Gas Dehydration with PELADOW DG Calcium Chloride

Table of Contents

I. Introduction

As the need for domestic natural gas increases, calcium chloride dehydration can help make certain wellheads more profitable to operate. Gas from remote or offshore wellheads, gas of a low flow rate, or gas which is high in sulphur content may benefit from dehydration with PELADOW* DG calcium chloride.

The size and almond shape of these briquettes minimize bridging and channeling that can occur during unexpected changes in the gas composition, gas flow, or ambient conditions. The almond shape also minimizes pressure drop, which is critical in wellhead operations.

Calcium chloride is an excellent desiccant which, as it passes from a solid to a liquid state, can absorb more than 3.5 times its weight in water. Even in its liquid state as a brine, the chemical continues to absorb water at significant rates.

The four advantages of calcium chloride dehydrators

1. *Energy efficient*—No energy-consuming equipment is part of the basic design of a calcium chloride dehydrator. In locations of extreme cold, it may be necessary to incorporate a heating unit to maintain system temperature. But a calcium chloride unit consumes a fraction of the energy required by glycol units.
2. *Low labor costs*—Other than the recharging of the dry desiccant beds, calcium chloride dehydrators require little or no attention. They can function up to six months unattended.
3. *Reduced fire hazard*—Calcium chloride is not flammable, and the dehydration system requires no open flame.
4. *Competitive equipment costs*—Calcium chloride dehydrators usually cost a fraction of comparatively sized glycol and molecular sieve dehydrator units.

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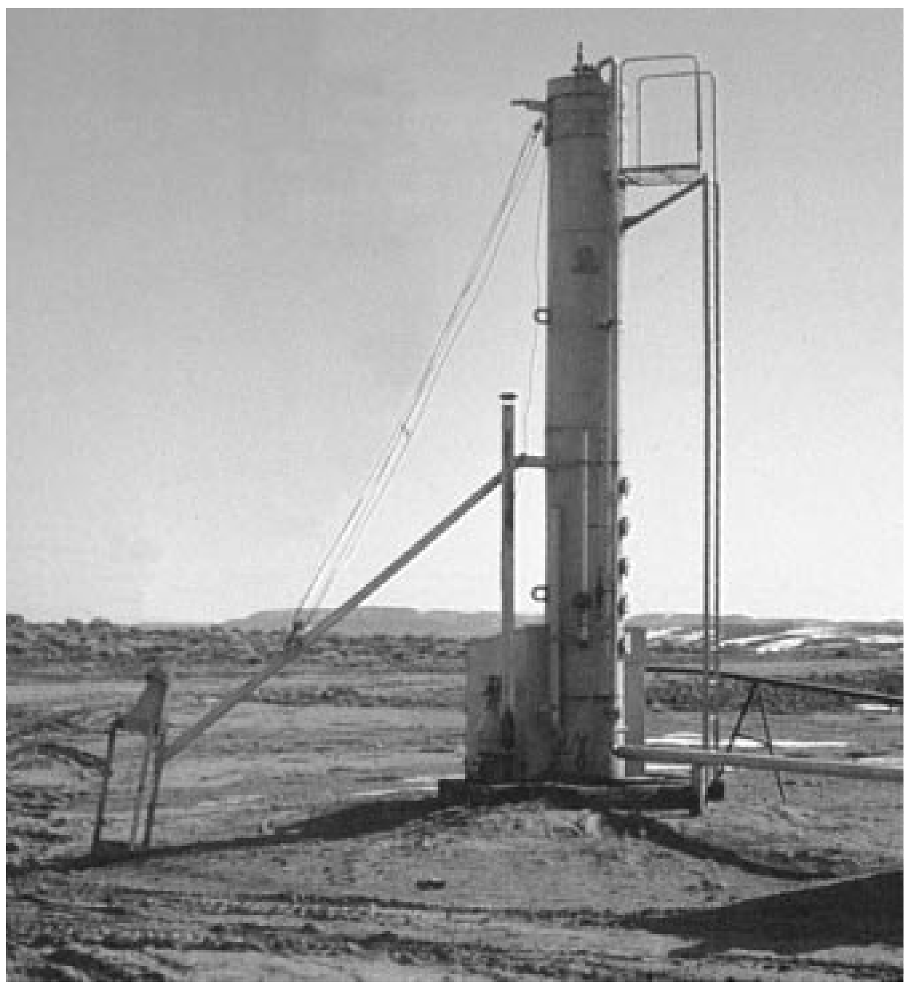
Guidelines on when to consider calcium chloride dehydration

Operational Limits

	Glycol (TEG)	Calcium Chloride ($CaCl_2$)
Dew-point depression	**50-90°F:** Greater dew-point depressions achieved with additional trays, vacuum regeneration, or DRIZO process.	**55-70°F:** This range typically is sufficient to dry gas to the normal pipeline specification of 2-7 lbs H_2O per 1 MMSCF.
Feed gas pressure	**300-3000 psig:** TEG functions well throughout this range but is exceptionally suited to lower pressures.	**125-3000 psig:** Optimum performance occurs with pressures greater than 700 psig. Desiccant usage increases as pressure decreases.
Feed gas temperature	**40-100°F:** Temperatures greater than 100°F require addition of gas-stripping or DRIZO facilities.	**40-100°F:** Temperatures greater than 100°F usually require aerial coolers.



Conditions Favorable to Calcium Chloride Dehydration Units

	Glycol (TEG)	**Calcium Chloride ($CaCl_2$)**
Remote locations	The complexity of glycol dehydrators, plus the fact that most make use of an open flame, requires supervision, safety, and maintenance at remote locations—especially offshore wellheads. Typically, gas-glycol pumps, which significantly increase operating costs, must be used in regions with unreliable electrical power.	The relative simplicity of the concept and design of these units makes them ideal in offshore and periodically snowbound locations. Depending on operating conditions, a large number of calcium chloride units can be left unattended for up to six months.
Low gas flow	Flow rates lower than 300 Mscfd are often accommodated by having a single glycol unit service several wellheads.	As long as pressure is sufficient, calcium chloride units function especially well at very low flow rates—from 50 to 20,000 Mscfd. Further, the lower the flow rate, the longer a calcium chloride unit can function unattended between rechargings.
Acidic conditions	Acidic conditions in glycol result from acid constituents of the natural gas or through oxidation of the glycol itself. Glycol oxidation is normally well controlled in a properly designed reboiler system. But gas containing high proportions of H_2S in the presence of high temperatures can result in the release of pollutants into the atmosphere during regeneration.	Calcium chloride is essentially non-reactive with H_2S or CO_2, and requires no special pretreatment of gases containing these acid constituents.
Salt contamination	Sodium chloride (NaCl) in the gas remains a potential problem for glycol dehydration units. An improperly maintained inlet scrubber or mist extractor could result in salt crystallization in the heating tubes and subsequent damage to the tubes themselves.	Salt contamination is never a problem in calcium chloride units. Even if NaCl brine gets through the wellhead knock-out, it would be pushed down by the $CaCl_2$ brine dripping from the trays and is unlikely to ever reach the bed section.

II. PELADOW DG Calcium Chloride

PELADOW DG calcium chloride is an almond shaped, briquetted, 91% (min.) calcium chloride product that is specially designed to be used for dehydration of gas and liquid hydrocarbons.

1. Applications

PELADOW DG calcium chloride is used to dehydrate both gas and liquid hydrocarbons such as natural gas, LPG, kerosene, and diesel fuel. In addition to hydrocarbons, PELADOW DG has been used to dry chlorinated solvents and air.

The special design of PELADOW DG calcium chloride helps minimize the bridging and channeling in vessels that can occur with normal deliquescent salts.

Under most conditions, PELADOW DG calcium chloride is capable of absorbing about one pound of water per one pound of product in liquid hydrocarbon drying systems. For natural gas systems, depending on operating conditions and drier design, one pound of PELADOW DG can absorb 3.5 pounds of water.

2. Availability

PELADOW DG calcium chloride is available in 400 lb drums and 2100 lb sacks. Special packaging sizes may be available on request.

3. Physical Properties

Table 1 presents some typical physical properties of PELADOW DG. In addition to its calcium chloride content, these are considered the most important properties relative to the use of PELADOW DG in dehydration applications.

Additional physical properties of PELADOW DG calcium chloride and solutions of calcium chloride are either found in other sections of this manual or in Dow's "Calcium Chloride Handbook." (Form No. 173-01534-396)

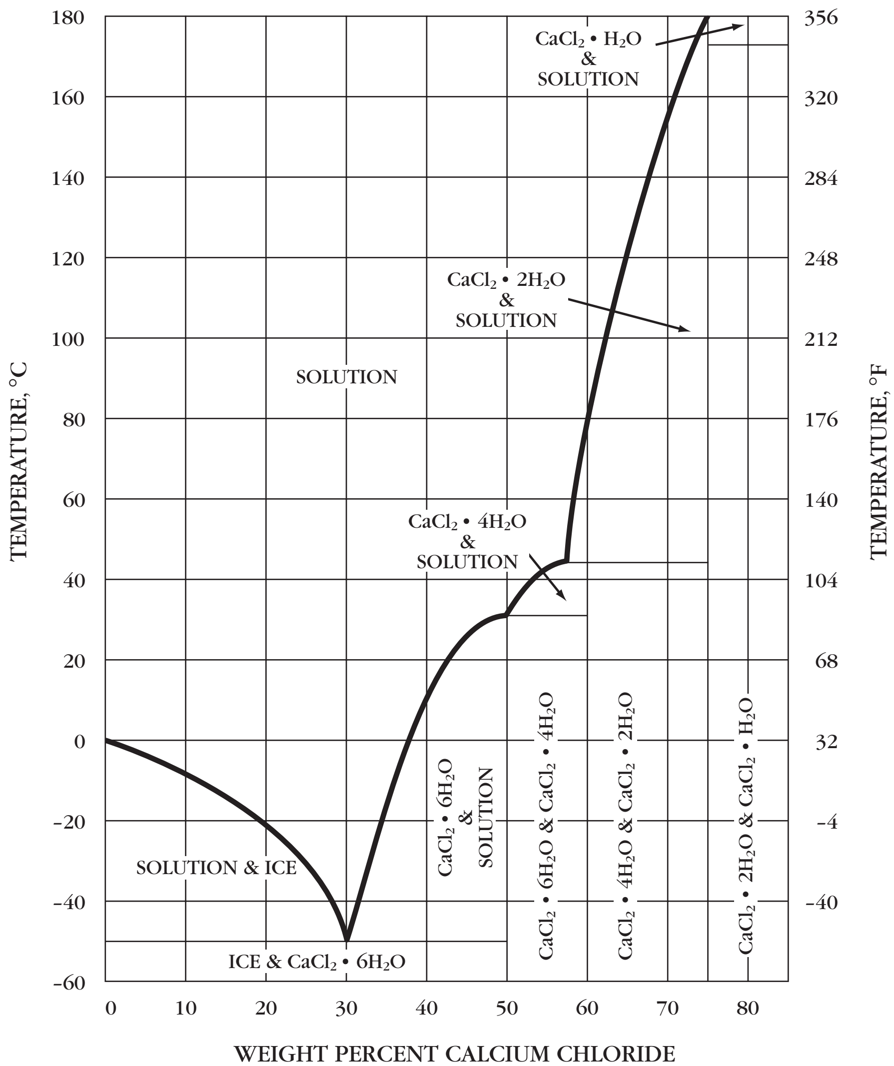
Table 1 – Typical Physical Properties of PELADOW DG

Typical Assay	91% - 92% calcium cloride 3 - 4% alkali chroides
Appearance	White almond shaped briquettes
Odor	None
Briquette Size	Approx. 0.7" thick at thickest point, 1.1" length
Sieve Analysis	85% > 1/2 inch 94 - 100% > 1/4 inch
Bulk Density	60 - 68 lbs./cu. ft.
Briquette Density	1.86 - 1.88 g/cc
Briquette Porosity	15 - 20%
Bed Void Space (Loose Fill)	45 - 50%
Pressure Drop	0.01 to 0.1 psi/ft. of bed height
Angle of Repose	28°

4. Calcium Chloride Phase Diagram

Figure 1 is a portion of the phase diagram for pure calcium chloride. It shows that a number of hydrates of calcium chloride form during drying. It also shows the temperature limits for stability of various hydrates at a pressure of one atmosphere.

