

COMPARISON OF SODIUM CHLORIDE AND A 3:1 MIXTURE
OF SODIUM CHLORIDE AND CALCIUM CHLORIDE
AS USED FOR HIGHWAY ICE CONTROL

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Research Project R-61 G-110
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Michigan State Highway Department
John C. Mackie, Commissioner
Lansing, August 1962

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Synopsis

This project was initiated in cooperation with the Office of Maintenance to compare the ice melting properties of salt (sodium chloride as normally used in Michigan and elsewhere for ice control purposes) with those of a 3:1 mixture of salt and calcium chloride. Two forms of this mixture were compared; one in which the sodium chloride was natural rock salt and another in which this ingredient was a manufactured product.

The treatments were evaluated in sixty-seven storm conditions during January and February 1962. All application and handling methods followed normal winter ice control procedures. From these tests enough significant data were obtained to support the following conclusions:

1. There was no appreciable difference between the effectiveness of plain salt and the mixtures at temperatures from 6 to 32 F.
2. The mixtures did not store or handle as well as rock salt and there was some inconvenience and loss of material due to hardening.
3. Both forms of the mixture performed in about the same manner.
4. Straight salt, being cheaper, easier to store, and as effective as the 3:1 mixture, should continue as the Department's primary ice control chemical. To obtain faster melting at temperatures below 15 F, a substantial increase in the amount of calcium chloride appears necessary.

During the past several years, rock salt has been the most widely used chemical for removing ice and snow from highway pavements during winter maintenance operations. In addition to being the most economical chemical available for this purpose, rock salt usually can be handled and stored with less difficulty than other ice control materials, and generally its performance is satisfactory within normal storm temperature ranges. At lower temperatures, say 15 F or below, calcium chloride is often used either alone or in combination with rock salt to increase the rate of melting.

Several agencies, including the New York Thruway Authority, the Ohio Turnpike Commission, University of Minnesota, and Washtenaw County, Michigan, have conducted field and laboratory tests to determine

the effectiveness of different mixtures of rock salt and calcium chloride (1, 2, 3). Although results of these tests were quite variable, they furnished the basis for a recommendation by the calcium chloride industry that a 3:1 ratio of rock salt to calcium chloride was the most efficient mixture for a normal range of winter temperature conditions.

The Michigan State Highway Department has also used calcium chloride as an additive to rock salt in order to speed up ice melting rates at lower temperatures. Generally this work has not been done under controlled conditions, usually consisting of adding a few bags of calcium chloride to a truckload of rock salt at the time of spreading.

In order to determine the true effectiveness of salt-calcium chloride mixtures under Michigan's winter weather conditions, the Office of Maintenance in cooperation with the Research Laboratory Division initiated a field research project in December 1961. It was realized that optimum ratios of the two salts might vary for different storm conditions, but also that it would be impractical to store and test a variety of mixtures. For this reason the 3:1 ratio, as recommended by the calcium chloride industry through its Institute, was selected for the test purposes.

After several committee meetings and conferences at which all interested parties, including the suppliers of the mixtures, had a chance to comment on the proposed testing program, Research Project 61 G-110 was initiated by the Research Laboratory Division to be handled as a joint project with the Office of Maintenance. The primary purpose of the study was to determine the effectiveness of a 3:1 mixture of rock salt and calcium chloride as compared with rock salt alone when used for winter ice control. In addition, two forms of the mixture itself were to be compared; one in which the sodium chloride was a natural rock salt, the other in which the sodium chloride was a manufactured salt (Cubidow). All of the mixtures were to be prepared and delivered by the supplier in bulk. Rock salt or synthetic salt was to be delivered and stored in the normal manner.

Testing Procedures

Nineteen storage areas were selected throughout the southern part of Michigan from which supplies would be taken for the tests (Fig. 1). At least one form of the mixture (containing either natural or synthetic salt) was available at each of these sites. At seven of the sites, supplies of both forms of the mixture were available. All storage and test areas to which the materials were applied are shown by District in Figs. 2 through 6.

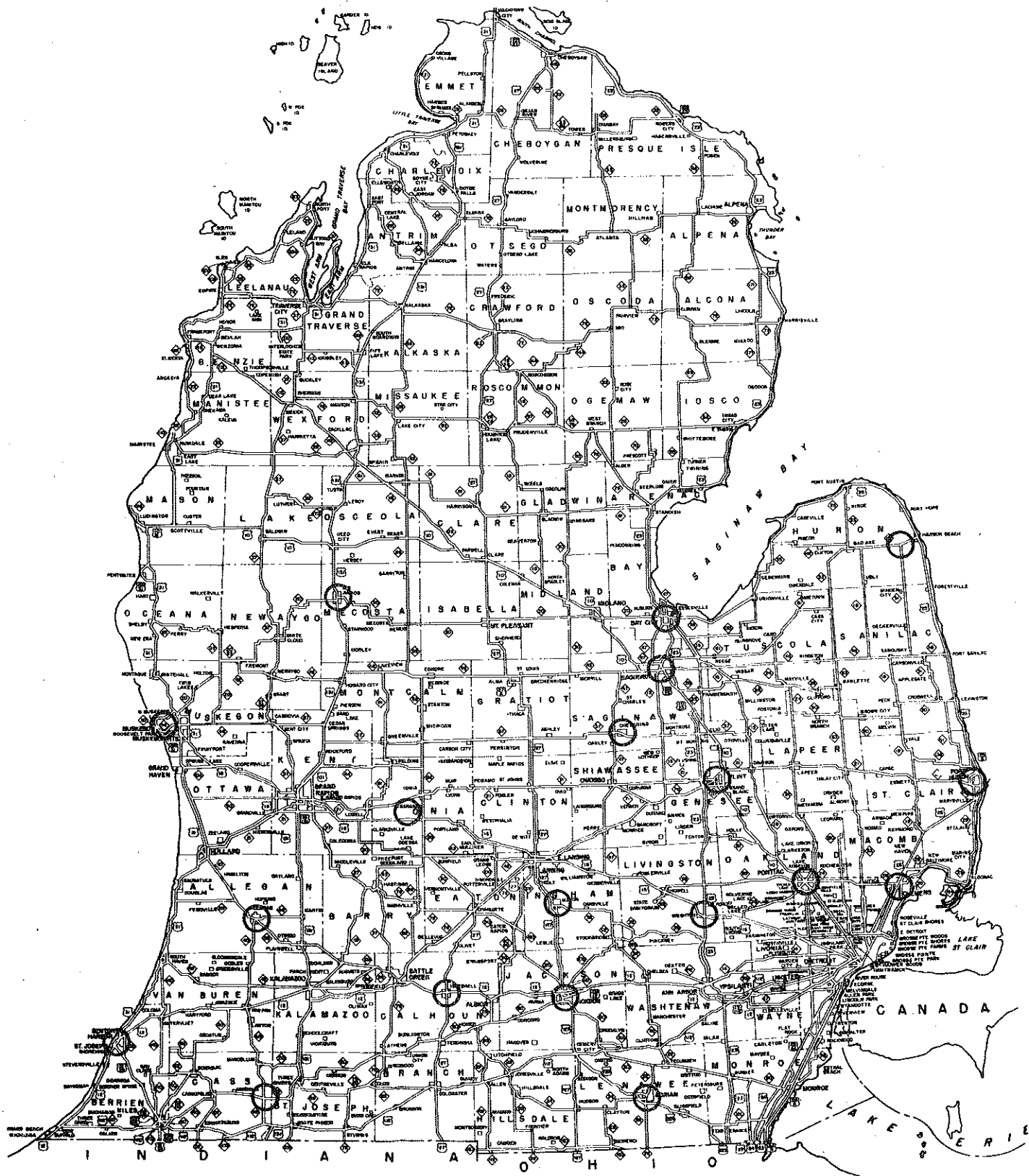
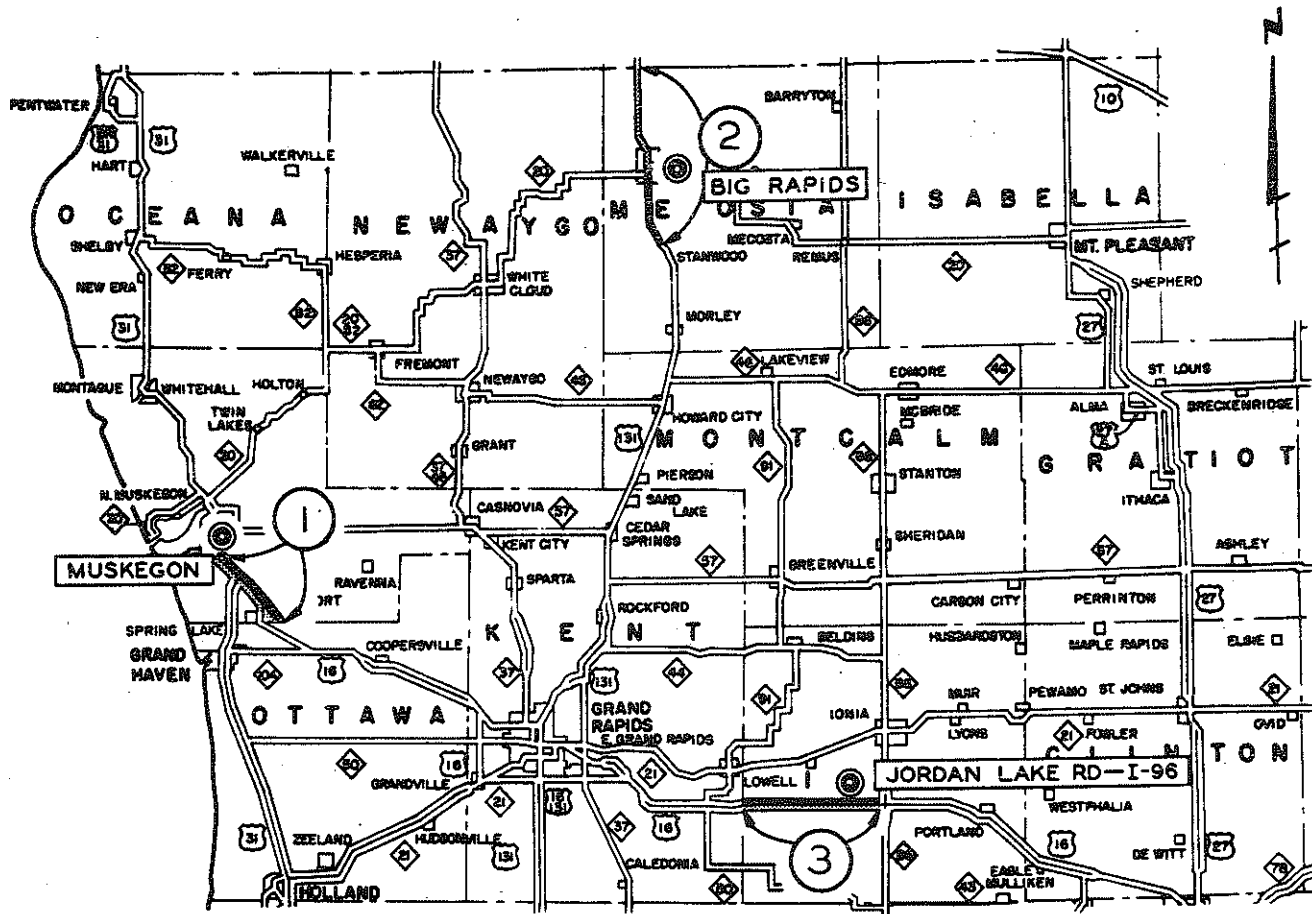


