An *IPRF* Research Report

Innovative Pavement Research Foundation

Airport Concrete Pavement Technology Program

IPRF Report

Evaluation of Lab and Field Performance of LithMelt Deicer

Programs Management Office

5420 Old Orchard Road

Skokie, IL 60077

May 2010

An ***IPRF*** Research Report

Innovative Pavement Research Foundation

Airport Concrete Pavement Technology Program

Report IPRF 01-G-002-05-10

Evaluation of Lab and Field Performance of LithMelt Deicer

Principal Investigator / Coordinator

Prasada Rao Rangaraju, Ph.D., P.E.

Department of Civil Engineering

Clemson University

Clemson, SC 29634

Programs Management Office

5420 Old Orchard Road

Skokie, IL 60077

May 2010

This report has been prepared for the Innovative Pavement Research Foundation under the Airport Concrete Pavement Technology Program by Clemson University. Funding is provided by the Federal Aviation Administration under Cooperative Agreement Number 01-G-002-05-10. Dr. Satish Agarwal is the Manager of the FAA Airport Technology R&D Branch and the Technical Manager of the Cooperative Agreement. Mr. Jim Lafrenz is the Program Director for the IPRF.

ACKNOWLEDGEMENTS

The author would like to acknowledge the support of Innovative Pavements Research Foundation (IPRF) and Federal Aviation Administration (FAA) for sponsoring this study. Gratitude is expressed to personnel of Cryotech Deicing Technology and FMC Lithium Division for providing the deicers for this study, and Colorado Springs Airport (COS) for making their pavements available for application of the deicer and its field performance evaluation. In particular, thanks are extended to Mr. Troy Stover and Mr. Kevin Paradee of COS Airport for coordinating the field application and evaluation of deicers. Also, the efforts of SMI, Inc. and Keweenaw Research Center in evaluation of LithMelt deicer are appreciated.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

With growing concerns about the aggressive influence of potassium acetate based deicing chemicals on long-term durability of concrete pavements, LithMelt deicer was developed as a benign alternative that does not induce alkali-silica reaction distress in concrete or corrode metallic components while being safe for environment.

This report presents findings from laboratory and field investigation conducted to assess the properties and performance of LithMelt deicer. In this investigation, the potential of LithMelt deicer to cause alkali-silica reaction distress in mortar specimens containing a wide range of reactive aggregate mineralogy was assessed. In addition, the deicing and anti-icing performance of LithMelt in laboratory and field conditions was examined, and finally the conformance of LithMelt deicer to AMS 1435A guide specifications was critically evaluated. In each of these evaluations, the performance of LithMelt deicer was compared to Cryotech E36® deicer. The field evaluation of LithMelt deicer was conducted at Colorado Springs Airport, while the laboratory based investigations were conducted at Clemson University, SMI, Inc. and Keweenaw Research Center at Michigan Technological University.

Results from these studies indicate that the LithMelt deicer did not promote alkali-silica reaction in any of the test specimens compared to Cryotech E36® deicer solution. However, Cryotech E36® deicer caused substantial expansion and extensive cracking in all of the test specimens. Field studies suggested that LithMelt deicer could be easily pumped and sprayed using conventional equipment used on airfield pavements and its performance in this regard was very similar to that of Cryotech E36® deicer. In terms of the deicing and anti-icing effectiveness, LithMelt deicer was found to be less effective than Cryotech E36® deicer at the dosage rate that was applied in the field. Lack of adequate LithMelt deicer and dispensing equipment at the site prevented from conducting additional field trials to assess the effectiveness of LithMelt at higher dosage levels. LithMelt deicer was found to conform to all the requirements of AMS 1435 guide specifications for liquid runway deicing and anti-icing applications. LithMelt deicer did not exhibit any harmful impact on environment or other metallic hardware, and no flocculation or precipitation was noticed upon long-term storage. Based on these studies, LithMelt deicer can be considered to be a more benign deicer towards concrete pavements than other potassium acetate based deicers. However, the need to conduct additional investigation to determine more effective dosage rates in field was highlighted.

1. INTRODUCTION

Recent investigation into deterioration of concrete pavements at certain airports has indicated that alkali-aggregate reaction, in particular alkali-silica reaction (ASR), was the principal mechanism involved in causing the distress. Further laboratory investigations revealed that deicers such as potassium acetate and others that are routinely used on these pavements could have promoted these reactions and caused premature failure (Rangaraju and Olek, 2005).

In an effort to develop an alternate deicer/anti-icer that is not aggressive towards concrete durability while satisfactorily meeting the performance requirements of AMS 1435A specifications for runway liquid deicing/anti-icing agents, a lithium modified potassium acetate-based liquid deicing agent – LithMelt was developed by FMC Lithium Corporation. Lithium compounds when used in fresh concrete as admixtures have long been known to significantly mitigate ASR in concrete (McCoy et al. 1951; FHWA Lithium 2006). Indeed, several lithium-based chemical admixtures have been developed as effective mitigation measures for ASR when used as an ingredient in concrete. Topical application of lithium-bearing solutions on concrete surfaces affected by ASR has also been explored as a pavement rehabilitation measure. Although the primary purpose of the LithMelt is not topical treatment of ASR-affected pavements, its use as a deicer/anti-icer is expected to provide a much more benign environment than potassium acetate deicer/anti-icers, while effectively performing as a deicing and anti-icing agent.

The primary purpose of this investigation was to evaluate the performance of LithMelt as a deicing and anti-icing agent under lab and field conditions and its potential to cause ASR distress in laboratory test specimens. In addition, the impact of LithMelt on environment and other metallic and non-metallic hardware elements that are typically present on airfield pavements and aircrafts was also investigated. Also, in this investigation the performance of LithMelt was compared against the performance of Cryotech E36®, a widely used potassium acetate based deicing/anti-icing agent.

2. SCOPE AND OBJECTIVES OF THE STUDY

The four main objectives of this study are as follows:

1. Determine the potential of LithMelt deicer/anti-icer to cause alkali-silica reaction in concrete
2. Evaluate the deicing and anti-icing performance of LithMelt in lab conditions following the SHRP test procedures for ice melting, ice penetration and ice undercutting.
3. Investigate the field performance of LithMelt in deicing and anti-icing under typical winter-weather conditions. In particular, emphasis will be placed on:
    a. Comparing the relative effectiveness of LithMelt and Cryotech E36® in deicing and anti-icing of pavements through friction measurements on pavement surfaces
    b. Evaluate the ability of conventional delivery trucks, pumps and sprays to effectively handle and apply LithMelt deicer in field to adequately deice and anti-ice the pavement surfaces
    c. Evaluate if any flocculation of LithMelt deicer occurred under typical storage conditions
4. Evaluate the properties and performance of LithMelt deicer per AMS 1435A Specification. The specific aspects evaluated under this objective include:
    a. Physical and chemical properties and storage behavior of LithMelt deicer/anti-icer
    b. Biodegradability and ecological impact of LithMelt deicer/anti-icer
    c. Potential of LithMelt deicer/anti-icer to cause corrosion in metallic and degradation of non-metallic elements that are typically exposed on airfield pavements and aircrafts

The studies on the effect of LithMelt deicer on alkali-silica reaction in concrete were conducted at Clemson University. The deicing and anti-icing behaviors of LithMelt in lab conditions were evaluated by Keweenaw Research Center (KRC) at Michigan Technological University. The field evaluation of LithMelt deicer was conducted at Colorado Springs airport by the Airport Operations personnel at the COS airport. Finally, the testing of LithMelt deicer/anti-icer per AMS 1435A specification for its physical and chemical properties, effect on environment and metallic/non-metallic components, and storage behavior were conducted by SMI, Inc in Miami, Florida. In all of the studies, the performance of LithMelt was compared against the performance of Cryotech E36®.

3. MATERIALS

In this investigation two deicers were evaluated. LithMelt is a deicer/anti-icer solution based on lithium modified potassium acetate from FMC Lithium Corporation (LithMelt, 2008). Cryotech E36® is a potassium acetate-based deicer/anti-icer solution from Cryotech Deicing Technology division of General Atomics International Services Corporation (Cryotech, 2009).

3.1. Deicers/Anti-Icers

The LithMelt deicer is a 45% wt. solution of lithium acetate potassium acetate solution. This deicer is a clear to slightly tan clear solution with slight vinegar-like odor. It has a density of 1.248 g/cc (10.4 lb/gal) at 25°C and a pH of 10.8 - 11.4 at 25°C. The Cryotech E36® is 50% wt. solution of potassium acetate that has a clear-colorless to light straw-color. This liquid deicer has a specific gravity of 1.28 at 20°C and a pH ranging between 10.5 and 11.5 at 20°C. This deicer is often dyed blue.

3.2. Cement

The cement that was used in the evaluation of deicer's potential to induce ASR was a high-alkali Type I cement with an equivalent alkali content of 0.83% $Na_2O_{eq.}$

3.3. Aggregates

In this study, four types of reactive aggregates were used. These include:

Spratt Limestone – This aggregate is obtained from Spratt quarry in Ontario Province of Canada. It primarily consists of calcite with minor amounts of dolomite and about 10% insoluble residue. The reactive component of the rock is reported to consist of 3% to 4% of microscopic chalcedony and black chert, which is finely dispersed in the matrix (Rogers 1999). This aggregate has an established history of being alkali-silica reactive in field structures and has been used as a reference aggregate in numerous ASR studies.

NM Rhyolite – Reactive gravel from Las Placitas Gravel Pit from Bernalillo County in New Mexico. This aggregate primarily consists of rhyolite that has shown very high levels of reactivity (Barringer 2000, Touma et al. 2001).

NC Argillite – This aggregate is a quarried material from the slate belt of North Carolina from Goldhill Quarry in North Carolina. This aggregate primarily consists of reactive metatuff/argillite. This aggregate has an established history of poor field performance in several bridge structures in North Carolina (Leming et al. 1996).

SD Quartzite – This aggregate is obtained from crushing quarried rock from Dell Rapids quarry, located in the southeastern South Dakota. This aggregate consists of strained quartz grains that are cemented with interstitial secondary quartz cement. In addition, the interstitial matrix also consists of microcrystalline quartz, hematite and kaolinite. This aggregate has an established history of being reactive in concrete pavements in Minnesota and South Dakota (Rangaraju 2000).

4. EXPERIMENTAL PROGRAM

This section describes the experimental program for each of the four objectives of this investigation. The results from each of these investigations are presented in the section 5.1-5.4.

4.1. Effect of LithMelt and Cryotech E36® deicer on Alkali-Silica Reaction

In order to evaluate the effect of deicing chemicals – LithMelt and CryotechE-36 – on alkali-silica reaction in concrete, a series of mortar bars tests based on EB70 protocol were conducted. The EB-70 mortar bar test protocol is similar to the standard ASTM C 1260 test method with the exception that the 1 normal sodium hydroxide (1N NaOH) soak solution is replaced with potassium acetate deicer solution (such as Cryotech E36® deicer solution) as the soak solution (Engineering Brief No. 70, 2005). In case of tests with LithMelt deicer, the EB 70 test method was modified to replace the Cryotech E36® deicer with LithMelt deicer as the soak solution.

In these tests, a suite of four well-known alkali-silica reactive aggregates – Spratt limestone (Spratt), New Mexico rhyolite (NM), South Dakota quartzite (SD) and North Carolina argillite (NC) were used. Mortar bars prepared with these aggregates were subjected to respective deicer solutions and the length-change in the mortar bars was monitored over a period of 28 days. Mortar bar expansions that are less than 0.100 % at 14 days in the test were considered to indicate that the deicer solution was innocuous and did not promote alkali-silica reaction significantly.

4.2. Ice Melting, Ice Penetration and Ice Undercutting Ability of LithMelt and Cryotech E36® Deicers

The deicing and anti-icing performance of LithMelt and Cryotech E36® deicer/anti-icers, under lab conditions, was evaluated using test procedures described in the SHRP –H-332 publication (SHRP, H-332, 1992). This evaluation included the following test methods:

a. Ice Melting Test in accordance with SHRP H-205.2 Test Procedure – Test method for Ice Melting of Liquid Deicing Chemicals.
b. Ice Penetration Test in accordance with SHRP H-205.4 Test Procedure – Test method for Ice Penetration of Liquid Deicing Chemicals.
c. Ice Undercutting Test in accordance with SHRP H-205.6 Test Procedure – Test method for Ice Undercutting by Liquid Deicing Chemicals.
d. A non-standard lab friction test in accordance with a method developed at Keweenaw Research Center (KRC). This test was designed to produce results that are comparable to the results from SAAB friction tester.

A description of the test methods and detailed results are provided in Appendix A.

4.3. Deicing and Anti-icing Performance of LithMelt and Cryotech E36® in Field (COS Airport)

The effectiveness of deicers/anti-icers in restoring the frictional characteristics of the pavement is evaluated by measuring and comparing the braking performance of the pavement before and after application of the deicers. The braking performance of the pavement was determined using a TES Instrument – Mk3 Electronic Decelerometer. The TES values that indicate different levels of pavement braking performance are as follows (see Table 1):

Table 1 – Relation between TES Values and Braking Performance

TES Value	Braking Performance
0.20 and less	NIL
0.30 – 0.40	POOR
0.40 – 0.50	FAIR
0.50 and above	GOOD

The field performance of the LithMelt and Cryotech E36® deicer/anti-icer was evaluated at COS airport on the night of December 8, 2008, between 1:00 am and 3:45 am. The performance of the LithMelt and Cryotech E36® deicers was examined on concrete pavements (Taxiway

Connectors Echo-2 and Echo-5) as well as asphalt pavement (Runway 17R/35L and Taxiway Connector Alpha-7). The weather conditions at the time of application were as follows:

a. Temperature – ranged between 20 °F – 23 °F
b. Relative humidity – ranged between 66% – 73%
c. Wind speed – ranged between 21 mph – 30 mph
d. Pavement surface temperature – ranged between 25.0 °F – 26.1°F

The dosage rate of LithMelt deicer application in the field ranged between 0.90 – 1.00 gallons per 1000 feet of deicer application. This dosage rate was based on prior experience of COS personnel with Cryotech E36® deicer for the ambient conditions present at the time of application.

