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Anti-Icing Study:

Controlled Chemical Treatments

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1 Abstract

Environmental and financial considerations dictate that chemical usage in winter highway maintenance operations must be accomplished in the most efficient manner possible. The objective of this study was to develop correlations between meteorologic parameters and chemical effectiveness, to better understand the optimum conditions for which a particular chemical application is most effective. This information is of practical benefit when used in conjunction with predictive meteorologic information. The emphasis on the chemical treatment was anti-icing, since chemicals are more efficiently utilized for adhesion prevention, than for removing ice or compacted snow already in place.

By anti-icing, it is not inferred that chemical treatment alone will, in general, be sufficient to maintain an acceptable level of performance. Instead, it implies that pre-treatment will allow a satisfactory road condition to be maintained by the chemical when used in conjunction with mechanical means of removal.

Although the major emphasis of this study was to assess the anti-icing properties of each chemical for different scenarios, some tests included deicing to some extent, out of necessity. There will likely be cases in which anti-icing is insufficient to maintain acceptable conditions throughout a storm and chemical re-application may be required if attempts to remove the ice and snow are not successful by highway crews.

2 Executive Summary

The project described in this report was funded by the Strategic Highway Research Program (SHRP) under Contract No. SHRP-90-H208B to **KRC**, Keweenaw Research Center, Michigan Technological University in June 1991 and continued through March 1993.

The major objective of this study is to optimize the use of chemicals as anti-icers by looking at how effective each chemical is under certain meteorological conditions and attempting to minimize the application rate of each without compromising the safety afforded by the use of larger amounts of chemical to keep roads clear of snow and ice. Anti-icing is a promising alternative to deicing, since much less chemical is needed to eliminate bonding of ice and snow when the chemical is applied directly on the pavement surface prior to a precipitation event.

The test consisted of a major controlled field operation in which several different chemicals were tested and their effectiveness monitored through changing weather conditions. Chemicals were applied at prescribed rates over several test sections set up on an unused asphalt runway near KRC. Whenever possible, the chemicals were applied prior to a storm event. Pavement surface conditions were monitored throughout the storms after chemical application simulation of road maintenance operations such as plowing were also conducted on a pre-determined schedule.

After completion of each test, the data obtained were input into a PC-based statistical package designed to analyze the results on a day to day basis as well as cumulatively over the test period.

Overall, the use of chemicals in an anti-icing scenario seems to be quite promising. The use of reduced application rates that are typically used for deicing, when applied onto the pavement surface, can eliminate the strong bonds between ice and highway materials. Liquid chemicals seemed to be more effective, in many cases, than did the dry chemicals. This is probably due to the fact that the liquids can be better distributed over the pavement surface. Study of other chemical types as well as further studies using some of the same chemicals tested under this contract would be advantageous to a better understanding of anti-icing methods.

3 Introduction

The testing of the effectiveness of anti-icing was conducted as a controlled field study during the winter of 1991-92. Thirteen combinations of chemicals and concentrations were examined on a test site at KRC. One of the original 13, namely dry NaCl and solid $CaCl_2$ was replaced by liquid NaCl during the latter part of the winter season, but only three tests could be performed.

Thirteen test sections, measuring 12 ft by 100 ft each, were set up on the unused runway at the Houghton County Memorial Airport, near KRC. Weather forecasts were monitored on a daily basis in an attempt to apply chemicals prior to predicted precipitation events. When a storm was predicted, chemicals were applied at pre-determined rates over the sections using small, push-type spreaders. Prior to the application of chemicals, an attempt was always made to remove any snow or ice present on the pavement by use of conventional snow removal techniques.

Chemicals applied to the sections were left untouched until the beginning of a precipitation event. When snow and/or freezing rain began to fall, a test was begun. This consisted of measuring the friction coefficient of each section using a Saab Friction Tester on a 15 minute interval. After a period of two hours, a decision was always made whether to plow, reapply chemicals or stop testing due to insurmountable precipitation conditions such as snowfalls too heavy to keep up with or winds that made anti-icing infeasible. In any case, however, an attempt was always made to plow before any other decision was made.

After the completion of a test, the data obtained was entered into several base files in a computer program. These files were formatted for use in a statistical software package and the results analyzed daily, as well as over the entire winter period.

Despite the problems associated with executing a major field study of this type, considerable knowledge as to the effectiveness of anti-icing as a means of snow and ice control on pavements was gained and the results are contained in this report.

4 Test Procedures

4.1 The Saab Friction Tester

The Saab Friction Tester was used to measure the average friction coefficient for each of the test sections on interval throughout each test. The Saab operates by use of a fifth wheel located under the car and the friction data is printed on a strip chart located inside the vehicle. The device plots a reading every 3 ft and then averages the readings over a length of 100 ft. The test sections were set up so as to obtain an average reading over the 100 ft length. Figure 1 is an example of a friction record obtained from a test for the liquid chemicals.

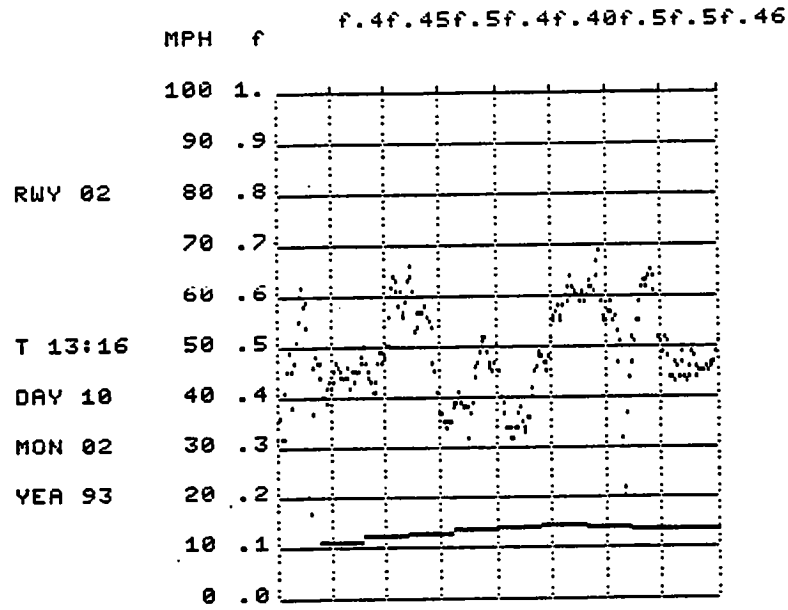


Figure 1. Example Friction Record.

The friction coefficient readings are plotted against time for each of the chemicals tested. A legend is included at the bottom of each plot that indicates the occurrence of maintenance activities that were performed throughout the test. These activities are explained in a later section.

4.2 Meteorological Data Collection

A weather and pavement condition monitoring system was received from Climatronics on December 13, 1991. This system was installed in a personal computer as well as wired into the field. Pavement sensors were purchased and installed. This system was never made operational due to software problems.

Meteorological data was collected using standard measurement devices as well as with the on-site weather station at KRC. The pavement surface temperature was collected using an infrared thermometer. Measurements were taken on the control section coincident with each Saab friction run. Several measurements of pavement temperature were also made on individual test sections.

The parameters that were continuously measured by the KRC weather station are as follows:

- ambient air temperature at several elevations
- temperature profile in the snow pack
- temperature profile in the ground
- water equivalent precipitation
- current snow depth (ultrasonic measurement)
- precipitating snow density (calculated from 2 previous items)
- wind speed and direction at several elevations

- relative humidity
- total solar radiation (0.28 - 2.8 micron)
- incoming infrared radiation (4 - 50 micron)

Figure 2 is an example of a meteorological file for a given test.

DATE 920102 S-time 1037	Wind Max 24 hrs m/s	Wind Max 12 hrs m/s	Wind m/s	Wind Dir	Temp Max 24 hrs 2m	Temp Max 12 hrs 2m	TEMP 2m	Temp Road	Precip Rate water mm/15	RH	Incomin Short Wave W/	Long Wave W/m2
26	1.99	1.99	1.88	23.00	1.72	-1.07	-0.97	-3.00	0.00	98.3	71.7	318.7
39	1.99	1.99	2.15	21.40	1.72	-1.07	-0.84	-3.00	0.00	96.4	60.3	320.0
53	1.99	1.99	2.28	21.50	1.72	-1.07	-0.71	-3.00	0.10	96.2	96.3	319.4
68	1.99	1.99	1.88	21.60	1.72	-1.07	-0.56	-3.00	0.00	96.0	115.0	319.3
83	1.99	1.99	2.55	21.20	1.72	-1.07	-0.42	-3.00	0.00	95.9	143.4	320.2
98	1.99	1.99	2.32	22.30	1.72	-1.07	-0.28	-3.00	0.00	95.9	151.7	319.2
112	1.99	1.99	2.32	23.10	1.72	-1.07	-0.14	-3.00	0.00	95.9	132.0	316.0
128	1.99	1.99	1.92	23.40	1.72	-1.07	0.00	-3.00	0.00	92.8	161.7	319.2
143	1.99	1.99	2.28	22.80	1.72	-1.07	-0.14	-3.00	0.00	92.0	159.1	318.2
153	1.99	1.99	2.55	23.10	1.72	-1.07	-0.28	-3.00	0.00	92.0	212.0	315.2

Figure 2. Example Meteorological File.

Each file contains a column for time from beginning of testing, the maximum wind speed for the periods 24 hours and 12 hours prior to the start of the test and the average wind speed and direction for intervals throughout each test. Also included are the maximum ambient air temperatures for the 24 and 12 hour periods prior to testing as well as the ambient air temperatures at intervals throughout the test. A column for pavement temperatures for tests when this parameter was measured is also included. Precipitation rate, relative humidity and short and long wave radiation are also tabulated. These files are used as direct inputs into the statistical package utilized for data analysis.

4.3 Chemical Spreaders

Several different types of chemical spreaders were used during the testing. These spreaders were tested and calibrated to dispense the proper amount on each test section prior to the start of the test season. Figure 3 shows the three basic types of spreaders used. On the left is a broadcast spreader, the type used for NaCl solids, NaCl - $CaCl_2$ liquid mix and NaCl - $CaCl_2$ solid mix. The spreader in the center is the type used to dispense CMA, $MgCl_2$, and KAc liquids. On the right is a spreader developed at KRC to apply CMA and urea solids.

Some problems were noticed with clogging of the nozzles when applying $MgCl_2$ but if the chemical was kept mixed this was minimized. Also, this clogging became less apparent when a new batch of chemicals was obtained. No problems were encountered with the other chemicals.

When the decision was made to apply liquid NaCl no liquid spreader was available for this chemical. A hand held pump type spreader was used for the three tests that resulted. This spreader is not shown in the photo.

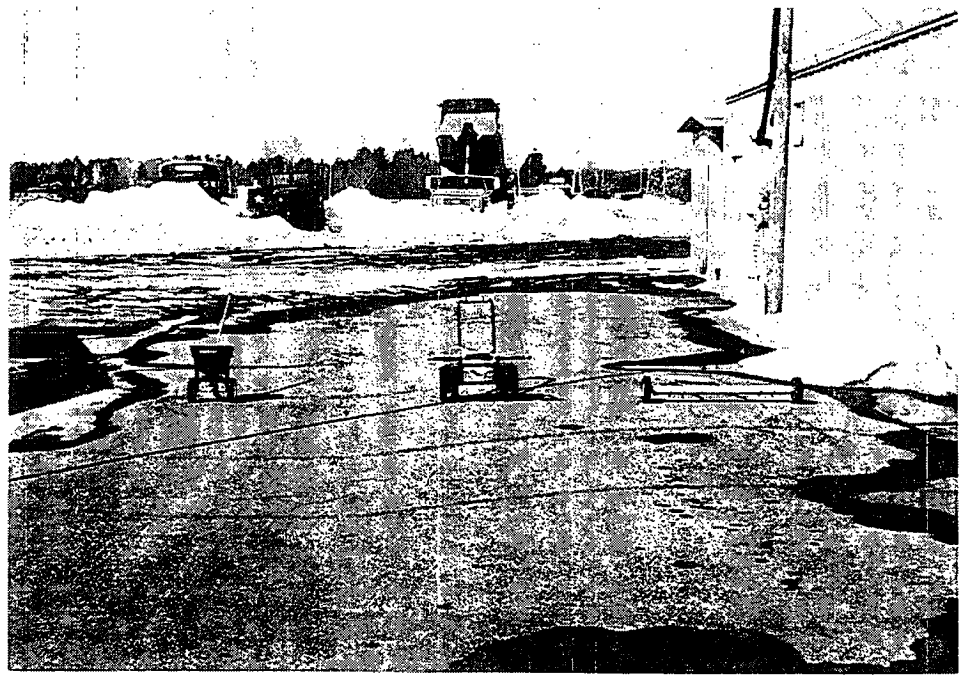


Figure 3. Chemical Spreader Types Used

4.4 Chemical Application Rates

Chemical application rates and amounts of chemical to be applied were finalized with SHRP personnel and the results are shown in Figure 4.

Chemical	Type/Concentration	Application Rate	Amount per Section	Section Number
NaCl	Solid	100 lb/lane mi	1.89 lb	T7
NaCl	Solid	200 lb/lane mi	3.79 lb	T8
$NaCl/CaCl_2$	Solid/Solid (5:1)	100 lb/lane mi	1.58 lb/0.31 lb	T9
$NaCl/CaCl_2$	Solid/Liquid (32%/10 gal/T)	100 lb/lane mi	1.86 lb/35.7 cc	T10
$MgCl_2$	Liquid/27%	100 lb/lane mi	1.54 gal	T6
CMA	Liquid/25%	100 lb/lane mi	1.16 gal	T2
CMA	Liquid/25%	200 lb/lane mi	2.32 gal	T3
Potasium Acetate	Liquid/50%	100 lb/lane mi	0.51 gal	T4
Potasium Acetate	Liquid/50%	200 lb/lane mi	1.02 gal	T5
Urea	Solid	100 lb/lane mi	1.89 lb	T13
CMA	Solid	100 lb/lane mi	1.89 lb	T11
CMA	Solid	200 lb/lane mi	3.79 lb	T12
Control	-----	-----	-----	T1

Figure 4. Chemical Application Rates

The application rates remained the same throughout the test period until March 24, 1992 at which time it was decided along with SHRP personnel to discontinue the testing of sodium chloride/$CaCl_2$ (dry) and to replace it with liquid sodium chloride at 22% concentration and at a dry chemical rate of 100 lb/lane mi. Since this decision was made late in the winter season, only three tests were conducted.

4.5 Test Section Layout

The runway which is used for the testing was closed to air traffic for the season in early December 1991, as a result of the first "permanent" snowfall of the winter. This event constituted the end of pretest preparations and the start of field testing.

The test course setup was measured and marked out on the runway to be utilized for the study while the pavement was still clear of snow. Immediately following the first major storm of the season, the pavement was dedicated solely to testing. The course was composed of 12 ft wide by 100 ft long test sections separated by a 200 ft buffer zone. Figure 5 shows the layout and location of the chemicals.

The first storm consisted of a heavy wet snowfall which resulted in substantial power outages and traffic immobilization throughout the area. This storm arrived following generally warm conditions. Thus, the ground and pavement were still quite warm. Following the storm, snow was removed from the perimeter of the runway, i.e., the zone utilized for this study. An "access working lane" of compressed snow was developed on the grassy area along the asphalt.

During this setup period, the temperature dropped and remained at subfreezing temperatures, in the neighborhood of -15 to -17^0 C. Inadvertently, a layer of refrozen slush and ice resulted following the removal of snow using a rotary snowplow. Extraordinary efforts were made to remove this layer mechanically, ranging from a road grader to hand tools. Attempts were made to remove this without resorting to chemical deicing, since it was felt that chemical use might influence subsequent testing and the effectiveness of their application was doubtful for the temperature range encountered.

A second unanticipated problem (which was not immediately perceived) developed during the setup. Snow on the center portion of the runway was melting from below and, due to the slight crown on the runway, slowly contributed to icing on the test sections. This problem was alleviated by clearing the center section of the runway. However, a furrow to act as a wind break for the course was left.

Finally, the use of chemicals was attempted *as a last resort*. A balanced ratio for the chemicals called for in the testing protocol were applied to the prescribed locations, but to no avail. The sections were finally cleared to satisfactory testing conditions during a warming period. This was then followed by a very heavy rainfall which completely cleaned the course leaving an ideal testing surface, free of chemical contamination.

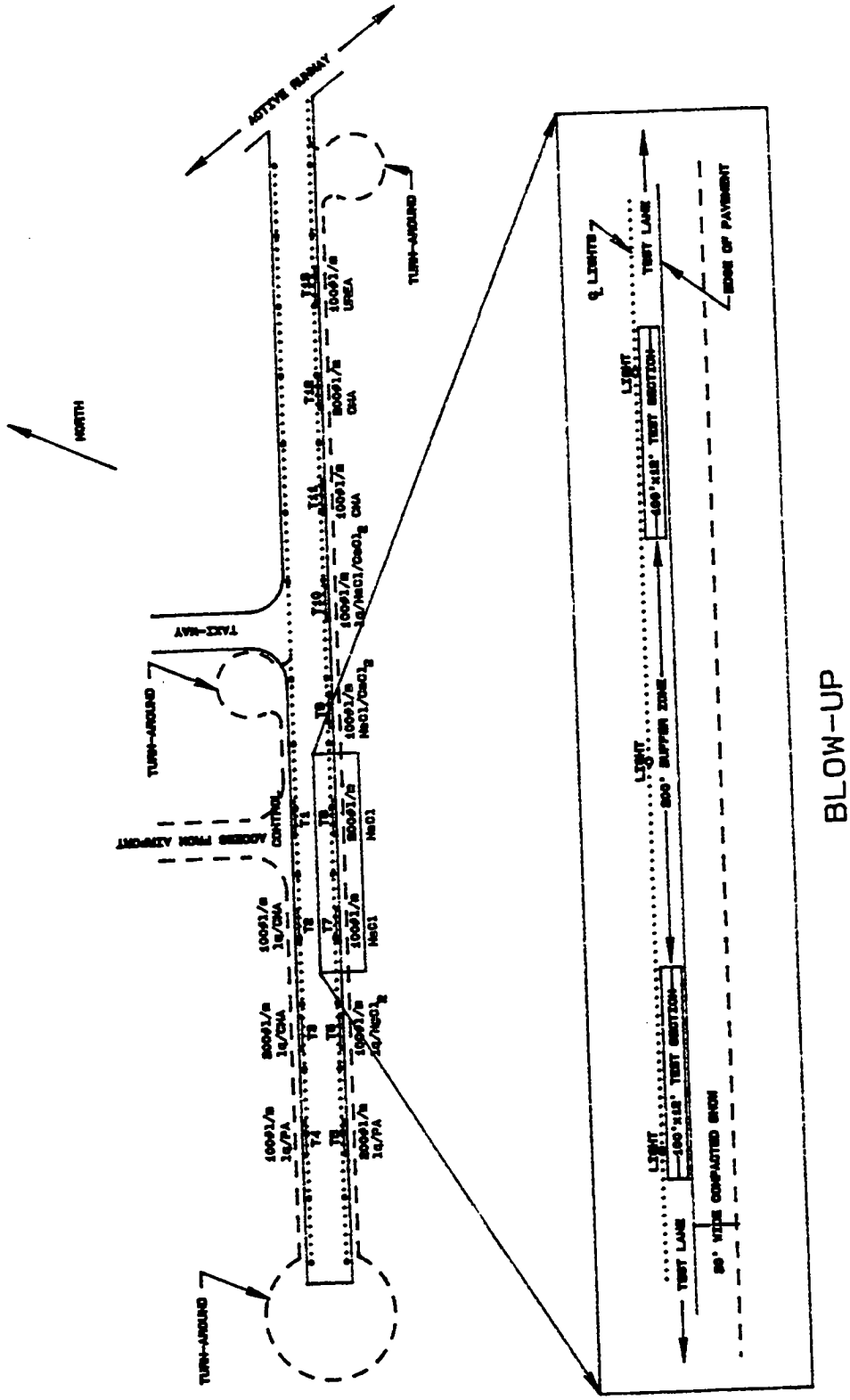


Figure 5. Layout and Location of Chemicals.

4.6 SOBO 20

A SOBO 20 chemical on pavement testing unit was received and initial attempts to calibrate it were unsuccessful. The problem proved to be faulty circuitry. A replacement electronics unit for the instrument was sent from MN/DOT. Figure 6 shows the results for the calibration using de-ionized water (which yielded the best results). Repeatability with the instrument was problematic, and it is likely that this instrument was also defective. Field results were erratic as well.

x 0.5 SCALE
SOLUTION A: 8.6% NaCl by weight

5 DROPS Expected Readings: 5+/-1		10 DROPS Expected Reading: 10+/-1	
TEST 1	4	TEST 1	11
TEST 2	3.5	TEST 2	9
TEST 3	5	TEST 3	7

x 0.1 SCALE
SOLUTION A: 8.6% NaCl by weight

5 DROPS Expected Readings: 10+/-1		10 DROPS Expected Reading : 14+/-1	
TEST 1	8	TEST 1	12
TEST 2	12	TEST 2	11
TEST 3	9	TEST 3	13

Figure 6. SOBO 20 Calibration.

4.7 Overall Test Procedure

The test plan was finalized and was implemented for all of the tests performed during this field study. If possible, the chemicals were applied prior to the onset of a storm. Saab runs were made on a 15 minute interval after the start of precipitation, and the test was continued for two hours, at which point a decision was made as to whether plowing was necessary. If plowing was deemed necessary, all sections were plowed and the friction was measured. At this point a decision was made to reapply chemicals to the sections that did not come up to an average friction value of 0.5. This value was chosen to fit into range of friction coefficients that best describes wet pavement. [2]. This range is generally chosen to be 0.45 to 0.6. If all of the sections had not reached this value, the test was continued through a second two hour block, only if conditions indicated that doing so would result in any one chemical reaching the 0.5 value. If weather conditions were such that it was obvious that the additional application of chemicals had no merit, the test was stopped.

In cases where the precipitation event had started before chemicals were applied, application was always preceded by plowing and the procedure following plowing was the same as above.
The original plan was to traffic the test sections with a multi-wheeled traffic simulation trailer. This was discontinued when it was realized that cross-contamination between test sections could not be eliminated despite extensive modifications to the trailer to attempt to blow the snow and chemicals off of the tires after each section. The trailer was still used, however, for testing that was designed to look at how well the chemicals perform when heavy snow is packed onto the sections.

4.8 Miscellaneous Maintenance and Test Procedures

Throughout the test period several operations were performed that were not "normal" as far as the original test plan was concerned. These methods were used to facilitate tests or outcomes when scheduled maintenance or meteorologic events were unsuccessful.

Whenever one of these methods was used, it is either mentioned in the test scenario or on the friction plot. These methods include use of a snowblower to produce a "simulated" snowfall during periods when snowfall events were not predicted, the use of the traffic simulation trailer to pack snow onto pre-applied chemicals to ascertain their ability to prevent bonding, and the use of sweepers in an attempt to remove the thin film of snow left after plowing by conventional means. Attempts were also made to use a water truck to spray water over the sections to simulate freezing rain during periods when pavement temperatures were relatively low and no precipitation was forecast. All of these methods were used as a last resort, however.

5 Data Analysis Procedures

The data collected during this field test were analyzed using several different methods as described in the following sections. Each of these methods was performed for a specific reason and each can be used separately or in combination to get an overall indication of how well each chemical performed under a certain set of circumstances.

5.1 Average and Maximum Friction

Perhaps the most important measurable factor that can be used to determine how well each chemical performs is the friction value, which we obtained using the Saab Friction Tester. If a test section (chemical) reaches some desired friction value during a test, the outcome of applying the chemical is, at least in part, successful. If average friction over the test period remains above a given acceptable value, this is another indication that the chemical is performing with some success. In terms of maximum friction, a chemical that brings the friction up to a value comparable to wet pavement is likely to be quite successful. Values of maximum friction less than that of wet pavement, when compared with average friction, can also give some indication as to the performance of the chemical application.

In order to compare the relative efficacy of each of the chemicals, an analysis using the friction values obtained during each test and under varying environmental conditions was performed. The Friedman analysis [1] was used for each test on each chemical by comparing the friction value at each 15 minute time interval and ranking these values from 1 to 13. From these interval rankings, a sum of ranks throughout a test period is made.

The Friedman test is a non-parametric two-way analysis of variance test. It treats each test time within a given day as a block in which it ranks the friction coefficient values. The ranks of a treatment over that day are then summed and compared to those of the other treatments to a level of significance of 0.05. The analysis is based on the hypothesis that there is no difference in the distributions and it determines the probability that the hypothesis is correct. This test was repeated for each test day.

5.2 *Effect*

During a single test, many things can happen that designate how a chemical performed. Among the possible scenarios are:

- Friction starts low and stays low.
- Friction starts low and increases throughout the test.
- Friction starts high and stays high.
- Friction starts high and decreases throughout the test.
- Friction starts low, increases and then drops off toward the end of the test.
- Friction starts high, drops off and then increases again.

Considering the many scenario perturbations it is obvious that the use of maximum or average friction may be deceiving. In order to examine the qualitative aspect of each test by some means beyond the average and maximum friction values, a method was devised to place a numerical value on the performance. This value, called *Effect*, is designed to subjectively quantify the performance of a chemical throughout an entire test period. For instance, a test section may have started out with a friction value of 0.7 at the beginning of the test. Due to the fact that snow was falling or temperatures dropped considerably during the initial part of the test, the friction may have dropped off rapidly. This section would have a high value for maximum and possibly average friction but may not have actually performed well overall. There is a possibility that any one section may rank either high or low with standards of friction, but the overall performance may not be reflected.

In order to give some quantitative basis to the perceived effectiveness, the performance of the chemicals as the combination of three independent contributions is considered. These are (A) the time it takes for chemicals to start to work, (B) the average friction obtained throughout a test and (C) how well each chemical sustained an acceptable value throughout the test period. All of the friction results were analyzed and the final decision was made that a weighting of 20 should be attributed to (A), 60 to (B) and 10 to (C). Based on this decision a set of equations was designed to determine an overall value for effectiveness. The range of minimum to

maximum friction that was used for the calculations was 0.1 to 0.8. The value of 0.1 is representative of what the Saab friction tester would produce on glare ice and 0.8 for ice-free wet pavement.

The chemicals were ranked for each test by use of the following equation,

$$Effect = A + B + C, \tag{1}$$

whose coefficients are calculated as;

$$A = \frac{30}{t_{0.5}}, \quad 0 \le A \le 2 \tag{2}$$

$$B = (F_{avg} - 0.1) * 8.6, \quad 0 \le B \le 6 \tag{3}$$

$$C = (F_{max} + F_{end}) * 0.625, \quad 0 \le C \le 1 \tag{4}$$

Where:

$t_{0.5}$ = the time at which the Saab friction becomes ≥ 0.5,
F_{avg} = the average friction for the test,
F_{max} = the maximum friction attained during the test and
F_{end} = the friction value at the end of testing.

This method ranks the performance of the chemical over the duration of the test and results in a rating from 0 to 9, where 0 is very poor and 9 is excellent.

The coefficient A accounts for the time which it takes for the Saab friction to reach an acceptable value. This value has been set at 0.5 [2]. All times are taken assuming elapsed time from chemical application. The next Saab run after chemical application is at 15 minutes. If the friction value for a given test section has reached 0.5 at this point then $t_{0.5}$ = 15 and A = 2, the maximum it can attain. If the friction never reaches 0.5 then $t_{0.5}$ tends toward infinity and this value goes to 0. If the friction value does not reach 0.5 during a test A is set to zero.

The coefficient B accounts for the average friction throughout the test. Since maintaining the average friction over the period of the test at or above the desired value of 0.5 is considered to be the most important factor of chemical application, this portion of the ranking is given the most weight. For example, if the average friction for the entire test was 0.8, which is an expected value for ice-free wet pavement, the value for this coefficient would be 6. This is the maximum

value for this part of the rank. If average friction is 0.1, which is representative of black ice, this portion goes to 0.

The coefficient C determines how well each chemical performed in reaching and maintaining a high friction throughout the test. In this case, if the friction value increased to 0.8 and was still at 0.8 at the end of testing, the contribution to *effect* would be 1. This is the maximum for this part of the ranking. If both average and ending friction are 0.1, the contribution is 0.1, nearly 0. All other combinations range between 0 and 1.

In summary, the *Effect* equation (1) is the sum of the three coefficients and has a maximum value of 9 and a minimum of 0. These equations were developed by weighing the relative importance of each of the three friction considerations described and assigning a value to them. The *effect* was calculated for each chemical and each test and then corroborated with the visual assessment of the friction plots to insure that the outcome was reasonable in every case.

A simple example may clarify this ranking scheme. Consider the curves in Figure 7. These example curves are developed by the use of contrived data points chosen to illustrate six possible combinations for friction plots. Table 1 gives the result of the *effect* calculation for each of these six curves using equation 1. The curves are designated as C1, C2, C3, C4, C5 and C6 on both the graph and in the table. From the table it can be seen that *effect* can vary considerably dependent on the changes in friction throughout a test.

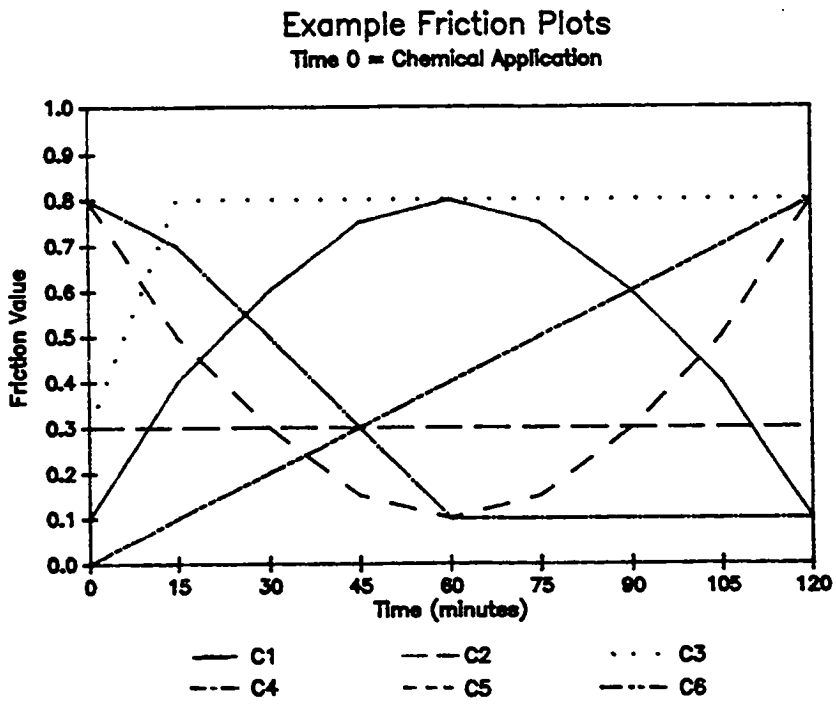


Figure 7. Example Friction Plots.

5.3 Pearson Correlations

The Pearson sample correlation [1] is a statistic whose value ranges from -1 to +1. A value of -1 or +1 implies that a perfect non-constant linear relationship exists between two variables. A correlation value near zero implies that there is no linear relationship. When two variables have a strong correlation (i.e., value near -1 or +1), the value of one variable can be used to predict the value of the other. However, this does not imply that a cause and effect relationship exists between the two variables.

To decide if a sample correlation is statistically significant one needs to determine the likelihood that there is no correlation between the two variables and yet the sample correlation is as large in magnitude as is observed. When such events have a low probability the correlation is considered to be significant. Typically a sample correlation is considered significant if its probability of occurring is less than 5%.

Data Set	$t_{0.5}$	F_{avg}	F_{max}	F_{end}	A	B	C	Effect
C1	30	0.50	0.80	0.10	1.0	3.4	0.6	5.0
C2	∞	0.30	0.30	0.30	0.0	1.7	0.4	2.1
C3	15	0.74	0.80	0.80	2.0	5.5	1.0	8.5
C4	15	0.31	0.80	0.10	2.0	1.8	0.6	4.4
C5	15	0.40	0.80	0.80	2.0	2.6	1.0	5.6
C6	75	0.40	0.80	0.80	0.4	2.6	1.0	4.0

Table 1: Example of *Effect* Calculations

It must be noted that when determining significant correlations using the above criteria for a large number of pairs of variables there is a high probability that at least one non-significant correlation will be judged to be significant. This is a common problem which the following example demonstrates. A cancer test may have only a 5% chance of giving a false positive. However if this test is given to 10 randomly selected individuals who do not have cancer, the probability that at least one of the 10 will test positive is 40%. For 30 individuals, the probability is 78% and in 100 cases it is almost a certainty. In our data, we examine some 99 correlations.

5.4 Bonferroni Criteria

The Bonferroni criteria [1] provide an approach to determining statistically significant correlations which reduces the likelihood of false positives and is the approach that we used in our analysis. The Bonferroni approach determines the probability of significant correlations so that the likelihood of having one or more false positives in a matrix of sample correlations is say 5% or 1%.

6 Results - Separate Test Days

During the winter of 1991-92, 27 successful tests were performed. Attempts to perform tests on a limited budget during the winter of 1992-93 were all unsuccessful.

6.1 Synoptic Scenarios

Synoptic scenarios for each of the test days can be found in Appendix A.

6.2 Meteorological Data

Tables containing the meteorological data collected for each test day can be found in Appendix B.

6.3 Friction Data

Friction data as measured by the Saab friction tester for each test can be found in Appendix C. The data have been separated into groups of liquid and solid chemicals only to minimize clutter on the graphs.

6.4 Friedman Results - Separate Test Days

The Friedman analysis was performed on the friction data for each test day. The resulting plots are contained in Appendix D.

The relative ranking of the 13 treatments is given on the top of the graph along with the value for the sum of ranks. The larger the sum the better the overall performance of the chemical application. The bars on the graph depict groups of chemicals which cannot be statistically distinguished from one another.

7 Overall Results

7.1 SOBO 20

The results from the SOBO unit using de-ionized water are given in Figure 8. As can be seen from the table the readings vary considerably and are suspect. The unit never did perform as it was designed.

7.2 Statistical Results - Average Friction

Once the sums have been obtained for each test individually, as shown in Appendix D, the ranking for the entire winter period can be obtained by simply ranking the results for each chemical for all of the tests performed. Figure 9 is the result for this ranking for the 27 tests.

SECTION	CHEMICAL	DATE: 03/09/92 READING	LB/LANE MILE	DATE: 03/24/92 READING	LB/LANE MILE	DATE: 03/25/92 READING	LB/LANE MILE	DATA: 03/31/92 READING	LB/LANE MILE
1	CONTROL	0	0	0	0	0	0	0	0
2	100# LIQUID CMA	0.4	35.2	0.4	35.2	1.3	114.4	1.5	165
3	200# LIQUID CMA	0.6	44	5	550	3	330	5.5	740
4	100# POTASSIUM ACETATE	0.5	44	2.5	220	2	170	0.8	70.4
5	200# POTASSIUM ACETATE	4	330	0.8	70.4	4.5	376.8	2	170
6	100# MAGNESIUM CHLORIDE	2	88	4.5	315.4	7	391	5.5	238
7	100# SOLID NaCl	0.4	17.6	0.7	30.8	0.5	22	5	220
8	200# SOLID NaCl	0.7	30.8	0.7	30.8	0.8	35.2	5	220
9	100# NaCl/SOLID CaCl2	0.4	17.6	4	181.7	4	181.7	0.1	4.4
10	100# NaCl/LIQUID CaCl2	0.4	17.6	2.5	110	0.9	39.6	0.1	4.4
11	100# SOLID CMA	0.4	35.2	0.2	17.6	0.1	8.8	0,1.1	0,96.8
12	200# SOLID CMA	0.9	79.2	0.7	61.6	0.8	70.4	0.6	52.8
13	100# UREA	0.1		8		0		0	

* AFTER 2 CHEMICAL APPLICATIONS

ALL READINGS TAKEN AFTER CHEMICAL APPLICATION

Figure 8. SOBO 20 Results.

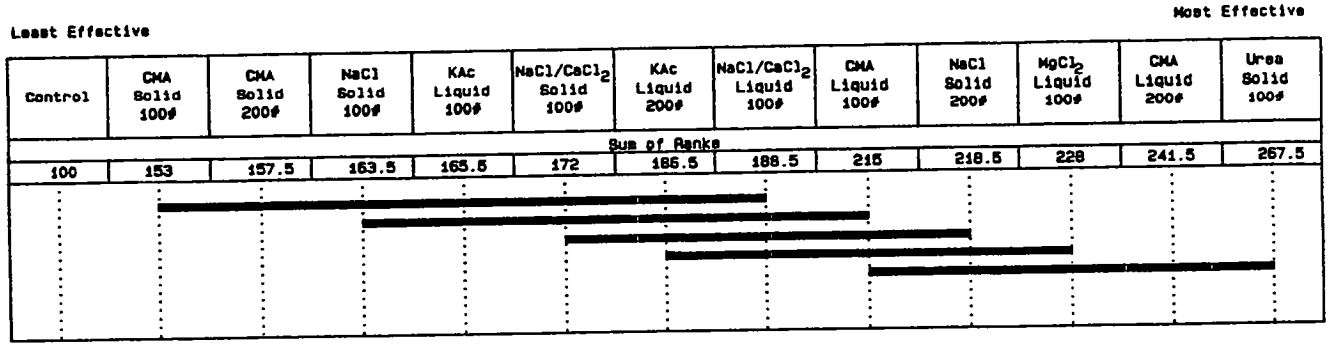


Figure 9. Friedman Analysis - Sum of Ranks (27 tests).

Once again, the relative ranking of the 13 treatments is given on the top of the graph along with the value for the sum of ranks. The larger the sum the better the overall performance of the chemical application. The bars on the graph depict groups of chemicals which cannot be statistically distinguished from one another.

7.3 Statistical Results - *Effect*

Figure 10 contains the results for the *effect* calculations for all of the 27 test days. Figure 11 contains the values of coefficient A, Figure 12 for B and Figure 13 for C.

