



CALCIUM CHLORIDE HANDBOOK

**A Guide to Properties, Forms,
Storage and Handling**

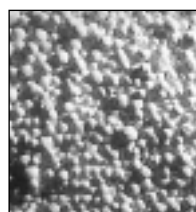
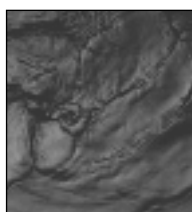


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The Responsible Care® Commitment

Dow is committed to the safe and responsible use of its products. Because of this commitment, Dow has adopted the Guiding Principles of the Responsible Care initiative.

Dow is well positioned to endorse the Responsible Care initiative because several programs have already been implemented toward the responsible management of the chemicals Dow sells. Dow's calcium chloride products and its related environmental stewardship program is one of

those initiatives. The stewardship program for calcium chloride is a comprehensive program of safety literature and materials, regulatory and environmental information and other stewardship resources available to all Dow customers. It is designed to provide all users of Dow calcium chloride with materials they may need to use, and dispose of calcium chloride in a safe and responsible manner.

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Calcium chloride is one of the most versatile of the basic chemicals. It has been produced commercially for well over 100 years. The properties and characteristics of calcium chloride make it useful in a large number of applications.

This handbook details the significant properties of calcium chloride in its pure form and in the specific commercial forms available from Dow. The properties of pure calcium chloride are generally very similar to those of commercial products since they contain only a small percentage of other substances.

This handbook gives instructions on dissolving solid forms of calcium

chloride and diluting and concentrating liquid forms. It discusses equipment, materials of construction and methods of handling and storing calcium chloride. Finally, it gives important precautions to be observed in the interest of safety and environmental protection.

Recognizing that no handbook can possibly cover every question, we welcome questions related to the use of this highly versatile chemical. Call or write The Dow Chemical Company, Customer Information Center, 690 Building, Midland, Michigan 48674. Phone 1-800-447-4369.

Calcium Chloride Products available from Dow

The Dow Chemical Company markets calcium chloride under the trademarks LIQUIDOW*, DOWFLAKE* and PELADOW*. LIQUIDOW calcium chloride is a solution. DOWFLAKE and PELADOW calcium chloride are both solid forms. DOWFLAKE calcium chloride is sold as a 77–80% calcium chloride flake while PELADOW calcium chloride is available as a 90% pellet and a 91–92% briquette. Complete product specifications are available through your Dow sales representative or through our Customer Information Group at 800-447-4369. The following is a brief description of each product.

LIQUIDOW

LIQUIDOW calcium chloride is manufactured in concentrations of 28% to 42% and 45% and is also available in a Food Grade formulation (32% calcium chloride). LIQUIDOW food grade calcium chloride meets or exceeds Food Chemicals Codex (FCC IV) monograph for calcium chloride solution and complies with FDA Good Manufacturing Practice Guidelines. It also meets American Water Works Association (AWWA) Standard B-550 and is Kosher certified.

During colder seasons — late fall through early spring — it is important to ship high concentration solutions in insulated trucks to avoid crystallization. Weaker solutions (less than 32–35%) can be shipped in regular trucks.

Table 1 shows approximate volume-weight relationships between LIQUIDOW, DOWFLAKE and PELADOW (90% and 94–97%) products, and approximate freezing points for calcium chloride solutions. LIQUIDOW calcium chloride meets ASTM D 98 classification “Type L.”

DOWFLAKE

DOWFLAKE calcium chloride is manufactured in flake form. The product contains approximately 78% calcium chloride and about 17% water from crystallization. This form of calcium chloride is also known as the “dihydrate.”

DOWFLAKE 77–80% calcium chloride meets ASTM D 98 classification as “Type S, Grade 1, Class A.” DOWFLAKE 77–80% process grade calcium chloride meets or exceeds Food Chemicals Codex (FCC IV) monograph for calcium chloride dihydrate and complies with FDA

Good Manufacturing Guidelines. It also meets the American Water Works Association (AWWA) standard B-550 and is Kosher certified.

The bulk density of DOWFLAKE calcium chloride is 51 to 60 pounds per cubic foot and its angle of repose is approximately 30° from the horizontal. However, due to the storage properties of DOWFLAKE, it is customary, in order to obtain gravity flow, to design storage bins with slopes steeper than the angle of repose for the dry material. The minimum serviceable angle from the horizontal for DOWFLAKE is approximately 45°.

Table 1 — Solid Calcium Chloride Equivalence @ 25°C (77°F)

	Typical Concentration of LIQUIDOW		
	32%	35%	38%
Pounds DOWFLAKE equivalent to 1 gallon LIQUIDOW	4.51	5.06	5.64
Pounds PELADOW 90% equivalent to 1 gallon LIQUIDOW	3.86	4.34	4.83
Pounds Anhydrous Calcium Chloride 94–97% Mini-pellets equivalent to 1 gallon LIQUIDOW	3.70	4.16	4.63
Gallons LIQUIDOW equivalent to 1 ton DOWFLAKE	444	395	355
Gallons LIQUIDOW equivalent to 1 ton PELADOW 90%	518	461	414
Gallons LIQUIDOW equivalent to 1 ton Anhydrous Calcium Chloride 94–97% Mini-pellets	540	481	432
Gallons LIQUIDOW in 1 liquid ton	182	177	173
Freezing Point	-27°C (-17°F)	-7°C (20°F)	9°C (48°F)

DOWFLAKE calcium chloride meets the following gradation requirements:

Table 2 — Gradation Requirements of DOWFLAKE

Sieve Size	Weight Percent Passing
3/8-in.	100
No. 4	80–100
No. 30	0–5

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Pellets

Pelletized concentrated calcium chloride is manufactured in pellet (PELADOW), briquette (PELADOW DG) or Mini-pellets (Anhydrous) form. Pellet form products are 90–92% calcium chloride (PELADOW) or an anhydrous 94–97% calcium chloride. The high calcium chloride content and the pellet form are the principal differences between these products and DOWFLAKE calcium chloride. PELADOW meets ASTM D 98 specification “Type S, Grade 2, Class B.” Anhydrous Calcium Chloride 94–97% Mini-pellets meets ASTM D 98 specification “Type S, Grade 3, Class B.”

Dow also produces pelletized calcium chloride that is suitable as a direct additive for human foods: FOOD GRADE Anhydrous 94–97% Calcium Chloride Mini-Pellets. This highly concentrated form of calcium chloride meets or exceeds the Food Chemical Codex (FCC IV) monograph for solid calcium chloride, is manufactured according to FDA Good Practice Guidelines, meets American Water Works Association (AWWA) standard B-550, and is Kosher certified. (In this booklet, all physical property information that pertains to Anhydrous Calcium Chloride 94–97% Mini-Pellets also applies to our FOOD GRADE Anhydrous Calcium Chloride 94–97% Mini-Pellets.)

For indirect use in food processing, Dow produces BRINERS CHOICE* Anhydrous Calcium Chloride. BRINERS CHOICE anhydrous calcium chloride meets or exceeds the Food Chemicals Codex (FCC IV) monograph for aqueous solutions of calcium chloride, is manufactured according to the FDA Good Manufacturing Practice Guidelines, meets American Water Works Association (AWWA) standard B-550, and is Kosher certified.

The bulk densities of pelletized products vary. See Table 5. This data is available on sales specifications of each specific product or by contacting your nearest Dow Sales representative. The angle of repose of these products varies between 25° and 32° from the horizontal.

However, due to the storage properties of pelletized products, it is customary, in order to obtain gravity flow, to design storage bins with slopes steeper than the angle of repose for the dry material. The minimum serviceable angle from the horizontal for pelletized products is approximately 35°.

PELADOW DG

PELADOW DG calcium chloride is the latest improvement in calcium

chloride for dehydration applications. This product is briquetted in an “almond” shape. The briquettes are designed to reduce the amount of bridging and channeling that occurs occasionally in dehydrators. PELADOW DG calcium chloride has a minimum of 91% calcium chloride.

Table 4 presents some typical physical properties of PELADOW DG calcium chloride. In addition to its calcium chloride content, these are considered the most important properties relative to the use of PELADOW DG in dehydration.

PELADOW and Anhydrous Calcium Chloride 94–97% Mini-pellets products meet the following gradation requirements:

Table 3 — Gradation Requirement of Pelletized Products

PELADOW		Anhydrous Calcium Chloride 94–97% Mini-pellets	
Sieve Size	Weight Percent Passing	Sieve Size	Weight Percent Passing
3/8-in.	100	No. 4	100
No. 4	80–100		
No. 20	0–10	No. 8	80–100
No. 30	0–10	No. 30	0–4

TABLE 4 — Typical Physical Traits of PELADOW DG

Bulk Density	60–68 lb/ft ³
Briquette Density	1.86–1.88 g/cc
Briquette Porosity	15–20%
Bed Void Space (Loose Pack)	45–50%
Briquette Shape	Almond
Briquette Size	Approx. 0.69" thick at thickest point, 1.1" length
Angle of Repose	28°

Table 5 — Bulk Densities of Pellet and Flake Calcium Chloride

Product	Bulk Density
PELADOW Calcium Chloride	58–66 lbs./cu. ft.
Anhydrous Calcium Chloride 94–97% Mini-pellets	52–58 lbs./cu. ft.
BRINERS CHOICE Anhydrous Calcium Chloride	52–58 lbs./cu. ft.
DOWFLAKE 77–80% Calcium Chloride	51–60 lbs./cu. ft.
DOWFLAKE Process Grade Calcium Chloride	51–60 lbs./cu. ft.

*Trademark of The Dow Chemical Company

Properties of Pure Calcium Chloride

Literature data on the physical properties of calcium chloride, its hydrates and solutions refer generally to pure material. Pure calcium chloride, however, is only available in smaller quantities from chemical reagent supply houses. LIQUIDOW, DOWFLAKE, PELADOW, and PELADOW DG brand calcium chloride are commercial grades of calcium chloride which contain other trace elements and compounds manufactured within the limits defined by The American Society for Testing and Materials (ASTM) Standards. Data specific to these commercial materials are given in this handbook. Other physical properties of interest, which have been determined only for pure calcium chloride are included in this section since they can be applied to Dow's calcium chloride products with an error of a few percent, which is accurate enough for most purposes.

Temperature Scale

Most modern physical property data are given in terms of the Celsius (°C) scale of temperature and this is the primary scale for graphs and tables in this handbook. However since the Fahrenheit (°F) scale is still extensively used, Fahrenheit temperature will also be given when convenient. Conversion of temperatures can be done through the use of the following equations.

$$\text{From } ^\circ\text{F to } ^\circ\text{C}, \text{ } ^\circ\text{C} = 5/9(^{\circ}\text{F} - 32)$$

$$\text{From } ^\circ\text{C to } ^\circ\text{F}, \text{ } ^\circ\text{F} = (9/5 \times ^\circ\text{C}) + 32$$

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 6. This data was compiled from the literature and files of The Dow Chemical Company. Note that the thermo-

chemical 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.

Data regarding temperature rise resulting from dissolution of DOWFLAKE and PELADOW calcium chloride is summarized in Figure 4 on page 11 of this handbook.

