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Silica Gels



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Introduction to Silica Gel

Silica Gel, the highest capacity adsorbent available today, is a porous, granular, amorphous form of silica, synthetically manufactured from the chemical reaction between sulfuric acid and sodium silicate. The internal structure of silica gel is composed of a vast network of inter-connected microscopic pores which attract and hold water, alcohols, hydrocarbons and other chemicals by the phenomena known as physical adsorption and capillary condensation. When used as a desiccant, standard grades of silica gel can adsorb 40% of their own weight of water. Water removal is so efficient with silica gel that dew points as low as —100°F may be obtained.

The action of silica gel is truly reversible because the equilibrium can be shifted towards conditions in which the physical forces holding the adsorbate disappear. For instance, silica gel will desorb an adsorbate at elevated temperatures and upon cooling will regain its same original capacity. This process of adsorption-desorption can be repeated almost indefinitely without significantly impairing the efficiency of the silica gel. During adsorption or desorption, the internal structure of silica gel does not experience any physical or chemical change. Even when saturated with water, silica gel looks and feels dry.

One of the most salient features of silica gel is its versatility. Over 25 different types (grades) of granular silica gels are available to satisfy a vast and always increasing field of industrial and laboratory applications.

Silica Gel Application Guide on pages 8 and 9.

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Davison Silica Gels

Silica Gel Application Guide on pages 8 and 9.

TYPICAL CHEMICAL AND PHYSICAL PROPERTIES OF SILICA GEL

CHEMICAL INERTNESS

Silica gel is chemically inert, non-toxic, non-deliquescent, dimensionally stable and non-corrosive. It is compatible with most materials except strong alkalies and hydrofluoric acid. Silica gel is resistant to most acidic streams and is therefore, used in the drying or purification of acid vapors or liquids.

HIGH PURITY

Silica gel is extremely pure by commercial standards as shown in Table 1. Because of the very low content of metallic compounds it exhibits maximum resistance to fouling when used in the treating of organic vapors. *Pure silica is much less active as a cracking catalyst than silica plus metal combinations.* Therefore, during regeneration at high temperatures and pressures, there is less tendency for the different organic components to crack, react and deposit coke on the surface of the silica gel with a corresponding loss in capacity.

PHYSICAL STRENGTH

Silica gel is a hard, rugged material with excellent crushing strength characteristics. It exhibits a hardness of 5 in the Moh's mineralogical scale. It also exhibits superior attrition resistance characteristics compared to other adsorbents, such as alumina.

The inherent strength of silica gel has permitted the design and operation of economical deep fixed adsorption beds. Beds as deep as 25 ft., without internal supports, have operated for several years without noticeable evidence of particle crushing, attrition or dusting.

SURFACE AREA

Silica gel adsorption characteristics result from its huge surface area due to the highly porous nature of the particle. Standard grades of silica gel exhibit an internal surface area of approximately 800 square meters per gram. This means that if the internal area of 1 gram of silica gel could be extended across a field it would occupy

TABLE I
TYPICAL PHYSICAL AND CHEMICAL CHARACTERISTICS OF SILICA GELS

Chemical Analysis (dry basis)

	Units	Type of Gel: Regular Density	Type of Gel: Intermediate Density
Silica as SiO_2	% wt.	99.71	99.68
Iron as Fe_2O_3	% wt.	0.03	0.01
Aluminum as Al_2O_3	% wt.	0.10	0.10
Titanium as TiO_2	% wt.	0.09	0.02
Calcium as CaO	% wt.	0.01	0.07
Sodium as Na_2O	% wt.	0.02	0.06
Zirconium as Zr_2O	% wt.	0.01	0.03
Trace Elements	% wt.	0.03	0.03

Physical Analysis

	Units	Type of Gel: Regular Density	Type of Gel: Intermediate Density
Pore Volume	cc/gm	0.43	1.15
Pore Diameter (Average)	Angstroms	22	140
Surface Area	sq. meters/gm	750-800	340
Total Volatile at 1750°F	% wt.	5-65	4.5
Specific Heat	BTU/lb./°F	0.22	0.22
True Density (no porosity)	lbs./cu. ft.	137	137
Apparent Bulk Density	lbs./cu. ft.	45	25
Thermal Conductivity	BTU/sq. ft./hr./°F/in.	1	1

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about 800 square meters. To visualize this even further, we can say that a teaspoonful of silica gel has an internal area equivalent to a football field including the two end zones. All of this area is available for the removal of impurities or adsorbates.

HIGH CAPACITY

The equilibrium capacities of silica gel and other desiccants are shown on Fig. 1. In this figure, the desiccant capacity is plotted against the relative humidity (ratio of partial pressure to vapor pressure). In Fig. 2, the equilibrium capacity is related to the silica gel temperature as a function of the water partial pressure. The equilibrium capacity of silica gel hardly varies with temperature at constant relative saturation.

In addition to its high equilibrium capacity, silica gel exhibits superior mass transfer characteristics. In dynamic applications, the excellent mass transfer rate properties of silica gel assure a rapid approach to equilibrium. This results in high useful or working capacities, optimum adsorbent utilization and minimum adsorbent requirements.

