The use of magnesium chloride to improve storage and handling properties of deicing salt piles in sub-freezing weather

Jerry L. Poe

Technical Director, IMC Salt Company
8300 College Boulevard, Overland Park, Kansas 66210, USA

The paper will discuss the use of magnesium chloride to improve storage and handling properties in sub-freezing weather of deicing salt piles. The primary salt source will be the Canadian rock salt. Decrease in pile lumping from magnesium chloride addition at various levels will be discussed both from laboratory work and a practical study. An analysis of the enhanced melting performance from laboratory study of the magnesium chloride addition will be addressed. Finally, the economics of the addition of the magnesium chloride versus performance will be discussed

1. INTRODUCTION

In the past fifty years, the use of sodium chloride as a deicer on public roadways has been a standard practice. Sodium chloride has been viewed as the optimal balance between cost and performance. Sodium chloride will melt more accumulated ice on roadways per dollar than any other commercially available deicer in use today. The increase in highway safety by using salt a deicing medium as compared to no deicer is well documented.[1] In 1998, a total of ten million tons of salt was used on highways and streets in North America.[2].

Although, sodium chloride is the most cost effective deicer used today, it has a number of restrictions to its performance. Most notable of these restrictions to this report are the tendency of salt to freeze into lumps in sub freezing weather and reduced ice melting performance below fifteen degrees Fahrenheit. The lumps that form in storage piles are often quite large. They are usually the result of added moisture to the sodium chloride from the lack of a totally covered storage pile.

When treating deicing salt, sodium ferrocyanide (YPS) is added to prevent caking. Large lumps of salt are evidence of caking in salt piles. The caking is caused by brine that has collected on the surface of the salt crystal drying and fusing crystals together. The caking occurs many times to form the large lumps of salt. Lumps that are found in frozen salt are the result of brine freezing between crystals, which although similar in appearance, have a very different cause. Sodium ferrocyanide will significantly reduce caking in salt until the surface brine on the crystals is cold enough to freeze. When the brine freezes, the addition of an additive to lower the freezing point of the surface brine becomes necessary to prevent lump formation. The purpose of this work is determine an optimal level to add magnesium chloride brine to salt to enhance the freezing stability of a storage pile. Further to study the impact of the addition on storage characteristics of the salt and deicing performance.

2. EXPERIMENTAL

Samples of rock salt produced from the IMC Salt Company's Goderich Ontario Mine were obtained for study. The test was performed to determine a maximum level for the salt so that it can be handled and loaded into delivery vehicles successfully. This is a critical issue to consumers, and must be addressed, as vehicles are used from thirty thousand tons ships to one ton parking lot spreaders. The approach to testing was determined to be done at two levels.

2.1 Laboratory Flow Testing

The first approach was to use a laboratory procedure that involved spraying magnesium chloride brine at four different levels on rock salt and measuring flow properties through a calibrated flow test funnel with an opening of 23 millimeters. The test procedure used a funnel with adequate opening area to allow a 100 gram sample to pass through the opening in more than one second and with no more than four taps on the funnel to maintain flow. The test was performed on a blank, and levels of one, three, five, and seven gallons of magnesium chloride brine per ton rock salt. Flow testing was performed at intervals of one, four, and twenty-four hours after treatment. The results of this work are presented below.

Table 1
Flow Testing of Rock Salt with Various levels of Magnesium Chloride

Treatment Level Gal/ton	One Hour (sec.)	Four Hours (sec.)	Twenty Four Hours (sec.)
Control	1.34	1.36	1.36
1	1.41	1.34	1.39
3	1.54	1.60	1.51
5	2.07	2.20	2.23
7	2.35	3.91*	3.84*

*These tests each required the taps to discharge

The results showed that a maximum of five gallons per ton magnesium chloride added as a saturated brine with a concentration of thirty one percent could be added to the salt before the flow properties of the rock salt degraded below acceptable load and transport handling characteristics.