Figure 1 – Phase Diagram for $CaCl_2$ and Water Solutions



5. Physical Properties of Hydrates

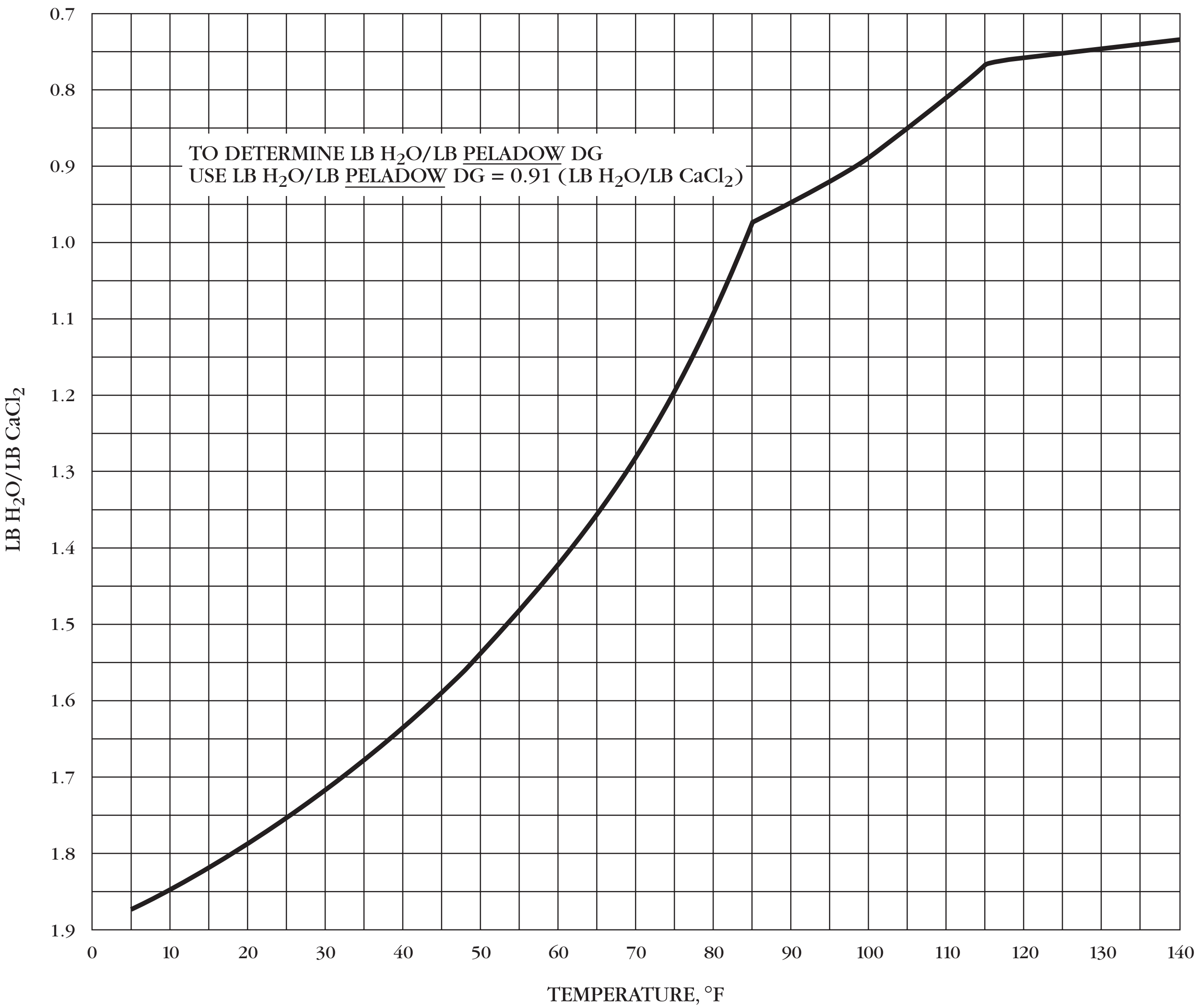
The physical properties of pure anhydrous calcium chloride and the hydrates of calcium chloride shown in Figure 1 are listed in Table 2. This data was compiled from the literature and files of The Dow Chemical Company. Note that the thermochemical values have negative signs when the process is exothermic, i.e., gives off heat. This convention follows present National Bureau of Standards practice. A positive sign or no sign indicates the process is endothermic, i.e., absorbs heat. Anhydrous calcium chloride and the lower hydrates emit a large amount of heat when dissolved in water; this may cause a temperature rise great enough to boil water and create a safety hazard.

Table 2 – Properties of Calcium Chloride Hydrates [1, 3, 11]

Property	$CaCl_2 \cdot 6H_2O$	$CaCl_2 \cdot 4H_2O$	$CaCl_2 \cdot 2H_2O$	$CaCl_2 \cdot H_2O$	$CaCl_2$
Composition (% $CaCl_2$)	50.66	60.63	75.49	86.03	100
Molecular Weight	219.09	183.05	147.02	129	110.99
Melting Point[1] (°C)	29.9	45.3	176	187	772
(°F)	85.8	113.5	349	369	1424
Boiling Point[2] (°C)	—	—	174	183	1935
(°F)	—	—	345	361	3515
Density at 25°C (77°F), g/cm^3	1.71	1.83	1.85	2.24	2.16
Heat of Fusion (cal/g)	50	39	21	32	61.5
(Btu/lb)	90	70	38	58	110.6
Heat of Solution[3] in H_2O (cal/g)	17.2	–14.2	–72.8	–96.8	–176.2
(to infinite dilution) (Btu/lb)	31.0	–25.6	–131.1	–174.3	–317.2
Heat of Formation[3] at 25°C (77°F), kcal/mole	–623.3	–480.3	–335.58	–265.49	–190.10
Heat Capacity at 25°C (77°F), cal/g (°F, Btu/lb)	0.34	0.32	0.28	0.20	0.16

[1]Incongruent melting point for hydrates.
[2]Temperature where dissociation pressure reaches one atmosphere for hydrates.
[3]Negative sign means that heat is evolved (process exothermic).

Figure 2 – Crystallization Temperatures of $CaCl_2$ - Water System



The relationship between crystallization temperature and $H_2O/CaCl_2$ ratio for solutions of pure $CaCl_2$ is shown in Figure 2. These results can be used with little error as also indicated for PELADOW DG.

III. Process Considerations

1. Process Description

A typical calcium chloride dehydrator is shown in Figure 3. Our discussion will pertain to this specific type of equipment although PELADOW DG calcium chloride could also be used in other similar types of equipment.

Figure 3 shows how gas and liquids flow in the dehydrator. The unit is designed to take advantage of the excellent desiccant properties of PELADOW DG as a solid and in solution. The lower or separator section is a gas-liquid separator which separates free liquids, hydrocarbons and water, from the inlet gas stream. The middle or tray section is the liquid absorption section where the brine removes most of the water in a series of trays. The upper or bed section contains the solid PELADOW DG calcium chloride, which absorbs the final amount of water and furnishes the brine feed for the tray section.

A. Separator Section

Incoming wet gas and free liquids flow through the dehydrator from the bottom upward, passing through a liquid disengager, where the free liquids are removed. Any water and liquid hydrocarbons are discharged separately from the column. Gas free from entrained liquids now flows up to the tray section.

B. Tray Section

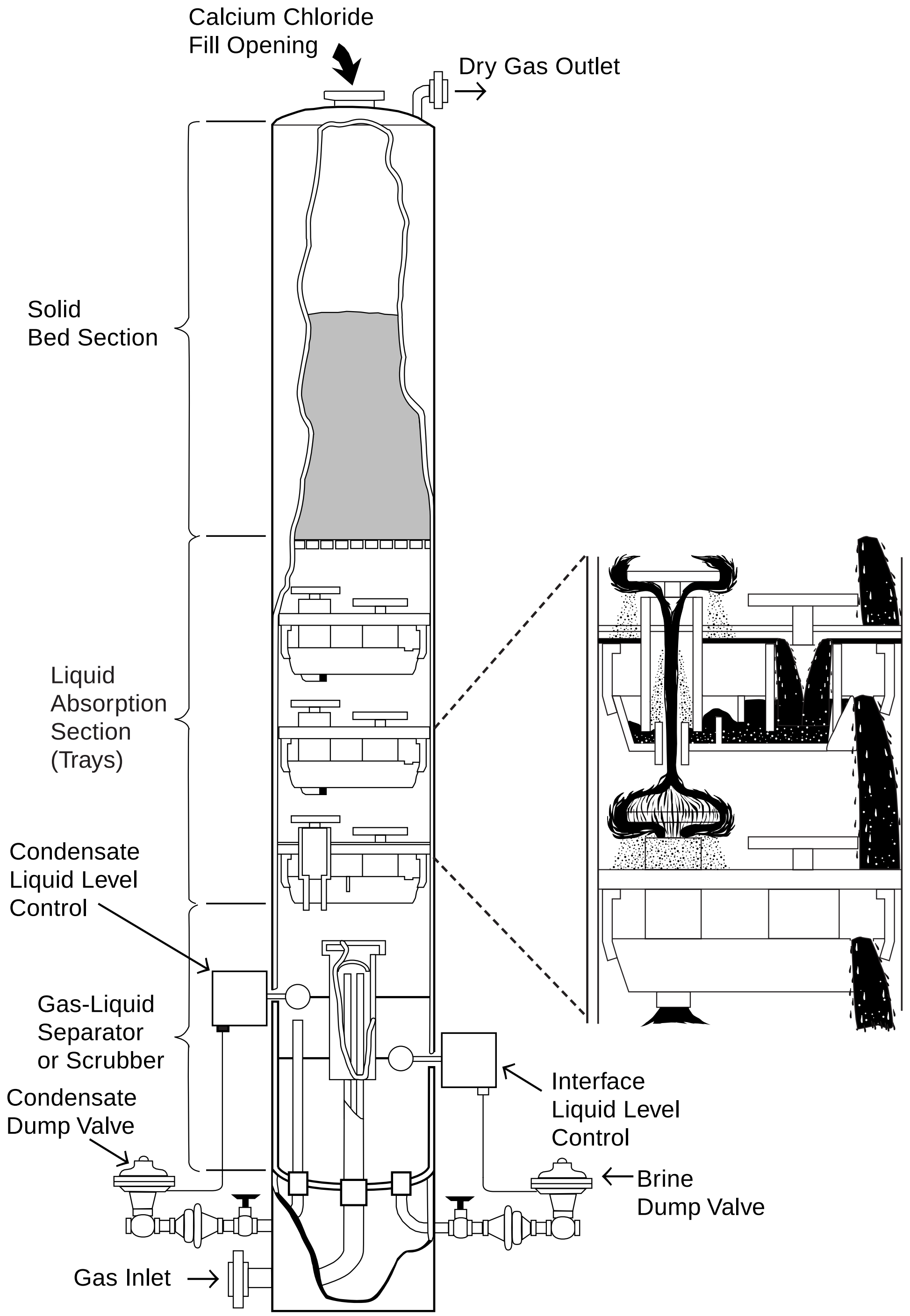
In this portion of the column, the concentrated brine dripping from the bed section absorbs water from the gas as it flows downward from tray to tray, countercurrent to the wet gas. Nozzles on each tray provide contact of the brine and gas in an intimate mixture. As the brine flows downward it is diluted continuously, and as the gas flows upward it is dehydrated. In a typical operation, approximately 70% of the water present in the gas is absorbed by the tray section and the brine is diluted to 20-25% calcium chloride. Brine leaving the tray section joins any free water that was present and is discharged from the column. The gas enters the bed section for final water removal.