The comparative evaluation between LithMelt and Cryotech E36® was based on results from field tests using the TES equipment on pavement sections treated with LithMelt and prior field experience with Cryotech E36® at similar application rates. Due to limitations in the equipment that was available for deicer application and the need to keep the airfield pavements operational at all the times, the COS airport operations crew conducted systematic frictional assessment of the pavement only on sections treated with LithMelt deicer. Also, due to the limitations of the deicer application equipment and the time, the performance of LithMelt was evaluated only at one dosage rate (0.90 - 1.00 gals per 1000 feet). Before application of the LithMelt deicer on the pavement surface, the handling and spraying characteristics of the deicer were qualitatively assessed by the field personnel. Also, signs of any flocculation in the storage tanks were visually assessed. These qualities of LithMelt deicer were compared against Cryotech E36 deicer.

4.4 Properties and Performance of LithMelt per AMS 1435A Specification for Liquid Deicing/Anti-Icing Agents

AMS specification 1435A governs the properties and performance of liquid runway deicing and anti-icing agents (AMS 1435A, 1999). In order to verify if the LithMelt deicer met the AMS 1435A specification, a series of tests were conducted to determine the physical and chemical properties of the deicer, and evaluate its impact on environment and other metallic/non-metallic hardware components that are typically exposed to deicer solutions on airfield pavements and aircrafts. This investigation was conducted by SMI, Inc. A summary of results from this investigation is presented in the Results and Discussion section of this report, however, a comprehensive report of findings from this investigation is included in Appendix B.

5. RESULTS AND DISCUSSION

5.1. Potential of LithMelt and Cryotech E36® Deicer/Anti-icer to Cause Alkali-Silica Reaction

Figures 1 through 3 show the mortar bar expansion results from the tests conducted to evaluate the potential of 1N NaOH solution, Cryotech E36® deicer and LithMelt deicer, respectively. Based on the results from the standard ASTM C 1260 test results shown in Figure 1, it is evident that all the four aggregates are alkali-silica reactive in nature, with NM source being the most reactive and SD source being the least reactive among the aggregates evaluated. Figure 2 clearly shows that the deleterious effects of Cryotech Deicer E36, with significant expansion (i.e. > 0.100%) in all the mortars bars were observed within a span of 14 days. In fact, the deicer is aggressive enough to cause greater than 1.00% expansion in mortar bars with NM aggregate within the first three days of the test. Figure 3 shows the influence of LithMelt deicer on mortar bar expansions. It is evident from these results that LithMelt significantly suppressed the mortar bar expansion with three of the four aggregates (Spratt, NC and SD) and significantly mitigated alkali-silica reaction. With NM aggregate, although LithMelt did not suppress the mortar bar expansion to below 0.100 % at 14 days, significant reduction in expansion compared to Cryotech E36® deicer was observed. In fact, much of the expansion observed with NM aggregate occurred within the first 3 days of the test, with little expansion thereafter.

These findings clearly suggest that unlike Cryotech E36®, LithMelt deicer does not induce any deleterious ASR-related expansion in mortar bars containing reactive aggregate.

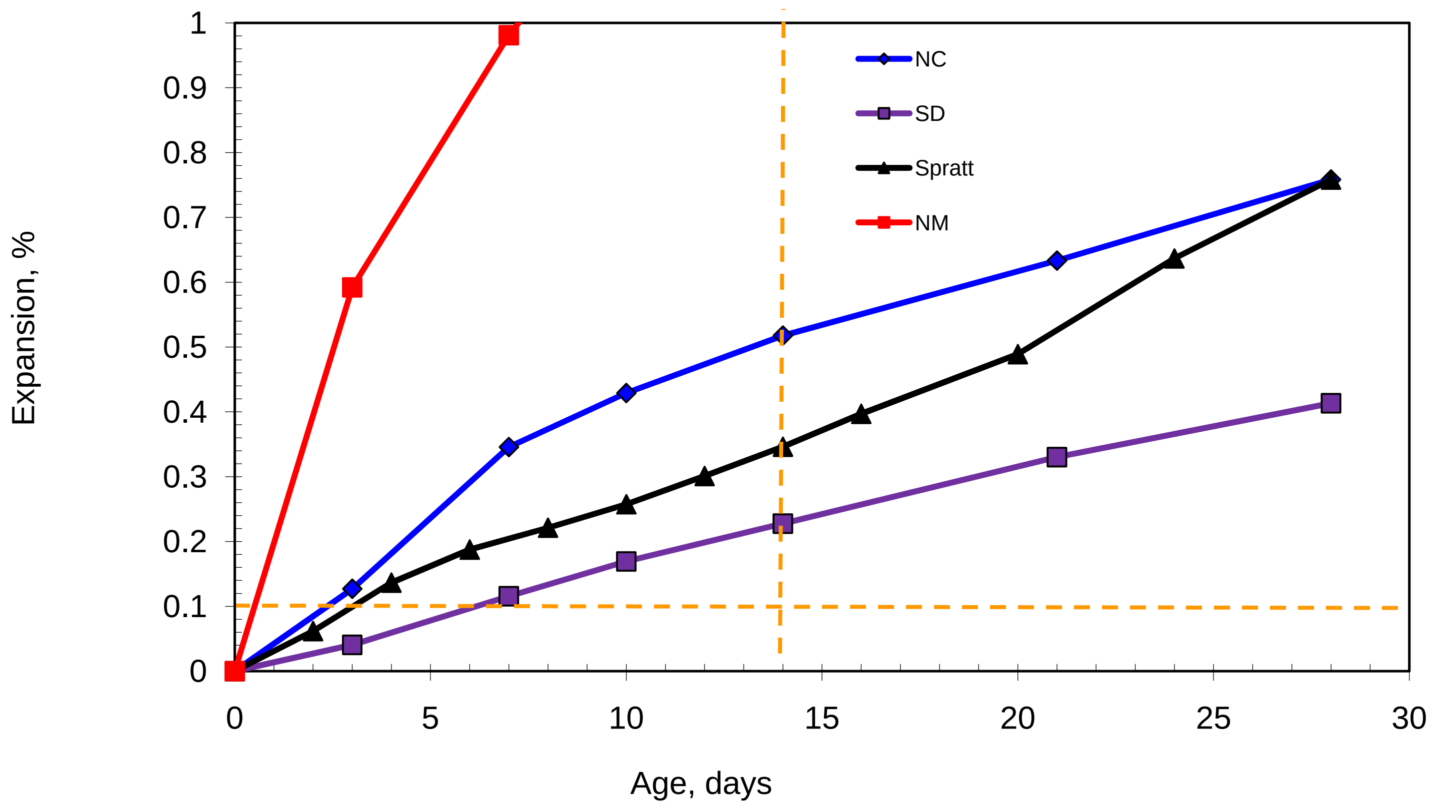


Figure 1 – Expansion of Mortar Bars in 1N NaOH Soak Solution (Standard ASTM C 1260 Test)

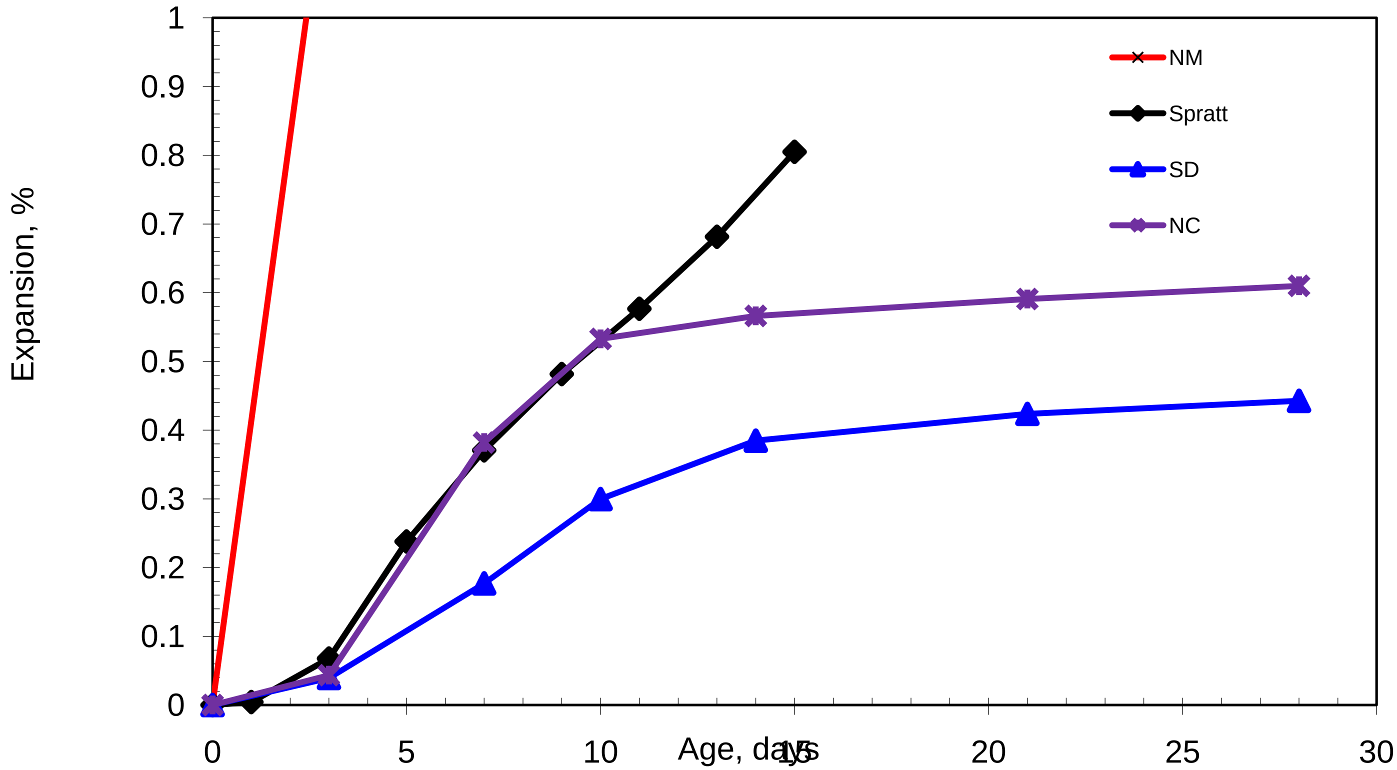


Figure 2 – Expansion of Mortar Bars in Cryotech E36® Deicer Solution (EB70 Test Method)

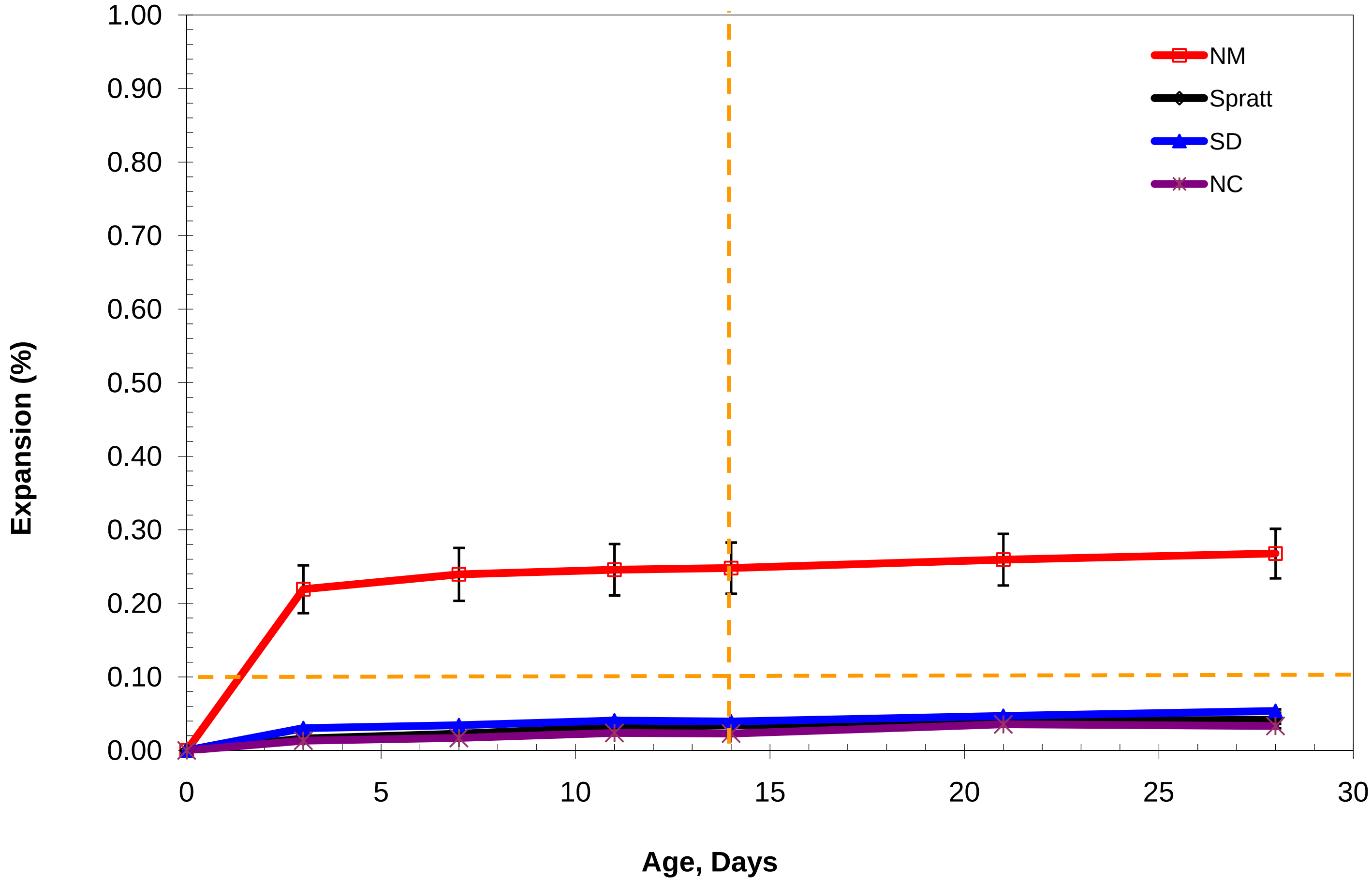


Figure 3 – Expansion of Mortar Bars in LithMelt Deicer Solution (EB70 Test Method)

5.2. Evaluation of Deicing and Anti-icing Performance of LithMelt and Cryotech E36® in Lab

The deicing and anti-icing performance of commercial products such as Cryotech E36® and LithMelt is typically evaluated using the test procedures described in the SHRP-H-332 document – Hand Book of Test Methods for Evaluating Chemical Deicers. Accordingly, three important parameters of deicers – the ice melting behavior, the ice penetration behavior and the ice undercutting behavior – are determined. In addition, kinetic friction tests are conducted to assess the relative performance of deicer solutions.

