$MgCl_2$ MAGNESIUM CHLORIDE

TECHNICAL MANUAL

North American Salt Company
A Compass Minerals Company

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A Compass Minerals Company

INTRODUCTION

This manual is meant to provide a point of reference for technical data relating to Magnesium Chloride for FreezGard®, DustGard® and MagnaPro® product lines. The manual is by no means exhaustive and new data and information will be periodically reviewed and added to ensure the content of the manual is up to date and relevant.

FreezGard® MAG CHLORIDE LIQUID DE-ICER™

DustGard® MAG CHLORIDE ROAD STABILIZER™

MagnaPro® INDUSTRIAL USE MAGNESIUM CHLORIDE

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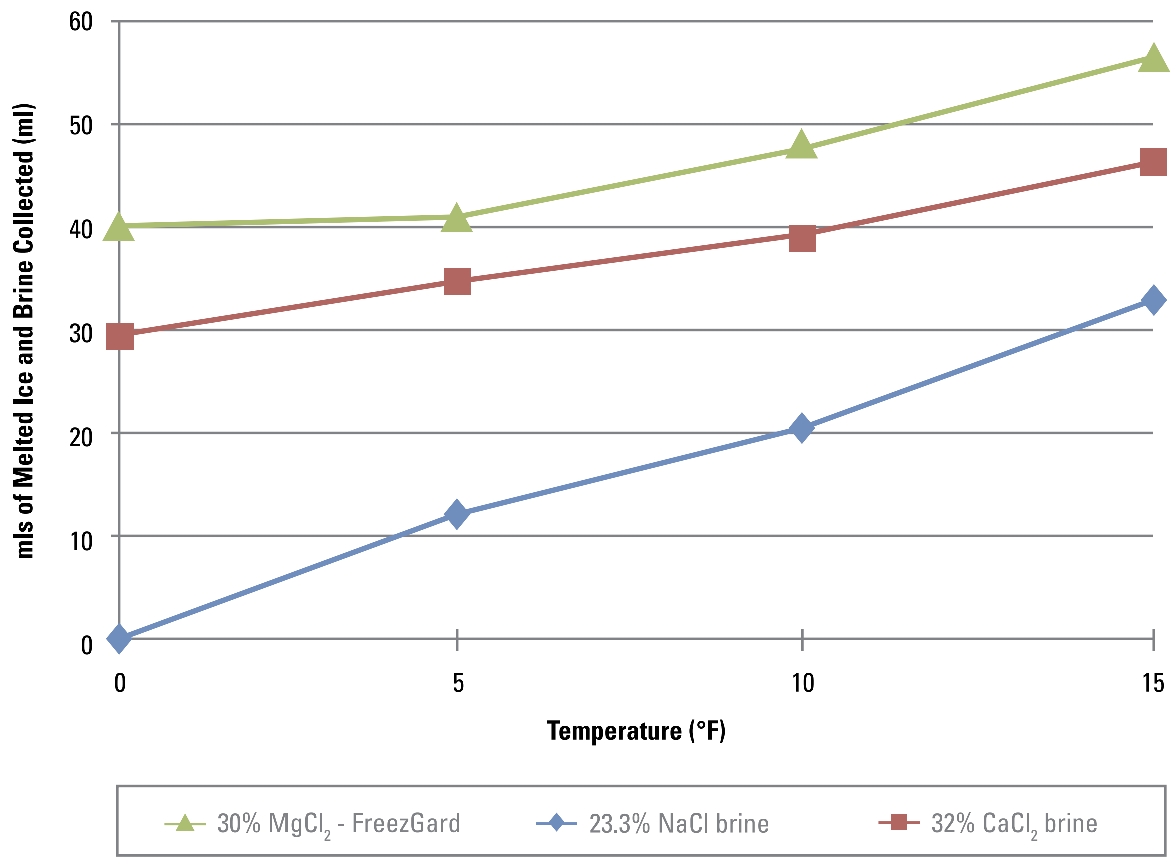
ICE MELTING PERFORMANCE

Test protocol: All ice melt tests were conducted using a modified test protocol from the federally funded Strategic Highway Research Program. 200ml of distilled water was frozen in stainless steel trays (W19cmxL29cmxD13cm) to the prescribed temperature. 25ml of each de-icer was cooled to the prescribed temperature. The de-icers were pipetted over the ice and the testing commenced. Brine samples were collected at 60 minutes. Values include 25ml of liquid deicer applied.

