Abridgment

Field Evaluation of Oil- and Gas-Produced Brines as Highway Deicing Agents

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ABSTRACT

Field tests conducted as part of a project to assess the potential of West Virginia waste oil and gas field brines for highway deicing purposes are discussed. Brine characteristics and current disposal practices are reviewed along with published accounts of brine use. A detailed discussion of the field test program is presented, including an analysis of the brine used, descriptions of the high pressure brine applicator unit, the test sites, brine storage, and a description of the methodology used on a typical application run. Results of eight test runs indicated that waste brines were effective deicing agents over a wide variety of weather and pavement conditions. Bare pavement was achieved rapidly with both high pressure and gravity application, even at temperatures as low as 15°F, because of the significant amounts of calcium in the brine. Skid-resistance measurements, made by using a portable tester, showed a substantial increase in pavement skid resistance after brine application. Refreezing was not found to be a significant problem. Study of the impacts of natural brines on construction materials and on the environment as well as the economics of storage and handling is also under way as part of the overall project.

Under the constraints of environmental problems and tight operating budgets, highway agencies are seeking ways to minimize the use of deicing chemicals. One approach is the use of naturally occurring salt brines that are a waste product of oil and gas production. As a liquid, brine has the advantages of being fast acting and does not blow or bounce off the road. Use of natural brine for deicing purposes could solve several problems simultaneously. The oil and gas industry would be able to dispose of an unwanted by-product and highway agencies could acquire a deicing material at minimal cost. Furthermore, the natural brine that is used would be applied at controlled rates rather than discharged directly to the environment, as is currently done in some regions.

Before advocating a major natural brine deicing program, there are a number of issues that should be evaluated. For example, the quantity of brine available for highway deicing in a given geographical region must be assessed. Transportation and storage costs must be estimated. Brine quality from the major producing formations must be determined, including both the major salts and the minor trace elements. It would be desirable to compare brines with commercial deicing agents relative to melting, skid resistance, refreezing of roadway surfaces, and effects on transportation materials. A comprehensive research project is in progress at West Virginia University to address these issues. In this paper the field tests conducted during the winter of 1981-1982 are discussed.

BACKGROUND

Naturally occurring salt brines may be thought of as connate or entrapped sea water. Brines are often associated with oil and gas deposits and are brought to the surface during production as a by-product. The quantity of brine produced or separated from the oil or gas varies greatly with the type of formation, age of the well, and how the field is managed. Production of brine from gas and oil wells may range from negligible amounts to more than 30 gal per thousand cubic feet of gas and to more than 50 gal per barrel (42 gal) of oil.

The major constituents of sea water and some typical brines are given in Table 1 (1). A number of trace constituents such as barium, strontium, lead, and zinc will also be found in most brines. Brines tend to increase in concentration with depth, but a brine taken from a given formation and location will usually be relatively constant in concentration with time.

Brine disposal is a significant and costly problem for oil and gas producers. The high concentration of dissolved salts found in brines and the large volumes involved present the potential for serious and long-term contamination of groundwa-

TABLE 1 Analyses of Natural Brines (mg/L)

State	Formation	Chloride	Sulfate	Bicarbonate	Sodium	Calcium	Magnesium	Total[a]
	Ocean waters (mean)	19,410	2,700	-	10,710	420	1,300	34,540
Michigan	Dundee Limestone	161,200	155	60	66,280	25,740	4,670	258,105
Oklahoma	Wilcox Sand	89,990	515	65	44,020	9,460	1,990	146,040
Oklahoma	Arbuckle Limestone	101,715	120	60	50,345	10,160	2,120	164,520
Kansas	Hunton Limestone	76,797	207	61	40,284	5,440	1,790	124,579
Pennsylvania	Oriskany Sandstone	169,000	0	-	57,100	35,900	3,510	265,510
Ohio	Clinton Sand	154,000	524	23	52,300	37,200	5,090	249,137
West Virginia	Chemung[b]	134,720	-	-	59,800	23,180	3,014	220,715
West Virginia	Oriskany[b]	181,050	-	-	75,860	54,820	3,276	315,006

Note: Data adopted in part from Miller (1).
[a]Total for constituents shown.
[b]Analyzed and used during this study.

ters. The preferred method of brine disposal today is injection into the formation of origin or another formation. However, although underground disposal is quite feasible is some regions, there are significant limitations on the use of this method in many sections of the country.

Natural brines have been used as deicing agents for many years; some of the published accounts date back to the 1950s (2,3). A number of state, county, and local highway agencies (especially in New York, Pennsylvania, and Michigan) have used or are using natural brine deicers; but most experiences have not been reported in the literature. It appears that no comprehensive evaluation has been conducted on the use of natural brines for highway deicing.

