5	
30	40	0.0080	3	7,000	2	
20	30	0.0070	2	6,000	1.5	
10	20	0.0060	1.5	5,000	1	
0	10	0.0050	1	4,000	0.8	
-10	8	0.0040	0.8	3,000	0.6	
-20	6	0.0030	0.6	2,000	0.4	
-30	4	0.0020	0.4	1,000	0.3	
-40	3	0.0015	0.3	800	0.2	
-50	2	0.0010	0.2	600	0.1	
-60	1	0.0008	0.1	400	0.08	
-70	0.8	0.0006	0.08	200	0.04	
-80	0.6	0.0004	0.06	100	0.02	
-90	0.4	0.0003	0.04	80	0.01	
-100	0.2	0.0002	0.02	40	0.008	
	0.1	0.0001	0.01	20	0.004	
	0.08	0.00008	0.008	10	0.002	
	0.06	0.00006	0.006	8	0.001	
	0.04	0.00004	0.004	4	0.0008	
	0.02	0.00002	0.002	2	0.0004	
	0.01	0.00001	0.001	1	0.0002	

Fig. 9.....Moisture Content of Air at One Atmosphere Pressure

Fig. 9 shows the moisture content of air at one atmosphere pressure.

SORPTION DEHUMIDIFIERS FOR ELEVATED PRESSURES

The same sorption principles which pertain to low-pressure (approximately atmospheric) dehumidification apply to drying of high-pressure air, process gases, etc. The sorbents described previously can be used with equal effectiveness.

Equipment design may vary considerably in detail, but most basic adsorption units utilize dual bed construction for continuous operation and either internal or external heat source with air or process gas as reactivation purge for liberating previously adsorbed moisture. A single ad-

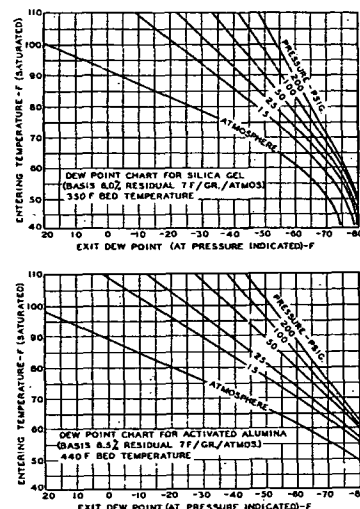


Fig. 10....Typical Performance Data for Solid Sorption Dehumidifiers at Elevated Pressures

sorbent bed may be used for intermittent drying requirements. Absorption units are generally constructed in the same manner as atmospheric pressure units, except that they are enclosed in vessels suitable for the operating pressure.

Either compressing of the gas to be dehumidified or pre-cooling by water, brine, or refrigeration will reduce the total moisture load to be handled by the sorbent permitting use of smaller drying units and permitting lower dew-point performance. The performance of the complete system consisting of pre-cooler and sorbent dryer must be investigated at various temperatures to determine the most economic operating level.

Applications include drying compressed air for processing, testing, and instrument use. Drying of air and gases have made many processes possible or effective in the chemical, petroleum, and steel industries.

Typical performance data for solid sorption dehumidifiers for pressures up to 200 psig are shown in Fig. 10.

A dew-point conversion chart is shown in Fig. 11. This chart is of value to determine changes in air dew points due to compression or expansion.

USES OF SORPTION DEHUMIDIFIERS

Sorption dehumidification equipment is used where it is desirable to control the removal of moisture from the air independent of the dry-bulb temperature of the air. Such a procedure is required in many industrial processes where the relative humidity must be controlled during the manufacture and preservation of the product.

In comfort air-conditioning dehumidification, with cooling, may serve advantageously under certain design conditions

Dehumidification by Sorbent Materials

such as high moisture load in comparison to sensible heat load, high ratio of fresh air to recirculated air, and internal load variation.

Sorption type dehumidification, in combination with refrigeration, is applied in industrial areas requiring either dew-point or dry-bulb temperatures below the freezing point of water, eliminating the formation of frost or ice on refrigeration coils. This particular function is illustrated by its use in wind tunnels to produce dew points as low as -60 F. It is also employed in low temperature process tunnels and chill rooms.

Other applications include supplying dry air to prevent condensation of moisture on cold surfaces, dehumidification of warehouses or storage rooms for military supplies as well as certain commercial products, and maintaining a dry atmosphere in cargo holds on ships. A more recent development is found in the dehumidification of underground caves.