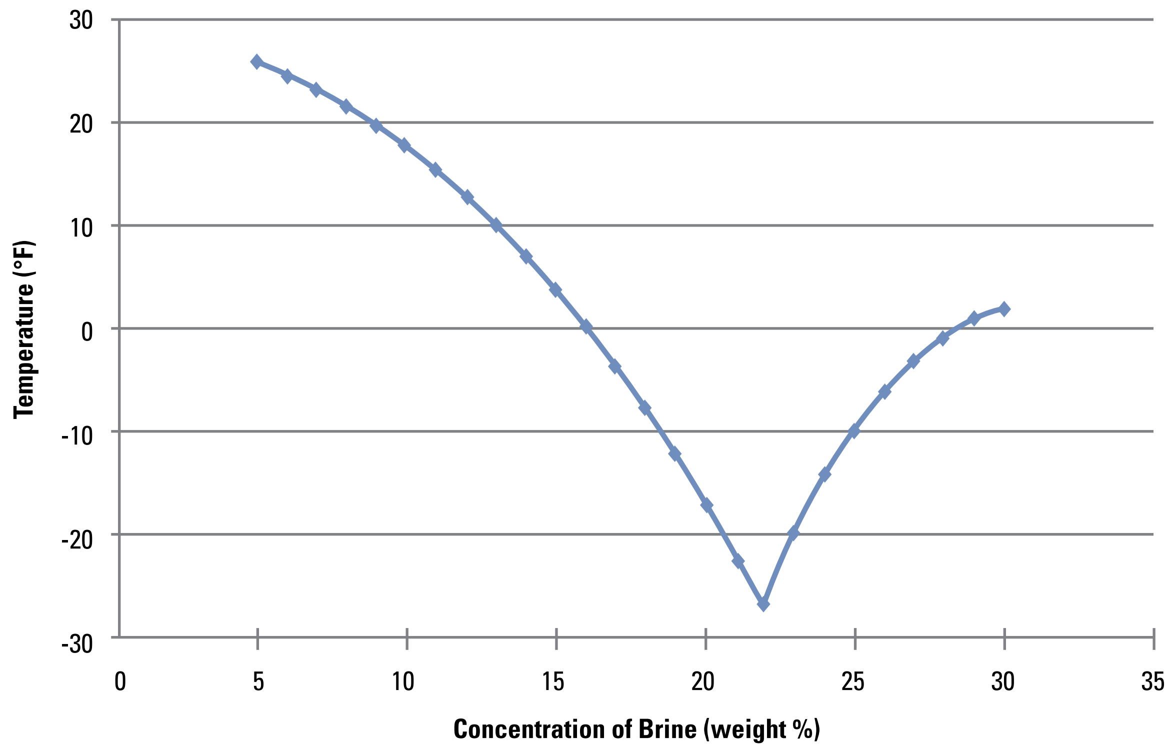
MODIFIED 60MIN SHRP H-205-2 ICE MELTING CAPACITY



$MgCl_2$ SOLUTION FREEZE CURVE (EUTECTIC)

This freeze curve depicts what often occurs when magnesium chloride is used in deicing applications. As the initial 30% $MgCl_2$ solution melts ice or becomes more dilute from snow or rain, the freezing point of the entire solution decreased until it achieves the eutectic point or lowest freezing point. Further dilution causes the freezing point to increase and approach the freezing point of water. The eutectic composition for the $MgCl_2$-water system in this figure is 22% $MgCl_2$ and 78% water by weight which freezes at -27ºF.

$MgCl_2$ SOLUTION FREEZE CURVE (EUTECTIC)



Concentration (% $MgCl_2$)	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Freezing Point (ºF)	26.4	25	23.5	21.8	20	17.9	15.7	13.1	10.3	7.3	4	0.4	-3.5	-7.7	-12.2	-17.3	-23	-27	-20	-14	-10	-6	-3	-1	1	2