This superior mass transfer rate results from two important inherent characteristics of silica gel: 1) The irregular granular shape. 2) A vast inter-connected porous structure which permits the rapid diffusion of adsorbates to the adsorption sites.

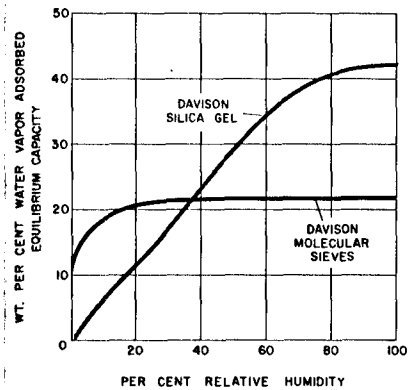

Fig. 1. Effect of relative humidity on desiccant capacity.

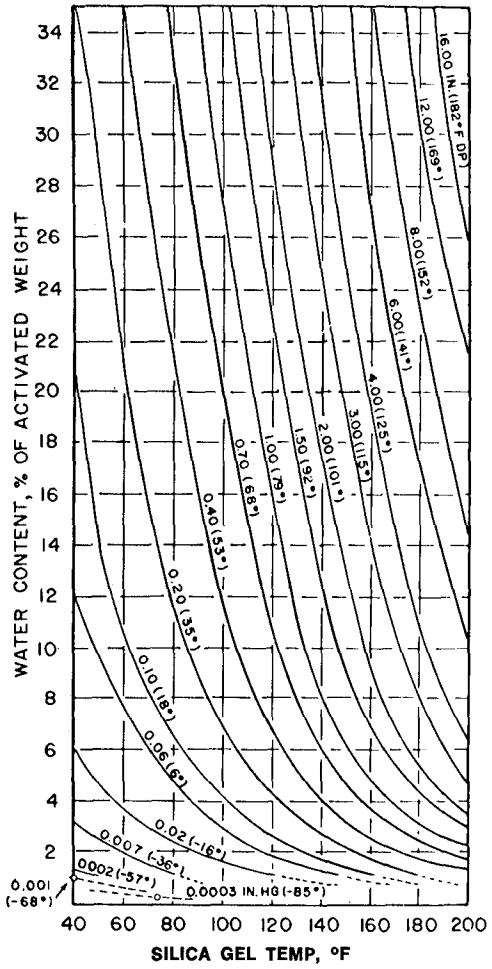

Fig. 2. Water capacity of Silica Gel as a function of temperature at various partial pressures (Equilibrium isopiestics). Dew points corresponding to partial pressures are given in parentheses on isopiestic lines.

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How Silica Gel Works
In Gas Phase

The amount of vapor that silica gel will adsorb from a given gas mixture depends upon the relative saturation (equivalent to relative humidity) of the vapor in the system. Although many theories have been proposed governing the adsorption of silica gel, none describe it perfectly. The most logical explanation for the behavior of silica gel lies in a combination of theories proposed by Freundlich, Ganguly, Langmuir, Zsigmondy and Patrick. In brief, the concept is as follows:

1. The pores of silica gel may be regarded as multiple connection channels, or capillaries, of varying widths. The initial vapor condensing in the pores is essentially a monomolecular layer which will form even at very low relative humidities.
2. Further adsorption is in the form of capillary attraction with the condensed liquid in the capillary forming a meniscus concave to the vapor phase. The vapor pressure over this meniscus is lower than the normal vapor pressure of the liquid by an amount proportional to the degree of curvature. Hence, in small capillaries, such as the narrower sections of the pore channels, vapors can condense at pressures far below the normal vapor pressure. Hence, small diameter pores give larger lowering of the pressure, resulting in more adsorption at low relative pressures. As the relative pressure increases, adsorption in the larger pores takes place.

Patrick has shown that for intermediate and high ranges of relative pressure, which apply to most commercial uses of silica gel, the adsorption of vapors is on a volume basis proportional to the relative pressure of the vapor and to the surface tension of the condensed liquid as follows:

$$V = \frac{KP\,\sigma}{Po}$$

V = Vol. of liquid adsorbed
P = Partial Pressure
Po = Saturation pressure
σ = Surface tension of liquid
K = Constant

A log-log plot based upon this relationship gives a straight line, independent of temperature, that applies to many vapors (but which is least accurate for water vapor).

From the above it is obvious that the pores of regular density silica gel, which have a total volume of about 40 cc/100 g.m., will hold approximately 40 cc of any condensed vapor at 100% relative saturation (P/Po). Furthermore, the total volume of adsorbed vapor decreases with decreased relative saturation.

Since surface tension is zero at the critical temperature, silica gel will not adsorb vapors of liquids at temperatures approaching the critical point.