MOISTURE LOAD CALCULATIONS

The application of dehumidification equipment to maintain spaces at low dew point requires careful calculation of the internal moisture gain in the room from all sources. The internal moisture gain consists of latent load from the occupants, process load from any products which give up moisture, exposed water surfaces in the space, open gas flame, water-vapor migration through cracks around the doors, windows, and other openings in the room (infiltration), and moisture transmitted through the building surfaces.

The latent load from people, exposed water surfaces, open gas flame, and moisture transmitted through building surfaces are found in the appropriate Gutz chapters. The internal latent load due to water-vapor transfer through cracks, conveyor slots, and open doors has not been standardized and is generally calculated by engineers on the basis of judgment and experience.

Calculation of the dehumidification required to maintain lower than normal moisture content in a given room begins with determination of the rate of moisture gain in the room from all sources. It is common practice, when maintaining a low humidity ratio, to recirculate a large percentage of the air in the room through the dehumidifier, and to add only enough outdoor air to meet the needs of the problem. The humidity ratio of the mixture of outdoor and recirculated air and the dehumidifier performance data can be used to calculate the humidity ratio of the air leaving the dehumidifier. The difference between the humidity ratio of the air in the room and that of the dehumidified air entering the room represents the effective dehumidification per pound of air. The rate of internal moisture gain in grains per minute, divided by the effective dehumidification in grains per pound of air, equals the air quantity required in pounds per minute. The following typical example using arbitrary values shows a general method of determining the dehumidifying requirements. Sensible heat determination considerations are discussed in other chapters, and are purposely omitted here.

Example 1: A sorption dehumidifier is to be used to maintain indoor conditions of 73 F and 20 percent relative humidity, i.e., 24.1 grains per pound of dry air, 30 F dew point, in a room 20 ft x 30 ft x 10 ft high, having a total wall, ceiling, and floor surface area of 2200 sq ft. Outdoor design conditions are 72 F dew point (118.4 grains per pound).

Internal sources of moisture are: 4 occupants; an open natural gas burner using 15 cu ft of natural gas per hour; an open top water tank, having an area of 2 sq ft exposed surface, in which water is maintained at 87 F, with air movement over the

water surface being 100 fpm. Determine the quantity and condition of the dehumidified air to be supplied to the room.

Solution: The internal moisture gain consists of items 1 to 5.

- From occupants: $4 \times 1800/60 = 120$ Grains per Minute
- From burned gas: $15 \times 650/60 = 162$ 1 cu ft natural gas produces approximately 650 grains of moisture.
- From exposed water surface: $2 \times 20 = 40$ Evaporation from water surface is assumed to be 20 grains per (minute) (square foot) at 87 F water with air movement of 100 fpm.
- From infiltration: $6000 \times 13.56 \times (118.4 - 24.1) = 696$ One air change, 6000 cu ft, assumed per hour (see Chapter 11).
- Moisture transmitted through room surface: $2200 \times 3 \times (0.783 - 0.176) = 67$

Permeability assumed to be 3 grains per (square foot) (hour) (inch Hg vapor-pressure difference on two sides of wall).

Total moisture gain from internal sources 1085

Let q be the air delivered to the room, pounds per minute. Let it be assumed for this problem that 85 percent of the air is recirculated and 15 percent is outdoor air. Enough air must be supplied to replace leakage from the system or to satisfy normal ventilating requirements for the occupants of the room as given in Chapter 6, whichever is greater. The amount is estimated from experience or obtained by test.

The humidity ratio of the mixture of recirculated and outdoor air entering the dehumidifier is then:

$$\frac{0.85q(24.1) + 0.15q(118.4)}{0.85q + 0.15q} = 38.3 \text{ grains per pound entering dehumidifier.}$$

From the manufacturer's performance data for the dehumidifier to be used it is determined that with 38.3 grains per pound of entering air the leaving condition is 6.5 grains per pound.

Effective dehumidification in the room is $24.1 - 6.5$ or 17.6 grains per pound of supply air.

Then $q = \frac{1085 \text{ grains per minute}}{17.6 \text{ grains per pound}} = 61.6 \text{ lb air per minute}$ minimum that must be supplied to the room to maintain 30 F dew point.

Note that this value represents the minimum requirement for the arbitrary conditions set forth and that in practice, safety margins should be added to the outdoor air percentage value and to the calculated internal moisture gain.

VAPOR TRANSFER TO DEHUMIDIFIED SPACE

The walls enclosing a dehumidified space are subjected to a vapor-pressure differential. The pressure of the vapor outside the walls tends to force moisture through the walls into the dehumidified zone of relatively low vapor pressure. As this process can be an unnecessary load on the dehumidifying equipment, provisions should be made for keeping the vapor transfer to a minimum. Also, if the space is cooled below the ambient dew point, there is a possibility that condensation may occur within the walls, unless vapor