TABLE 6 — Properties of Calcium Chloride Hydrates

Property	CaCl ₂ ·6H ₂ O	CaCl ₂ ·4H ₂ O	CaCl ₂ ·2H ₂ O	CaCl ₂ ·H ₂ O	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) (°F)	29.9 85.8	45.3 113.5	176 349	187 369	773 1424
Boiling Point ² (°C) (°F)	— —	— —	174 345	183 361	1935 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) (Btu/lb)	50 90	39 70	21 38	32 58	61.5 110.6
Heat of Solution ³ in H ₂ O (cal/g) (to infinite dilution) (Btu/lb)	17.2 31.0	-14.2 -25.6	-72.8 -131.1	-96.8 -174.3	-176.2 -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·°C or Btu/lb·°F	0.34	0.32	0.28	0.20	0.16

¹Incongruent melting point for hydrates.

²Temperature where dissociation pressure reaches one atmosphere for hydrates.

³Negative sign means that heat is evolved (process exothermic).

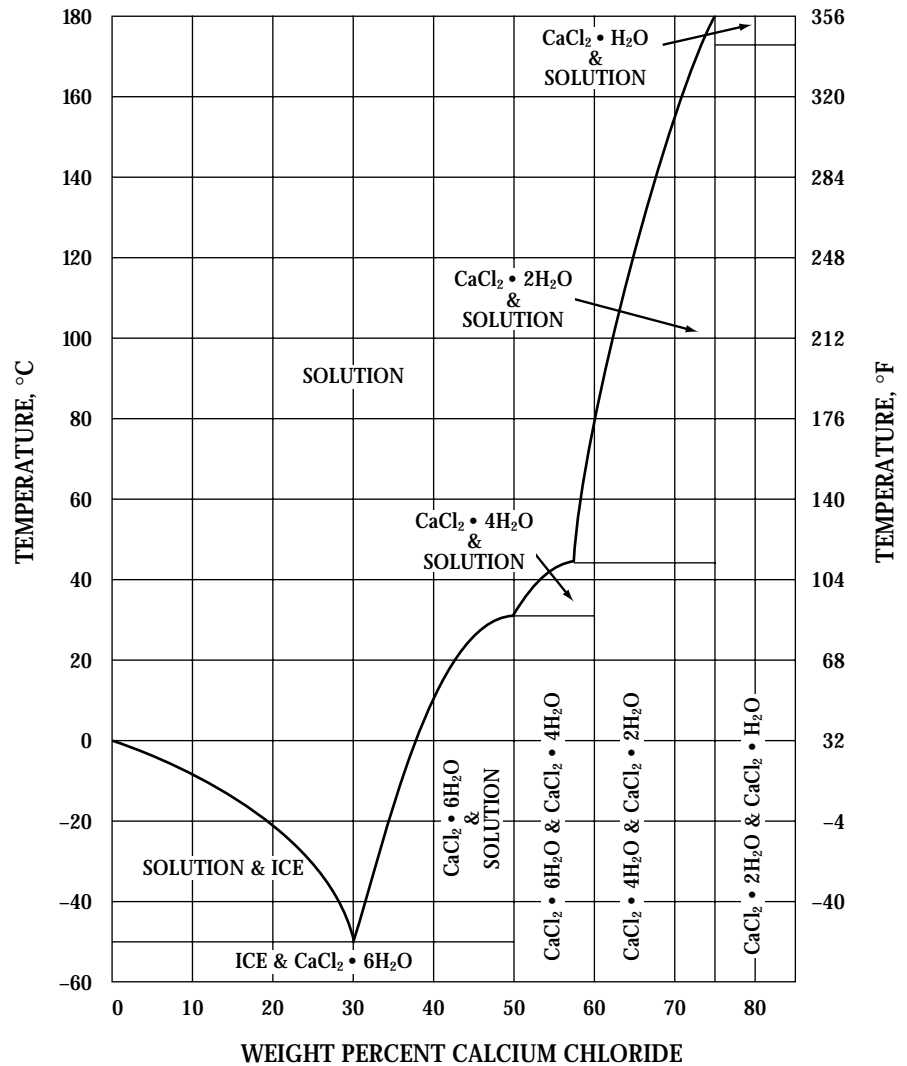
Solubility

Although calcium chloride is highly soluble in water at ordinary temperatures, solid phase separation will occur under certain temperature-concentration conditions. These conditions are defined by the phase diagram of the CaCl_2 -water system shown in Figure 1. The heavy solid line indicates the point at which a given solution becomes saturated with respect to a solid phase, either ice or a calcium chloride hydrate. Four hydrates have been identified in the published literature: $\text{CaCl}_2 \cdot 6\text{H}_2\text{O}$, $\text{CaCl}_2 \cdot 4\text{H}_2\text{O}$, $\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$ and $\text{CaCl}_2 \cdot \text{H}_2\text{O}$.

As an example of how to use the phase diagram, if a 25% solution of calcium chloride is cooled below -29°C (-20°F), crystals of ice begin to form and the concentration of the remaining solution increases. As cooling is continued, more ice separates out and the solution gradually thickens and may appear solid. However, true solidification does not occur until the temperature reaches -50°C (-59°F), at which point the remaining solution, now at a concentration of 29.6%, crystallizes as a mixture of ice and calcium chloride hexahydrate.

When solutions of concentrations greater than 29.6% are cooled, the initial solid phase is a calcium chloride hydrate and the concentration of the remaining solution decreases. Concentrated solutions of calcium chloride have a marked tendency to supercool, i.e., the temperature of the solution may fall several degrees below the line on

Figure 1 — Phase Diagram for CaCl_2 and Water Solutions



the phase diagram without crystallization taking place. When crystals finally do form in these supercooled solutions, the temperature of the mixture will rise back to the limit defined by the phase diagram.

Crystallization points of commercial calcium chloride brines will differ slightly from pure calcium chloride.

TABLE 7 — Approximate Properties of Solutions of DOW Calcium Chloride

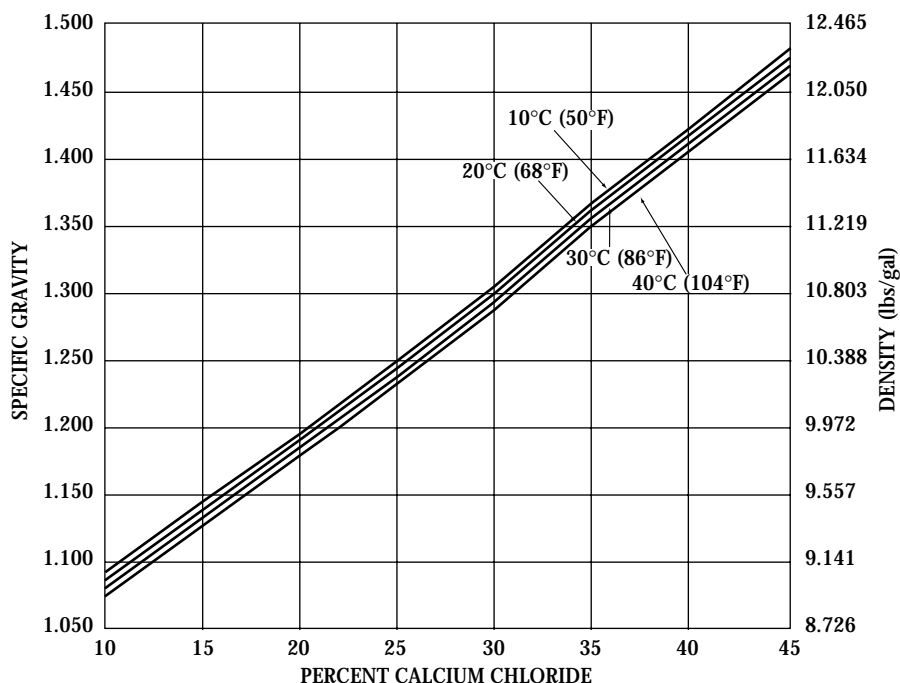
% CaCl ₂	Approx. Specific Gravity @ 77°F (25°C)	Weight lb/gal @ 77°F (kg/liter @ 25°C)	Gallons per Ton of Sol. @ 77°F (liters/dry metric ton @ 25°C)	Gallons per Dry Ton @ 77°F (liters/dry metric ton @ 25°C)	DOWFLAKE 77–80% CaCl ₂ Equivalent lb/gal of Sol. @ 77°F (kg/liter @ 25°C)	PELADOW 90%–92% CaCl ₂ Equivalent lb/gal of Sol. @ 77°F (kg/liter @ 25°C)	Anhydrous Calcium Chloride 94–97% Mini-pellets CaCl ₂ Equivalent lb/gal of Sol. @ 77°F (kg/liter @ 25°C)	Approx. Freezing Point in °F (°C)
0	1.000	8.31 (0.997)	—	—	—	—	—	+32 (0)
10	1.090	9.06 (1.087)	221 (920)	2,208 (9,200)	1.16 (0.139)	1.00 (0.119)	0.96 (0.114)	+20 (–7)
11	1.100	9.14 (1.097)	219 (912)	1,989 (8,287)	1.29 (0.155)	1.10 (0.133)	1.06 (0.127)	+18 (–8)
12	1.110	9.22 (1.107)	217 (903)	1,808 (7,528)	1.42 (0.170)	1.22 (0.146)	1.16 (0.140)	+16 (–9)
13	1.120	9.31 (1.117)	215 (895)	1,653 (6,887)	1.55 (0.186)	1.33 (0.160)	1.27 (0.153)	+14 (–10)
14	1.129	9.38 (1.126)	213 (888)	1,523 (6,334)	1.68 (0.202)	1.44 (0.173)	1.38 (0.166)	+12 (–11)
15	1.139	9.47 (1.136)	211 (880)	1,408 (5,869)	1.82 (0.218)	1.56 (0.187)	1.50 (0.179)	+10 (–12)
16	1.149	9.55 (1.146)	209 (873)	1,309 (5,454)	1.96 (0.235)	1.68 (0.201)	1.61 (0.193)	+8 (–13)
17	1.159	9.63 (1.156)	208 (865)	1,222 (5,089)	2.10 (0.252)	1.80 (0.216)	1.72 (0.207)	+5 (–15)
18	1.169	9.71 (1.165)	206 (858)	1,144 (4,769)	2.24 (0.269)	1.92 (0.231)	1.84 (0.221)	+2 (–17)
19	1.179	9.80 (1.175)	204 (851)	1,074 (4,479)	2.39 (0.286)	2.05 (0.245)	1.96 (0.235)	–1 (–18)
20	1.189	9.88 (1.185)	202 (844)	1,012 (4,219)	2.53 (0.304)	2.17 (0.261)	2.08 (0.250)	–4 (–20)
21	1.199	9.96 (1.195)	201 (837)	956 (3,985)	2.68 (0.322)	2.30 (0.276)	2.20 (0.264)	–8 (–22)
22	1.209	10.05 (1.205)	199 (830)	905 (3,772)	2.83 (0.340)	2.43 (0.291)	2.33 (0.279)	–12 (–24)
23	1.219	10.13 (1.215)	197 (823)	858 (3,578)	2.99 (0.358)	2.56 (0.307)	2.45 (0.294)	–16 (–27)
24	1.228	10.20 (1.224)	196 (817)	817 (3,404)	3.14 (0.377)	2.69 (0.323)	2.58 (0.309)	–20 (–29)
25	1.240	10.30 (1.236)	194 (809)	777 (3,236)	3.30 (0.396)	2.83 (0.340)	2.71 (0.325)	–25 (–32)
26	1.251	10.40 (1.247)	192 (802)	740 (3,084)	3.47 (0.416)	2.97 (0.356)	2.85 (0.341)	–31 (–35)
27	1.263	10.50 (1.259)	190 (794)	706 (2,942)	3.63 (0.436)	3.12 (0.374)	2.98 (0.358)	–38 (–39)
28	1.275	10.60 (1.271)	189 (787)	674 (2,810)	3.81 (0.456)	3.26 (0.391)	3.12 (0.375)	–46 (–43)
29	1.287	10.69 (1.283)	187 (779)	654 (2,688)	3.97 (0.477)	3.41 (0.409)	3.26 (0.392)	–53 (–47)
29.6	1.294	10.75 (1.290)	186 (775)	629 (2,619)	4.08 (0.490)	3.50 (0.420)	3.35 (0.402)	–60 (–51)
30	1.298	10.79 (1.294)	185 (773)	618 (2,578)	4.15 (0.498)	3.56 (0.427)	3.41 (0.409)	–52 (–47)
31	1.310	10.89 (1.306)	184 (766)	592 (2,470)	4.33 (0.519)	3.71 (0.445)	3.55 (0.426)	–34 (–37)
32	1.322	10.99 (1.318)	182 (759)	569 (2,371)	4.51 (0.541)	3.86 (0.463)	3.70 (0.444)	–17 (–27)
33	1.334	11.09 (1.330)	180 (752)	547 (2,278)	4.69 (0.563)	4.02 (0.482)	3.85 (0.462)	–4 (–20)
34	1.345	11.18 (1.341)	179 (746)	526 (2,193)	4.87 (0.585)	4.18 (0.501)	4.00 (0.480)	+10 (–12)
35	1.357	11.28 (1.353)	177 (739)	507 (2,112)	5.06 (0.607)	4.34 (0.520)	4.16 (0.498)	+20 (–7)
36	1.369	11.38 (1.365)	176 (733)	488 (2,035)	5.25 (0.630)	4.50 (0.540)	4.31 (0.517)	+30 (–1)
37	1.381	11.48 (1.377)	174 (726)	471 (1,963)	5.45 (0.653)	4.67 (0.560)	4.47 (0.536)	+39 (+4)
38	1.392	11.57 (1.388)	173 (720)	455 (1,891)	5.64 (0.676)	4.83 (0.580)	4.63 (0.555)	+48 (+9)
39	1.404	11.67 (1.400)	171 (714)	439 (1,832)	5.84 (0.700)	5.00 (0.600)	4.79 (0.575)	+55 (+13)
40	1.416	11.77 (1.412)	170 (708)	425 (1,771)	6.04 (0.724)	5.17 (0.621)	4.96 (0.594)	+61 (+16)
41	1.428	11.87 (1.424)	168 (702)	411 (1,713)	6.24 (0.748)	5.35 (0.631)	5.12 (0.614)	+65 (+18)
42	1.439	11.96 (1.435)	167 (697)	398 (1,659)	6.44 (0.773)	5.52 (0.662)	5.29 (0.634)	+69 (+21)
45	1.474	12.25 (1.470)	163 (680)	363 (1,512)	7.07 (0.848)	6.06 (0.727)	5.80 (0.696)	+78 (+26)