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...In Liquid Phase (Selectivity)

A. Relative Adsorbability of Different Compounds

The following general rules apply to selective adsorption:

1. A liquid which shows low interfacial tension against a solid (a high pressure) is readily adsorbed by that solid.
2. Liquids are most readily adsorbed from solvents in which they are least soluble. (Conversely, a good solvent makes a good desorbing agent.)
3. Highly polar liquids are readily adsorbed by silica gel. In a given homologous series, such as methyl alcohol, ethyl alcohol, propyl alcohol, and butyl alcohol, the extent of adsorbability decreases in order of decreasing polarity. For instance, in progressing from methyl alcohol (highly polar) to butyl alcohol (less polar) the adsorbability decreases. Compounds with (OH) hydroxyl groups, such as alcohols and phenols, are strongly adsorbed, as well as oxygen-containing compounds, such as esters, aldehydes, ketones, and organic acids.

   The relative order of adsorbability for several compounds is as follows:

   Water (most readily adsorbed)
   Alcohols
   Aromatics
   Di-Olefins
   Olefins
   Paraffins (least readily adsorbed)

4. For compounds of similar chemical groups the higher the molecular weight, the more selectively it is adsorbed.
5. For hydrocarbons of similar molecular weight, adsorbability usually increases with number of double bonds per molecule.

B. Variables Affecting Selectivity, Capacity, Rate of Adsorption and Sharpness of Resolution

1. The selectivity of a particular grade of silica gel in the preferential adsorption of one compound over another depends upon pore diameter, mesh size, and percolation rate.
2. The dynamic capacity of silica gel for adsorbing a particular compound is governed chiefly by the internal surface area (for given average pore diameter). The greater the surface area, the greater the dynamic capacity.
3. The rate of adsorption and sharpness of resolution are dependent chiefly upon the particle size of the silica gel and the manner of packing in the column. In general, a fine particle size gives optimum sharpness of resolution.

C. How Selectivity Is Used In Chemical Industry

Selective adsorption is a means of separating compounds by the preferential adsorption of one molecule over another. It effectively replaces fractional distillation in many applications, and in some processes has been successful where other means of separation have failed. Davison silica gel is used for the selective adsorption of a long list of liquids or solids in solution including hydrocarbons, steroids, and organic acids.

Two broad size ranges of silica gel are available for this purpose: finely divided material and granular material.

Finely divided silica gel is used commercially by mixing it with the feed stock to form a slurry, which is subsequently filtered. The silica gel and adsorbed liquids are recovered on the filter.

Granular material is generally used in a packed column through which the liquids to be adsorbed are percolated. The more strongly adsorbed liquids are retained by the silica gel near the inlet of the column, while the less strongly adsorbed liquids are retained in order of decreasing adsorbability in the remainder of the column. The adsorbed fractions are removed from the silica gel by a desorbing agent, after which the silica gel is ready to be reused.



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Fundamentals of Dynamic Adsorption

By definition, dynamic adsorption is the process by which an adsorbent, such as silica gel, removes an impurity (such as water) from a continuously flowing gas or liquid stream. This process is intrinsically in an unsteady state; conditions in the silica gel bed continuously change with time and position. To better understand dynamic adsorption, let us visualize what happens within a dynamic adsorption unit.

Consider a column packed with freshly activated silica gel in an atmosphere of an adsorbate-free gas. For purposes of simplification, consider that a wet air stream is to be dried with the silica gel. Refer to Fig. 3.

As air first enters the bed, water is diffused and adsorbed within the pores of the gel structure in a relatively thin layer. As more air enters the column, it passes through this layer to a slightly lower level where the incremental water is adsorbed. The rest of the silica gel bed is still unused and the air exits the column in equilibrium with the highly activated silica gel.

Water transfer from the air to the silica gel, therefore, occurs through a zone where the adsorbate (water) content is reduced from its inlet to its outlet concentration. This finite length of bed, where the adsorbate transfer occurs, is known as the mass transfer zone (MTZ). As cycle time progresses, this MTZ continuously moves away from the inlet end of the bed. Upstream of the MTZ, the silica gel reaches an equilibrium with the feed gas while downstream of the MTZ, the highly active silica gel is essentially in equilibrium with the dry exit gas.

Therefore, as time proceeds and more wet air enters the column, a greater portion of the inlet section of the bed becomes saturated and the MTZ is further displaced from the entrance end.

Eventually, the downstream boundary of the mass transfer zone reaches the exit of the column and the bed is said to be saturated or exhausted, and breakthrough occurs. (Exit dew point begins to rise.)