All of these tests were conducted at the Keweenaw Research Center in Michigan Technological University. Detailed results from this investigation are presented in Appendix A. However, a brief summary of the test procedure and comparative performance of Cryotech E36® deicer and LithMelt deicer is provided below.

5.2.1. Ice Melting Behavior

Ice melting test determines the total volume of ice that can be melted by an applied amount of deicer. In this test an ice disk is created in a standard petri-dish at a designated temperature. After application of a specified amount of the deicer on the surface of the ice disk, the amount of brine produced (i.e. mix of chemical and melt water) is recorded at time intervals up to 60 minutes. This test is conducted at three different temperatures: 25°F, 15°F and 5°F. The results of this test are provided in Table 2

Table 2 – Amount of brine created from application of 1 gram of deicer solution on the surface of ice sample at the end of 60 minutes

Deicer Type	**Temperature of Ice**		
	25°F	**15°F**	**5°F**
Cryotech E36®	3.55 mL/g	1.53 mL/g	0.62 mL/g
LithMelt	3.44 mL/g	1.53 mL/g	0.64 mL/g

Based on these results it is apparent that both Cryotech E36® and LithMelt resulted in comparable ice melting behavior, at all the temperatures investigated.

5.2.2. Ice Penetration Behavior

Ice penetration test is designed to assess the thickness of ice that can be penetrated by a deicer to allow it to reach the pavement surface. In this test a small amount of deicer is applied on the top surface of an ice column. The ice contains a dye that reacts with deicer to indicate the depth of penetration of deicer. The results of the tests are given as the depth of deicer penetration into ice with time. Readings are taken up to 60 minutes at intervals. This test is conducted at three different temperatures: 25°F, 15°F and 5°F. The results of this test are provided in Table 3.

Table 3 –Depth of penetration of brine per 1 milligram of deicer solution at the end of 60 minutes

Deicer Type	**Temperature of Ice**		
	25°F	**15°F**	**5°F**
Cryotech E36®	0.26 mm/mg	0.13 mm/mg	0.06 mm/mg
LithMelt	0.26 mm/mg	0.13 mm/mg	0.04 mm/mg

Based on these results it is apparent that both Cryotech E36® and LithMelt resulted in comparable ice penetration behavior, at all the temperatures investigated.

5.2.3. Ice Undercutting Behavior

Ice undercutting test is designed to assess the amount of ice that can be loosened from the pavement by undercutting at the bond interface. In this test an ice layer of approximately 1/8" thickness is created on top of a mortar block, by freezing the required amount of water. Holes with a diameter of 5mm and are created in the ice layer by melting through the ice. Once the holes are produced, a small amount of deicer solution is placed in the holes. As the deicer undercuts the ice at the interface with the mortar block, the dye in the ice reacts with deicer solution producing a colored zone of undercutting. The amount of undercutting is monitored over a period of 60 minutes. The results of the tests are given as the area of ice undercut per milligram of deicer applied. This test is conducted at three different temperatures: 25°F, 15°F and 5°F. The results of this test are provided in Table 4.

Table 4 –Area of ice undercut per 1 milligram of deicer solution at the end of 60 minutes

Deicer Type	**Temperature of Ice**		
	25°F	**15°F**	**5°F**
Cryotech E36®	5.49 mm^2/mg	1.77 mm^2/mg	1.12 mm^2/mg
LithMelt	5.63 mm^2/mg	1.61 mm^2/mg	1.12 mm^2/mg

Based on these results it is apparent that both Cryotech E36® and LithMelt resulted in comparable ice penetration behavior, at all the temperatures investigated.

5.2.4. Friction Tests

In this test, a friction measurement is made by pulling the rubber block over a pavement sample at a constant speed and measuring the load and displacement as the test progresses. From these tests, an average force required to move the block can be obtained and the coefficient of friction can be calculated. The deicer chemical in question is applied uniformly over the surface of the pavement sample to simulate application rates of 0, 10 and 20 gallons per 1000 ft^2. After each application of deicer, the friction test is conducted and the coefficient of friction is determined. All the friction tests are conducted at 70°F. In this study, the friction tests were conducted using not only the Cryotech E36 and LithMelt deicers on the pavement surface, but also under other standard conditions such as dry, water, oil and ice conditions. The coefficient of friction from these tests is given in Table 5.

Table 5 – Coefficient of Friction on Application of Deicers and Under Other Standard Conditions

Fluid	Coefficient of Friction
Dry	0.88
Water	0.77
LithMelt	0.66
Cryotech E36	0.66
Oil	0.38
Ice	0.10

Based on these results, it can be said that both deicers – LithMelt and Cryotech E36, perform identically.

5.3. Field Performance of LithMelt Deicer at COS Airport

The field performance of LithMelt deicer was evaluated at COS airport on December 8, 2008 by the COS airport operations personnel. This evaluation was conducted on two concrete pavement sections (Taxiway Connectors Echo-2 and Echo-5) and two asphalt pavement sections (Runway 17R/35L and Taxiway Connector Alpha-7). As part of this evaluation the pre-treatment and post-treatment frictional characteristics of the pavements were evaluated using the TES Instruments Mk3 Electronic Decelerometer. In addition, qualitative assessment of handling and spraying characteristic of LithMelt were evaluated along with any flocculation of the deicer in the storage tanks.

5.3.1. Investigation on Concrete Taxiway Connectors Echo-2 and Echo-5

Time:	01:03 am
Air Temp:	23° F
RH:	66%
Winds:	21 mph
Surface Temp:	26.1° F

Concrete Taxiway Connector Echo-2

Echo-2 was previously untouched and had a 1/8" layer of ice covered with a thin, "crunchy" layer of frozen snow. Prior to chemical application, an average TES reading of 0.21 was recorded. An initial application of LithMelt was made at a rate of 0.9 gallons per 1000 feet, with a truck speed of 20 mph. After approximately 20 minutes, a second TES test produced little to no change in the TES values. Only after a second chemical application, a third TES test produced an average reading of 0.29. However, a final test reading (shortly thereafter) revealed a TES value of 0.21 as the surface re-froze.

Concrete Taxiway Connector Echo-5

Echo-5 was previously swept and had a thin layer of ice and a corresponding TES average of 0.25 prior to the first deicer application. LithMelt was applied at a rate of 1.0 gallons per 1000 feet, at a speed of 22 mph. Similar to the E-2 test, there was little to no change in surface friction after the first application. After the second application, the TES values jumped to an average of 0.34. This value remained unchanged when it was checked 15 minutes later.

5.3.2. Investigation on Asphalt Runway and Taxiway Connectors Alpha-7

Time:	03:45 am
Air Temp:	20° F
RH:	73 %
Winds:	30 mph
Surface Temp:	25.0° F

Asphalt Runway 17R/35L (Grooved Surface)

This surface had similar untouched ice contaminant levels as Echo-2, and had a pre-treated TES reading of 0.17. Fifteen minutes after the first treatment of LithMelt (applied at a rate of 1.0 gallon per 1000 feet, at a speed of 22 mph), the surface friction was measured and a TES value of 0.244 was measured. Subsequently, the runway was swept full length and width before a second treatment of LithMelt at a same dosage level was applied. At this time, a TES measurement yielded a value of 0.29. Subsequently, the surface conditions did not improve substantially until later that afternoon.

Asphalt Taxiway A-7

This pavement surface had similar pre-treatment characteristics (i.e. a TES value of 0.17) as runway 17R/35L. Alpha-7 was treated with LithMelt (applied at a rate of 1.0 gallon per 1000 feet at a speed of 22 mph). A TES reading of 0.19 was obtained 20 minutes later and, as a result, a NOTAM (Notice to Airmen) was issued and the surface was closed. Alpha-7 was not reopened until 12:20pm.

Based on these results, it appears that at the dosage rates applied in the field (i.e. 0.9 – 1.0 gallons per 1000 feet) the LithMelt deicer did not perform adequately. Unfortunately, additional evaluation of LithMelt at higher dosage levels could not be done at the time of this investigation.

5.3.3. Handling, Spraying and Flocculation Characteristics of LithMelt Deicer

Observations made by field personnel at COS airport on the ability of conventional pumps to handle/transfer the LithMelt deicer from tanks to trucks, and the ability of the conventional spray trucks to apply a uniform coating of the LithMelt deicer on the pavement, showed that no problems were encountered. In this regard the performance of LithMelt deicer was found to be very comparable to that of Cryotech E36® deicer. No flocculation was observed in LithMelt deicer tanks upon storing the deicer for several weeks at ambient conditions. These findings support results from long-term (one-year) storage tests conducted by SMI, Inc. and reported in Appendix B.

5.4. Properties and Performance of LithMelt per AMS 1435A Specification for Liquid Deicing/Anti-Icing Agents

The biodegradability of the deicer solutions and their ecological impact are determined as per AMS specification 1435A. Also, the ability of the deicer fluids to corrode metallic and non-metallic components is established through conforming to AMS specification 1435A. In addition, certain physical characteristics of deicers such as flash point, freezing point and pH of the deicers are established through tests conforming to ASM 1435A specification.

These tests were conducted on LithMelt deicer by SMI, Inc and a detailed report of findings is attached in Appendix B. However, a summary of findings is provided below.

Based on the work conducted by SMI, Inc. the following are the key findings:

5.4.1. Properties of LithMelt Deicer

Flash Point:	No flash to 100°C
Specific Gravity:	1.238 @ 60°F
pH:	10.9
Freezing Point:	-15°C

5.4.2. Environmental Impact of LithMelt Deicer

The biodegradability of deicer is established through BOD and COD values, established using the APHA standard methods of examination of water and waste water. Based on these tests, the 5-day Biological Oxygen Demand (BOD) of the LithMelt deicer was found to be 0.28 kg O_2/kg fluid. The 5-day Chemical Oxygen Demand (COD) of the LithMelt deicer was found to be 0.34 kg O_2/kg fluid.

Ecological behavior of deicers relates to their aquatic toxicity. The LC_{50} concentration of deicer is used as an indicator of the aquatic toxicity of deicer solutions. The LC_{50} concentration (in milligrams per liter) represents the highest concentration at which 50% of the test species survive. Based on the tests conducted as per AMS 1435A specification, the 48-hour LC_{50} concentration for Daphnia magna species (in a static system) was found to be 1,225 mg/L. For pimephasles promelas species (in a static system), the 96-hour LC_{50} concentration was found to be 1,850 mg/L.

The trace contaminant levels of LithMelt deicer were as follows:

Sulfur:	12 ppm
Halogens:	1200 ppm
Phosphate:	< 1 ppm
Nitrate:	<10 ppm
Heavy Metals (Pb, Cr, Cd, Hg)	< 1 ppm

5.4.3. Impact of LithMelt on Metals, Non-Metals and Scaling Resistance of Concrete

AMS 1435A specification covers a wide range of corrosion and degradability tests to evaluate the impact of deicers on a range of materials, including aircraft metals, plastics, painted surfaces and concrete. Based on all the tests conducted, it was found that LithMelt deicer successfully conforms to all the requirements of AMS 1435A specification. A more detailed report of findings on this subject matter is presented in Appendix B.

6. CONCLUSIONS

Based on the different studies conducted in this investigation, the following conclusions can be drawn about the performance of LithMelt deicer/anti-icer solution:

1. LithMelt deicer/anti-icer solution did not cause any deleterious levels of expansion in mortar bars containing alkali-silica reactive aggregates, unlike Cryotech E36 deicer solution and 1N NaOH solution. Therefore, it can be concluded that LithMelt deicer does not have the potential to induce alkali-silica reaction in concrete containing marginal aggregates.

2. The performance of LithMelt in ice melting, ice penetration and ice undercutting as per the SHRP test methods was found to be satisfactory for use in winter weather conditions to improve the performance of pavements. In these laboratory tests, the performance of LithMelt was found to be comparable to that of Cryotech E36 deicer/anti-icer solution.