	DATE	Control	CMA 100	CMA 200	KAc 100	KAc 200	MgCl2 100	NaCl 100	NaCl 200	NaCl/CaCl2 100	NaCl/CaCl2 100 Liq	Solid CMA 100	Solid CMA 200	Urea 100
1	12/12/91	3.8	9.2	9.0	9.1	9.0	9.1	8.7	8.5	9.1	8.7	8.9	8.9	8.7
2	12/13/91	4.9	5.2	5.0	5.0	5.3	5.1	5.0	4.4	4.9	4.9	4.5	4.8	4.9
3	12/20/91	2.3	2.4	2.7	2.2	2.3	2.9	2.0	2.0	1.9	2.3	2.3	2.0	2.4
4	01/02/92	3.3	8.7	8.8	8.6	8.7	8.8	6.0	6.7	5.6	6.2	5.7	6.2	6.9
5	01/06/92	6.8	8.0	6.6	6.2	5.6	5.9	5.9	5.4	5.0	4.9	4.9	4.1	5.6
6	01/08/92	4.2	4.7	5.7	4.6	5.6	5.4	4.6	4.7	4.5	4.7	4.6	4.5	4.9
7	01/09/92	4.5	2.6	2.6	2.7	2.8	3.4	2.6	2.6	2.7	2.6	2.6	2.1	2.8
8	01/10/92	5.5	4.7	4.9	2.1	1.8	4.6	2.3	2.2	2.2	2.5	2.1	2.4	4.4
9	01/11/92	3.2	6.9	8.7	8.3	6.2	8.7	5.1	6.7	5.4	5.9	4.9	6.0	5.9
10	01/22/92	2.2	4.6	4.7	2.6	3.0	3.4	2.6	3.6	2.4	2.7	2.5	2.6	2.8
11	01/23/92	1.6	2.6	4.2	3.1	4.5	4.6	2.5	2.6	2.6	2.8	2.7	2.6	2.6
12	01/27/92	2.1	3.4	3.7	3.4	3.2	3.5	3.1	3.9	2.9	2.4	1.9	2.8	2.3
13	01/28/92	1.5	2.7	2.5	2.1	2.4	2.5	2.1	2.3	2.1	2.2	2.3	2.4	2.1
14	01/30/92	1.7	5.1	5.3	4.1	4.8	4.9	4.4	6.7	5.6	6.4	6.1	6.4	5.8
15	01/31/92	1.7	2.4	3.1	2.4	3.2	3.7	2.6	3.2	2.6	2.9	2.8	3.2	2.9
16	02/06/92	0.2	2.4	2.4	2.7	2.7	2.4	2.7	2.9	2.2	2.2	2.1	2.2	2.7
17	02/10/92	1.8	2.0	2.8	2.3	2.4	2.5	2.4	2.5	2.5	2.1	1.7	1.7	2.2
18	02/11/92	2.1	1.8	2.0	2.2	2.1	2.1	2.4	2.2	2.2	2.1	2.1	1.9	2.5
19	02/12/92	1.9	2.1	2.4	2.1	2.0	2.3	2.0	2.3	2.2	2.3	2.3	2.5	2.5
20	02/13/92	1.5	2.6	4.3	1.9	3.0	4.4	2.3	2.3	2.2	2.0	2.1	2.2	2.5
21	02/14/92	1.7	7.5	8.7	4.2	8.3	8.8	8.6	8.8	7.1	5.2	6.4	8.6	8.9
22	02/20/92	1.7	4.7	4.4	4.4	4.0	3.6	1.8	4.3	4.3	1.6	1.7	3.7	2.0
23	02/24/92	2.1	6.2	7.1	5.4	6.5	7.4	5.1	5.6	4.8	5.2	4.7	5.0	5.2
24	02/25/92	3.4	7.5	8.5	6.5	7.5	8.5	5.6	6.2	6.2	6.2	5.8	6.7	7.6
25	02/27/92	6.6	6.6	7.6	6.6	7.5	8.9	7.9	8.0	8.8	8.0	8.8	8.7	9.2
26	03/09/92	1.8	2.4	1.9	2.4	2.1	2.7	2.5	2.2	2.6	2.6	2.7	2.3	2.7
27	04/01/92	4.2	2.5	4.0	2.5	5.6	5.7	2.4	5.0	2.6	2.8	2.7	2.6	5.9

Figure 10. *Effect* Values for All Tests.

	DATE	Control	CMA 100	CMA 200	KAc 100	KAc 200	MgCl2 100	NaCl 100	NaCl 200	NaCl/CaCl2 100	NaCl/CaCl2 100 Liq	Solid CMA 100	Solid CMA 200	Urea 100
1	12/12/91	0.3	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
2	12/13/91	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
3	12/20/91	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	01/02/92	0.2	2.0	2.0	2.0	2.0	2.0	0.5	0.7	0.4	0.5	0.4	0.5	0.7
5	01/06/92	2.0	2.0	0.9	0.6	0.6	0.6	0.5	0.5	0.4	0.4	0.4	0.3	0.6
6	01/08/92	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
7	01/09/92	0.7	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	01/10/92	2.0	2.0	2.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0
9	01/11/92	0.3	0.7	2.0	2.0	0.5	2.0	0.3	0.7	0.4	0.4	0.3	0.5	0.4
10	01/22/92	0.0	0.5	0.5	0.0	0.0	0.3	0.0	0.3	0.0	0.0	0.0	0.0	0.0
11	01/23/92	0.0	0.0	0.3	0.3	0.3	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	01/27/92	0.0	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.0	0.0	0.0	0.0
13	01/28/92	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14	01/30/92	0.0	0.5	0.4	0.2	0.3	0.3	0.3	0.9	0.9	0.9	0.9	0.9	0.9
15	01/31/92	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	02/06/92	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17	02/10/92	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18	02/11/92	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	02/12/92	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	02/13/92	0.0	0.1	0.1	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	02/14/92	0.0	1.0	2.0	0.3	2.0	2.0	2.0	2.0	1.0	0.5	0.7	2.0	2.0
22	02/20/92	0.0	2.0	2.0	2.0	2.0	2.0	0.0	2.0	2.0	0.0	0.0	2.0	0.0
23	02/24/92	0.0	0.4	0.7	0.2	0.5	0.7	0.2	0.2	0.1	0.2	0.1	0.2	0.2
24	02/25/92	0.3	1.2	2.0	0.8	1.2	2.0	0.4	0.4	0.5	0.5	0.4	0.8	1.2
25	02/27/92	0.8	0.8	1.2	0.8	1.2	2.0	1.2	1.2	2.0	1.2	2.0	2.0	2.0
26	03/09/92	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27	04/01/92	0.3	0.0	1.0	0.0	2.0	2.0	0.0	2.0	0.0	0.0	0.0	0.0	2.0

Figure 11. Coefficient A for All Tests.

	DATE	Control	CMA 100	CMA 200	KAc 100	KAc 200	MgCl2 100	NaCl 100	NaCl 200	NaCl/CaCl2 100	NaCl/CaCl2 100 Liq	Solid CMA 100	Solid CMA 200	Urea 100
1	12/12/91	2.9	6.1	6.0	6.1	6.0	6.1	5.7	5.6	6.1	5.7	5.9	5.9	5.7
2	12/13/91	2.3	2.6	2.4	2.5	2.6	2.5	2.4	1.9	2.3	2.3	1.9	2.2	2.3
3	12/20/91	1.8	1.9	2.2	1.7	1.8	2.3	1.6	1.6	1.5	1.9	1.8	1.6	1.9
4	01/02/92	2.1	5.8	5.8	5.6	5.7	5.8	4.5	4.9	4.2	4.7	4.3	4.7	5.2
5	01/06/92	4.0	5.0	4.8	4.6	4.1	4.4	4.5	4.0	3.7	3.7	3.7	3.1	4.1
6	01/08/92	1.6	2.2	3.1	2.1	2.9	2.8	2.1	2.2	1.9	2.2	2.1	2.0	2.3
7	01/09/92	3.0	2.1	2.1	2.1	2.3	2.6	2.1	2.1	2.2	2.2	2.1	1.6	2.3
8	01/10/92	2.8	2.2	2.3	1.7	1.5	2.0	1.9	1.8	1.8	2.0	1.7	1.9	1.9
9	01/11/92	2.2	5.2	5.7	5.3	4.7	5.7	3.7	5.0	3.9	4.4	3.5	4.4	4.4
10	01/22/92	1.7	3.5	3.5	2.0	2.5	2.6	2.1	2.8	2.0	2.2	2.0	2.1	2.3
11	01/23/92	1.3	2.1	3.3	2.4	3.6	3.6	2.0	2.1	2.1	2.3	2.2	2.1	2.2
12	01/27/92	1.6	2.3	2.6	2.3	2.2	2.5	2.2	2.8	2.1	1.8	1.5	2.2	1.8
13	01/28/92	1.1	2.2	2.0	1.6	1.9	2.0	1.7	1.8	1.7	1.8	1.8	1.9	1.7
14	01/30/92	1.4	3.8	4.1	3.1	3.6	3.8	3.4	4.9	4.0	4.6	4.4	4.7	4.2
15	01/31/92	1.3	1.9	2.5	1.9	2.6	2.8	2.1	2.6	2.1	2.3	2.3	2.6	2.4
16	02/06/92	0.0	2.0	2.0	2.2	2.2	2.0	2.2	2.4	1.8	1.8	1.6	1.8	2.2
17	02/10/92	1.3	1.5	1.9	1.7	1.8	1.9	1.9	2.0	1.8	1.6	1.3	1.3	1.7
18	02/11/92	1.7	1.4	1.6	1.7	1.6	1.6	1.9	1.7	1.8	1.7	1.7	1.5	2.0
19	02/12/92	1.5	1.7	1.9	1.7	1.6	1.8	1.6	1.8	1.8	1.9	1.9	2.1	2.0
20	02/13/92	1.2	1.9	3.2	1.5	2.3	3.3	1.8	1.7	1.7	1.6	1.7	1.8	2.0
21	02/14/92	1.4	5.5	5.7	3.1	5.3	5.8	5.6	5.8	5.1	3.8	4.7	5.6	5.8
22	02/20/92	1.3	2.0	1.8	1.8	1.4	1.1	1.3	1.6	1.7	1.2	1.2	1.2	1.4
23	02/24/92	1.7	4.8	5.5	4.2	5.0	5.7	3.9	4.4	3.6	4.0	3.6	3.8	4.0
24	02/25/92	2.5	5.3	5.5	4.8	5.3	5.6	4.1	4.8	4.6	4.6	4.3	5.0	5.4
25	02/27/92	4.9	4.9	5.4	4.9	5.2	5.9	5.7	5.7	5.8	5.7	5.8	5.7	6.2
26	03/09/92	1.4	1.9	1.5	2.0	1.6	2.0	2.1	1.8	2.2	2.1	2.2	1.8	2.2
27	04/01/92	3.1	2.0	2.3	1.9	2.8	2.9	1.9	2.3	2.1	2.2	2.1	2.1	3.2

Figure 12. Coefficient B for All Tests.

	DATE	Control	CMA 100	CMA 200	KAc 100	KAc 200	MgCl2 100	NaCl 100	NaCl 200	NaCl/CaCl 100	NaCl/CaCl 100 Liq	Solid CMA 100	Solid CMA 200	Urea 100
1	12/12/91	0.7	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2	12/13/91	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.5	0.6	0.6	0.5	0.6	0.6
3	12/20/91	0.4	0.5	0.5	0.4	0.5	0.6	0.4	0.4	0.4	0.4	0.4	0.4	0.4
4	01/02/92	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
5	01/06/92	0.8	0.9	0.9	1.0	0.9	0.9	1.0	0.9	1.0	0.8	0.8	0.8	0.9
6	01/08/92	0.6	0.5	0.7	0.5	0.7	0.7	0.5	0.6	0.5	0.6	0.6	0.5	0.6
7	01/09/92	0.8	0.5	0.5	0.5	0.5	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5
8	01/10/92	0.6	0.6	0.6	0.4	0.3	0.6	0.4	0.4	0.4	0.5	0.4	0.5	0.5
9	01/11/92	0.7	1.0	1.0	1.0	1.0	1.0	1.0	1.1	1.0	1.1	1.1	1.0	1.1
10	01/22/92	0.5	0.6	0.6	0.5	0.5	0.5	0.4	0.5	0.4	0.5	0.4	0.5	0.5
11	01/23/92	0.3	0.5	0.6	0.5	0.7	0.7	0.4	0.5	0.5	0.5	0.4	0.5	0.5
12	01/27/92	0.5	0.9	0.8	0.8	0.8	0.8	0.7	0.9	0.7	0.6	0.4	0.6	0.5
13	01/28/92	0.3	0.5	0.5	0.4	0.5	0.5	0.4	0.5	0.4	0.4	0.4	0.4	0.4
14	01/30/92	0.3	0.9	0.9	0.8	0.8	0.8	0.7	1.0	0.8	0.9	0.8	0.9	0.7
15	01/31/92	0.3	0.4	0.5	0.4	0.6	0.6	0.5	0.6	0.5	0.5	0.5	0.6	0.5
16	02/06/92	0.1	0.4	0.4	0.5	0.5	0.4	0.4	0.5	0.4	0.4	0.4	0.4	0.4
17	02/10/92	0.5	0.4	0.7	0.6	0.6	0.6	0.5	0.5	0.6	0.5	0.4	0.4	0.5
18	02/11/92	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.5
19	02/12/92	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
20	02/13/92	0.3	0.6	0.9	0.4	0.7	0.9	0.5	0.5	0.5	0.4	0.4	0.5	0.5
21	02/14/92	0.3	1.0	1.0	0.9	0.9	1.0	1.0	1.0	1.0	0.9	1.0	1.0	1.0
22	02/20/92	0.4	0.7	0.6	0.7	0.6	0.5	0.5	0.7	0.6	0.4	0.5	0.5	0.5
23	02/24/92	0.4	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
24	02/25/92	0.7	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
25	02/27/92	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
26	03/09/92	0.3	0.4	0.4	0.4	0.4	0.6	0.4	0.4	0.4	0.4	0.5	0.4	0.5
27	04/01/92	0.8	0.5	0.6	0.6	0.8	0.8	0.4	0.7	0.5	0.5	0.5	0.5	0.7

Figure 13. Coefficient C for All Tests.

In order to make use of the calculated *effect*, a value that was deemed *acceptable* was determined. Figure 14 is a friction plot for a hypothetical test. In this test the friction starts out at a value of 0.1 and comes up to 0.5 (see Section 4.7) at a time of 45 minutes. The friction then remains at 0.5 throughout the rest of the test period. The calculated *effect* for this scenario is 4.0. This value has been chosen to depict the *acceptable effect* for a test.

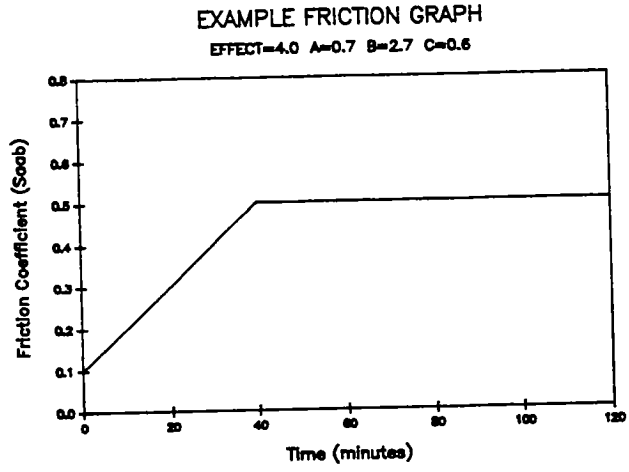


Figure 14. Acceptable *Effect* Calculation Plot.

After calculating the *effect* values for each chemical for all of the tests run during the winter period, the Friedman analysis was performed on these results. Figure 15 gives the results of these calculations for the 27 tests.

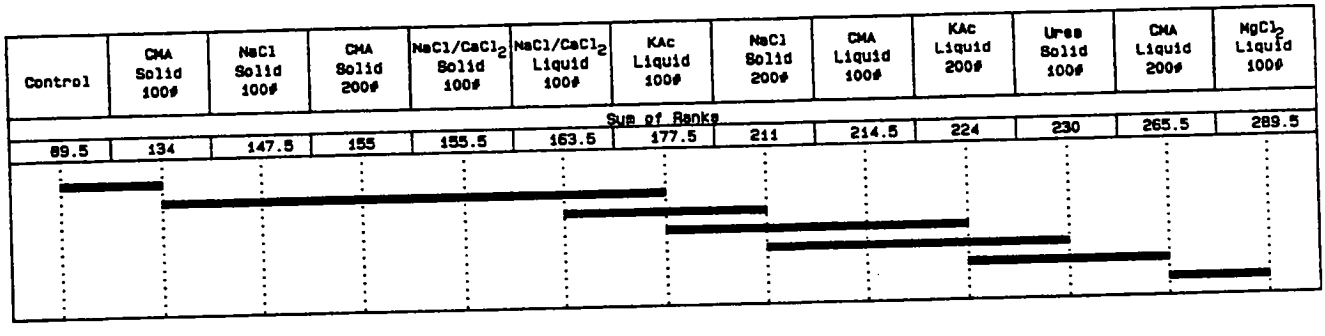


Figure 15. Friedman Analysis - *Effect* Values (27 tests).

The Pearson sample correlation and the Bonferroni probabilities [1] were computed for each combination of the treatment *effect* rating and the corresponding environmental parameters.

Using this, the only environmental parameter that we found to be clearly statistically significant with treatment *effect* is pavement temperature. Other parameters may be correlated with treatment *effect* but our data did not show them to be statistically significant.

The statistically significant sample correlations between the environmental parameters, such as pavement temperature and air temperature or relative humidity and short wave radiation, in our data are consistent with what one would expect. Figures 16 and 17 show the environmental parameter correlations and their Bonferroni probabilities for all 27 tests.

	WS	AIRTEMP	PAVETEM	RH	SWAVE	LWAVE
WS	1.000					
AIRTEMP	-0.016	1.000				
PAVETEM	0.117	0.753	1.000			
RH	0.391	0.446	0.221	1.000		
SWAVE	-0.097	-0.555	-0.149	-0.637	1.000	
LWAVE	0.273	0.660	0.301	0.797	-0.706	1.000

Figure 16. Pearson Correlations for 27 Tests - Weather Parameters.

	WS	AIRTEMP	PAVETEM	RH	SWAVE	LWAVE
WS	0.000					
AIRTEMP	1.000	0.000				
PAVETEM	1.000	0.000	0.000			
RH	0.659	0.297	1.000	0.000		
SWAVE	1.000	0.040	1.000	0.005	0.000	
LWAVE	1.000	0.003	1.000	0.000	0.001	0.000

Figure 17. Bonferroni Probabilities for 27 Tests - Weather Parameters.

The statistically significant probabilities are boxed. Because pavement temperature and air temperature are positively correlated at 0.753, one might expect treatment *effect* and air temperature to be correlated also, even though our data does not show this. It may be that because other environmental parameters were not constant during the testing there is an interaction effect which obscured this correlation. It may be that the functional relationship between treatment *effect* and air temperature is not linear.

To examine for linear relationships, we first compared treatment effect with the environmental parameters. Figure 18 shows the result of the Pearson correlations and Figure 19 gives the Bonferroni probabilities.

	Control	CMA 100#	CMA 200#	KAc 100#	KAc 200#	MgCl2 100#	NaCl 100#	NaCl 200#	NaCl/CaCl2 100	NaCl/CaCl2 100 Liq.	Solid CMA 100#	Solid CMA 200#	Urea 100#
WS	-0.122	-0.092	-0.139	0.001	-0.067	-0.142	-0.123	0.006	0.086	-0.008	-0.006	-0.012	-0.103
AIRTEMP	0.228	0.551	0.513	0.469	0.436	0.424	0.392	0.381	0.381	0.448	0.405	0.377	0.340
PAVETEMP	0.356	0.646	0.629	0.566	0.644	0.639	0.614	0.661	0.640	0.628	0.615	0.627	0.634
RH	-0.060	0.225	0.192	0.224	0.060	0.084	0.018	-0.008	0.027	0.071	-0.013	-0.018	-0.093
SWAVE	0.033	-0.020	0.107	-0.022	0.174	0.219	0.228	0.251	0.216	0.133	0.210	0.255	0.313
LWAVE	-0.116	0.277	0.197	0.280	0.094	0.057	0.063	-0.019	0.065	0.095	0.026	0.008	-0.091

Figure 18. Pearson Correlations for 27 Tests - Weather Parameters and *Effect.*

	Control	CMA 100#	CMA 200#	KAc 100#	KAc 200#	MgCl2 100#	NaCl 100#	NaCl 200#	NaCl/CaCl2 100	NaCl/CaCl2 100 Liq.	Solid CMA 100#	Solid CMA 200#	Urea 100#
WS	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
AIRTEMP	1.000	0.061	0.129	0.285	0.481	0.576	0.908	1.000	1.000	0.398	0.755	1.000	1.000
PAVETEMP	1.000	0.006	0.009	0.044	0.006	0.007	0.014	0.004	0.007	0.009	0.014	0.010	0.008
RH	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
SWAVE	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
LWAVE	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Figure 19. Bonferroni Probabilities for 27 Tests- Weather Parameters and *Effect.*

Figure 19 shows that the only strong statistical correlation between *effect* and weather parameters is the pavement temperature. This correlation is highly significant in all tests except for the control. An example of the relationship between these two variables is given for liquid CMA at 100 lb/lane mi. in Figure 20. Plots for the remainder of the treatments can be found in Appendix E.

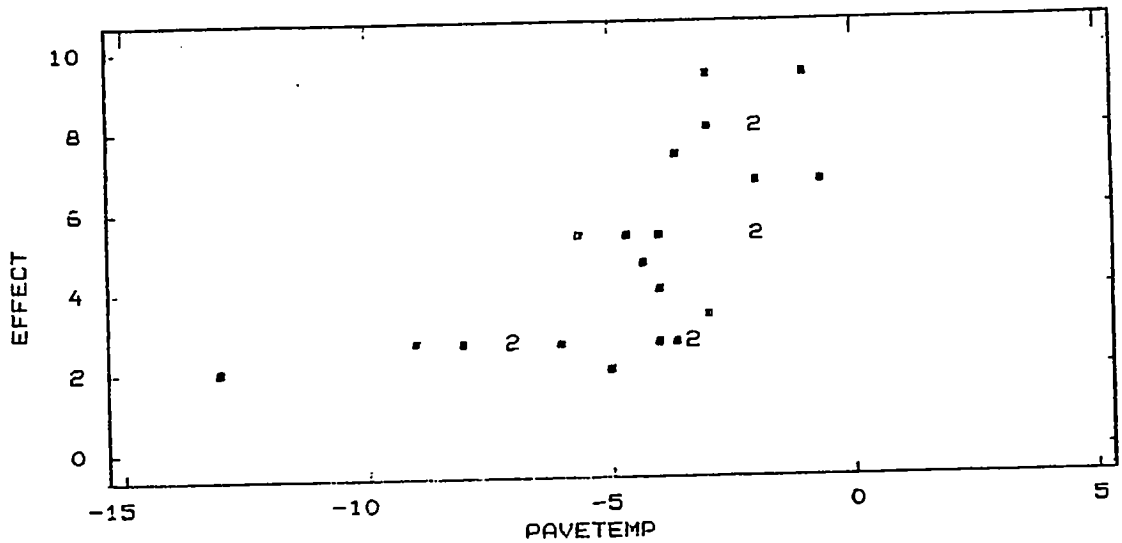


Figure 20. Pavement Temperature-*Effect* Relationship for 27 tests (liquid CMA at 100 lb/lane mi.).

Examination of all of these sets of data revealed that in no instance did the *effect* achieve an acceptable value of 4 (discussed earlier) below a temperature of -6° C (+21°F). Realizing this, the Friedman analysis was performed for the tests where the pavement temperature was above -6° C. This was done for both friction and *effect* and the results are given in Figures 21 and 22.

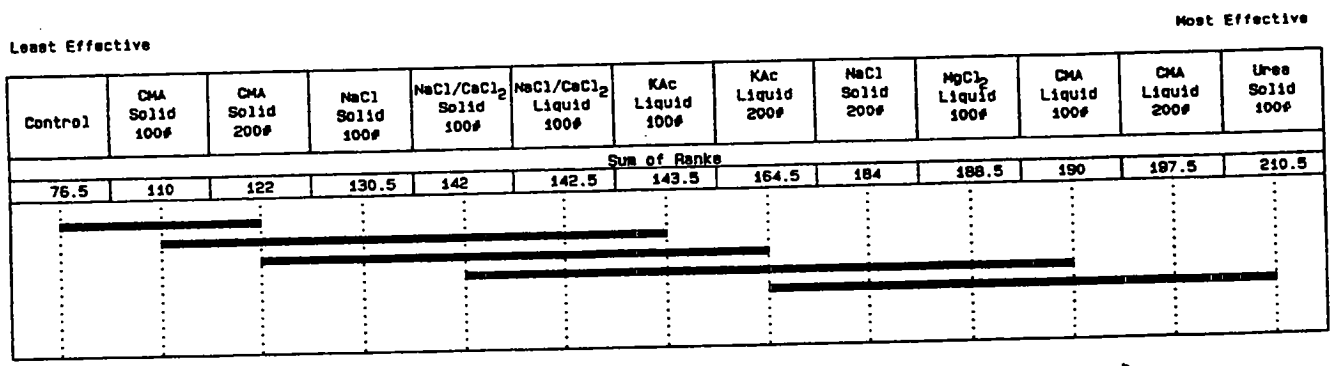


Figure 21. Friedman Analysis - Sum of Ranks (21 tests).

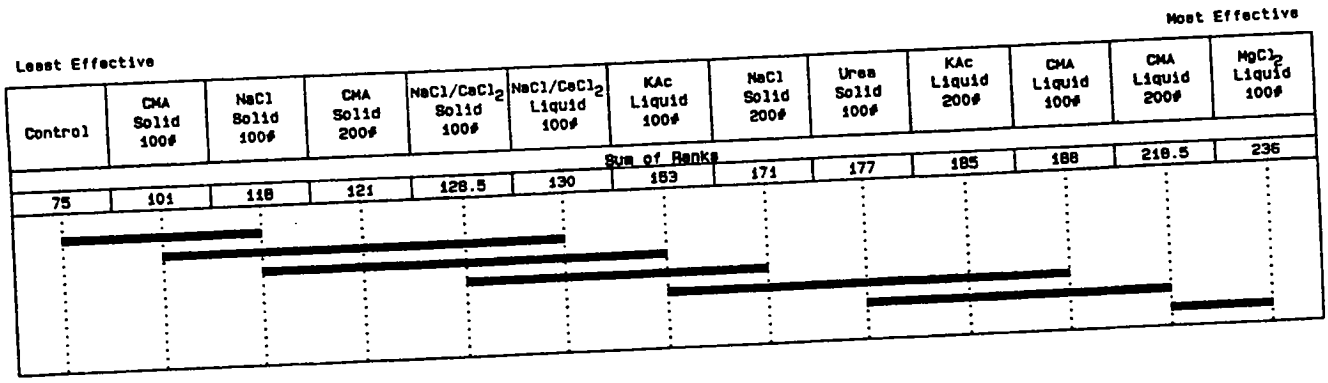


Figure 22. Friedman Analysis - *Effect* Values (21 tests).

Comparing the result for the 21 tests to the overall results (27 tests) for friction, the top five applications remain the same although the order of ranking changes somewhat. Also, the bottom four are the same in both analyses. Looking at the *effect* results, the changes between the two sets of tests are less dramatic. The only two applications that change rank are the urea solid and the CMA liquid at 100 lb/lane mi.

If it appeared that there is a non-linear functional relationship, we transformed the data and then calculated the correlation. For example, treatment *effect* might appear to increase exponentially with air temperature as in Figure 23. Then taking the logarithm of treatment *effect* and plotting that against air temperature might result in a statistically significant correlation. Figure 24 shows the log plot for the same data as in Figure 23. Obviously, at least in this attempt, using the logarithm did not substantially improve the relationship. This method was used for all of the applications and the results were the same.

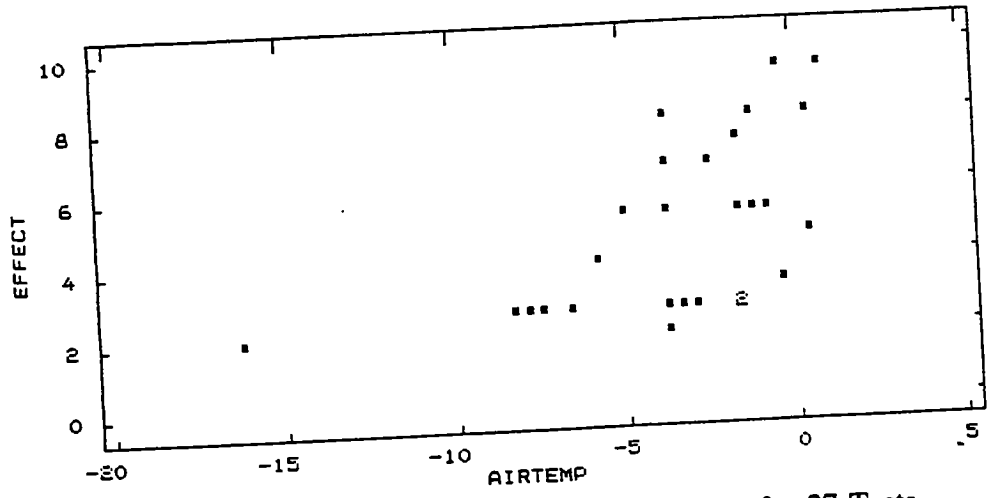


Figure 23. Air Temperature - *effect* Relationship for 27 Tests (liquid CMA at 100 lb/lane mi.).

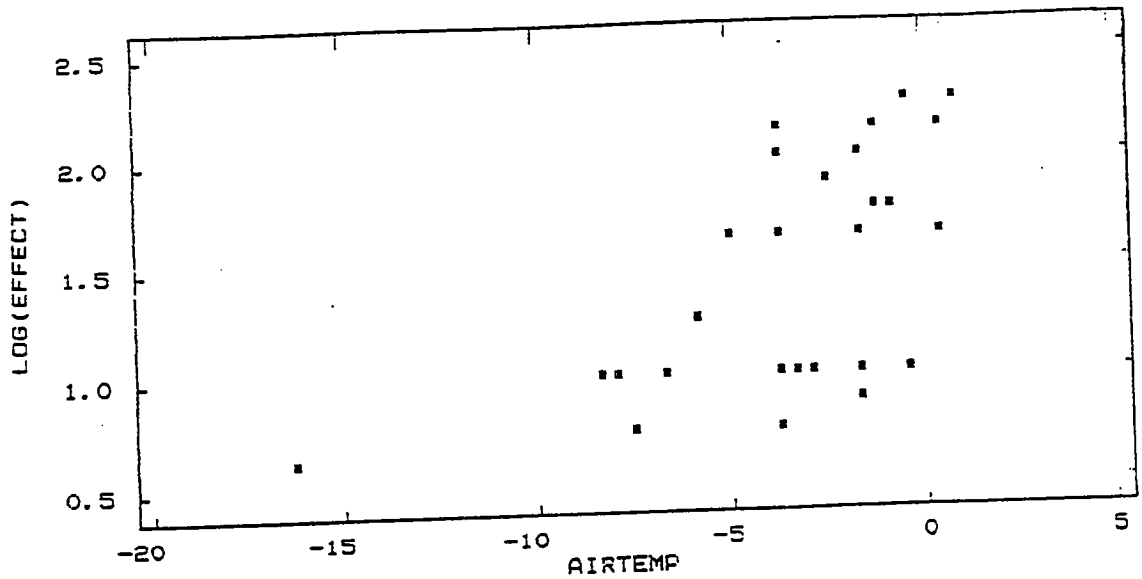


Figure 24. Log of Effect Versus Air Temperature for 27 Tests (liquid CMA at 100 lb/lane mi.).

Figures 25 (all days) and 26 (pavement temperature above -6^0 C) depict how each application performed in terms of *effect* and percent of days that the average *effect* was above a given value. From these graphs it can be seen how each chemical performed in terms of, for instance, reaching an *effect* of 5 or 6.

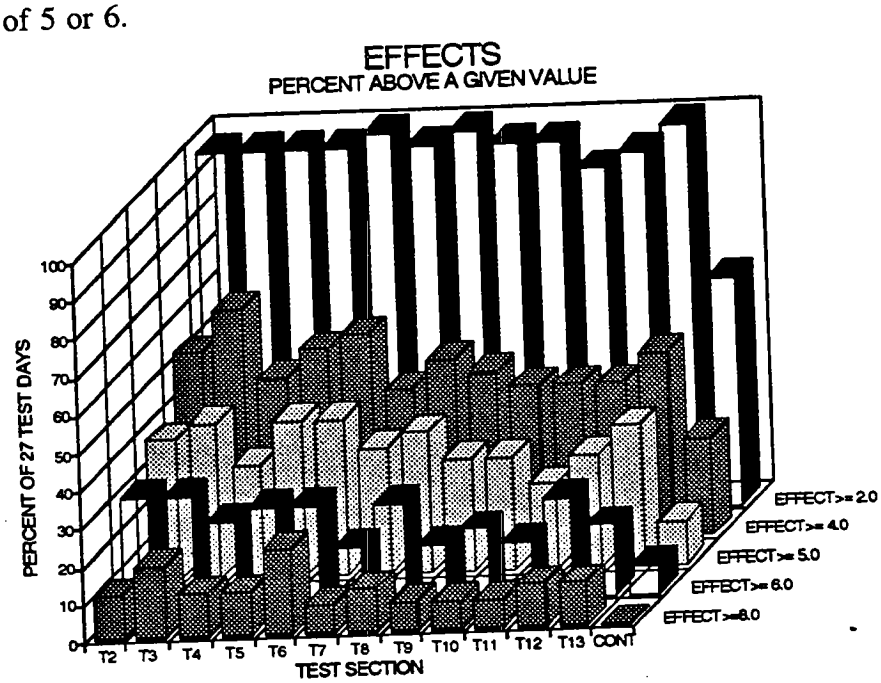


Figure 25. Average *Effect* Percentages for 27 Tests.

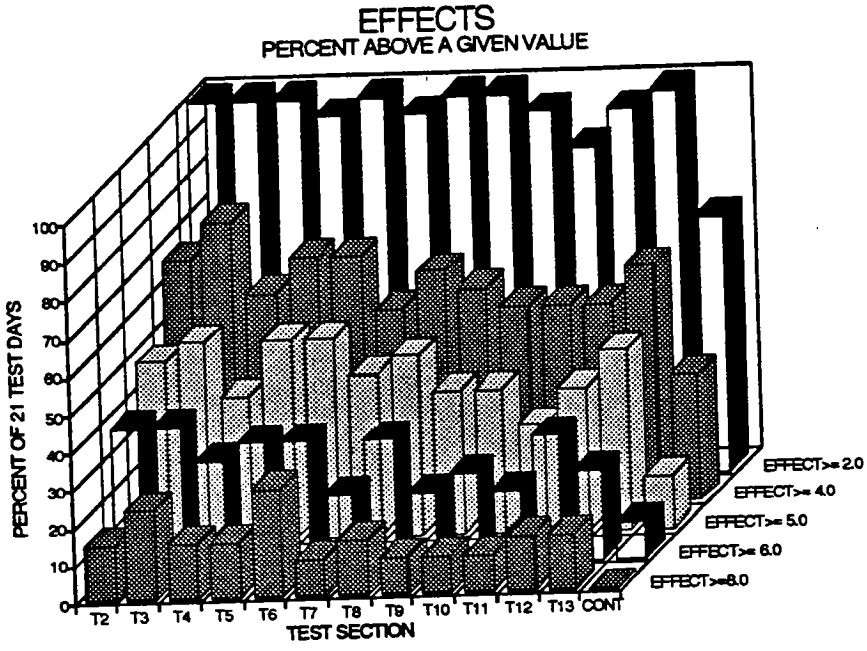


Figure 26. Average *Effect* Percentages for 21 Tests - Pavement Temperature Above -6^0 C.

The *effect* data were analyzed in several other ways including the results given in Figures 27 through 31. These graphs indicate how well each application performed on average for several different scenarios, all showing the *effect* values above or below the arbitrarily chosen acceptable value 4.0. Figure 27 gives the results for all of the tests performed. For example, looking at treatment 2, liquid CMA at 100 lb/lane mi., it was on average 0.5 above the *acceptable* value of 4.0. Figure 28 shows the results for tests where pavement temperature was above -6^0 C. Figure 29 shows 10 tests where chemicals were applied prior to the onset of any precipitation. Figure 30 gives eight tests during which chemicals were placed on top of the snow. Four days when chemicals were placed on top of snow and the pavement temperature was above -6^0 C are plotted in Figure 31.

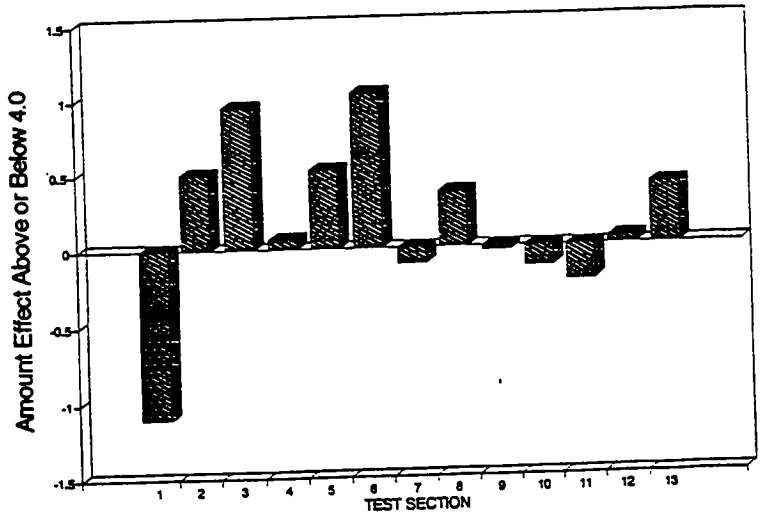


Figure 27. *Effect* Values Above or Below 4.0 for 27 Tests.

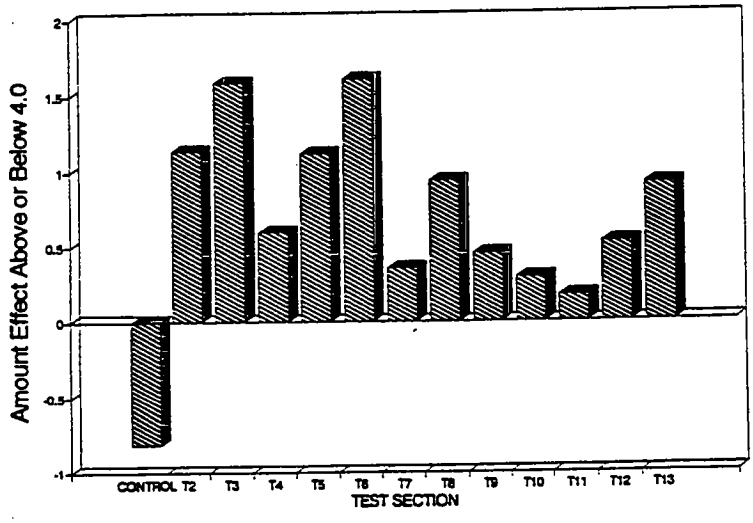


Figure 28. *Effect* Values Above or Below 4.0 for 21 Tests. Pavement Temperature Above -6° C.

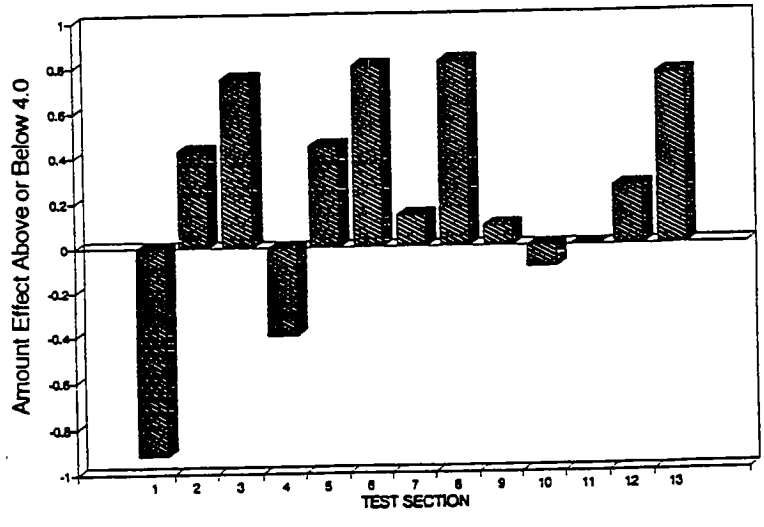


Figure 29. *Effect* Values Above or Below 4.0 for 10 Tests. Chemicals Applied before Start of Precipitation.