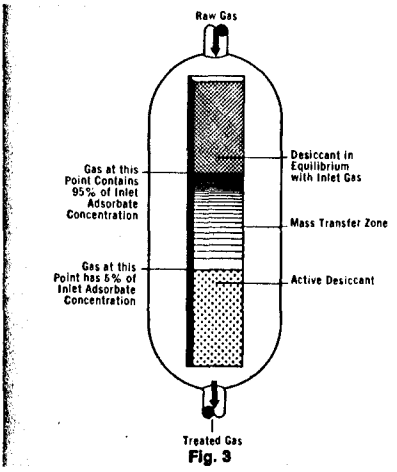

Fig. 3

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Silica Gel App

Natural Gas	Low dew point drying, hydrocarbon dew point control, hydrocarbon recovery of gasoline fractions.
Refining	Drying of Reformer recycle gas, Kerosene jet fuels, fractionated hydrocarbons, hydrogen, inert atmospheres, and a wide variety of other hydrocarbon liquids and gases.
Chemical/Petrochemical	Low dew point drying of innumerable gases and liquids such as H_2, N_2, CCL_4, H_2S, HCL, SO_2, Refrigerants, Ethylene, Benzene etc. In addition, purification of gases and liquids are easily accomplished. A few examples are: Removal of Benzene, Toluene and other aromatics from paraffinic streams, purification of monomer feed streams, adsorption and recovery of misc. chemicals such as SO_2, chloroform, acetic acid, methanol and various solvents.
Industrial Gases	Drying of inlet air, and hydrocarbon removal from the rich liquid in LOX plants. In addition Silica Gel is used in drying product gases (H_2, N_2, Argon).
Refrigeration	Because of its high water and acid capacity Silica gel is used for refrigerant dryers in automotive and commercial refrigeration systems.
Insulating Glass	Used alone or in combination with Davison Molecular Sieves, silica ge assures maximum protection against water and hydrocarbon dew points under the widest range of climactic conditions.

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lication Guide

Commercial and Military Packaging	Numerous package configurations using Silica Gel are used for protection against moisture, mildew and odor in pharmaceuticals, foods, packaging of metallic products, delicate instruments and equipment.
Telecommunications	Underground Telephone cables are protected by drying equipment containing Silica Gel. In addition, above ground cable splices utilize silica gel in the splice to eliminate cable failure.
Flower Drying	Color indicating Silica Gel dries flowers.
Humidity indicators	Silica gels which indicate changes in relative humidities by a change of color.
Chromatagraphic medias	Ultra pure, specially sized silica gels used for chromatagraphic separations. PONA analysis is a good example.
Catalyst Carriers	1) High porosity and chemical inertness allow desired metals deposition resulting in efficient finished catalysts. 2) Reactant carrier.
Buffer Adsorbent	Special high capacity Silica Gels designed for liquid water adsorption (almost 100% capacity) used as a "Buffer" to protect other adsorbents.
Cigarette filters	Used for nicotine and tar removal.
Raw material	Source of silica in several high purity chemical processes.
Finely Divided	Micron-sized silicas used as carriers and dispersants for oil and water; flatting agents for paint; anti-caking and free-flow agents for foods and pharmaceuticals.

For other areas of application, please contact the Davison Adsorbent Technical Service Dept.

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REGENERATION

When a silica gel bed becomes saturated, its original capacity can be restored by the process known as regeneration. Regenerating a bed consists of desorbing or stripping the adsorbate(s) present in the gel porous structure at the end of the adsorption period. To maintain process continuity during the regeneration of this bed, the feedstream is diverted to a second bed which was made adsorbate-free by a previous regeneration (Fig. 4).

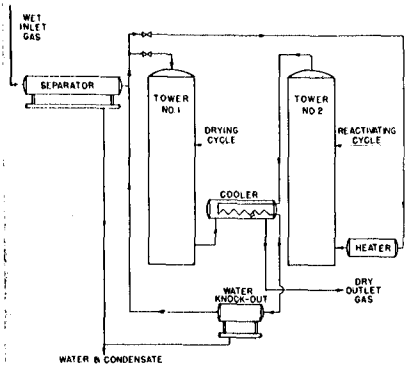

Fig. 4. Thermal swing regeneration flow diagram of a typical dual tower dehydrator, showing Tower No. 1 drying and Tower No. 2 regenerating.

Regeneration can be accomplished in four ways. Each method is used commercially, the choice depending on technical and economic considerations.

All four methods depend on the same principle — the conditions surrounding the adsorbent are changed to those corresponding to a very low equilibrium capacity. In general, the greater the difference between the equilibrium capacities of adsorption and regeneration, the more rapid and complete the regeneration.

1. The "thermal swing" involves heating to a temperature at which the adsorptive capacity is reduced to a low level so that the adsorbate leaves the silica gel surface and is easily removed by a small stream of purge gas. This can be done at operating pressure, or at a reduced pressure.
2. The "pressure swing" similarly depends on reducing the adsorptive capacity by lowering the pressure at essentially constant temperature.
3. The third method removes the adsorbate, without changing the temperature or pressure, by passage of a fluid (liquid or gas) containing no adsorbable molecules, and in which the adsorbate is soluble or miscible.
4. The final method also does not involve changing the temperature of pressure, but depends on passage of a fluid containing a high concentration of an adsorbable molecule. Because of this high concentration, these molecules are able to displace material previously adsorbed. In the case of liquids, the resulting mixture is then separated, by distillation, into a saleable product of high purity and the regenerating fluid (which is reused).

Regeneration of a silica gel bed is usually accomplished by thermal reactivation. Silica gel requires the lowest temperature level and the lowest amount of heat for adequate regeneration than any other type of commercial adsorbent.

The degree of regeneration required depends on the requirements to be placed on the adsorbent in successive adsorption cycles. For a gas dehydrator, this means the effluent water content of the main process stream. The lowest attainable effluent water dewpoint (equilibrium) depends on the amount of water left on the silica gel during regeneration. This residual water loading is dependent upon both the water dew point of the regeneration gas and the regeneration temperature.