3. Field evaluation of LithMelt indicated that this deicer/anti-icer solution slightly improved the frictional characteristics of the pavement at the dosage rates applied (i.e. 0.90 – 1.0 gallons per 1000 feet). However, the level of improvement was not found to be sufficient to restore adequate frictional characteristics of the pavement and open the pavement for service. Cryotech E36® deicer was found to be effective under the same ambient conditions at comparable dosage levels (i.e. 0.90 – 1.0 gallons per 1000 feet). Additional testing of LithMelt deicer at higher dosage levels was not conducted and consequently performance of LithMelt at other dosage levels is not known.

4. Conventional pumping and spraying equipment was found to be adequate and satisfactory in handling and spraying LithMelt deicer. In this regard, LithMelt deicer was found to behave very similar to Cryotech E36®. No flocculation was observed in LithMelt deicer under ambient storage conditions at the COS airport.

5. LithMelt was found to conform to all the requirements of AMS 1435A specification for use as a runway liquid deicing/anti-icing agent. In particular, no negative impacts on the

environment or other metallic/non-metallic components that are typically found on airfield pavements and aircrafts were observed. No long-term storage related problems such as flocculation were observed.

7. RECOMMENDATIONS

In this investigation, it was found that LithMelt deicer/anti-icer performed adequately in a variety of lab investigations. However, its performance in field was found to be less than adequate at the one dosage rate that was evaluated (i.e. 0.90 – 1.0 gallons per 1000 feet). It is not certain if the LithMelt would have performed better at higher dosage levels. In order to get a more thorough understanding of the performance of LithMelt deicer in field conditions, it is recommended that a comprehensive study be conducted in which LithMelt deicer is applied at different dosage rates followed by a systematic evaluation of the frictional characteristics of the pavement. Unfortunately, in the present study adequate equipment was not readily available to dispense the deicer at different dosage rates, and the application of deicer was conducted under time constraints that prevented a systematic evaluation of the LithMelt product.

8. REFERENCES

1. Rangaraju, P.R. and Olek, J. "Potential for ASR in Concrete in Presence of Airfield Deicing Chemicals" Final Report, IPRF-01-G-002-03-9, February, 2007, p. 127.

2. Thomas, M.D.A, Fournier, B., Folliard, K.J, Ideker, J.H., and Resendez, Y. "The Use of Lithium to Prevent or Mitigate Alkali Silica Reaction in Concrete Pavements and Structures" Federal Highway Administration, FHWA-HRT-06-133, March 2007, p. 47.

3. McCoy, W.J., Caldwell, A.G., "A New Approach to Inhibiting Alkali-Aggregate Expansion," Journal of the American Concrete Institute, 47, 1951, pp. 693-706.

4. LithMelt, Product Data Sheet - "LithMelt Liquid Anti-Icer/Deicer" FMC Lithium Division, http://www.fmclithium.com/Portals/FMCLithium/content/docs/DataSheet/QS-PDS-805%20r0.pdf, Accessed on June 14, 2010, FMC Lithium Division, 2008, p. 4.

5. Cryotech E36, Fact Sheet, "Cryotech E36 Liquid Runway Deicer", Cryotech Deicing Technology, http://www.cryotech.com/products/pdf/e36_fs.pdf, Accessed June 14, 2010, p.2

6. Rogers, C. "Multi-Laboratory Study of Accelerated Mortar Bar Test (ASTM C 1260) for Alkali-Silica Reaction" C*ement, Concrete and Aggregates*, *CCAGDP*, 21(2), p.191-200, 1999.

7. Barringer, W.L. Application of Accelerated Mortar Bar Tests to New Mexico Aggregates, *Proceedings of 11th International Conference on Alkali-Aggregate Reactions in Concrete*, Quebec City, Quebec, Canada, pp. 563-572, June 2000.

8. Leming, M. L. Mitchell, J.F., and Ahmad, S. H., Investigation of Alkali-Silica Reactivity in North Carolina Highway Structures, *Center for Transportation Engineering Studies/ NCDOT Report 23241-94-6*, p. 168, 1996.

9. Touma E. T., Fowler, D.W., Carasquillo R.L. Alkali-Silica Reaction in Portland Cement Concrete: Testing Methods and Mitigation Alternatives, *Technical Report ICAR 301-1F*, International Center for Aggregate Research, University of Texas, Austin, p. 520, 2001.

10. Rangaraju, P.R. A Lab Study on Alkali-Silica Reactivity of Quartzites Used in Concrete Pavements of Minnesota. *Proceedings of 11th International Conference on Alkali-Aggregate Reactions in Concrete*, Quebec City, Quebec, Canada, pp. 453-462, June 2000.

11. Engineering Brief No. 70, "Accelerated Alkali-Silica Reactivity in Portland cement Concrete Pavements Exposed to Runway Deicing Chemicals", FAA Memorandum, December 2005, p. 8.

12. SHRP H-332 "Handbook of Test Methods for Evaluating Chemical Deicers" Final Report SHRP H-332, Federal Highway Administration, Washington D.C., 1992, p. 290.

13. AMS 1435A Guide Specification, "Fluids, Generic, Deicing/Anti-Icing, Runways and Taxiways, Society of Automotive Engineers International, 1999.

9. APPENDIX A – Laboratory Deicer Performance Evaluation Using SHRP H-332 Test Methods

Keweenaw Research Center

Michigan Technological University

Houghton, MI

Keweenaw Research Center

Laboratory Deicer Performance Evaluation

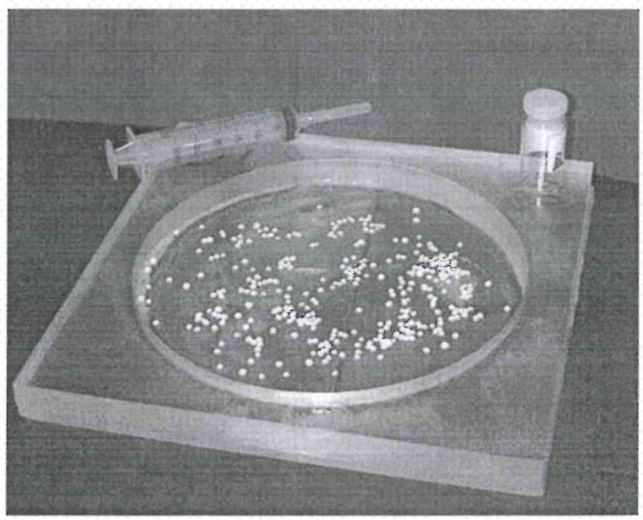
Chemicals FMC 121707 and KAc

February 2008

For

FMC Corporation, Lithium Division
Attn: Claudio Manissero

Seven Lakepointe Plaza
2801 Yorkmont Road, Suite 300
Charlotte, NC 28208
Phone: 704-868-5305
Fax: 704-868-538



By
Russ Alger

MichiganTech
Michigan Technological University
Houghton, MI

ICE MELTING

The Ice Melting tests were performed using SHRP H-205.2, **Test Method for Ice Melting of Liquid Deicing Chemicals**. The method for this testing can be found in the Strategic Highway Research Program, National Research Council, publication designated SHRP-H-332. This is the **Handbook of Test Methods for Evaluating Chemical Deicers**. This test is designed to assess the total volume of ice that can be melted by an applied amount of deicer.

Figure 1 is a photo of the test apparatus used for ice melting. In general, an ice sample is created in a standard plexiglass© dish. After application of a specified amount of chemical, the amount of brine created (mix of chemical and meltwater) is recorded at time intervals up to 60 minutes. This testing was performed at three different temperatures: 25°, 15°, and 5° F. The results are given in tabular and graphical form as milliliters of brine collected per gram of liquid deicer applied, which can be seen on the following pages. The approximate amount of deicer applied for each test was 3.8 mL for the 25°, 15°, and 5° testing. Three repetitions of the ice-melting tests were completed for each of the 2 chemicals at each temperature. The results from each temperature were averaged, thus giving a single melting performance amount for each temperature.

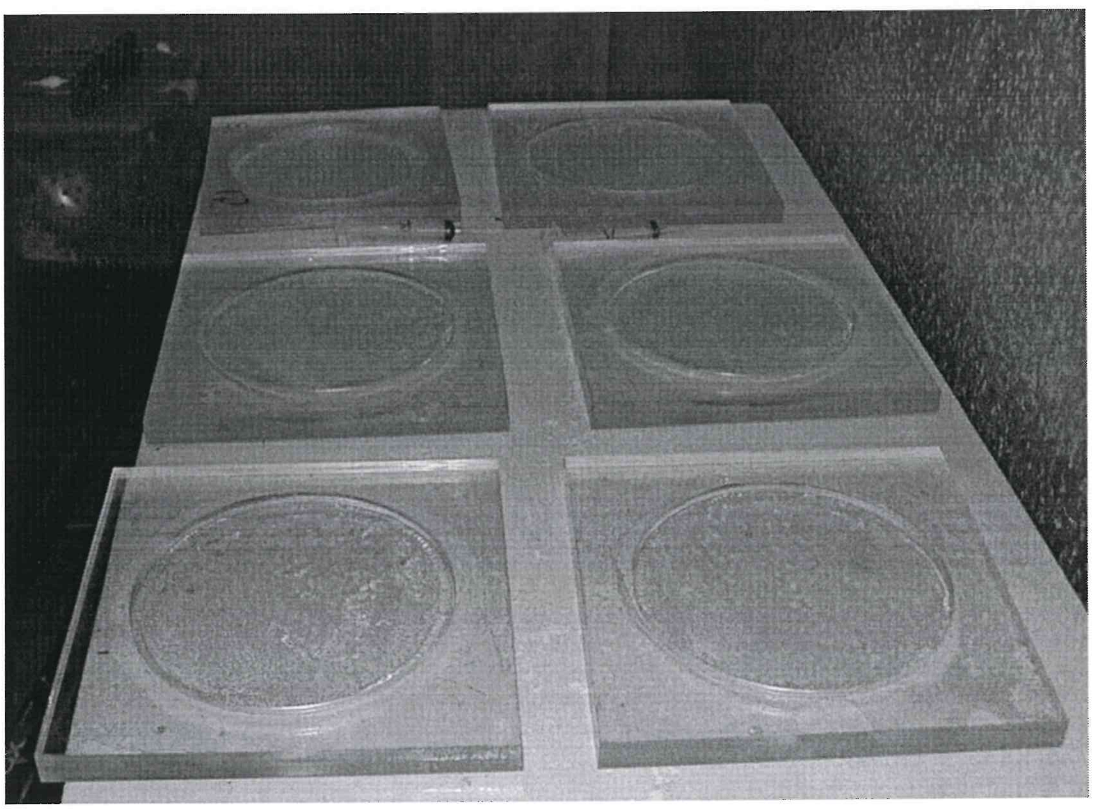


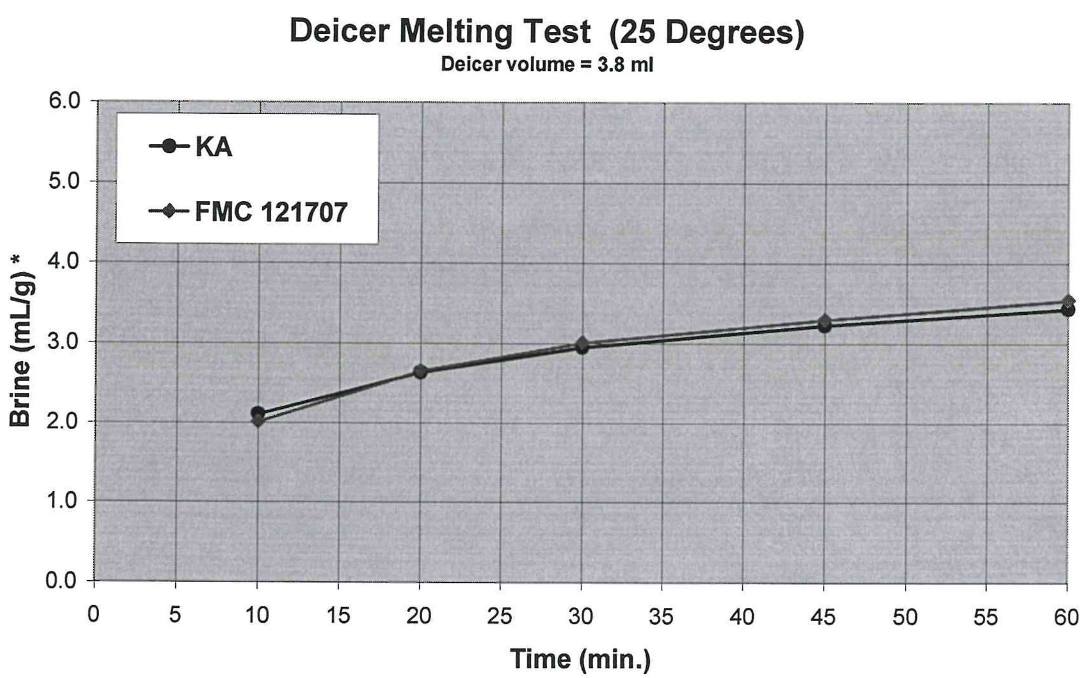
Figure 1: Typical Ice Melting Samples.