Figure 1. Location of storage areas for test materials.



LEGEND

- ② STOCKPILE - 3:1 MIXTURE (SYNTHETIC SALT)
- ⊙ STOCKPILE - 3:1 MIXTURE (NATURAL SALT)
- ⊕ STOCKPILES - BOTH MIXTURES
- ▨ TEST AREA - 3:1 MIXTURE (SYNTHETIC SALT)
- ▧ TEST AREA - 3:1 MIXTURE (NATURAL SALT)
- TEST AREA - PLAIN SALT (NORMAL TREATMENT)



NOTE:
 STOCKPILES OF PLAIN SALT, USED FOR
 NORMAL ICE CONTROL TREATMENT, ALSO
 LOCATED AT EACH STORAGE SITE.

Figure 2. Storage and test sites - District 5.

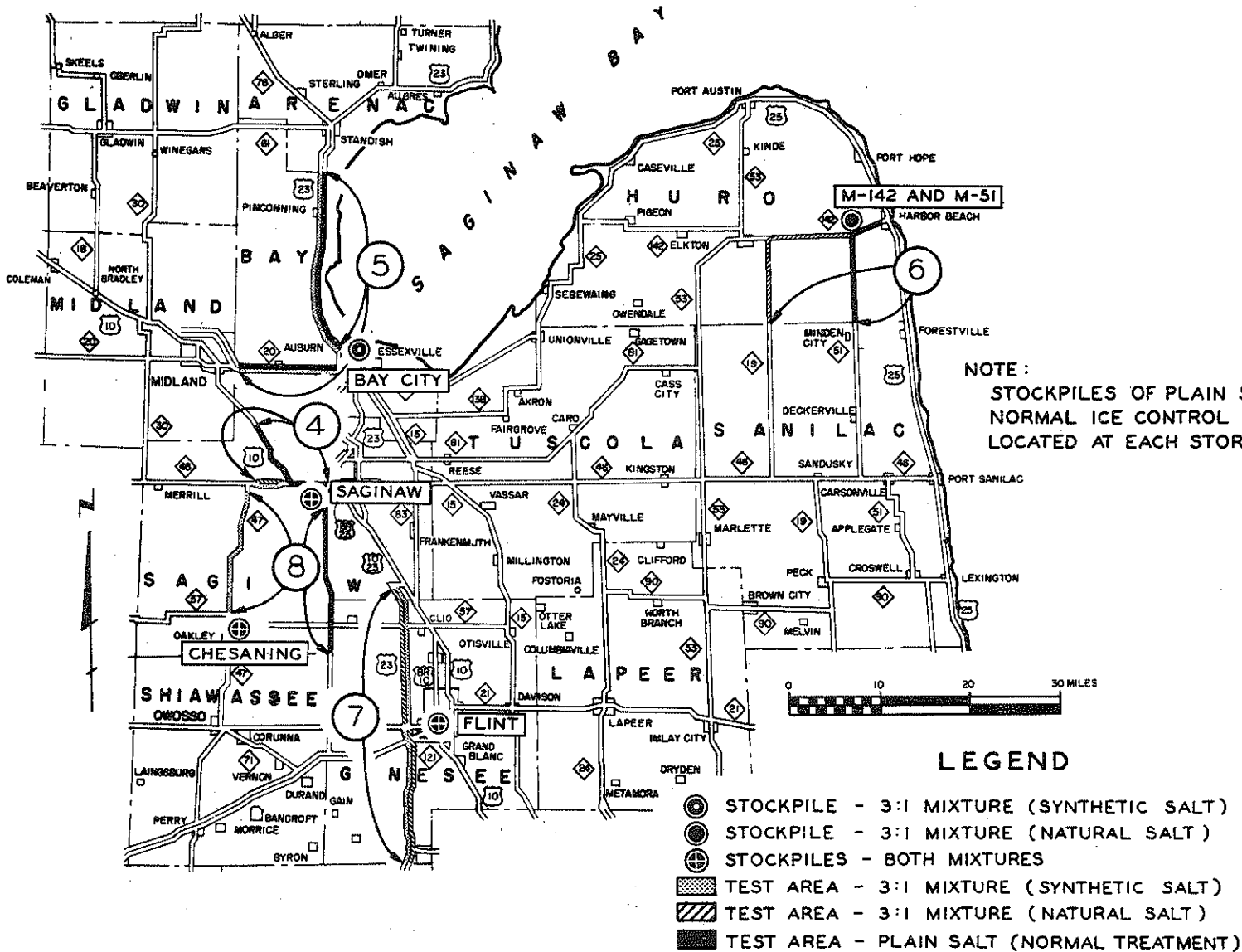


Figure 3. Storage and test sites - District 6.