This is better understood by referring to Fig. 5. This graph is an isosteric equilibrium diagram correlating the gas water dew point, the residual water loading and the operating temperature. For instance, if a silica gel bed is regenerated at a relatively low temperature, (250°F), with a relatively wet gas, (60°F) dew point, the equilibrium residual water content would be 1%. The same bed when cooled to an operating temperature of 75°F would produce an effluent water dew point of approximately −50°F. For regeneration temperatures higher than 350°F, the residual water content is usually negligible and even greater dew point depressions are obtainable. For instance, if a silica gel bed is reactivated at 400°F in a relatively dry atmosphere, dew points well below −80° F can be expected in dynamic applications. **The maximum regeneration temperature for silica gel is 600° F.**

The thermal requirements for adequate regeneration includes the following heat loads:

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- Sensible heat for the bed.
- Adsorbate heat of desorption.
- Sensible heat for the vessel walls and bed supports.

Frequently, silica gel beds are internally insulated to minimize the heat load for the vessel walls and the radiation losses.

Small silica gel beds are sometimes heated with internal coils. Because of the low thermal conductivity of the silica gel this method becomes very inefficient for large beds (>1 ft. ID). For these larger units direct heating with a hot gas stream is preferred. The gas is usually heated in either a high pressure steam heat exchanger or in a direct fired heater. In addition to elevating the bed temperature the gas also serves to carry away the desorbed adsorbates from the bed.

The gas rate required for regeneration depends on :

- The total heat load
- The specific heat of the regenerating gas
- The dynamics of heat and mass transfer
- The time available for regeneration

Countercurrent heating is usually preferred in order to minimize the residual water (or any other adsorbate) content at the exit end of the bed. This assures maximum dew point depression as discussed before. (Fig. 5.)

After a bed of silica gel has been heated during regeneration, a cooling period must follow to return the bed to adsorption temperature. This is most conveniently done by using the same regeneration gas stream but by-passing the heater. If wet gas is used for cooling purposes, cocurrent cooling is preferred. Since some water preloading always occurs with wet gas, it is advantageous to produce this preloading at the entrance rather than at the exit end of the bed. Obviously cooling with the adsorbing tower effluent will minimize preloading.

Design methods for estimation of regeneration requirements are beyond the scope of this brochure. However, the Davison Technical Service Department is available to provide such estimates.

Factors Affecting The Dynamic Capacity Of Silica Gel Adsorbers

1. VELOCITY AND BED DEPTH

Tall, slender silica gel beds exhibit higher dynamic capacities than short, squat beds for any given mass flow rate, adsorbate content, pressure and temperature. Therefore, high velocities combined with longer depths result in more efficient silica gel utilization than low velocities combined with shallower bed depths.

For example any of the following air drying designs would give equivalent performance if adequate gas distributors are used:

Bed Diameter (ft.)	Height (ft.)	Silica Gel Poundage (lbs.)	Useful Water Capacity (% wt.)
4	12.5	7050	19.5
4.5	10.2	7320	18.7
5	8.6	7600	18.0
5.5	7.4	7870	17.4
6	6.4	8130	16.8
6.5	5.6	8400	16.3

Observe how the small diameter, deep beds exhibit significantly better capacities than the shallow beds.

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Summarizing, assuming sufficient depth is provided for proper mass transfer zone development, increasing fluid velocity always increases the adsorbate mass transfer rate and therefore, the dynamic capacity.

For gas phase applications, the maximum superficial velocity in upflow operations is determined by bed movement and fluidization considerations. This velocity depends on the fluid density, particle density, and shape and size of the adsorbent. A design graph for silica gel Grade 03, plotted using a correlation by Ledoux*, is shown in Fig. 6. Since with downflow operations the potential danger of fluidization is eliminated, it is possible to operate at higher velocities. The maximum permissible velocity in downflow operations is approximately 1.8 times the maximum upflow velocities.

A significant decrease in capacity is experienced if the velocity is reduced so that turbulent conditions no longer exist. Under laminar conditions, fluid dispersion and inefficient contact result in poor adsorbent utilization and low capacities.

2. EFFLUENT ADSORBATE CONTENT

The useful capacity of a silica gel bed depends, among other things, upon the effluent adsorbate content demanded of it. Since the length of the mass transfer zone increases with lower effluent concentrations, treating gases to lower concentrations would exhibit lower capacities. This is graphically shown on Fig. 7, where the useful capacity of a silica gel drier at low air pressure (5 psig) is plotted against the relative humidity for different effluent dew points. Referring to this graph, it can be observed that in the drying of the water saturated stream the useful capacity dropped from 11% to 4% when the effluent dew point was decreased from 0 to −80°F.

An example of the behavior of silica gel in an atmospheric pressure drier with a shallow bed, drying air at 85% relative humidity and 70°F is given in Fig. 8. The curves show the change of outlet dew point and outlet dry bulb temperature as the drying cycle progresses. Curves showing the reactivation cycle are on the right hand side of the graph.