FIELD TEST PROGRAM

A portable hydrodynamic brine applicator system designed by the Connecticut Department of Transportation for application of brine at 300 psi was acquired through the FHWA. A complete description of this system has been prepared by Pickett and Carney (4). The unit was mounted on a 9-ton dump-body truck obtained from the West Virginia Department of Highways.

Spraying was carried out on campus roadways designated by the West Virginia University (WVU) Physical Plant. The roads designated initially were low-volume roadways situated away from the main campuses of the University. They are characterized by relatively narrow pavements, sharp horizontal curvature, and short length. All sites had bituminous wearing surfaces. Truck speeds on these roads were extremely low because of the short roadway length and restricted geometry. Low speed, in combination with the starting and stopping associated with the short length, resulted in high brine application rates. As the field study continued and the effectiveness of brine as a deicer and the reliability of the spray unit were demonstrated, the investigators were given responsibility for treating some of the more important campus roads. The higher speeds attainable on these routes resulted in more realistic brine application rates.

Brine used (see Table 1) in the field study was produced from gas wells in West Virginia and was obtained free of charge. Deliveries of brine were made throughout the winter to several types of aboveground closed steel storage tanks located on the WVU campus. All tanks were made of carbon steel and had been previously used for other purposes.

DESCRIPTION OF APPLICATION AND EVALUATION PROTOCOL

Each time snow removal or ice control efforts were initiated, the spray unit was driven to the brine storage facilities on campus for filling. The truck and spray unit were weighed before and after brine application to determine the amount of brine applied. During the runs a passenger in the truck used a stopwatch to measure application times. Another individual was outside the vehicle collecting snow and runoff samples both before and after application, and taking temperature measurements and photographs.

The British portable tester device was used to collect limited skid-resistance data. The British pendulum number (BPN) values obtained on snow-covered pavements in this study were not used as measures of pavement skid resistance but rather were used to indicate whether the deicing agent had been successful in breaking the bond between the pavement and the snowpack (the higher the BPN, the greater the frictional resistance). For this reason, the authors caution that the readings obtained in this study should not be compared with other wet pavement BPN values.

SUMMARY OF RESULTS

As the field testing progressed, it was observed that corrosion products from the steel spray bar tended to plug the spray nozzle openings (0.08-in. diameter), which resulted in reduced sprayer effectiveness and required periodic cleaning of nozzles. In addition, it was believed that the high initial cost of the spray unit coupled with potential maintenance problems associated with the high pressure system might reduce the attractiveness of the unit. Therefore, the unit was converted to essentially a gravity flow unit by removing every other nozzle from the spray bar for the last two runs of the season.

As indicated by the data in Table 2, eight field runs were made. The brines were generally effective in melting snow and ice and achieving bare pavement within a relatively short period of time. Only two test runs (runs 7 and 8) were made by using the

TABLE 2 Summary of Field Test Results of WVU Campus Roadways

Run No.	Date	Temperature (°F)	Snow Depth (in.)	Roadway Cover Type	Mode of Delivery	Brine Source	Sites Treated[a]	Avg Speed (mph)	TDS (lb) per TLM[b]	Comments
1	12/17/81	28-30	1-2	Loose snow	Pressure	Chemung	ER, H, A, L, D	–	697	Produced bare pavement quickly
2	1/9/82	14-17	2	Loose snow	Pressure	Chemung	ER, SB, H, A, D, L	4-10	1,480	Better melt-off than campus roads treated with dry salt; SB road became bare after treatment as it received traffic; temperature fell rapidly throughout period
3	1/16/82	28-31	1.25-2	Loose snow	Pressure	Chemung	ER, FB, H, A	<6	1,693	Rapid melt-off; bare pavement
4	1/25/82	16-22	3-4	Packed snow	Pressure	Chemung	SB, EC, ER, MC, PP	11.5-15	355	Bare pavement achieved; good melt-off
5	2/11/82	17-19	3-4	Packed snow and ice	Pressure	Oriskany	ER	10.6	1,422	Melt-off slower because of low temperature and packed ice
6	2/13/82	21-25	2-2.25	Loose snow	Pressure	Oriskany	ER, FB, EC, PP, C	4-10.3	1,750	Excellent, rapid melt-off, some traffic, partial plowing
7	3/3/82	25	1	Packed snow and ice	Gravity	Oriskany	PP	12.0	534	Rapid melt-off; bare pavement
8	4/6/82	26-30	0.5-1	Packed snow	Gravity	Chemung	EC	7.4	506	Good melt-off

[a] Site key: EC = Evansdale Campus, MC = Medical Center, FB = Facilities Building, ER = Engineering (rear), H = Horticultural Farm, A = Airport, L = Livestock Farm, D = Dairy Farm, SB = Stadium Bypass, PP = Physical Plant (access road), and C = Coliseum.
[b] Pounds of total dissolved solids (TDS) per two lane mile (TLM) of highway.

gravity application. Under the conditions present, gravity application appeared to be as effective as the high-pressure spray in achieving melt-off. A discussion of the runs in which skid-resistance data were collected is presented in the following paragraphs.