LEGEND

- ⊙ STOCKPILE - 3:1 MIXTURE (SYNTHETIC SALT)
- STOCKPILE - 3:1 MIXTURE (NATURAL SALT)
- ⊕ STOCKPILES - BOTH MIXTURES
- ▨ TEST AREA - 3:1 MIXTURE (SYNTHETIC SALT)
- ▩ TEST AREA - 3:1 MIXTURE (NATURAL SALT)
- TEST AREA - PLAIN SALT (NORMAL TREATMENT)

NOTE:

STOCKPILES OF PLAIN SALT, USED FOR NORMAL ICE CONTROL TREATMENT, ALSO LOCATED AT EACH STORAGE SITE.

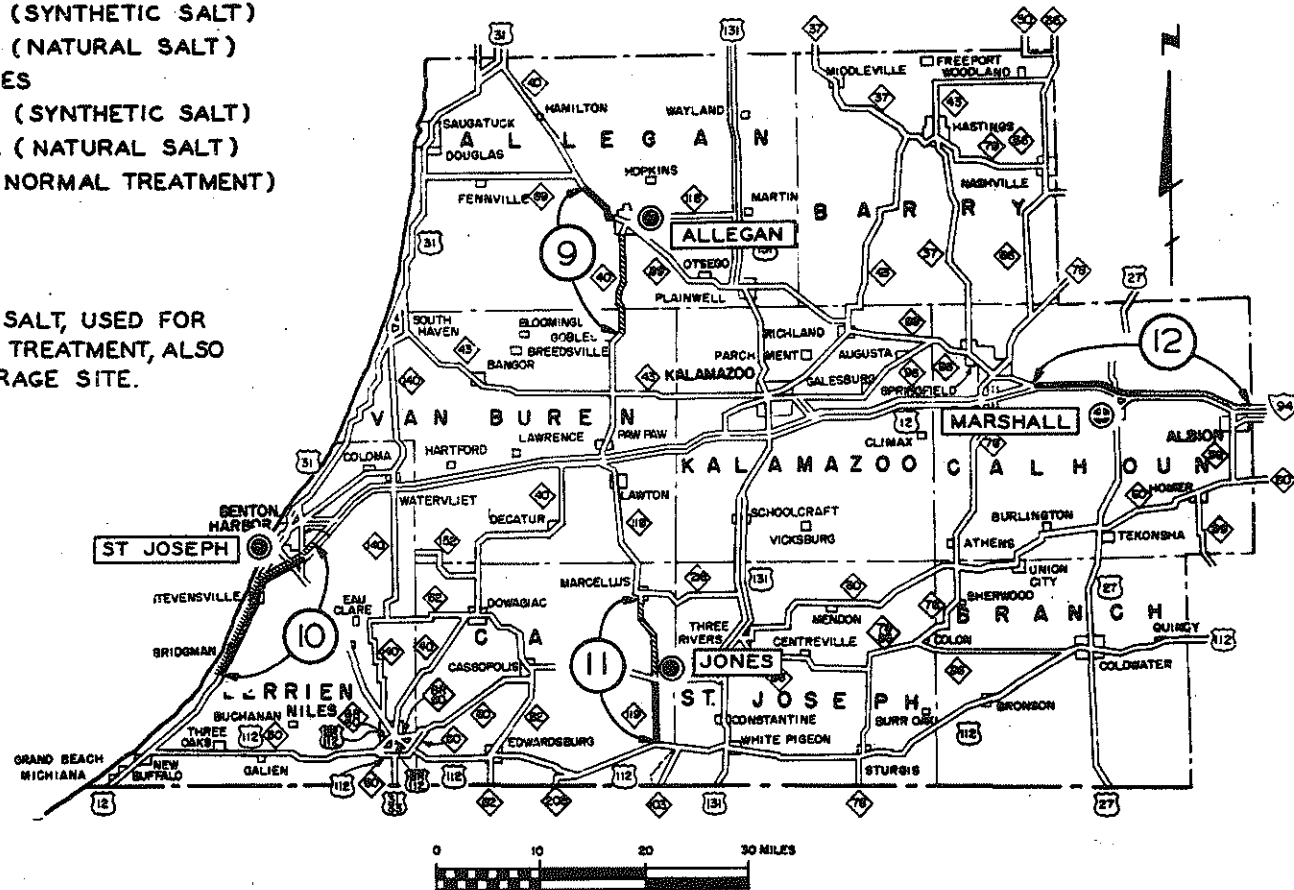
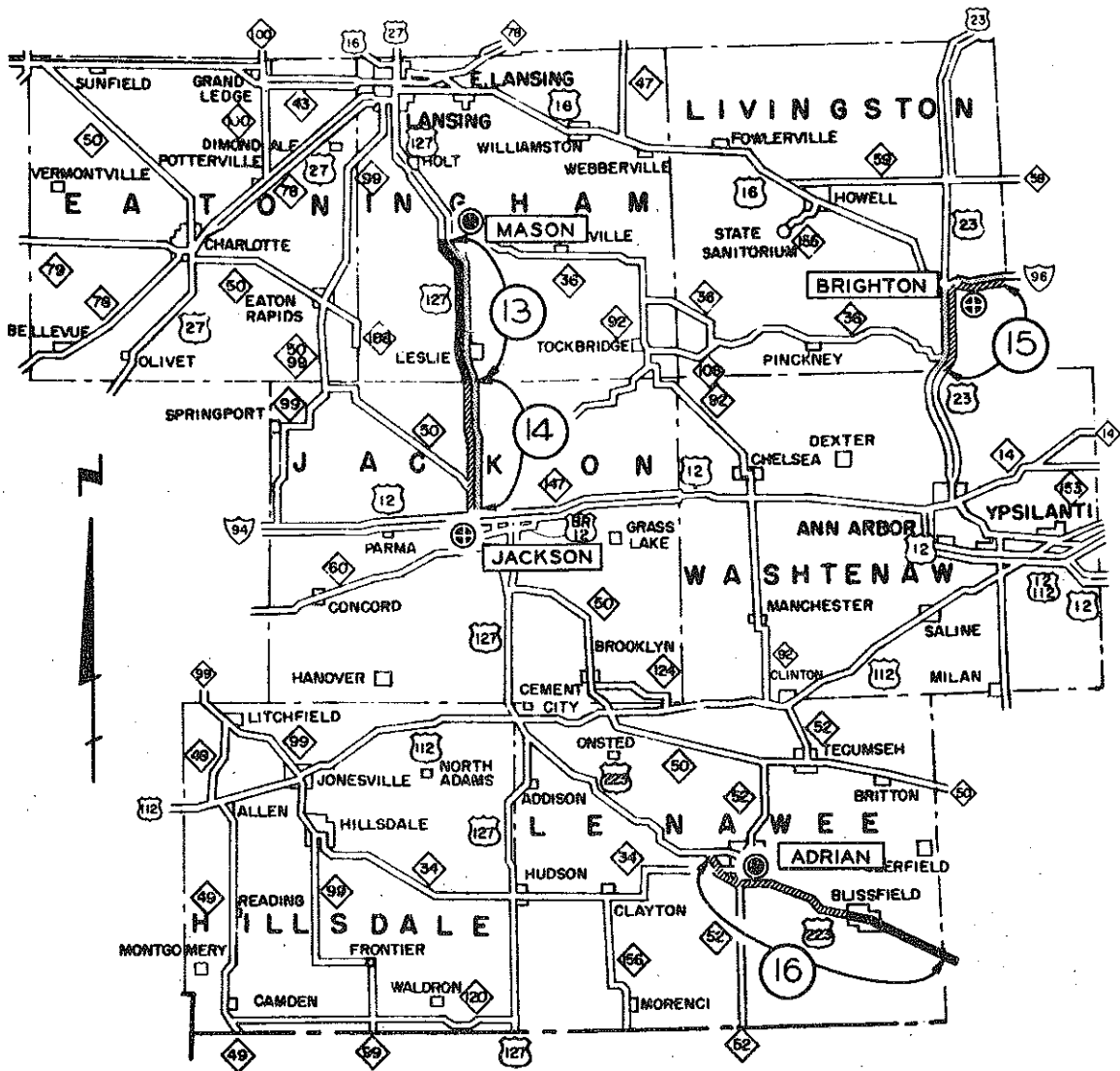


Figure 4. Storage and test sites - District 7.