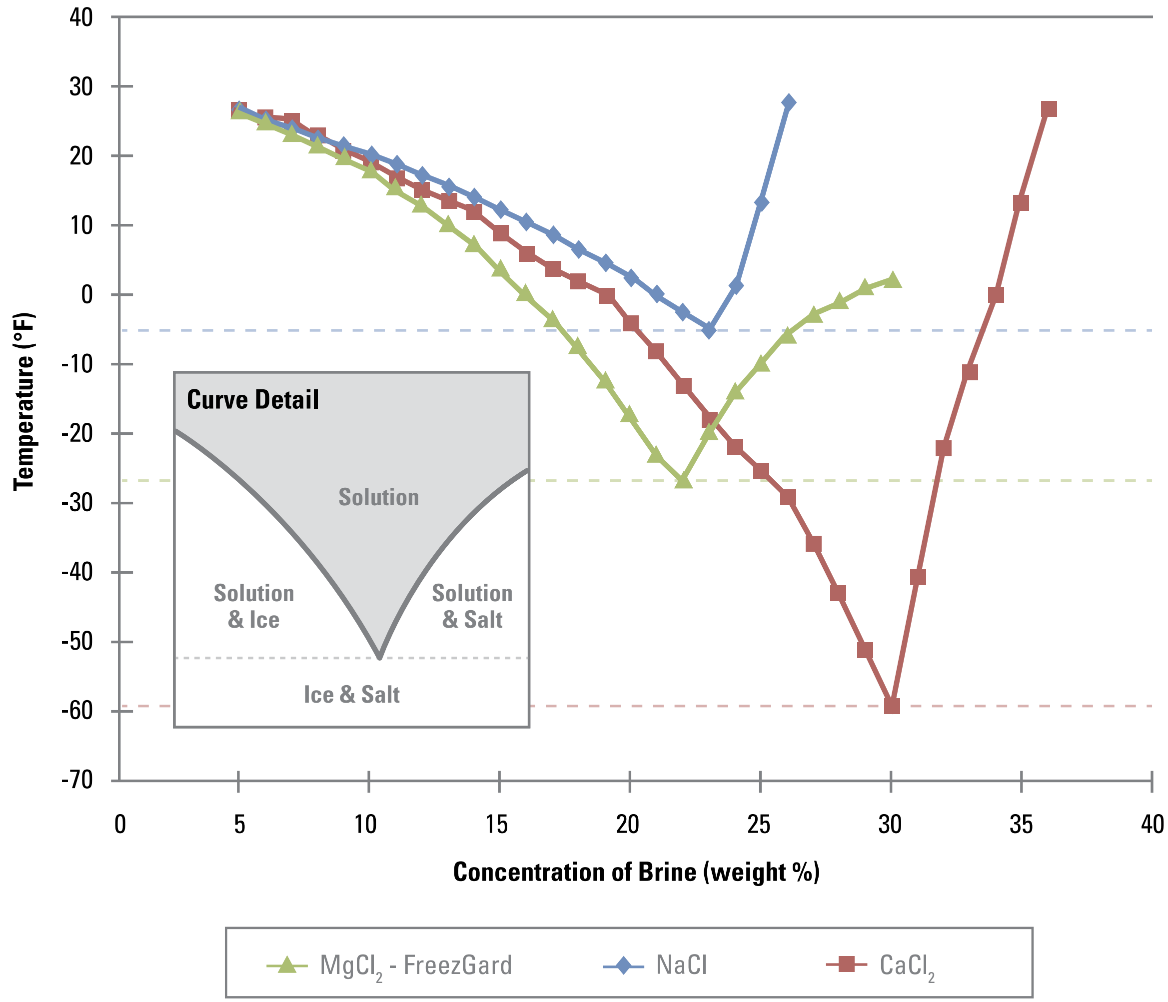
DE-ICER SOLUTION FREEZE CURVES (EUTECTIC)

The freezing point of a brine can best be described by reference to the phase diagram of a salt-water solution as shown. Above this curve, the salt is totally in solution. The lowest temperature on the curve is called the eutectic temperature. Below this temperature (and below the dashed line), no solution exists, only a mixture of ice and solid salt. A mixture of ice and salt solution exists to the left of the solid curve and above the dashed line. A mixture of solid salt and salt solution exists to the right of the solid curve and above the dashed line. Thus, the solid curve describes the freezing point of a brine as a function of the concentration of the salt solution.

*The freezing point of the brine solution decreases with increasing concentration up to the eutectic composition. The freezing point of the brine solution will increase as the concentration increases beyond the eutectic composition.

*Brine solutions having a concentration less than the eutectic composition have a freezing point lower than the melting temperature of pure ice or 32ºF.

SOLUTION FREEZING POINT CURVES



THE THERMOCHEMISTRY OF THE HYDRATES OF $MgCl_2$

Magnesium chloride is very hygroscopic. Water can become chemically bound to form a series of hydrate compounds ($MgCl_2 . nH_2O$, n = 1, 2, 4, 6, 8, 12).

At room temperature the most fully hydrated form of magnesium chloride is the hexahydrate, $MgCl_2 . 6H_2O$. Its dehydration proceeds by the following reaction:

$MgCl_2 . 6H_2O(s) = MgCl_2 . 4H_2O(s) + 2H_2O(v)$

Over the temperature range 298-390K, where the solid hexahydrate is stable.