C. Bed Section

PELADOW DG calcium chloride is a strong desiccant which consists primarily of anhydrous calcium chloride. In the solid state, calcium chloride in contact with water vapor forms four hydrates before being converted to a liquid solution. The concentrated brine that is formed still has much water-absorbing capacity, and this is the basis for operation of the tray section. When the gas leaving the top tray enters the bed section, it moves upward, first contacting brine on the briquette surfaces in the lower portion of the bed. As the gas moves upward through the bed section, it contacts successively drier and drier calcium chloride (lower hydrate states).

As the briquettes are consumed in the lower portion of the bed, the weight of the material above causes the bed to settle so that the bed level gradually diminishes as time progresses. Typically, the operation is continued until approximately two feet of briquettes remain in the bed. At this time, breakthrough (high outlet humidity) starts to occur, so the bed section is recharged with fresh anhydrous material.

Figure 3 – Calcium Chloride Dehydrator [8]



Using the approach described on page 10, up to 3.5 lb H_2O/lb calcium chloride can be absorbed. It is this high water-absorbing capacity, coupled with the lack of a requirement for regeneration equipment, that makes PELADOW DG calcium chloride so desirable for absorption of water from gas.

In some cases, however, it may be desirable to operate without trays. In this case, brine drips off the bed and is discharged without further contact with the entering gas. Then, approximately 1 lb H_2O/lb calcium chloride is removed. The precise $H_2O/CaCl_2$ ratio varies with the temperature of operation, since the brine dripping from the bed section is nearly saturated. Approximately the same outlet gas dew point or humidity will be achieved if the trays are not used. However, full utilization of the calcium chloride will not be realized when trays are not used.

2. Pressure Drop

For a unit containing both tray and bed sections, the normal pressure drop across the complete column is less than 8 psi.

3. Heat Effects

Under the normal temperatures (50-120°F) and pressures (300-3,000 psia) encountered, heat effects due to the heat evolved upon absorption of water vapor by calcium chloride are negligible. However, when a high temperature, low pressure gas is dehydrated, it may be desirable to check the heat effects.

4. Bridging and Channeling

A. Bridging

The fusion or joining together of adjacent calcium chloride briquettes is known as bridging. Under normal operation, as the chemical is consumed the bed settles to a lower level. However, when bridging occurs, the bed may adhere to the sides of the column and the chemical will be consumed from the bottom up. This condition causes an erroneous bed level to be indicated and can cause some difficulty in determining when a unit needs recharging.

Bridging can be caused for a variety of reasons, most of them related to cyclic operating conditions. The following reasons can contribute to bridging:

- *Decrease in the bed temperature.* A decrease in the bed temperature can cause freezing of the concentrated brine that is in contact with the calcium chloride particles. Adjacent pellets are then fused into a solid calcium chloride bridge.
- *Removing the dehydrator from service, leaving it idle; then placing it back in service.* This can cause bridging if there is a decrease in the bed temperature. Also, because water tends to diffuse from the saturated brine on the briquette surfaces into the briquettes, the brine tends to crystallize and bridge the adjacent pellets together.
- *Wet gas in contact with bed section.* A unit that is operating well below its rated capacity will allow a wetter gas to contact the bed section. This is due to poor brine/gas mixing on the trays, and the resulting inefficient dehydration. Then there will be more brine present on the briquettes in the bed section and, if an upset occurs, a worse case of bridging is likely to result. For this reason, dehydrators without brine trays are more prone to bridging problems than those that use trays.
- *Free water in the bed section.* If free water or dilute brine enters the bed section (by flooding because of too high a gas rate, for example), conditions are conducive to bridging. After the flooded condition is corrected, the bed will start to dry out and brine freezing on the briquettes can cause bridging.

In general, any condition that tends to dry the bed after it has been in a wetted condition can cause some degree of bridging. When bridging is observed, usually when the dehydrator is being recharged, the bed can be dropped by pouring water around the outer edge at the side of the vessel. Sometimes, manual assistance is required in dislodging the bed.

Fortunately, bridging by itself is not a serious problem. However, once a bed of calcium chloride is bridged, channeling can occur and this can affect dehydrator performance.

B. Channeling

Channeling usually takes place after bridging has occurred. In this case, the gas seeks the path of least resistance through the bed. Eventually a hole is developed through the bed due to the dissolution of the calcium chloride in this path.

When channeling occurs, breakthrough (poor dew point depression) starts prematurely and this is good evidence that channeling has taken place.

When channeling has occurred, the dehydrator must be opened and the bed section redistributed by a procedure similar to that used for bridging.

Fortunately, the unique size and shape of PELADOW DG calcium choride typically prevent bridging and the associated channeling, making it the ideal choice when this dehydration technique is used.

IV. Humidity Calculations

PELADOW DG is capable of drying natural gas under a wide variety of stream conditions to meet or exceed pipeline specifications. However, if calculating the humidity in dried gas is necessary, without going into the theoretical chemical calculations, the following equation can be used.

$$H = \frac{P_{CaCl_2} \times H_w}{P_{water}}$$

Where,

H = humidity of natural gas in equilibrium with $CaCl_2$ solution or hydrate
P_{CaCl_2} = vapor pressure of $CaCl_2$ solution or hydrate at system temperature
P_{water} = vapor pressure of pure water at system temperature
H_w = humidity of natural gas saturated with water

Using the above formula, under normal operating conditions, and data found on water-gas, and water-calcium chloride equilibrium found in the appendix, water levels in dried natural gas can be easily calculated. Several examples using this formula for determining water content follow.

Example calculations

(1) 50 percent brine is in equilibrium with natural gas at 100°F and 1000 psi. What is the water content of the natural gas?

$$H = \frac{p_{CaCl_2}}{p_{water}} H_w = \frac{0.21}{0.95} (60.4) = 13.3 \text{ lb } H_2O/\text{MMCF at 14.7 psia and } 60°F$$

(2) $CaCl_2 \cdot 2H_2O$ is in equilibrium with natural gas at 100°F and 1000 psia. What is the water content of the natural gas?

$$H = \frac{p_{CaCl_2}}{p_{water}} H_w = \frac{0.0455}{0.95} (60.4) = 2.89 \text{ lb } H_2O/\text{MMCF at 14.7 psia and } 60°F$$

Examples 1 and 2 illustrate the preferred method of calculating the humidity and dew point. The dew point achieved by a calcium chloride solution or hydrate is a function of pressure, so a plot of dew point versus contact temperature cannot be valid for all pressures. Table 3 compares the dew point achieved for the contact temperature of 100°F and for pressures of 14.7 and 1000 psia. For normal brine concentrations up to 50%, the dew point variation with pressure is small. However, the dew point variation is more pronounced as the concentration of the calcium chloride increases. If the dew point obtained at 14.7 psia were assumed constant and were used to calculate humidities at 1000 psia, significant errors could result. For instance, for calcium chloride dihydrate, an error in the humidity of approximately 45% would result and for a 50% brine, an error of approximately 6% would result.

For ease of use, the appendix contains water content of natural gas-calcium chloride solution/hydrate under a wide variety of temperature and pressure operating conditions.

Equilibrium water content of other gases, such as air, dried using PELADOW DG can also be calculated using the same formula outlined above.

Table 3 – Effect of Pressure Upon Dew Point

	Contact Temperature = 100°F Dew Point Achieved (°F)	
$CaAl_2$ Solution or Hydrate	**14.7 psia**	**1000 psia**
10% solution	98.4	98.4
20% solution	94.1	94.1
30% solution	84.8	84.4
40% solution	70.7	69.8
50% solution	53	51.2
$CaCl_2 \cdot 4H_2O$	41.2	38.3
$CaCl_2 \cdot 2H_2O$	14.5	9.3

V. Equipment Design and Evaluation

There are two types of equipment in use which may be defined according to the type of gas-$CaCl_2$ contacting employed.

- solid bed only
- solid bed + trays

In this section, design methods are shown for these two types. Only that portion of the total design needed for clarity is provided. Insulation and heating to prevent freeze-ups in cold weather, total column height determination, hardware details, etc., are not included. Persons requiring information of this nature are directed to the appropriate equipment manufacturer.

Two types of problems are of concern. The first is the design of a dehydrator for a given set of conditions, the second is the performance evaluation of an existing dehydrator.

1. Solid Bed Dehydrator

In a unit that employs a solid bed, the outlet humidity obtained will vary with time. Initially, a low humidity will be obtained. Over a period of several hours, the outlet humidity will rise to a nearly steady-state value which is maintained until the bed level drops to about two feet. Then breakthrough will occur and the unit must be charged with a new supply of PELADOW DG calcium chloride.

The maximum gas velocity in the bed section is limited by entrainment considerations. If the velocity is too high, entrainment may be excessive, and in extreme cases all brine that is formed may be carried overhead with the gas. Table 4, based upon entrainment considerations, gives the maximum allowable gas rates for the bed section of dehydrator columns.

The outlet humidity after steady-state has been reached may be determined by assuming that the gas is in equilibrium with $CaCl_2{\bullet}4H_2O$. This is a conservative rule-of-thumb that has been determined by lab experiments and also field experience. Figure 9 gives the humidity of natural gas in equilibrium with $CaCl_2{\bullet}4H_2O$. For temperatures above 113.5°F, the extrapolated values at 120, 130, and 140°F in Figure 9 may be used as a rough guide to the outlet humidities at these temperatures. This same outlet humidity will be achieved if there are trays below the bed section also.

Table 4 – Maximum Dehydrator Capacities in MMCF/D at 14.7 psia and 60°F

	Diameter (in.)		
Pressure (psia)	**20**	**24**	**30**
100	1.9	2.7	42.
250	3.0	4.3	6.6
500	4.2	6.0	9.4
750	5.1	7.4	11.5
1000	5.9	8.5	13.3
1200	6.5	9.4	14.5
1500	7.2	10.5	16.3
2000	8.3	12.1	18.8
2500	9.3	13.5	21.0
3000	10.2	14.8	23.0

For other diameters, $C = C_t \left(\frac{D}{D_t}\right)^2$,
where C = capacity, D = diameter, and the subscript "t" refers to an entry in the above table at the same pressure.

