Chemical Melting of Ice and Snow on Paved Surfaces

David A. Dunnery

When it is impossible to remove ice from paved surfaces by mechanical means, chemical agents are employed either to completely melt the ice or to partially melt it so that it can be broken up and removed by brooming or scraping. Chlorides, which have long been used for this purpose, are objectionably corrosive. Urea, which is also widely used, is ineffective below the eutectic temperature of 11 F and is marginally effective below ~ 15 F. A noncorrosive liquid agent has been formulated for use at temperatures down to 0 F. During the winter of 1969 and 1970 the agent was tested at LaGuardia Airport in New York and at Union Carbide laboratories. Results of these tests are reported.

Union Carbide first became interested in a chemical de-icer for pavements in response to 2 problems that airport operations crews were encountering in their use of sand. The sand they were using contained varying amounts of water. The freezing of this water in the sand pile created large hard lumps of material that would bind or even break the auger assembly in the sand trucks. Also, when the sand was applied to the runway it was often blown away by the jet blast. It was proposed to treat the sand with an ice-melting chemical that would prevent formation of frozen lumps and, by melting the ice immeidately in contact with the sand, would allow the sand to socket itself in the ice and thus stay put.

This technique was quite successful and is now routinely employed at many airports, among them being those operated by the Port of New York Authority. However, there is strong pressure to avoid the use of sand altogether on runways. Sand is ingested by jet engines where it erodes the turbine blades and can also stick to operational surfaces of the aircraft, such as flap tracks and landing gear. We, therefore, sought to develop a technique of chemical de-icing that would allow complete removal of ice and snow from runways, thus eliminating the need for sand. A proprietary product was developed and submitted for corrosion studies. Any material that comes in contact with aircraft must be noncorrosive to metal and painted surfaces. The material passed the hydrogen embrittlement and cadmium corrosion tests and a sandwich corrosion test in which the fluid is layered between strips of various aluminum alloys and run through temperature humidity cycles. On February 10, 1970, it was accepted by the Air Transport Association for use on runways at LaGuardia.

Meanwhile, we had been testing the product on nonoperational areas at LaGuardia Airport. These tests were of 2 kinds: anti-icing in which the fluid was applied before precipitation, and de-icing in which the capacity of the material to assist in the removal of packed snow and ice was examined.

In our first test on January 6, 2 sections of an asphalt service road were treated, one at 1 gal/1,000 sq ft and one at 1 gal/10,000 sq ft using an agricultural sprayer. A 2-inch snow fell on the area during the night while the temperature was about 24 F. No freezing was observed at the snow pavement interface, and the snow could be completely removed by plowing.

On January 20, a 500- by 30-ft area of a concrete taxiway was heavily treated (1 gal/125 sq ft) to determine the effect of the fluid on braking action. During the night a light blowing snow fell at a temperature of 10 F. The blowing snow stuck to the wet surface of the test area and it was completely snow-covered while the rest of the pavement still had only scattered patches of accumulation. After being plowed, the test area was clean and wet, completely free of snow, while the rest of the taxiway had scattered patches of packed snow.

We did not get an opportunity this winter to test at LaGuardia the protection the agent would afford in a freezing rain. Simulated tests were run in the parking lot at our Tarrytown labs. Test patches were treated with the product at 1 gal/1,000 sq ft. The next morning, at a prevailing temperature of 18 F, water was sprayed on the area as a fine drizzle equivalent to a 1/16-in. rain. The water froze immediately on the untreated area, but on the test patch no freezing occurred. Another 1/16 in. of drizzle was applied, and again no freezing occurred. Water was then sprayed continuously until crystallization was observed. The ice was mechanically weak and not bonded to the surface. This material was pushed off the treated surface, and the equivalent of another 1/16 in. of fine drizzle was applied. This froze to glare ice, but the ice was mechanically weak and not bonded to the pavement, so that it could be readily removed by prodding with a scraper. In these anti-icing tests the agent was applied to the pavement well before precipitation began and, therefore, had the opportunity to work itself well into the surface imperfections. If it had been applied to a wet surface it would have been somewhat less effective, being more susceptible to being swept away in the water runoff.

Our first de-icing test was on January 12 on an asphalt service road at LaGuardia. The surface was plowed after a 2-in. snowfall. Approximately 1/16 in. of packed snow remained, with occasional bare spots. The temperature was then 20 F. The road was sprayed with 1 gal/500 sq ft. Melting of the packed snow began immediately and was complete within half an hour.