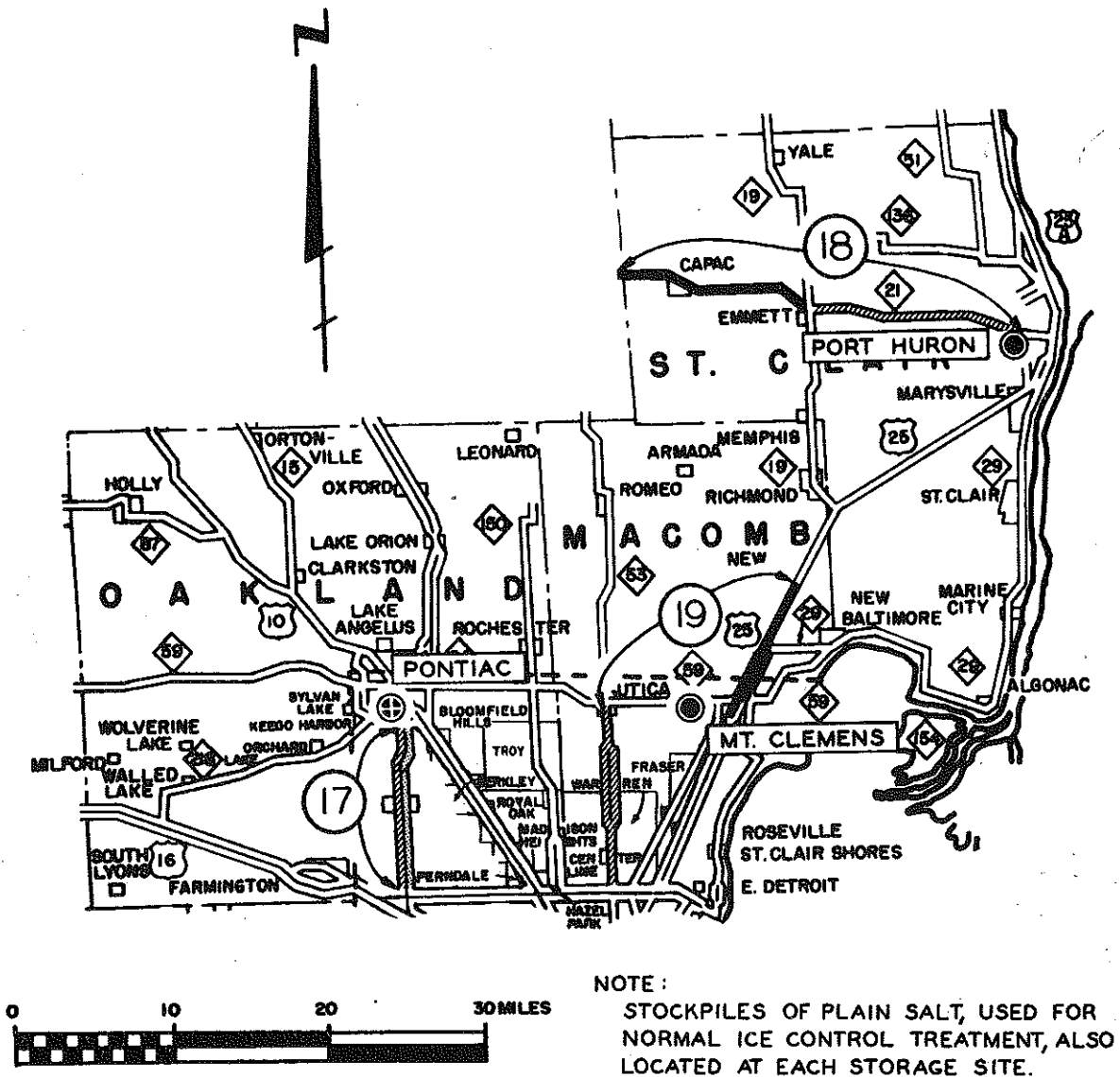


NOTE:
 STOCKPILES OF PLAIN SALT, USED FOR
 NORMAL ICE CONTROL TREATMENT, ALSO
 LOCATED AT EACH STORAGE SITE.

LEGEND

- ⊙ STOCKPILE - 3:1 MIXTURE (SYNTHETIC SALT)
- STOCKPILE - 3:1 MIXTURE (NATURAL SALT)
- ⊕ STOCKPILES - BOTH MIXTURES
- ▨ TEST AREA - 3:1 MIXTURE (SYNTHETIC SALT)
- ▧ TEST AREA - 3:1 MIXTURE (NATURAL SALT)
- TEST AREA - PLAIN SALT (NORMAL TREATMENT)

Figure 5. Storage and test sites - District 8.



LEGEND

- STOCKPILE - 3:1 MIXTURE (SYNTHETIC SALT)
- STOCKPILE - 3:1 MIXTURE (NATURAL SALT)
- ⊕ STOCKPILES - BOTH MIXTURES
- ▨ TEST AREA - 3:1 MIXTURE (SYNTHETIC SALT)
- ▧ TEST AREA - 3:1 MIXTURE (NATURAL SALT)
- TEST AREA - PLAIN SALT (NORMAL TREATMENT)

Figure 6. Storage and test sites - District 9.

After the mixtures were delivered they were tested for salt and calcium chloride content and stored in the manner usual at the site involved. In some cases the material was stored in protected areas; in others it was covered with sand or plastic tarpaulins.

Under the general supervision of the District Maintenance Engineer, the local foreman for operations calibrated all the equipment involved and maintained it ready for use. He determined the quantities of chemicals to be used for each storm and supervised their application to the roadway surface, following normal acceptable maintenance procedures. The planned rate of application varied with each storm condition but was the same for each material spread for each test condition.

The action of the chemicals was observed and reported on the form shown in Fig. 7. This form was completed independently by both the local superintendent and by designated Soils and Materials Engineers in the Districts. The overall operation was coordinated by the Research Laboratory Division, which also assembled the data and prepared the final report.

The test sections for each application were selected so that traffic conditions and type of pavement (bituminous or Portland cement) were essentially the same for each form of treatment. In order to minimize the effects of traffic and other variables the form of treatment was alternated between sections for each successive test.

When all tests were completed, the data were analyzed by the Research Laboratory Division and correlated with the variables. From these data, comparison was made between the melting rate of rock and the salt-calcium chloride mixtures throughout the range of temperatures encountered.

Test Results

Prior to storm conditions the mixtures of rock salt and calcium chloride were studied for uniformity of mixing and storage properties. Laboratory analysis of the mixtures showed that the required 25 percent of calcium chloride was present in all cases, but that the ratio of salt to calcium chloride varied considerably throughout a stockpile due to segregation. Extreme conditions were from 10- to 40-percent calcium chloride (design mix was 25 percent). The normal variation, however, was between 15 and 30 percent.

REPORT ON PERFORMANCE OF SALT AND SALT/CHLORIDE MIXTURES
Research Project 61 G-110

General Information

Test site office: _____ Reported by: _____

Date of test: _____ Time at start of storm: _____

Type of pavement surface: Concrete (), Asphalt ()

Equipment used for spreading: _____

Planned rate of application (lbs per mile): _____ Was mixture sampled: Yes (), No ()

Temperature { Start _____ Humidity { Start _____ Wind Velocity { Start _____
Finish _____ Finish _____ Finish _____

Sky cover: Cloudy (), Clear (), Partly Cloudy ()

Precipitation: Snow (), Sleet (), Freezing Rain (), None ()

General weather conditions during test: _____

Kind of frozen layer: Fresh snow (), Packed snow (), Ice (), Slush ()

Test Methods and Results

Test Data	Plain Salt	Mixture A (Natural Salt)	Mixture B (Mfg. Salt)
Time of application { Start _____ Finish _____			
Designation of test site			
Length of treated area (speedometer miles)			
Width of treated area (feet)			
Quantity applied (tons)			
Average daily traffic			
Thickness of frozen layer (inches)			
Percent of test area frozen at start			
Time required to obtain acceptable surface			
Width of treated area cleared			
Best form of treatment - check (✓)			
Appearance of treated area after 24 hrs. (dry, moist, slick, etc.)			

Comments concerning the value of the mixtures as compared with plain rock salt: _____

Approved: _____
District Coordinator

Figure 7. Form used to report test conditions and results.