The following example illustrates the design procedure for a solid bed dehydrator.

Example 1

It is desired to dehydrate a natural gas stream saturated with water vapor.

Gas Rate: 4 MMSCF/D
Temperature: 80°F
Pressure: 1000 psia

Recharging PELADOW DG calcium chloride is desired no more frequently than every 15 days and a solid bed operation will be used. What diameter should the column be and what will the outlet humidity be?

Gas Humidity

Normally the inlet gas is assumed to be saturated with water. Sometimes, this is not the case and then the actual inlet humidity should be used.

Inlet - 33.6 lb H_2O/MMSCF from Table 6
Outlet - 4.2 lb H_2O/MMSCF from Figure 9

Water Removed

(33.5-4.2) lb H_2O/MMSCF x 4 MMSCF/D = 117.2 lb H_2O/day

Amount of PELADOW DG Required

Assume saturated brine at 80°F drips from the bed. From Figure 2, the brine contains about 1.1 lb H_2O/lb $CaCl_2$.

As stated in Section II, PELADOW DG contains a minimum of 91% $CaCl_2$.

$$\frac{117.2 \text{ lb } H_2O\text{/day x 15 days}}{(1.1 \text{ lb } H_2O\text{/lb } CaCl_2)\ (0.91 \text{ lb } CaCl_2\text{/lb PELADOW DG})} = 1756 \text{ lbs PELADOW DG}$$

Per Table 1, the bulk density is about 65 lb/ft^3, so 27 ft^3 of PELADOW DG will be required.

Column diameter and bed height

Assume 20" column: 2.182 ft^3/ft of height. The allowable gas rate from Table 4 is 5.9 MMSCF/day, so this is acceptable.

$$\text{Bed Height} = \frac{27 \text{ ft}^3}{2.182 \text{ ft}^3\text{/ft}} + 2 \text{ ft} = 14.4 \text{ ft}$$

The bed will be recharged when it reaches two-foot level.

2. Solid Bed + Tray Dehydrator

The outlet humidity from the dehydrator is still found from Figure 9 as in the solid bed unit. To determine the number of trays required, some graphical calculations must be made. A water material balance relating the amount of water in the gas leaving the column to the amount of water in two passing internal streams in the tray section results in the operating line equation.

$$X_n = \frac{V}{L} H_n{+1} - \frac{V}{L} H_o$$

In this equation

X_n = lb H_2O/lb $CaCl_2$ leaving the n^{th} tray

H_n+1 = lb H_2O/MMSCF leaving the n+1^{st} tray

L = $CaCl_2$ rate (lb/time) (anhydrous basis)

V = gas rate (MMSCF/time)

H_o = outlet gas humidity (lb H_2O/MMSCF)

The equilibrium line is calculated by methods introduced previously.

Table 5 – Equilibrium Line Calculation for Example 2

% $CaCl_2$	$\frac{(lb\ H_2O)}{lb\ CaCl_2}$	Temp. at which Solution has the Same Vapor Pressure as Water (°F)	$CaCl_2$ Solution Vapor Pressure (mm Hg)	Humidity ($H = (p^*/p^*_w)\ H_w$) (lb H_2O/MMSCF)
45	1.222	44	7.34	9.41
40	1.5	53	10.39	13.19
35	1.857	60	13.25	17.00
30	2.333	66	16.36	20.98
25	3	71	19.43	24.92
20	4	75	22.23	28.51

Humidity of Saturated Gas at 80°F, 1000 psia Hw = 33.6 lb H_2O/MMSCF
Vapor Pressure of Water at 80°F p^*_w = 26.22 mm Hg

Example 2

Determine the design of a dehydrator incorporating both trays and a bed section. The same conditions as in Example 1 will be used.

Gas Rate: 4 MMSCF/day
Temperature: 80°F
Pressure: 1000 psia

Gas Humidity

Inlet (H_i): 33.6 lb H_2O/MMSCF
Outlet (H_o): 4.2 lb H_2O/MMSCF

Water Removed

117.6 lb H_2O/day as before
Basis: 3.5 lb H_2O/lb $CaCl_2$

(This is the concentration of the brine leaving the last tray. It is specified by the designer.)

Tray Calculation

Figure 4 (on page 21) shows the method. The operating line is drawn connecting the outlet humidity (H_o) on the horizontal axis with X = 3.5 lb H_2O/lb $CaCl_2$ at the inlet humidity (H_i = 33.6 lb H_2O/MMSCF). The equilibrium line is calculated as shown in Table 5.

Figure 4 shows that six trays are required to do the dehydration job. Actually, five trays are not quite enough and six trays will more than do the job. This means the brine will be more dilute than 3.5 lb H_2O/lb $CaCl_2$.

Amount of PELADOW DG Required

As stated in Section II, PELADOW DG calcium chloride contains a minimum of 91 percent $CaCl_2$.

$$\frac{117.2 \text{ lb } H_2O/\text{day}}{(3.5 \text{ lb } H_2O/\text{lb } CaCl_2)\ (0.91 \text{ lb } CaCl_2/\text{lb PELADOW DG}} = 36.8 \text{ lb/day}$$

Bed Height

Assume 40-day recharge interval
Consumption of PELADOW DG in 40 days = 1472 lb
Volume of PELADOW DG = 1472 lb = 22.6 ft^3

The 24" diameter column has a volume of 3.142 ft^3/ft, so the height is

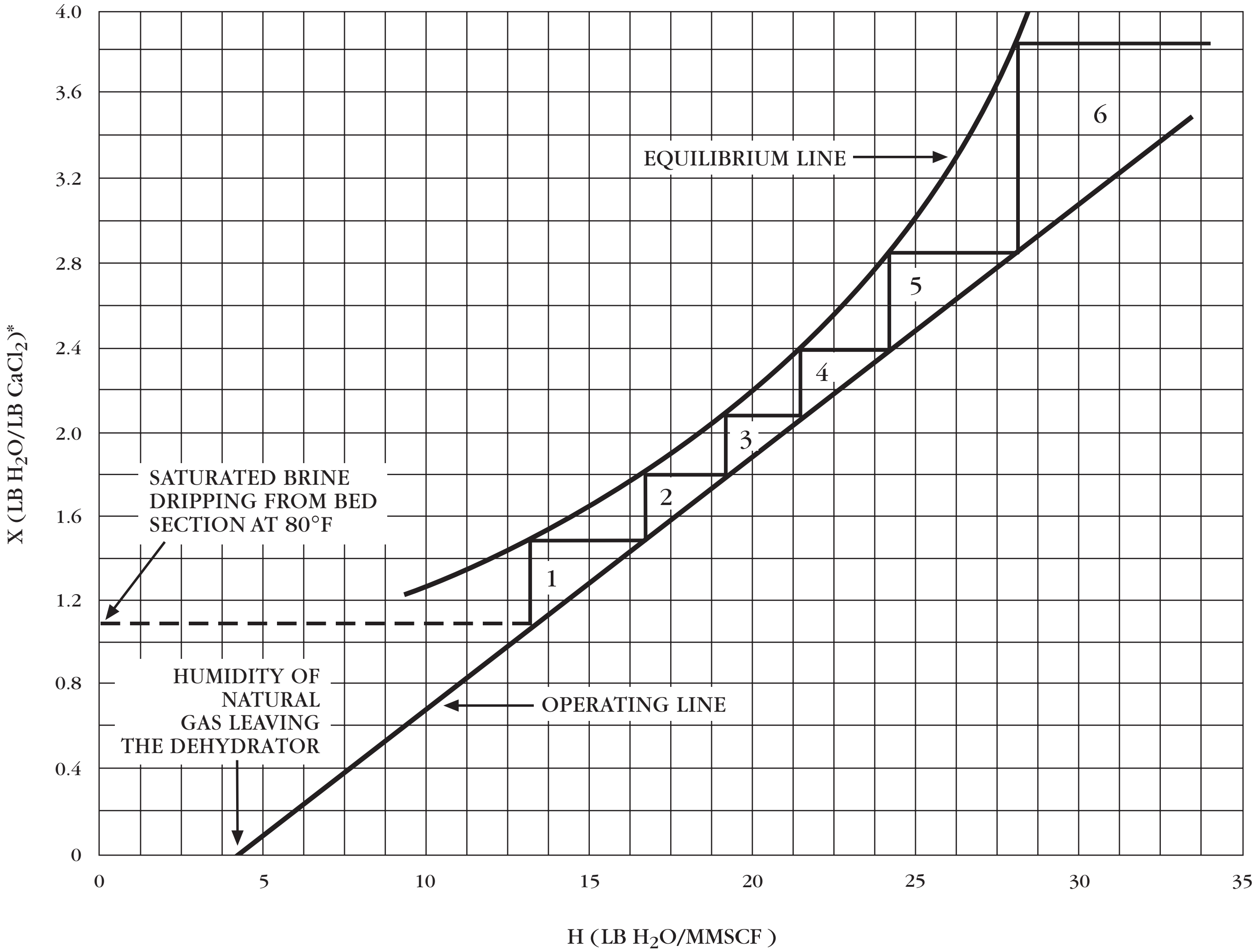
$$\frac{22.6 \text{ ft}^3}{3.142 \text{ ft}^3/\text{ft}} + 2 \text{ ft left at recharge} = 9.21 \text{ ft} \approx 9.25 \text{ ft}$$

Brine Volume Leaving Dehydrator

The brine concentration is 3.5 lb H_2O/lb $CaCl_2$ or 22.2 percent $CaCl_2$.
The density is 1.20 x 8.34 lb/gal = 10.0 lb/gal.

$$\frac{36.8 \text{ lb PELADOW DG/day} \times 0.91 \text{ lb } CaCl_2/\text{lb PELADOW DG}}{(0.222 \text{ lb } CaCl_2/\text{lb brine})\ (10 \text{ lb brine/gal})} = 15.1 \text{ gal/day}$$

Figure 4 – Tray Calculation Example 2



*NOTE THAT THIS IS LB H_2O/LB $CaCl_2$, NOT LB H_2O/LB PELADOW DG. PELADOW DG IS 91% $CaCl_2$ MINIMUM.

Example 2 illustrates the design procedure used when any number of trays can be put in to accomplish the desired job. If the number of trays is fixed as in a standard model, or if it is desired to evaluate the performance of an existing column, the procedure is somewhat different.

Now the method becomes a trial-and-error solution. First, an operating line is constructed assuming a certain concentration for the brine leaving the bottom tray. The number of trays is then found by calculation and if it is not the number in the existing column, then the procedure must be repeated.

VI. Safety Precautions

In general, PELADOW DG calcium chloride and its solutions present the same handling problems as other inorganic chlorides such as sodium chloride.

Contact of solid material with the eye is likely to produce irritation or injury. Effects may include conjunctival irritation with edema, as well as temporary corneal damage.

Single prolonged exposures of solid material to the skin may result in some reddening, while repeated prolonged contacts may cause appreciable irritation and possibly a mild burn.

In 5% and 10% solutions, calcium chloride has only a slight effect on intact skin. Prolonged contact may be expected to result in some slight irritation. Solutions stronger than 10% may, upon prolonged or repeated contact, cause slight to marked irritation, even a burn, depending upon the concentration.