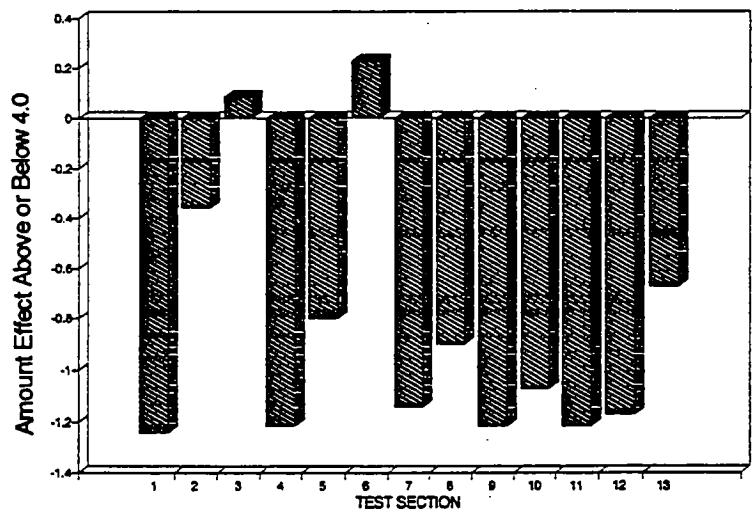


Figure 30. *Effect* Values Above or Below 4.0 for 8 Tests. Chemicals on Top of Snow.

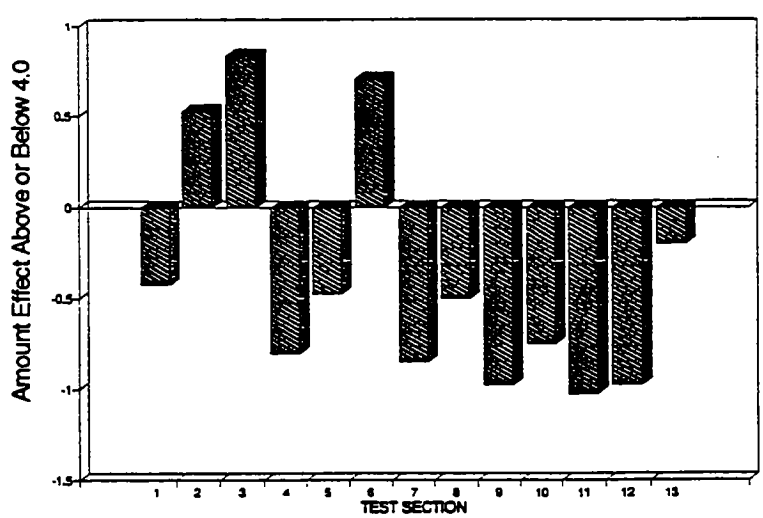


Figure 31. *Effect* Values Above or Below 4.0 for 4 Tests. Chemicals on Top of Snow - Pavement Temperature Above -6° C.

7.4 Multiple Treatments

A statistical analysis of tests that contained more than one application of chemicals during a single test period was also performed. Second applications of chemicals were made in cases when anti-icing was inadequate for one reason or another and after two hours the decision was made to re-apply. Of the 27 tests run during the winter, seven had a second application after two hours. Because of the paucity of data, care should be taken before drawing any conclusions from these results.

Figure 32 shows the Friedman analysis for the seven tests with all of the data included for the entire test period. The trends are for the most part the same as those reported earlier for all 27 tests: liquids perform better than the solids, with the exception of the urea.

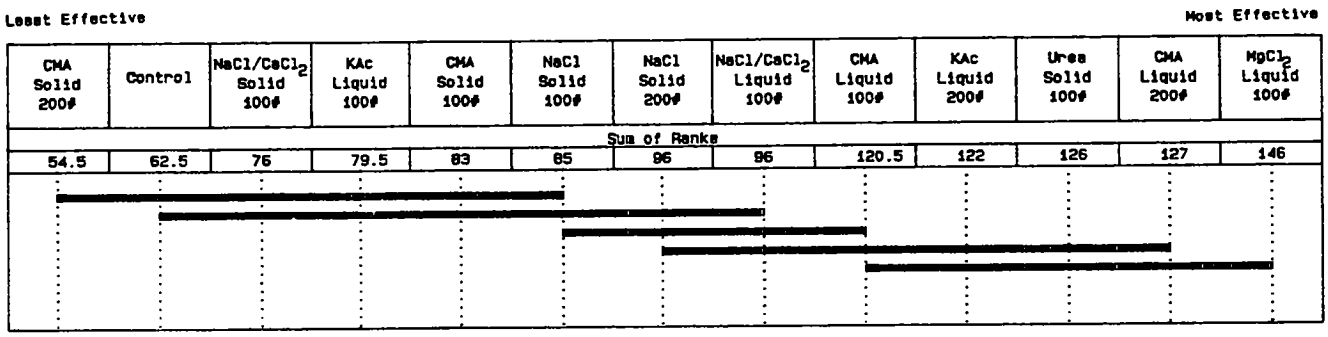


Figure 32. Friedman Results - Double Application - All Data.

Figure 33 shows the result of the Friedman analysis for the first two hours of the seven tests. It can be seen that the relative order of effectiveness of the chemicals has changed somewhat, but most importantly that it is difficult to separate the chemicals from each other, as indicated by the fact that only three bars exist and the overlap between them is substantial. This result should be obvious, since the reason for applying chemicals a second time is the fact that the first application was not adequate.

Figure 34 is the Friedman graph for the second application of chemicals. This result is not as expected, due to the fact that all of the liquids, with the exception of the potassium acetate at 100 lb/lane mi., performed better than the solids. It is probable that the anti-icing effect of the liquids was adequate to get favorable results from a second application. Keep in mind that only seven sets of data were available for this analysis, however.

The *Effect* values were analyzed in terms of the three components A, B and C in an attempt to assess the chemicals in the three separate categories.

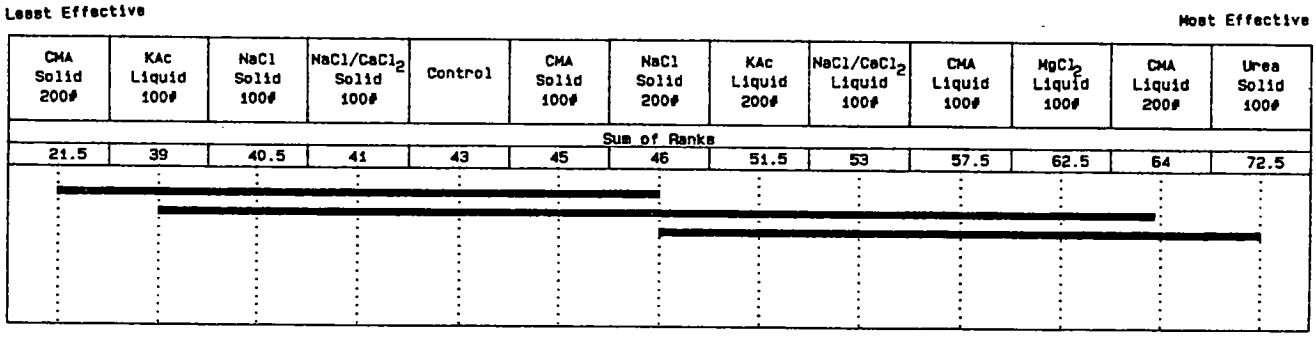


Figure 33. Friedman Results - Double Application - First 2 Hours.

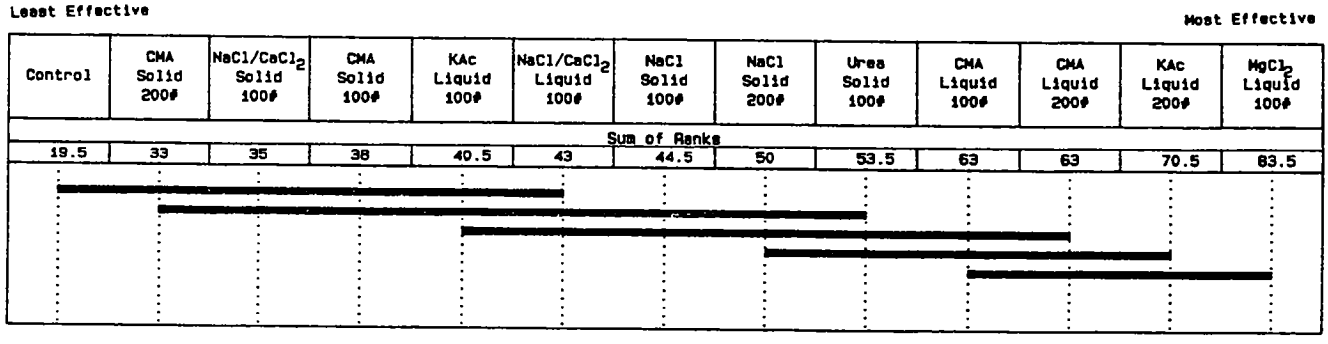


Figure 34. Friedman Results - Double Application - Second 2 Hours.

Figure 35 shows the result of the Friedman analysis for the A values, which should give a good indication of how fast each chemical begins to work. This result is for all of the 27 tests performed.

Figure 36 is the result of the Friedman analysis for the A values where the pavement temperature was at or above -6^0 C. In both cases, the order that each chemical performed in comparison to the others is identical. For the most part, the liquids were faster than the solids using the A value as the indicator.

Performing the same analysis on the B values results in Figures 37 and 38 for the 27 and 21 tests respectively.

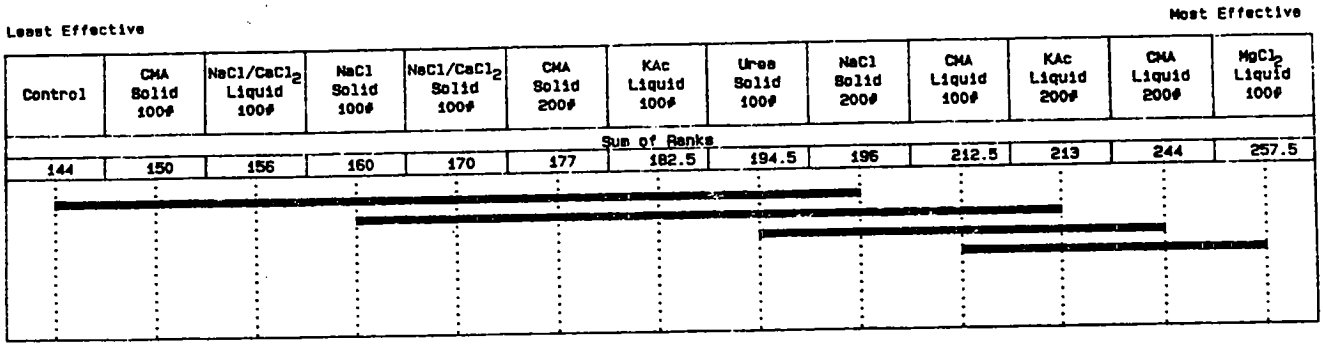


Figure 35. Friedman Results - A Values - 27 Tests.

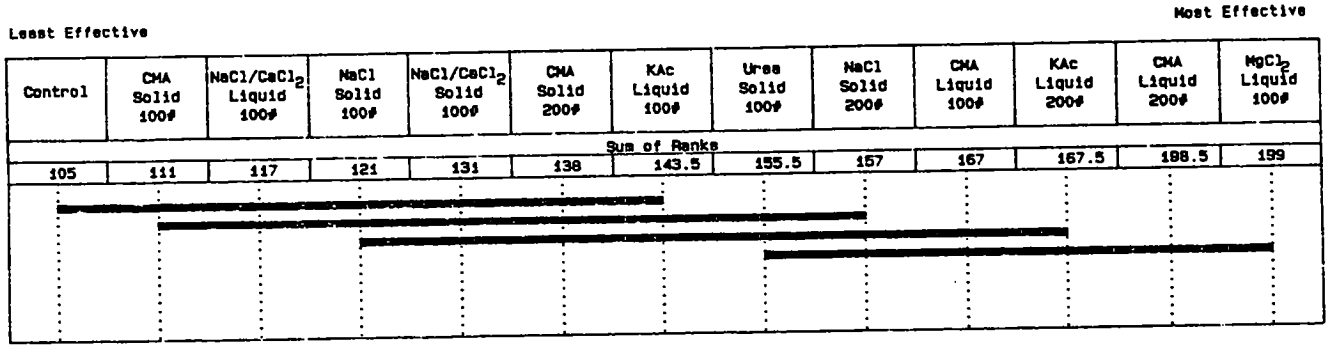


Figure 36. Friedman Results - A Values - 21 Tests.

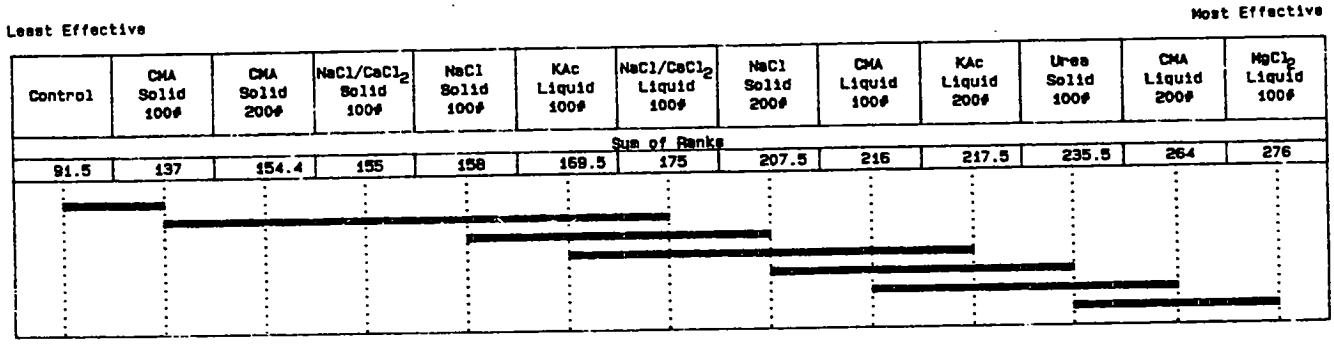


Figure 37. Friedman Results - B Values - 27 Tests.

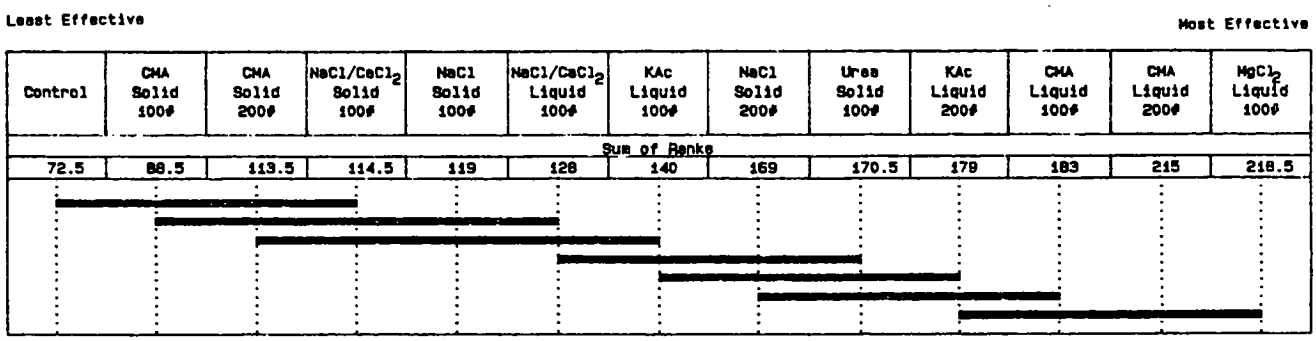


Figure 38. Friedman Results - B Values - 21 Tests.

The B value should give a good indication as to how effective each chemical is at attaining an acceptable value of average friction. There are some subtle differences between the 27 and 21 test analyses. For the most part, the liquids are again superior to the solids. The most important difference between the two results is that the urea falls behind two of the liquids when the temperature is brought up to -6^0 C. This indicates that the urea may perform better than some of the other chemicals at the colder temperatures.

Finally, examining the C values by use of the Friedman analysis, the result is as shown in Figures 39 and 40 for the two test groupings. The C value should give an indication of how well the chemicals can maintain a higher friction value with time.

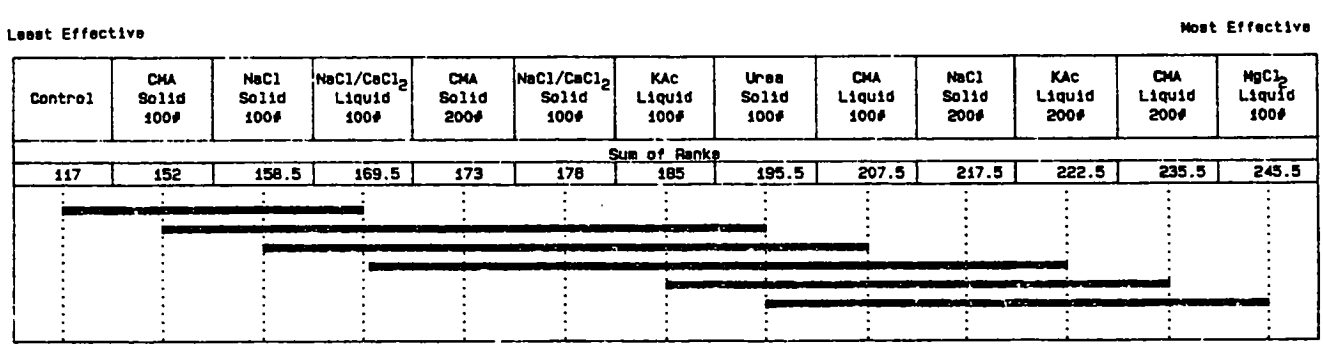


Figure 39. Friedman Results - C Values - 27 Tests.

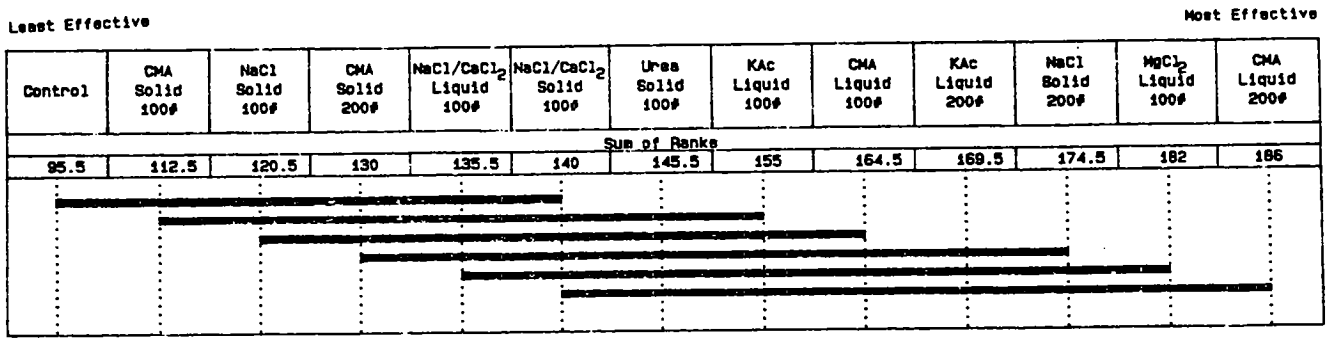


Figure 40. Friedman Results - C Values - 21 Tests.

The liquids are once again grouped as the better performers with the exception of the 200 lb/lane mi. application of NaCl. This indicates, as is probably already well known, that salt tends to have a long-term effect at least at the higher dosage.

Considerable effort was put into looking at partial correlations in the data. This analysis examines how each of the variables affects the others in an attempt to eliminate redundant parameters. The intent was to see if eliminating a meteorological parameter may make the correlations between the others stronger. One variable at a time was eliminated, and in some cases, pairs of variables. This analysis did not produce any meaningful results.

8 Overview

The use of freezing point depressants for anti-icing is effective. In many instances when chemicals were applied before snow fell, most of the snow was easily removed mechanically, but a thin film or layer of saturated snow remained which could not be removed with a plow blade. The influence of the chemicals was visually apparent in these instances; the snow was much thinner than on the untreated sections or the buffer zones, and the treated sections were translucent and sometimes *appeared* to be bare. However, in instances when a low friction was recorded, close inspection revealed that a very thin ice layer was present. In these cases, even power sweeping did not generally provide dramatic improvement, but---depending on pavement temperature---another application of chemical was effective in removing the snow, especially by using liquids. This can be seen best by examining the seven tests where a second application of chemicals was made. On several occasions, when these areas had their overburden removed, this final thin layer would then clear with no further effort. However there were some instances in which this film remained. It was quite frustrating in that it gave the impression that the film was

almost gone but would not produce the desired level of frictional performance. This can be seen by examining the friction plots and noticing those tests where friction levels did not increase immediately after plowing. The result of trafficking with the Saab every 15 minutes and on several occasions with pick-up trucks running at approximately one pass per minute, did not affect this outcome.

This film could sometimes be removed with the additional application of chemical in a quantity which would have been insufficient to deice the untreated section with any of the chemicals examined. In these cases the liquid chemicals were more effective than solids in removing the layer. Figures 41 through 44 are friction plots for two days when this clearly occurred. These longer tests were not included in the overall analysis since they were considered to be of a different sort, but individual examination provides additional information. Liquids appeared to work the best in all tests in which chemicals were applied on top of snow which had been pretreated.

Visually the liquids produced a more even pattern of anti-icing. This is likely due, at least in part, to the fact that they are not as easily displaced as are the solids once they are applied to the bare pavement. When the liquids were placed on the thin film of slush or ice as described above, they were much more effective in removing this thin layer. When considering deicing such as this, the liquids were much faster. However, if there was a substantial mat of snow, the liquids were not always as effective as the dry chemicals. The latter appeared to have the advantage of boring through and not becoming diluted as quickly. Deicing in such conditions was not generally effective at the low rates applied.

9 Conclusions

Liquids appear to be more effective than dry chemicals for anti-icing applications. Certainly this is the case for the CMA liquid vs dry, the only one of the chemicals for which we have a direct comparison. The one exception to this was the dry urea. This ranking of the urea is somewhat surprising since visually it did not appear to perform as well as the liquids. Figure 45 is an overview of the results obtained for the different analyses performed on the test data. The boxes highlight the test sections on which liquid chemicals were applied. As can be seen, the majority of the liquids seem to perform better than the solids. In fact in the last four columns (greatest effectiveness), 38 of the 44 possible entries are liquids. Several different methods were used to compare the results. Since these methods differ from each other quite drastically, and seem to all come to the same conclusion, the probability that liquids will perform better than solids as anti-icers is promising and should be investigated further.

A thin layer often remains after plowing off snow which has accumulated on top of treated pavement but this is effectively treated with another light application of chemical. In this instance the liquids were superior. Dry chemicals are probably better in attempting to remove a thick mat but would require a larger amount of chemical. None of the chemicals tested were effective below -6^0 C.

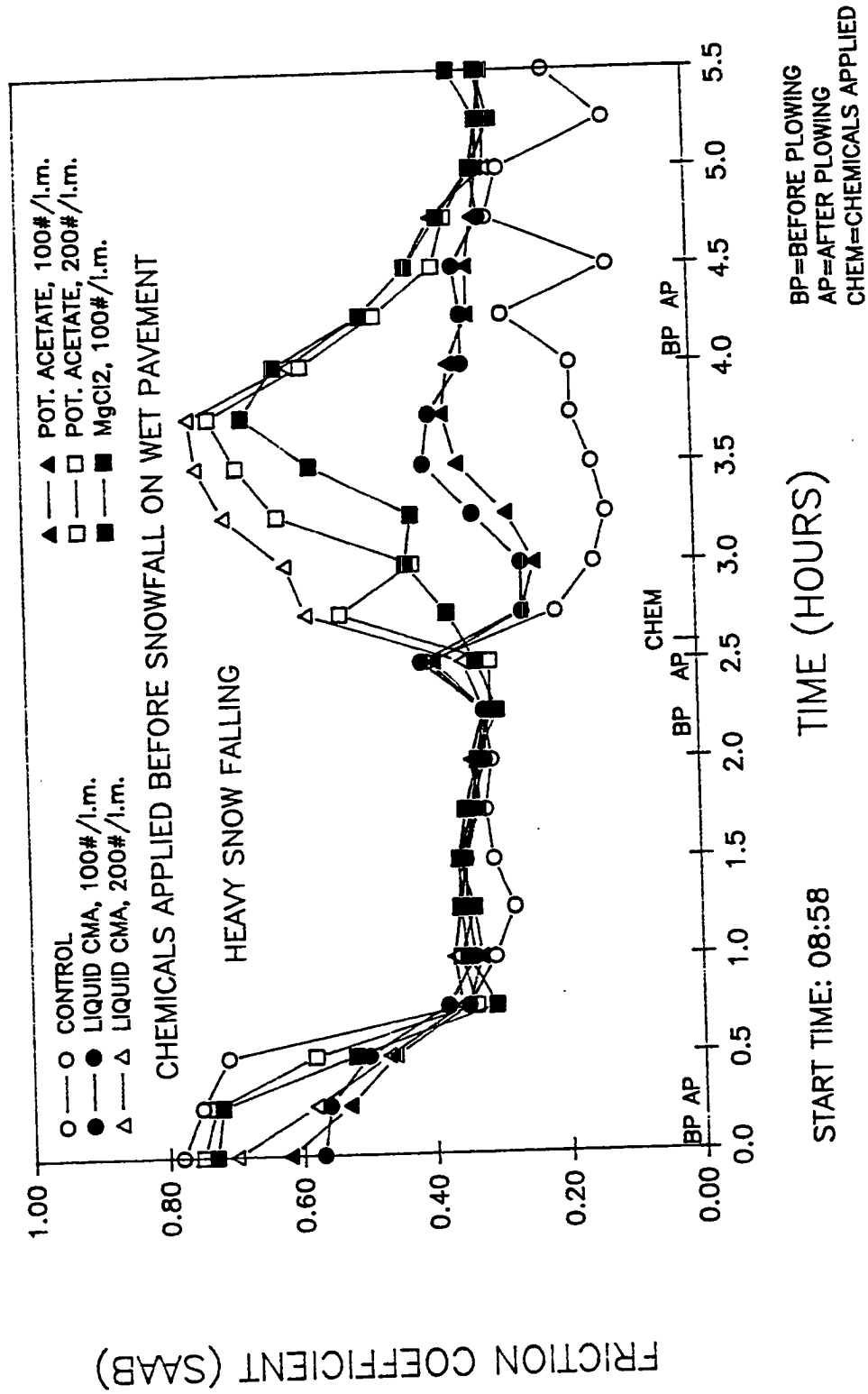


Figure 41. Friction Values - 92/01/08 - Liquids.

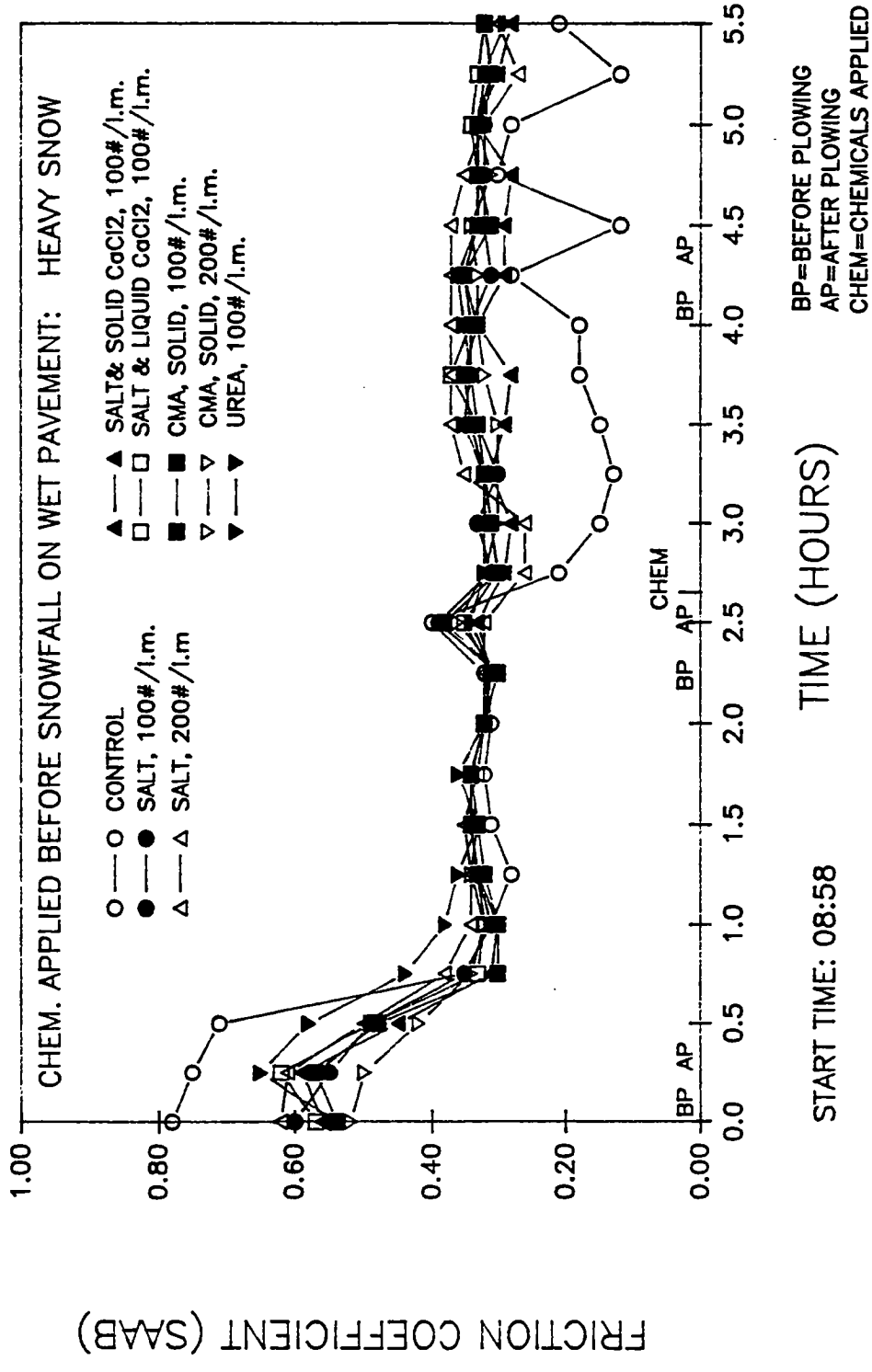


Figure 42. Friction Values - 92/01/08 - Solids

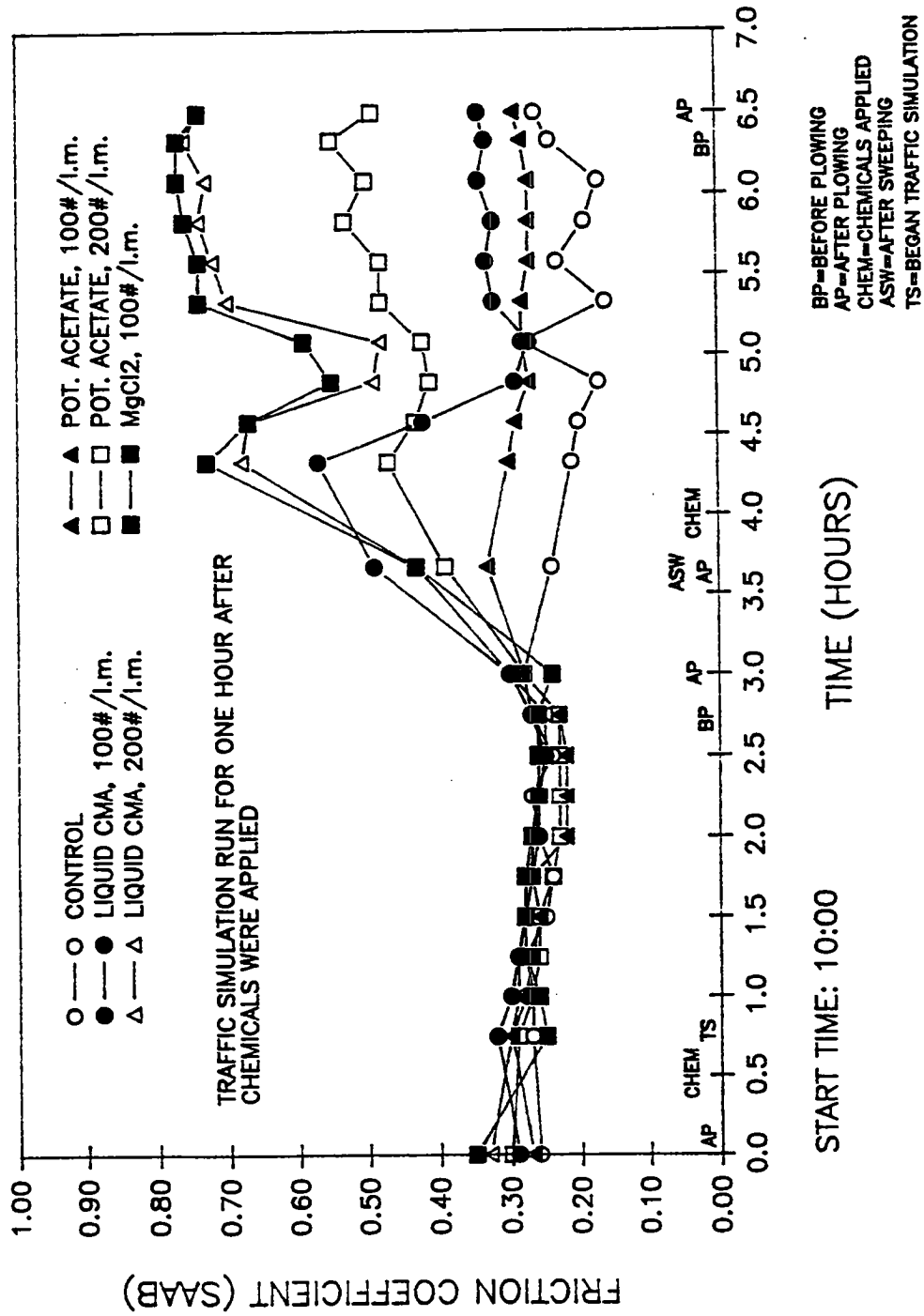


Figure 43. Friction Values - 92/02/13 - Liquids.

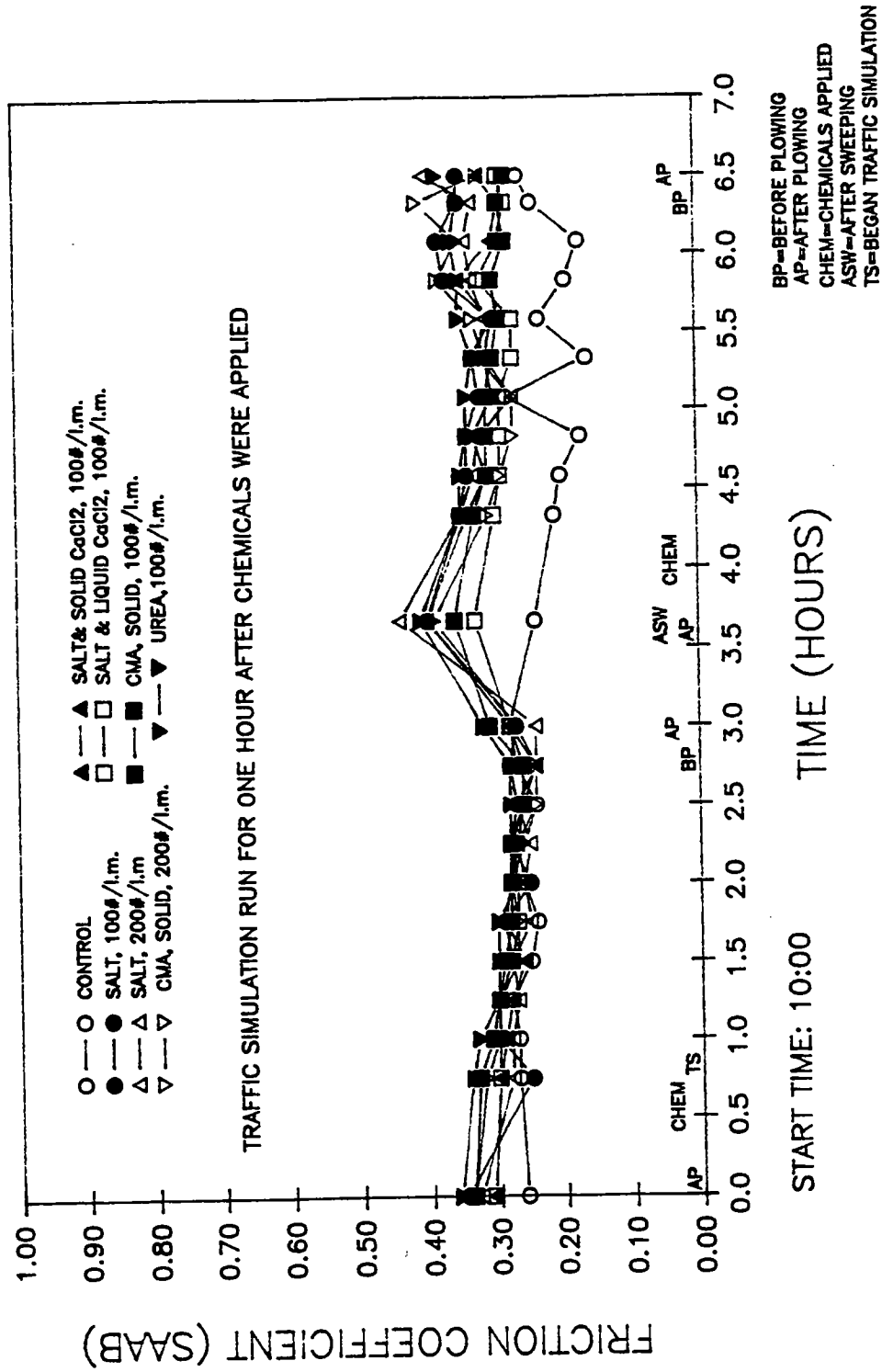


Figure 44. Friction Values - 92/02/13 - Solids.

Friedman Test Results

Listed in Increasing Order of Effectiveness For Each Set of Tests

All Effects (27 Cases)	T1	T11	T7	T12	T9	T10	T4	T8	T2	T5	T13	T3	T6
Effects for 21 Cases Pave. Temp. >= -6 C	T1	T11	T7	T12	T9	T10	T4	T8	T13	T5	T2	T3	T6
"A" Effect Values 27 Cases	T1	T11	T10	T7	T9	T12	T4	T13	T8	T2	T5	T3	T6
"A" Effect Values 21 Cases	T1	T11	T10	T7	T9	T12	T4	T13	T8	T2	T5	T3	T6
"B" Effect Values 27 Cases	T1	T11	T12	T9	T7	T4	T10	T8	T2	T5	T13	T3	T6
"B" Effect Values 21 Cases	T1	T11	T12	T9	T7	T10	T4	T8	T13	T5	T2	T3	T6
"C" Effect Values 27 Cases	T1	T11	T7	T10	T12	T9	T4	T13	T2	T8	T5	T3	T6
"C" Effect Values 21 Cases	T1	T11	T7	T12	T10	T9	T13	T4	T2	T5	T8	T6	T3
2-Test Days (7 Cases) Both Tests Included	T12	T1	T9	T4	T11	T7	T8	T10	T2	T5	T13	T3	T6
2-Test Days (7 Days) 1st Test	T12	T4	T7	T9	T1	T11	T8	T5	T10	T2	T6	T3	T13
2-Test Days (7 Cases) 2nd Test	T1	T12	T9	T11	T4	T10	T7	T8	T13	T2	T3	T5	T6

Denotes Liquid Chemicals

T1 = CONTROL
T2 = CMA, LIQUID, 100#
T3 = CMA, LIQUID, 200#
T4 = KAc, LIQUID, 100#
T5 = KAc, LIQUID, 200#

T6 = $MgCl_2$, LIQUID, 100#
T7 = NaCl, SOLID, 100#
T8 = NaCl, SOLID, 200#
T9 = $NaCl/CaCl_2$, SOLID, 100#
T10 = $NaCl/CaCl_2$, LIQUID, 100#

T11 = CMA, SOLID, 100#
T12 = CMA, SOLID, 200#
T13 = UREA, SOLID, 100#

Figure 45. Overall Friedman Results.