It was found that the mixtures did not store and handle as well as the rock salt, unless they were placed indoors or in covered bins. Considerable quantities of the mixture had to be discarded due to lumping and crusting, or spreading operations would have been seriously hampered.

Sixty-seven storm conditions were included in this study during the winter period of January and February 1962. Specific data from a number of storms were not used in the analysis because of different variables entering the work or due to difficulties in following planned procedures. General comments and observations were considered, however, in all cases where these appeared pertinent. Tests were attempted at temperatures ranging from 6 to 33 F, but because of prolonged storm conditions or slow action of the chemicals when the temperature was below 15 F, no complete comparison tests could be made for these lower temperature conditions.

As a result of checking all variables in the individual tests, and eliminating storms for which test conditions were not entirely comparable, 22 tests were selected for comparing straight rock salt with the rock salt-calcium chloride mixture, nine tests for comparing straight rock salt with the manufactured salt-calcium chloride mixture, and six tests for comparing the two types of mixtures.

The different applications are compared graphically in Fig. 8 on the basis of the time required to obtain a satisfactory surface after spreading the chemicals. The overall results of these data indicate little difference between the melting rates of plain salt and the mixtures. In some cases the observers felt that salt alone, although slower acting than the mixture, melted more ice. The mix in which rock salt rather than synthetic salt was used seemed to have a slightly higher rate of melting in many cases. This difference was not great, however.

Several variables were present during these tests, the most important of which were the percentage of calcium chloride in the mixtures, the temperature during testing, the relative humidity during testing, the application rate, and the traffic count. To determine the effect on melting time of each of these variables, the differences in melting time for rock salt and the mixture were plotted against each single variable. Figs. 9 through 13 show no trends in these data to indicate that individual variables had any significant effect on the comparative melting times of rock salt and the mixtures. These data show merely that with the other variables present, there is no significant trend in melting time due to a specific variable.

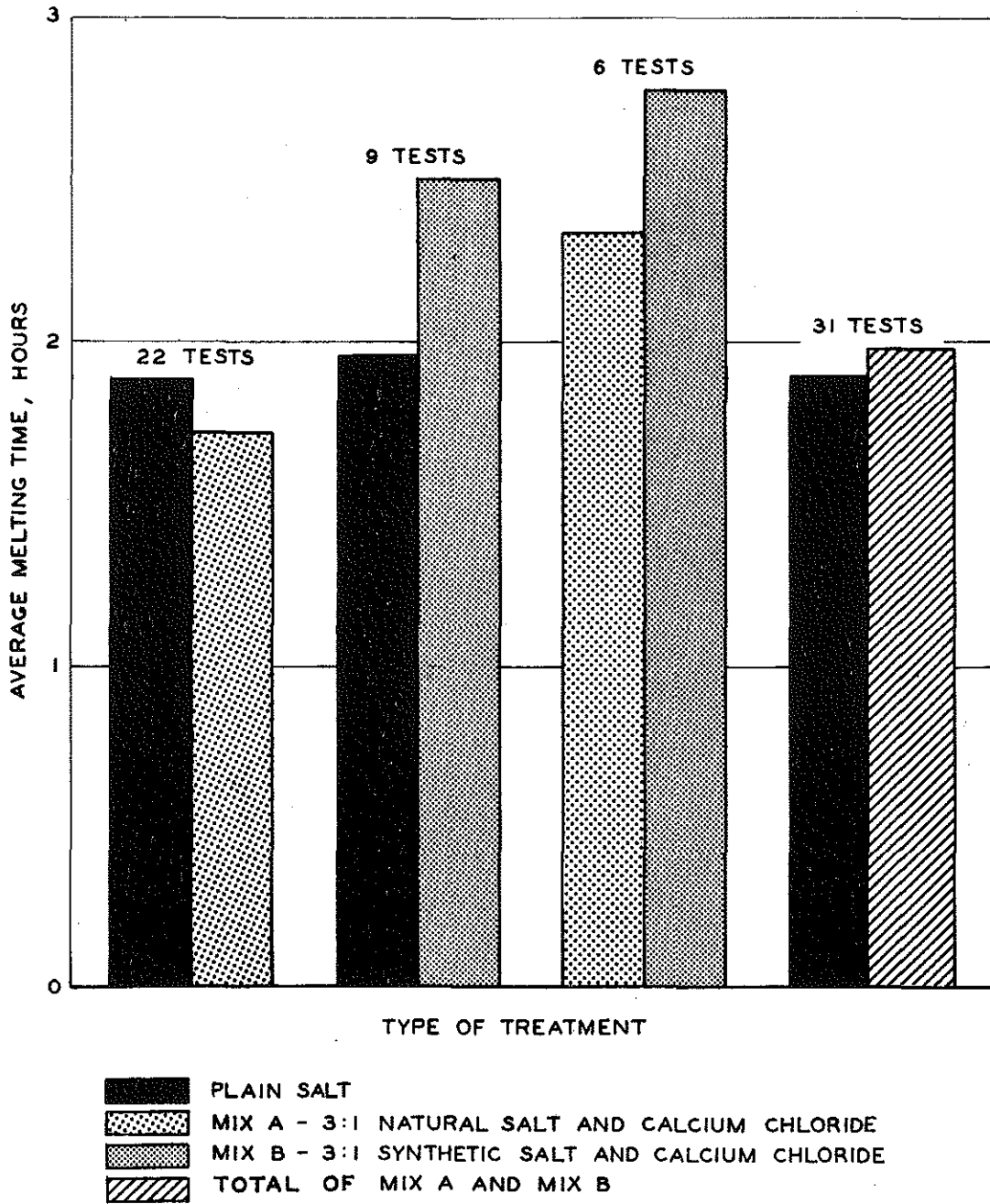


Figure 8. Effectiveness of the different ice melting applications.