Solution Properties of DOW Calcium Chloride

Solutions of LIQUIDOW, DOWFLAKE and PELADOW have the same properties at the same concentration. The properties of specific gravity, density and freezing points are given in Table 7 for calcium chloride solutions. (Specific gravities at various temperatures are shown in Figure 2). In addition to the above mentioned properties, the amount of DOWFLAKE, PELADOW and Anhydrous Calcium Chloride 94–97% Mini-pellets per gallon of solution at a given strength is presented in Table 7.

Pages 18–19 of this handbook give detailed instructions and formulas for solution make-up and dilution of DOW calcium chloride.

**Figure 2— Specific Gravity vs. % Calcium Chloride
at Various Temperatures**



Analysis

The American Society for Testing and Materials has adopted methods for sampling and analyzing calcium chloride. The fundamental procedures for analysis of these products are found in ASTM Designation E 449. For all tables and graphs in this

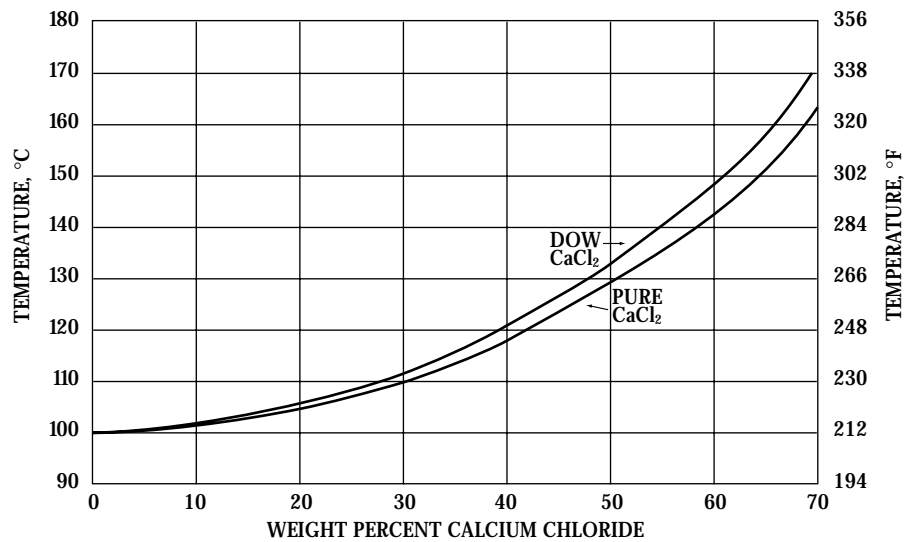
handbook, the entry “% Calcium Chloride” should be understood to be the value determined by E 449 methods. Copies of current issues of these test methods are available from:

American Society for
Testing and Materials
1916 Race Street
Philadelphia, PA 19103

Boiling Point

The boiling point of a liquid is the temperature at which its vapor pressure becomes equal to the atmospheric pressure. This temperature varies with different atmospheric pressure; a pressure of 760 mm of mercury is regarded as the standard atmosphere for boiling points. Figure 3 shows the boiling points of 0–70% aqueous solutions of pure and DOW commercial calcium chloride. Solutions of pure calcium chloride above 69% cannot be prepared by boiling at 760 mm pressure because dihydrate begins to separate as a solid phase and the solution composition remains constant. Boiling points of commercial calcium chloride vary with the amount and the kind of impurities present. The curve shown (in Figure 3) represents an average Dow material from which any individual sample should not be expected to deviate by more than 1°C (2°F).

Figure 3 — Boiling Points of Calcium Chloride Solutions

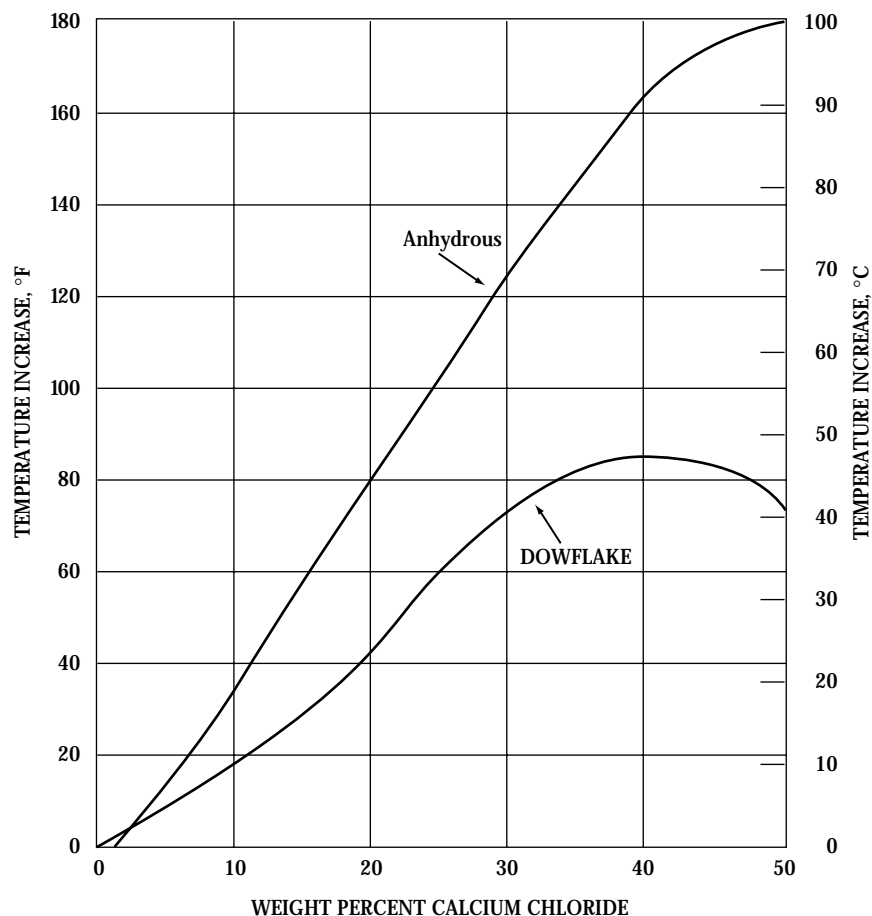


Temperature Increase in Dissolving DOWFLAKE or Anhydrous Calcium Chloride

When DOWFLAKE or Anhydrous calcium chloride is dissolved in water, considerable heat is liberated. This temperature increase is shown in Figure 4 for concentrations up to 50% calcium chloride. For example, the heat generated in preparing a 40% calcium chloride solution with DOWFLAKE would result in a temperature increase of approximately 47°C (84°F). With Anhydrous, the temperature increase would be approximately 91°C (164°F). Thus, if the temperature of the water is 23°C (74°F), the final solution temperature will exceed 68°C (155°F) for DOWFLAKE and 114°C (238°F) for Anhydrous. These temperature calculations are theoretical in that they do not account for heat loss.

In the interest of safety and to avoid the requirement for specialized handling practices, **hot water should never be used** for dissolving DOWFLAKE or Anhydrous calcium chloride. To illustrate the importance of using water at ambient temperatures, consider the make-up of a 34% solution of Anhydrous. When such a solution is prepared, the temperature rise due to dissolution of the Anhydrous calcium chloride is 78°C (140°F). If warm water — for example, water at 49°C (120°F) — is used, the temperature of the resulting solution will be 127°C (260°F). As shown in Figure 3, Boiling Points of Calcium Chloride Solutions, on page 13, this temperature is above the boiling point of 34% solution, and considerable pressure will be created from the vaporizing liquid. Therefore, always use cool water when dissolving DOWFLAKE and Anhydrous calcium chloride.