10 References

[1] W.J. Conover. *Practical Nonparametric Statistics.* John Wiley & Sons, New York, second edition, 1980.

[2] T. J. Yager, W.A. Vogler, and P. Baldasare. *Summary Report on Aircraft and Ground Vehicle Friction Correlation Test Results Obtained under Winter Runway Conditions during Joint FAA/NASA Runway Friction Program.* Technical Memorandum, National Aeronautics and Space Administration, Hampton, Virginia, March 1988.

APPENDIX A

Synoptic Scenarios - Individual Tests

12-12-91. The test took place during a mixed rain and snow event which produced a wet pavement. Chemicals were applied just as the pavement was beginning to freeze.

12-13-91. No new chemicals were added to the previous application from the day before. The effect of this earlier chemical application was monitored from the start of snowfall. By 22:25 approximately 35 mm of snow had accumulated.

12-19-91. Friction data shows the general condition of the pavements the day prior to a predicted snow storm. Chemicals were applied in anticipation of the storm. On 12-20-91 the storm had begun along with testing.

01-02-92. Testing began at 1030 after a light dusting of snow. Light, wet snow continued until about 1145.

01-03-92. Light dusting of snow on sections. Testing residual chemicals from previous day.

01-06-92. Approximately 2" of new wet snow. Testing residual chemicals.

01-07-92. Snow has accumulated on the test sections. Testing residual. Plowed and swept during test.

01-08-92. Chemicals applied before start of precipitation on wet pavement. Started to snow at 0900. 0915 snowing heavily. 0930 snow starting to accumulate. 1030 still snowing heavily accumulation of about 3/16". 1100 still heavy snowfall, about 1/2" accumulation. 1130 chemicals applied after plowing, still heavy snowfall. 1200 light snowfall. Plowed at 1320, still heavy snowfall.

01-09-92. 0830 about 1" accumulation of snow. Chemicals applied at 1030 after plowing. 1045 some blowing snow starting to collect on sections. Dry pavement in some buffer zones. 1230 blowing snow is accumulating on the sections.

01-10-92. Chemicals applied to snow/ice covered sections after plowing at 1345. 1415 starting to snow and blow. 1430 snow starting to accumulate. 1445 snowing heavily. 1530 still snowing. 1615 plowed all sections.

01-11-92. 0945 sections are covered with a thin layer of snow after plowing. Chemicals applied at 1000. No precipitation.

01-22-92. Test sections have patchy thin layers of ice and snow after plowing. Chemicals applied at 1015. Applied snow with the blower and ran a test after rolling and plowing.

01-23-92. Approximately 3" of wet snow fell overnight on top of a chemical application performed the previous evening. Testing started at 0830. Testing started out with light rain that changed to snow. Sections were plowed and swept at 1000 and chemicals again applied at 10:30.

Snow became heavy along with high winds. Testing was terminated at 1230 because of a total whiteout.

01-27-92. Testing began at 1000. Residual chemicals from 01-23-92. Snow from previous storm was rolled and then plowed. Light snow fell during the test at times. Sections were plowed and swept at 1510.

01-28-92. Chemicals were applied onto clear pavement at 1200. Snow was blown onto the sections using the snow blower.

01-30-92. 0745 test of residual chemicals. Plowed and swept sections after heavy snow had fallen overnight. No new precipitation after start of testing.

01-31-92. 0900 all of the sections are covered with frozen snow and ice. The surface is too rough to run the Saab. Sections cleaned with grader and then plowed. Chemicals applied at 1320. Snow and high winds until about 1430 when it cleared and the sun came out.

02-06-92. 0930 sections were covered with a thin layer of ice from freezing rain. Chemicals were applied in the a.m. The sections were swept at 1300. Testing was performed in high winds and blowing snow.

02-10-92. Snow had fallen over the weekend on top of chemicals applied on 02-07-92. Light snow was steady throughout the test period. New chemicals applied at 1500 for next day's testing.

02-11-92. Rolled snow from overnight on chemicals from previous day. 1300 light snow falling after plowing. 1400 mostly sunny.

02-12-92. Test sections cleaned with grader and plowed. Residual test. Bright sunshine until 1445 then cloud cover.

02-13-92. 1030 applied chemicals with thin snow or ice glaze. Light snow falling until 1120 when the snow started to come down harder. At 1230 all of the sections are covered with snow. Plow and sweep the course and apply chemicals at 1400. Snowing until about 1525.

02-14-92. Test run with residual from the previous day. Some of the sections are partly bare. Sun is out brightly. Applied chemicals and snow in late afternoon and left for Monday.

02-20-92. Applied chemicals to clear sections at 0850. 1030 blowing snow is starting to stick in places. Starting to snow at 1100. At 1115 the snow is falling heavily. 1200 snow has been falling heavily with high winds and the visibility is very low. 1220 the course has large drifts. At 1300 there is 12" of snow on the sections. Plow and end test.

02-24-92. Start test at 1030. 1050 apply chemicals on sections with thin layer of snow on them. Light snow falling throughout test.

02-25-92. After cleaning sections, chemicals were applied at 1045. Light snow falling until 1200.

02-27-92. Applied chemicals to clear pavement at 1000. Snow applied with blower and rolled.

03-09-92. Chemicals applied at 0815 on thin layer of snow from overnight snowfall. Snow and blowing snow. 0900 snowing heavily and blowing. Running traffic simulation on the outer edge of the sections. 1130 reapplied chemicals. Blizzard setting in.

04-01-92. Started testing at 0745. Snowing lightly, has snowed during the night. 0820 snowing harder, running suburban for traffic. Suburban seems to be tending to pack snow onto the pavement. 1015 reapplied chemicals, sun came out and most of the sections are wet pavement.

APPENDIX B

Meteorological Data - Individual Tests

DATE 911212 S-time 1745	Wind Max 24 hrs m/s	Wind Max 12 hrs m/s	Wind m/s	Wind Dir	Temp Max 24 hrs 2m	Temp Max 12 hrs 2m	Temp 2m	Temp Road	Precip Rate water mm/15	RH	Incomin Short Wave	Long Wave W/m2
0	3.11	3.11	2.82	287.30	2.70	2.70	0.56	-1.00	0.00	97.4	0.3	339.0
33	3.11	3.11	1.88	263.30	2.70	2.70	0.56	-1.00	0.00	97.0	0.3	338.8
45	3.11	3.11	2.28	251.60	2.70	2.70	0.56	-1.00	0.00	97.8	0.3	338.8
60	3.11	3.11	3.44	265.30	2.70	2.70	0.56	-1.00	0.00	97.0	0.3	341.1
75	3.11	3.11	3.89	264.30	2.70	2.70	0.70	-1.00	0.00	96.3	0.3	341.8
90	3.11	3.11	3.71	262.40	2.70	2.70	0.83	-1.00	0.00	96.1	0.3	341.2
105	3.11	3.11	3.71	266.70	2.70	2.70	0.97	-1.00	0.00	96.1	0.3	343.2
120	3.11	3.11	3.53	266.50	2.70	2.70	1.10	-1.00	0.00	96.1	0.3	342.6
135	3.11	3.11	3.80	269.00	2.70	2.70	0.97	-1.00	0.01	97.2	0.3	343.1
150	3.11	3.11	5.27	262.50	2.70	2.70	0.83	-1.00	0.00	96.9	0.3	342.0

Meteorological Data --- 12-12-91.

DATE 911213 S-time 0724	Wind Max 24 hrs m/s	Wind Max 12 hrs m/s	Wind m/s	Wind Dir	Temp Max 24 hrs 2m	Temp Max 12 hrs 2m	Temp 2m	Temp Road	Precip Rate water mm/15	RH	Incomin Short Wave	Long Wave W/m2
0	6.28	6.28	2.05	281.60	2.70	2.04	-4.65	-2.00	0.00	76.2	0.2	213.1
55	6.28	6.28	2.77	304.40	2.70	2.04	-5.00	-2.00	0.00	74.9	0.2	213.3
600	6.28	6.28	4.96	106.40	2.70	2.04	-1.70	-2.00	0.00	66.2	0.6	289.7
709	6.28	6.28	5.86	97.30	2.70	2.04	-0.83	-2.00	0.00	84.2	0.6	308.7
727	6.28	6.28	4.11	114.20	2.70	2.04	-0.70	-2.00	0.00	84.1	0.6	309.7
740	6.28	6.28	4.16	125.90	2.70	2.04	-0.56	-2.00	0.00	81.6	0.6	310.6
755	6.28	6.28	4.43	121.00	2.70	2.04	-0.56	-2.00	0.00	80.4	0.6	312.0
850	6.28	6.28	2.55	128.50	2.70	2.04	-0.97	-2.00	0.00	82.6	0.6	315.0
865	6.28	6.28	3.08	133.50	2.70	2.04	-1.10	-2.00	0.04	67.7	0.6	311.8
887	6.28	6.28	0.00	0.00	2.70	2.04	-1.25	-2.00	0.01	89.6	0.6	313.5
891	6.28	6.28	0.00	0.00	2.70	2.04	-1.40	-2.00	0.05	95.0	0.0	313.5
906	6.28	6.28	0.00	0.00	2.70	2.04	-1.55	-2.00	0.03	95.9	0.0	313.3
921	6.28	6.28	0.00	0.00	2.70	2.04	-1.70	-2.00	0.04	95.9	0.0	313.7
936	6.28	6.28	0.00	0.00	2.70	2.04	-1.70	-2.00	0.04	95.9	0.6	312.6
951	6.28	6.28	0.00	0.00	2.70	2.04	-1.70	-2.00	0.03	95.9	0.6	313.0
966	6.28	6.28	0.00	0.00	2.70	2.04	-1.70	-2.00	0.02	95.9	0.6	312.7
982	6.28	6.28	0.00	0.00	2.70	2.04	-1.70	-2.00	0.02	95.9	0.5	313.6
996	6.28	6.28	0.00	0.00	2.70	2.04	-1.70	-2.00	0.00	95.9	0.6	311.7

Meteorological Data --- 12-13-91.

DATE 911219 S-time 1100	Wind Max 24 hrs m/s	Wind Max 12 hrs m/s	Wind m/s	Wind Dir	Temp Max 24 hrs 2m	Temp Max 12 hrs 2m	Temp 2m	Temp Road	Precip Rate water mm/15	RH	Incomin Short Wave	Long Wave W/m2
0	1.98	0.49	0.98	156.20	-5.18	-17.18	-4.20	0.00	0.00	73.1	255.7	197.9
100												
173	1.98	0.49	2.19	137.20	-5.18	-17.18	-10.40	0.00	0.00	57.4	286.6	203.0

Meteorological Data --- 12-19-91.

DATE 911220 S-time 0741	Wind Max 24 hrs m/s	Wind Max 12 hrs m/s	Wind m/s	Wind Dir	Temp Max 24 hrs 2m	Temp Max 12 hrs 2m	Temp 2m	Temp Road	Precip Rate water mm/15	RH	Incomin Short Wave	Long Wave W/m2
0								-6.00	0.00			
34	4.50	4.50	2.20	178.00	-3.70	-3.70	-2.25	-7.00	0.00	96.90	0.00	311.00
49	4.50	4.50	2.50	185.00	-3.70	-3.70	-1.98	-7.00	0.00	95.70	0.00	312.00
66	4.50	4.50	3.00	184.00	-3.70	-3.70	-1.70	-7.00	0.00	92.40	0.00	311.00
83	4.50	4.50	2.90	189.00	-3.70	-3.70	-1.70	-7.00	0.00	92.10	4.00	313.00
94	4.50	4.50	2.50	187.00	-3.70	-3.70	-1.70	-7.00	0.00	92.00	8.00	313.00
109	4.50	4.50	3.00	189.00	-3.70	-3.70	-1.70	-7.00	0.00	92.00	9.00	313.00
124	4.50	4.50	3.10	182.00	-3.70	-3.70	-1.70	-7.00	0.00	92.00	13.00	313.00
139	4.50	4.50	3.00	190.00	-3.70	-3.70	-1.55	-7.00	0.00	92.00	21.00	314.00
154	4.50	4.50	2.70	185.00	-3.70	-3.70	-1.40	-7.00	0.00	92.00	22.00	314.00
169	4.50	4.50	3.30	191.00	-3.70	-3.70	-1.25	-6.00	0.00	92.00	30.00	314.00
183	4.50	4.50	3.00	192.00	-3.70	-3.70	-1.10	-6.00	0.00	90.90	31.00	316.00
246	4.50	4.50	3.00	193.00	-3.70	-3.70	-0.97	-6.00	0.00	88.60	33.00	315.00
274	4.50	4.50	4.50	221.00	-3.70	-3.70	-0.42	-5.00	0.00	88.10	52.00	315.00
289	4.50	4.50	4.00	227.00	-3.70	-3.70	-0.14	-5.00	0.00	88.10	53.00	316.00
304	4.50	4.50	4.20	226.00	-3.70	-3.70	0.00	-5.00	0.00	88.1	63.0	317.0
319	4.50	4.50	5.20	234.00	-3.70	-3.70	0.14	-4.00	0.00	88.1	73.0	316.0
334	4.50	4.50	4.50	228.00	-3.70	-3.70	0.28	-4.00	0.00	88.1	71.0	317.0
349	4.50	4.50	4.40	239.00	-3.70	-3.70	0.42	-4.00	0.00	88.1	83.0	317.0
356	4.50	4.50	5.30	242.00	-3.70	-3.70	0.56	-3.00	0.00	88.1	92.0	318.0
370	4.50	4.50	5.30	242.00	-3.70	-3.70	0.42	-3.00	0.00	88.1	51.0	317.0

Meteorological Data --- 12-20-91.

DATE 920102 S-time 1037	Wind Max 24 hrs m/s	Wind Max 12 hrs m/s	Wind m/s	Wind Dir	Temp Max 24 hrs 2m	Temp Max 12 hrs 2m	TEMP 2m	Temp Road	Precip Rate water mm/15	RH	Incomin Short Wave W/	Long Wave W/m2
26	1.99	1.99	1.88	23.00	1.72	-1.07	-0.97	-3.00	0.00	98.3	71.7	318.7
39	1.99	1.99	2.15	21.40	1.72	-1.07	-0.84	-3.00	0.00	96.4	60.3	320.0
53	1.99	1.99	2.28	21.50	1.72	-1.07	-0.71	-3.00	0.10	96.2	96.3	319.4
68	1.99	1.99	1.88	21.60	1.72	-1.07	-0.56	-3.00	0.00	96.0	115.0	319.3
83	1.99	1.99	2.55	21.20	1.72	-1.07	-0.42	-3.00	0.00	95.9	143.4	320.2
98	1.99	1.99	2.32	22.30	1.72	-1.07	-0.28	-3.00	0.00	95.9	151.7	319.2
112	1.99	1.99	2.32	23.10	1.72	-1.07	-0.14	-3.00	0.00	95.9	132.0	316.0
128	1.99	1.99	1.92	23.40	1.72	-1.07	0.00	-3.00	0.00	92.8	161.7	319.2
143	1.99	1.99	2.28	22.80	1.72	-1.07	-0.14	-3.00	0.00	92.0	159.1	318.2
153	1.99	1.99	2.55	23.10	1.72	-1.07	-0.28	-3.00	0.00	92.0	212.0	315.2

Meteorological Data --- 01-02-92.

DATE 920103 S-time 0816	Wind Max 24 hrs m/s	Wind Max 12 hrs m/s	Wind m/s	Wind Dir	Temp Max 24 hrs 2m	Temp Max 12 hrs 2m	Temp 2m	Temp Road	Precip Rate water mm/15	RH	Incomin Short Wave W/	Long Wave W/m2
0	2.24	1.48	0.18	6.20	2.68	-1.08	0.00	0.00	0.00	99.8	0.0	323.6
194	2.24	1.48	0.98	11.20	2.68	-1.08	0.97	0.00	0.02	99.8	53.5	330.5

Meteorological Data --- 01-03-92.

DATE 910106 S-time 0855	Wind Max 24 hrs m/s	Wind Max 12 hrs m/s	Wind m/s	Wind Dir	Temp Max 24 hrs 2m	Temp Max 12 hrs 2m	Temp 2m	Temp Road	Precip Rate water mm/15	RH	Incomin Short Wave W/	Long Wave W/m2
0	3.48	3.48	2.86	40.10	0.72	-0.43	0.00	-4.00	0.00	99.5	5.9	334.7
62	3.48	3.48	3.44	40.20	0.72	-0.43	0.00	-4.00	0.00	96.4	14.2	333.4
79	3.48	3.48	3.26	39.10	0.72	-0.43	0.00	-3.00	0.00	96.0	24.8	335.0
95	3.48	3.48	3.22	41.00	0.72	-0.43	0.00	-3.00	0.00	96.0	30.5	333.1
110	3.48	3.48	3.67	38.80	0.72	-0.43	0.00	-3.00	0.00	95.9	31.3	332.3
125	3.48	3.48	3.31	42.80	0.72	-0.43	0.14	-3.00	0.00	95.9	31.7	332.6
140	3.48	3.48	3.40	43.30	0.72	-0.43	0.28	-3.00	0.00	95.9	32.0	333.9
155	3.48	3.48	3.93	38.90	0.72	-0.43	0.42	-3.00	0.00	95.9	33.0	334.2
170	3.48	3.48	3.58	41.20	0.72	-0.43	0.56	-3.00	0.00	95.9	37.7	332.9
185	3.48	3.48	3.04	40.30	0.72	-0.43	0.56	-3.00	0.00	95.9	40.5	332.7

Meteorological Data --- 01-06-92.

DATE 920107 S-time 0824	Wind Max 24 hrs m/s	Wind Max 12 hrs m/s	Wind m/s	Wind Dir	Temp Max 24 hrs 2m	Temp Max 12 hrs 2m	Temp 2m	Temp Road	Precip Rate water mm/15	RH	Incomin Short Wave W/	Long Wave W/m2
0	4.46	4.46	2.99	5.80	0.84	0.84	-4.27	0.00	0.00	95.5	6.3	300.6
118	4.46	4.46	3.67	9.40	0.84	0.84	-4.85	0.00	0.00	95.9	80.8	298.2
300	4.46	4.46	4.60	11.90	0.84	0.84	-4.40	0.00	0.00	90.8	248.3	295.4
309	4.46	4.46	4.47	11.90	0.84	0.84	-4.40	0.00	0.00	89.5	225.1	286.4
317	4.46	4.46	4.43	13.80	0.84	0.84	-4.40	0.00	0.00	87.7	311.3	272.5
325	4.46	4.46	4.25	14.10	0.84	0.84	-4.40	0.00	0.00	86.2	248.1	244.9
341	4.46	4.46	3.98	11.10	0.84	0.84	-4.40	0.00	0.00	84.8	166.9	244.2

Meteorological Data --- 01-07-92.

DATE 920108 S-time 0858	Wind Max 24 hrs m/s	Wind Max 12 hrs m/s	Wind m/s	Wind Dir	Temp Max 24 hrs 2m	Temp Max 12 hrs 2m	Temp 2m	Temp Road	Precip Rate water mm/15	RH	Incomin Short Wave W/	Long Wave W/m2
0	7.01	6.59	5.27	10.40	-1.74	-2.52	-0.80	-8.00	0.00	98.9	8.4	315.8
15	7.01	6.59	5.14	11.00	-1.74	-2.25	-1.30	-6.00	0.00	99.5	8.6	312.8
30	7.01	6.59	4.92	11.40	-1.74	-1.98	-2.80	-6.00	0.00	99.7	8.5	307.5
45	7.01	6.59	4.96	12.60	-1.74	-1.70	-3.80	-5.00	0.01	99.8	9.3	310.3
60	7.01	6.59	5.01	12.20	-1.74	-1.70	0.20	-5.00	0.01	99.8	20.5	321.7
75	7.01	6.59	4.96	12.60	-1.74	-1.70	-0.50	-5.00	0.01	99.8	31.2	322.9
90	7.01	6.59	4.92	17.00	-1.74	-1.70	-0.60	-6.00	0.00	99.8	55.6	323.5
105	7.01	6.59	4.92	15.50	-1.74	-1.70	-0.50	-6.00	0.00	99.8	32.2	325.2
120	7.01	6.59	5.01	14.80	-1.74	-1.55	0.90	-6.00	0.00	99.9	41.8	331.1
135	7.01	6.59	5.27	13.10	-1.74	-1.40	0.90	-6.00	0.00	99.8	63.5	332.1
150	7.01	6.59	5.41	14.40	-1.74	-1.25	0.20	-6.00	0.00	99.9	82.9	332.3
165	7.01	6.59	4.92	13.40	-1.74	-1.10	-0.20	-6.00	0.00	99.9	63.3	331.8
180	7.01	6.59	5.10	12.90	-1.74	-1.10	-0.10	-6.00	0.00	99.9	80.2	332.3
195	7.01	6.59	4.87	13.40	-1.74	-1.10	0.90	-6.00	0.00	99.9	77.0	334.8
210	7.01	6.59	4.87	13.80	-1.74	-1.10	1.20	-3.00	0.00	99.9	45.7	336.0
225	7.01	6.59	5.45	13.10	-1.74	-1.10	2.10	-3.00	0.00	99.9	47.0	336.6
240	7.01	6.59	5.59	14.30	-1.74	-0.97	2.50	-3.00	0.00	99.9	55.2	337.1
255	7.01	6.59	4.56	14.40	-1.74	-0.83	2.70	-3.00	0.00	99.9	53.6	333.6
270	7.01	6.59	4.56	67.10	-1.74	-0.70	3.40	-3.00	0.00	99.9	67.4	337.2
285	7.01	6.59	4.51	96.90	-1.74	-0.56	3.50	-2.00	0.00	99.9	75.7	337.7
300	7.01	6.59	4.20	100.10	-1.74	-0.56	3.90	-3.00	0.00	99.9	59.9	336.1
315	7.01	6.59	3.26	89.70	-1.74	-0.56	3.60	-3.00	0.00	99.9	56.3	338.0
330	7.01	6.59	3.26	84.20	-1.74	-0.56	2.90	-3.00	0.00	99.9	63.2	338.0

Meteorological Data --- 01-08-92.

DATE 920109 S-time 0845	Wind Max 24 hrs m/s	Wind Max 12 hrs m/s	Wind m/s	Wind Dir	Temp Max 24 hrs 2m	Temp Min 12 hrs 2m	Temp 2m	Temp Road	Precip Rate water mm/15	RH	Incomin Short Wave W/	Long Wave W/m2
0	5.24	5.24	5.54	44.20	2.31	-0.37	-2.20	-3.00	0.00	99.8	0.1	301.8
95	5.24	5.24	4.92	54.70	2.31	-0.37	-3.05	-3.00	0.00	96.0	45.6	302.5
121	5.24	5.24	4.92	67.30	2.31	-0.37	-3.18	-3.00	0.00	96.0	58.0	302.5
136	5.24	5.24	4.25	58.60	2.31	-0.37	-3.30	-3.00	0.00	95.9	79.9	302.4
151	5.24	5.24	5.19	46.40	2.31	-0.37	-3.30	-4.00	0.00	95.9	93.2	302.2
166	5.24	5.24	5.27	61.50	2.31	-0.37	-3.30	-4.00	0.00	95.9	119.7	300.5
181	5.24	5.24	5.54	54.00	2.31	-0.37	-3.30	-4.00	0.00	95.9	130.2	301.1
196	5.24	5.24	4.96	46.90	2.31	-0.37	-3.30	-4.00	0.00	95.9	126.8	299.5
211	5.24	5.24	5.41	45.80	2.31	-0.37	-3.30	-4.00	0.00	95.9	116.2	296.0
226	5.24	5.24	4.34	47.50	2.31	-0.37	-3.30	-4.00	0.00	95.9	102.5	299.9
241	5.24	5.24	3.71	55.20	2.31	-0.37	-3.30	-4.00	0.00	95.9	94.0	299.1
266	5.24	5.24	3.75	38.10	2.31	-0.37	-3.45	-4.00	0.00	95.9	110.9	297.8
287	5.24	5.24	3.53	51.50	2.31	-0.37	-3.60	-4.00	0.00	95.9	92.5	300.2
302	5.24	5.24	3.89	58.10	2.31	-0.37	-3.75	-4.00	0.00	95.9	76.6	299.4
317	5.24	5.24	3.67	54.50	2.31	-0.37	-3.90	-4.00	0.00	95.9	75.7	299.8
332	5.24	5.24	3.67	54.00	2.31	-0.37	-3.90	-4.00	0.00	95.9	73.1	299.8

Meteorological Data --- 01-09-92.

DATE 920110 S-time 1332	Wind Max 24 hrs m/s	Wind Max 12 hrs m/s	Wind m/s	Wind Dir	Temp Max 24 hrs 2m	Temp Min 12 hrs 2m	Temp 2m	Temp Road	Precip Rate water mm/15	RH	Incomin Short Wave W/	Long Wave W/m2
0	4.44	4.44	2.64	32.20	-3.56	-3.56	-4.00	-3.00	0.00	99.8	59.3	301.5
30	4.44	4.44	2.64	32.80	-3.56	-3.56	-3.90	-3.00	0.00	99.8	63.4	304.9
45	4.44	4.44	2.95	33.30	-3.56	-3.56	-3.90	-3.00	0.00	99.8	97.1	302.2
60	4.44	4.44	2.95	31.10	-3.56	-3.56	-3.90	-4.00	0.00	99.8	61.3	303.0
75	4.44	4.44	3.13	31.30	-3.56	-3.56	-3.90	-4.00	0.00	98.7	69.7	302.9
90	4.44	4.44	2.68	31.90	-3.56	-3.56	-3.90	-4.00	0.04	98.1	49.0	302.6
105	4.44	4.44	2.73	28.80	-3.56	-3.56	-3.90	-4.00	0.00	97.4	47.6	301.9
120	4.44	4.44	2.10	27.50	-3.56	-3.56	-3.90	-4.00	0.01	96.2	31.8	301.5
135	4.44	4.44	2.32	28.70	-3.56	-3.56	-3.90	-4.00	0.01	95.9	32.2	301.0
150	4.44	4.44	1.83	25.20	-3.56	-3.56	-3.90	-6.00	0.01	96.0	9.7	303.5
176	4.44	4.44	1.48	26.30	-3.56	-3.56	-3.90	-6.00	0.01	96.0	9.1	301.8

Meteorological Data --- 01-10-92.

DATE 920111 S-time 0914	Wind Max 24 hrs m/s	Wind Max 12 hrs m/s	Wind m/s	Wind Dir	Temp Max 24 hrs 2m	Temp Min 12 hrs 2m	Temp 2m	Temp Road	Precip Rate water mm/15	RH	Incomin Short Wave W/	Long Wave W/m2
0	3.43	1.07	0.00	21.20	-2.51	-3.35	-3.05	-5.00	0.00	99.8	9.0	309.8
30	3.43	1.07	1.03	20.40	-2.51	-3.35	-2.80	-5.00	0.00	99.8	10.0	307.7
75	3.43	1.07	1.34	16.00	-2.51	-3.35	-2.80	-5.00	0.00	99.8	38.2	304.5
90	3.43	1.07	2.01	14.70	-2.51	-3.35	-2.80	-5.00	0.00	99.8	53.0	307.3
105	3.43	1.07	2.77	14.10	-2.51	-3.35	-2.53	-5.00	0.00	99.8	66.0	305.8
120	3.43	1.07	2.95	16.00	-2.51	-3.35	-2.25	-3.00	0.00	99.8	102.3	307.8
135	3.43	1.07	3.22	18.20	-2.51	-3.35	-1.98	-3.00	0.00	97.7	152.7	301.5
150	3.43	1.07	3.67	16.00	-2.51	-3.35	-1.70	-3.00	0.00	96.0	211.3	281.5
165	3.43	1.07	3.71	15.50	-2.51	-3.35	-1.28	-3.00	0.00	95.0	234.5	285.2
180	3.43	1.07	3.08	17.70	-2.51	-3.35	-0.85	-3.00	0.00	92.0	227.1	276.6
195	3.43	1.07	3.49	16.20	-2.51	-3.35	-0.43	-2.50	0.00	92.1	219.4	288.1

Meteorological Data --- 01-11-92.

DATE 920122 S-time 1009	Wind Max 24 hrs m/s	Wind Max 12 hrs m/s	Wind m/s	Wind Dir	Temp Max 24 hrs 2m	Temp Max 12 hrs 2m	Temp 2m	Temp Road	Precip Rate water mm/15	RH	Incomin Short Wave W/	Long Wave W/m2
0	4.95	4.95	3.98	23.90	-3.58	-6.27	-4.13	-3.00	0.00	96.0	53.3	304.4
30	4.95	4.95	3.80	23.50	-3.58	-6.27	-3.58	-3.00	0.00	96.0	75.1	306.3
155	4.95	4.95	4.20	21.30	-3.58	-6.27	-1.98	-3.00	0.00	96.3	144.0	311.2
245	4.95	4.95	4.11	26.00	-3.58	-6.27	-0.56	-3.00	0.00	95.9	114.9	313.3
280	4.95	4.95	3.58	23.10	-3.58	-6.27	-0.56	-3.00	0.00	95.9	111.0	316.6
295	4.95	4.95	3.40	24.40	-3.58	-6.27	-0.56	-2.00	0.00	95.9	110.4	313.1
310	4.95	4.95	3.84	24.00	-3.58	-6.27	-0.56	-2.00	0.00	95.9	99.5	321.2
325	4.95	4.95	3.71	83.20	-3.58	-6.27	-0.56	-5.00	0.00	95.9	95.0	314.5
340	4.95	4.95	3.80	121.20	-3.58	-6.27	-0.56	-5.00	0.00	95.9	91.8	315.1
355	4.95	4.95	3.93	117.70	-3.58	-6.27	-0.56	-5.00	0.00	95.9	82.0	317.8
370	4.95	4.95	4.07	118.00	-3.58	-6.27	-0.56	-5.00	0.00	95.9	75.4	319.2
385	4.95	4.95	4.25	120.10	-3.58	-6.27	-0.56	-5.00	0.00	95.9	74.1	313.9
400	4.95	4.95	4.29	122.70	-3.58	-6.27	-0.56	-8.00	0.00	95.9	53.9	314.7
415	4.95	4.95	3.44	125.40	-3.58	-6.27	-0.56	-8.00	0.00	95.9	35.9	320.5
450	4.95	4.95	3.04	98.50	-3.58	-6.27	-0.56	-8.00	0.04	96.6	10.6	317.1
630	4.95	4.95	1.03	123.10	-3.58	-6.27	0.00	-1.00	0.00	99.8	2.2	327.6
650	4.95	4.95	1.79	113.60	-3.58	-6.27	0.00	-1.00	0.11	99.8	1.9	329.1
660	4.95	4.95	2.10	131.20	-3.58	-6.27	0.00	-1.00	0.01	99.8	2.0	330.8

Meteorological Data --- 01-22-92.

DATE 920123 S-time 0856	Wind Max 24 hrs m/s	Wind Max 12 hrs m/s	Wind m/s	Wind Dir	Temp Max 24 hrs 2m	Temp Max 12 hrs 2m	Temp 2m	Temp Road	Precip Rate water mm/15	RH	Incomin Short Wave W/	Long Wave W/m2
0	4.47	3.11	2.32	52.10	0.80	0.80	-1.70	-4.00	0.00	99.8	5.2	322.1
15	4.47	3.11	2.55	55.50	0.80	0.80	-1.70	-4.00	0.00	99.8	7.6	317.8
30	4.47	3.11	3.08	53.80	0.80	0.80	-1.70	-4.00	0.00	99.8	9.5	319.0
45	4.47	3.11	3.22	55.70	0.80	0.80	-1.70	-4.00	0.00	99.8	20.4	319.7
60	4.47	3.11	3.08	55.60	0.80	0.80	-1.70	-4.00	0.00	99.8	26.9	319.1
105	4.47	3.11	3.40	57.20	0.80	0.80	-1.70	-4.00	0.00	99.8	28.7	316.0
120	4.47	3.11	4.07	60.90	0.80	0.80	-1.83	-4.00	0.00	99.8	39.7	318.1
135	4.47	3.11	4.16	58.80	0.80	0.80	-1.95	-4.00	0.01	99.9	57.1	318.3
150	4.47	3.11	4.51	56.60	0.80	0.80	-2.08	-4.00	0.00	99.8	79.8	317.1
165	4.47	3.11	5.45	57.70	0.80	0.80	-2.20	-4.00	0.00	99.8	101.1	313.8
180	4.47	3.11	5.50	60.20	0.80	0.80	-2.90	-4.00	0.00	99.8	93.6	314.5
195	4.47	3.11	5.19	60.60	0.80	0.80	-3.60	-4.00	0.00	99.8	105.3	318.4

Meteorological Data --- 01-23-92.

DATE 920127 S-time 1245	Wind Max 24 hrs m/s	Wind Max 12 hrs m/s	Wind m/s	Wind Dir	Temp Max 24 hrs 2m	Temp Max 12 hrs 2m	Temp 2m	Temp Road	Precip Rate water mm/15	RH	Incomin Short Wave W/	Long Wave W/m2
0	5.10	5.10	3.71	6.70	-5.28	-5.28	-5.60	-4.50	0.00	88.6	202.1	292.3
30	5.10	5.10	3.98	4.40	-5.28	-5.28	-5.90	-4.40	0.00	88.6	203.2	287.9
50	5.10	5.10	3.31	4.80	-5.28	-5.28	-5.97	-4.40	0.00	88.2	196.6	294.5
60	5.10	5.10	2.68	5.90	-5.28	-5.28	-6.10	-4.40	0.00	87.8	197.3	293.5
75	5.10	5.10	3.13	7.10	-5.28	-5.28	-5.97	-4.40	0.00	88.3	163.9	291.0
90	5.10	5.10	2.73	6.50	-5.28	-5.28	-5.85	-3.60	0.00	88.2	159.4	295.4
115	5.10	5.10	2.73	16.10	-5.28	-5.28	-5.73	-3.60	0.00	88.4	178.6	291.3
125	5.10	5.10	2.50	5.00	-5.28	-5.28	-5.60	-3.60	0.00	88.1	202.5	287.4
140	5.10	5.10	1.65	11.70	-5.28	-5.28	-5.73	-3.60	0.00	88.0	174.2	280.3
145	5.10	5.10	1.79	5.10	-5.28	-5.28	-5.85	-3.60	0.00	88.0	171.4	268.4
160	5.10	5.10	1.97	7.40	-5.28	-5.28	-5.98	-3.60	0.00	86.8	206.2	248.2

Meteorological Data --- 01-27-92.

DATE 920128 S-time 1033	Wind Max 24 hrs m/s	Wind Max 12 hrs m/s	Wind m/s	Wind Dir	Temp Max 24 hrs 2m	Temp Min 12 hrs 2m	Temp 2m	Temp Road	Precip Rate water mm/15	RH	Incomin Short Wave W/	Long Wave W/m2
0	4.61	2.42	1.48	27.90	-4.69	-9.28	-6.25	-3.00	0.00	86.1	242.5	247.7
270	4.61	2.42	1.16	28.10	-4.69	-9.28	-0.56	-3.20	0.00	72.7	184.3	294.3
285	4.61	2.42	2.10	29.30	-4.69	-9.28	-0.56	-3.00	0.00	72.7	127.9	284.0
300	4.61	2.42	1.83	29.50	-4.69	-9.28	-0.56	-3.00	0.00	73.3	98.9	292.9
315	4.61	2.42	2.59	30.60	-4.69	-9.28	-0.56	-3.00	0.00	72.1	111.7	288.5
330	4.61	2.42	2.10	29.50	-4.69	-9.28	-0.56	-3.00	0.00	69.4	113.4	284.3
345	4.61	2.42	1.52	30.30	-4.69	-9.28	-0.56	-3.00	0.00	71.4	90.0	275.5
360	4.61	2.42	2.01	32.70	-4.69	-9.28	-0.56	-3.00	0.00	68.7	54.5	282.2
375	4.61	2.42	1.92	28.70	-4.69	-9.28	-0.56	-3.00	0.00	72.2	33.2	299.8
390	4.61	2.42	0.72	28.40	-4.69	-9.28	-0.56	-3.00	0.00	72.5	31.4	284.6
405	4.61	2.42	1.25	27.40	-4.69	-9.28	-0.56	-3.80	0.00	72.4	19.1	288.0
420	4.61	2.42	2.95	32.80	-4.69	-9.28	-0.56	-3.80	0.00	68.6	9.5	273.4

Meteorological Data --- 01-28-92.

DATE 920130 S-time 0810	Wind Max 24 hrs m/s	Wind Max 12 hrs m/s	Wind m/s	Wind Dir	Temp Max 24 hrs 2m	Temp Min 12 hrs 2m	Temp 2m	Temp Road	Precip Rate water mm/15	RH	Incomin Short Wave W/	Long Wave W/m2
0	5.42	5.42	6.66	52.70	2.19	2.19	-0.83	-2.00	0.00	99.8	0.2	311.9
30	5.42	5.42	5.99	53.70	2.19	2.19	-1.10	-2.00	0.00	99.8	5.8	306.5
50	5.42	5.42	5.05	47.10	2.19	2.19	-1.10	-2.00	0.00	99.8	9.3	307.3
65	5.42	5.42	5.77	52.30	2.19	2.19	-1.10	-2.00	0.00	99.1	11.9	305.5
80	5.42	5.42	6.66	58.40	2.19	2.19	-1.10	-2.00	0.00	95.9	28.8	305.7
95	5.42	5.42	6.62	48.60	2.19	2.19	-1.10	-2.00	0.00	94.6	60.4	308.7
110	5.42	5.42	6.48	57.60	2.19	2.19	-1.25	-2.00	0.00	93.1	84.0	302.8
125	5.42	5.42	6.26	52.00	2.19	2.19	-1.40	-2.00	0.00	94.5	152.5	295.2
140	5.42	5.42	5.95	49.80	2.19	2.19	-1.55	-2.00	0.00	95.8	115.8	302.5
155	5.42	5.42	5.54	53.90	2.19	2.19	-1.70	-2.00	0.00	95.8	121.6	301.8

Meteorological Data --- 01-30-92.

DATE 920131 S-time 1210	Wind Max 24 hrs m/s	Wind Max 12 hrs m/s	Wind m/s	Wind Dir	Temp Max 24 hrs 2m	Temp Min 12 hrs 2m	Temp 2m	Temp Road	Precip Rate water mm/15	RH	Incomin Short Wave W/	Long Wave W/m2
0	6.82	6.82	3.84	4.30	-0.49	-3.38	-7.80	-8.00	0.00	86.4	211.1	281.0
15	6.82	6.82	3.71	6.60	-0.49	-3.38	-7.80	-8.00	0.00	89.10	208.30	286.40
30	6.82	6.82	4.29	3.70	-0.49	-3.38	-7.80	-8.00	0.00	86.80	199.60	284.00
50	6.82	6.82	3.71	5.40	-0.49	-3.38	-7.80	-8.00	0.00	84.3	205.2	284.0
65	6.82	6.82	4.07	5.80	-0.49	-3.38	-7.80	-8.00	0.00	85.7	238.0	276.7
80	6.82	6.82	4.07	6.30	-0.49	-3.38	-7.80	-8.00	0.00	86.1	221.0	283.2
95	6.82	6.82	4.02	3.50	-0.49	-3.38	-7.80	-8.00	0.00	84.5	222.9	280.2
110	6.82	6.82	4.25	6.00	-0.49	-3.38	-8.08	-8.00	0.00	82.5	244.4	279.4
125	6.82	6.82	3.62	7.50	-0.49	-3.38	-8.35	-8.00	0.00	86.4	247.7	280.8
140	6.82	6.82	4.20	5.70	-0.49	-3.38	-8.63	-8.00	0.00	87.8	224.1	278.7
155	6.82	6.82	3.89	5.10	-0.49	-3.38	-8.90	-8.00	0.00	82.1	319.5	254.8
170	6.82	6.82	4.11	5.30	-0.49	-3.38	-8.75	-8.00	0.00	78.9	277.5	248.1
185	6.82	6.82	4.20	6.00	-0.49	-3.38	-8.60	-8.00	0.00	76.9	310.0	237.4
205	6.82	6.82	3.58	5.90	-0.49	-3.38	-8.45	-8.00	0.00	79.3	292.5	239.9

Meteorological Data --- 01-31-92.