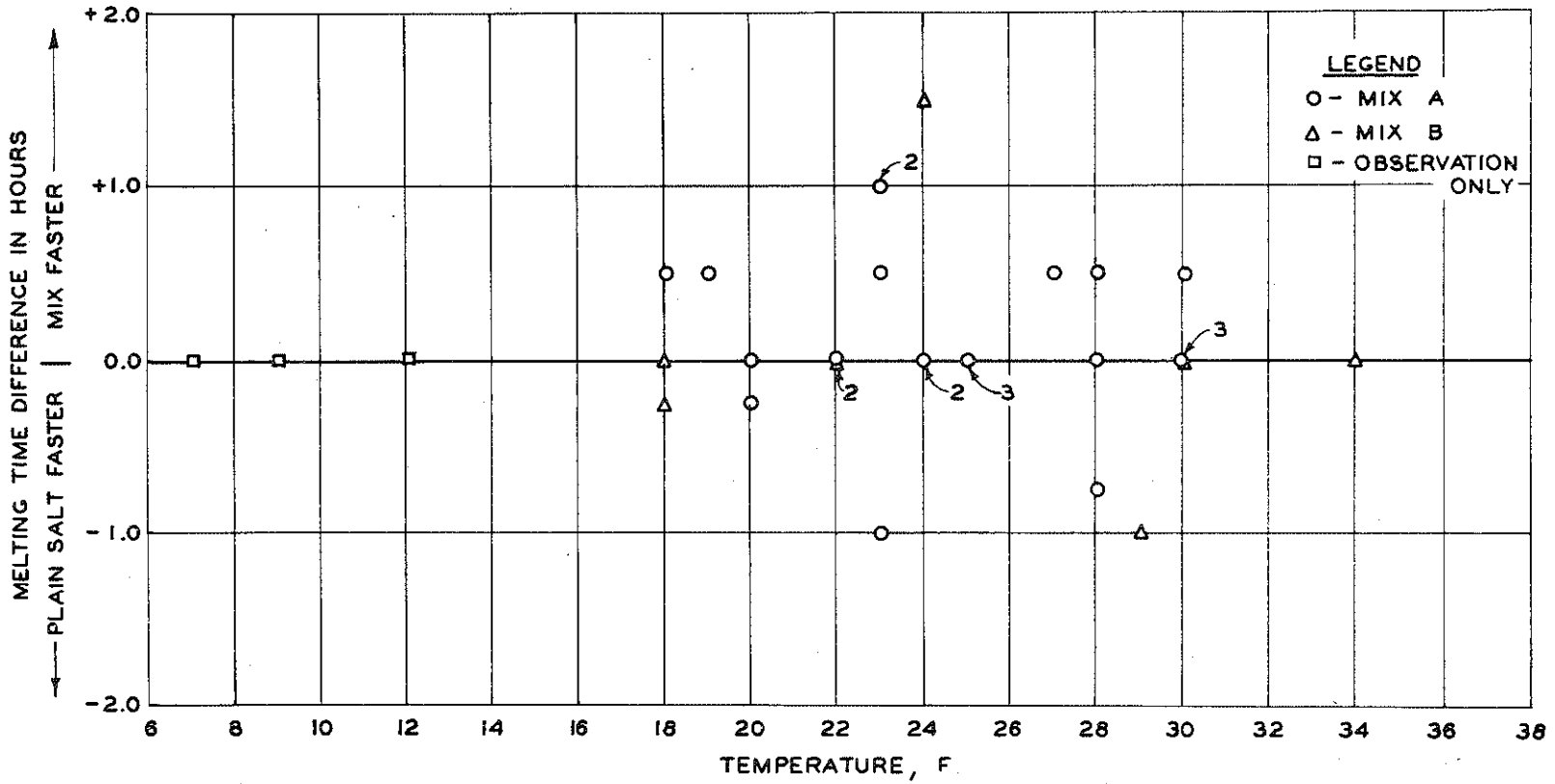


Figure 9. Effect of temperatures on melting time difference between plain salt and mixtures.

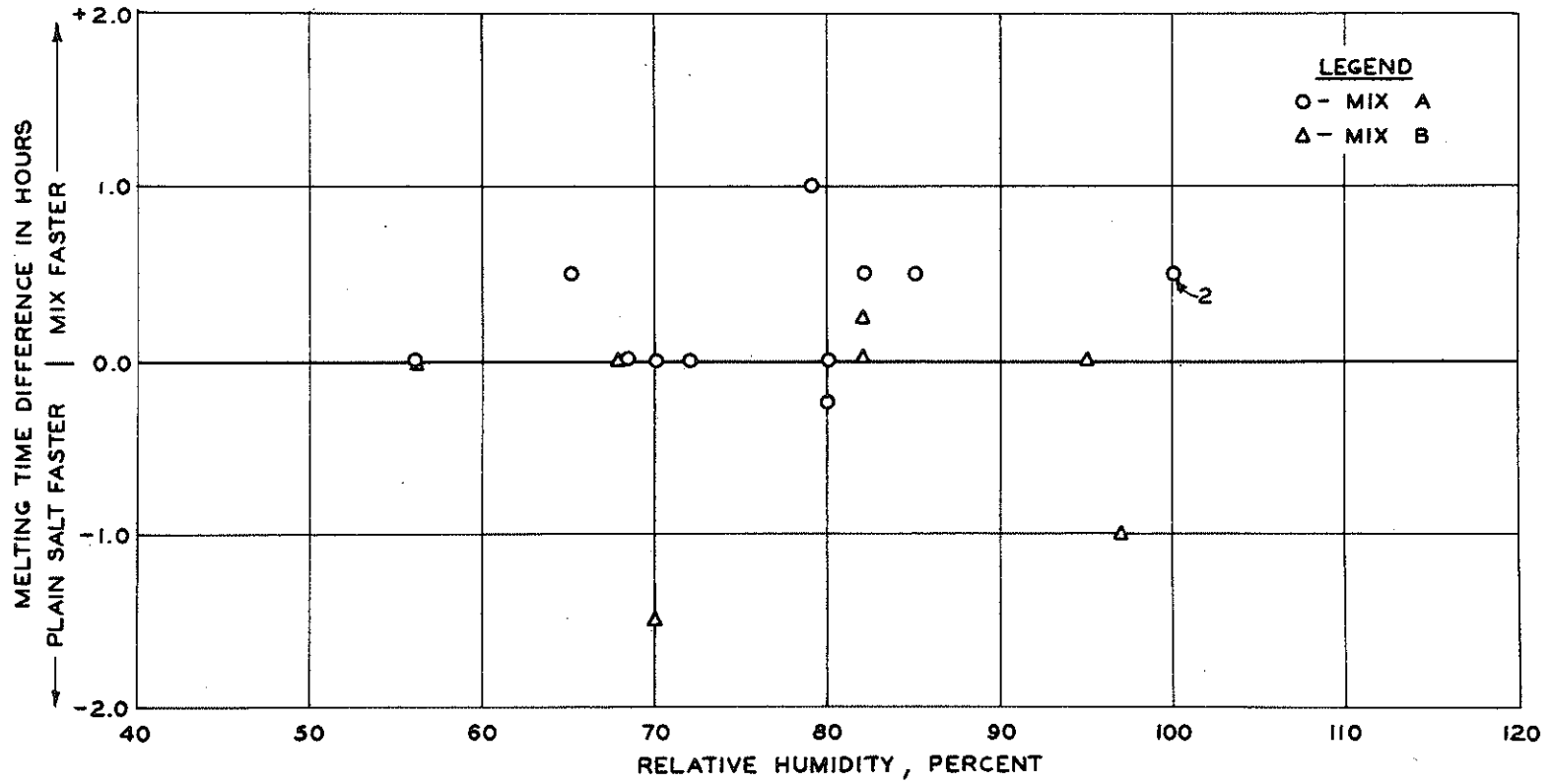


Figure 10. Effect of relative humidity on melting time difference between plain salt and mixtures.

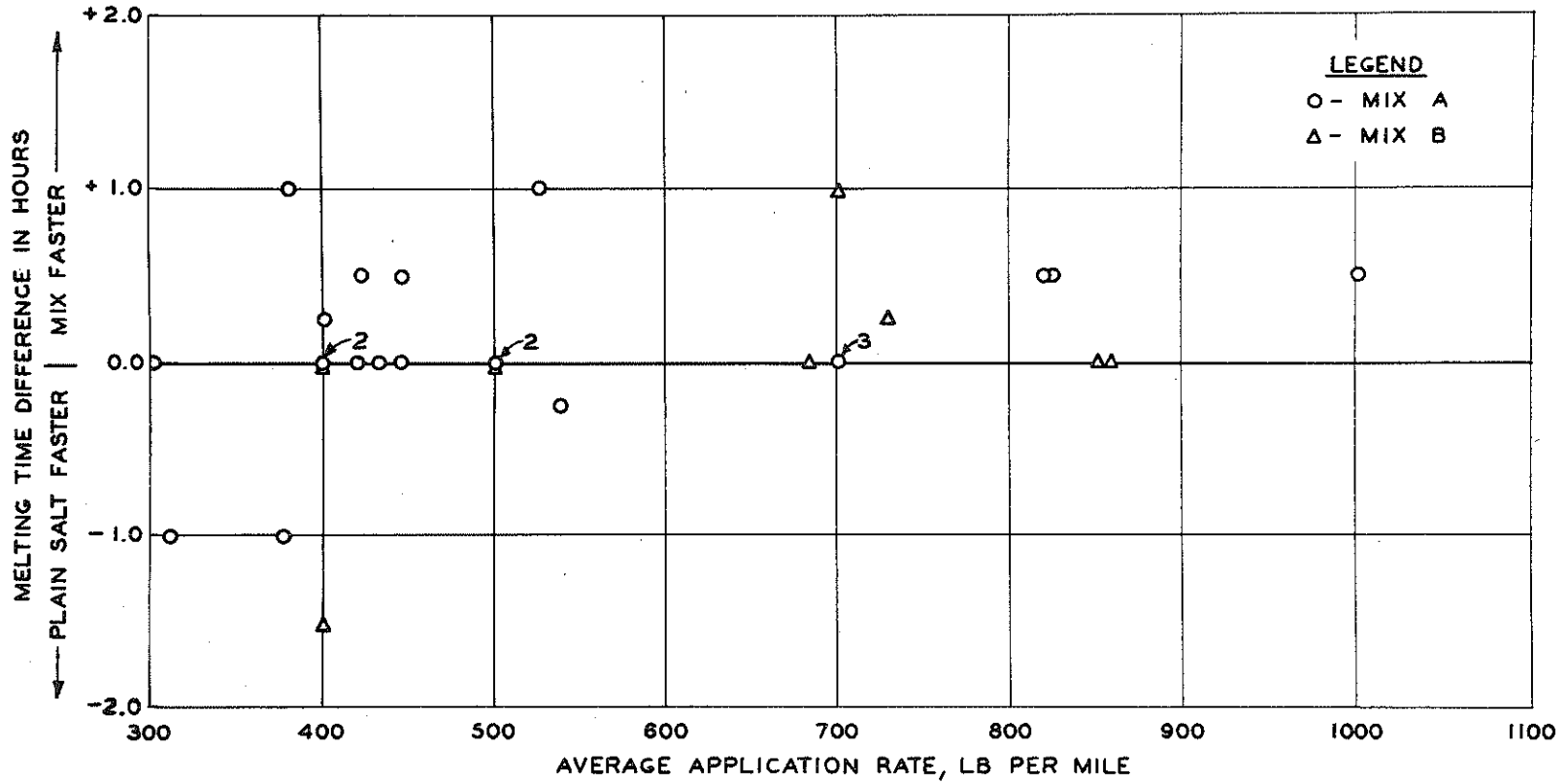


Figure 11. Effect of application rate on melting time difference between plain salt and mixtures.