Reasonable handling, care, and cleanliness, plus the use of safety goggles, should be sufficient to prevent injurious contact. Where gross skin contamination with solid or solutions does occur, the affected area should be washed thoroughly with copious quantities of flowing water and a physician summoned.

Considerable heat is released when anhydrous calcium chloride is dissolved in water. Personnel dissolving PELADOW DG or washing out equipment should be careful not to come into contact with any hot solution formed during these operations. Some splashing can occur.

VII. Disposal of Solutions

When disposing of calcium chloride solutions, care should be taken to prevent large amounts of brine from entering drinking water supplies, or being spread onto plants and shrubbery. Solutions should be disposed of in areas where a buildup of salt concentration will not be objectionable and where allowed by federal, state, and local regulations. When the product being dried constitutes a disposal hazard, disposal of brine used to dry that material should be consistent with disposal procedures for the hazardous product itself.

VIII. Bibliography

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IX. Appendix

Table 6 – Equilibrium Moisture Content of Natural Gases Above the Critical Temperature [2]

Pounds per MMSCF (14.7 psia, 60°F)

°F	14.7	100	200	300	400	500	600	700	800	900	1000
-40	9.1	1.5	0.88	0.66	0.55	0.49	0.44	0.41	0.39	0.37	0.36
-38	10.2	1.7	0.98	0.73	0.61	0.54	0.49	0.45	0.43	0.41	0.39
-36	11.5	1.9	1.1	0.80	0.63	0.59	0.54	0.50	0.47	0.45	0.43
-34	12.8	2.1	1.2	0.90	0.74	0.65	0.59	0.55	0.51	0.49	0.47
-32	14.4	2.4	1.3	0.99	0.82	0.72	0.65	0.60	0.57	0.54	0.51
-30	16.0	2.6	1.5	1.1	0.91	0.79	0.72	0.66	0.62	0.59	0.56
-28	17.8	2.9	1.6	1.2	1.0	0.87	0.79	0.72	0.68	0.64	0.61
-26	19.8	3.2	1.8	1.3	1.1	0.96	0.86	0.79	0.74	0.70	0.67
-24	22.0	3.6	2.0	1.5	1.2	1.1	0.95	0.87	0.81	0.77	0.73
-22	24.4	4.0	2.2	1.6	1.3	1.2	1.0	0.95	0.89	0.84	0.80
-20	27.0	4.4	2.4	1.8	1.5	1.3	1.1	1.0	0.97	0.92	0.87
-18	30.0	4.9	2.7	2.0	1.6	1.4	1.2	1.1	1.1	1.0	0.95
-16	33.1	5.4	3.0	2.2	1.8	1.5	1.4	1.2	1.2	1.1	1.1
-14	36.7	5.9	3.3	2.4	1.9	1.7	1.5	1.4	1.3	1.2	1.1
-12	40.5	6.5	3.6	2.6	2.1	1.8	1.6	1.5	1.4	1.3	1.2
-10	44.8	7.2	4.0	2.9	2.3	2.0	1.8	1.6	1.5	1.4	1.3
-8	49.3	7.9	4.3	3.1	2.5	2.2	1.9	1.8	1.6	1.5	1.5
-6	54.6	8.7	4.7	3.4	2.8	2.4	2.1	1.9	1.8	1.7	1.6
-4	59.8	9.5	5.2	3.7	3.0	2.6	2.3	2.1	1.9	1.8	1.7
-2	65.7	10.4	5.7	4.1	3.3	2.8	2.5	2.3	2.1	2.0	1.9
0	72.1	11.4	6.2	4.5	3.6	3.1	2.7	2.5	2.3	2.1	2.0
2	79.1	12.5	6.8	4.9	3.9	3.3	3.0	2.7	2.5	2.3	2.2
4	86.8	13.7	7.4	5.3	4.3	3.6	3.2	2.9	2.7	2.5	2.4
6	95.1	15.0	8.1	5.8	4.6	4.0	3.5	3.2	2.9	2.7	2.6
8	104	16.4	8.8	6.3	5.1	4.3	3.8	3.4	3.2	3.0	2.8
10	114	17.9	9.6	6.9	5.5	4.7	4.1	3.7	3.4	3.2	3.0
12	124	19.5	10.5	7.5	6.0	5.1	4.5	4.0	3.7	3.5	3.3
14	136	21.3	11.4	8.1	6.5	5.5	4.8	4.5	4.0	3.7	3.5
16	148	23.2	12.4	8.8	7.0	5.9	5.2	4.7	4.3	4.0	3.8
18	161	25.2	13.5	9.6	7.6	6.4	5.7	5.1	4.7	4.4	4.1
20	176	27.4	14.6	10.4	8.2	7.0	6.1	5.5	5.1	4.7	4.4
22	192	29.8	15.9	11.3	8.9	7.5	6.6	5.9	5.5	5.1	4.7
24	208	32.4	17.2	12.2	9.7	8.2	7.2	6.4	5.9	5.5	5.1
26	226	35.1	18.7	13.2	10.5	8.8	7.7	6.9	6.3	5.9	5.5
28	246	38.1	20.2	14.3	11.3	9.5	8.3	7.5	6.8	6.3	5.9
30	276	41.3	21.9	15.4	12.2	10.3	9.0	8.0	7.4	6.8	6.4
32	289	44.7	23.7	16.7	13.2	11.1	9.7	8.7	7.9	7.3	6.9
34	313	48.4	25.6	18.0	14.2	11.9	10.4	9.3	8.5	7.9	7.4
36	339	52.4	27.7	19.4	15.3	12.9	11.2	10.0	9.2	8.5	7.9
38	367	56.6	29.9	20.1	16.5	13.9	12.1	10.8	9.8	9.1	8.5
40	396	61.1	32.2	22.6	17.8	14.9	13.0	11.6	10.6	9.8	9.1
42	428	66.0	34.8	24.4	19.2	16.0	13.9	12.5	11.3	10.5	9.8
44	462	71.2	37.5	26.2	20.6	17.2	15.0	13.4	12.2	11.2	10.5
46	499	76.7	40.3	28.2	22.2	18.5	16.1	14.4	13.1	12.0	11.2
48	538	82.6	43.4	30.3	23.8	19.9	17.3	15.4	14.0	12.9	12.0
50	580	89.0	46.7	32.6	25.6	21.3	18.5	16.5	15.0	13.8	12.9
52	624	95.7	50.2	35.0	27.4	22.9	19.8	17.7	16.1	14.8	13.8
54	672	103	54.0	37.6	29.4	24.5	21.3	18.9	17.2	15.8	14.7
56	721	111	57.9	40.3	31.5	36.7	22.8	20.3	18.3	16.9	15.7
58	776	119	62.1	43.2	33.8	28.1	24.4	21.7	19.6	18.0	16.8
60	834	128	66.6	46.3	36.2	30.1	26.1	23.2	21.0	19.3	17.9
62	895	137	71.4	49.6	38.7	32.2	27.9	24.7	22.4	20.6	19.1
64	960	147	76.5	53.1	41.4	34.4	29.8	26.4	23.9	22.0	20.4
66	1030	157	81.8	56.8	44.3	36.8	31.8	28.2	25.5	23.4	21.8
68	1100	168	87.6	60.7	47.3	39.3	33.9	30.1	27.2	25.0	23.2
70	1180	180	93.7	65.0	50.6	42.0	36.2	32.1	29.0	26.6	24.7
72	1260	192	100	63.4	54.0	44.8	38.6	34.2	30.9	28.4	26.3
74	1350	206	107	74.0	57.6	47.7	41.1	36.4	32.9	30.2	28.0
76	1440	220	114	79.0	61.4	50.9	43.8	38.8	35.0	32.1	29.8
78	1540	235	122	84.2	65.5	54.2	46.7	41.3	37.3	34.2	31.7
80	1650	250	130	89.8	69.7	57.7	49.7	44.0	39.7	36.3	33.6
82	1760	267	138	95.6	74.2	61.4	52.8	46.7	42.1	38.6	35.7
84	1870	285	148	102	79.0	65.3	56.2	49.7	44.8	41.0	37.9
86	2000	303	157	108	84.1	69.5	59.7	52.8	47.6	43.5	40.3
88	2130	323	167	115	89.4	73.8	63.5	56.1	50.5	46.2	42.7
90	2270	344	178	123	95.0	78.5	67.4	59.5	53.6	49.0	45.3
92	2410	366	189	130	101	83.3	71.5	63.1	56.8	51.9	47.8
94	2570	389	201	138	107	86.4	75.9	67.0	60.3	55.0	50.6
96	2730	413	214	147	114	93.8	80.5	71.0	63.9	58.3	53.9
98	2900	439	227	156	121	99.5	85.3	75.2	67.6	61.8	57.0

Table 6 – Equilibrium Moisture Content of Natural Gases Above the Critical Temperature (Continued)

Pounds per MMSCF (14.7 psia, 60°F)