DATE 920206 S-time 0830	Wind Max 24 hrs m/s	Wind Max 12 hrs m/s	Wind m/s	Wind Dir	Temp Max 24 hrs 2m	Temp Max 12 hrs 2m	Temp 2m	Temp Road	Precip Rate water mm/15	RH	Incomin Short Wave W/	Long Wave W/m2
0	4.08	4.08	4.43	48.40	2.06	-1.26	-2.48	-3.00	0.00	99.9	10.1	348.4
300	4.08	4.08	8.36	57.30	2.06	-1.26	-2.80	-3.00	0.00	96.9	114.6	341.5
315	4.08	4.08	7.73	56.20	2.06	-1.26	-2.80	-3.00	0.00	99.8	107.0	341.7
330	4.08	4.08	7.64	58.30	2.06	-1.26	-2.80	-3.00	0.00	99.8	125.0	344.2
345	4.08	4.08	7.51	56.80	2.06	-1.26	-2.80	-3.00	0.00	99.8	127.9	341.5
360	4.08	4.08	6.97	57.30	2.06	-1.26	-2.80	-3.00	0.00	99.8	118.1	343.7
375	4.08	4.08	6.66	56.00	2.06	-1.26	-2.80	-4.00	0.01	99.8	107.7	343.5
390	4.08	4.08	6.97	57.20	2.06	-1.26	-2.93	-4.00	0.00	99.8	100.1	342.5
405	4.08	4.08	6.93	57.80	2.06	-1.26	-3.05	-4.00	0.01	99.8	93.8	343.3
420	4.08	4.08	7.11	56.60	2.06	-1.26	-3.18	-3.00	0.00	99.8	83.3	340.7
435	4.08	4.08	6.53	55.40	2.06	-1.26	-3.30	-3.00	0.01	99.8	75.5	339.1

Meteorological Data --- 02-06-92.

DATE 920210 S-time 1015	Wind Max 24 hrs m/s	Wind Max 12 hrs m/s	Wind m/s	Wind Dir	Temp Max 24 hrs 2m	Temp Max 12 hrs 2m	Temp 2m	Temp Road	Precip Rate water mm/15	RH	Incomin Short Wave W/	Long Wave W/m2
0	4.29	3.95	3.22	38.50	-2.62	-2.62	-5.00	-6.00	0.00	95.5	119.3	326.0
15	4.29	3.95	3.44	38.30	-2.62	-2.62	-4.70	-6.00	0.00	95.9	123.6	323.5
30	4.29	3.95	3.13	37.80	-2.62	-2.62	-4.40	-5.00	0.00	95.9	157.8	328.7
45	4.29	3.95	3.35	40.40	-2.62	-2.62	-4.00	-5.00	0.01	95.9	125.5	328.5
60	4.29	3.95	3.49	38.00	-2.62	-2.62	-3.60	-5.00	0.00	95.9	135.8	330.0
75	4.29	3.95	3.13	39.50	-2.62	-2.62	-3.20	-5.00	0.00	95.9	228.8	331.2
90	4.29	3.95	3.71	38.90	-2.62	-2.62	-2.80	-5.00	0.00	95.7	270.4	330.8
105	4.29	3.95	4.02	42.20	-2.62	-2.62	-2.93	-4.00	0.00	94.7	306.1	329.4
120	4.29	3.95	3.93	38.30	-2.62	-2.62	-3.05	-4.00	0.00	94.3	247.7	331.4
135	4.29	3.95	4.07	38.80	-2.62	-2.62	-3.18	-4.00	0.00	95.9	213.0	330.7
150	4.29	3.95	3.84	41.30	-2.62	-2.62	-3.30	-3.00	0.00	95.9	221.7	331.9
165	4.29	3.95	4.25	43.20	-2.62	-2.62	-3.18	-3.00	0.01	95.9	196.2	331.9

Meteorological Data --- 02-10-92.

DATE 920211 S-time 1300	Wind Max 24 hrs m/s	Wind Max 12 hrs m/s	Wind m/s	Wind Dir	Temp Max 24 hrs 2m	Temp Max 12 hrs 2m	Temp 2m	Temp Road	Precip Rate water mm/15	RH	Incomin Short Wave W/	Long Wave W/m2
0	5.49	5.26	3.26	39.30	1.66	-8.16	-16.10	-13.00	0.00	80.9	377.1	265.0
15	5.49	5.26	3.40	45.10	1.66	-8.16	-16.10	-13.00	0.01	80.0	371.9	260.9
30	5.49	5.26	3.22	48.20	1.66	-8.16	-16.10	-13.00	0.00	80.3	388.1	263.9
45	5.49	5.26	3.71	33.30	1.66	-8.16	-16.10	-13.00	0.00	79.3	309.8	255.3
60	5.49	5.26	3.17	50.40	1.66	-8.16	-16.25	-12.00	0.00	79.0	491.1	264.3
75	5.49	5.26	3.53	57.80	1.66	-8.16	-16.40	-12.00	0.00	72.5	515.4	221.2
90	5.49	5.26	3.80	57.10	1.66	-8.16	-16.55	-12.00	0.00	71.8	456.5	210.7
105	5.49	5.26	3.13	56.80	1.66	-8.16	-16.70	-14.00	0.00	70.9	431.4	202.9
120	5.49	5.26	3.84	58.20	1.66	-8.16	-16.70	-14.00	0.00	75.1	297.7	212.2
135	5.49	5.26	3.22	53.80	1.66	-8.16	-16.70	-14.00	0.00	71.9	462.9	214.3

Meteorological Data --- 02-11-92.

DATE 920212 S-time 1330	Wind Max 24 hrs m/s	Wind Max 12 hrs m/s	Wind m/s	Wind Dir	Temp Max 24 hrs 2m	Temp Max 12 hrs 2m	Temp 2m	Temp Road	Precip Rate water mm/15	RH	Incomin Short Wave W/	Long Wave W/m2
0	3.50	1.94	1.30	26.40	-8.36	-8.36	-10.27	-9.00	0.00	48.7	532.2	222.6
60	3.50	1.94	1.25	24.50	-8.36	-8.36	-8.73	-9.00	0.00	50.8	394.9	228.4
75	3.50	1.94	1.25	24.20	-8.36	-8.36	-8.30	-9.00	0.00	48.0	329.5	248.1
90	3.50	1.94	1.39	25.00	-8.36	-8.36	-7.90	-9.00	0.00	47.8	283.0	272.5
105	3.50	1.94	1.92	26.50	-8.36	-8.36	-7.50	-9.00	0.00	46.1	297.4	291.5
120	3.50	1.94	2.10	27.10	-8.36	-8.36	-7.10	-9.00	0.00	44.3	243.5	281.6
135	3.50	1.94	2.10	29.70	-8.36	-8.36	-6.70	-9.00	0.00	41.8	217.9	294.1
150	3.50	1.94	2.15	29.10	-8.36	-8.36	-6.55	-9.00	0.00	40.3	244.8	270.3

Meteorological Data --- 02-12-92.

DATE 920213 S-time 1000	Wind Max 24 hrs m/s	Wind Max 12 hrs m/s	Wind m/s	Wind Dir	Temp Max 24 hrs 2m	Temp Max 12 hrs 2m	Temp 2m	Temp Road	Precip Rate water mm/15	RH	Incomin Short Wave W/	Long Wave W/m2
0	3.21	3.21	2.41	42.20	-2.74	-2.74	-4.73	-8.00	0.00	99.1	78.6	328.9
45	3.21	3.21	2.95	46.20	-2.74	-2.74	-3.90	-8.00	0.02	99.8	104.7	331.2
60	3.21	3.21	2.73	44.60	-2.74	-2.74	-3.90	-7.00	0.01	99.4	145.1	330.8
75	3.21	3.21	2.32	47.80	-2.74	-2.74	-3.90	-7.00	0.01	97.8	161.6	330.8
90	3.21	3.21	2.50	52.10	-2.74	-2.74	-3.90	-7.00	0.04	99.5	99.1	332.2
105	3.21	3.21	3.58	69.00	-2.74	-2.74	-3.90	-7.00	0.01	98.1	140.4	329.7
120	3.21	3.21	3.55	65.10	-2.74	-2.74	-3.90	-7.00	0.01	96.0	194.2	330.0
135	3.21	3.21	3.40	65.00	-2.74	-2.74	-3.90	-7.00	0.00	95.9	215.1	330.5
150	3.21	3.21	3.44	63.80	-2.74	-2.74	-3.90	-7.00	0.01	95.9	140.1	329.8
165	3.21	3.21	3.75	41.70	-2.74	-2.74	-3.90	-7.00	0.00	96.5	129.4	329.8
180	3.21	3.21	3.75	59.80	-2.74	-2.74	-4.03	-6.00	0.00	96.0	218.1	330.4
220	3.21	3.21	3.53	62.80	-2.74	-2.74	-4.15	-6.00	0.00	95.9	171.0	328.4
260	3.21	3.21	3.58	63.60	-2.74	-2.74	-4.40	-6.00	0.01	95.9	194.1	327.6
275	3.21	3.21	3.89	59.00	-2.74	-2.74	-4.70	-6.00	0.00	95.9	219.2	329.2
290	3.21	3.21	3.93	61.20	-2.74	-2.74	-4.85	-6.00	0.00	95.9	105.1	325.3
305	3.21	3.21	3.89	58.30	-2.74	-2.74	-5.00	-7.00	0.00	95.9	149.1	326.8
320	3.21	3.21	3.89	60.00	-2.74	-2.74	-4.85	-7.00	0.00	92.9	201.6	326.0
335	3.21	3.21	3.67	66.80	-2.74	-2.74	-4.70	-7.00	0.00	92.0	188.1	323.2
350	3.21	3.21	4.29	65.00	-2.74	-2.74	-4.55	-7.00	0.00	92.0	179.3	320.8
365	3.21	3.21	3.71	60.30	-2.74	-2.74	-4.40	-7.00	0.00	92.0	187.7	316.3
380	3.21	3.21	3.58	65.50	-2.74	-2.74	-4.40	-7.00	0.00	89.4	187.8	307.4
390	3.21	3.21	4.34	66.10	-2.74	-2.74	-4.40	-7.00	0.00	88.1	163.4	301.8

Meteorological Data --- 02-13-92.

DATE 920214 S-time 1030	Wind Max 24 hrs m/s	Wind Max 12 hrs m/s	Wind m/s	Wind Dir	Temp Max 24 hrs 2m	Temp Max 12 hrs 2m	Temp 2m	Temp Road	Precip Rate water mm/15	RH	Incomin Short Wave W/	Long Wave W/m2
0	3.85	0.16	1.52	31.20	1.77	-2.90	-4.83	-4.00	0.00	84.1	204.3	297.9
15	3.85	0.16	1.48	30.00	1.77	-2.90	-4.40	-4.00	0.00	82.4	267.6	289.8
30	3.85	0.16	1.30	29.60	1.77	-2.90	-4.13	-4.00	0.00	75.4	330.4	258.1
45	3.85	0.16	1.56	28.90	1.77	-2.90	-3.85	-1.00	0.00	73.7	368.7	262.0
60	3.85	0.16	1.52	28.00	1.77	-2.90	-3.58	-1.00	0.00	73.7	375.2	267.7
75	3.85	0.16	1.43	27.50	1.77	-2.90	-3.30	0.00	0.00	72.2	452.7	275.1
90	3.85	0.16	1.83	27.80	1.77	-2.90	-3.03	0.00	0.00	72.1	428.2	258.4
105	3.85	0.16	1.83	30.50	1.77	-2.90	-2.75	-2.00	0.00	73.5	470.2	254.1
120	3.85	0.16	1.52	32.50	1.77	-2.90	-2.48	-2.00	0.00	69.3	463.7	258.0

Meteorological Data --- 02-14-92.

DATE 920220 S-time 0819	Wind Max 24 hrs m/s	Wind Max 12 hrs m/s	Wind m/s	Wind Dir	Temp Max 24 hrs 2m	Temp Max 12 hrs 2m	Temp 2m	Temp Road	Precip Rate water mm/15	RH	Incomin Short Wave W/	Long Wave W/m2
0	4.08	3.18	5.90	17.60	0.12	-2.30	-5.85	-4.00	0.00	95.9	9.8	311.0
6	4.08	3.18	6.57	17.00	0.12	-2.30	-5.73	-4.00	0.00	95.9	12.9	308.6
167	4.08	3.18	7.73	19.10	0.12	-2.30	-4.55	-4.00	0.00	92.0	117.4	315.1
176	4.08	3.18	8.49	20.10	0.12	-2.30	-4.70	-4.00	0.00	92.0	86.3	316.3
191	4.08	3.18	8.31	19.40	0.12	-2.30	-4.85	-4.00	0.00	93.7	60.8	319.8
206	4.08	3.18	7.69	19.00	0.12	-2.30	-5.00	-5.00	0.00	97.4	58.4	326.1
221	4.08	3.18	6.97	17.50	0.12	-2.30	-5.00	-5.00	0.02	99.8	54.6	323.6
236	4.08	3.18	7.29	17.90	0.12	-2.30	-5.00	-5.00	0.05	99.8	55.2	323.4
251	4.08	3.18	7.02	16.90	0.12	-2.30	-5.00	-5.00	0.04	99.8	54.9	322.7
266	4.08	3.18	7.11	16.00	0.12	-2.30	-5.00	-5.00	0.04	99.8	71.4	322.8
281	4.08	3.18	6.71	16.40	0.12	-2.30	-5.00	-5.00	0.06	99.8	96.6	326.8
292	4.08	3.18	6.62	16.00	0.12	-2.30	-5.00	-5.00	0.04	99.8	109.3	323.9

Meteorological Data --- 02-20-92.

DATE 920224 S-time 1040	Wind Max 24 hrs m/s	Wind Max 12 hrs m/s	Wind m/s	Wind Dir	Temp Max 24 hrs 2m	Temp Max 12 hrs 2m	Temp 2m	Temp Road	Precip Rate water mm/15	RH	Incomin Short Wave W/	Long Wave W/m2
0	5.07	2.69	4.07	16.00	-1.58	-1.58	-2.80	-2.00	0.01	99.9	170.3	331.0
28	5.07	2.69	4.16	15.80	-1.58	-1.58	-2.65	-2.00	0.01	99.9	201.6	330.7
36	5.07	2.69	4.02	16.40	-1.58	-1.58	-2.50	-2.00	0.01	99.8	190.4	334.2
50	5.07	2.69	3.89	17.60	-1.58	-1.58	-2.35	-2.00	0.01	99.8	190.6	328.0
65	5.07	2.69	4.20	17.00	-1.58	-1.58	-2.20	-2.00	0.00	99.8	228.5	332.0
80	5.07	2.69	4.29	16.00	-1.58	-1.58	-2.20	-2.00	0.01	99.8	233.2	333.0
95	5.07	2.69	4.38	15.80	-1.58	-1.58	-2.20	-2.00	0.01	99.8	219.1	329.9
110	5.07	2.69	4.56	17.00	-1.58	-1.58	-2.20	-2.00	0.00	99.8	213.7	333.4
125	5.07	2.69	4.96	16.10	-1.58	-1.58	-2.20	-2.00	0.00	99.8	233.6	333.6
140	5.07	2.69	4.47	16.30	-1.58	-1.58	-2.08	-2.00	0.01	99.8	226.7	335.1
175	5.07	2.69	5.05	16.90	-1.58	-1.58	-1.95	-2.00	0.00	99.8	261.1	329.5
187	5.07	2.69	4.92	16.40	-1.58	-1.58	-1.83	-1.00	0.01	99.8	257.1	332.8
200	5.07	2.69	5.05	16.10	-1.58	-1.58	-1.70	-1.00	0.01	99.8	274.4	331.4
215	5.07	2.69	4.65	16.40	-1.58	-1.58	-1.70	-1.00	0.01	99.8	272.3	332.2
230	5.07	2.69	4.51	16.20	-1.58	-1.58	-1.70	-1.00	0.00	99.8	262.9	337.1
245	5.07	2.69	4.87	16.60	-1.58	-1.58	-1.70	-1.00	0.01	99.8	230.1	335.3
260	5.07	2.69	4.16	15.80	-1.58	-1.58	-1.70	-1.00	0.01	99.8	207.7	330.9
275	5.07	2.69	4.25	15.30	-1.58	-1.58	-1.95	-1.00	0.00	99.9	189.9	337.1
290	5.07	2.69	4.11	15.40	-1.58	-1.58	-2.20	-1.00	0.01	99.9	155.5	337.0

Meteorological Data --- 02-24-92.

DATE 920225 S-time 1030	Wind Max 24 hrs m/s	Wind Max 12 hrs m/s	Wind m/s	Wind Dir	Temp Max 24 hrs 2m	Temp Max 12 hrs 2m	Temp 2m	Temp Road	Precip Rate water mm/15	RH	Incomin Short Wave W/	Long Wave W/m2
0	5.07	3.14	4.02	31.40	2.18	0.60	-1.83	-2.00	0.01	99.8	178.9	330.6
35	5.07	3.14	5.05	44.50	2.18	0.60	-1.70	-2.00	0.00	93.8	252.9	324.8
45	5.07	3.14	4.56	22.80	2.18	0.60	-1.70	-2.00	0.00	92.8	264.0	330.0
60	5.07	3.14	4.60	53.80	2.18	0.60	-1.70	-2.00	0.00	93.5	210.5	326.6
75	5.07	3.14	4.92	32.90	2.18	0.60	-1.70	-2.00	0.00	92.1	246.6	327.2
90	5.07	3.14	5.01	48.20	2.18	0.60	-1.70	-2.00	0.00	92.3	283.7	331.7
105	5.07	3.14	4.02	54.30	2.18	0.60	-1.42	-2.00	0.00	93.6	329.1	319.8
120	5.07	3.14	4.16	44.30	2.18	0.60	-1.13	-2.00	0.00	92.3	332.7	327.2
135	5.07	3.14	3.98	50.80	2.18	0.60	-0.85	-2.00	0.00	94.0	298.0	324.3
150	5.07	3.14	4.02	53.70	2.18	0.60	-0.56	-2.00	0.00	92.5	358.8	326.9
164	5.07	3.14	3.84	53.00	2.18	0.60	-0.56	-2.00	0.00	92.1	325.7	320.3

Meteorological Data --- 02-25-92.

DATE 920227 S-time 1204	Wind Max 24 hrs m/s	Wind Max 12 hrs m/s	Wind m/s	Wind Dir	Temp Max 24 hrs 2m	Temp Max 12 hrs 2m	Temp 2m	Temp Road	Precip Rate water mm/15	RH	Incomin Short Wave W/	Long Wave W/m2
0	8.02	8.02	6.93	30.80	2.65	2.17	-5.00	0.00	0.00	66.9	499.3	241.8
14	8.02	8.02	6.30	48.30	2.65	2.17	-4.73	0.00	0.00	67.4	455.9	246.2
24	8.02	8.02	5.23	43.30	2.65	2.17	-4.45	0.00	0.00	68.1	507.4	242.4
39	8.02	8.02	5.36	59.50	2.65	2.17	-4.18	0.00	0.00	64.5	578.1	241.8
54	8.02	8.02	5.01	53.10	2.65	2.17	-3.90	0.00	0.00	65.2	597.9	243.6
69	8.02	8.02	4.43	58.50	2.65	2.17	-3.90	-1.00	0.00	63.8	603.9	242.6
84	8.02	8.02	5.23	47.90	2.65	2.17	-3.90	-1.00	0.00	65.6	603.6	245.2
99	8.02	8.02	5.14	58.20	2.65	2.17	-3.90	-1.00	0.00	67.1	603.8	242.8
114	8.02	8.02	4.78	50.10	2.65	2.17	-3.90	-1.00	0.00	65.1	467.2	248.6
129	8.02	8.02	4.51	54.40	2.65	2.17	-3.75	-1.00	0.00	64.8	536.1	258.8

Meteorological Data --- 02-27-92.

DATE 920309 S-time 0743	Wind Max 24 hrs m/s	Wind Max 12 hrs m/s	Wind m/s	Wind Dir	Temp Max 24 hrs 2m	Temp Max 12 hrs 2m	Temp 2m	Temp Road	Precip Rate water mm/15	RH	Incomin Short Wave W/	Long Wave W/m2
0	7.39	7.39	4.47	15.90	3.03	2.72	-6.70	-6.00	0.00	95.6	9.1	300.9
44	7.39	7.39	4.65	35.90	3.03	2.72	-7.08	-6.00	0.00	89.9	28.8	296.7
62	7.39	7.39	4.96	21.30	3.03	2.72	-7.20	-6.00	0.01	91.8	33.6	300.2
77	7.39	7.39	4.43	10.70	3.03	2.72	-7.35	-6.00	0.00	95.4	46.9	299.9
92	7.39	7.39	4.65	4.10	3.03	2.72	-7.50	-6.00	0.00	95.9	67.2	299.5
107	7.39	7.39	4.69	11.90	3.03	2.72	-7.65	-6.00	0.00	93.2	109.0	298.1
122	7.39	7.39	4.92	12.90	3.03	2.72	-7.80	-6.00	0.00	91.8	129.0	297.3
137	7.39	7.39	5.50	3.70	3.03	2.72	-8.08	-6.00	0.00	88.3	161.1	293.9
152	7.39	7.39	6.21	4.40	3.03	2.72	-8.35	-6.00	0.00	90.0	166.9	295.0
167	7.39	7.39	5.90	3.40	3.03	2.72	-8.63	-6.00	0.00	88.6	169.6	294.7
197	7.39	7.39	5.45	6.80	3.03	2.72	-8.90	-6.00	0.00	91.7	166.2	293.5
243	7.39	7.39	6.26	6.00	3.03	2.72	-8.90	-6.00	0.00	85.7	247.6	286.8
257	7.39	7.39	6.21	6.00	3.03	2.72	-8.90	-6.00	0.00	85.4	259.4	290.0
272	7.39	7.39	5.72	7.00	3.03	2.72	-8.90	-6.00	0.00	84.6	239.1	285.0
287	7.39	7.39	5.50	10.20	3.03	2.72	-8.90	-4.00	0.00	86.9	221.3	281.8
302	7.39	7.39	5.63	8.40	3.03	2.72	-8.90	-4.00	0.00	86.4	230.8	281.9
317	7.39	7.39	6.93	3.60	3.03	2.72	-8.90	-4.00	0.00	85.5	235.2	283.8
332	7.39	7.39	5.63	4.70	3.03	2.72	-9.03	-4.00	0.00	90.3	195.3	284.4
347	7.39	7.39	6.75	13.50	3.03	2.72	-9.15	-4.00	0.00	88.3	239.3	283.0
362	7.39	7.39	6.39	6.70	3.03	2.72	-9.28	-4.00	0.00	87.9	238.8	282.6
373	7.39	7.39	6.39	11.00	3.03	2.72	-9.40	-4.00	0.00	87.9	217.0	281.4

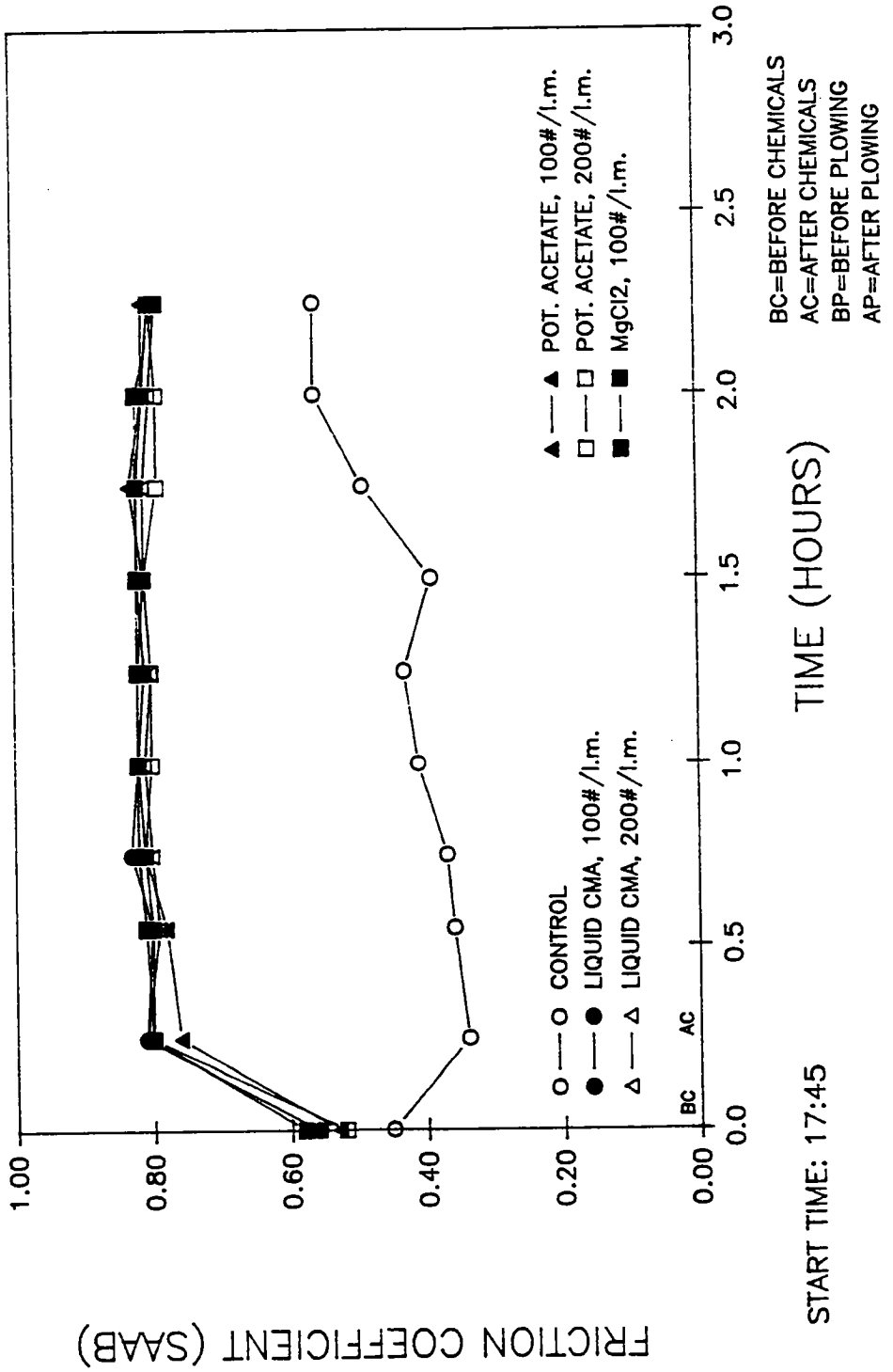
Meteorological Data --- 03-09-92.

DATE 920401 S-time 0746	Wind Max 24 hrs m/s	Wind Max 12 hrs m/s	Wind m/s	Wind Dir	Temp Max 24 hrs 2m	Temp Max 12 hrs 2m	Temp 2m	Temp Road	Precip Rate snow mm/15	RH	Incomin Short Wave	Long Wave W/m2
0	6.20	5.30	1.00	47.00	0.30	-2.50	-7.22	-4.00	0.10	73.0	123.0	230.0
14	6.20	5.30	1.20	46.00	0.30	-2.50	-6.94	-4.00	0.00	66.1	161.0	230.0
29	6.20	5.30	2.40	52.00	0.30	-2.50	-6.66	-4.00	0.10	63.0	177.0	231.0
44	6.20	5.30	3.50	52.00	0.30	-2.50	-6.39	-4.00	0.00	60.6	245.0	232.0
59	6.20	5.30	4.10	44.00	0.30	-2.50	-6.11	-4.00	0.00	56.9	290.0	232.0
74	6.20	5.30	4.40	43.00	0.30	-2.50	-6.25	-4.00	0.00	59.5	342.0	236.0
89	6.20	5.30	4.60	37.00	0.30	-2.50	-6.39	-2.00	0.00	59.7	239.0	239.0
104	6.20	5.30	4.60	46.00	0.30	-2.50	-6.53	-2.00	0.00	60.9	434.0	240.0
119	6.20	5.30	5.00	47.00	0.30	-2.50	-6.67	-2.00	0.00	57.6	480.0	240.0
130	6.20	5.30	4.90	45.00	0.30	-2.50	-6.53	-2.00	0.00	58.5	519.0	244.0

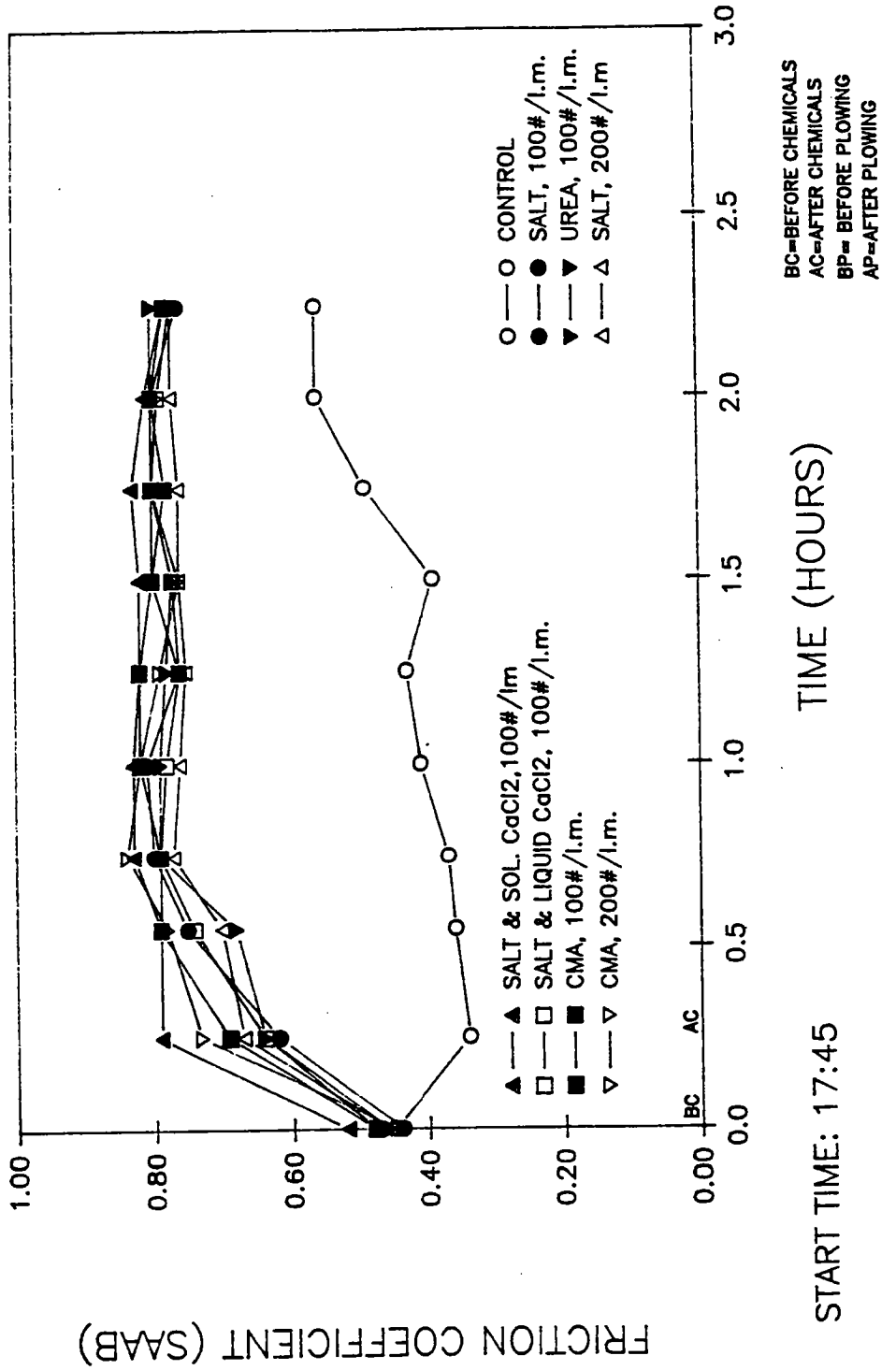
Meteorological Data --- 04-01-92.

APPENDIX C

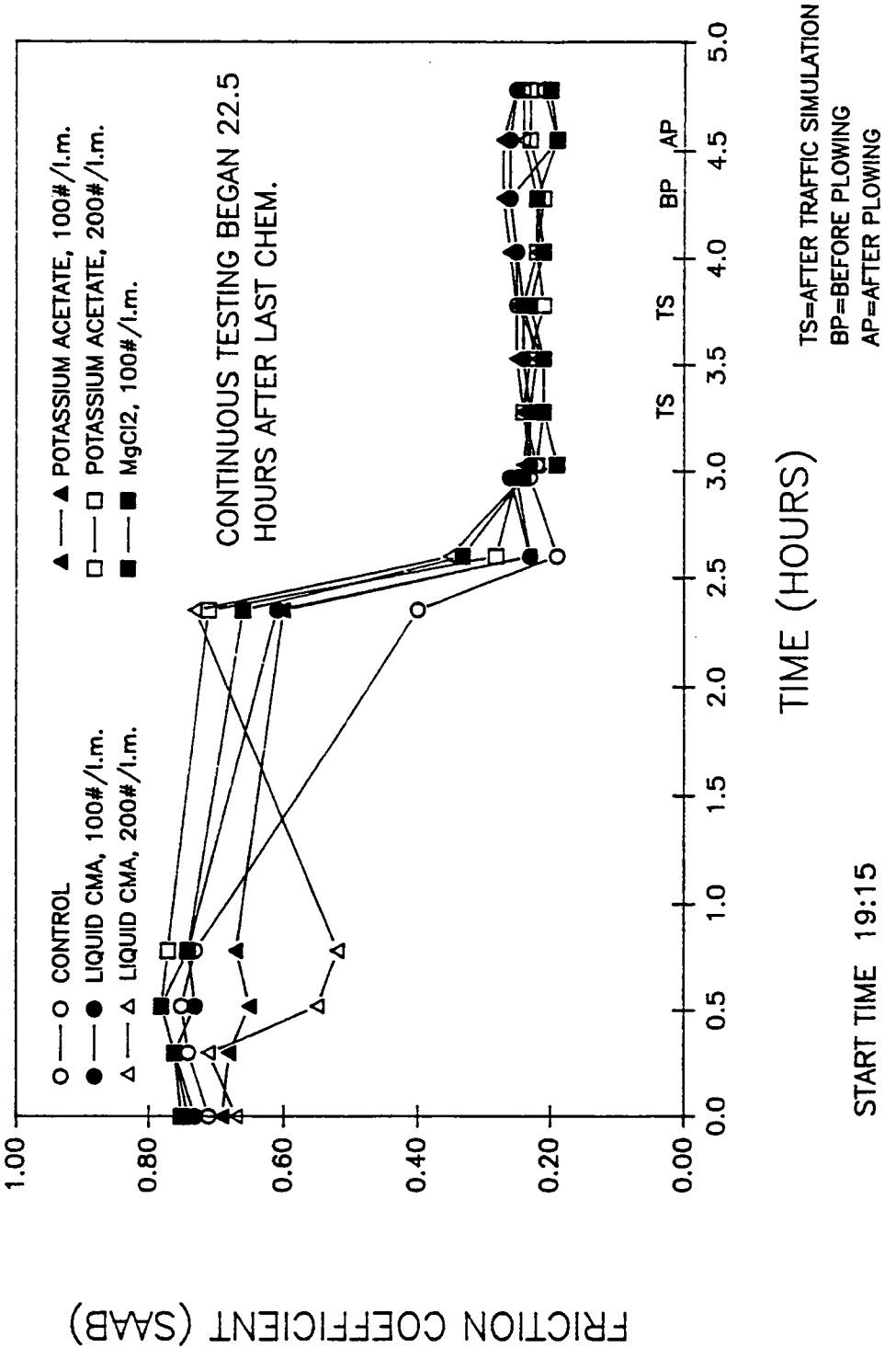
Friction Values - Individual Tests



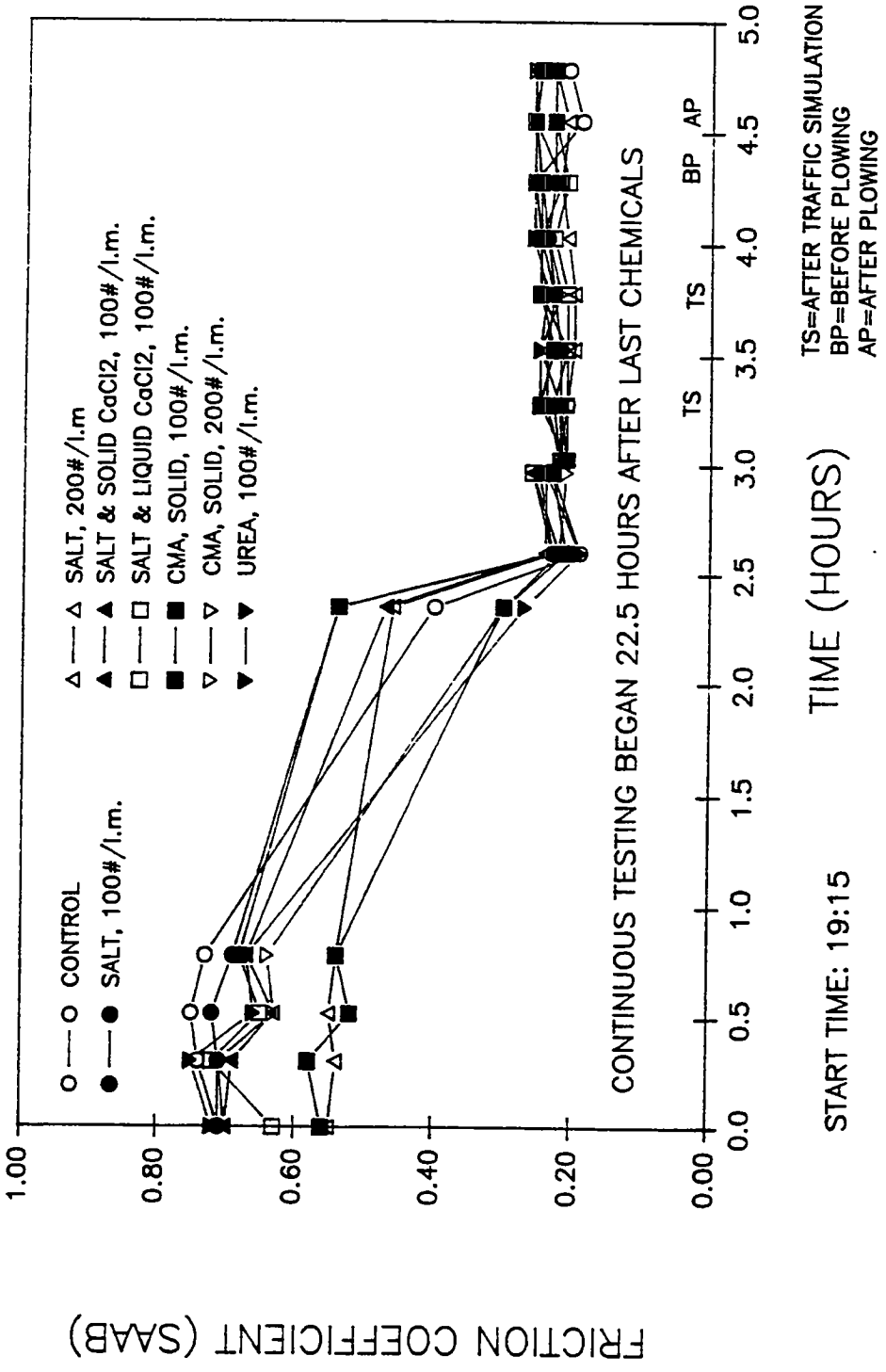
Friction Values --- 12-12-91 --- Liquids.