The dehydration of $MgCl_2 . 4H_2O$ occurs by conversion to the dihydrate by the reaction:

$MgCl_2 . 4H_2O(s) = MgCl_2 . 2H_2O(s) + 2H_2O(v)$

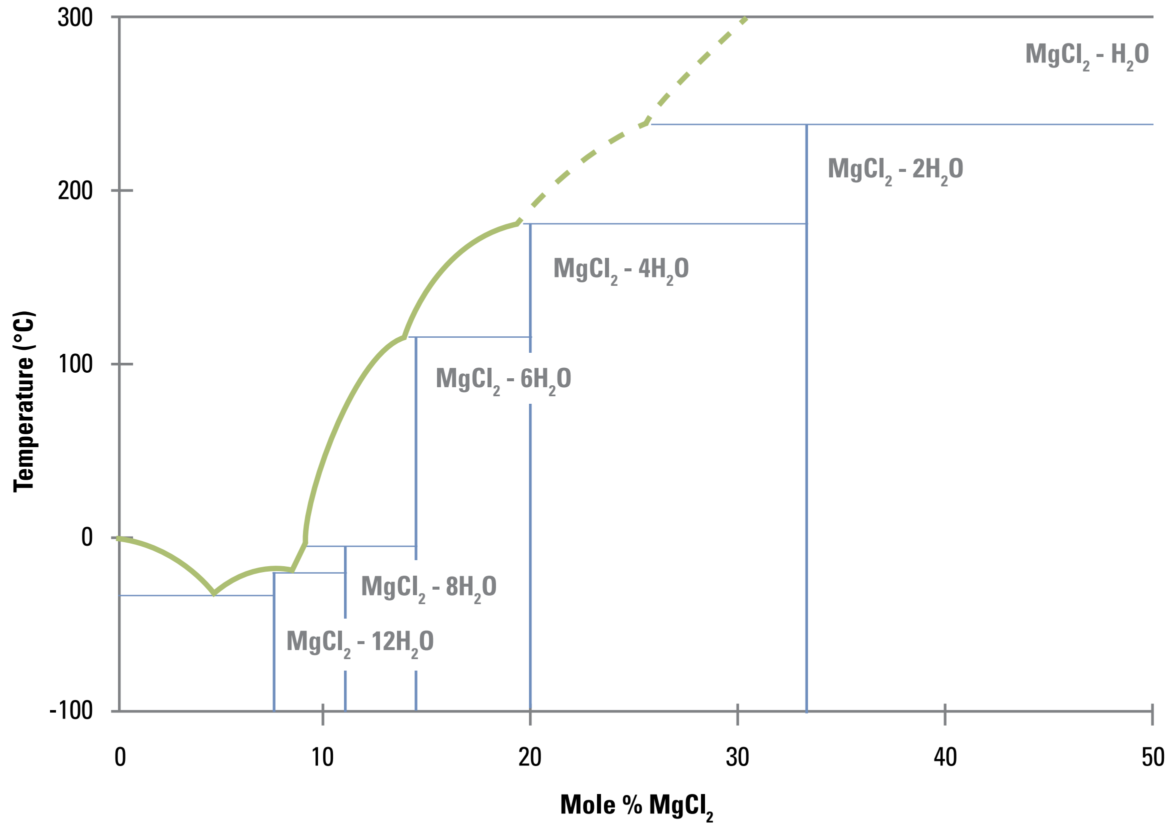
Dehydration of the solid dihydrate by conversion to the monohydrate occurs by the reaction:

$MgCl_2 . 2H_2O(s) = MgCl_2 . H_2O(s) + H_2O(v)$

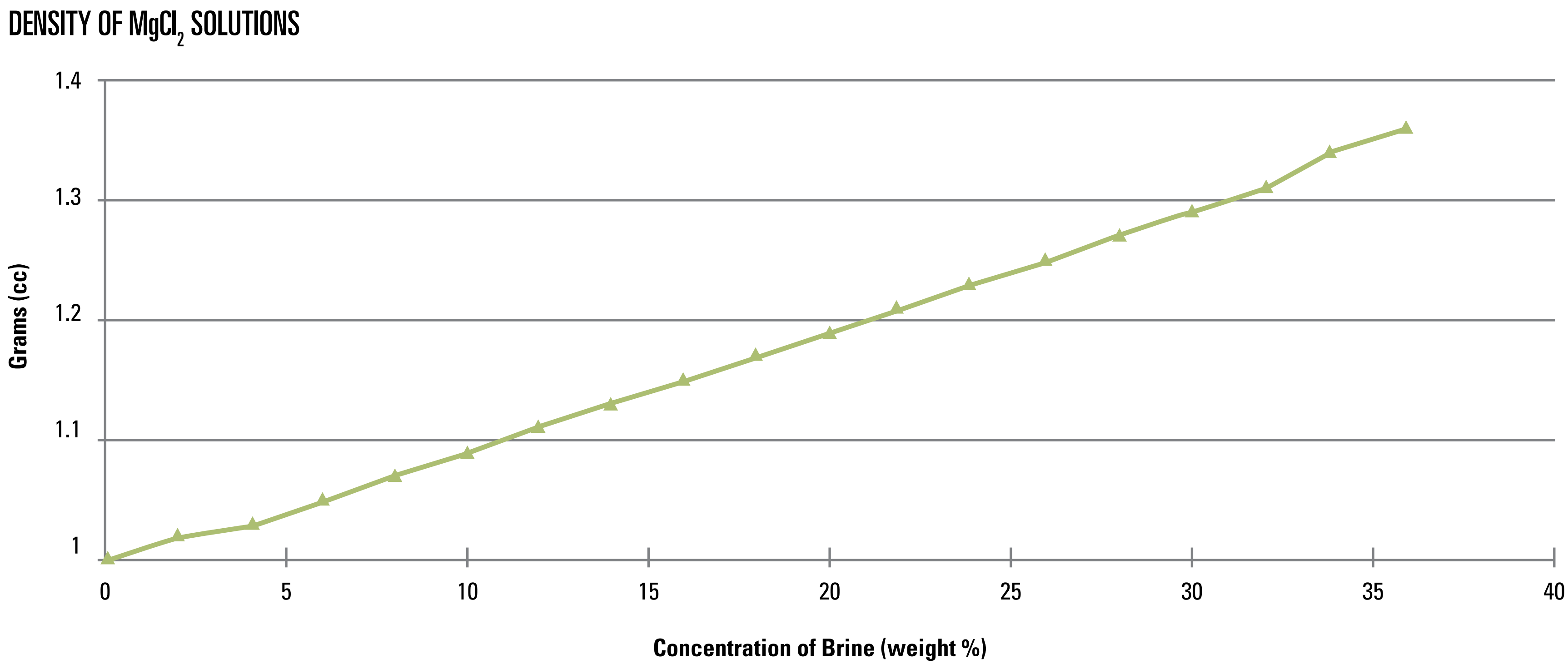
It should be noted that dehydration of the dihydrate can also proceed by hydrolysis:

$MgCl_2 . 2H_2O(s) = MgOHCl(s) + HCl(g) + H_2O(v)$

HYDRATED $MgCl_2$



DENSITY OF $MgCl_2$ SOLUTIONS



Concentration (% $MgCl_2$)	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36
Density g/cc	1	1.02	1.03	1.05	1.07	1.09	1.11	1.13	1.15	1.17	1.19	1.21	1.23	1.25	1.27	1.29	1.31	1.34	1.36

MIXING INSTRUCTIONS FOR $MgCl_2$ BRINE PRODUCTION FROM $MgCl_2$ CRYSTALS

To add water to FreezGard crystals to achieve a pre-determined concentration, follow the chart below. The first column shows the quantity of crystals to be added to a gallon of water. The second can be used with an existing tank or vessel of known quantity. In the second case, multiply the capacity of the tank (gallons) with the number shown in the column and add that quantity of crystals. Then, fill the rest of the tank with water. Converting crystals to liquid can be helpful in deicing application, for horse arena dust control, and for other industrial uses.

Desired (% $MgCl_2$)	lbs $MgCl_2 . 6H_2O$ Crystals per Gal Water	lbs $MgCl_2 . 6H_2O$ Crystals per Gal of final solution
0	0.00	0.00
2	0.37	0.36
4	0.78	0.73
6	1.23	1.12
8	1.72	1.52
10	2.27	1.94
12	2.87	2.36
14	3.56	2.81
16	4.33	3.27
18	5.21	3.74
20	6.22	4.23
22	7.39	4.73
24	8.77	5.25
26	10.42	5.79
28	12.41	6.33
30	14.88	6.89
32	18.01	7.47
34	22.13	8.06
36	27.76	8.66

EFFECT ON CONCRETE

In 2010, the Indiana Joint Transportation Research Project (INDOT JTRP) and Purdue University undertook a major research project to investigate the effects of de-icing chemicals on the durability of concrete.