Figure 4 — Theoretical Temperature Increases in Preparing Aqueous Solutions of DOWFLAKE or Anhydrous (94%)



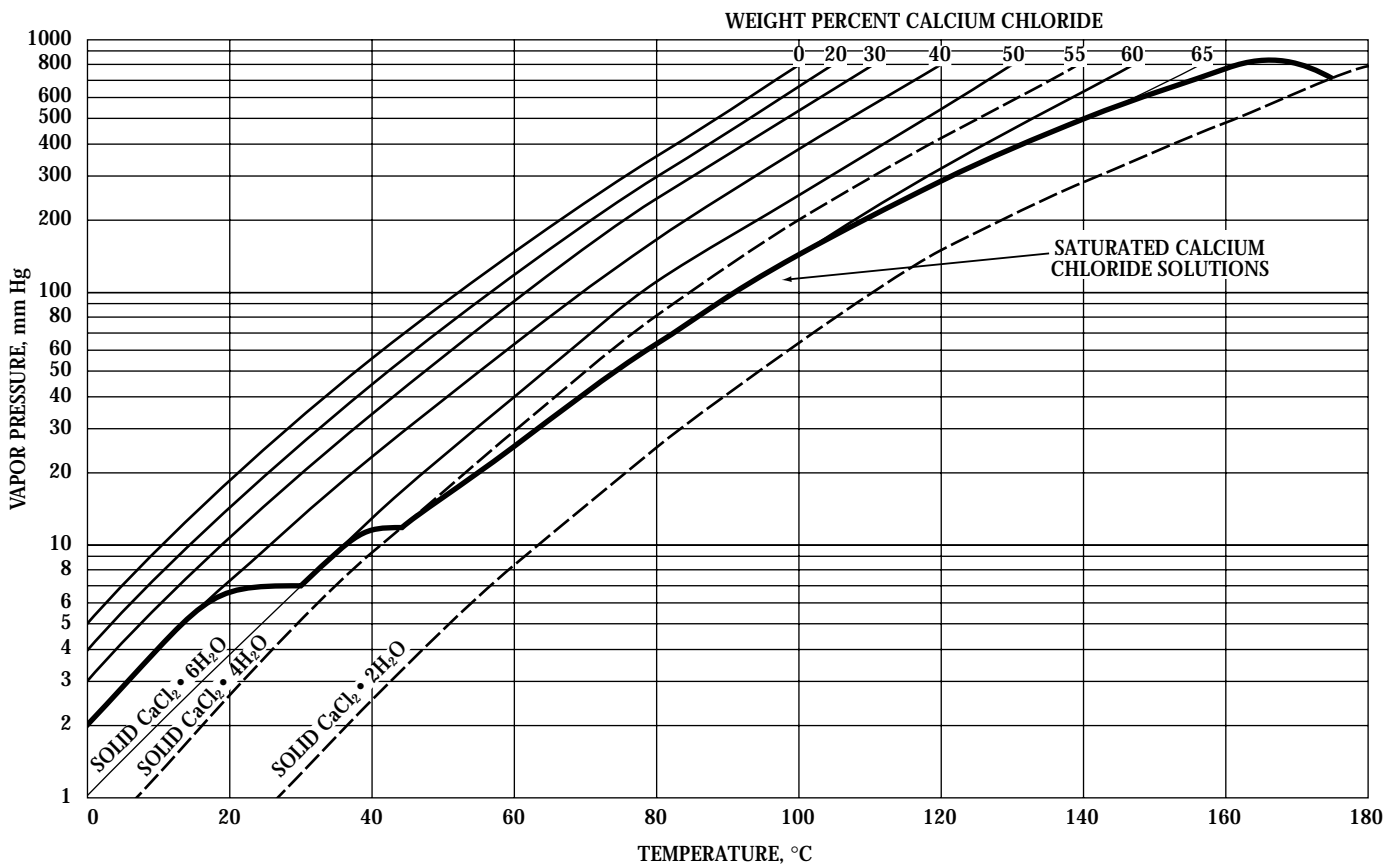
Vapor Pressure

Figure 5 shows the vapor pressure of calcium chloride solutions and the dissociation pressures of three hydrates. These values refer to pure CaCl_2 ; for commercial material a correction should be read from Figure 3. For example, according to Figure 3, a 60% solution of DOW calcium chloride boils about 7°C (13°F) higher than 60% pure CaCl_2 and the vapor pressure curve for DOW 60% calcium chloride is therefore shifted 7°C (13°F) higher than the 60% curve of Figure 5.

The relative humidity of air in equilibrium with calcium chloride solutions is readily obtained from Figure 5. As an example, the vapor pressure of pure water at 25°C (77°F) is 24 mm while the vapor pressure of a 30% calcium chloride solution is 15 mm. The relative humidity is simply the ratio $15/24$ multiplied by 100, or 63%. The saturated solution curve gives the minimum water vapor pressure needed for solid calcium chloride hydrates to deliquesce, i.e., form a solution. At 30°C (86°F), a typical summer temperature, the water

vapor pressure needed to liquefy calcium chloride is 7 mm, corresponding to 22% relative humidity. Since summer humidities are usually higher than 22%, calcium chloride liquid, flakes or pellets will pick up water from the air and either dilute or dissolve. This property makes calcium chloride useful in dehumidification of air and other gases and in dust control applications. The moisture absorption properties of DOWFLAKE and PELADOW calcium chloride are discussed further in the section titled "Atmospheric Moisture Absorption."

Figure 5 — Vapor Pressure of Calcium Chloride Hydrates and Solutions



Atmospheric Moisture Absorption

Calcium chloride is both hygroscopic and deliquescent. Thus, solid material will absorb moisture from the air until it dissolves, and the solution will continue to absorb moisture until an equilibrium is reached between the vapor pressure of the solution and that of the air. If the humidity of the air increases, more moisture is absorbed by the solution; if it decreases, water evaporates from the solution to the air.

The rate at which moisture is absorbed by a given quantity of DOWFLAKE or PELADOW calcium chloride or its solutions depends upon (1) the surface area of the calcium chloride exposed to the air, (2) the rate at which air circulates over the calcium chloride and (3) the water vapor pressure of the air in relation to that of the calcium chloride.

Table 8 shows the amount of water absorbed per pound of DOWFLAKE and Anhydrous Calcium Chloride 94–97% Mini-pellets and the concen-

tration of the resultant solution at various relative humidities. The same information is presented graphically in Figures 6 and 7. The data shows that in an atmosphere having a relative humidity of 40% and a temperature of 25°C (77°F), one pound of water is absorbed per pound of DOWFLAKE calcium chloride and 1.4 pounds of water is absorbed per pound of Anhydrous Calcium Chloride 94–97% Mini-pellets if the system is allowed to reach equilibrium. As the relative humidity increases, the amount of water absorbed likewise increases

TABLE 8 — Atmospheric Humidities in Equilibrium with Solutions of DOWFLAKE 77–80% Calcium Chloride and Anhydrous Calcium Chloride 94–97% Mini-pellets at 25°C (77°F)

Relative Humidity Percent	Final Solution Percent CaCl_2	Pounds of Water Absorbed per lb DOWFLAKE (77–80%)	Pounds of Water Absorbed per lb Anhydrous Calcium Chloride 94–97% Mini-pellets
95	5.2	14.0	17.3
90	10.4	6.5	8.2
85	14.8	4.3	5.4
80	19.1	3.1	4.0
75	22.6	2.5	3.2
70	25.6	2.1	2.7
65	28.3	1.8	2.4
60	31.1	1.5	2.1
55	33.8	1.3	1.8
50	36.0	1.2	1.6
45	37.8	1.1	1.5
40	39.5	1.0	1.4
35	41.7	0.9	1.3
30	43.9	0.8	1.2

until at 95% relative humidity, one pound of DOWFLAKE calcium chloride will absorb approximately 14.0 pounds of water and one pound of Anhydrous Calcium Chloride 94–97% Mini-pellets will absorb approximately 17.3 pounds of water.

The ability of calcium chloride to absorb moisture makes it useful in many construction, commercial and industrial applications.

Figure 6 — Percent Relative Humidity of Air in Equilibrium with Solution of DOWFLAKE or PELADOW Calcium Chloride at 25°C (77°F).

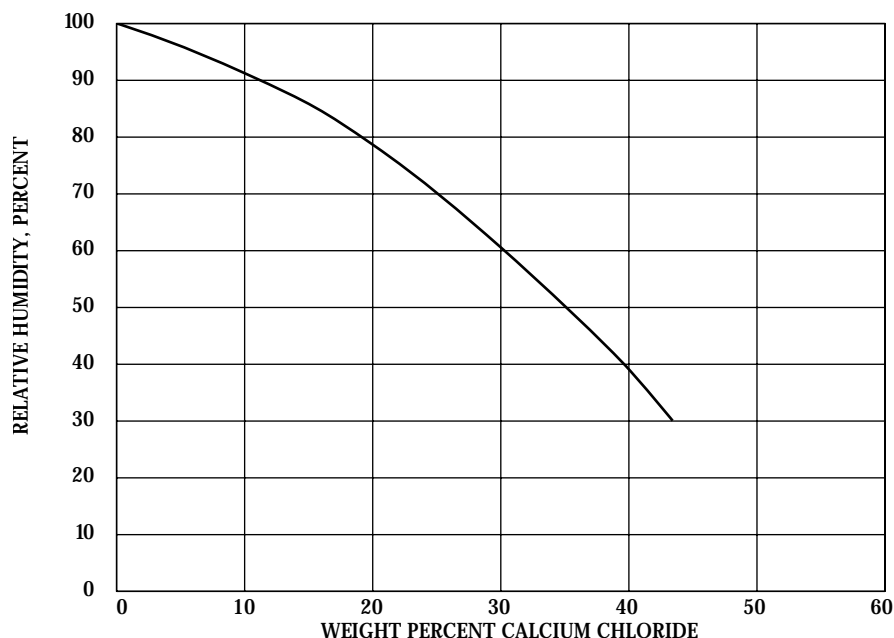
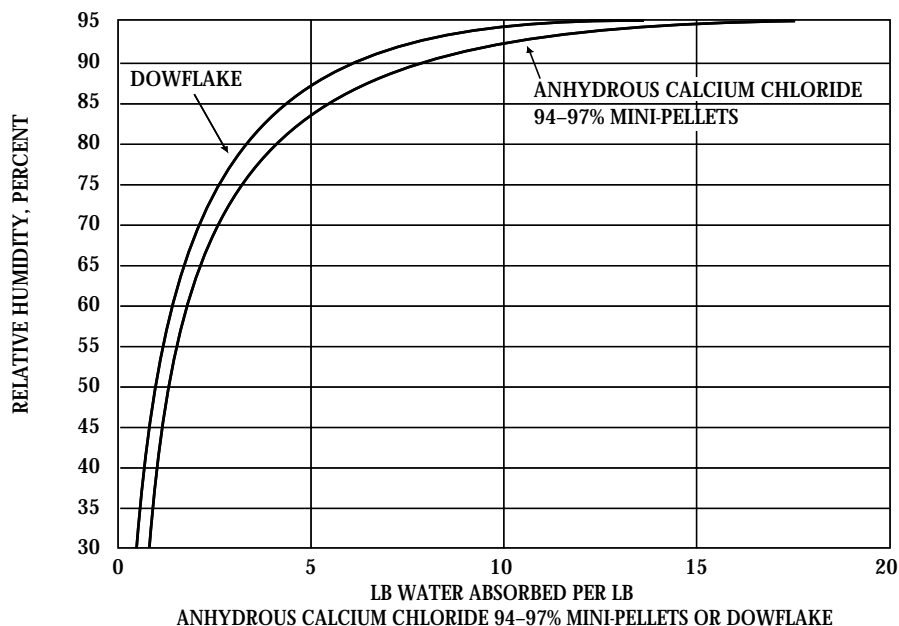


Figure 7 — Atmospheric Humidities in Equilibrium with Anhydrous Calcium Chloride 94–97% Mini-pellets and DOWFLAKE Calcium Chloride at 25°C (77°F)