2.2 Pile Freezing Point Depression of Salt Pile Testing

As the freezing point depression of the magnesium chloride was the focus of this work, a procedure was generated to model the temperatures encountered during winter storage in North America. One hundred grams of rock salt of gradation between eight and ten Tyler Screen mesh (1.68-3.36 millimeters) was treated with magnesium chloride brines at the equivalent of one, three, five, and seven gallons of saturated magnesium chloride brine per ton of salt. In all cases, 3.26 grams of water was added to the salt. The weights ranged from a total water and magnesium chloride weight of 3.26 grams, in the blank to 3.68 grams in the seven pound per gallon treatment. It was felt that this would accurately model a salt pile that was exposed to winter elements in North America.

The material was then placed on 7.5 centimeter glass dishes and placed in a constant temperature chamber at –6.7, -17.7, and –40°C. The piles were examined at the end of 60 minutes and ninety minutes to determine if freezing had occurred in any of the samples. The results are recorded below

Table 2
Pile Freezing Point Depression of Salt Pile Results at Ninety Minutes

Treatment Level Gal/ton	-6.7 (°C) Frozen	-17.7 (°C) Frozen	-40°C) Frozen
Control	Clumping	Yes	Yes
1	No	Yes	Yes
3	No	Yes	No
5	No	No	No
7	No	No	No

2.3 Outside Storage Testing

Outside storage testing was performed at the IMC Salt Mine in Goderich Ontario. The objective of the testing protocol was to determine the long term stability of salt treated with magnesium chloride during actual storage conditions. The environment at Goderich Ontario is a humid northern climate, due to the test area being adjacent to Lake Huron, of the Great Lakes, and was viewed as a worst case test site.

The test area consisted of five test stations. The site for each test station was leveled and a pit was dug in the center for a catch basin. The test area was covered with a twenty foot by twenty foot impermeable membrane that sloped to a central catch basin. In the catch basin was a one inch pipe that drained into a buried fifty five gallon drum. The drum was used to collect for quantification any brine leaching from the salt pile during treatment with magnesium chloride brine or subsequent storage.

Photograph 1
Placement Of Drum In Catch Basin

On each of the five test areas, ten tons of salt treated with different levels of magnesium chloride was placed. The piles were then covered with a top membrane to reduce direct contact with precipitation. A test site was established with no salt and used as a dry station. The station was set up to collect rainwater levels to deduct from the brine totals of the other test stations for an accurate measurement of the brine run-off..

Photograph 2
Completed Test Area

During the first fourteen days the piles were placed outside the average temperature was −1.8°C (28.8°F) and the relative humidity averaged at 55 percent. There were a two snow events during this time, but the covering on the piles prevented direct contact of the snow on the salt. At the end of fourteen days, the amount of brine in each of the drums were measured and the results were as follows:

Table 3
Results of Treated Salt runoff at Fourteen Days

Treatment Level Gal/ton	Drum Volume (U.S. Gal.)
Control	0
Control	0.0
4	1.0
5	8.5
6	25.6
7	31.6

2.4 Ice Melting Performance Testing

To complete the evaluation, an ice melting evaluation was performed. Although, the actual added levels of magnesium chloride added to the salt is low, some enhancement of performance could reasonably be expected due to the higher ice melting capacity of magnesium chloride. The Strategic Highway Research Program Procedure SHRP H-205.1[3] was used as a model to perform the tests. The results recorded below are for twenty minutes time periods at twenty degrees Fahrenheit. Testing was performed in duplicate and the results recorded below.

Table 4
Ice Melting Performance of Rock Salt with Various levels of Magnesium Chloride.

Treatment Level Gal/ton	Test 1 (ml)	Test 2 (ml)	Average (ml)
Control	4.95	5.02	4.99
1	5.64	5.27	5.46
3	6.26	6.41	6.34
5	7.41	7.56	7.49
7	7.42	7.20	7.31
9	7.62	7.74	7.68

3. CONCLUSIONS

After evaluating both testing in the laboratory and the field, a number of conclusions can be drawn from the data. Both flow testing and outdoor storage indicated that salt has a stable treatment range that that exhibits handling properties that are little degraded from untreated salt, but with enhanced pile freeze proofing. Handling is a significant portion of this work, but performance improvement was also noted and will be discussed.