The Purdue Study offered an important conclusion in the world of deicer vs. concrete testing. It demonstrated that accelerated testing of concrete under high temperature conditions produces an artificially high amount of damage. Lower temperature, longer lasting tests which more closely replicate deicing conditions showed that magnesium chloride is far less damaging to concrete than predicted from high temperature testing.

PURDUE STUDY OBJECTIVES

- To investigate the effects of de-icing chemicals on durability of concrete.
- To evaluate the chemical interactions of de-icing chemicals with concrete matrix and aggregates.
- To compare the effects of de-icing chemicals on plain (Type I) and fly ash (FA_{20}) concretes.

EXPERIMENTAL PARAMETERS

Previous studies utilized a wide range of de-icer concentrations, temperature and lengths of exposure cycles. Some combinations resulted in unrealistic exposure conditions, which might have affected the results.

This study used the same total ionic concentrations for all de-icers, realistic (in terms of temperature and duration) freezing and thawing cycles and also realistic (in terms of temperature and concentrations) wetting and drying cycles.

The Wetting - Drying (WD) cycles

- 16 hours of wetting (submerged specimens) at 4°C (40°F)
- 8 hours of drying (out of the solution, 23°C (73°F)

The Freezing-Thawing (FT) cycles

- 6 hours long cycles (-20°C to +20°C (-4°F to 68°F)

Simulation of realistic conditions is mostly based on the fact that the study attempted to replicate the conditions in the sealed joints of the pavements, which are the places typically undergoing deterioration upon damage to the sealant. At these locations, there is an accumulation of concentrated salt brine, which will continue to infiltrate the microstructure of concrete not only during the winter but also during the summer season.

EFFECT ON CONCRETE

MAIN FINDINGS:

- Plain concrete specimens (made with Type I Portland cement) stored in calcium chloride solution and exposed to wetting/drying (WD) cycles exhibited significant surface deterioration. Testing of these specimens needed to be halted after 168 WD cycles as at this point the spalling became quite excessive and it became difficult to reliably measure the relative dynamic modulus of elasticity.
- In contrast, specimens exposed to $MgCl_2$ solution did not develop any signs of surface deterioration until after experiencing about 275 WD cycles and the overall deterioration remained light until the termination of the test (after 350 cycles).
- Plain concrete specimens (made with Type I Portland cement) stored in calcium chloride solution and exposed to Wetting/Drying (WD) cycles exhibited significant mass loss due to severe spalling of the edges. In contrast, specimens stored in magnesium chloride did not experience any mass loss even when exposed to a total of 350 WD cycles solution (i.e., after experiencing more than twice the number of WD cycles than specimens exposed to $CaCl_2$ solution).
- Specimens exposed to $CaCl_2$ solution exhibited early (after 20-30 cycles) decrease in the value of relative dynamic modulus of elasticity (RDME). The RDME was reduced by 20% (from the original value) after about 154 WD cycles.
- Although specimens exposed to the $MgCl_2$ solution started showing similar rate of decrease in the value of the RDME, this trend only started after about 200 WD cycles and the 20% reduction (from the original value) was observed only after 350 WD cycles.
- Plain concrete specimens (made with Type I Portland cement) stored in calcium chloride solution and exposed to freezing/thawing (FT) cycles exhibited continuous mass loss due to severe spalling of the edges. In contrast, specimens stored in magnesium chloride experienced continuous mass increase.
- However, even fly ash specimens exposed to $CaCl_2$ solution exhibited continuous, progressive loss in the value of the relative dynamic modulus of elasticity RDME during the duration of the test (i.e., 300 FT cycles). No such reduction was observed for specimens exposed to the $MgCl_2$ solution exposed to the same number of FT cycles.