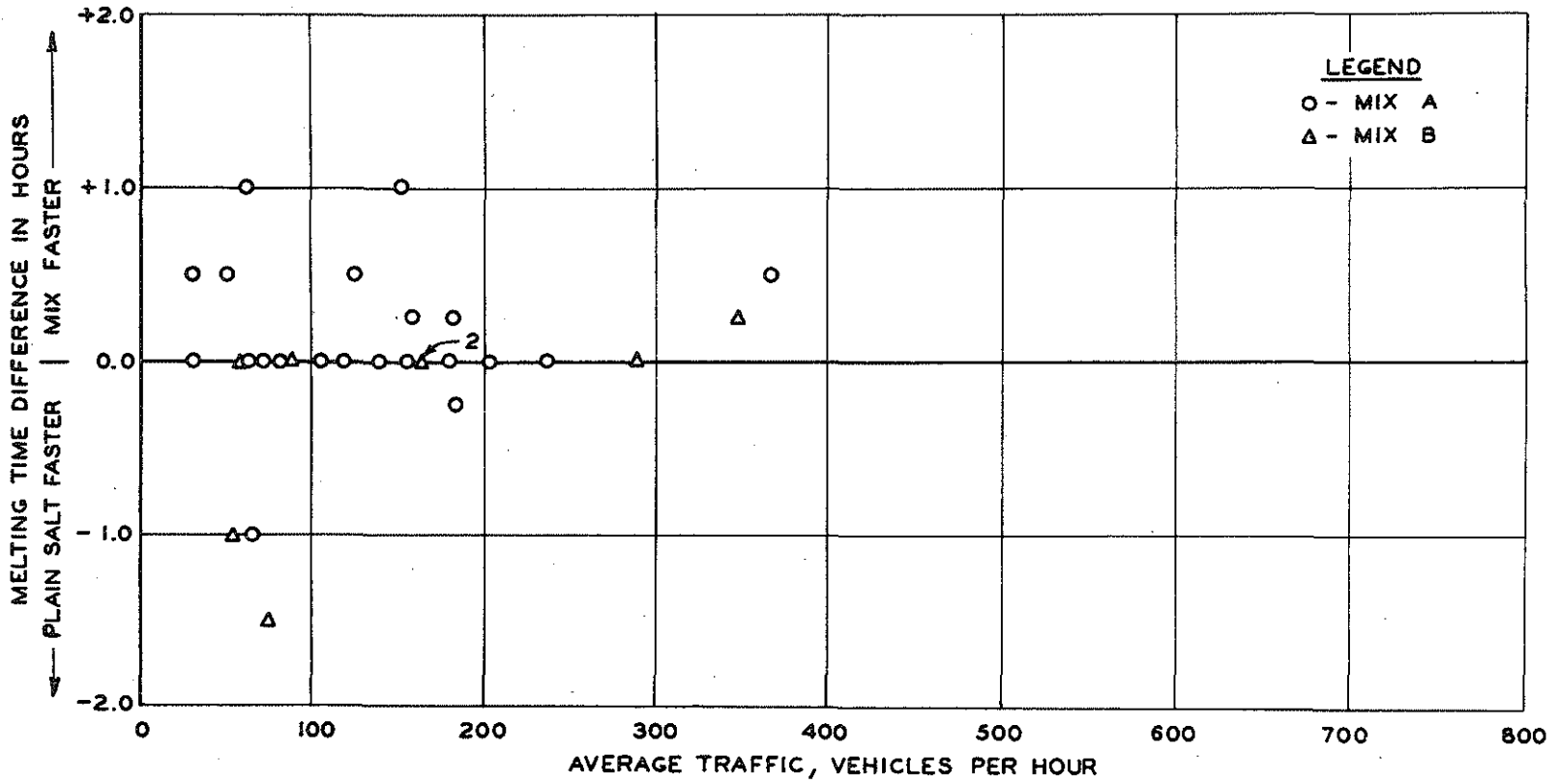


Figure 12. Effect of traffic volume on melting time difference between plain salt and mixtures.

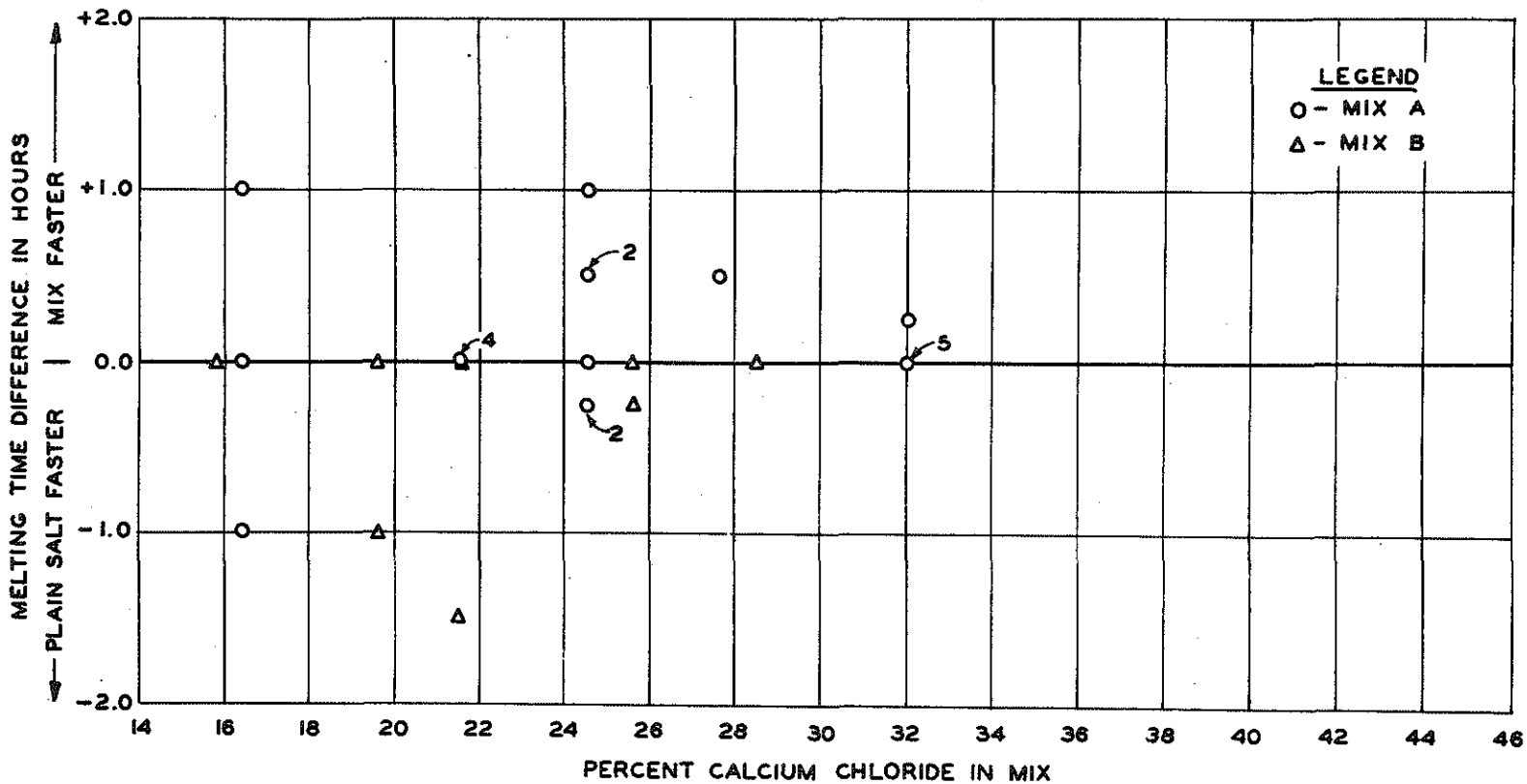


Figure 13. Effect of amount of calcium chloride in the mixture on melting time difference between plain salt and mixtures.