25^{o} F Melting Test

FMC 121707	V = 3.8 ml	25 Degrees			
Deicer Weight(g)	4.6543	4.6491	4.6788	4.661	
Time (min.)	Trial 1 (mL)	Trial 2 (mL)	Trial 3 (mL)	Ave.	mL/g
10	13	13.5	13	13.17	2.01
20	16.5	16	16	16.17	2.65
30	18	18	17.5	17.83	3.01
45	19.5	19	19	19.17	3.30
60	20.5	20.5	20	20.33	3.55

KA	V = 3.8 ml	25 Degrees			
Deicer Weight(g)	4.7659	4.7624	4.7449	4.758	
Time (min.)	Trial 1 (mL)	Trial 2 (mL)	Trial 3 (mL)	Ave.	mL/g
10	14	13.5	14	13.83	2.11
20	16.5	16	16.5	16.33	2.63
30	18	18	17.5	17.83	2.95
45	19	19	19.5	19.17	3.23
60	20	20	20.5	20.17	3.44

Note: mL/g is calculated with original fluid volume removed.

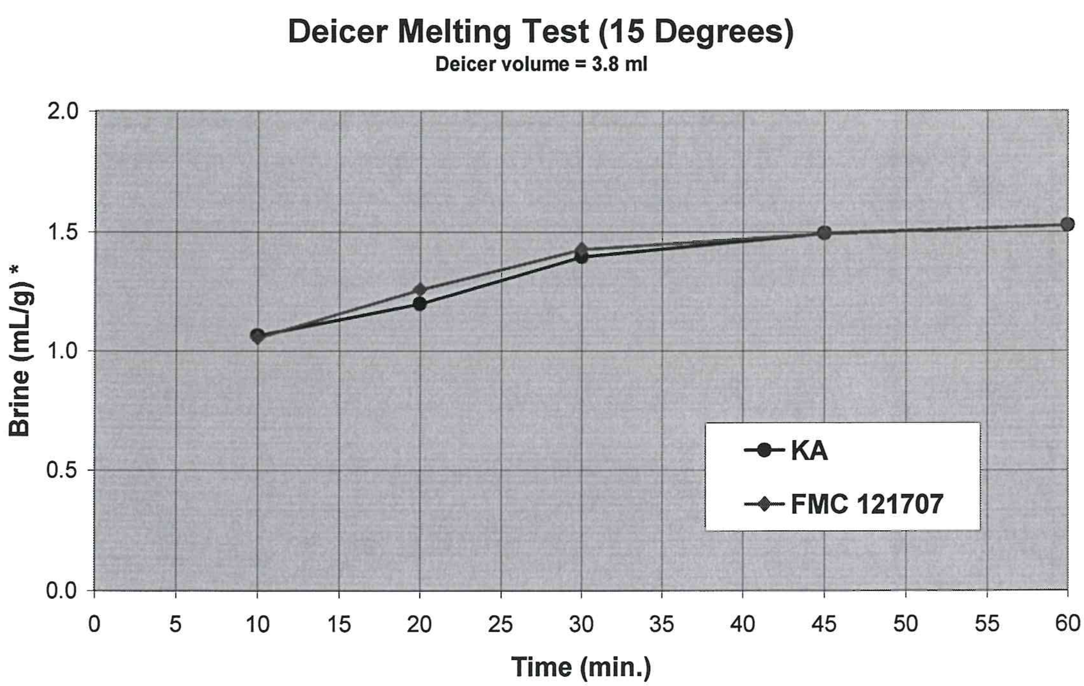


15° F Melting Test

FMC 121707	V = 3.8 ml	15 Degrees			
Deicer Weight(g)	5.0133	4.8771	4.9082	4.9329	
Time (min.)	Trial 1 (mL)	Trial 2 (mL)	Trial 3 (mL)	Ave.	mL/g
10	9	9	9	9.00	1.05
20	10.5	10	9.5	10.00	1.26
30	11	11	10.5	10.83	1.43
45	11.5	11	11	11.17	1.49
60	11.5	11.5	11	11.33	1.53

KA	V = 3.8 ml	15 Degrees			
Deicer Weight(g)	4.9214	5.0263	5.1741	5.041	
Time (min.)	Trial 1 (mL)	Trial 2 (mL)	Trial 3 (mL)	Ave.	mL/g
10	9	9.5	9	9.17	1.06
20	9.5	10	10	9.83	1.20
30	10.5	11	11	10.83	1.40
45	11	11.5	11.5	11.33	1.49
60	11	11.5	12	11.50	1.53

Note: mL/g is calculated with original fluid volume removed.

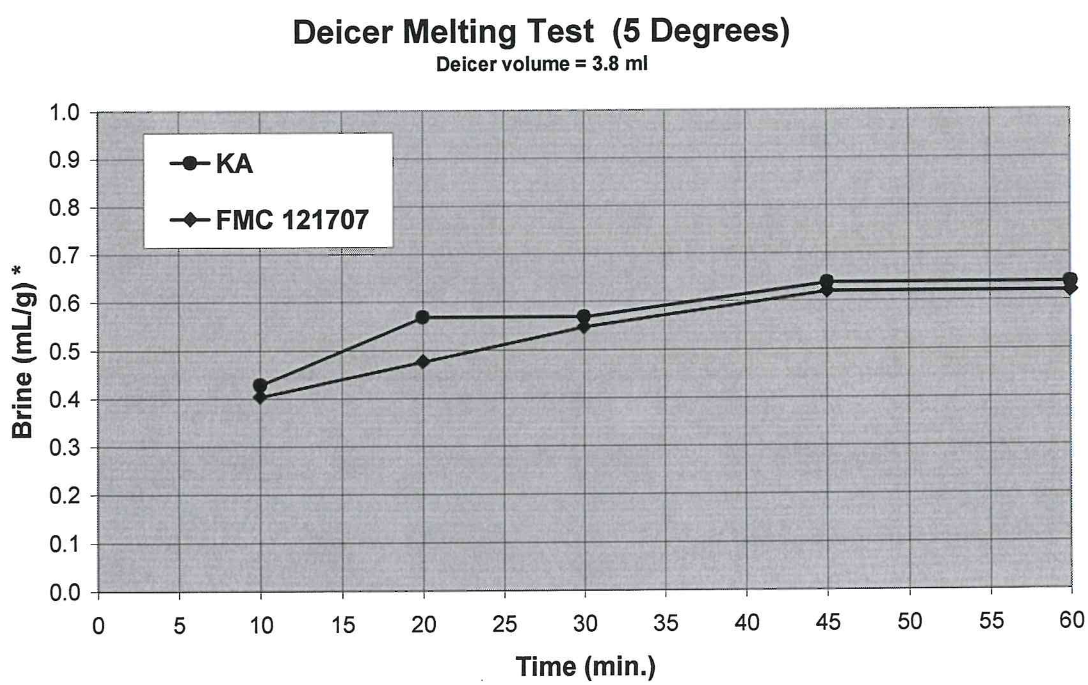


5^o F Melting Test

FMC 121707	V = 3.8 ml	5 Degrees			
Deicer Weight(g)	4.572	4.612	4.6795	4.6212	
Time (min.)	Trial 1 (mL)	Trial 2 (mL)	Trial 3 (mL)	Ave.	mL/g
10	5.5	6	5.5	5.67	0.40
20	6	6	6	6.00	0.48
30	6.5	6.5	6	6.33	0.55
45	7	6.5	6.5	6.67	0.62
60	7	6.5	6.5	6.67	0.62

KA	V = 3.8 ml	5 Degrees			
Deicer Weight(g)	4.7486	4.7063	4.7928	4.7492	
Time (min.)	Trial 1 (mL)	Trial 2 (mL)	Trial 3 (mL)	Ave.	mL/g
10	5.5	6	6	5.83	0.43
20	6.5	6.5	6.5	6.50	0.57
30	6.5	6.5	6.5	6.50	0.57
45	7	7	6.5	6.83	0.64
60	7	7	6.5	6.83	0.64

Note: mL/g is calculated with original fluid volume removed.



ICE PENETRATION

Ice Penetration Tests were performed using SHRP H-205.4, **Test Method for Ice Penetration of Liquid Deicing Chemicals**. The method for this testing can be found in the Strategic Highway Research Program, National Research Council, publication designated SHRP-H-332. This is the **Handbook of Test Methods for Evaluating Chemical Deicers**. This test is designed to assess the thickness of ice that can be penetrated by a deicer to allow it to reach the pavement surface.

Five repetitions of ice penetration were made for each deicer at each of the 3 temperatures (25°, 15°, and 5° F), as depicted in the published test method. Figure 2 is a photo of the test block used for ice penetration tests. The test is accomplished by preparing columns of ice in vertical tubes in the block. Deicer is applied on top of each column of ice. The ice contains dye that reacts with the brine to show the depth of melting as the test progresses. The results are given as depth of penetration versus time. The data is in tabular and graphical format in the following pages. Approximately 3 µL of deicer is used for each test.

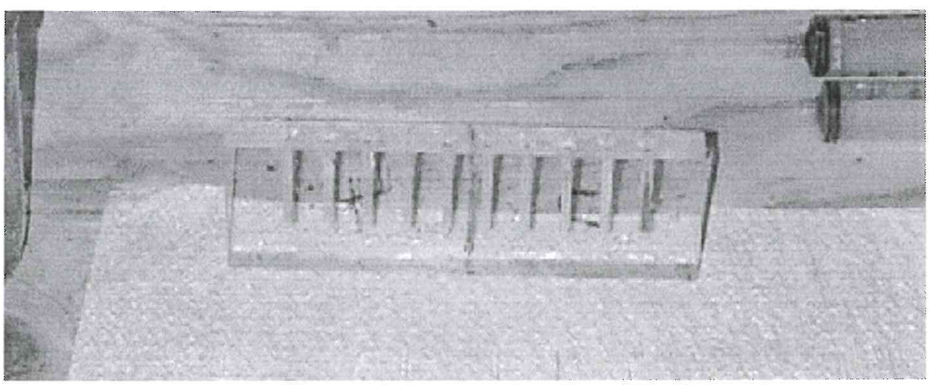
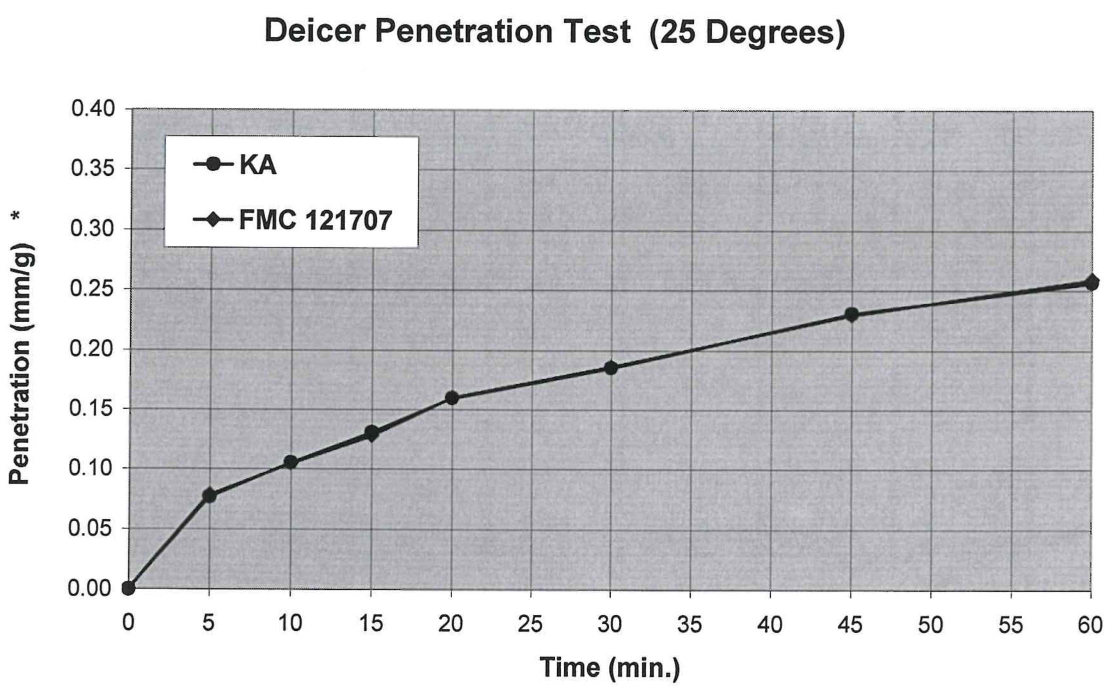


Figure 1: Penetration Test Block.