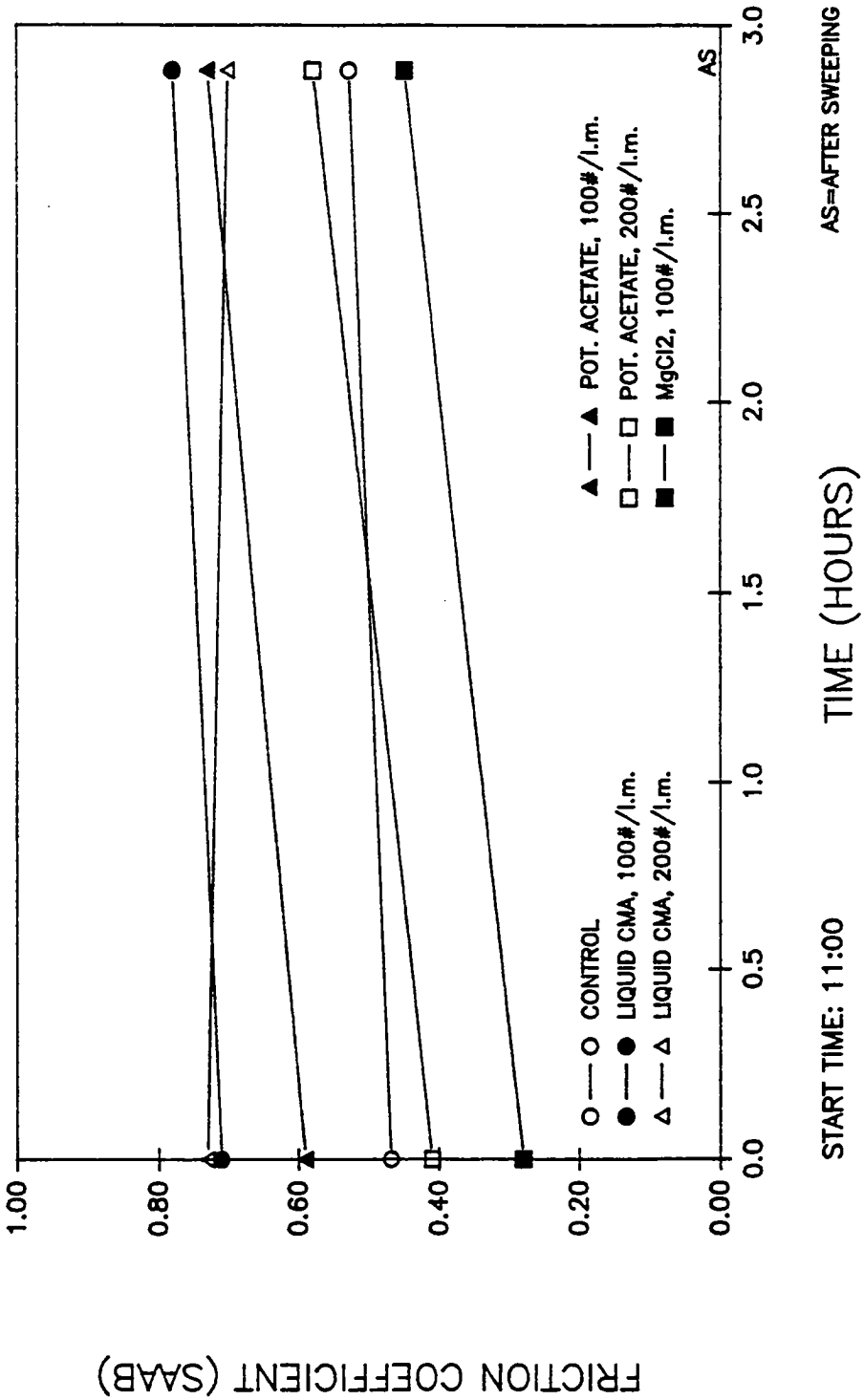
Friction Values --- 12-12-91 --- Solids.



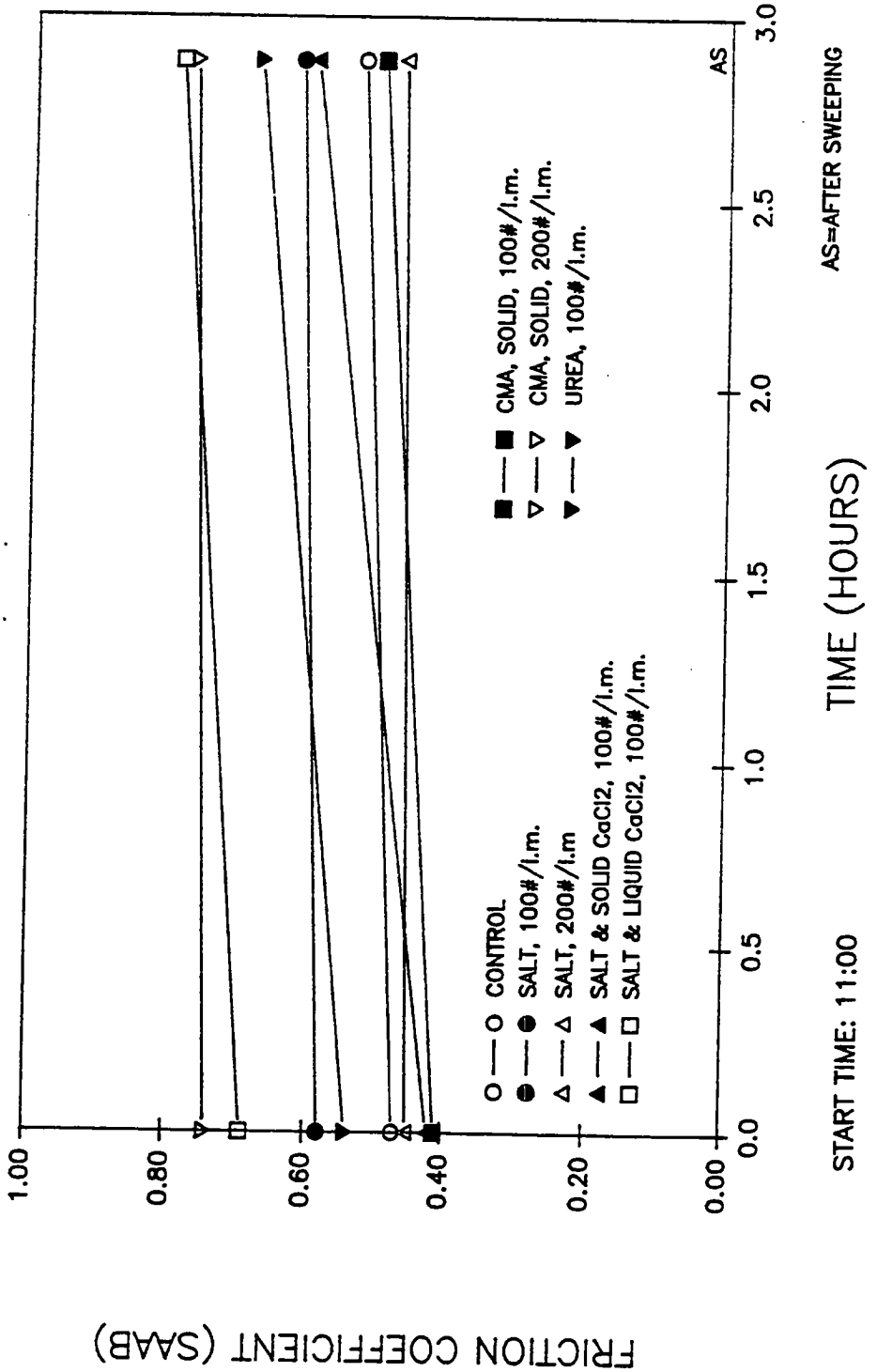
Friction Values --- 12-13-91 --- Liquids.



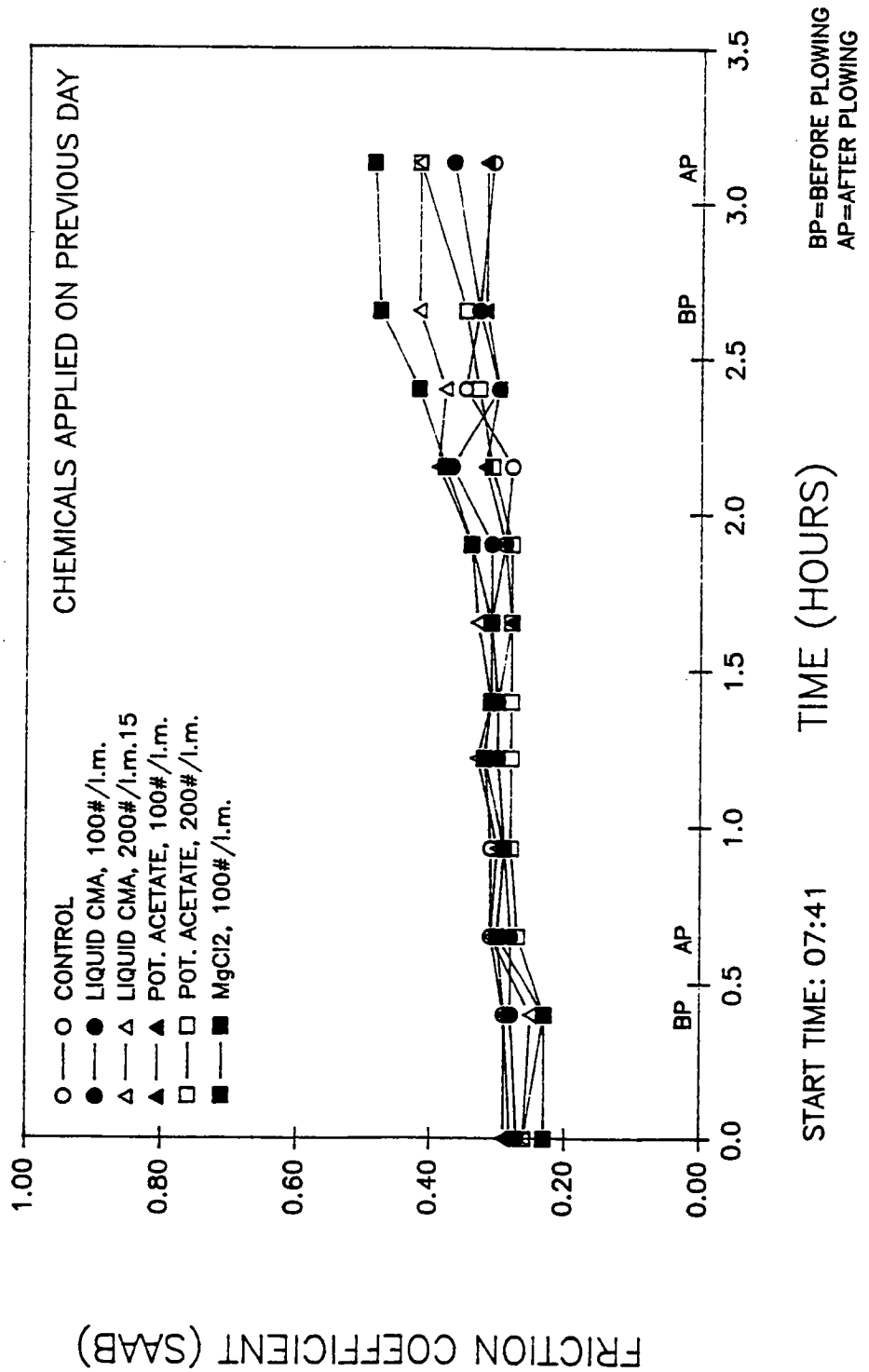
Friction Values --- 12-13-91 --- Solids.



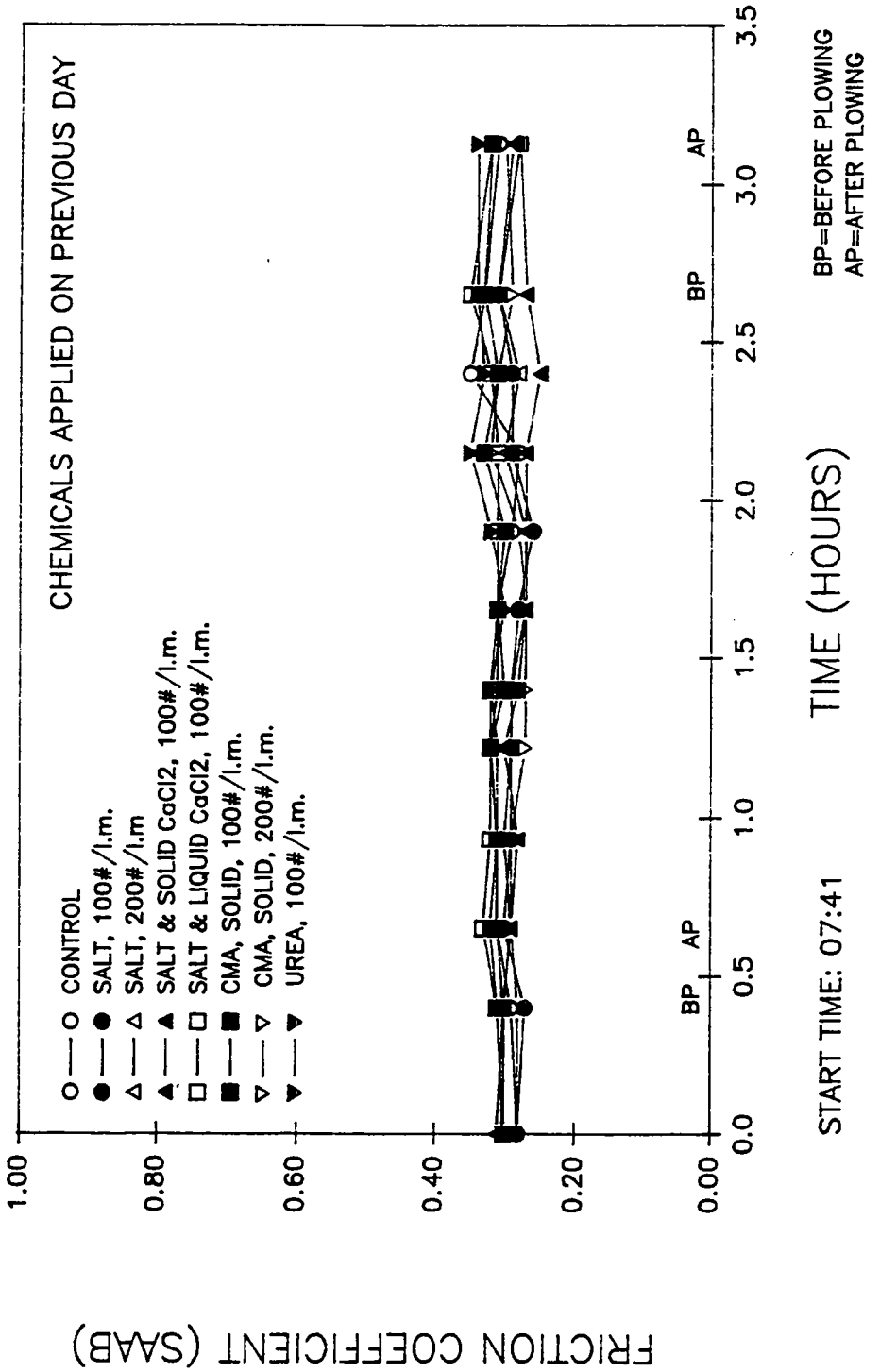
Friction Values --- 12-19-91 --- Liquids.



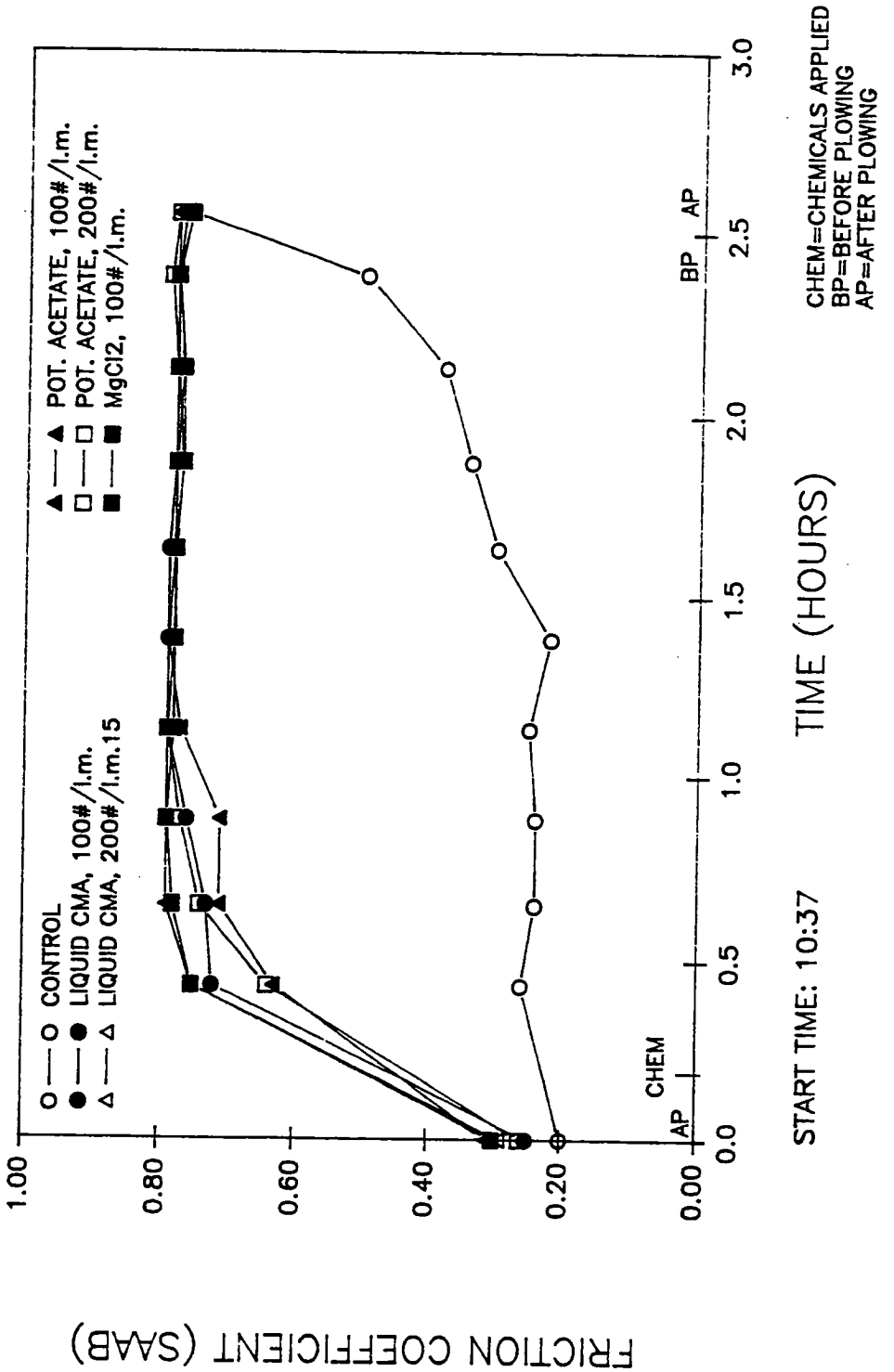
Friction Values --- 12-19-91 --- Solids.



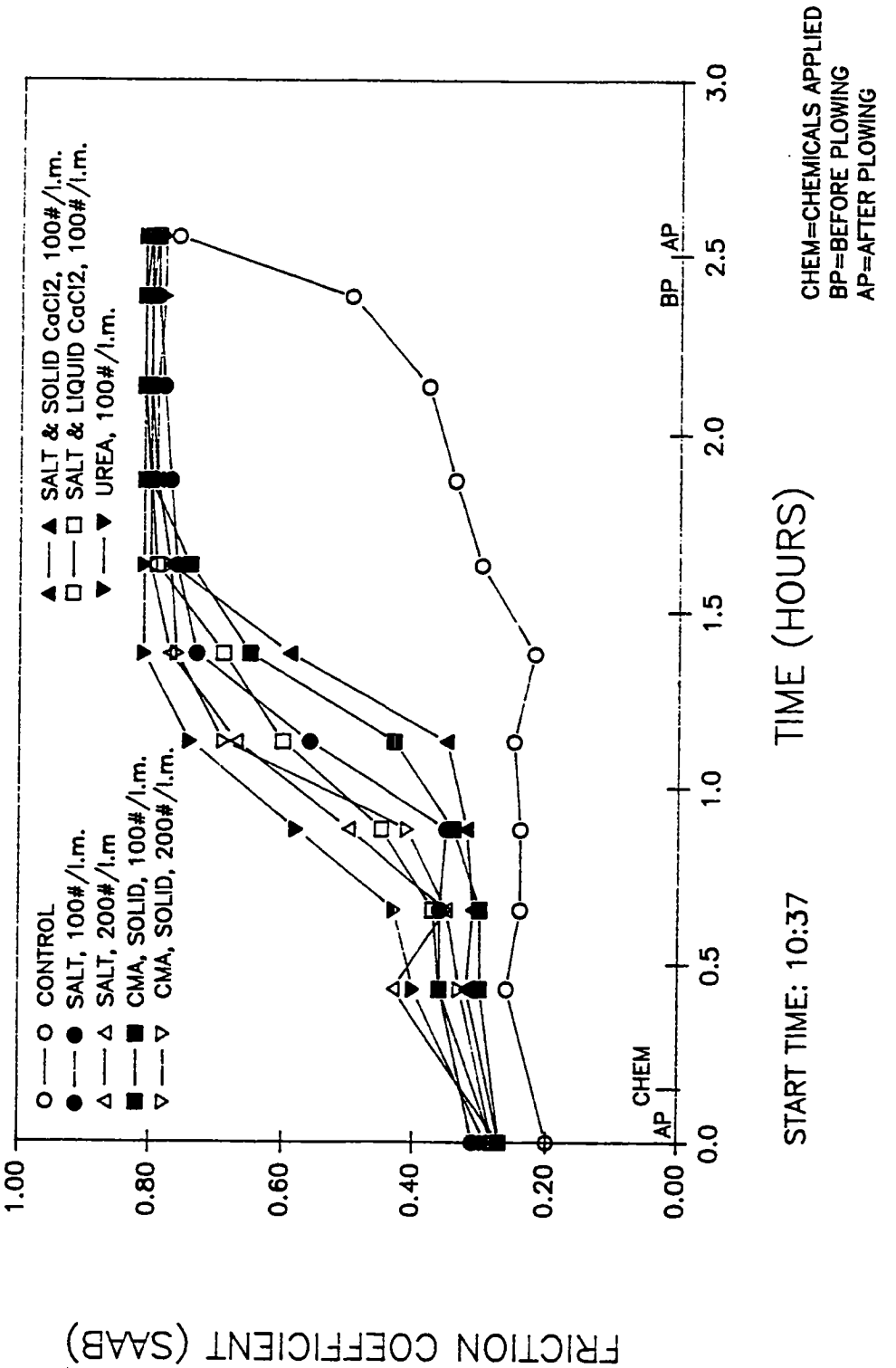
Friction Values --- 12-20-91 --- Liquids.



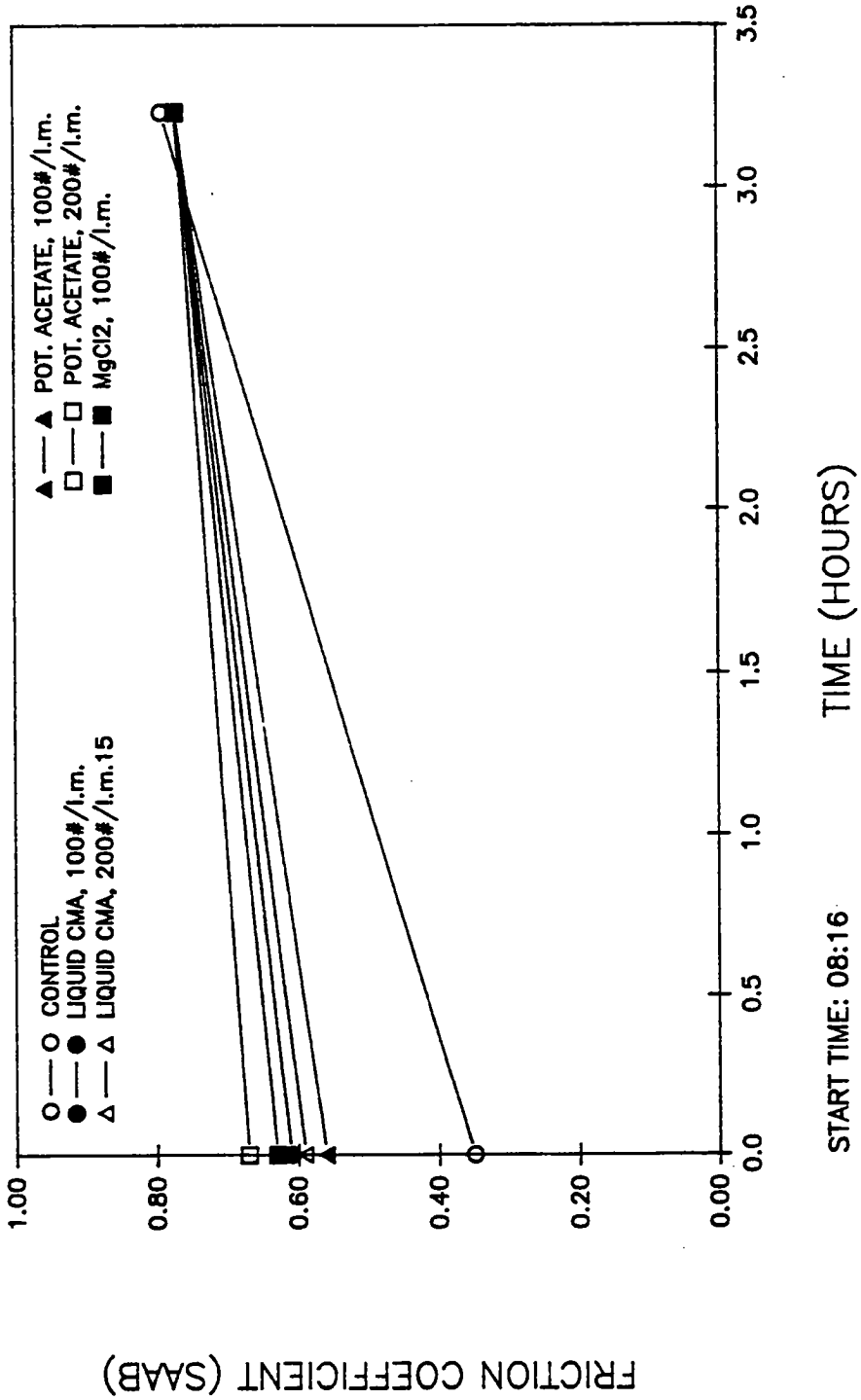
Friction Values --- 12-20-91 --- Solids.



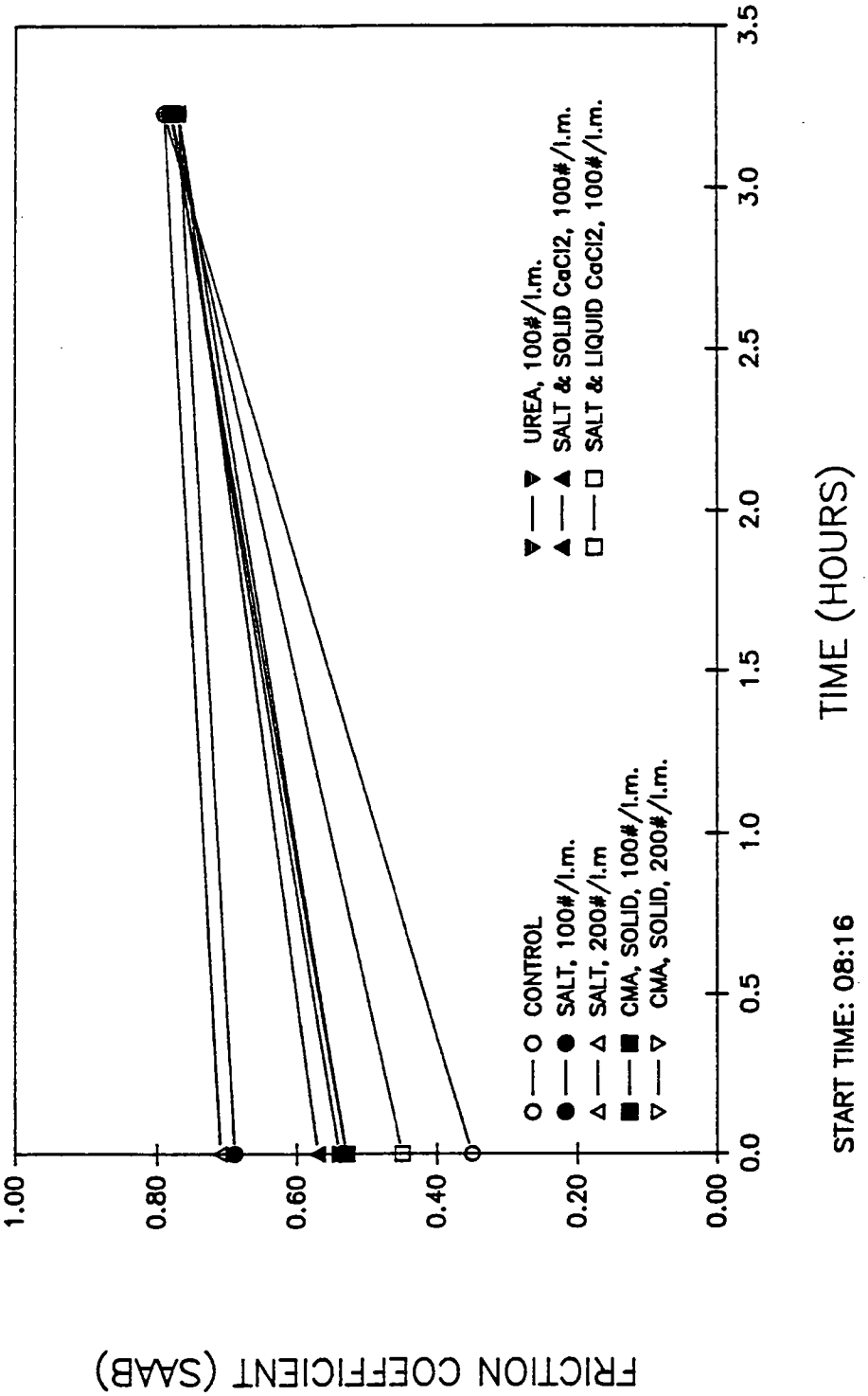
Friction Values --- 01-02-92 --- Liquids.



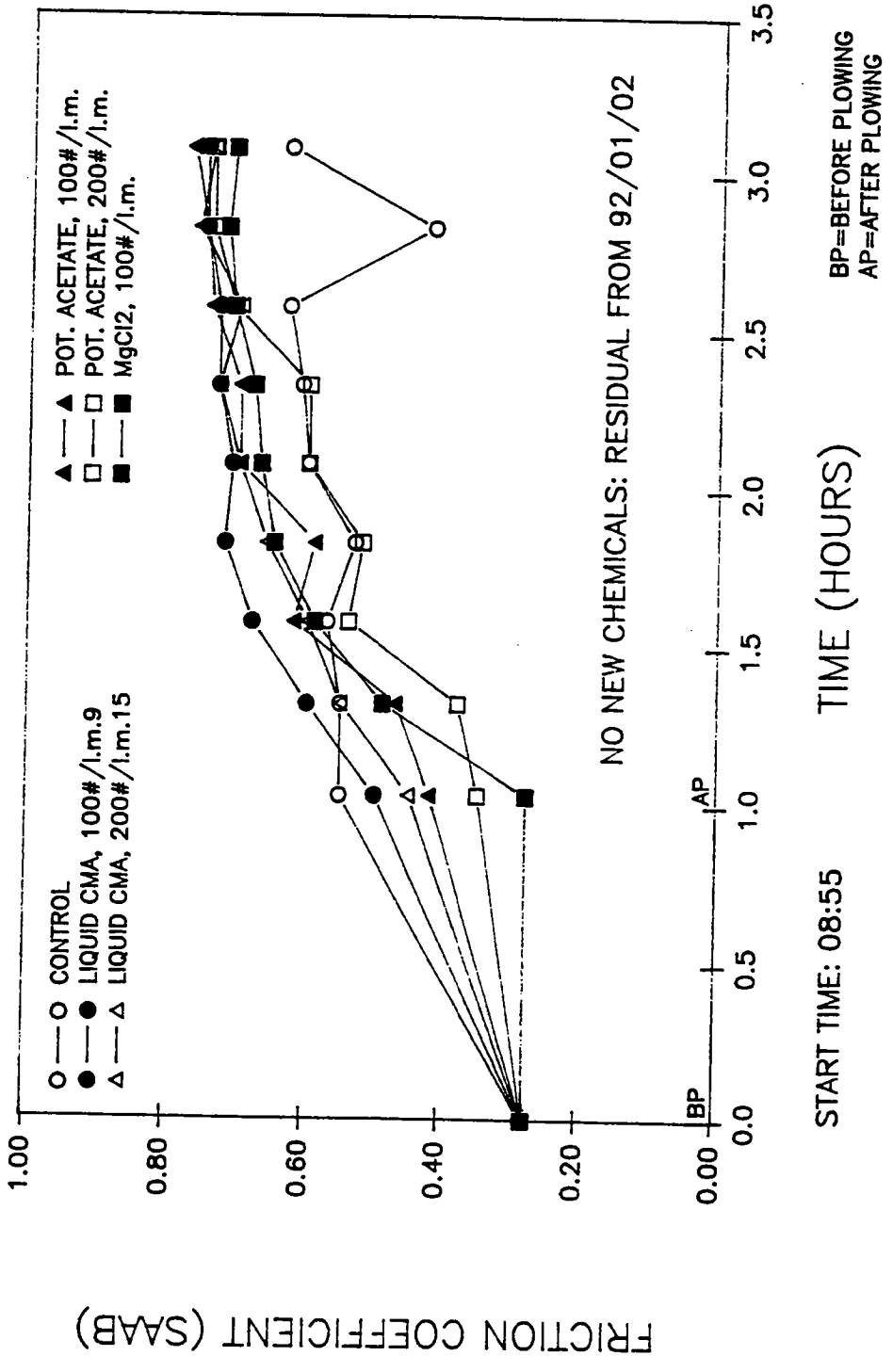
Friction Values --- 01-02-92 --- Solids.



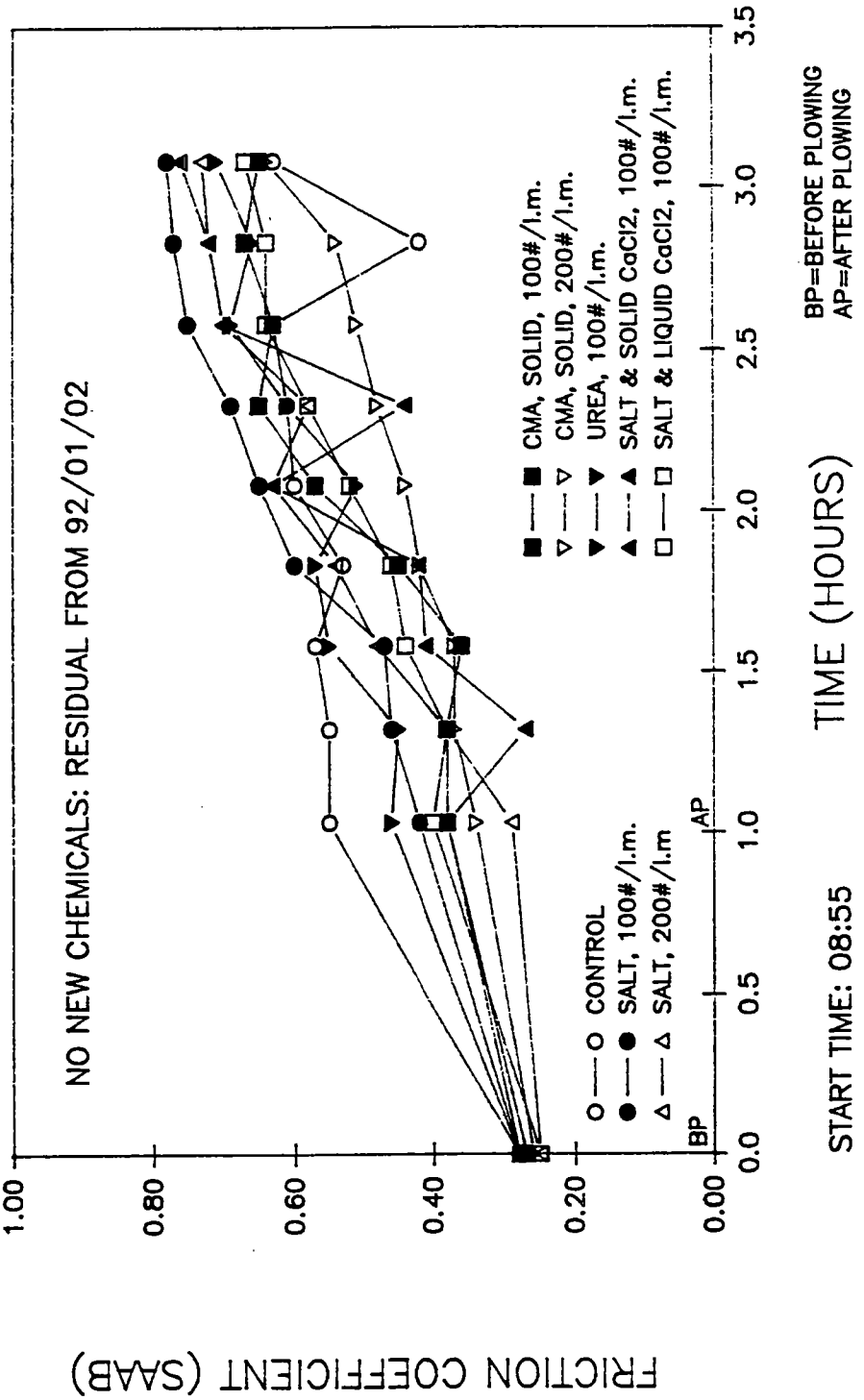
Friction Values --- 01-03-92 --- Liquids.