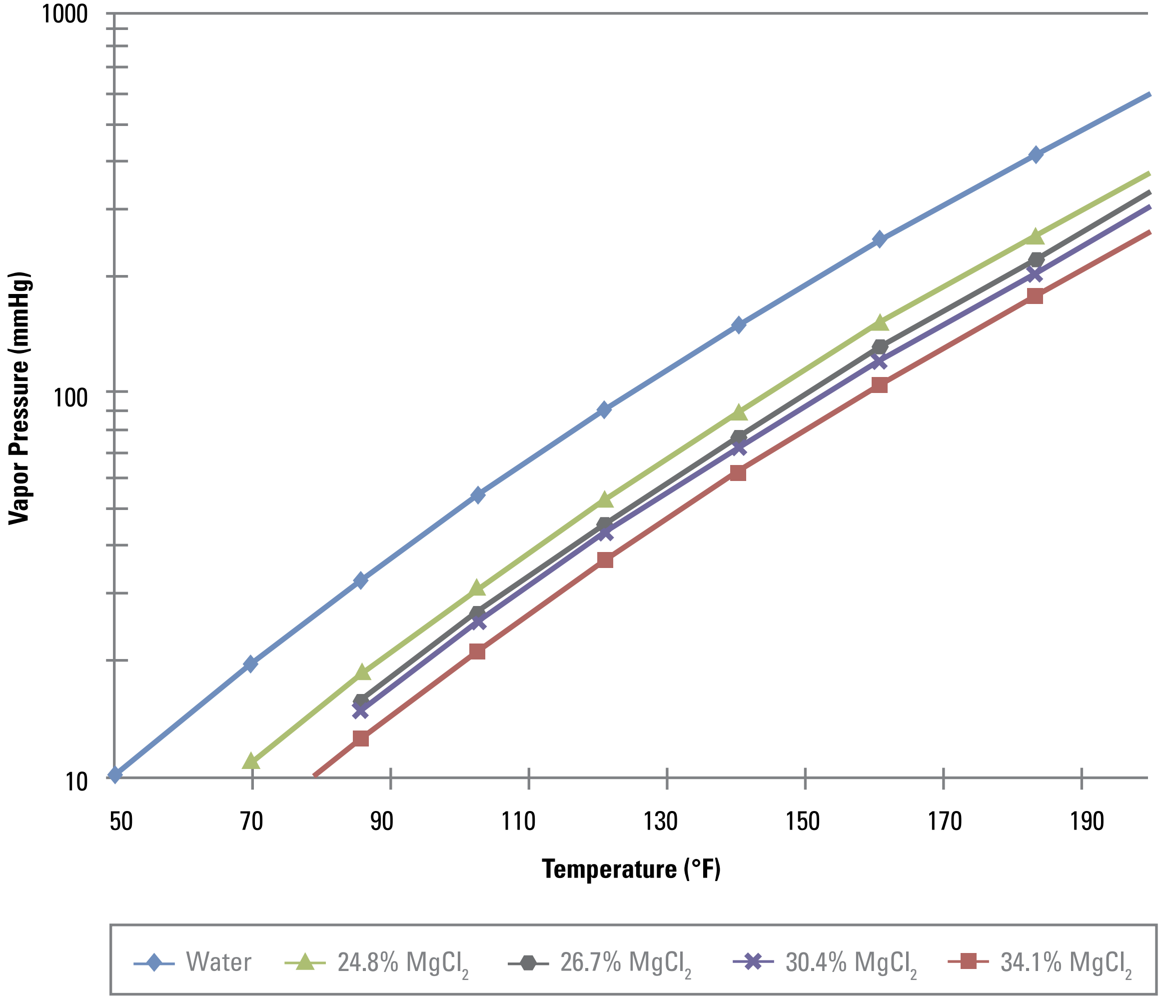
MAGNESIUM CHLORIDE
after 168 Freeze / Thaw cycles
in 15% $MgCl_2$ solution

CALCIUM CHLORIDE
after 168 Freeze / Thaw cycles
in 17% $CaCl_2$ solution

VAPOR PRESSURE

Vapor pressure is the pressure exerted by a vapor in thermodynamic equilibrium with its condensed phases (solid or liquid) at a given temperature in a closed system. The equilibrium vapor pressure is an indication of a liquid's evaporation rate. It relates to the tendency of particles to escape from the liquid (or solid).