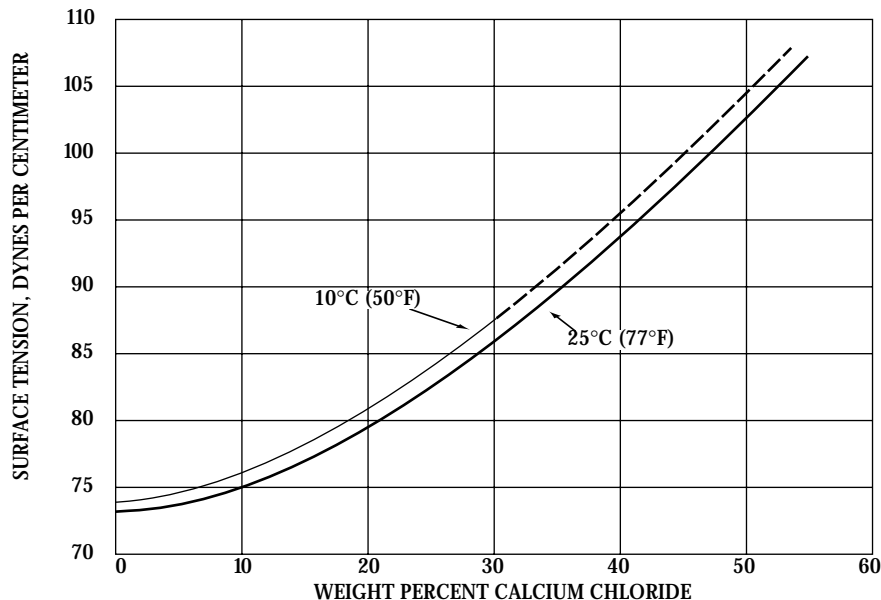


Surface Tension

Surface tension is that force on the surface of a liquid which tends to diminish the surface area to a minimum. It results because of differences in intermolecular attraction at the surface and in the interior of the liquid. At the surface all of the molecules are attracted inward, while in the interior the attraction is the same in all directions. Surface tension has an important effect on the wetting and penetrating ability of a liquid, and on its ability to form emulsions.

The lower the surface tension, the greater are these abilities. Figure 8 shows the surface tension of calcium chloride solutions at 10°C (50°F) and 25°C (77°F).

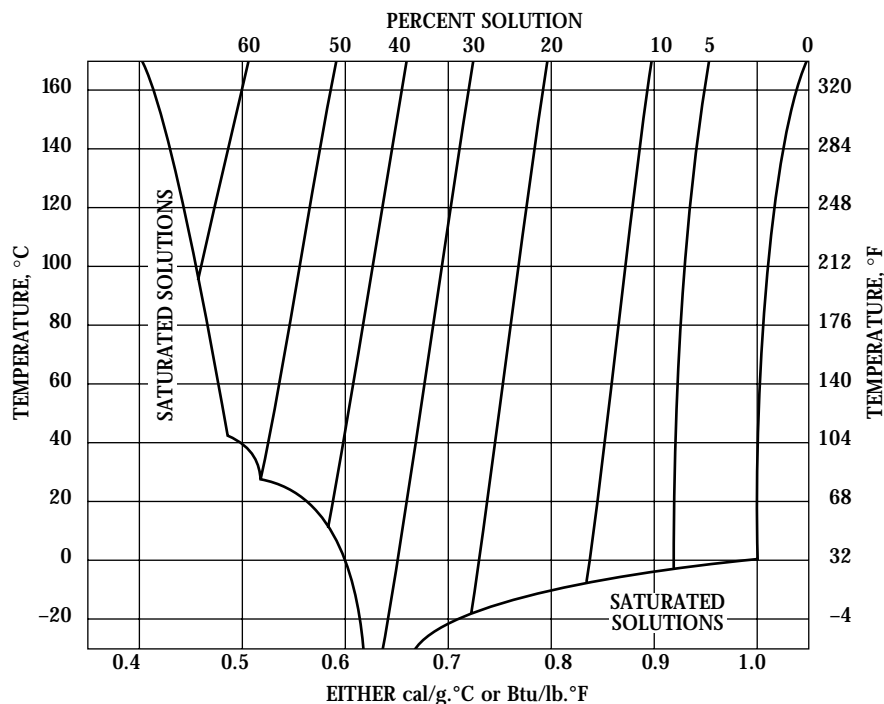
Figure 8 — Surface Tension of Pure Calcium Chloride Solutions



Specific Heat

Specific heat is the amount of heat required to raise a unit weight of a substance one degree in temperature at either constant pressure or constant volume. It can be expressed either as calories per gram per degree Celsius, or as British thermal units per pound per degree Fahrenheit, and the expressions are numerically equal. The specific heat of water is approximately 1 at ordinary temperatures. The specific heat of aqueous calcium chloride solutions of various concentrations is shown in Figure 9.

Figure 9 — Specific Heat of Aqueous CaCl₂



Viscosity

Viscosity is a measure of the internal friction of a liquid. As viscosity increases, the tendency to flow decreases. The viscosity of a solution of calcium chloride varies inversely with temperature at constant concentration and increases with increasing concentration at constant temperature. Table 9 and Figure 10 show the viscosities of calcium chloride solutions at various temperatures. If desired, viscosity values can readily be converted from centipoises to centistokes by dividing the centipoises by the density of the solution in grams per milliliter at the indicated temperature.

Figure 10 — Viscosity of Pure Calcium Chloride Solutions

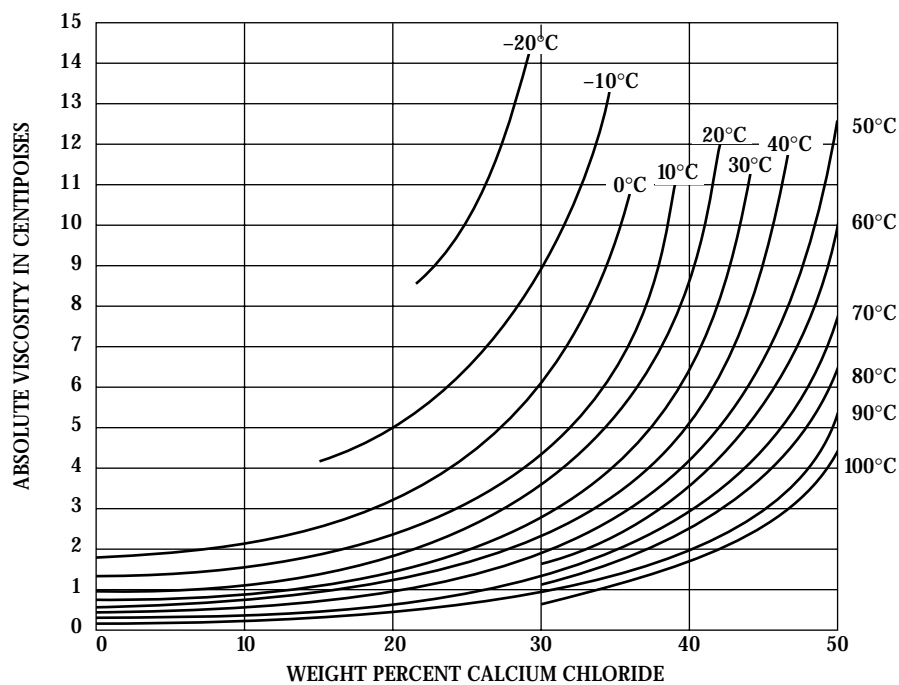


Table 9 — Absolute Viscosity in Centipoises of CaCl₂ Solutions

Weight % CaCl ₂	Temperature, °C												
	-20	-10	0	10	20	30	40	50	60	70	80	90	100
0	—	—	1.77	1.29	1.02	0.79	0.67	0.53	0.46	0.40	0.34	0.30	0.26
5	—	—	1.84	1.35	1.07	0.82	0.73	0.57	0.51	0.45	0.39	0.35	0.28
10	—	—	2.13	1.52	1.16	0.93	0.86	0.64	0.57	0.51	0.47	0.42	0.35
15	—	4.09	2.50	1.84	1.40	1.20	1.03	0.76	0.68	0.62	0.55	0.49	0.42
20	—	4.97	3.12	2.33	1.81	1.54	1.22	0.99	0.85	0.74	0.68	0.59	0.49
25	9.94	6.32	4.04	3.07	2.38	1.97	1.54	1.27	1.07	0.90	0.82	0.70	0.59
30	14.27	9.04	5.77	4.30	3.33	2.62	2.07	1.73	1.43	1.24	1.01	0.89	0.73
35	—	—	8.83	6.62	4.99	3.87	3.07	2.54	2.17	1.82	1.46	1.22	1.03
40	—	—	—	11.75	8.48	6.39	4.90	4.00	3.26	2.72	2.15	1.74	1.52
45	—	—	—	—	—	11.5	8.90	6.57	5.24	4.25	3.39	2.77	2.33
50	—	—	—	—	—	—	—	11.80	9.24	7.45	5.97	4.95	4.28

Making and Diluting Solutions

Solution Makeup Formulas (Formulas 1–3)

Percentages used in all examples are expressed as whole numbers, not as decimals. Weight of water is 8.31 lb/gal @ 25°C (77°F)

Formula 1

Formula for calculating the number of gallons of water to add to DOWFLAKE or PELADOW calcium chloride to obtain the desired percent solution at 25°C (77°F).

$$\left[\frac{\text{lb dry CaCl}_2 \times \% \text{ CaCl}_2^a}{\text{desired \% solution}} - \text{lb dry CaCl}_2 \right] \div 8.31$$

Example:

Making 34% solution from 70,000 pounds DOWFLAKE calcium chloride.

$$\left[\frac{70,000 \times 78}{34} - 70,000 \right] \div 8.31 = 10,901 \text{ gallons}^b$$

Formula 2

Formula for preparing a solution of a given strength and a given quantity.

Example:

$$\frac{\left(\frac{\text{weight sol.}}{\text{gal}} \times \text{capacity of tank} \right) - \left(\frac{\text{lb dry CaCl}_2}{\text{gal sol.}} \times \text{capacity of tank} \right)}{8.31}$$

Using DOWFLAKE calcium chloride to make a 34% solution in a tank of 3,400 gal capacity at 25°C (77°F)^b

$$(11.18 \times 3400) = 38,012 \text{ (pounds of solution)}$$

$$(4.87 \times 3400) = 16,558 \text{ (pounds of DOWFLAKE)}$$

$$(38,012 - 16,558) = 21,454 \text{ (pounds of water)}$$

$$\frac{21,454}{8.31} = 2,582 \text{ gallons (of water to use)}$$

Example:

Using PELADOW (91%) calcium chloride to make a 34% solution in a tank of 3,400 gal capacity at 25°C (77°F)^b

$$(11.18 \times 3400) = 38,012 \text{ (pounds of solution)}$$

$$(4.18 \times 3400) = 14,212 \text{ (pounds of PELADOW)}$$

$$(38,012 - 14,212) = 23,800 \text{ (pounds of water)}$$

$$\frac{23,800}{8.31} = 2,864 \text{ gallons (of water to use)}$$

Formula 3

Formula for determining the final volume in gallons of a solution at 25°C (77°F).

$$\frac{(\text{gal water added} \times 8.31) + (\text{lb dry CaCl}_2)}{\text{weight per gal sol.}}$$

Example:

Example for DOWFLAKE in Formula 1

$$\frac{(10,901 \times 8.31) + 70,000}{11.18} = 14,364 \text{ gallons}$$

Concentrating a weaker solution (Formula 4)