On February 10, the Air Transport Association approved the use of the fluid on runways. A 1,000-gal agricultural sprayer with a 30-ft spray bar was acquired to permit treatment of larger areas. An extra pump was attached raising its spraying capacity to 120 gal/min. The sprayer was delivered to LaGuardia on February 15 and was immediately put into action.

The storm was then in its twelfth hour, and about 3 in. of snow had accumulated. The temperature was then 21 F. Runway 1331 had been plowed and broomed repeatedly, leaving scattered patches of bare asphalt and packed snow. A 2,000-ft section was sprayed with 1 gal/500 sq ft. Melting of the packed snow began immediately with penetration of the packed snow and melting of the snow-pavement bond. The residual snow could be easily dislodged. Drifting snow eventually covered the test area, but there was no further bonding of snow to pavement.

The snowstorm was followed by freezing rain. At 1:00 p.m., runway 1331 was covered with glare ice between an eighth and a half inch thick. In some places the ice covered partially frozen residual packed snow. A previously untreated area was sprayed with 1 gal/500 sq ft; the temperature was 20 F. Immediate ice melting was noted, attended by snapping, cracking sounds. The de-icer penetrated the ice and destroyed the ice-asphalt bond to such a degree that the ice could readily be dislodged by scuffing the surface. Within 10 to 15 minutes of de-icer application a braking test was performed with a station wagon. The wheels broke through the weakened ice allowing the vehicle to be brought to a controlled stop. Within 15 minutes some areas had melted completely. The residue on the test area was then plowed onto another untreated area and ice melting on the new area was observed.

This proved to be the last storm of the season at LaGuardia, so further opportunities for testing there did not arise. We performed some tests on ice frozen in pans in a cold room at 20 F. The penetration disbonding effect was not observed. Melting occurred only at the ice surface, not at the ice-substrate interface. We prepared test patches in our parking lot by spraying water on asphalt at 18 F. On spraying these with 1 gal/500 sq ft, we again failed to produce this penetrating effect, melting only from the ice surface. We do not know why the kind of action observed at LaGuardia was not reproduced in our lab tests. Perhaps the ice produced in a storm is imperfect compared to that produced in our lab. Perhaps thermal stresses resulting from warming from the 25 F, at which most of the ice at LaGuardia had formed, to the 29 F, prevailing at the time it was treated, had generated microfissures through which the de-icer could penetrate and spread. At present, the possibility remains that glare ice will be encountered on which the fluid is not effective.

The fluid was also tested outside the Union Carbide laboratories in Montreal. There it was applied to areas covered with 3 in. of packed snow and ice representing residual

TABLE 1

MU METER TEST RESULTS

Application Rate (gal/sq ft)	μ	Application Rate (gal/sq ft)	μ
De-icing fluid		De-icing fluid	
0	0.77	1/500	0.67
1/2,000	0.72	1/400	0.65
1/1,000	0.68	Water	0.64-0.65
1/666	0.66		

TABLE 2

MATERIALS COST PER LANE-MILE PER INCH OF SNOWFALL TO PRODUCE INDICATED DEGREE OF MELTING

Temperature (deg F)	15 Percent Wet	30 Percent Wet
30	13	25.8
25	35	71
20	58	116
10	90	180

accumulation from several storms. There were layers of ice interspersed by layers of packed frozen snow. Fluid was applied at a level of 1 gal/125 sq ft. After an hour the material was scraped away. The fluid had penetrated and drained through the packed snow and ice and was now concentrated in the bottom half inch. Over two-thirds of the treated area the material was easily scraped from the surface, the ice pavement bond having been broken.

One further test was run at LaGuardia this winter to determine the effect on braking action of the de-icing fluid applied to a clean dry runway. We wished to learn if the fluid itself was sufficiently slippery to constitute a hazard. This test was run with the cooperation of American Airlines, who provided a Mu Meter, a friction coefficient testing device made by M. L. Aviation, Ltd., and marketed in this country by Soiltest, Inc. The test was performed on the touchdown area of runway 4-22, a concrete runway heavily tire-marked. The fluid was applied to a swath 20 by 500 ft, and the Mu Meter reading was obtained after each application (Table 1). Applications were repeated until the fluid was flowing freely on the surface. A parallel swath was then wet with water and its reading obtained. On the Mu Meter scale readings of 0.6 to 1.0 are rated good. The fluid is, therefore, considered no more deleterious to braking than is water.