25° F Penetration Test

FMC 121707		25 Degrees				Average	Penetration
Weight(mg)	171.8					34.36	per mg
Time (min)	Trial 1(mm)	Trial 2(mm)	Trial 3(mm)	Trial 4(mm)	Trial (5mm)	Ave. (mm)	Ave
0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
5	2.5	2.5	2.5	3.0	3.0	2.7	0.08
10	3.5	3.5	4.0	3.5	3.5	3.6	0.10
15	4.5	4.0	5.0	4.5	4.0	4.4	0.13
20	6.0	5.0	6.0	5.5	5.0	5.5	0.16
30	6.5	6.0	6.5	7.0	6.0	6.4	0.19
45	8.0	7.5	8.0	8.0	8.0	7.9	0.23
60	8.5	8.5	9.0	9.5	9.0	8.9	0.26

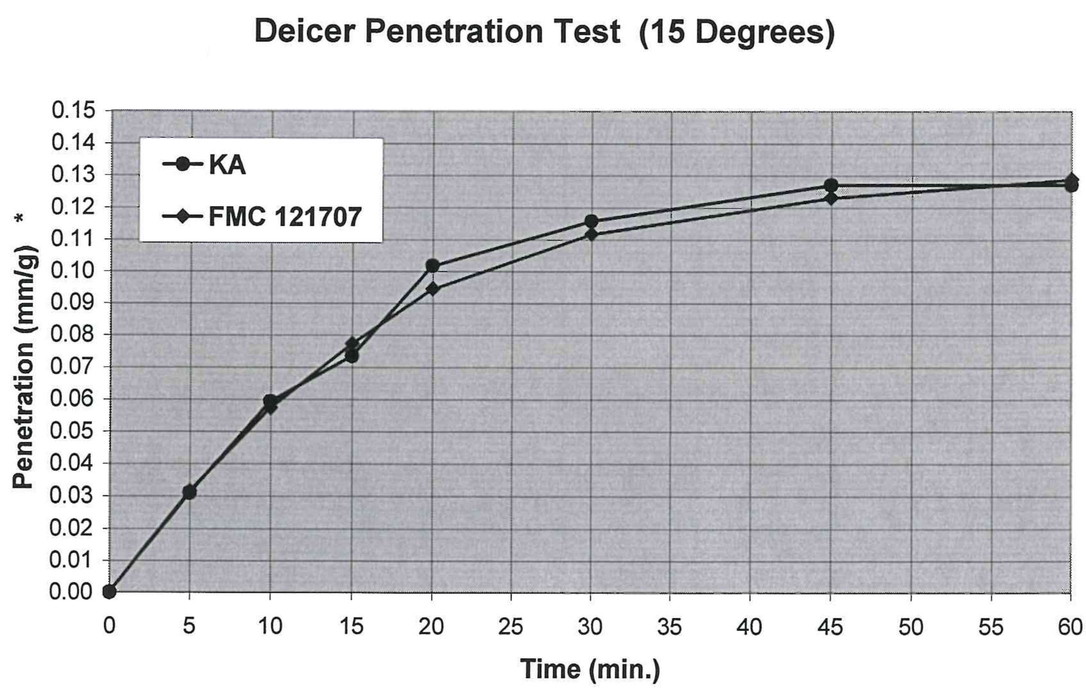
KA		25 Degrees				Average	Penetration
Weight(mg)	175.4					35.08	per mg
Time (min)	Trial 1(mm)	Trial 2(mm)	Trial 3(mm)	Trial 4(mm)	Trial (5mm)	Ave. (mm)	Ave
0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
5	2.5	3.0	3.0	2.5	2.5	2.7	0.08
10	3.5	4.0	4.0	3.5	3.5	3.7	0.11
15	4.0	5.0	5.0	4.5	4.5	4.6	0.13
20	5.0	6.5	6.0	5.0	5.5	5.6	0.16
30	6.0	7.0	7.0	6.5	6.0	6.5	0.19
45	8.0	8.0	8.5	8.5	7.5	8.1	0.23
60	9.0	9.5	9.0	9.0	8.5	9.0	0.26



15^o F Penetration Test

FMC 121707		15 Degrees				Average	Penetration
Weight(mg)	174.5					34.9	per mg
Time (min)	Trial 1(mm)	Trial 2(mm)	Trial 3(mm)	Trial 4(mm)	Trial 5(mm)	Ave. (mm)	Ave
0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
5	1.0	0.5	1.0	1.5	1.5	1.1	0.03
10	2.0	1.5	1.5	2.5	2.5	2.0	0.06
15	2.5	2.0	2.5	3.5	3.0	2.7	0.08
20	3.0	3.0	3.0	4.0	3.5	3.3	0.09
30	3.5	4.0	3.5	4.5	4.0	3.9	0.11
45	3.5	4.5	4.0	5.0	4.5	4.3	0.12
60	3.5	5.0	4.0	5.0	5.0	4.5	0.13

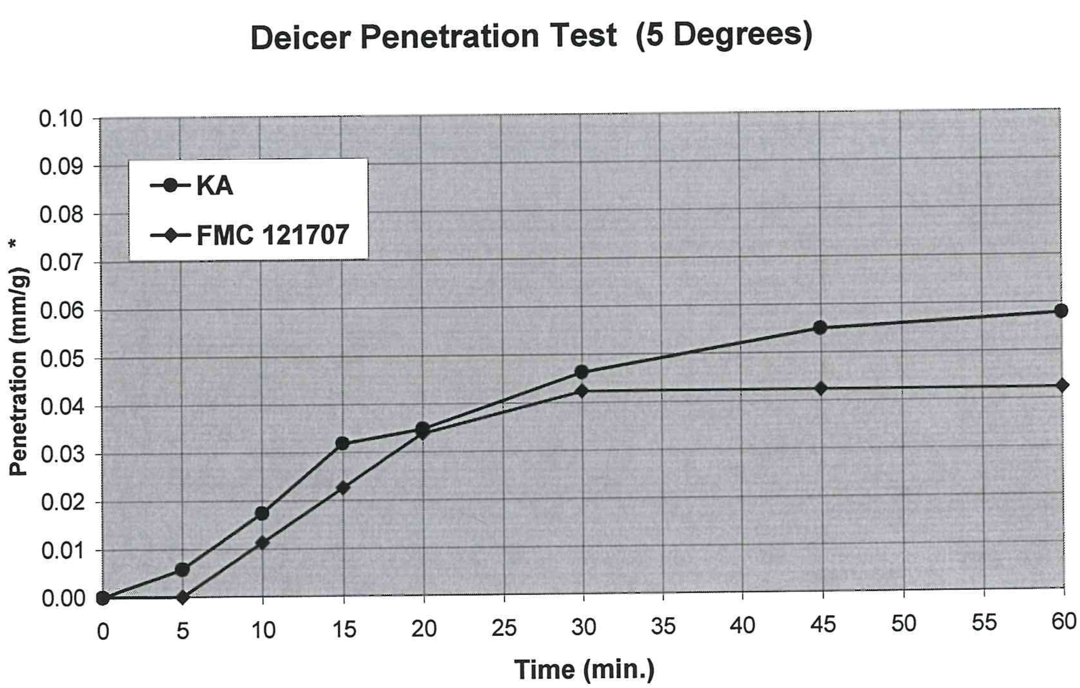
KA		15 Degrees				Average	Penetration
Weight(mg)	176.9					35.38	per mg
Time (min)	Trial 1(mm)	Trial 2(mm)	Trial 3(mm)	Trial 4(mm)	Trial 5(mm)	Ave. (mm)	Ave
0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
5	0.5	0.5	1.5	1.5	1.5	1.1	0.03
10	1.5	1.5	2.5	2.5	2.5	2.1	0.06
15	2.0	2.0	3.0	3.0	3.0	2.6	0.07
20	3.0	3.5	3.5	4.0	4.0	3.6	0.10
30	3.5	4.0	4.5	4.0	4.5	4.1	0.12
45	4.0	4.5	5.0	4.0	5.0	4.5	0.13
60	4.0	4.5	5.0	4.0	5.0	4.5	0.13



5° F Penetration Test

FMC 121707		5 Degrees				Average	Penetration
Weight(mg)	177.2					35.44	per mg
Time (min)	Trial 1(mm)	Trial 2(mm)	Trial 3(mm)	Trial 4(mm)	Trial 5(mm)	Ave. (mm)	Ave
0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
5	0.0	0.0	0.0	0.0	0.0	0.0	0.00
10	0.5	0.0	0.5	0.5	0.5	0.4	0.01
15	1.0	0.5	1.0	0.5	1.0	0.8	0.02
20	1.5	1.0	1.0	1.0	1.5	1.2	0.03
30	1.5	1.0	1.5	1.5	2.0	1.5	0.04
45	1.5	1.0	1.5	1.5	2.0	1.5	0.04
60	1.5	1.0	1.5	1.5	2.0	1.5	0.04

KA		5 Degrees				Average	Penetration
Weight(mg)	172.8					34.56	per mg
Time (min)	Trial 1(mm)	Trial 2(mm)	Trial 3(mm)	Trial 4(mm)	Trial 5(mm)	Ave. (mm)	Ave
0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
5	0.0	0.5	0.0	0.5	0.0	0.2	0.01
10	0.5	0.5	0.5	1.0	0.5	0.6	0.02
15	1.0	1.0	1.0	1.5	1.0	1.1	0.03
20	1.0	1.0	1.5	1.5	1.0	1.2	0.03
30	1.5	1.5	2.0	1.5	1.5	1.6	0.05
45	2.0	2.0	2.0	2.0	1.5	1.9	0.05
60	2.0	2.0	2.0	2.0	2.0	2.0	0.06



ICE UNDERCUTTING

Ice Undercutting Tests were performed using SHRP H-205.6, **Test Method for Ice Undercutting by Liquid Deicing Chemicals**. The method for this testing can be found in the Strategic Highway Research Program, National Research Council, publication designated SHRP-H-332. This is the **Handbook of Test Methods for Evaluating Chemical Deicers**. This test is designed to assess the amount of ice that can by loosened from the pavement by undercutting at the bond interface.

Five repetitions were made for undercutting for each deicer at each of the 3 temperatures (25°, 15°, and 5° F). Figure 3 is a photo of an undercutting test. This test is performed by freezing a layer of ice of approximately 1/8" thickness to the top of a mortar block. Holes with the diameter of 5 millimeters are melted through the ice to the concrete surface. Approximately 3 μL of deicer are placed in each hole. As did the penetration tests, the ice contains a dye that can be seen as melting occurs. The diameter of undercutting is measured for each application at time specific intervals. The results are reported as area of ice undercut per milligram of deicer used.

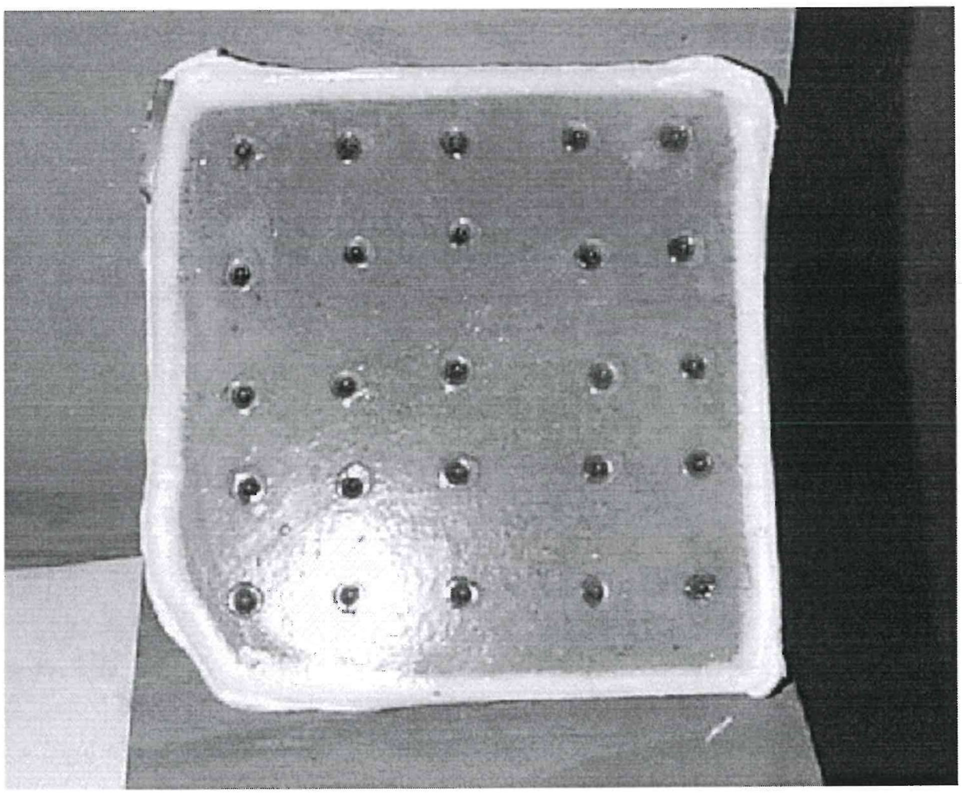
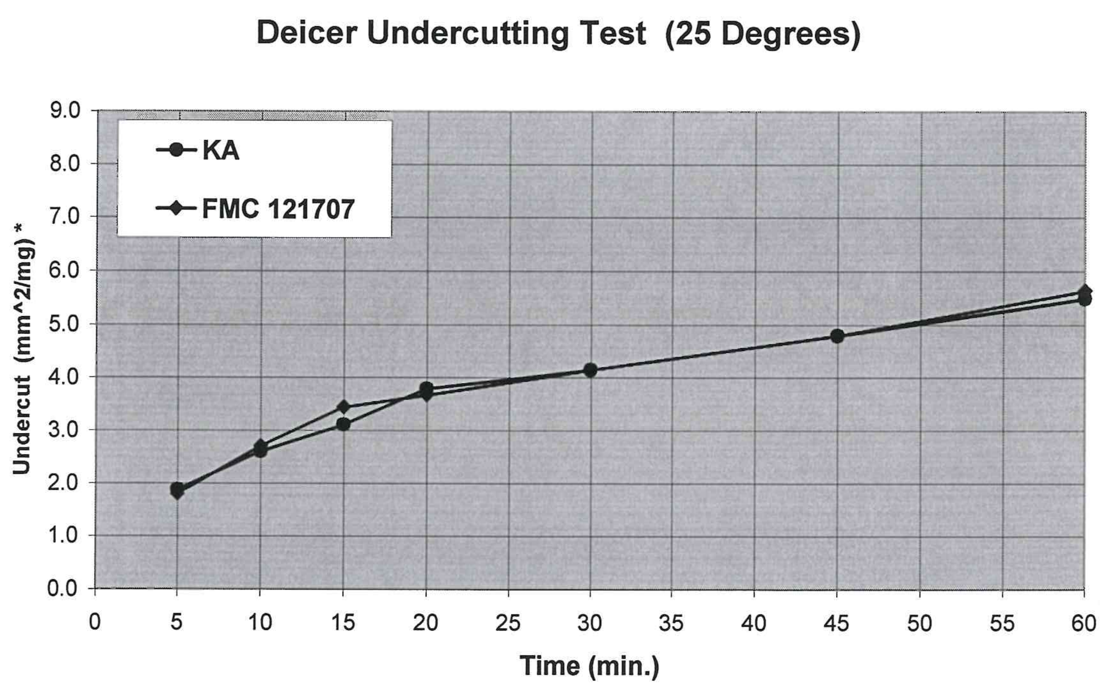


Figure 3. Typical Ice Undercutting Test.