Formula 4

Formula for calculating pounds of DOWFLAKE or PELADOW calcium chloride to add to a weak calcium chloride solution to obtain a stronger solution at 25°C (77°F).^c

$$\frac{(\% \text{ sol. desired} - \% \text{ weak sol.}) \times (\text{weight of weak in lb/gal})}{(\% \text{ CaCl}_2 \text{ in solid form} - \% \text{ solution desired})}$$

Example:

Desire to make 30% solution, starting with a 25% solution and using PELADOW (91% CaCl₂)

$$\frac{(30 - 25) \times (10.30)}{(91 - 30)} = \frac{0.84 \text{ lb PELADOW}}{\text{(per gal of weak solution)}}$$

Diluting a strong solution^d
(Formulas 5–7)

Formula 5

Formula for determining the number of gallons of water to add to a strong solution to obtain a weaker solution at 25°C (77°F).

$$\left(\frac{\% \text{ strong} - \% \text{ weak}}{\% \text{ weak}} \right) \times \text{sp gr strong}$$

Example:

Diluting 38% solution to 34% solution

$$\frac{38 - 34}{34} \times 1.392 = 0.164 \text{ gallons water (per gallon strong solution)}$$

Formula 6

Formula for determining the number of gallons of weak solution from each gallon of strong solution of LIQUIDOW calcium chloride.

$$\left(\frac{\text{sp gr strong} \times \% \text{ strong}}{\text{sp gr weak} \times \% \text{ weak}} \right)$$

Example:

Continuation of Formula 5 example

$$\left(\frac{1.392 \times 38}{1.345 \times 34} \right) = 1.157 \text{ gallons weak sol. (per gallon strong)}$$

Formula 7

Formula for determining the number of gallons of strong solution for a required number of gallons of weaker solution of LIQUIDOW calcium chloride.

$$\text{gal weak sol.} \times \left(\frac{\text{sp gr weak} \times \% \text{ weak}}{\text{sp gr strong} \times \% \text{ strong}} \right)$$

Example:

For 4,000 gal of 34% from 38%

$$4,000 \times \left(\frac{1.345 \times 34}{1.392 \times 38} \right) = 3,458 \text{ gallons (of strong solution)}$$

Effect of temperature

Since an aqueous solution is more dense when cool than warm, the correct unit weight must be used for the appropriate temperature. Below are some temperature ranges and corresponding unit weights of water.

Temperature	Weight in lb/gal
< 7°C (45°F)	8.34
7°C (45°F)–17°C (63°F)	8.33
18°C (64°F)–23°C (73°F)	8.32
24°C (75°F)–28°C (83°F)	8.31
29°C (84°F)–32°C (90°F)	8.30

Notes

- ^a DOWFLAKE (78% typical), PELADOW (91% typical), or Anhydrous Calcium Chloride 94–97% Mini-pellets (95% typical)
- ^b When calcium chloride is dissolved, its heat of solution causes the brine to expand and take up more space than it will when cooled. Additional tank capacity required is approximately 26 gallons for every 1000 gallons of 34% solution that is made up.
- ^c Dissolving rate in CaCl₂ solution is slower than dissolving in water.
- ^d To obtain quantities for producing a desired volume of weaker solution, use Formulas 5 and 7. Total water is then obtained by multiplying answers from Formulas 5 and 7.

Handling & Storage Guidelines

This section gives a brief overview of the information needed to successfully and safely handle liquid and dry calcium chloride. It is broken down into several sections that include handling and storage of both liquid and solid material and the dissolution of solid calcium chloride. Most of Dow's calcium chloride products are available in bulk rail cars, hopper trucks or tank trucks. General rail car precautions and preliminary procedures are found at the end of this section. Because no handbook can answer all questions, customers are encouraged to contact Dow to discuss additional property and handling questions.

Unloading and Storage of Solid Calcium Chloride

Bag Shipments

DOWFLAKE and PELADOW products are shipped in a variety of bag sizes, including one ton containers. The airtight bags used for shipment are either of the multiwall paper type, with a polyethylene barrier, or plastic. Bag shipments are made in truckload and carload quantities. Dow bagged material is on pallets and is shrink-wrapped for protection.

Storage should be in a dry, well ventilated room or building with a wood or concrete floor. The bags should be placed on pallets or planks raised about 4 inches above the floor to permit air to circulate below the bottom tier. Bags should be kept in a flat position unless they are being used. Turning the bags from a flat position can break the seal on the

bag valve sleeve. Once this happens the bag will not seal airtight again. Ordinarily, older bags should be used first. If, however, a bag becomes damaged it should be mended and used ahead of others. The tops of partially used bags should be rolled down tightly to the unused portion.

Full pallets with intact shrink-wrapped covers can be successfully stored outside. However, if individual bags must be temporarily stored outdoors, the bottom tier should be laid on raised planks or pallets and the pile protected by a waterproof covering.

Bulk Shipments

Bulk shipments are made in hopper cars of approximately 90 tons and hopper trucks of various capacities. Personal protective clothing and equipment must be worn throughout the unloading process.

General Considerations — Unloading

Bulk calcium chloride has been handled and moved by a number of methods including drag chains, screw conveyors, pneumatic conveyors, bucket elevators, belt conveyors and hopper-car unloaders. Before any system can be designed, considerations such as how much, and at what rate the material is to be conveyed, and how much degradation of the product is acceptable must be taken into consideration. The Dow Chemical Company encourages customers to discuss these considerations with our production experts.

General Considerations — Storage

Bulk calcium chloride may be stored in closed hoppers or silos. Storage of PELADOW calcium chloride is different from the storage of DOWFLAKE calcium chloride since the round spherical particles tend to flow more easily than the flat particles of DOWFLAKE. As with unloading, several considerations need to be taken into account when storing calcium chloride in bulk form, and Dow encourages customers to discuss these considerations with our production experts.

Bag Sizing for Dry Calcium Chloride

Experience has shown that bag sizing for dry calcium chloride is not as straightforward as it may seem. Bulk density of these products can vary due to numerous factors including variability in product bulk density, how the bulk material is transported and unloaded prior to bagging, the type of bag that is to be used, the type of bag filling equipment that is to be used and how the bags will be stacked and fit on the pallets.

Dow production and packaging experts, as well as bag vendors, can assist customers with bag sizing if needed.

Tank Truck Unloading of LIQUIDOW Calcium Chloride

Procedures for unloading tank trucks are similar to those for unloading tank cars except that pressures and fitting locations may vary from truck to truck. The driver of the calcium chloride tank truck is usually responsible for his own unloading.

Truckers should wear the same protective equipment and obey the safety precautions outlined in other sections of this Handbook. This includes goggles and rubber gloves at all times. Additional equipment, such as rubber suits and pants, a full face shield and rubber boots may be required under certain circumstances.

It is common practice to unload by air (Figure 11). For discharge elevations above 30 ft, it is recommended the calcium chloride be unloaded by using a pump (Figure 12).

Once the unloading is completed, water must be available so that the trucker can wash out and dilute any calcium chloride remaining in his unloading hose. Collection facilities should be provided to handle spills and wash out streams.

During cold weather operations, tank trucks that are not insulated will cool quickly. When the contents of the truck cool down, the possibility of crystallization increases. Generally, uninsulated trucks lose 3°C (5°F) to 6°C (10°F) per day, while insulated trucks will only lose 1°C (2°F) to 2°C (4°F) per day.

Figure 11 — Unloading of Tank by Air—Top and Bottom

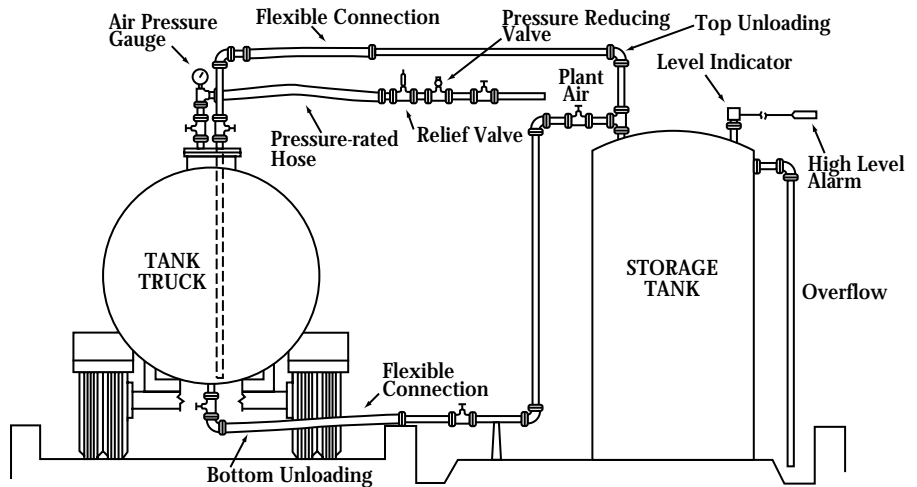
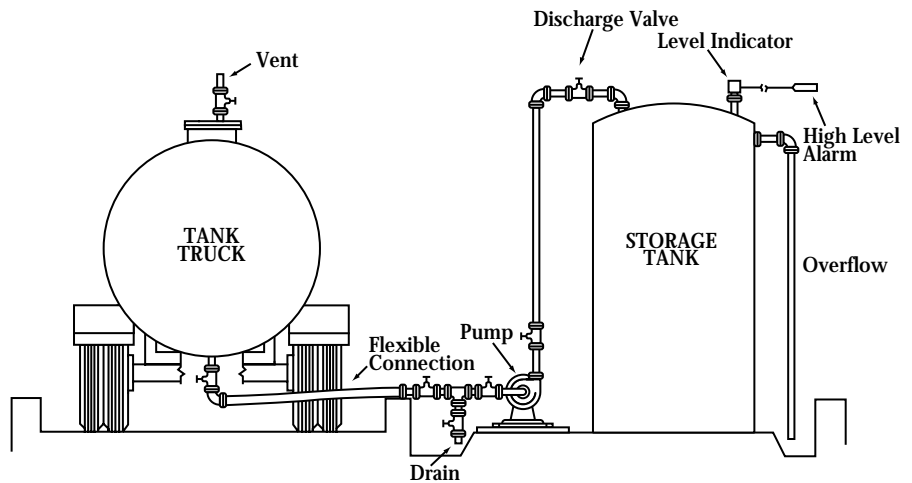


Figure 12 — Unloading of Tank Truck by Pump



Rail Car Unloading of LIQUIDOW Calcium Chloride

Rail Car Precautions and Preliminary Procedures

The following precautions and preliminary procedures are recommended:

1. All workers should be suitably trained for safe tank car unloading procedures.
2. All workers should familiarize themselves with the environmental, health and safe handling data for calcium chloride found in this Handbook as well as information contained in the Material Safety Data Sheet.
3. The unloading track should be level.
4. Once the car is spotted, set the hand brake and chock the wheels.
5. Metal caution signs should be locked to the track, preferably near the metering switch, at both ends of the car. Sign size should not be less than 12" by 15"; with the legend: STOP — TANK CAR CONNECTED. The letters should be in white on a blue background. The word STOP should be in gothic letters at least 4" high; the other letters should be at least 2" high. These signs should not be removed until the car is unloaded and all fittings are disconnected.
6. Unless the car is protected by a switch that is closed and locked, "derails" should be placed at the open end or ends of the siding not less than one car length from the car.
7. Partially unloaded tank cars should not be moved if at all possible.