In addition to the selected storms used in the above analysis, 28 other storm conditions were studied. Although for various reasons these did not have complete data available, comments as to the most effective method of treatment were expressed. The consensus of these tests showed that no advantage was obtained by using the mixtures as compared with plain salt. Fig. 14 shows the effectiveness of the different treatments for all of the significant storms studied, at all temperature ranges encountered. These data are expressed in percentages as based on comments and melting times required for 54 test conditions. For 63 percent of the storms no difference was noted between the effectiveness of straight salt and the mixtures. In 22 percent of the cases the plain salt was superior, and in 15 percent of the cases the mixture was considered to be better.

At lower temperatures, below 15 F, data were not complete because neither of the chemical applications was very fast acting, requiring additional applications or blading of the surface before a satisfactory condition could be obtained. In some cases another storm developed before the ice from the first was fully removed. However, at the lower temperatures, observations and data indicated no significant difference between the action of the salt alone and the mixtures.

In addition to the difficulty in successfully storing the mixtures there were several specific observations to the effect that the calcium chloride in the mixture left a damp, slick condition on the pavement which did not develop when straight salt was used. This condition, caused by the moisture drawing and retaining properties of calcium chloride, allowed blowing or drifting snow to adhere to the pavement and again build up a hazardous surface.

Conclusions

The magnitude and scope of the field operations made it impossible to control all the variables involved. However, the large number of tests and test conditions gave a good cross-section of results from which significant conclusions may be drawn. All the testing operations were performed using normal, acceptable winter maintenance procedures. From these tests the following conclusions are warranted:

1. There was no significant difference between the ice melting properties of plain salt (sodium chloride) and the 3:1 mixture of salt and calcium chloride. Where small differences were noted, plain salt performed better in 60 percent of the cases.

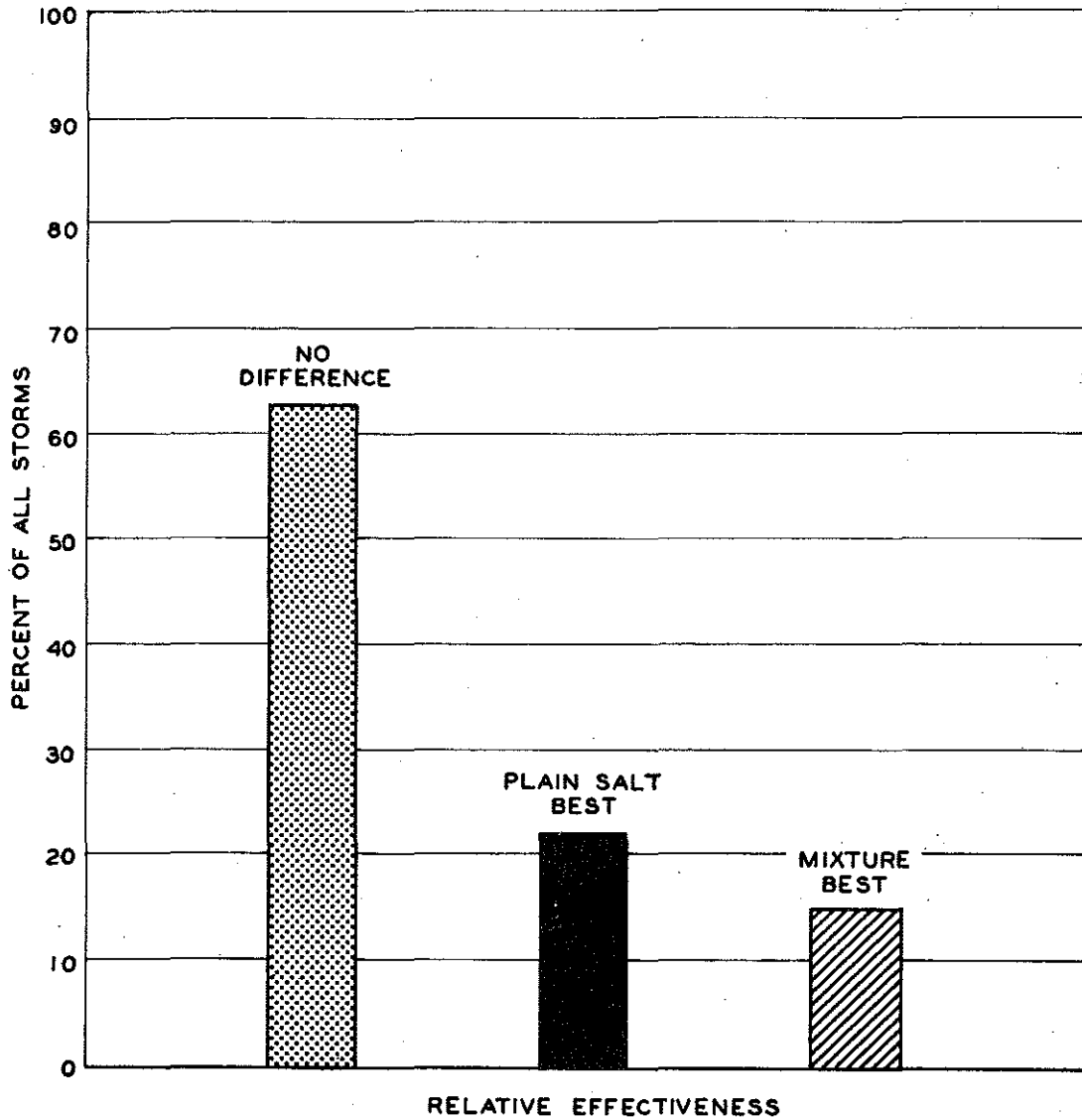


Figure 14. Effectiveness of treatments based on results of all storms studied.

2. The mixture in which rock salt was used as the sodium chloride ingredient was slightly superior to that in which synthetic sodium chloride was used. This difference, however, did not appear to be statistically significant.

3. The mixtures of salt and calcium chloride did not store and handle as well as rock salt under normal storage conditions. Considerable quantities of the mixtures were discarded due to lumping and crusting, and in some cases spreading operations were hampered.

4. Mixtures containing calcium chloride sometimes left a wet film on the cleared pavement which was slippery and allowed blowing snow to adhere and build up on the pavement surface.

5. Salt alone was as effective as the mixtures even at lower temperatures. However, neither performed very well when the temperatures were below 15 F.

6. Although traffic count, humidity, and quantity of treatment are known to affect the activity of ice control chemicals, none of these variables showed any appreciable influence on the general test findings.

7. Economic considerations were not included as a part of this study. It is known, however, that the cost of mixtures is higher than the cost of rock salt alone.

8. It is recommended that straight salt rather than the 3:1 mixture continue to be the Department's primary ice control chemical. Should it be desirable to increase melting rates at lower temperatures, however, a substantial increase in the ratio of calcium chloride to straight salt appears necessary.

References

1. Dickinson, William E. "Ice-Melting Properties and Storage Characteristics of Chemical Mixtures for Winter Maintenance." HRB Bull. 220 (1959) pp. 14-24.

2. Kinten, M. S., Pederson, L. P., and Toddie, A. J., Jr. "A Laboratory Study of Ice Removal by Various Chloride Salt Mixtures." HRB Bull. 220 (1959) pp. 1-13.

3. Lang, C. H., and Dickinson, W. E. "Snow and Ice Control in the Weedsport Section of the Syracuse Division: Winter of 1958-1959." N. Y. State Thruway Authority, undated.