25° F Undercutting Test

FMC 121707		25 Degrees					Average
Weight (mg)	169.7						33.94
Time (min)	Trial 1(mm)	Trial 2(mm)	Trial 3(mm)	Trial 4(mm)	Trial 5(mm)	Ave. (mm)	Undercut (mm^2/mg)
5	10	10	8	8	8	8.80	1.79
10	11	11	11	11	10	10.80	2.70
15	12	12	13	12	12	12.20	3.44
20	12	12	13	13	13	12.60	3.67
30	13	13	13	14	14	13.40	4.16
45	14	15	14	14	15	14.40	4.80
60	16	16	15	15	16	15.60	5.63

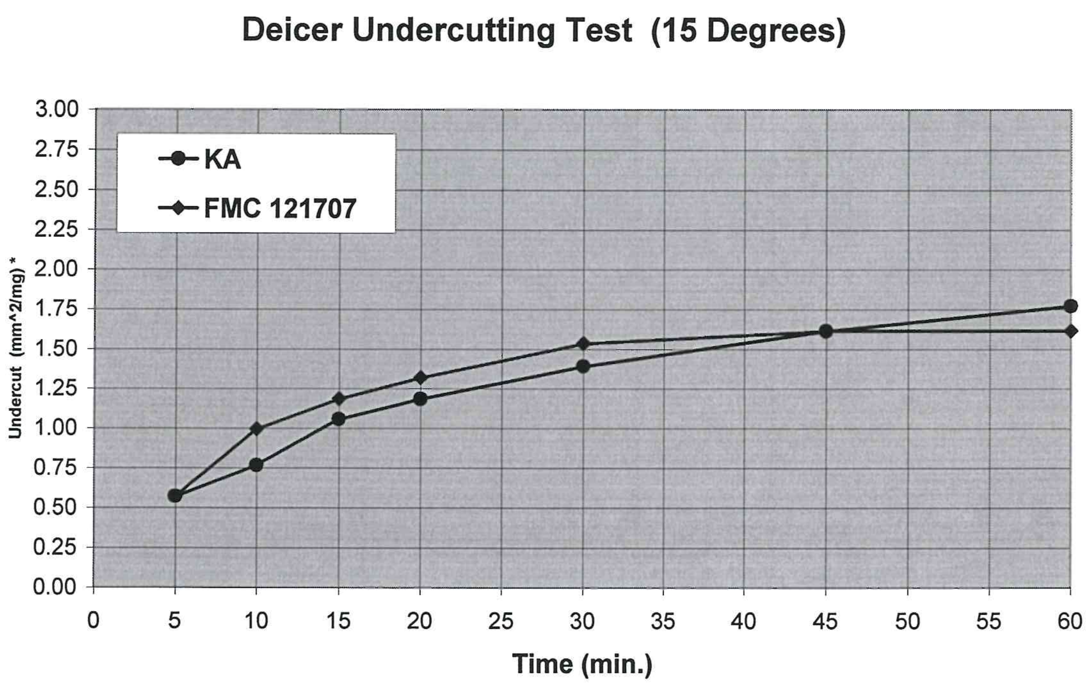
KA		25 Degrees					Average
Weight (mg)	170.8						34.16
Time (min)	Trial 1(mm)	Trial 2(mm)	Trial 3(mm)	Trial 4(mm)	Trial 5(mm)	Ave. (mm)	Undercut (mm^2/mg)
5	8	8	10	10	9	9.00	1.87
10	10	10	11	11	11	10.60	2.60
15	11	12	11	12	12	11.60	3.11
20	12	13	13	13	13	12.80	3.79
30	13	13	14	13	14	13.40	4.16
45	14	14	15	14	15	14.40	4.80
60	15	16	15	15	16	15.40	5.49



15° F Undercutting Test

FMC 121707		15 Degrees					Average
Weight (mg)	177.4						35.48
Time (min)	Trial 1(mm)	Trial 2(mm)	Trial 3(mm)	Trial 4(mm)	Trial 5(mm)	Ave. (mm)	Undercut (mm^2/mg)
5	5	5	5	5	5	5.00	0.57
10	6	6	6	8	7	6.60	1.00
15	7	7	7	8	7	7.20	1.18
20	7	7	7	9	8	7.60	1.32
30	8	7	8	9	9	8.20	1.54
45	8	7	8	9	10	8.40	1.61
60	8	7	8	9	10	8.40	1.61

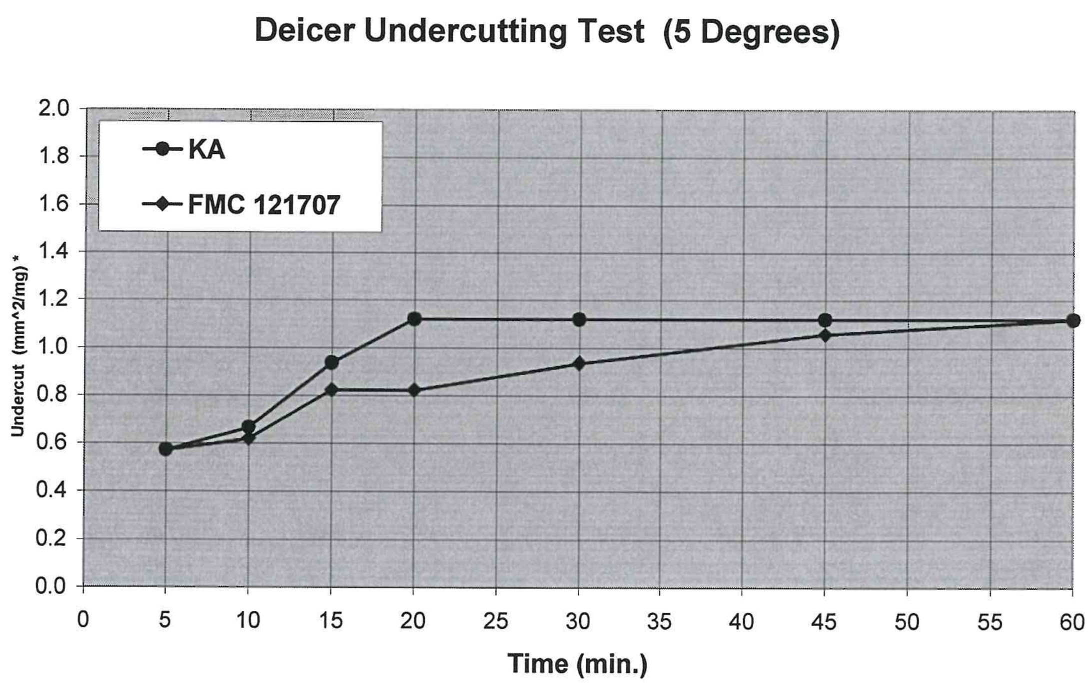
KA		15 Degrees					Average
Weight (mg)	185.9						37.18
Time (min)	Trial 1(mm)	Trial 2(mm)	Trial 3(mm)	Trial 4(mm)	Trial 5(mm)	Ave. (mm)	Undercut (mm^2/mg)
5	5	5	5	5	5	5.00	0.57
10	5	5	6	6	7	5.80	0.77
15	6	6	8	7	7	6.80	1.06
20	6	7	8	7	8	7.20	1.18
30	7	8	8	7	9	7.80	1.39
45	8	8	9	8	9	8.40	1.61
60	8	9	9	9	9	8.80	1.77



5^o F Undercutting Test

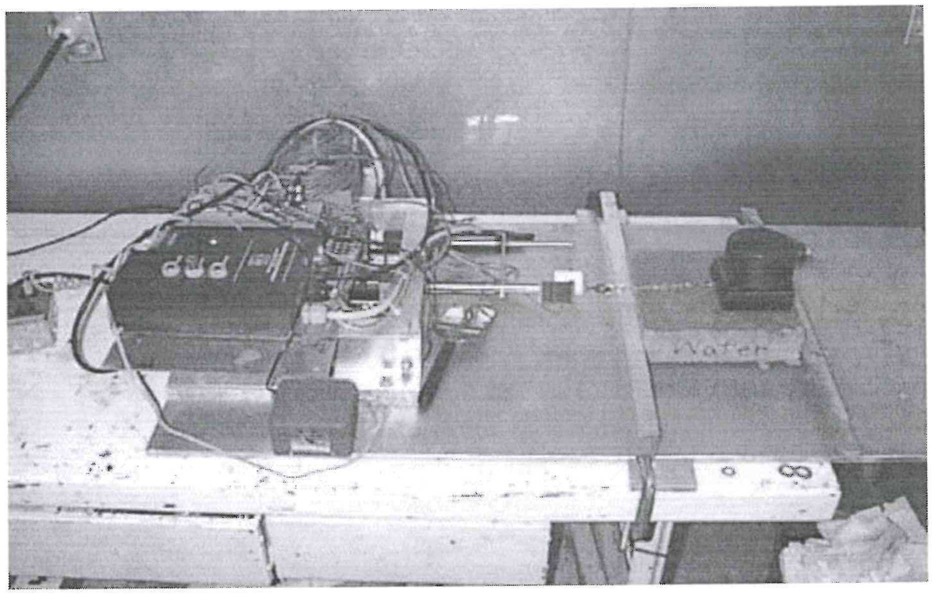
FMC 121707		5 Degrees					Average
Weight (mg)	172.8						34.56
Time (min)	Trial 1(mm)	Trial 2(mm)	Trial 3(mm)	Trial 4(mm)	Trial 5(mm)	Ave. (mm)	Undercut (mm^2/mg)
5	5	5	5	5	5	5.00	0.57
10	5	5	5	5	6	5.20	0.62
15	6	6	6	6	6	6.00	0.82
20	6	6	6	6	6	6.00	0.82
30	6	6	7	6	7	6.40	0.94
45	7	6	7	7	7	6.80	1.06
60	7	7	7	7	7	7.00	1.12

KA		5 Degrees					Average
Weight (mg)	191.7						38.34
Time (min)	Trial 1(mm)	Trial 2(mm)	Trial 3(mm)	Trial 4(mm)	Trial 5(mm)	Ave. (mm)	Undercut (mm^2/mg)
5	5	5	5	5	5	5.00	0.57
10	5	6	5	5	6	5.40	0.67
15	6	7	6	6	7	6.40	0.94
20	7	7	7	7	7	7.00	1.12
30	7	7	7	7	7	7.00	1.12
45	7	7	7	7	7	7.00	1.12
60	7	7	7	7	7	7.00	1.12



LAB FRICTION

Friction tests at KRC are performed using an apparatus designed to measure kinetic friction of a rubber block over a substrate (pavement) sample. There are other methods to measure friction in the lab, but the author has chosen and refined this particular one. The following is a photo of the KRC test apparatus.



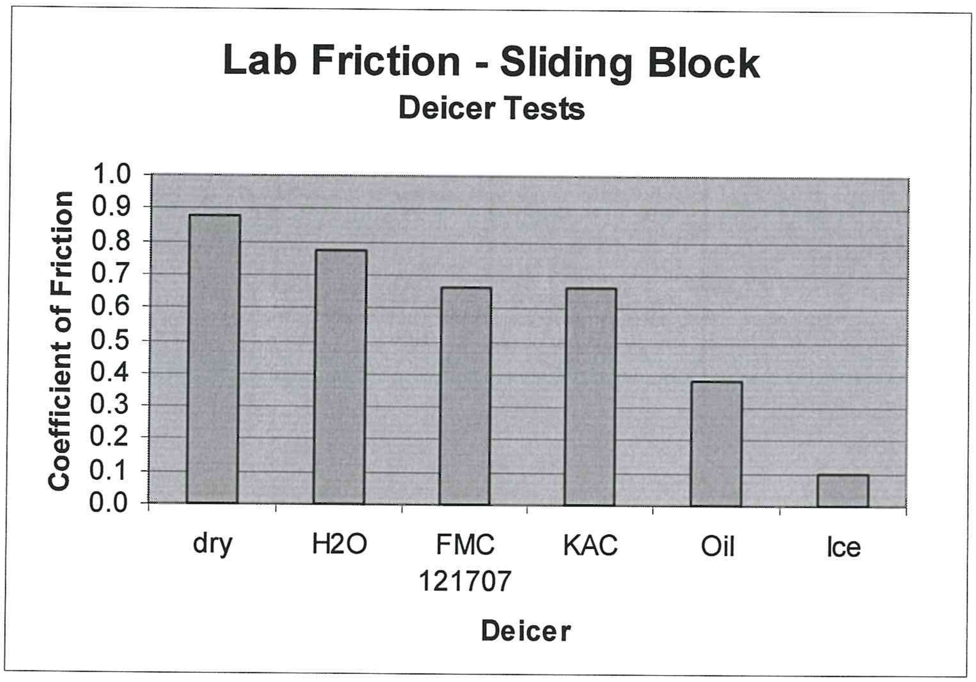
Friction Test Equipment.

The size of the block used in the KRC lab is approximately 4" by 4" in plan. The output friction numbers are designed to give results for friction comparable to those given by a SAAB friction tester.