°F	14.7	100	200	300	400	500	600	700	800	900	1000	1500	2000	2500	3000	3500	4000	4500	5000
100	3080	466	241	166	128	105	90.4	79.7	71.6	65.4	60.4	45.4	37.9	33.3	30.3	28.2	26.6	25.3	24.3
102	3270	495	256	176	136	112	95.8	84.4	75.9	69.2	63.9	74.9	40.0	35.5	32.0	29.7	28.0	26.6	25.6
104	3470	525	271	186	144	118	101	89.3	80.2	73.1	67.5	50.6	42.1	37.0	33.6	31.2	29.4	28.0	26.9
106	3680	557	287	197	152	125	107	94.5	84.9	77.4	71.4	53.4	44.5	39.1	35.5	32.9	31.0	29.5	28.3
108	3900	589	304	209	161	133	114	99.9	89.7	81.7	75.4	56.4	46.9	41.1	37.3	34.6	32.6	31.0	29.7
110	4130	624	322	221	170	140	120	106	94.7	86.3	79.6	59.4	49.4	43.3	39.3	36.4	34.2	32.5	31.2
112	4380	661	341	234	180	148	127	112	100	91.2	84.1	62.7	52.1	45.6	41.4	38.3	36.0	34.2	32.8
114	4640	700	360	247	191	157	134	118	106	96.2	88.7	66.1	54.8	48.0	43.4	40.2	37.8	35.9	34.4
116	4910	740	381	261	201	165	142	124	112	102	93.6	69.7	57.7	50.5	45.7	42.3	39.8	37.8	36.2
118	5190	783	403	276	213	175	149	131	118	107	98.7	73.4	60.7	53.1	48.0	44.4	41.7	39.6	37.9
120	5490	828	426	292	225	185	158	139	124	113	104	77.3	63.9	55.9	50.5	46.7	43.8	41.6	39.8
122	5800	874	449	308	237	195	166	146	131	119	110	81.3	67.2	58.7	53.0	49.0	45.9	43.6	41.7
124	6130	923	474	325	250	205	175	154	138	125	116	85.6	70.7	61.7	55.7	51.4	48.2	45.7	43.7
126	6470	974	500	343	264	216	185	162	145	132	122	89.9	74.2	64.7	58.4	53.9	50.5	47.8	45.7
128	6830	1030	528	361	278	228	195	171	153	139	128	94.7	78.0	68.0	61.3	56.6	53.0	50.2	48.0
130	7240	1090	559	382	294	241	206	181	162	147	135	99.8	82.1	71.5	64.4	59.4	55.6	52.6	50.3
132	7580	1140	585	400	308	252	215	189	169	154	141	104	85.8	74.7	67.3	62.0	58.1	55.0	52.5
134	7990	1200	617	422	324	266	227	199	178	162	149	110	90.1	78.4	70.6	65.0	60.9	57.6	55.0
136	8470	1270	653	446	343	281	240	210	188	171	157	116	94.9	82.5	74.2	68.3	63.9	60.3	57.7
138	8880	1330	684	468	359	294	251	220	197	179	164	121	99.2	86.2	77.5	71.3	66.7	63.1	60.2
140	9360	1410	721	492	378	310	264	231	207	188	173	127	104	90.4	81.3	74.7	69.9	66.0	63.0
142	9830	1480	757	517	397	325	277	243	217	197	181	133	109	94.6	85.0	78.1	73.0	69.0	65.8
144	10400	1560	799	545	419	343	292	256	229	207	191	140	115	99.3	89.2	81.9	76.5	72.3	68.9
146	10900	1640	840	573	440	360	307	269	240	218	200	147	120	104	93.0	85.7	80.0	75.6	72.0
148	11500	1720	882	602	462	378	322	282	252	229	210	154	126	109	97.6	89.6	83.6	78.9	75.6
150	12100	1810	928	633	486	397	338	296	264	240	220	161	132	114	102	93.8	87.5	82.5	78.6
152	12700	1910	975	665	510	417	355	311	277	252	231	169	138	119	107	98.0	91.4	86.2	82.1
154	13300	2000	1020	697	534	437	372	325	290	263	242	177	144	125	112	102	95.4	89.9	85.6
156	14000	2100	1070	732	561	458	390	341	305	276	253	185	151	130	117	107	100	94.0	89.4
158	14700	2200	1130	767	588	480	409	357	319	289	265	194	158	136	122	112	104	98.0	93.2
160	15400	2300	1180	802	615	502	427	374	333	302	277	202	165	142	127	116	108	102	97.1
162		2410	1230	841	644	526	447	391	349	316	290	211	172	149	133	122	113	107	101
164		2540	1300	883	676	552	459	410	366	332	304	221	180	155	139	127	118	111	106
166		2650	1350	922	706	570	490	428	382	346	317	231	188	162	145	132	123	116	110
168		2780	1420	967	740	604	514	449	400	363	332	242	196	169	151	138	128	121	115
170		2910	1490	1010	775	633	538	470	419	379	348	253	205	177	158	144	134	126	120
172		3040	1550	1050	810	661	562	491	437	396	363	263	214	184	164	150	139	131	124
174		3190	1630	1110	847	691	587	513	457	414	379	275	223	192	171	156	145	136	130
176		3330	1700	1160	885	722	613	535	477	432	396	287	233	200	178	163	151	142	135
178		3480	1780	1210	925	754	640	559	498	451	413	299	243	208	186	169	157	148	140
180		3640	1860	1260	967	789	670	585	521	471	432	313	253	217	194	177	164	154	146
182		3800	1940	1320	1010	821	697	609	542	491	449	325	263	226	201	184	170	160	152
184		3980	2030	1380	1060	860	730	637	567	513	470	340	275	236	210	191	177	167	158
186		4150	2120	1440	1100	897	761	664	591	535	490	354	287	245	218	199	184	173	164
188		4340	2210	1500	1150	936	794	693	617	558	511	369	298	256	227	207	192	180	171
190		4520	2300	1570	1200	974	827	721	642	581	531	384	310	266	236	215	199	187	177
192		4720	2410	1630	1250	1020	863	753	670	606	554	400	323	277	246	224	207	194	184
194		4920	2510	1700	1300	1060	900	785	698	631	578	417	336	288	256	233	215	202	191
196		5140	2620	1780	1360	1110	938	818	728	658	602	434	350	299	266	242	224	210	199
198		5350	2730	1850	1410	1150	976	851	757	684	626	451	364	311	276	251	232	218	206
200		5570	2840	1930	1470	1200	1020	885	788	712	651	469	378	323	286	260	241	226	213
202		5810	2960	2010	1530	1250	1060	922	821	741	678	488	393	336	298	271	251	235	222
204		6050	3080	2090	1600	1300	1100	960	854	771	705	507	408	349	309	281	260	243	230
206		6310	3210	2180	1660	1350	1150	999	889	803	734	528	423	363	321	292	270	253	238
208			3340	2270	1730	1400	1190	1040	924	835	763	548	441	377	334	303	280	262	248
210			3480	2360	1800	1460	1240	1080	961	858	793	569	458	390	346	314	290	271	256
212			3620	2450	1870	1520	1290	1120	999	902	824	591	475	405	359	325	301	281	266
214			3760	2550	1950	1580	1340	1160	1040	937	856	614	493	420	372	337	312	291	275
216			3910	2650	2020	1640	1390	1210	1080	973	889	637	512	436	386	350	323	302	285
218			4060	2760	2100	1710	1450	1260	1120	1010	924	662	532	453	401	363	335	313	296
220			4220	2860	2180	1780	1500	1310	1160	1050	959	687	551	469	415	376	347	324	306
222			4390	2980	2270	1840	1560	1360	1200	1090	996	713	572	487	431	390	360	336	318
224			4560	3090	2350	1910	1520	1410	1250	1130	1030	739	593	504	446	404	372	348	328
226			4730	3200	2440	1990	1680	1460	1300	1170	1070	767	615	523	462	418	386	360	340
228			4910	3330	2540	2060	1750	1520	1350	1220	1110	795	637	542	479	433	400	373	352
230			5100	3460	2630	2140	1810	1580	1400	1260	1150	824	660	561	495	448	413	385	363
240				4160	3170	2570	2180	1890	1680	1510	1380	985	787	658	589	532	490	456	430
250					3770	3060	2590	2250	2000	1800	1640	1170	932	790	695	628	577	538	506

Figure 5 – Dühring Plot For $CaCl_2$ Solutions [1, 3]

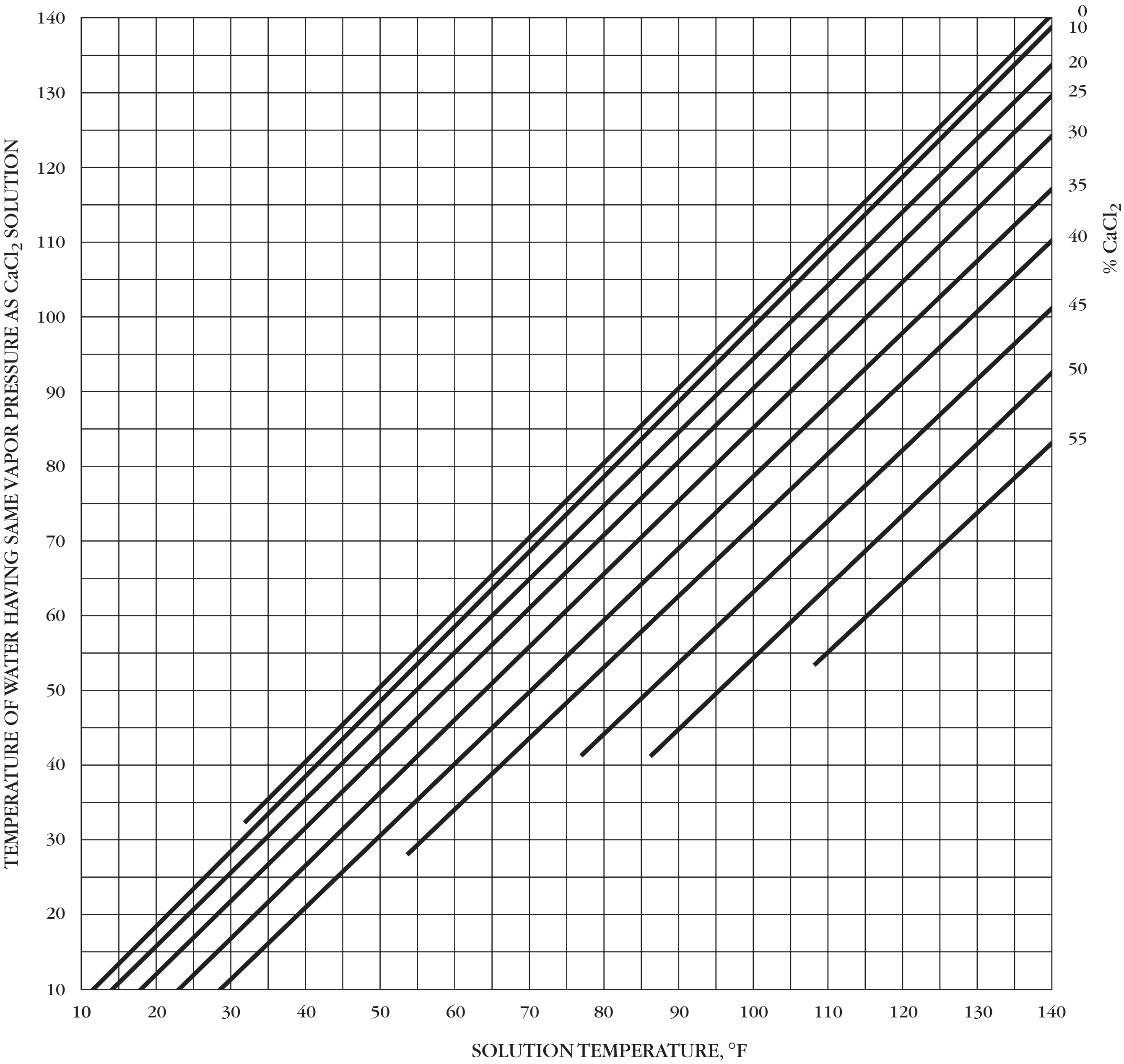


Figure 6 – Vapor Pressures of $CaCl_2$ Hydrates [3, 7, 9]