If it should become necessary to move a partially unloaded car, close the internal and external outlet valves, drain the connecting lines and disconnect all connections. If unloading by pressure, release the pressure on the tank car and lines before disconnecting. The dome cover must be closed and all bolt closures tightened securely before the tank car is moved.

8. Cars should be connected, unloaded and disconnected in daylight if at all possible. Adequate lighting should be provided if these operations must be done at night.
9. Before connecting the tank car to the unloading line, workmen should make sure that the storage tank is properly vented and that it will hold the entire contents of the car.
10. To open or close fittings on rail cars, wrenches or bars should be pushed instead of pulled. This will minimize the danger of falling if the tool should slip.
11. Under no circumstances should the car be entered.

Unloading Instructions — General

In general, the instructions in this section apply to both 28% to 42% and to 45% LIQUIDOW calcium chloride. However, because of the higher crystallization temperature of the 45% product, refer to additional information on steaming rail cars found in the section "Railway Tank Car Steaming" located on page 24 of this handbook. LIQUIDOW calcium chloride is shipped in tank cars having a capacity of usually 16,000 gallons. A general overview of a tank car and an unloading station is given in Figures 13 and 14.

Calcium chloride solutions are normally unloaded through the bottom outlet valve using either air pressure or a centrifugal pump to transfer the solution to a storage tank.

Unloading Through Bottom Outlet Valve by Pump

Personal protective clothing and equipment should be worn throughout the unloading process.

If gravity flow to the pump inlet is used, the outlet valve in the piping from the transfer pump should be throttled to prevent cavitation on the suction side of the pump. In all cases, the flow rate to the pump must be greater than the flow rate from the discharge side of the pump.

These steps should be followed when unloading liquid calcium chloride solutions:

1. Relieve any pressure buildup in the car by opening the vent valve, then open the manway cover. Keep manway open during the unloading operation.
2. Cautiously remove the protective plug below the valve on the bottom discharge leg.
3. Attach the unloading line.
4. Open the external bottom outlet valve.
5. Open the internal bottom outlet valve† to allow the calcium chloride solution to flow to the pump.
6. Start the pump.
7. Check for leaks.
8. Shut down, correct leaks as needed.

†If the internal outlet valve handle does not turn with moderate pressure, or if calcium chloride does not start to flow, it indicates that frozen calcium chloride is present in the bottom of the car and steaming is necessary. DO NOT ATTEMPT TO FORCE THE HANDLE. See section "Railway Tank Car Steaming" found on page 24 of this manual.

9. When the tank car is empty, stop the pump, close the tank car internal and external valves and disconnect and clean out the unloading hose with steam or water.
10. Prepare the car for return to Dow.

Unloading Through Bottom by Air Pressure

Personal protective clothing and equipment must be worn throughout the unloading process.

Air pressure should never exceed 50 psi.

These steps should be followed when unloading liquid calcium chloride solution:

1. Relieve any pressure buildup in the car by opening the vent valve.
2. Cautiously remove the plug from the external outlet valve.
3. Attach the unloading line.
4. Open the external outlet valve.

Then proceed as follows:

5. Recheck to be sure the manway cover is fastened securely and close the vent valve.
6. Connect the air supply line to the air inlet on the top of the car.
7. Open the internal outlet valve.[†]
8. Check for leaks.
9. Shut down, correct leaks as needed.
10. Apply air pressure until the car is empty.

NOTE: A drop in air pressure or the sound of air rushing through the discharge pipe indicates that the tank car is empty. Allow the flow of air to continue until the unloading line is empty.

Figure 13 — Tank Car Bottom Unloading Calcium Chloride Solution by Pump

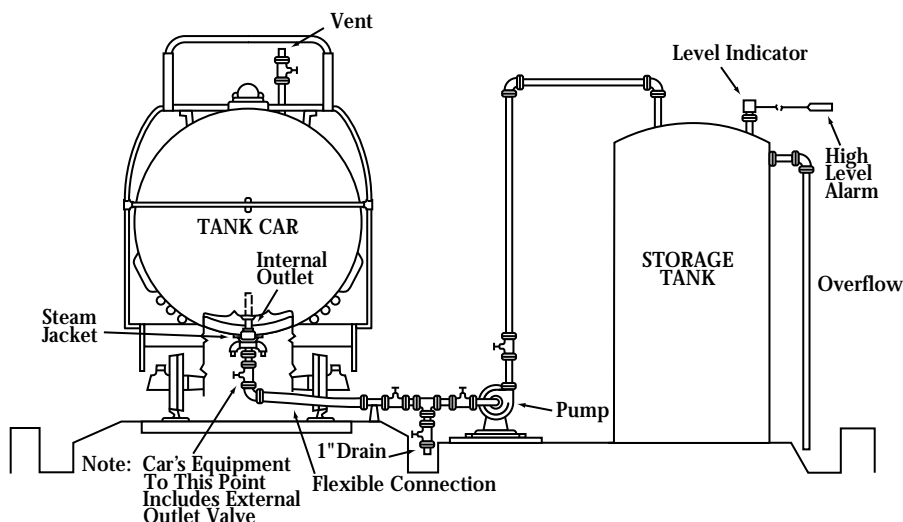
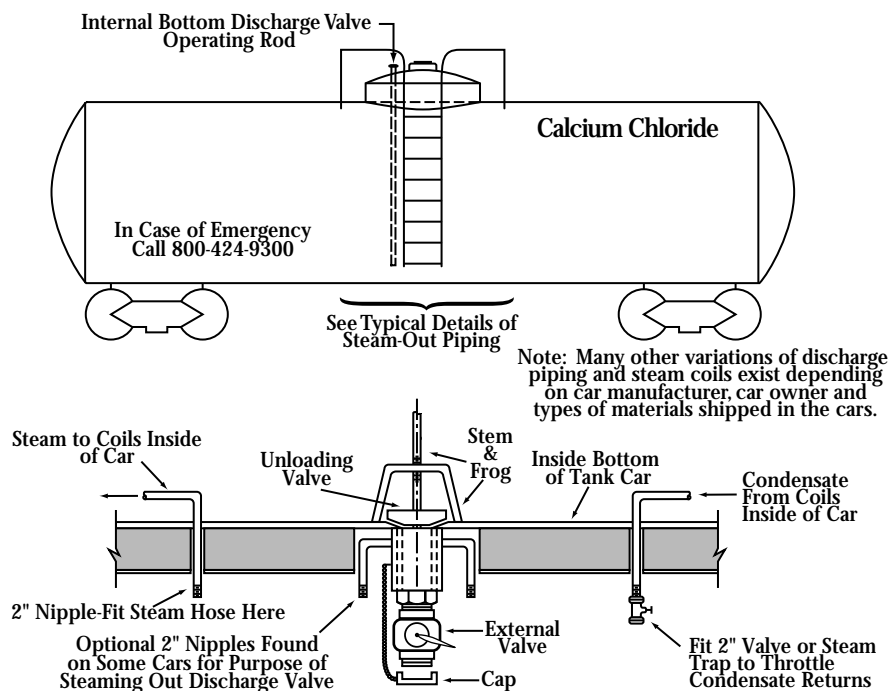


Figure 14 — Steam Coil Piping Diagram



[†]If the outlet valve handle does not turn with moderate pressure, or if calcium chloride does not start to flow, it indicates that frozen calcium chloride is present in the bottom of the car and steaming is necessary. DO NOT ATTEMPT TO FORCE THE HANDLE. See section "Railway Tank Car Steaming" found on page 24 of this manual.

11. Shut off the air supply line and close the valve to the storage tank.
12. Close the unloading valves on the rail car and carefully open the vent valve to completely relieve pressure.
13. Close the air inlet valve and disconnect the air supply line fitting from the air inlet on top of the car.
14. Prepare the car for return to Dow.

Railway Tank Car Steaming

Tank cars in service of LIQUIDOW calcium chloride are insulated to help prevent freezing. However, since commercial solutions do freeze at fairly high temperatures [42% solution begins to freeze at about 21°C (70°F)], transit delays during cold weather may cause some freezing. Therefore, it is always a good idea to check the solution temperature before unloading.

28 to 42% Solutions: If the temperature of a shipment of 28 to 42% solution is above 29°C (84°F), it can generally be unloaded without steaming. If the temperature is below 21°C (70°F), steaming is almost always necessary. Between 21°C (70°F) and 29°C (84°F), it is often a good idea to heat the car simply to reduce the viscosity of the solution for easier and faster unloading.

45% Solution: If the temperature of a shipment of 45% solution is above 35°C (95°F), it can generally be unloaded without steaming. If the temperature is below 26°C (79°F), steaming is almost always necessary. Between 26°C (79°F) and 35°C (95°F), it is often a good idea to heat the car simply to reduce the viscosity of the solution for easier and faster unloading.

Care in the Use of Steam

Steam pressure (150 lb maximum) should be built up gradually to avoid the rupture of the heating coils or steam jacketed outlet leg. Extreme care should be taken to keep the temperature of the contents below the point where the calcium chloride might expand and overflow the dome. Continued heating after the calcium chloride is liquefied will waste steam and may damage the special lining on the inside of the car.

The temperature of calcium chloride solutions should never exceed 79°C (174°F) in lined cars.

Never apply heat by blowing steam directly into a lined car without the express permission of Dow. Lined cars must not be used as mixing tanks.

Once the calcium chloride is completely in solution, the car is ready for sampling and unloading. Shut off and disconnect the steam lines before starting the unloading procedure. In extremely cold weather, continue the steam on the bottom outlet leg until the calcium chloride flow to storage has begun.

CAUTION: Continued steaming of the coils, after 1/4 of the solution has been unloaded, may cause severe damage to the lining of the car.

In cold weather, it may be necessary to preheat the unloading lines to prevent the lines from plugging. This can be done with a maximum of 15 psi steam tracing or by electrical heat tracing. Either way, the unloading line should be well insulated.

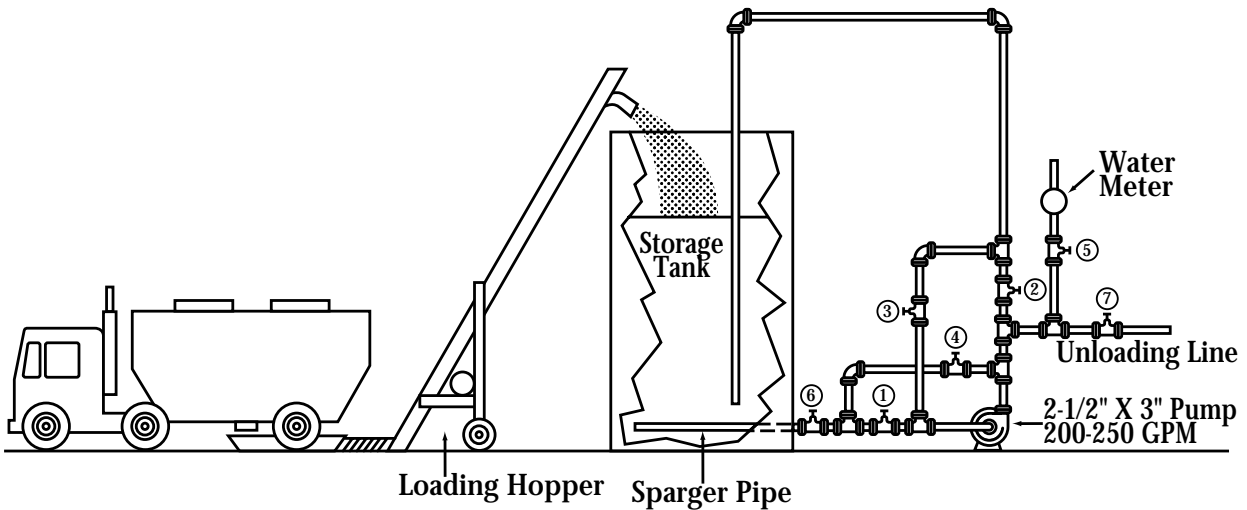
All horizontal portions of the unloading line leading to the top of the storage tank should be free-draining toward the tank. This will assure that this portion of the unloading line is empty except when unloading.