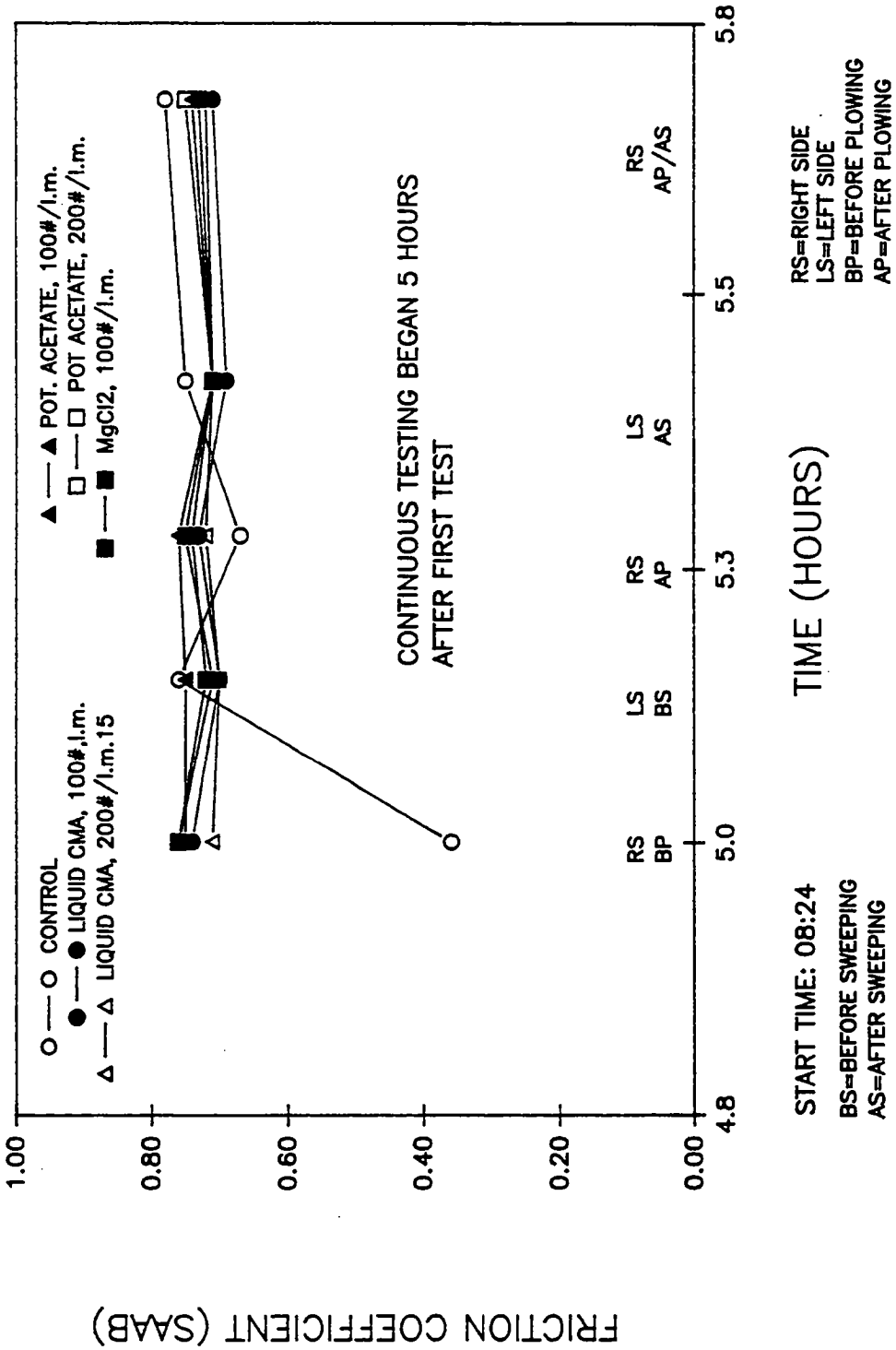
Friction Values --- 01-03-92 --- Solids.



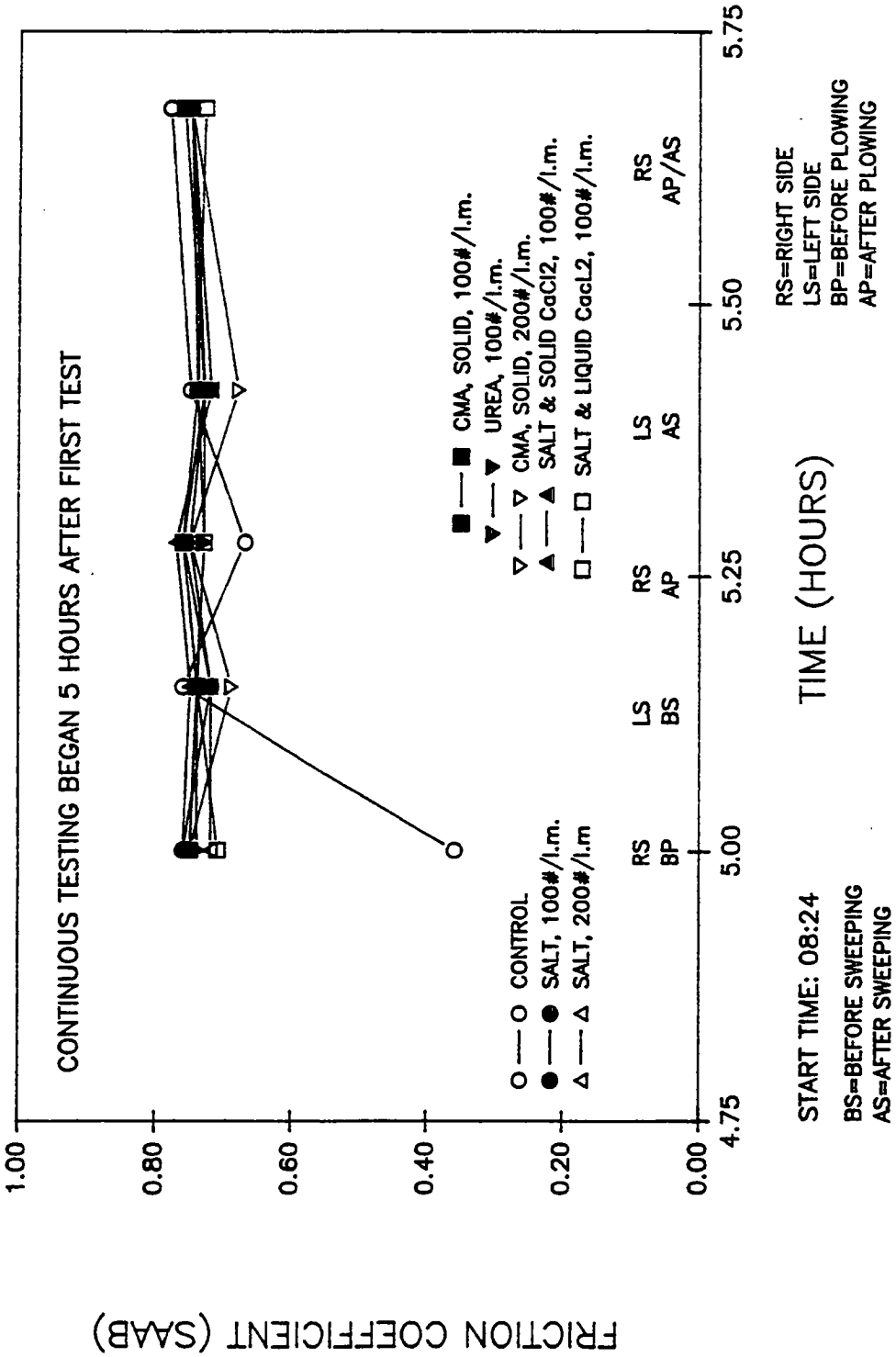
Friction Values --- 01-06-92 --- Liquids.



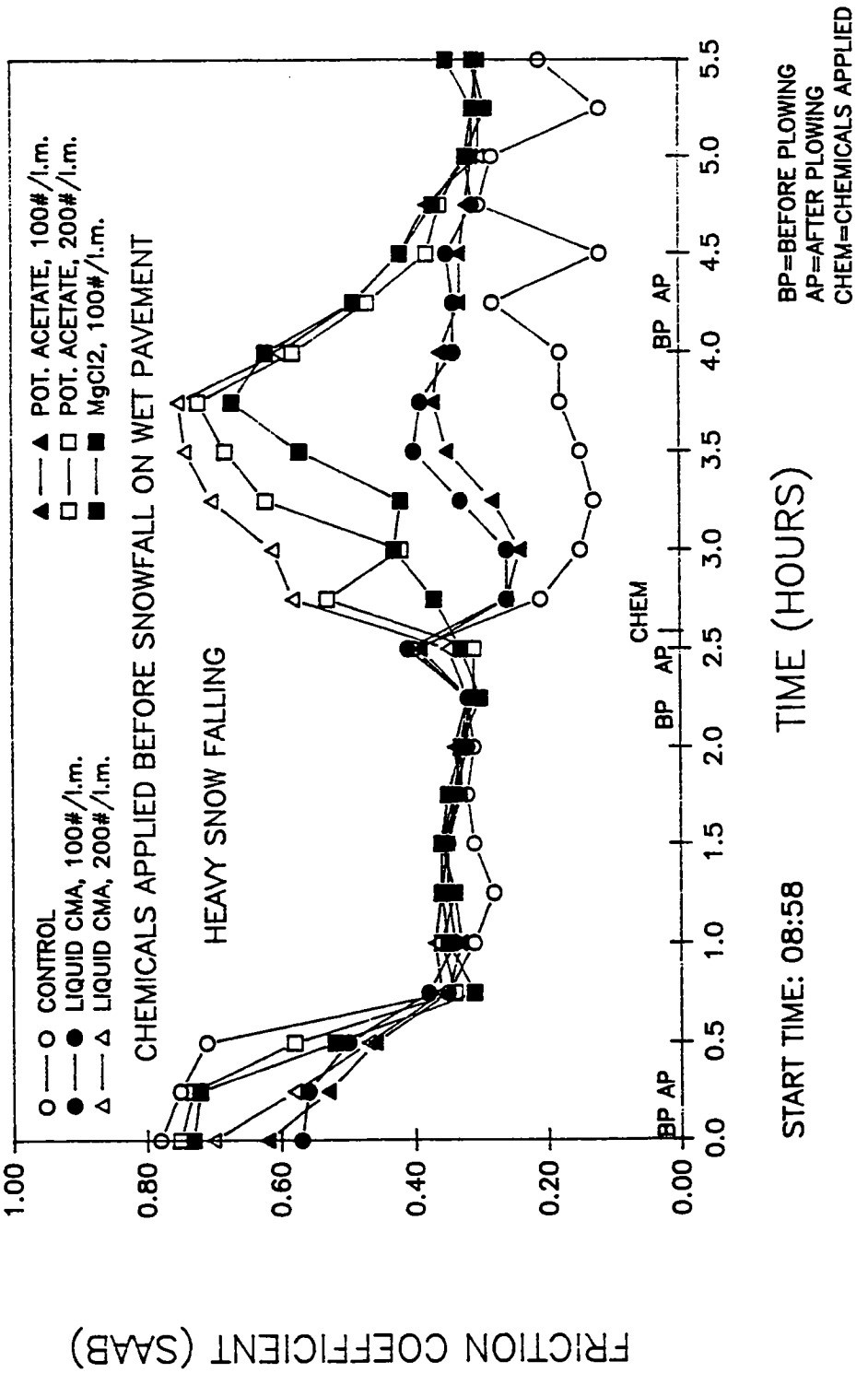
Friction Values --- 01-06-92 --- Solids.



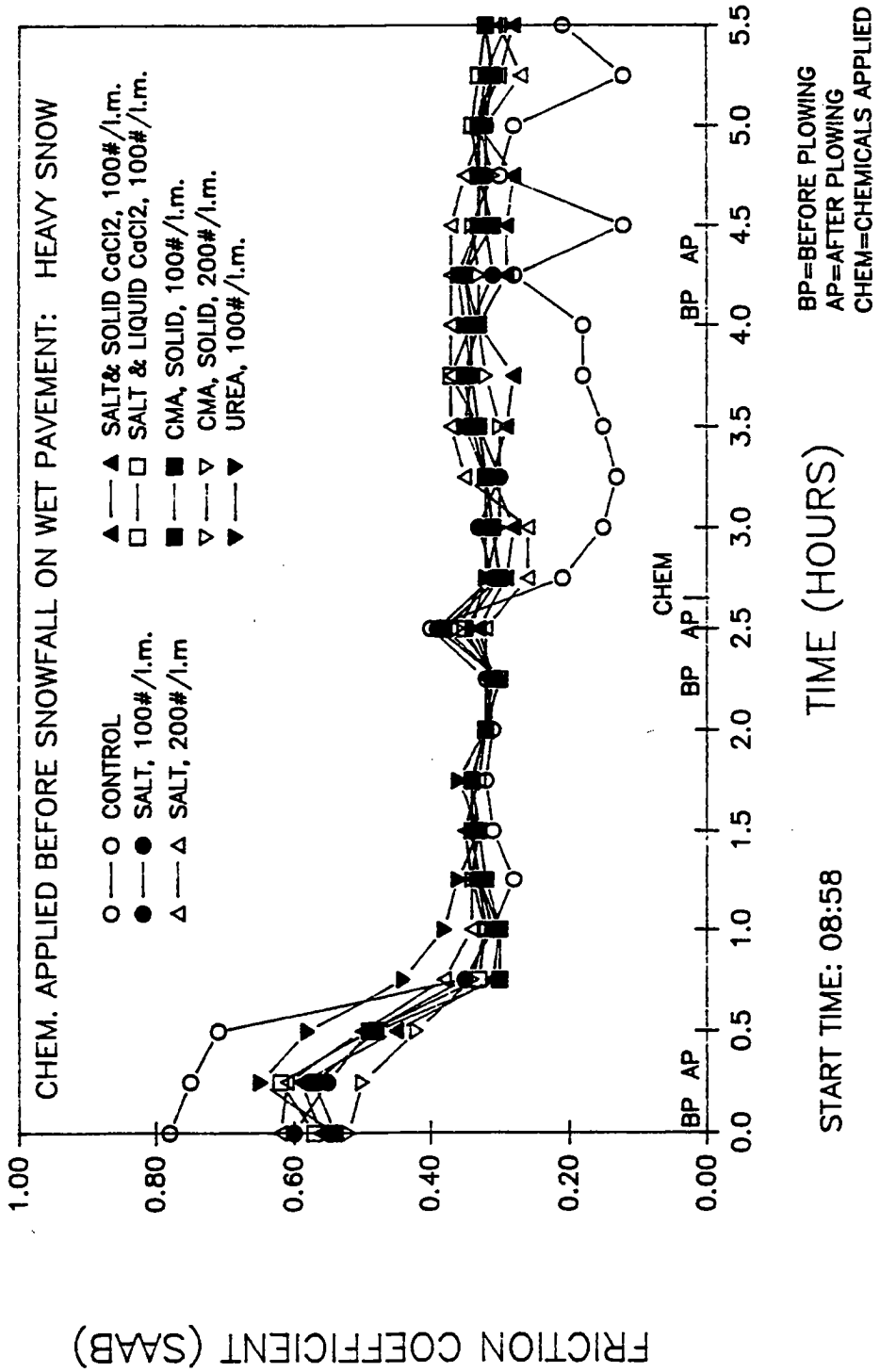
Friction Values --- 01-07-92 --- Liquids.



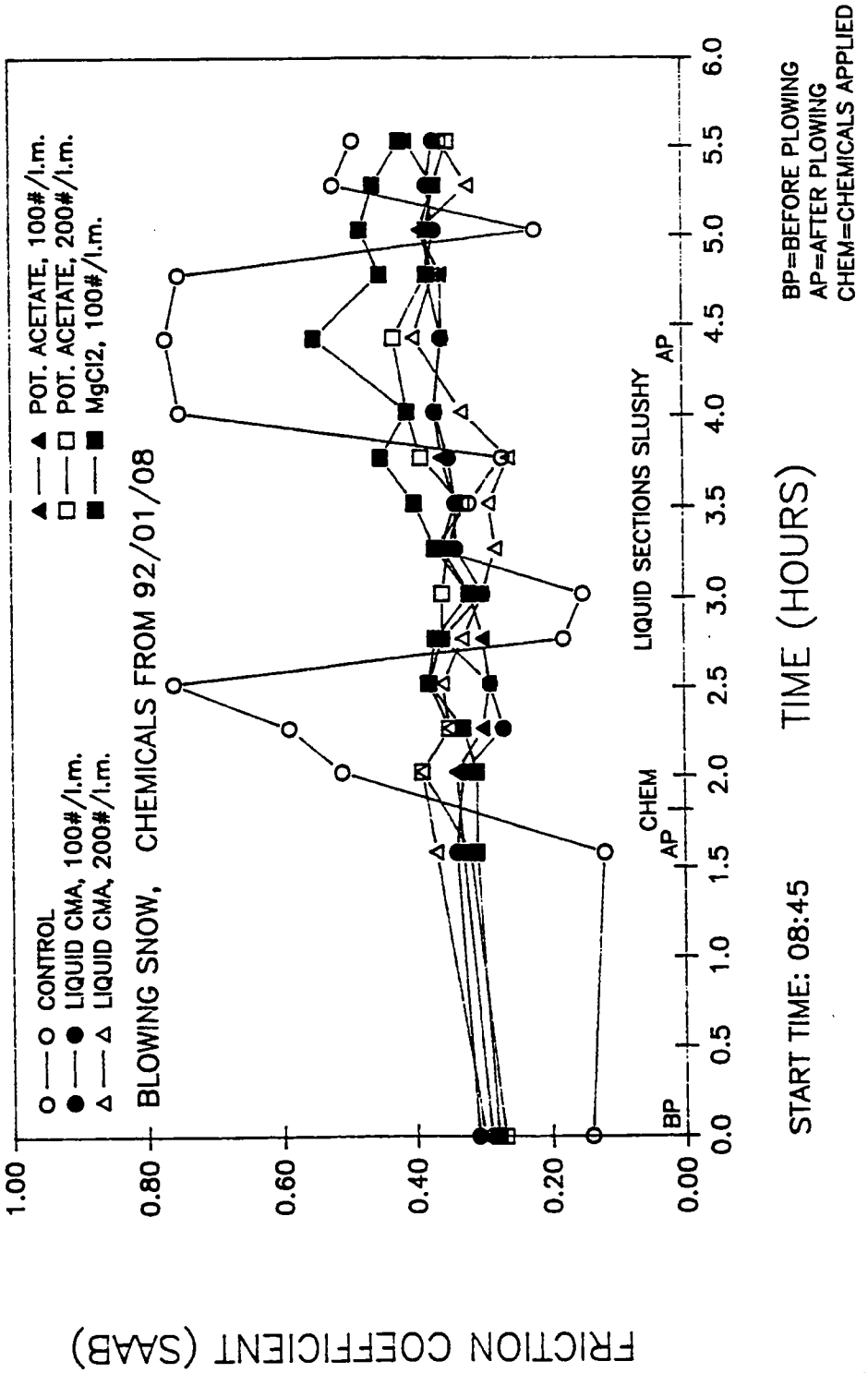
Friction Values --- 01-07-92 --- Solids.



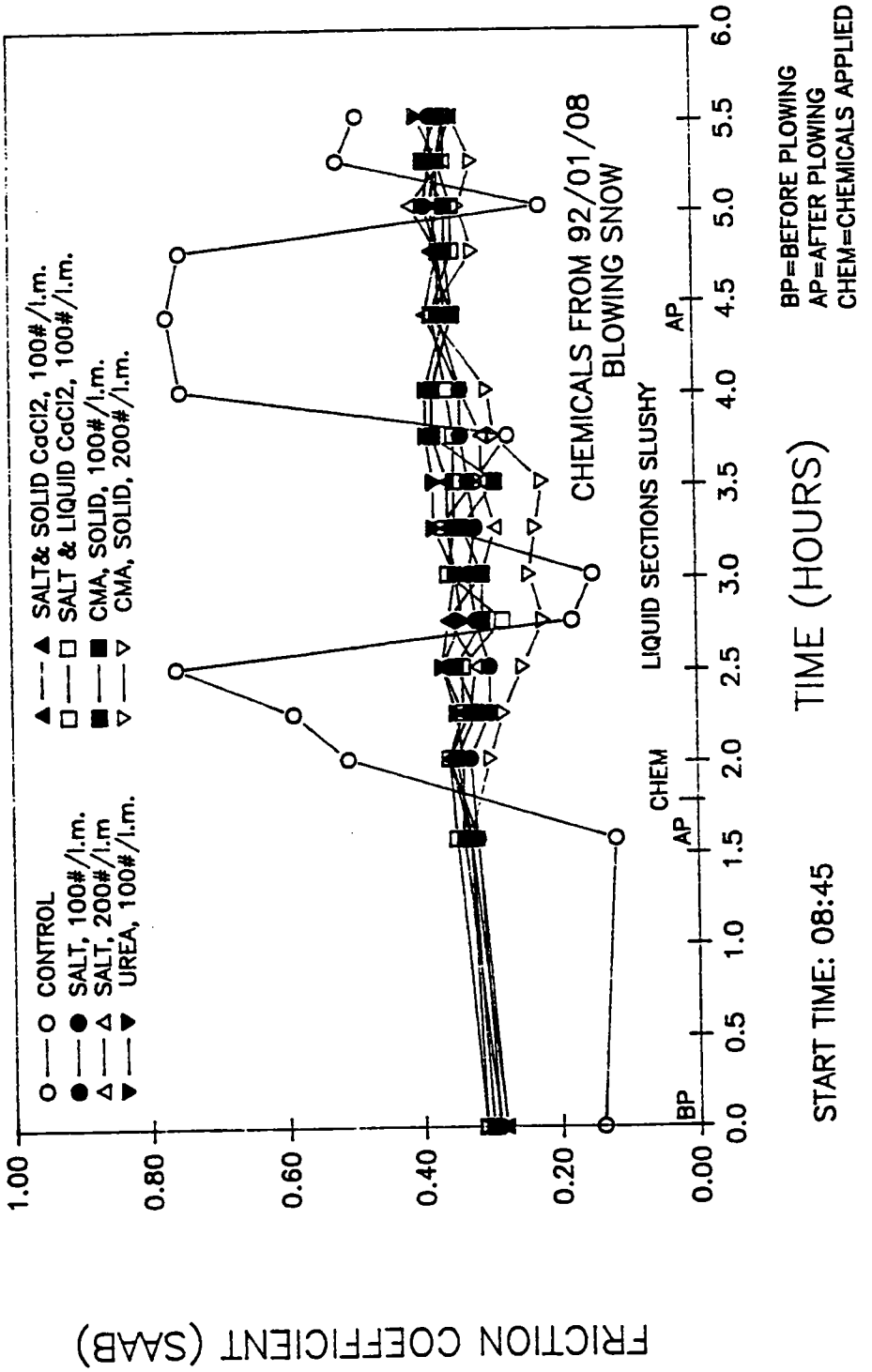
Friction Values --- 01-08-92 --- Liquids.



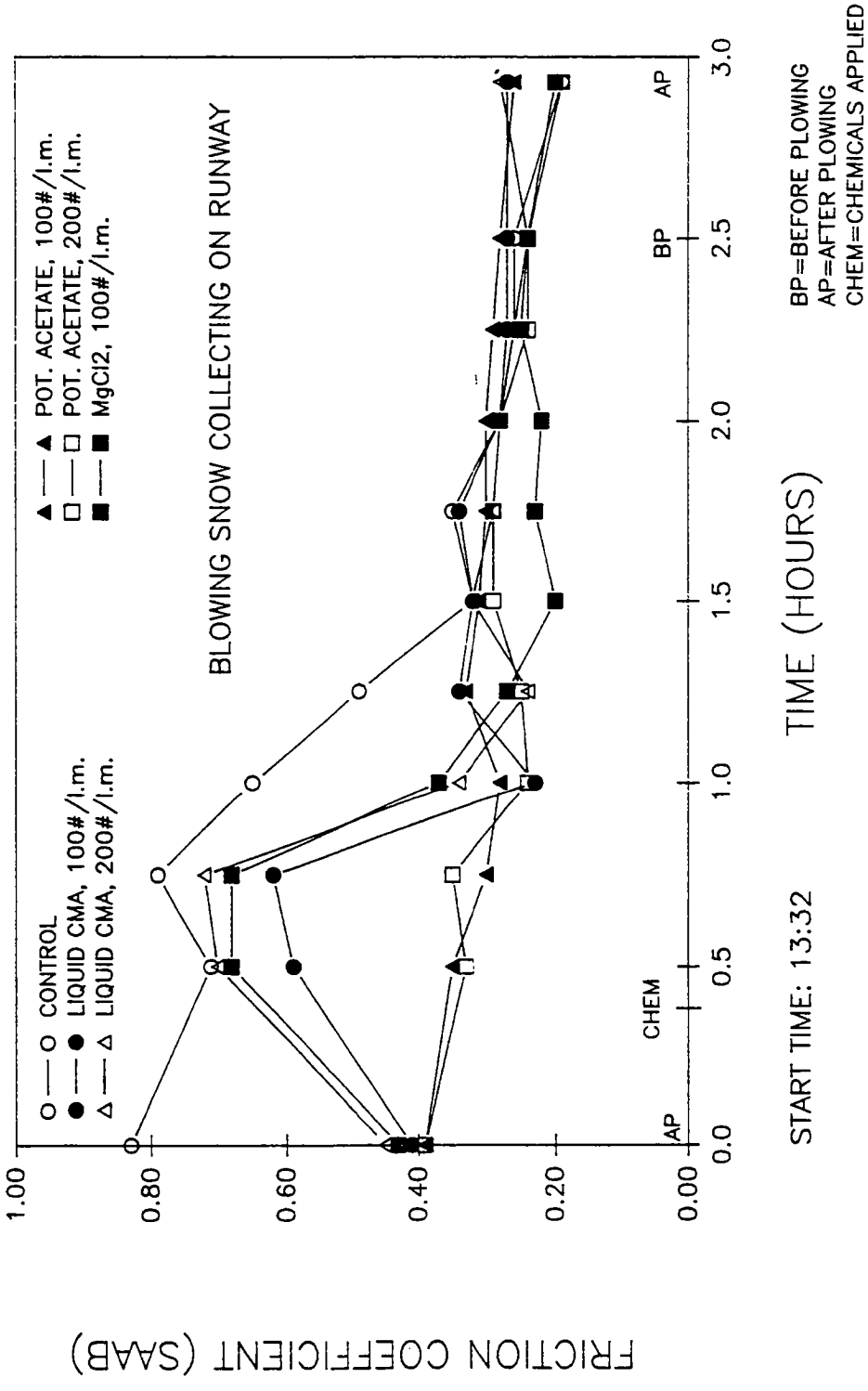
Friction Values --- 01-08-92 --- Solids.



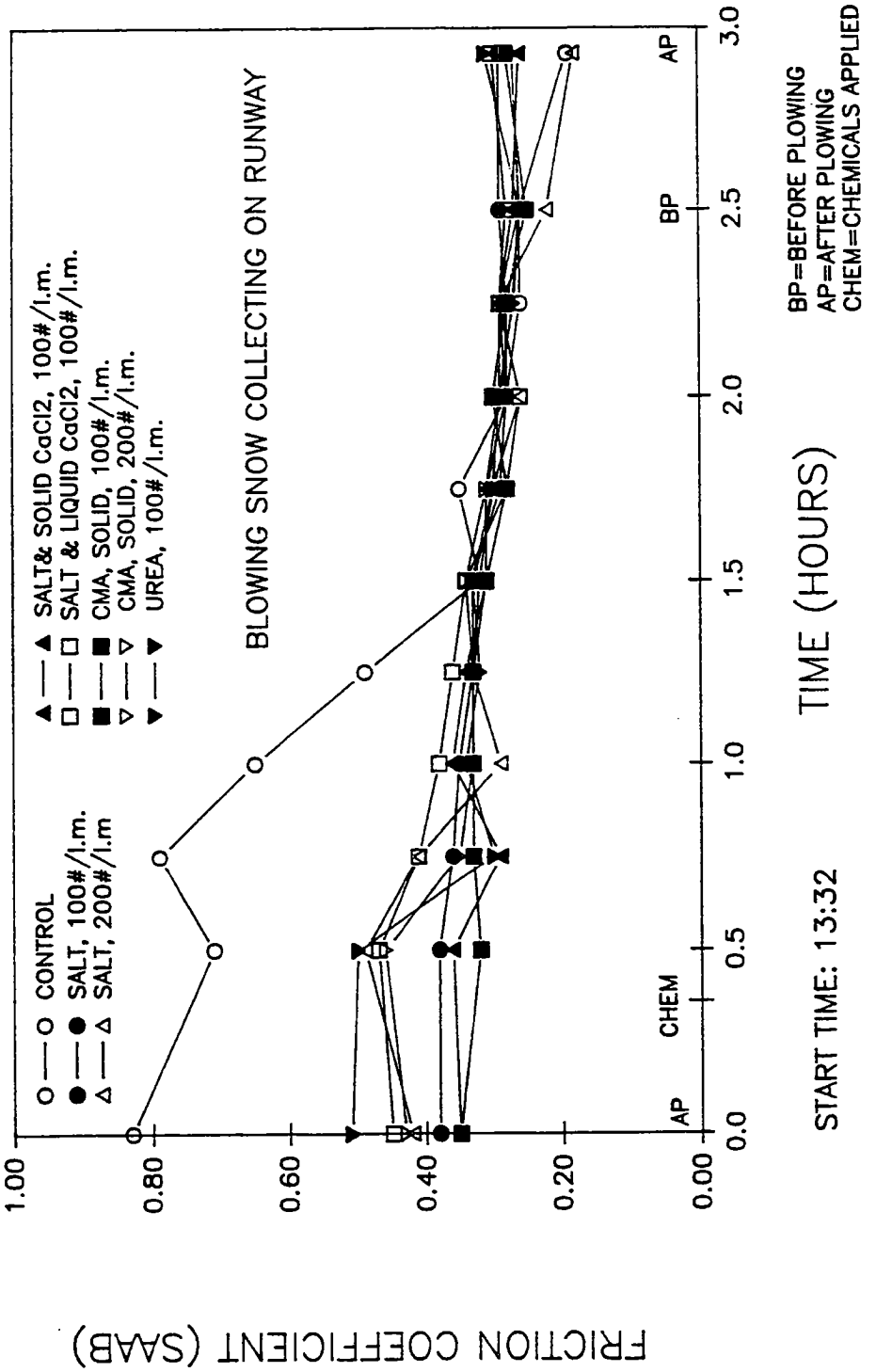
Friction Values --- 01-09-92 --- Liquids.



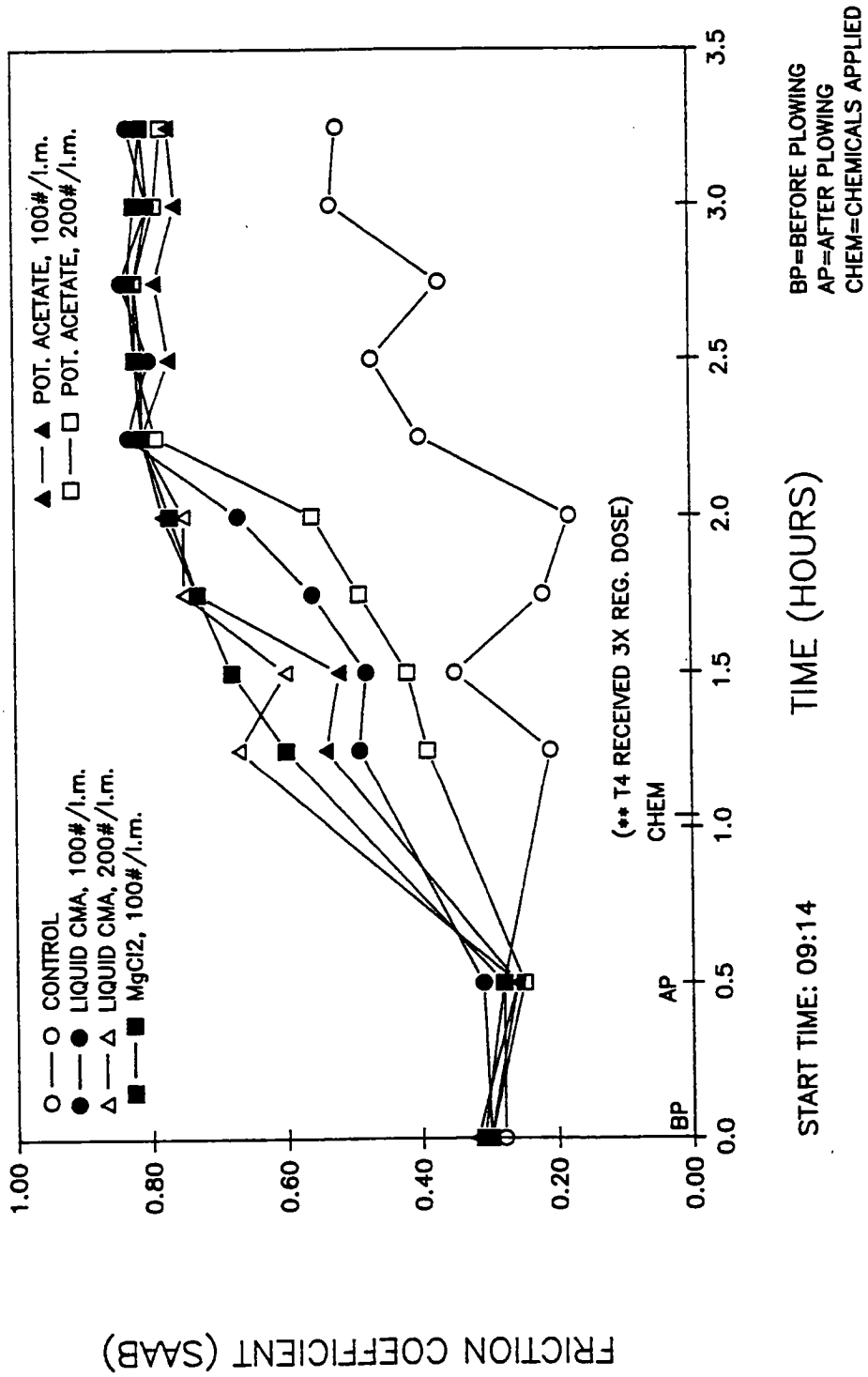
Friction Values --- 01-09-92 --- Solids.



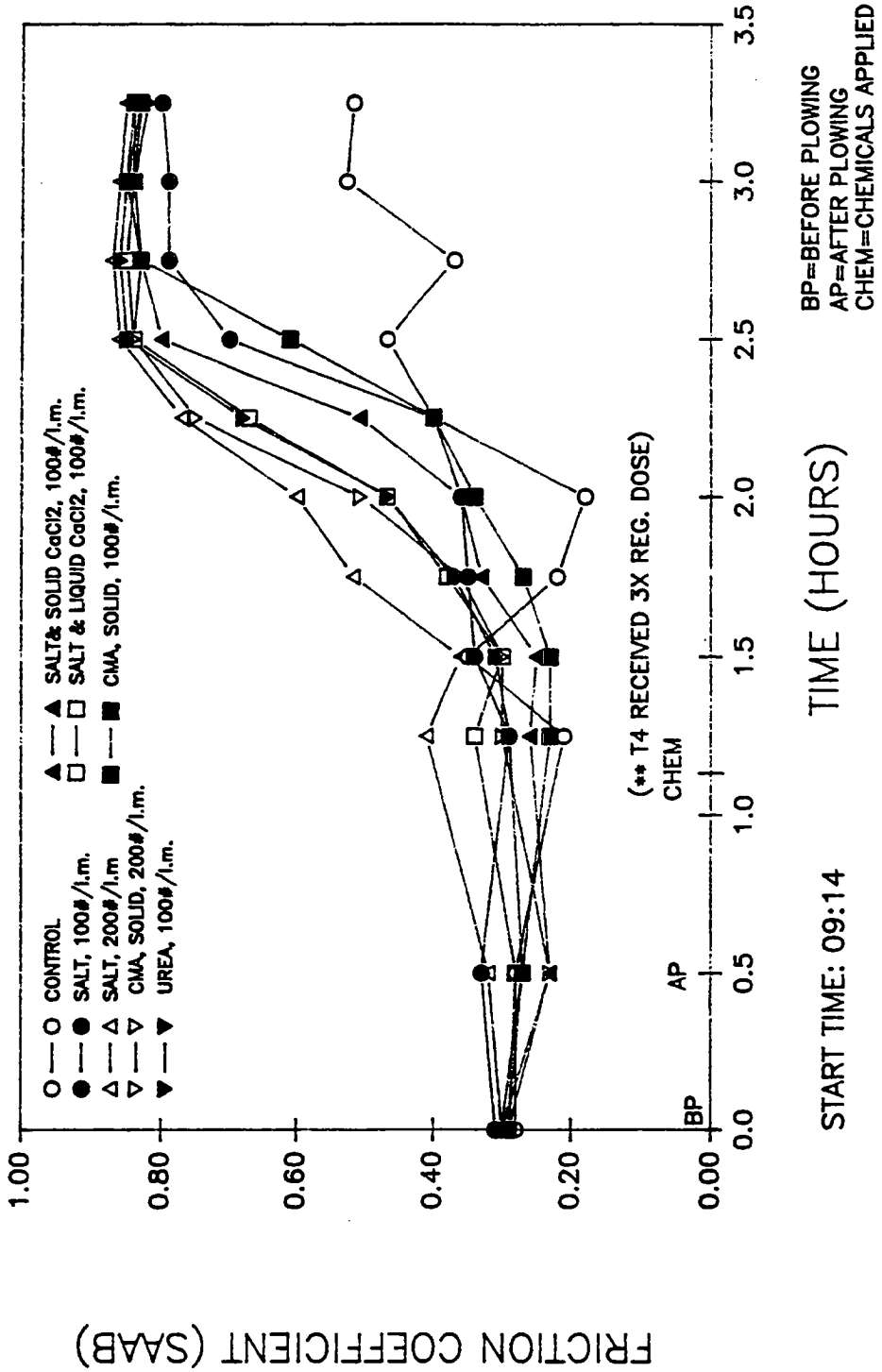
Friction Values --- 01-10-92 --- Liquids.



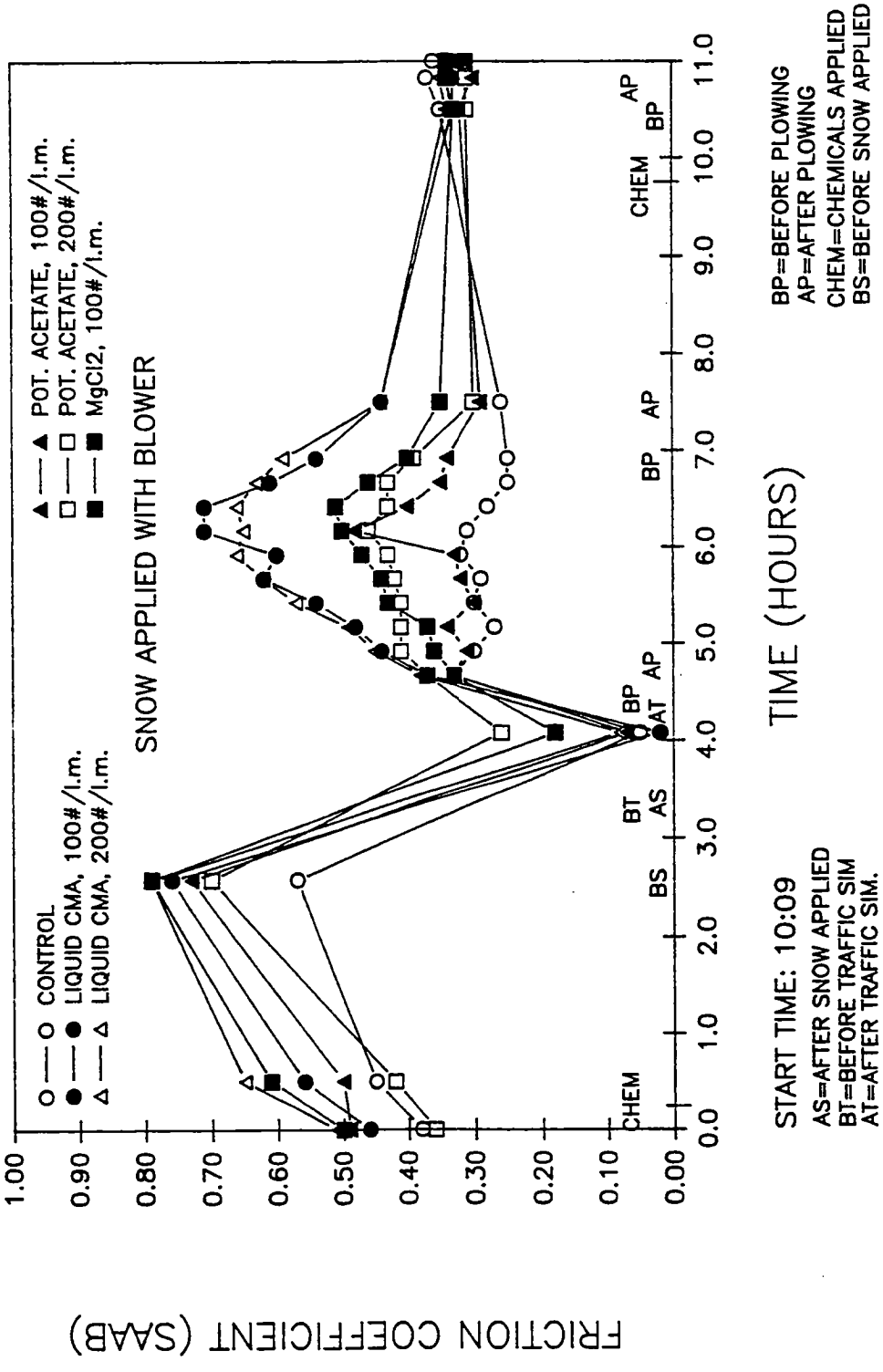
Friction Values --- 01-10-92 --- Solids.