A friction measurement is made by pulling the rubber block over a pavement sample at a constant speed and measuring the load and displacement as the test progresses. From these measurements, an average force to move the block can be obtained and the coefficient of friction can be calculated. Each chemical is applied uniformly over the surface of a pavement sample to simulate application rates of 0, and 20 gallons per 1000 ft^2. For purposes of comparison, 10 gallons per 1000 ft^2 is just enough chemical to slightly wet the surface of the pavement and 20 is a wet film. After each application of chemical, the friction is measured and an indication of "slipperiness" caused by the chemical film is obtained. Each friction scenario is tested 3 times.

The following table and graph contain the friction measurements taken in the lab using the rubber block. All tests except "Ice" are performed at 70°.

Fluid	Friction
dry	0.88
H2O	0.77
FMC 121707	0.66
KAC	0.66
Oil	0.38
Ice	0.10



10. APPENDIX B – AMS 1435A Evaluation of LithMelt Deicer

SMI, Inc.

Miami, FL

7.7.03

SMI, Inc.

12219 SW 131 Avenue
Miami, Florida 33186-6401 USA

Phone: (305) 971-7047
Fax: (305) 971-7048

Attn: Claudio Manissero
FMC Corp., Lithium Division
Seven Lake Point Plaza
2801 Yorkmont Rd Suite 300
Charlotte, NC 28208

Date: 02-Jun-2008

SMI/REF: 0804-382

Product: **LITHMELT DEICER (Lithium Potassium Acetate Solution)**
(received 25-Apr-2008)

Dilution: As received

AMS 1435A (Revised Aug, 1999)
FLUID, GENERIC, DEICING/ANTI-ICING
Runways and Taxiways

3.1	MATERIAL	
3.1.1	Environmental Information	
3.1.1.1	Biodegradability	Informational
3.1.1.2	Ecological Behavior (LC_{50})	Informational
3.1.1.3	Trace Contaminants	Informational
3.1.2	Appearance	Conforms
3.2	PROPERTIES	
3.2.1	Flash Point	Conforms
3.2.2	Specific Gravity	Informational
3.2.3	pH	Conforms
3.2.4	Freezing Point	Conforms
3.2.5	Effect on Aircraft Metals	
3.2.5.1	Sandwich Corrosion	Conforms
3.2.5.2	Total Immersion Corrosion	Conforms
3.2.5.3	Low Embrittling Cadmium Plate	Conforms
3.2.5.4	Hydrogen Embrittlement	Conforms
3.2.5.5	Stress-Corrosion Resistance	
	AMS 4911	Conforms
	AMS 4916	Informational
3.2.6	Effect on Transparent Plastics	
	MIL-P-25690 (Type C)	Conforms
	MIL-P-83310 (Polycarbonate)	Conforms
3.2.7	Effect on Painted Surfaces	Conforms
3.2.8	Effect on Unpainted Surfaces	Conforms
3.2.9	Rinsibility	Conforms
3.2.10	Runway Concrete Scaling Resistance	Conforms
3.2.11	Storage Stability	In progress

Respectfully submitted,

[signature]

Patricia D. Viani, SMI Inc.

3.1 Material: The composition of the fluid shall be optional with the manufacturer. The fluid may contain additives, such as corrosion inhibitors, urea, formamide, etc, as required to produce a product meeting the requirements of this specification.

3.1.1 Environmental information: The manufacturer of the fluid shall provide not less than the following information:

3.1.1.1 Biodegradability: Fluid shall be tested in accordance with APHA Standard Methods for Examination of Water and Waste Water. The manufacturer shall provide results of bioassays, which shall contain not less than the following information:

3.1.1.1.1 The percent of fluid biodegraded in five days at 20°C (68°F).

BOD: 0.28 kg O_2/kg fluid

Result Informational

3.1.1.1.2 The five day theoretical total oxygen demand (TOD) of the fluid, expressed in kilograms of oxygen per kilograms of fluid.

COD: 0.34 kg O_2/kg fluid

Result Informational

3.1.1.2 Ecological Behavior: A statement of the ecological behavior of the fluid, which shall include aquatic toxicity for the total formulation. The aquatic toxicity data shall be determined in accordance with EPA Methods 40 Code of Federal Regulations (CFR) Part 797.1300 and 797.1400 or OECD Guidelines for Testing of Chemicals (Organization for Economic Cooperation and Development, Methods 202 and 203, updated 1989) using test species required by regulatory agencies for permitted discharges. The LC_{50} concentration, the highest concentration at which 50 % of the test species survive, shall be given in milligrams per liter.

3.1.1.2 Ecological Behavior: continued:

EPA 40 CFR 797.1300 DAPHNID ACUTE TOXICITY TEST

Daphnia magna, static system
48 hour LC_{50}: 1,225 mg/L

EPA 40 CFR 797.1400 FISH ACUTE TOXICITY TEST

Pimephales promelas, static system
96 hour LC_{50}: 1,850 mg/L

Result ___ Informational ___

3.1.1.3 Trace Contaminants: Report the presence, percentage by weight, of sulfur, halogens, phosphate, nitrate, and heavy metals (lead, chromium, cadmium, and mercury).

Sulfur:	***12 ppm***	***(0.0012 %)***
Halogens:	***1200 ppm***	***(0.1200 %)***
Phosphate (P as P_2O_5):	***<1 ppm***	***(<0.0001 %)***
Nitrate (as NO_3):	***<10 ppm***	***(<0.0010 %)***
Heavy Metals:		
Lead (Pb):	***<1 ppm***	***(<0.0001 %)***
Chromium (Cr):	***<1 ppm***	***(<0.0001 %)***
Cadmium (Cd):	***<1 ppm***	***(<0.0001 %)***
Mercury (Hg):	***<1 ppm***	***(<0.0001 %)***

Result ___ Informational ___

3.1.2 Appearance: Fluid, as received by purchaser, shall be homogeneous, uniform in color, and free from skins, lumps, and foreign materials detrimental to usage of the product. If fluid is colored, it shall be blue.

Product is clear like water, uniform and homogeneous; exhibits no precipitate.

Result ___ Conforms ___

3.2. Physical Properties: The fluid, as supplied by vendor, shall conform to the following requirements: tests shall be performed in accordance with specified tests on the product in concentrated form as delivered by vendor, unless otherwise specified herein.

3.2.1 Flash Point: Shall be reported and shall be not lower than 100°C (212°F), determined in accordance with ASTM D 56 or ASTM D 93. In case of dispute, flash point determined in accordance with ASTM D 56 shall apply.

No flash to 100 °C

Result ______Conforms______

3.2.2 Specific Gravity: Shall be reported and shall be within ± 0.015 of the preproduction value established in 4.2.3 determined in accordance with ASTM D 891.

Specific gravity: 1.238 @ 60/60°F

Result ______Informational______

3.2.3 pH: Shall be 7.0 to 11.5 and within ± 0.5 of the preproduction value established in 4.2.3, determined in accordance with ASTM E 70.

pH: 10.9

Result ______Conforms______

3.2.4 Freezing Point:

3.2.4.1 Freeze point of fluid diluted 1:1 by weight with ASTM D 1193 Type IV water shall be reported and shall be lower than -14.5°C (+6°F) determined in accordance with ASTM D 1177.

Freezing point (1:1 dilution): -15 °C

Result ______Conforms______

3.2.4.2 Shall be reported and shall be within 4°C (7°F) of the preproduction value established in 4.2.3, determined in accordance with ASTM D 1177.

Freezing point (1:1 dilution): -15 °C

Result ______Informational______

3.2.5 Effect on Aircraft Metals:

3.2.5.1 Sandwich Corrosion: Specimens, after testing in accordance with ASTM F 1110, shall not show corrosion worse than control panels run using ASTM D 1193, type IV, water.

	2024-T3 Bare Anodized	2024-T3 Alclad	7075-T6 Bare Anodized	7075-T6 Alclad
PRODUCT	**1**	**1**	**1**	**1**
CONTROL	1	1	1	1

Result Conforms

3.2.5.2 Total Immersion Corrosion: The fluid, tested in accordance with ASTM F 483 except that panels of AMS 4376 shall be tested for 24 hours, shall neither show evidence of corrosion of panels nor cause a weight change of any test panel greater than shown in Table 1:

TEST PANEL	**WEIGHT CHANGE ($mg/cm^2/24hrs$)**	
	ALLOWABLE	**RESULTS**
AMS 4037 aluminum alloy, anodized as in AMS 2470	0.3	**+0.04**
AMS 4041 aluminum alloy	0.3	**0.01**
AMS 4049 aluminum alloy	0.3	**0.01**
AMS 4376 magnesium alloy, dichromate treated per AMS 2475	0.2	**0.01**
AMS 4911 titanium alloy	0.1	**0.01**
AMS 5045 carbon steel	0.8	**0.01**

Result Conforms

3.2.5.3 Low-Embrittling Cadmium Plate: Test panels, coated with low-embrittling cadmium plate, shall not show a weight change greater than 0.3 $mg/cm^2/24hrs$, determined in accordance with ASTM F 1111.

As received: 0.19 $mg/cm^2/24hrs$

Result Conforms

3.2.5.4 Hydrogen Embrittlement: The fluid shall be nonembrittling, determined in accordance with ASTM F 519, Type 1a, 1c, or 2a.

Specimens: Type 1c, cadmium plated per MIL-STD-870 Type I Class 1 .
Test temperature: 20°C (68°F); Load: 45%, immersed for 150 hr duration.

No failures within 150 hours.

Result Conforms

3.2.5.5 Stress-Corrosion Resistance: The fluid shall not cause cracks in AMS 4911 or MAM 4911 titanium alloy specimens, determined in accordance with ASTM F 945, Method A. *(3% salt control: cracking evident)*

As received: No cracking evident.

Result Conforms

3.2.5.5.1 The fluid shall be tested in accordance with ASTM F 945, Method A using AMS 4916 specimens. Report shall detail the effect of the fluid and the effect of control solution. The results shall be reported for informational purposes only. *(100 ppm salt control: cracking evident)*

As received: Cracking evident.

Result Informational

3.2.6 Effect on Transparent Plastics:

3.2.6.1 The fluid, at 25°C ± 2 (77°F ± 4), shall not craze, stain, or discolor MIL-P-25690 stretched acrylic plastic, determined in accordance with ASTM F 484.

Result Conforms

3.2.6.2 The fluid, at 25°C ± 2 (77°F ± 4), shall not craze, stain, or discolor MIL-P-83310 polycarbonate plastic, determined in accordance with ASTM F 484, except that the specimens shall be stressed for 30 minutes ± 2 to an outer fiber stress of 13.8 MPa (2000 psi).

Result Conforms

3.2.7 Effect on Painted Surfaces: The fluid, at 25°C ± 2 (77°F ± 4), shall neither decrease the paint film hardness by more than two pencil hardness levels nor shall it produce any streaking, discoloration, or blistering of the paint film, determined in accordance with ASTM F 502.

Result Conforms

3.2.8 Effect on Unpainted Surfaces: The fluid, tested in accordance with ASTM F 485, shall neither produce streaking nor leave any stains requiring polishing to remove.

Result Conforms

3.2.9 Rinsibility: The fluid shall be completely rinsible in tap water, determined in accordance with 3.2.9.1

3.2.9.1 A 75 x 200 mm panel of clear glass shall be cleaned to provide a surface free of waterbreak, dried, and coated with the deicer/anti-icer fluid by pouring the fluid over the panel while it is held in a horizontal position. The coated panel shall be inclined at an angle of approximately 45 degrees for 10 minutes ± 0.5, then placed in a horizontal position for 24 hours ± 0.25 at room temperature. After the 24 exposure, the panel shall be rinsed in tap water for 5 to 6 minutes, followed by a rinse with ASTM D 1193, Type IV, water, allowed to air dry at ambient temperature, and examined for visible traces of deicer/anti-icer fluid.

Result Conforms

3.2.10 Runway Concrete Scaling Resistance: The condition of the runway concrete surface shall have a rating not greater than 1 for 50 freeze-thaw cycles, determined in accordance with ASTM C 672 except that concrete shall:

- Be air-entrained with an air content as specified in ASTM C 672
- Have a minimum cement content of 510 pound per cubic yard ± 10 (302 kg/m^3 ± 6)
- Have a slump, 1.5 inches ± 0.5 (38 mm ± 13)

A 25 % by volume solution of the deicer/anti-icer fluid, as supplied by the manufacturer in commercial concentration, in tap water shall be substituted for calcium chloride. Performing more than one freeze-thaw cycle per day is acceptable.

Rating = 1

Result Conforms

3.2.11 Storage Stability: The fluid, after storage in accordance with ASTM F 1105, shall not exhibit separation or an increase in turbidity compared to unaged fluid. Any increase in turbidity shall be reported, but shall be acceptable if removed by mild agitation.

Result Due 25-Apr-2009

SMI, Inc.
12219 SW 131 Avenue
Miami, Florida 33186-6401 USA
Phone: (305) 971-7047
Fax: (305) 971-7048

Attn: Claudio Manissero
FMC Corp . Lithium Division
Seven Lake Point Plaza
2801 Yorkmont Rd Suite 300
Charlotte. NC 28208

Date 27-Apr-2009

SMI/REF: 0804-382ss

Product **LITHMELT DEICER (Lithium Potassium Acetate Solution)**
(received 25-Apr-2008)

Dilution: As received

Storage Stability testing per **AMS 1435A**
FLUID. GENERIC DEICING/ANTI-ICING
Runways and Taxiways

---

3 2 11 Storage Stability The fluid. after storage in accordance with ASTM F 1105 shall not exhibit separation or increase in turbidity compared to unaged fluid Any increase in turbidity shall be reported but shall be acceptable if removed by mild agitation

No evidence of separation or increase in turbidity.

Result Conforms

Respectfully submitted.

Patricia D Viani. SMI Inc.