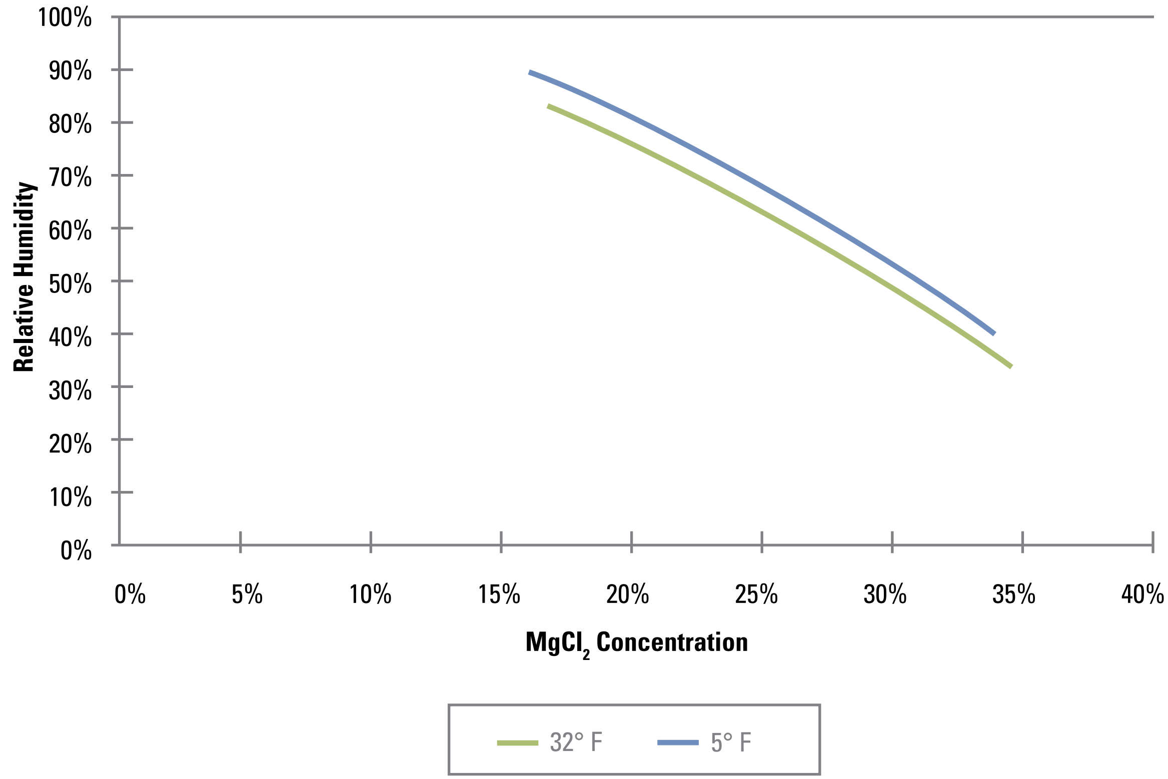
VAPOR PRESSURE OF $MgCl_2$ SOLUTIONS



RELATIVE HUMIDITY

Relative humidity is the ratio of the partial pressure of water vapor in an air-water mixture to the saturated vapor pressure of water at a given temperature. At humidity conditions above the line, the solution will tend to absorb atmospheric moisture until it reaches equilibrium. At humidity conditions below the line, the solution will dehydrate until it achieves equilibrium. The rate at which the solution will absorb or dehydrate depends on a variety of conditions.

EQUILIBRIUM $MgCl_2$ VS. RELATIVE HUMIDITY



VISCOSITY

Product	Conc (%)	SG	Viscosity (cP)
$MgCl_2$	30%	1.3	7.0
KCl	24%	1.2	1.0
NaCl	26%	1.2	2.0
K_2SO_4	10%	1.1	1.1
Ethylene Glycol	100%	1.1	21.0
$CaCl_2$	40%	1.1	9.0

VISCOSITIES (cP) FOR AQUEOUS MAGNESIUM CHLORIDE

Conc (M)	20° C	25°C	30°C	35°C	40°C	45°C	50°C
0.1	1.040	0.933	0.832	0.753	0.682	0.618	0.567
0.5	1.209	1.069	1.960	0.868	0.789	0.715	0.654
1.0	1.461	1.295	1.162	1.049	0.949	0.861	0.786
1.5	1.791	1.587	1.419	1.277	1.153	1.043	0.952
2.0	2.221	1.900	1.761	1.573	1.416	1.279	1.163
2.5	2.804	2.462	2.193	1.964	1.759	1.585	1.432
3.0	3.607	3.156	2.794	2.491	2.219	1.994	1.802
3.5	4.700	4.082	3.597	3.189	2.832	2.543	2.281
4.0	6.242	5.439	4.703	4.158	3.671	3.262	2.899
5.0	12.94	10.91	9.374	8.131	7.089	6.218	5.507

LIQUID $MgCl_2$ SPILL CONSIDERATIONS

- Magnesium chloride is a naturally occurring mineral which is generally regarded as non-hazardous.
- Since liquid $MgCl_2$ is often sprayed directly on road surfaces, minor spills should not present environmental problems under most circumstances. However, local, state/provincial, and federal regulations should be followed for all spills.
- Large releases can upset ecological conditions and should be cleaned up promptly.
- During spill cleanup, suitable personal protective equipment should be worn.
- Free standing liquid $MgCl_2$ should be pumped into a container for disposal in accordance with local, state/provincial, or federal regulations.
- Consult jurisdictional regulations for appropriate soil and air remediation requirements.
- Contact 800-693-3334 for additional information.