It is of interest to note that there is no outlet dew point plateau, followed by a relatively sharp increase in dew point or "break point" as is true of high pressure dehydrators. Instead, the outlet dew point drops to a minimum and then rises gradually. Obviously, the useful capacity or weight of water adsorbed by this bed, depends upon the outlet dew point desired. (The point at which the unit is set to switch beds and start reactivation.)

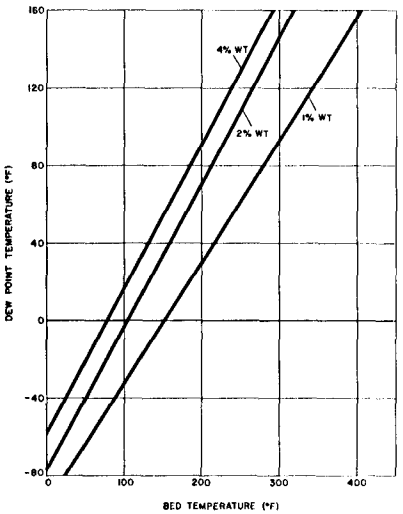

Fig. 5. Silica gel bed temperature at various water loadings.

3. RESIDUAL ADSORBATE LOADING

The amount of adsorbate present on the bed at the start of the adsorption period affects the dynamic capacity of silica gel. The higher the residual adsorbate loading, the lower the capacity. The amount of residual adsorbate is determined by the regeneration conditions. (See Fig. 5).

4. SYSTEM TEMPERATURE

The effect of temperature on useful capacity is an inverse one — higher temperatures causing lower useful capacities. Reference to Fig. 2 shows that the adsorptive capacity of silica gel, in equilibrium with air or gas of a given dew point, decreases at elevated temperatures.

When compounds are adsorbed on silica gel, heat is liberated equivalent to the latent heat of vaporization of the adsorbed liquid plus an additional amount of heat known as the heat of wetting. The sum of the latent heat plus the heat of wetting is the heat of adsorption. The heat of

*Ledoux, Edward, *Chemical Engineering*, March, 1948

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wetting of bone dry silica gel is approximately 400 BTU/lb. of water adsorbed. As the gel becomes saturated, the heat of wetting decreases and approaches zero as complete saturation is reached. For beds attaining useful capacities of approximately 10-15%, the average heat of wetting may be taken as 325 BTU/lb. water adsorbed. This, plus the latent heat of the liquid will be approximately 1300 BTU/lb. of water adsorbed. Since adsorption is confined almost entirely to the

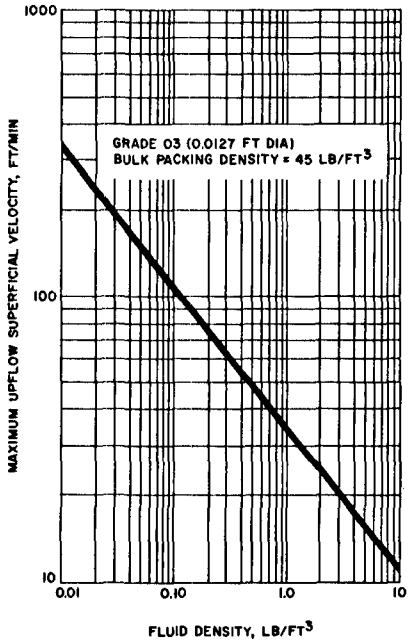

Fig. 6. Maximum Fluid Velocity.

"drying zone," the heat of adsorption is liberated only in this area. This results in a temperature peak or front which moves through the bed with the drying zone.

During dehydration the heat of adsorption is transformed into sensible heat that is dissipated into the silica gel, the metal of the container, and the dried gas. This results in a rise in temperature of both the bed and the gas.

For most calculations, the temperature rise of

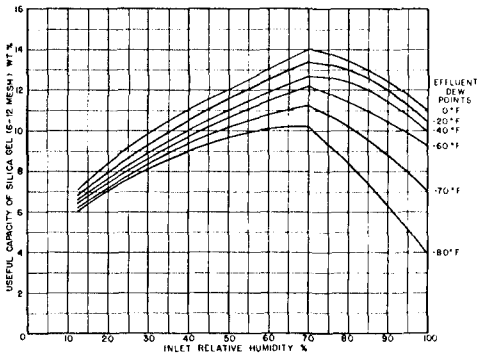

Fig. 7. Useful concentration of water in silica gel vs. inlet humidity for various effluent dew points. Low pressure (5 psig).

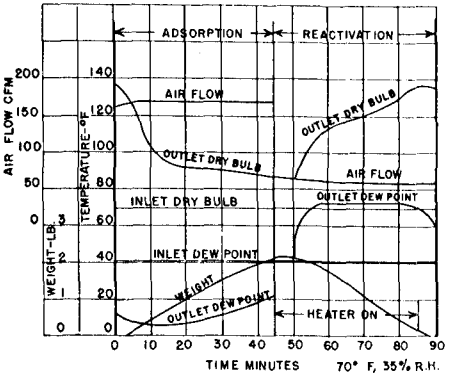

Fig. 8. Characteristic curves — silica gel in atmospheric pressure dehumidification.