3.1 Stability

A product must maintain free flowing characteristics so that it can both be loaded, but also unloaded or spread with a minimum of problems. The funnel flow test (Table 1) showed a dramatic decrease flow properties between five and seven gallon per ton magnesium chloride additive level. The time to discharge 100 grams of salt from the test funnel was 72% longer for 7 gallons per ton over five gallons per ton treatment after twenty four hours.

The Outside Storage Testing showed a substantially increased level of brine leaching from the salt at magnesium chloride additive levels above 5 gallons per ton. The results of a substantial amount of leachate could supply a set of environmental issues as well as housekeeping. On a storage and handling stability level, the five gallon per to additive level appears to be the maximum amount of additive that can be applied to retain long term storage and handling properties.

3.2 Performance

The laboratory scale freeze testing (Table 2) shows dramatic impact from the addition of magnesium chloride brine to deicing salt. The impact is a linear effect in the ranges of interest, with the more brine applied to the salt the lower the freeze protection. There is no optimal range in the case of brine addition. The amount added should be determined by flow characteristics (Table 1) and the associated freezing data will indicate the increase in freeze protection.

The ice melting data (Table 4) show a linear increase, as more magnesium chloride brine is added to the salt. The increase in melting performance from the magnesium chloride treatment is an expected but additional benefit to the freeze proofing treatment. Although, the ice melting performance result is expected to be modest as the amount of magnesium chloride brine applied to the salt, is in the range of one percent. The reason for the additional impact from the magnesium chloride to the ice melting performance of the salt is explained in the following section.

3.3 Advantages

Pre-wetting of salt before application is well known technique in North America.[4] The advantages of pre-wetting are twofold. The first is salt that is pre-wetted will have brine on the surface of the crystal which will accelerate the production of brine and improve ice melting performance. The pre-wetted salt will also perform to colder temperatures due to the efficiency of rapid brine production. The second advantage is that less of the pre-wetted salt will be lost during application as it has a higher tendency to stick to the application surface than bounce..

With these advantages from pre-wetting, the application of magnesium chloride to salt storage piles to prevent freezing will also have a major impact on the salt during deicing application. The effect on the salt from the added brine will be much the same as salt that is pre-wetted and have an increase performance from the additional magnesium chloride. Although, there is an ice melting increase from the added magnesium chloride brine, the impact of the in pre-wetting and freezing prevention will be more apparent.

The additional cost to treat the salt varies, but using current market values to treat salt at 5 gallons per ton would be an additional \$2.50 (USD) at \$0.50 per gallon of magnesium chloride brine at the Goderich Mine. With a delivered price of \$35.00 a ton, the additional cost would only be 7% of the delivered price. For the benefits listed above, this would appear to be a reasonable cost for the advantages listed.

3.4 Applicability

Applying magnesium chloride to deicing salt storage piles has all of the benefits mentioned above and has minimal additional cost per ton. The optimal rate of 5 gallons per ton will give storage pile freeze protection to -40^{0}C, prevent unwanted brine leaching from the pile, allow the salt to be delivered with good handling characteristics, and have the impact of pre-wetted salt upon application. With the advantages listed and the minimal cost, the addition of magnesium chloride brine would be of value in all deicing applications.

3.5 Suggestions

This paper has covered the advantages of using magnesium chloride to treat storage piles, other opportunities to explore from this text would be dry blending magnesium chloride with the treated salt to allow a lower effective ice melting temperature and greater performance. Another study would be examine the actual pre-wetting effect of magnesium chloride on salt as a separate entity. Additionally, the effects of calcium chloride on pile freeze proofing could also be studied.

REFERENCES

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