No response could be made to a snowstorm on February 9, 1982, because of being temporarily out of brine. Two days later the Engineering Road site was still covered with a slippery ice pack (BPN = 29.2) because Physical Plant crews had not treated the road. It was decided to treat the road (run 5) with two applications of brine.

Skid-resistance data and color photographs were acquired roughly 1, 3, and 24 hr after brine application. Within 0.5 hr, under light traffic conditions, the surface of the ice pack became mealy in texture. One hour after application darkened wheel tracks appeared (BPN = 35.4). At this point the sun came out and speeded up the melting process. Within 3 hr the pavement was basically wet (BPN = 69.4); after 5 hr the pavement was beginning to dry off. The next morning the humidity was high with temperatures in the mid-teens. There were some areas of refreezing in low spots on the pavement, but the main wheel paths were dry (BPN = 90.4).

Another snowstorm 2 days later provided an opportunity to acquire additional data at the Engineering Road site (run 6). Part of the road was left untreated to provide a comparison with the section receiving brine application. BPN values for the before condition were in the low 30s for both sites. One application of brine was made; snow continued to fall for another 1.5 hr. After 3 hr clouds broke up and some solar radiation was noticeable. Under light traffic conditions the wheel paths of the treated section became mainly clear, with a small amount of slush present. The BPN value had almost doubled to 63.8. The untreated section had packed snow in the wheel paths; the BPN value had increased only slightly to 36.6.

Brine application rates for each run are also provided in Table 2. In practice, typical salt (sodium chloride) application rates range from 300 to 700 lb per two-lane mile (TLM). In order to compare the application rate of brine to conventional deicing agents, brine strength may be expressed as total dissolved solids (TDS), which includes all the salts or dissolved solids in the brine. Thus the weight of TDS in natural brines is comparable to the weight of dry salt used in conventional deicing operations. The data in Table 2 indicate that brine application rates during the eight field test runs varied from 355 to 1,750 lb TDS per TLM (203 to 967 gal per TLM).

The high application rates used in some of the runs are not typical of the amount of salt that would be required in a full-scale brine application program. Deicing applications were initially carried out on short, low-volume roadways, which resulted in low average truck speeds. Another factor contributing to high brine use on certain runs was operator inexperience. As the winter progressed, deicing was also carried out on some higher type and longer roadways, thus allowing higher average truck speeds and reduced application rates.

As expected, traffic load and packing of snow also influenced application rates. The runs with the lowest brine application rates (runs 4, 7, and 8) were made principally on roads with higher traffic volumes and packed snow. Loose snow resulting from lack of plowing or little traffic tends to absorb brine, thereby considerably reducing its effectiveness just as would occur with use of rock salt.

CONCLUSIONS AND RECOMMENDATIONS

Results of field testing have demonstrated that waste oil and gas field brines are effective deicing agents over a wide variety of weather and pavement conditions. It was found that visible melting began to occur almost immediately after application, and bare pavement was achieved rapidly, even at temperatures of 15°F on low-volume roadways. The effectiveness of the brines at low temperatures may be attributed to the fact that the brines used contained significant amounts of calcium as well as sodium salts (see Table 1).

Skid-resistance measurements at various times after brine application indicated a substantial increase in pavement skid resistance. Refreezing was not found to be a significant problem. It would be desirable to perform similar tests under comparable conditions by using rock salt as a deicing agent.

Both simple gravity and high-pressure spray application of the brine achieved rapid melt-off and bare pavement. Based on the satisfactory results obtained with gravity application, it is recommended that additional field application of brine be carried out using this method. The increased simplicity and lower equipment and maintenance costs associated with gravity application appear to make this method attractive.

Brine was stored in aboveground steel tanks during the course of this work, as is common in the oil and gas industry. No problems were encountered with this method of storage, although other types of storage containers (such as fiberglass) are being evaluated.

Based on the results of the research thus far, use of by-product brines from the oil and gas industry appears to offer an effective and potentially cost-effective means of highway deicing. It is recommended that additional field testing be carried out on more typical higher type roadways with higher volumes by using the gravity mode of application.

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