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the dehydrated gas may be estimated from the following empirical rule:

Temperature rise is 10°F multiplied by the grains of water adsorbed per cubic foot of air and divided by the pressure, in atmospheres.

The temperature rise of a gas dried at elevated pressures is less than that dried at atmospheric pressure. This is because a given volume of air or gas at high pressure can remove much more heat as sensible heat due to the higher density of the compressed gas. Therefore, to obtain high useful capacity and low exit dew points, it is desirable to dissipate the heat of adsorption by any convenient means, such as cooling coils, or operation at elevated pressures.

5. INLET ADSORBATE CONTENT

An idea of how the influent adsorbate content affects the useful capacity of silica gel at essentially atmospheric pressure (5 psig) is presented in Fig. 7 which gives a family of curves obtained in a 24 inch bed with air saturated at 75°F in laboratory equipment. These curves show that under essentially adiabatic conditions at relative humidities above 70% the useful capacity is decreased due to the large amount of heat evolved during adsorption of the greater amount of water. The identical equipment operated at 115 psig with air saturated at 61°F, has a useful capacity of 27.4% with a −85°F dew point, showing that higher useful capacity can be attained for a given dew point under essentially isothermal conditions, because of better heat removal by the higher pressure air.

6. SYSTEM PRESSURE

The adsorptive capacity of silica gel varies according to the relative pressure (partial pressure of gas being adsorbed at a given temperature divided by the vapor pressure of that gas at the same temperature, or P/Po). This is equivalent to relative humidity in the case of moisture in air.

For a given mole fraction of gas in a system the partial pressure will be proportional to the mole fraction times total pressure. Hence, if the total pressure is increased, or decreased, the partial pressure and therefore the relative pressure (P/Po) will increase or decrease in direct proportion. This reaches a limit when the partial pressure equals the vapor pressure (at which point the relative pressure or relative humidity is 100%) under constant temperature conditions. Variations in adsorption with relative pressure must be determined experimentally for each gas in question. The curve is essentially independent of temperature.

In practice, operation at high pressures is also desirable because the heat of adsorption is dissipated more rapidly, due to the increased heat capacity (volume basis) of the compressed gas.

7. COADSORPTION

Often more than one component can be strongly adsorbed by silica gel. Since this can adversely affect the dynamic capacity for the desired adsorbate, allowance must be made for this effect.

8. PARTICLE SIZE AND SHAPE

Small particle size and irregular granular shape permit the most effective contact between gas and desiccant resulting in greatest efficiency. The effect of particle size and shape on the rate of movement of a −85°F dew point front through a laboratory column of desiccant is shown in Table II. Although the finer mesh material permits longer time on stream before reaching the break point, it also has a higher pressure drop. In general, a coarse mesh is used where large volumes of air or gas are to be dried, or where low pressure drop is important. The data, which are based upon inlet air at 75°F, 90% relative humidity, and a superficial velocity of 60 ft./min. show that granular shape and small particle size permit the longest drying cycle and, therefore, greatest capacity in low dew point operations.

Design methods for silica gel adsorption systems are beyond the scope of this publication. The Davison Technical Service Department is available to provide these services.

THROUGH LABORATORY COLUMN

DESICCANT	PARTICLE SIZE	LENGTH OF DRYING CYCLE
Granular silica gel	3- 8 mesh	8 minutes
Granular silica gel	6-16 mesh	10.5 minutes
Granular silica gel	14-20 mesh	13.1 minutes
Beaded silica gel	4- 8 mesh	3.7 minutes
Granular bauxite	4- 8 mesh	5.7 minutes

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Customer Technical Service

Davison Chemical provides technical assistance as a free service to our customers, for the process design of new silica gel and molecular sieve adsorption units, for the trouble-shooting of existing units, for the development of tailormade adsorbents with specific pore volumes and areas, or for the development of new applications.

Process designs of adsorption units include determination of the required adsorbent poundage, configuration of the system, bed dimensions (diameter and height), pressure drop estimates and regeneration requirements. Most common adsorption design problems are solved through computer programs via a cross country electronic network.

Troubleshooting of existing units is provided through process evaluation which includes analyses of used material to detect aging or contamination of the adsorbent.

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DAVISON CHEMICAL

W. R. Grace & Co.
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TECHNICAL BULLETIN

ADSORPTION DATA FROM
PIGMENTS, ADDITIVES & ADSORBENTS DEPARTMENT

GRACE
DAVISON CHEMICAL

ADS-16-571

Silica Gel Grade Chart and Application Guide

W. R. GRACE & CO. • DAVISON CHEMICAL DIVISION • PIGMENTS, ADDITIVES & ADSORBENTS DEPT. • BALTIMORE, MD. 21203 • (301) 727-3900