Let us now consider how the fluid would be used in highway operations. Its most effective use is as an anti-icing agent applied when an ice storm is imminent. The advantages of a liquid agent are that it can be applied evenly over the surface and it will not blow away as would a solid when applied to a dry pavement. An application rate of 1 gal/1,000 sq ft is sufficient to completely wet the surface if applied in a fine spray. At 10 ft per traffic lane and a fluid cost of 72 cents/gal, this treatment would lead to a materials cost of $37 per traffic lane-mile. The cost may restrict its use to critical areas such as bridges, bridge and tunnel approach ramps, and toll plazas. Here, the fact that the fluid will not lead to chemical attack on metal and concrete structures is an important consideration. The duration of the protection afforded depends on weather and traffic conditions and is thus indeterminate. The user would try to anticipate the icing condition by several hours.

When ice has formed on a highway or plowing has left a residue of packed snow, the fluid may be used as a de-icer. Here, the object is to penetrate the covering, breaking its bond to the pavement and enabling it to be broken up by traffic or removed by subsequent plowing. For ice up to an eighth of an inch or packed snow up to half an inch thick, an application rate of 1 gal/1,000 sq ft should be sufficient. The rate of action depends somewhat on temperature. At temperatures above 20 F action should be complete within half an hour even in the absence of agitation from passing traffic.

Another possible use of the fluid is in direct application to fresh snow in order to keep the snow plastic and mobile. Schaerer reports that snow containing 15 percent free water resists compacting and snow containing 30 percent free water was removed by traffic. The amount of agent needed to produce this degree of melting is a function of temperature. Knowing the water content that the agent would achieve on coming to equilibrium with ice at any given temperature, one can calculate the ice-melting capacity of the agent at that temperature. This calculation has been performed for 4 temperatures, and the results are given in Table 2 as materials cost per traffic lane-mile per inch of snowfall. The slush produced by this technique would differ in one important respect from slush produced by thermal melting. It would not freeze solid on subsequent cooling. Ice would freeze out as the temperature dropped, but some liquid would remain even to temperatures below zero keeping the slush plastic and weak.

Informal Discussion

John A. Cook

What fluid are you putting down?

Dunnery

The fluid is Union Carbide UCAR runway de-icing agent. It is a proprietary product, and I am not free to disclose its composition.

Don L. Spellman

Was the snapping and cracking you observed caused by the salt working its way underneath?

Dunnery

Yes, the ice was buckling and breaking as the material was spread.

Spellman

Pulling the ice away?

Dunnery

Yes, we could see the evidence.

J. G. Slubicki

If this fluid is used as an anti-icing agent, is it effective for a couple of hours or a couple of days?

Dunnery

This has not yet been determined. It would depend to some degree on how actively it is removed by traffic. I would expect the amount of protection to decline with time, but the rate would depend on traffic, weather, wind, and so forth. We do not know how long its effectiveness will last.

J. W. Renehan

How does this compare with liquid calcium?

Dunnery

In what respect?

Renehan

With respect to cost and efficiency.

Dunnery

I have not made any direct comparison. The cost of this fluid is 72 cents per gallon. I do not know what you would pay for calcium chloride.

Renehan

Calcium chloride in solution will do the same thing. I do not know what the range of temperature is for your solution, but calcium chloride in an aqueous solution will work at -10 F. I imagine it will also hold as good, but it is corrosive.

Dunnery

That is right. Calcium chloride cannot be considered for use on runways.

William F. Limpert

What is the vapor pressure of the material?

Dunnery

I do not know.

Limpert

This will have an effect on how long it is going to last.

Dunnery

It is a multicomponent system, and its vapor pressure will change with time; that is, as the more volatile materials disappear, the vapor pressure decreases. I do not know what the initial vapor pressure is; at 25 deg, the initial vapor pressure would be about 5 mm.

Limpert

Is it soluble or miscible in water?

Dunnery

Yes. No material would be effective as an anti-icing agent if it did not dissolve in water.

Limpert

My point is that, if it does have a very low vapor pressure and does stay around longer than salt brine or calcium chloride brine, this alone can contribute to corrosion merely by keeping metal moist even though by itself the material may be noncorrosive.

Dunnery

It would actually protect moist metal.

Limpert

Does it act as an inhibitor against moisture?

Dunnery

Yes. There is one more point I would like to make with regard to the environment. Ninety-eight percent of this formulation is bio-degradable immediately upon being exposed to the environment, so it would not be persistent in the environment.