Preparing the Empty Tank Car for Return to Dow

Once the tank car has been unloaded, it should be promptly released to the railroad (customer must notify their local railroad that Car # "XXX" is ready to go) for return to Dow by reverse routing. If the railroad does not pick up the car after being released; the customer should contact Dow. The following procedure should be carefully followed in preparing the empty tank car for return:

1. Close the internal bottom outlet valve. Close the external bottom outlet valve, disconnect the unloading line carefully and replace the bottom external outlet valve plug securely.
2. Disconnect the steam lines and blow out the heating coils with compressed air. Do not replace the caps on the inlet and outlet steam connections; let them hang by their chains.
3. If steam has been applied to the steam jacket of the bottom outlet leg, do not replace these caps after the steam line has been disconnected. Allow them to hang by their chains; otherwise the bottom outlet leg may freeze and crack.
4. After removing all connections, replace the closures on all other tank openings. Fasten the dome cover securely.

Figure 15 — Simple Piping Diagram for Mixing Tank for Truck Delivery



Dissolving Hopper Car and Truck Shipments of DOWFLAKE or PELADOW Calcium Chloride

Solid calcium chloride can be transported by hopper car or truck to a dissolving and storage tank. Figure 15 shows a typical design and gives operation instructions for unloading and dissolving from a truck. A similar arrangement can also be used for hopper cars.

Verify the weight and assay of calcium chloride in the hopper car or truck with Dow. Given this information, and the strength of the desired solution, formulas found in the "Physical Properties" section of this manual can be used to determine the amount of water needed for solution makeup. The use of any additional water will lower the strength of the final solution.

CAUTION: An extreme rise in temperature accompanies dissolving of calcium chloride in water. Do not use hot water. Hot solutions may cause thermal burns, care should be exercised to avoid contact. For complete information, see the Material Safety Data Sheet.

Hopper Car and Hopper Truck Shipments

The unloading procedure to follow is detailed below. Refer to Figure 15.

1. Place the required water in the dissolving tank by opening Valves 2 and 5 and closing Valves 1, 3, 4, 6 and 7.
2. Prime the pump by opening Valves 1, 2 and 6 and closing all other valves. Start the pump and operate until water is circulating bottom to top in tank.

3. Stop pump. Open Valves 3, 4 and 6; close others and start pump. This reverses the flow of liquid by pumping from the top of the tank into the bottom through a specially designed sparger pipe.
4. Elevate the calcium chloride by conveyor, or other means, into the top of the dissolving tank while continuously circulating the solution. When the dissolving is complete, the result will be a solution of the required specific gravity.
5. To empty the dissolving tank of final solution, open Valves 1, 6 and 7 and close all other valves. Start pump.

Materials of Construction Guidelines

Storage Hoppers and Silos for Dry Calcium Chloride

Carbon steel is suitable for both storage hoppers and silos. In general, 1/8-inch to 3/16-inch material should be added to the thickness to allow for normal corrosion losses. Silos should be of seal welded construction. Entrances and other openings of both units should likewise be gasketed to minimize the admission of moisture.

NOTE: Lab and field experience indicate that some aluminum alloys (5454, 5052) may be acceptable in dry calcium chloride service, however, performance data is limited.

Where special corrosion problems, or product quality requirements exist, synthetic coatings may be applied to the carbon steel surface. The type of coating selected will greatly depend upon the particular system design; the following types of coatings have proven effective:

1. Polymerized Epoxies
2. Vinyl Ester Resins

It is important to install all coatings in strict accordance with the manufacturer's instructions and practice preventive maintenance to assure long life for the coating.

Storage Tanks for Liquid Calcium Chloride

Calcium chloride solutions are heavier than water. Design storage systems accordingly.

1. Storage Tanks

Construction can be of either mild steel (preferably lined), fiberglass

or polyolefins. When specifying fiberglass or polyolefins, check with the supplier about performance for your operating conditions (temperature, load, susceptibility to bumping). Vents, manholes, overflows and proper pipe fittings should be included with the tanks.

For intermittent service using a steel tank, a protective coating on the inside of the tank is recommended. Refer to the list in the previous section on solid calcium chloride storage for acceptable coating types. Without a protective coating, a steel tank would be expected to corrode 2–20 mils per years. Iron-based corrosion products could contaminate and discolor the product.

A secondary containment dike may be required by law or regulation to contain spills.

2. Piping

Depending upon the product being stored, it might be necessary to use materials capable of withstanding temperatures up to 107°C (225°F). In that case, steel, plastic lined steel or other compatible materials will do the job. If temperatures will not be excessive [$<71^{\circ}\text{C}$ (160°F)], PVC pipe and fittings or other suitable nonmetals are acceptable. Selection of line sizes will be controlled by product flow rate, system design and pump specifications. Sizes should be established in conjunction with the pump supplier.

Connections to the tank car or truck, or sparger car, should be flexible hose to allow greater

flexibility in spotting tank cars. Thinwall pressure hose should not be used for suction or siphoning.

3. Pumps

Generally, if the pump supplier is given a description of the duty required (total head against which the pump is to operate and the density and temperature of the material to be pumped), they will make recommendations for materials of construction for the casing, drive shaft and impeller. A direct-drive, centrifugal pump having a capacity of at least 250 gpm will give optimum service. For long life, the motor speed should be 1750 rpm or less.

A pump of carbon steel construction is recommended. However, pumps constructed of Hastelloy alloy 20 have shown to be resistant to the effects of calcium chloride.

Packing seals for the pump should be made of graphite-impregnated Teflon® fluoropolymers, or mechanical seals.

4. Meters

Flow meters, such as magnetic flow, mass flow and turbine type, and density meters, such as U-tube and nuclear, have been successfully used in calcium chloride service. All meters should record total gallons and be kept in good operating condition. No aluminum or aluminum alloys or synthetics other than Teflon® fluoropolymers, Vitron 1 and neoprene should be incorporated with the meter.

5. Valves

Cast steel, iron and ductile iron lined with Teflon® fluoropolymers are suitable for general use with calcium chloride. Longer service life will be experienced under air-free (continuous use) conditions.

Valve life will be lengthened by keeping the valve yokes and stems clean and properly lubricated. Teflon® fluoropolymer or graphite impregnated packing should be used.

CAUTION: Yellow brass is not a suitable material for use with LIQUIDOW calcium chloride.

6. Pressure Gauges

Gauges should be provided at the pump, before and after filters and near the process incorporating calcium chloride. They should be protected by a sealed diaphragm filled with non-hydrocarbon fluid. Gauges are also advisable on steam and air lines and on equipment where gases or liquids are handled.

7. Sample Valve

Three-quarter-inch valves terminating in a steel nipple should be provided as needed in each system to enable product sampling.

8. Strainers (Optional)

Use steel-cased, dual-line strainers having 100-mesh reinforced wire screen baskets. The unit should be equipped with a control valve enabling one side to continue in operation while the other is being serviced. It is suggested that strainers be used on truck unloading lines close to the tanks and that filters be used on the process line close to the process.

9. Filters (Optional)

Filter(s) should be sized for the desired flow rate. Generally, 100 micron elements are suitable. However, filters down to 25 microns have been successfully used for additional removal of insoluble material.

10. Temperature Indicators

The temperature of the products may be accurately monitored with a dial thermometer installed in a thermo-well.

11. Level Indicator

The product level in tanks should be measurable to determine inventory.

12. Electrical Equipment

Calcium chloride brines can be corrosive to electrical equipment and cause malfunctioning. Exposed electrical equipment should conform to NEMA 4x standards as a minimum. Electric motors should be totally enclosed fan-cooled (TEFC) with adequate horsepower. Guidelines for push-button (PB) or motor-starting:

1. Clean dry areas — PB station complete with oil-tight enclosure.
2. Outdoors, wet or corrosive areas — PB station complete with NEMA 4x glass polyester enclosure with acrylic nameplate.
3. Terminal boxes — NEMA 4x.

Environmental Considerations

Calcium chloride is refined from naturally occurring brine materials which are relatively low in toxicity and should present no unusual hazards to the environment under most circumstances.

Users of calcium chloride should abide by all local, state and federal laws and regulations concerning air and water discharges.

Health Hazards and Handling Precautions

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

Reasonable handling, care and cleanliness plus the use of safety goggles should be sufficient to prevent injurious contact under normal operating conditions. Where temperatures are above 52°C (125°F) or if the possibility of contact exists, further personal protective measures may be necessary.

For complete health hazard and handling information, see the Material Safety Data Sheets (MSDS) for the specific calcium chloride product. Different handling conditions may dictate more stringent safety precautions given in this section. All persons who may be involved with calcium chloride handling should review the MSDS.

Oral Toxicity

This product is low in single dose oral toxicity. It is not likely to pose a problem from ingestion of small amounts due to normal handling. However, deliberate ingestion of larger amounts may cause injury in the form of irritation to the mouth, throat and gastrointestinal tract.

Eye Contact

Because calcium chloride is a concentrated inorganic salt, it may cause moderate to severe eye irritation with possible corneal injury. Heat generated by dissolving solid calcium chloride may cause more intense effects due to thermal burns.

Contaminated eyes should be flushed thoroughly with copious quantities of flowing water for at least 15 minutes; get medical attention promptly.

Skin Contact

Short single exposure is not likely to cause significant skin irritation. Repeated or prolonged exposure may cause skin irritation or even a burn. Effects may be intensified on wet or abraded skin. **HOT SOLUTIONS WILL CAUSE THERMAL BURNS AND INTENSIFY CHEMICAL EFFECTS UPON CONTACT.**

Calcium chloride is not likely to be absorbed through the skin. However, where gross skin contamination with solid CaCl_2 or solutions does occur, the affected area should be washed thoroughly with plenty of water while removing contaminated clothing. Thoroughly wash contaminated clothing before reuse.

Inhalation

Vapors are unlikely due to physical properties. Mists and dusts may cause irritation to the upper respiratory tract. Provide adequate ventilation.

Additional Precautions

It should be emphasized that in dissolving solid or diluting concentrated liquid calcium chloride, considerable heat will be generated.

Thus one is cautioned against building up pressure in a closed container and advised to avoid contact with hot equipment or hot solutions. Never use hot water to dissolve solid calcium chloride.

Leather clothing (gloves, shoes) may be stiffened and ruined if they come into contact with calcium chloride.

Disposal Precautions

When disposing of calcium chloride solutions (for example, when cleaning out mixing and processing equipment), care should be taken to prevent the brine from entering drinking water supply wells or from spreading onto plants and shrubbery in excessive amounts.

The addition of water (free from objectionable matter) to the brine may adequately dilute its concentration within acceptable limits for sewer disposal as allowed by federal, state and local regulations. For further information pertinent to specific disposal conditions, contact federal, state or local authorities.

For more information, call

1-800-447-4369

Or visit us on the web at

www.dowcalciumchloride.com

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