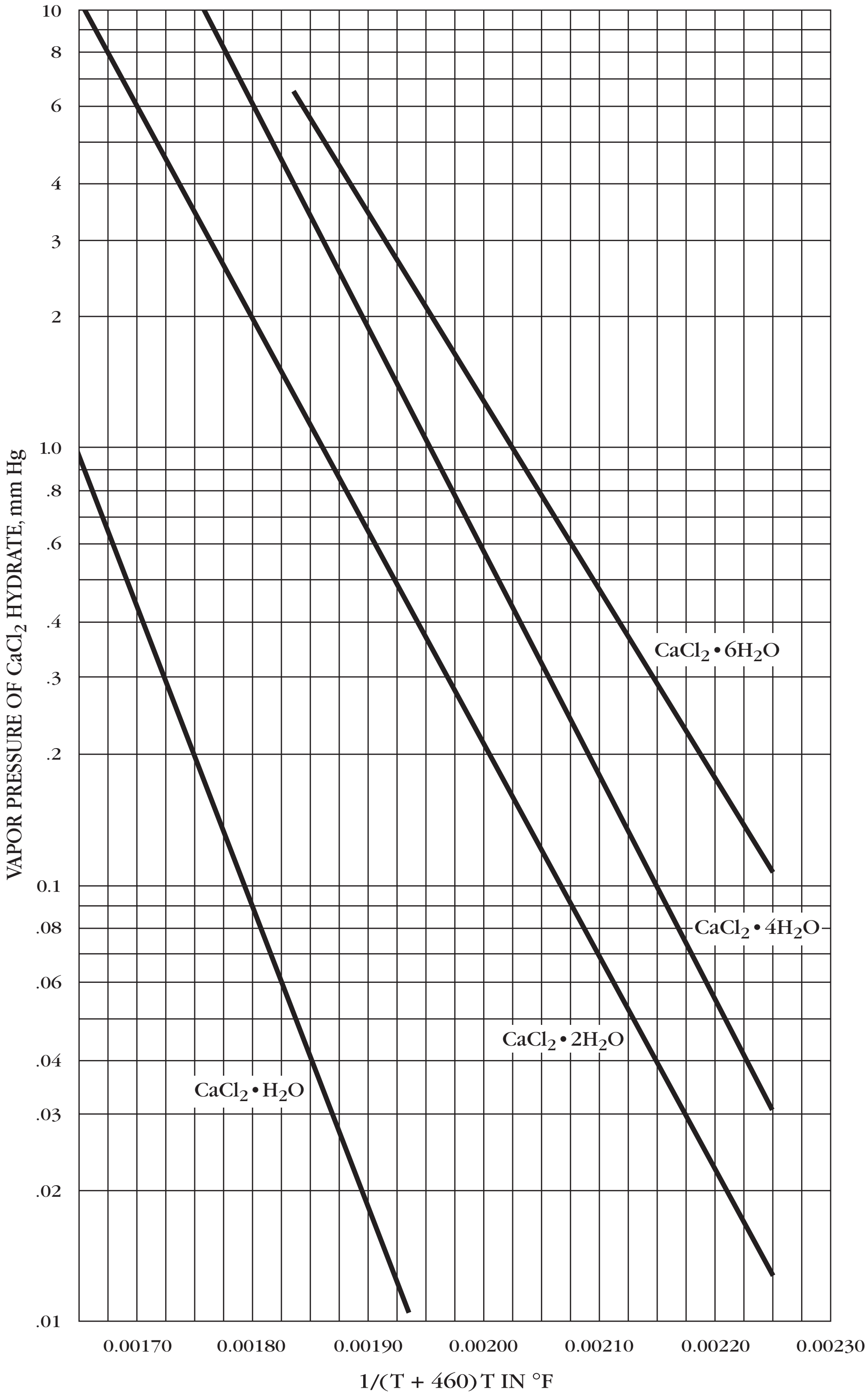


Figure 7 – Water Content of Natural Gas in Equilibrium with $CaCl_2 \cdot H_2O$

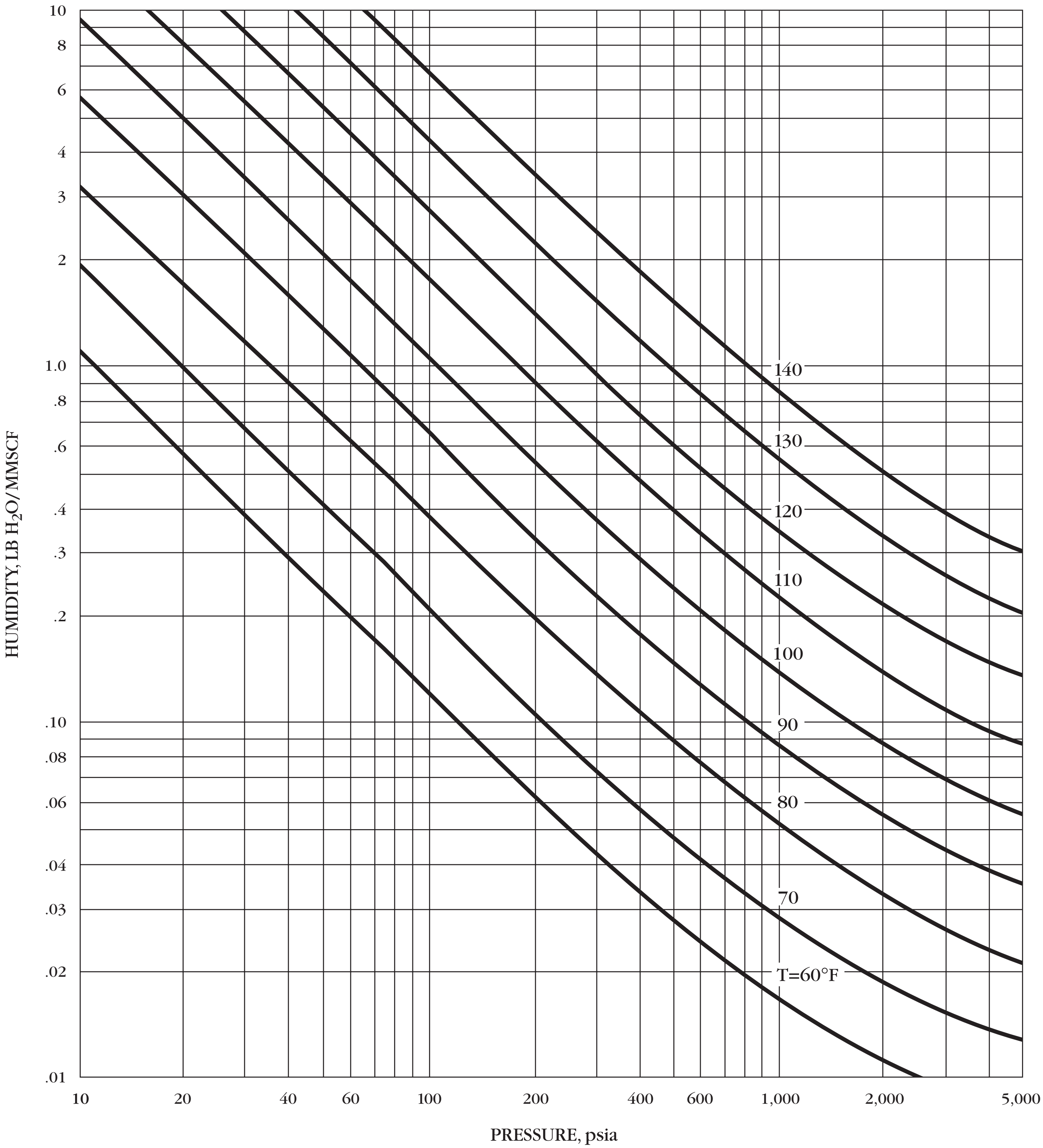


Figure 8 – Water Content of Natural Gas in Equilibrium with $CaCl_2 \cdot 2H_2O$

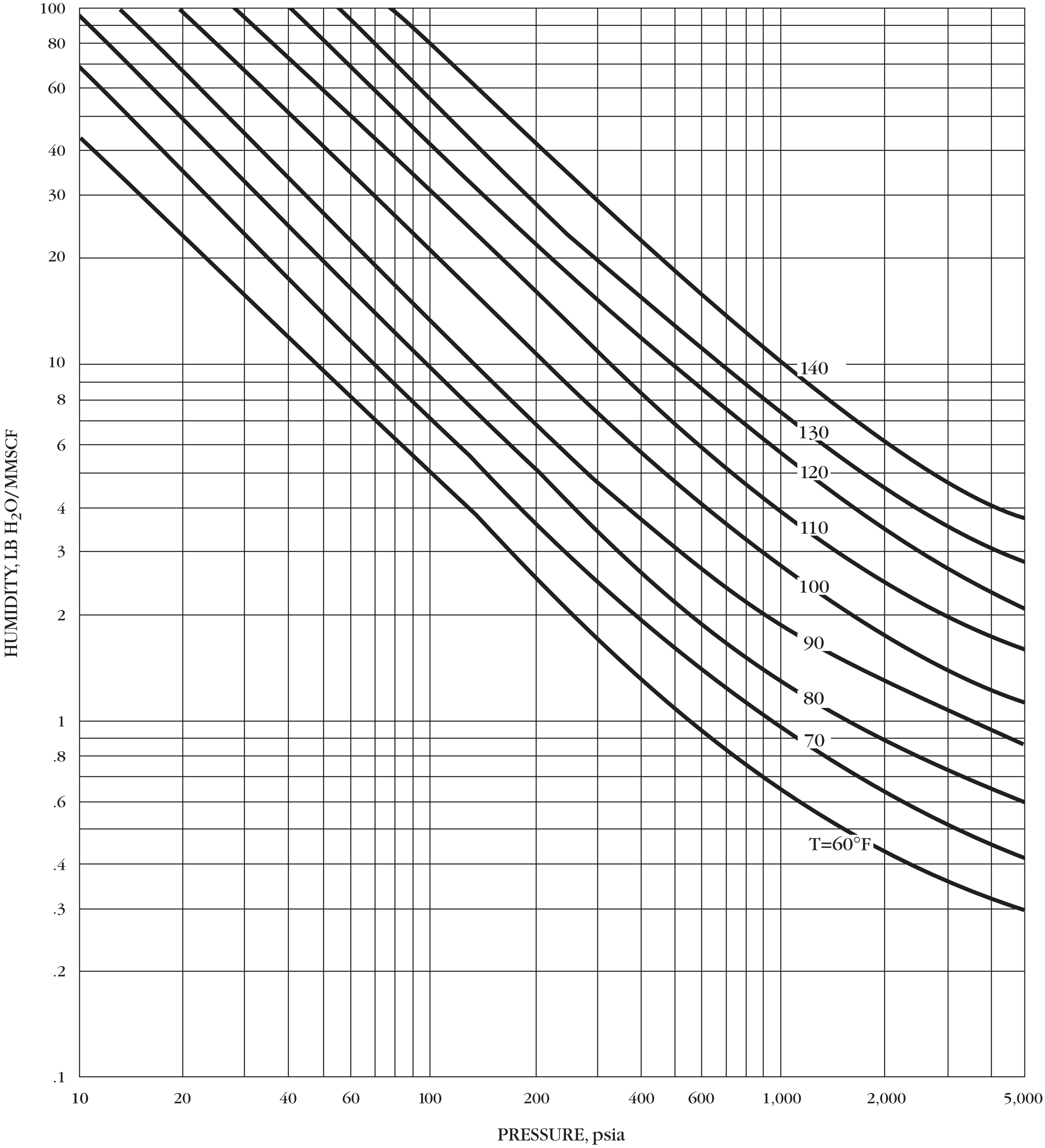


Figure 9 – Water Content of Natural Gas in Equilibrium with $CaCl_2 \cdot 4H_2O$

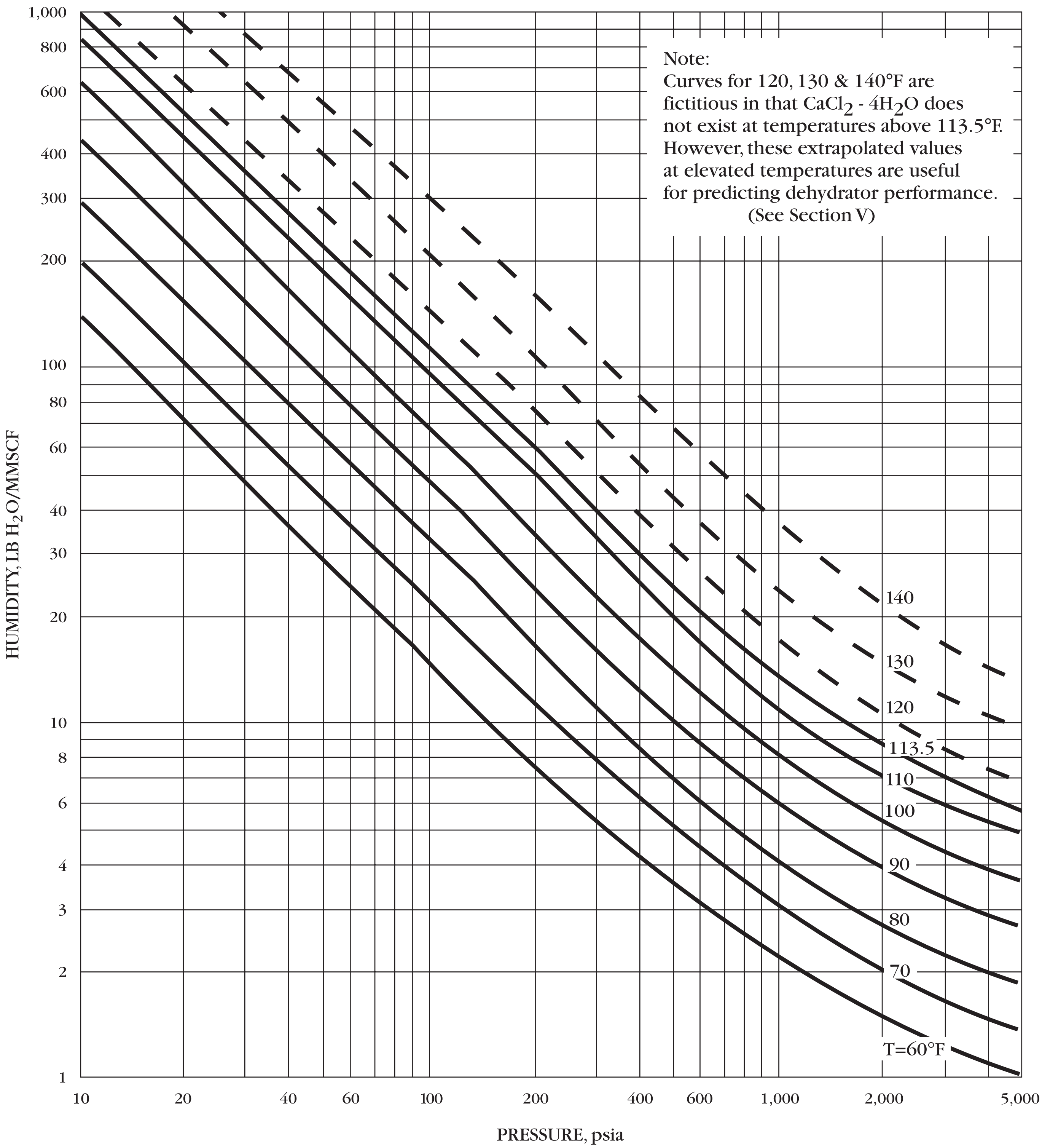


Figure 10 – Water Content of Natural Gas in Equilibrium with $CaCl_2 \cdot 6H_2O$

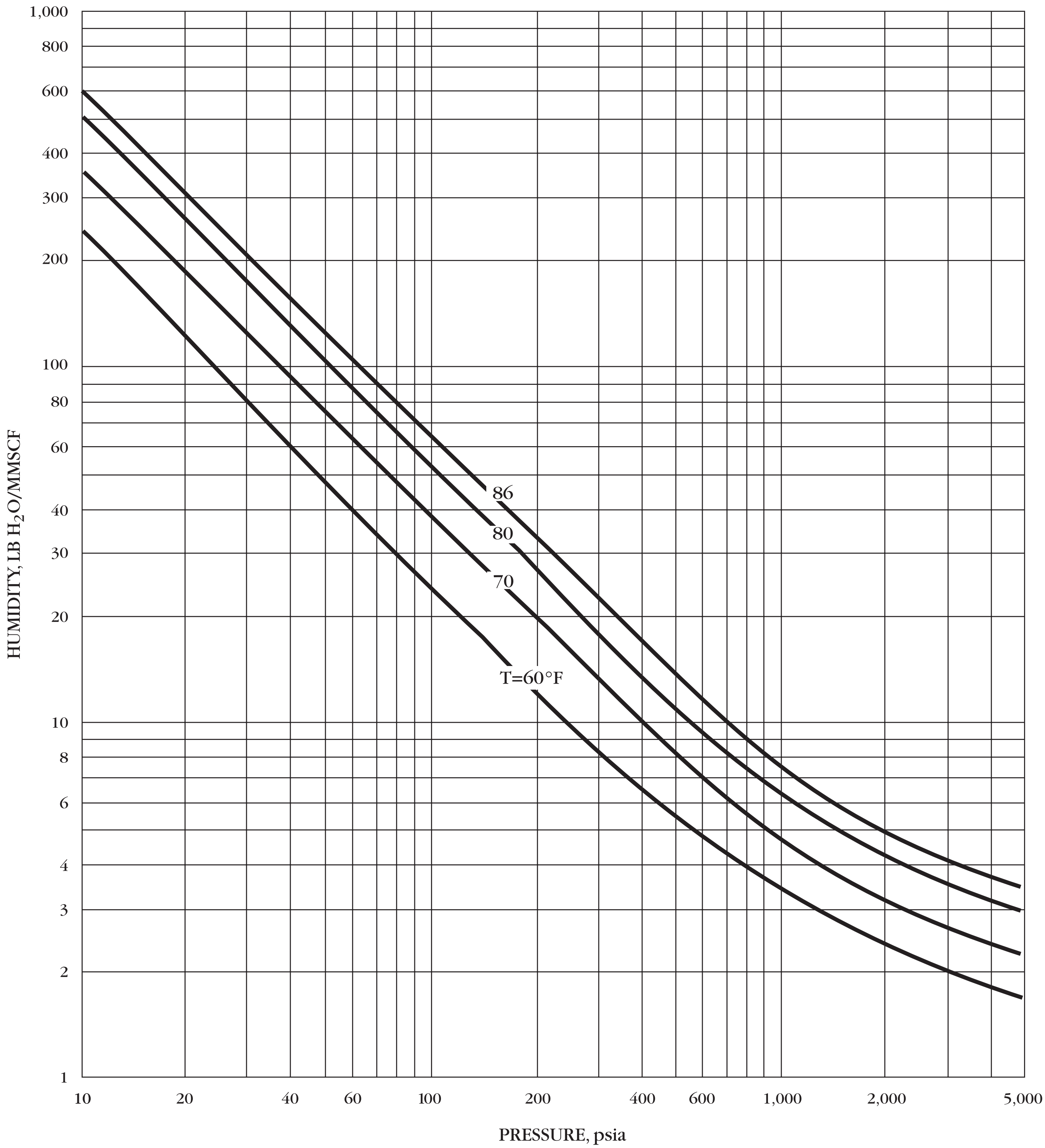