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PROPERTIES OF DAVISON

GRADE	01	03	04	05	11	12	13	15	28	35	37	40	41
TYPE	RD	RD	RD	RD	RD	RD	RD	RD	RD	RD	RD	RD	RD
SPECIAL CHARACTERISTICS	Tailored Particle Size Distribution						3% Blue Indicating Gel	High Purity					
PARTICLE SIZE (Tyler Sieve)	3-8	on 8	8-14	6-16	28-200	28-200	28-200	20-65	20-40	12-42	12-42	6-12	3-9
BULK DENSITY (lbs./cu. ft.)	46.0	45.0	45.0	46.0	46.5	46.0		46.0	45.0	45.0	45.0	45.0	45.0
TOTAL VOLATILE %@1750° F (Max.)	5.5	6.0	5.5	5.5	6.0	6.0		6.0	6.5	6.0	5.5	5.5	5.5
SURFACE AREA (Sq. Meters/Gram)	720-760	720-760	720-760	720-760	720-760	720-760	720-760	720-760	720-760	720-760	720-760	720-760	720-760
PORE VOLUME (CC/Gram)	.43	.43	.40	.43		.43		.43				.43	.43
TYPICAL EQUILIBRIUM ADSORPTION (wt. %) at													
5% RH													
10% RH	8.0	7.7	7.7	7.7	6.7	7.0	6.7		8.0			7.2	7.7
20% RH	14.2	14.7	14.7	14.7	12.0	12.0	12.0		13.5	14.4	14.6	13.7	14.7
40% RH	27.5	27.4	27.4	27.4	24.0	24.5	24.0		24.0	26.5	26.4	26.5	26.0
60% RH	34.0	33.0	33.0	33.0	33.6	33.0	33.6					32.5	32.0
80% RH	36.8	35.3	35.3	35.3	36.0	36.0	36.0					35.3	35.0
COMMENTS												Meets MIL-D-3716 Type II Grade H Spec	Meets MIL-D-3716 Type I Grade H Spec
TYPICAL USE CODE (See Back Page)	A	B	C	D	E	F	G	F	H	I	I	J	K

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I GRANULAR SILICA GELS

42	43	44	45	46	52	59	62	80	91	113	407	408	922	923	938	950
RD	RD	RD	RD	RD	RD	ID	ID	RD	ID	Silica Alumina	RD	RD	RD	RD	RD	RD
Blue Indicating Gel	Blue Indicating Gel	Blue Indicating Gel	3% Blue Indicating Gel	3% Blue Indicating Gel	Hydrogel		High Purity		Hydrogel				High Purity	High Purity	Green Indicating Gel	High Purity
6-16	14-20	3-8	8-20	12-28	thru 100	3-8	60-200	50-200		thru 250	8-20	12-28	200-325	100-200	6-16	60-200
48.0	47.5	47.0	46.8	43.0	65.0	25.0	25.0	37.0		31.0	47.0	44.0	46.0	46.0	48.0	46.0
5.6	5.6	5.6	6.0	6.0	68	3.5	6.5	8.0		12.0	5.75	5.75	6.0	6.5	6.5	6.5
720-760	720-760	720-760	720-760	720-760	720-760	340	340	600		550	720-760	720-760	700	700	710	700
						1.15	1.15	.70		.75			.45	.40		.40
			5.3	5.3							4.9					
6.9	6.9	6.9	7.5	7.5		2.0					7.5	7.0			6.9	
13.1	11.7	11.7	14.1	14.1		3.0					14.5	13.0			11.4	
24.0	23.0	23.0	26.4	26.4		5.0					26.4	25.0			22.6	
29.1	31.0	31.0				8.0					31.9				30.2	
31.0	33.5	33.5				17.0					35.0				33.5	
						94% water capacity at 100% R.H.									Meets IG-327 Spec	
L	L	L	M	M	N	O	P	R	S	T	U	U	V	V	W	V

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SILICA GEL USE CHART

Use Code	Grade	Application
A	01	Dehydration of gases, trace hydrocarbon removal. Usually recommended for special applications where particle size is critical.
B	03	For natural gas and other industrial gases. 1) Bulk dehydration. 2) Hydrocarbon recovery.
C	04	Contaminant removal in safety equipment.
D	05	Liquid and gas dehydration—special because of controlled particle size distribution.
E	11	Tele communication industry.
F	12, 15	Chromatographic gels.
G	13	Drying of flowers.
H	28	Refrigerant drying—brickettes.
I	35, 37	Packaging—Because of size they could be used in selected liquid applications.
J	40	Liquid and gas dehydration.
K	41	Gas dehydration—because of particle size it is also recommended for hydrocarbon recovery.
L	42, 43, 44	Indicating—blue to pink.
M	45, 46	Insulating glass—contain 3% indicating gel for inplant control.
N	52	High purity silica source (Chemical raw material)
O	59	Non decrepitating—mainly used to top off beds of other gels in order to protect them from entrained liquid water.
P	62	Special fine size chromatographic gels.
R	80	Cigarette filter. Nicotine and tar removal.
S	91	Hydrogel—contains about 70% by wt. of water—introduces H_2O into a system e.g. battery separators.
T	113	A silica alumina combination for special organic separations.
U	407, 408	Bulk liquid dehydration such as refrigerants.
V	922, 923, 950	Ultra high purity chromatographic gels.
W	938	Special indicating gel. Green to yellow @0-4% RH.

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