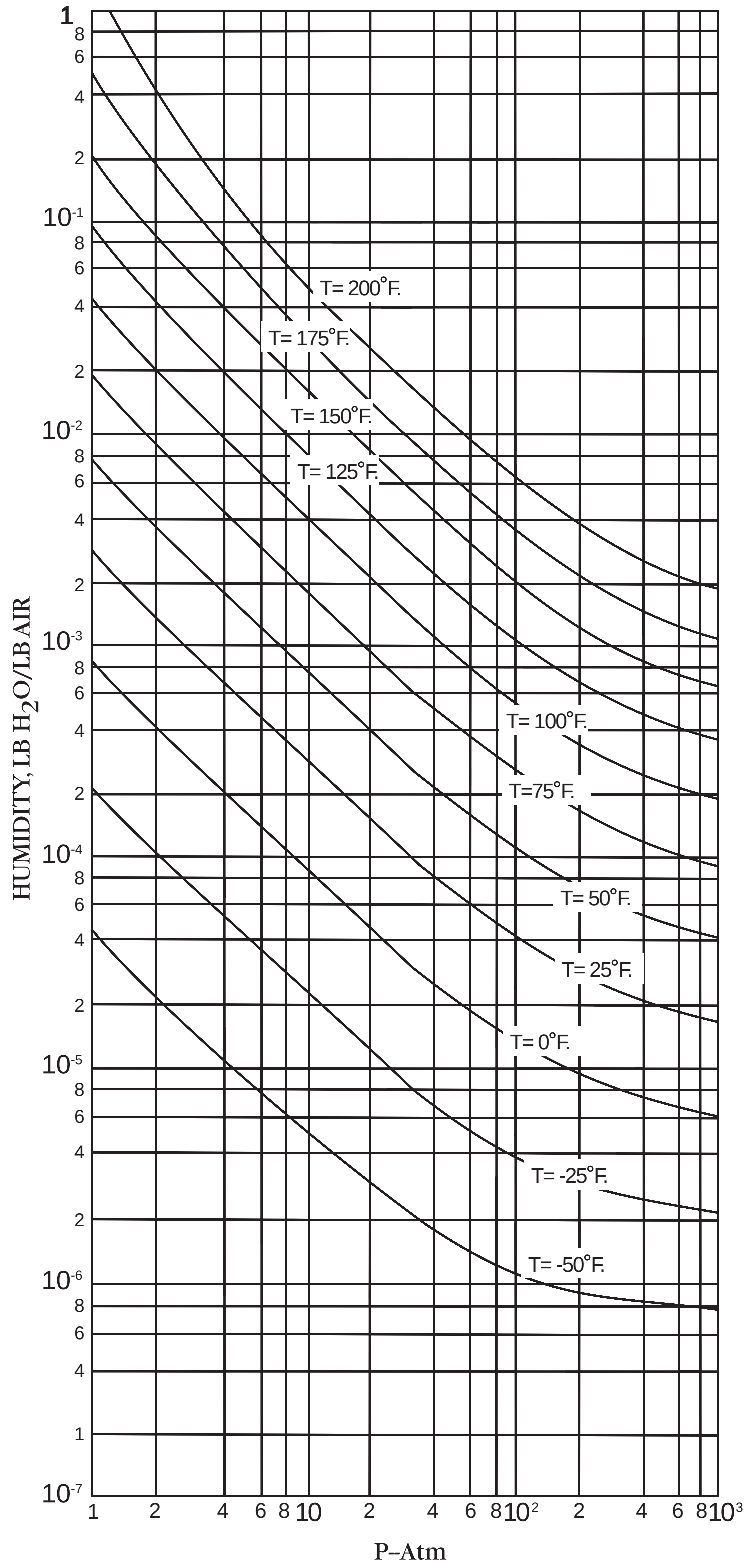


Figure 11 – Water Content of Saturated Air [6]



The Next Step

As you can see, gas dehydration with PELADOW DG calcium chloride offers many advantages under the right conditions. Determining whether a system using PELADOW DG is a good solution for you is easy, too. Just call 1-800-447-4369 and we'll put you in touch with a dehydration specialist.

For more information call
1-800-447-4369
In Canada, call
1-800-363-6250

Published May 1998.

Printed in U.S.A. Form No. 173-01611-598AMS
McKAY144339