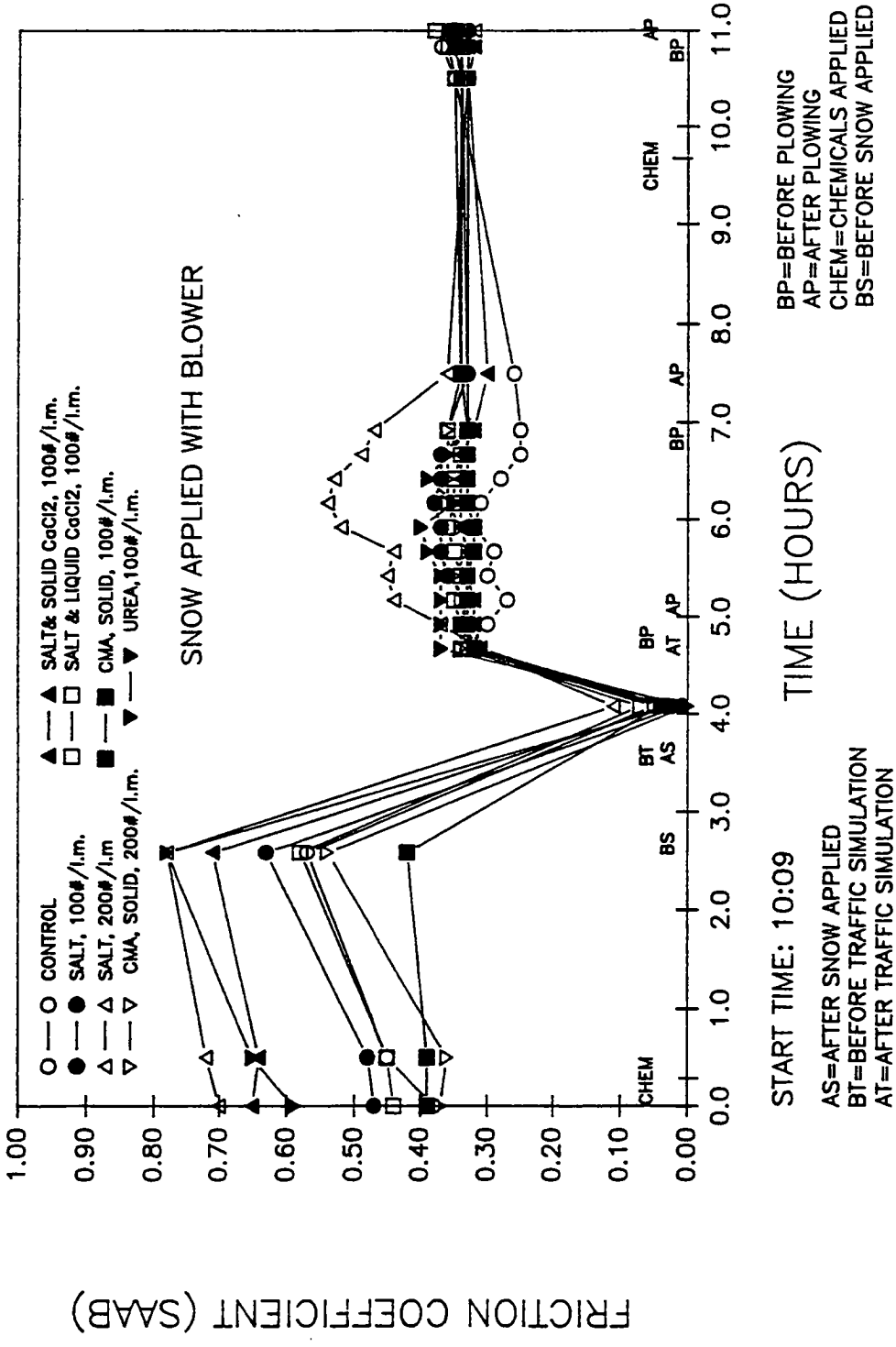
Friction Values --- 01-11-92 --- Liquids.



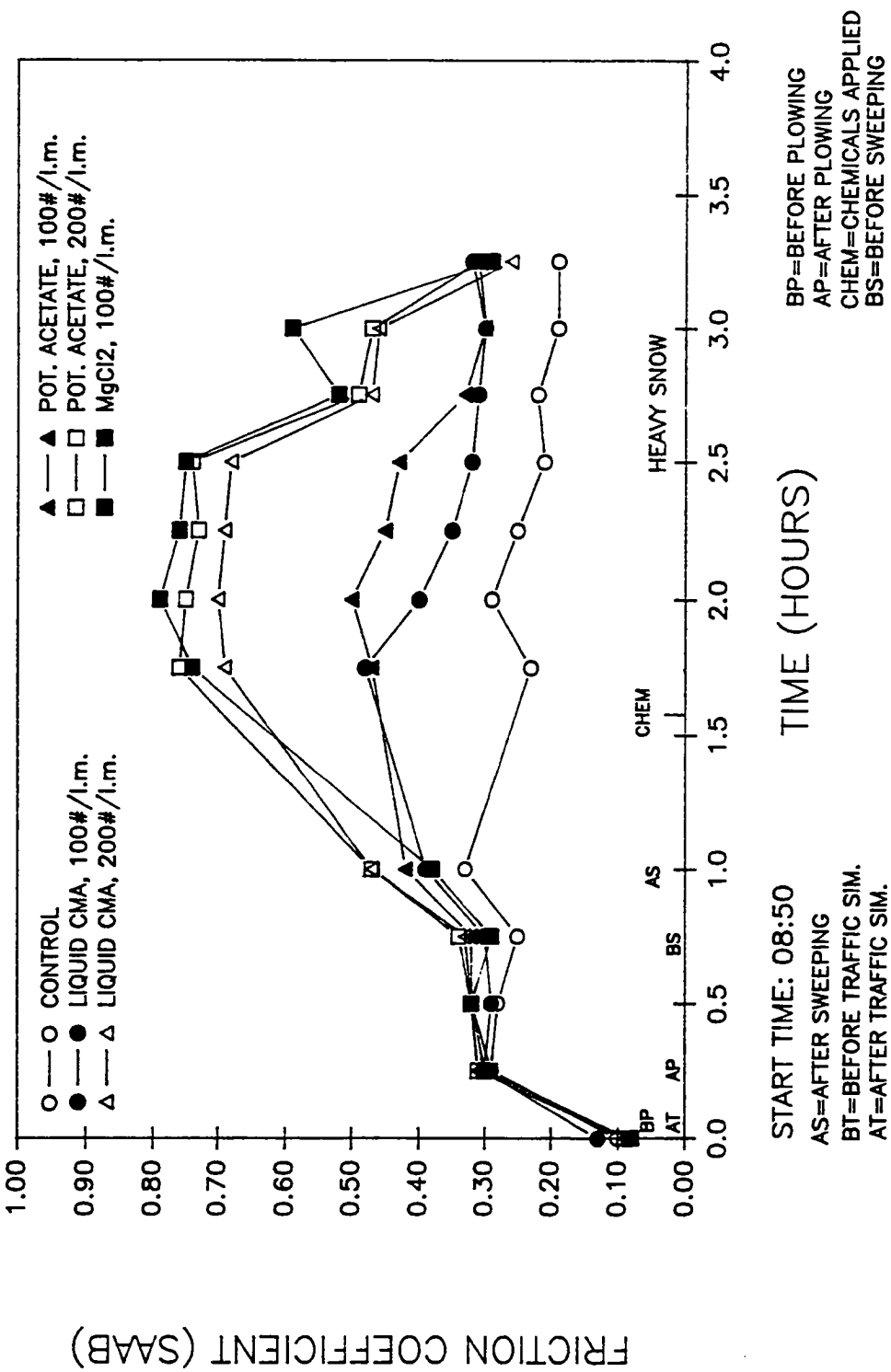
Friction Values --- 01-11-92 --- Solids.



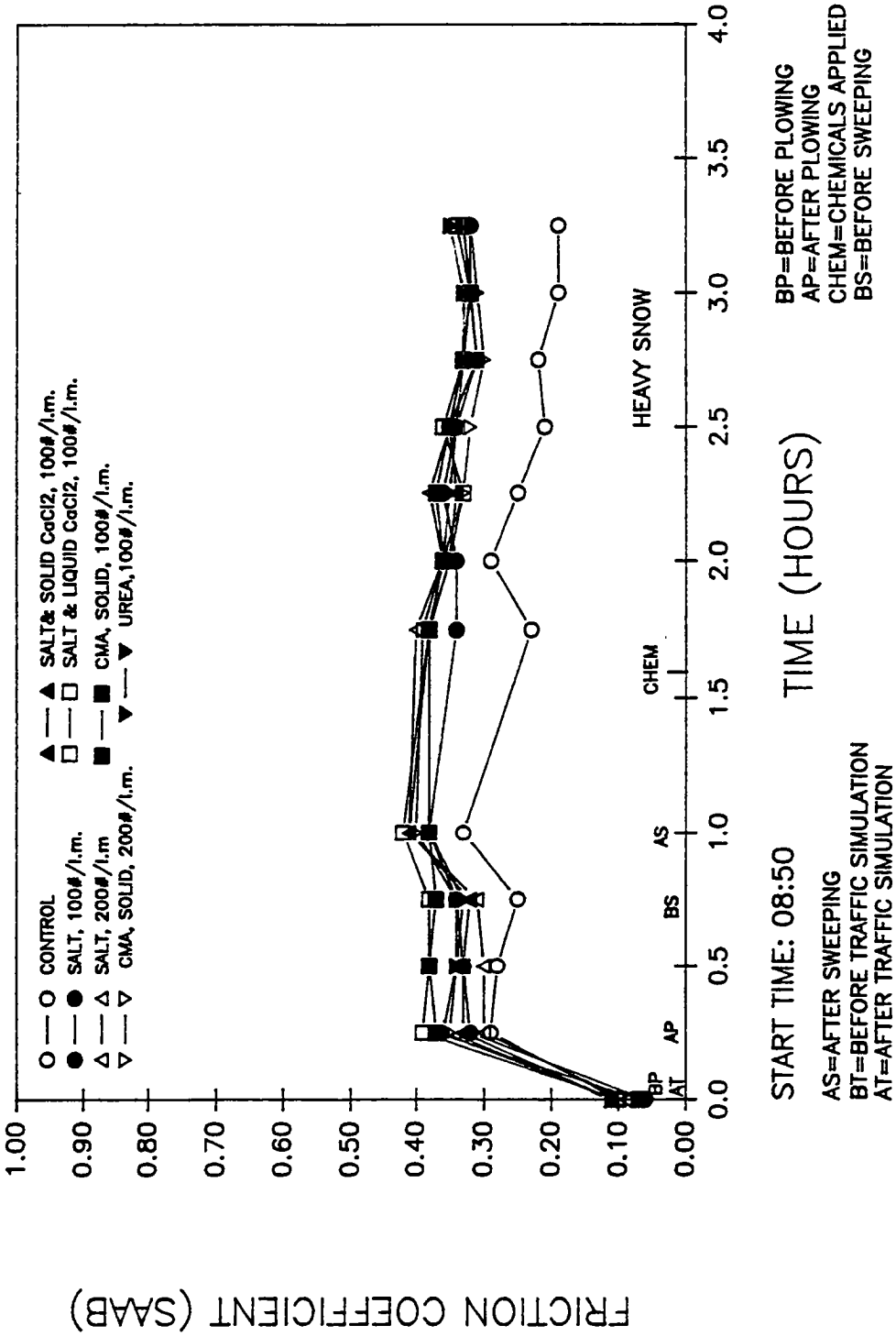
Friction Values --- 01-22-92 --- Liquids.



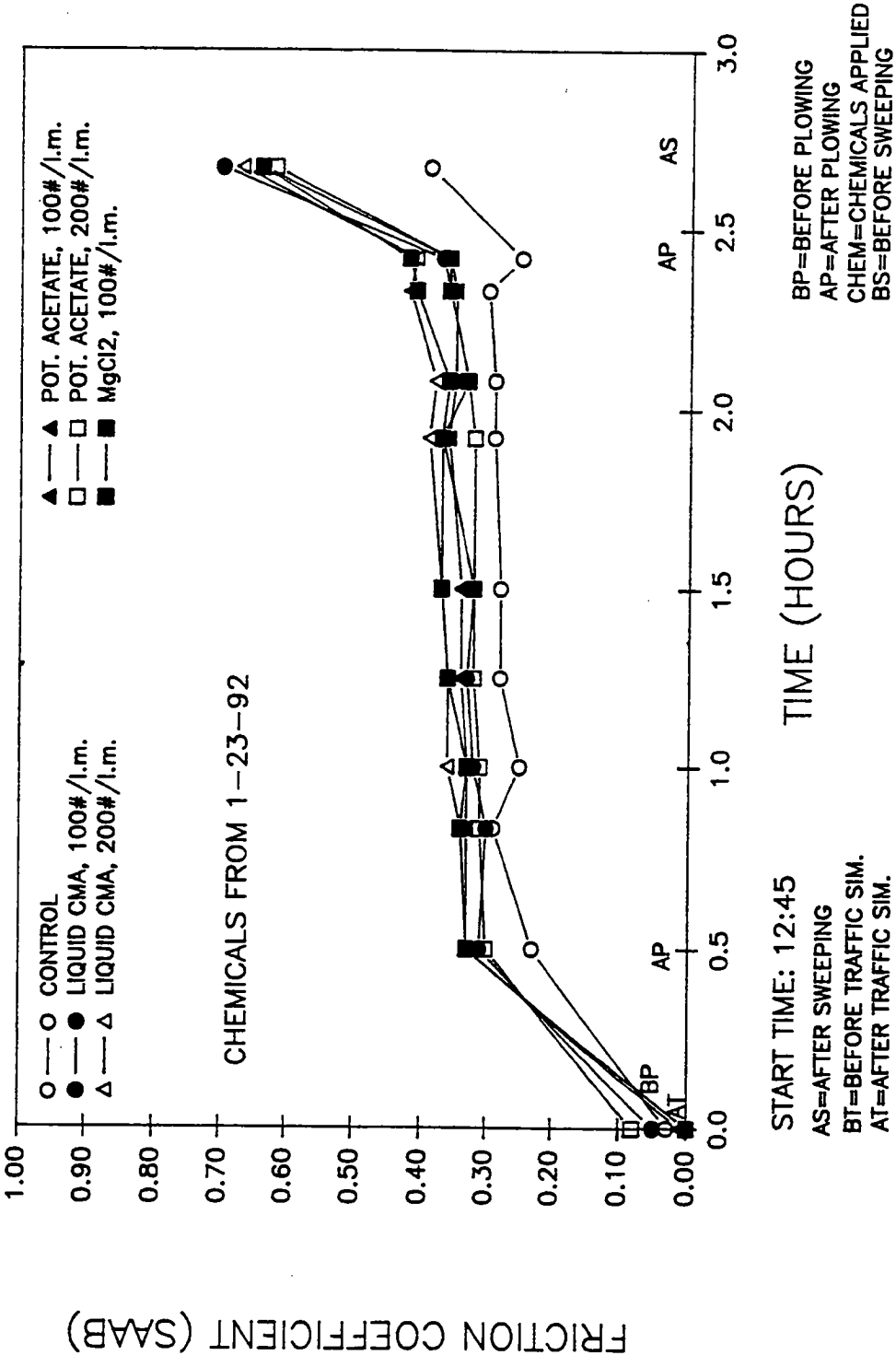
Friction Values --- 01-22-92 --- Solids.



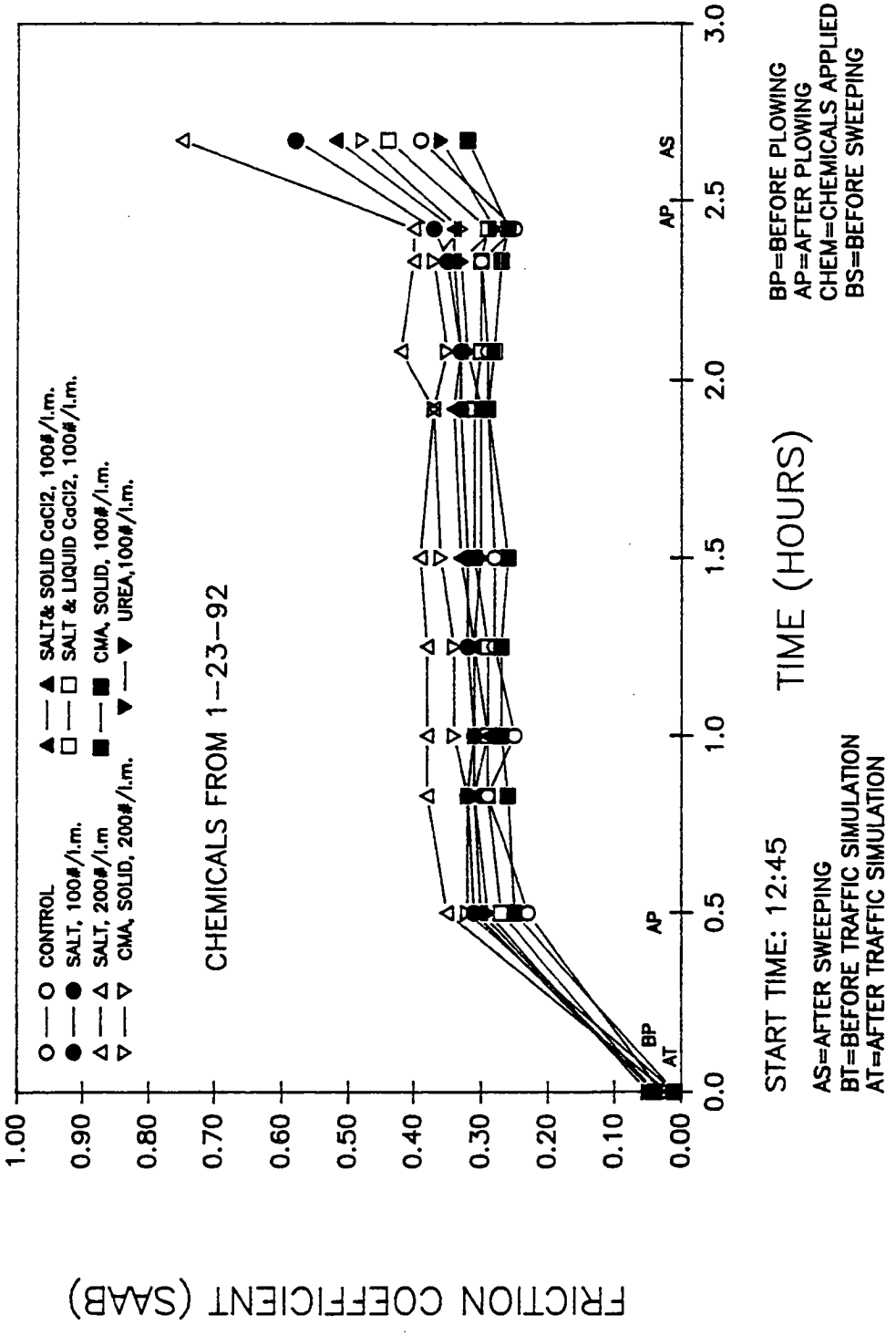
Friction Values --- 01-23-92 --- Liquids.



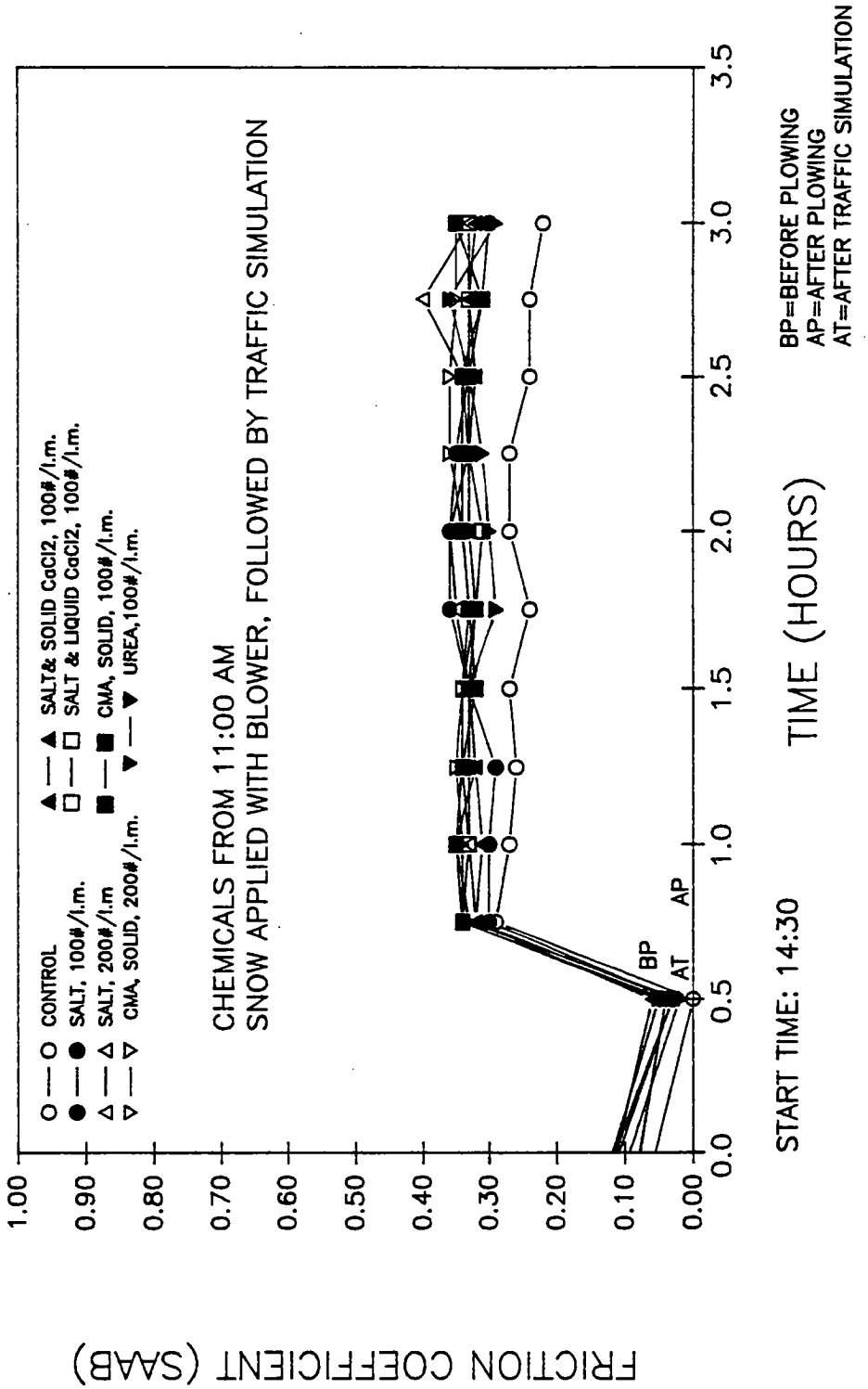
Friction Values --- 01-23-92 --- Solids.



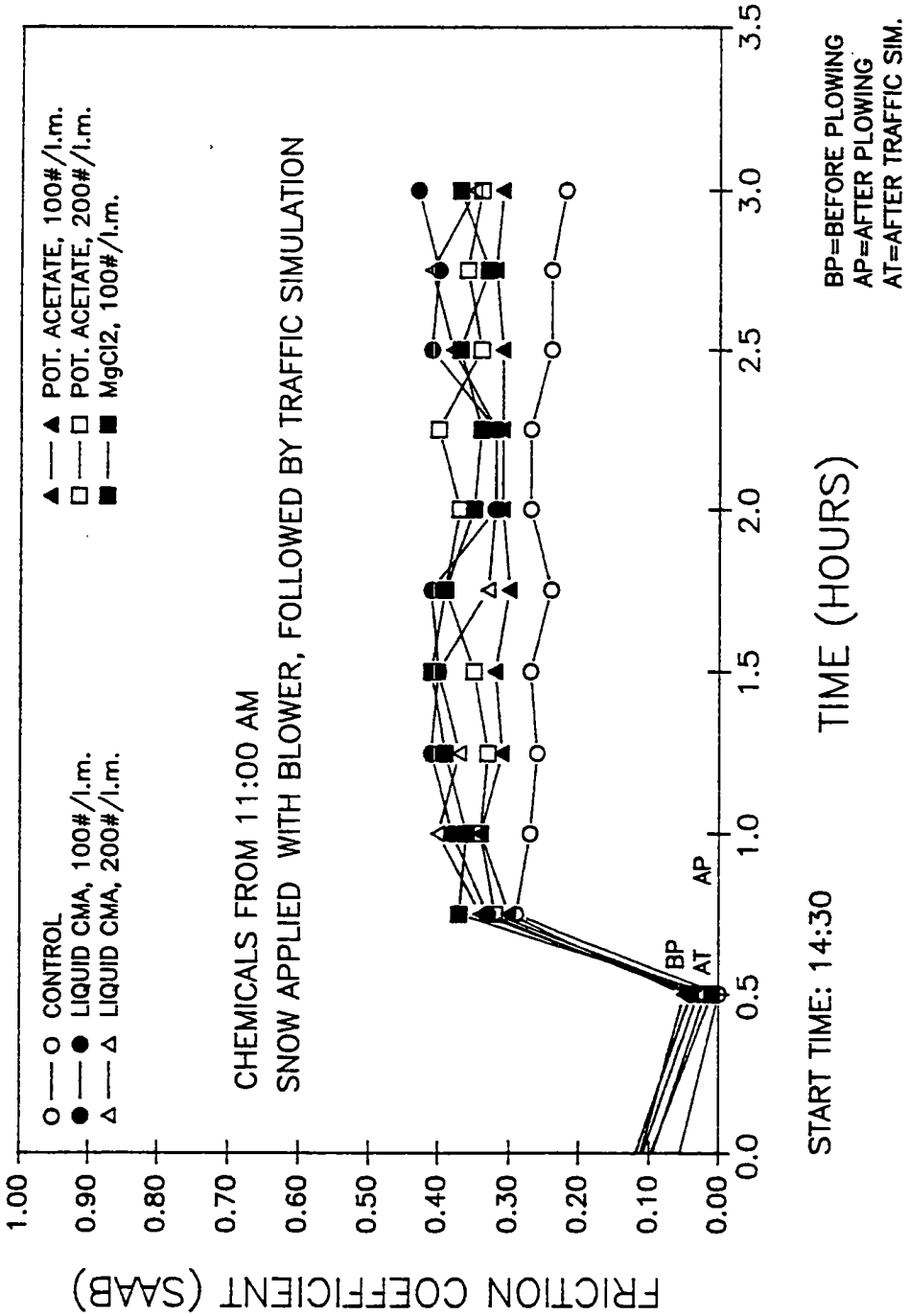
Friction Values --- 01-27-92 --- Liquids.



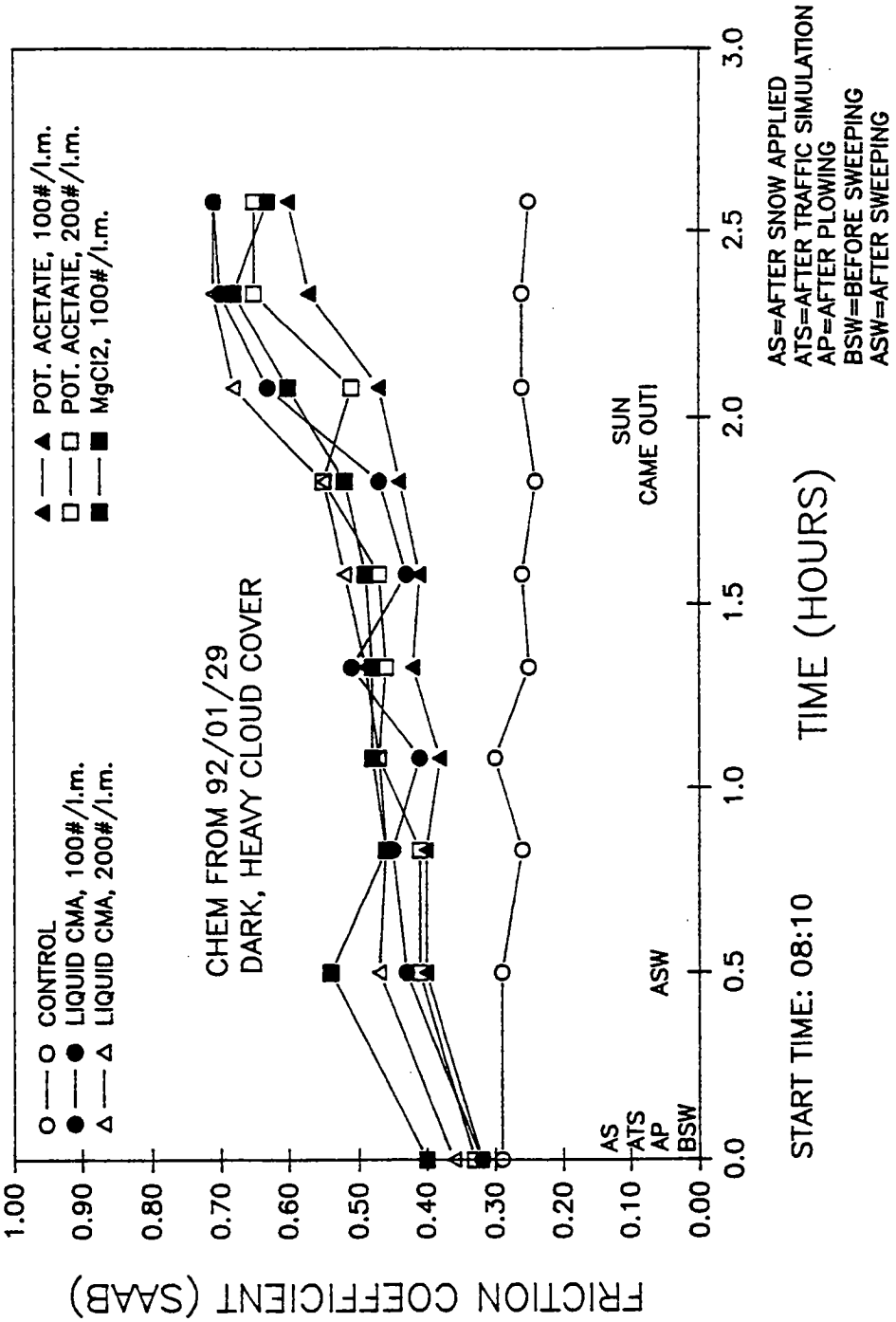
Friction Values --- 01-27-92 --- Solids.



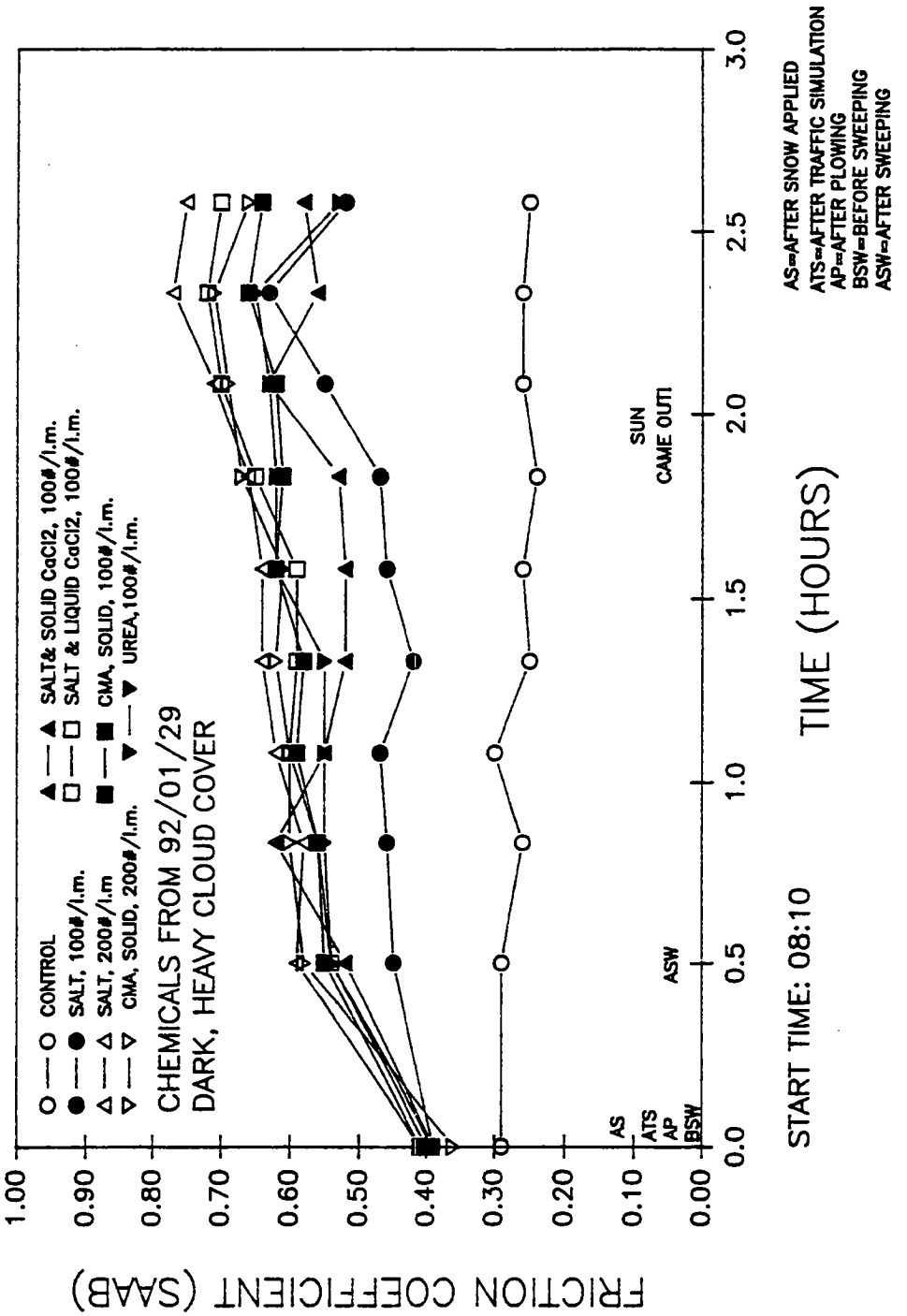
Friction Values --- 01-28-92 --- Liquids.



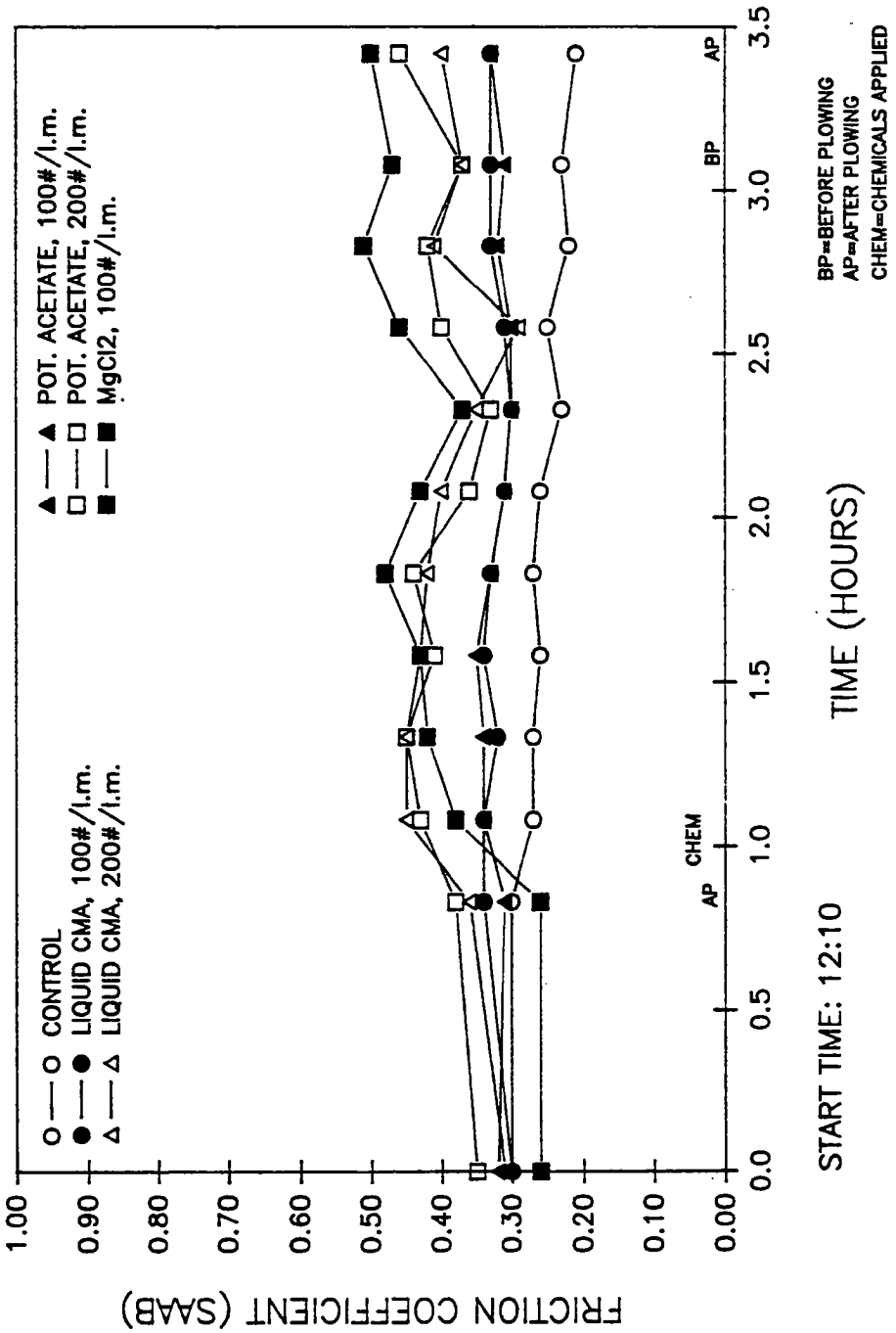
Friction Values --- 01-28-92 --- Solids.



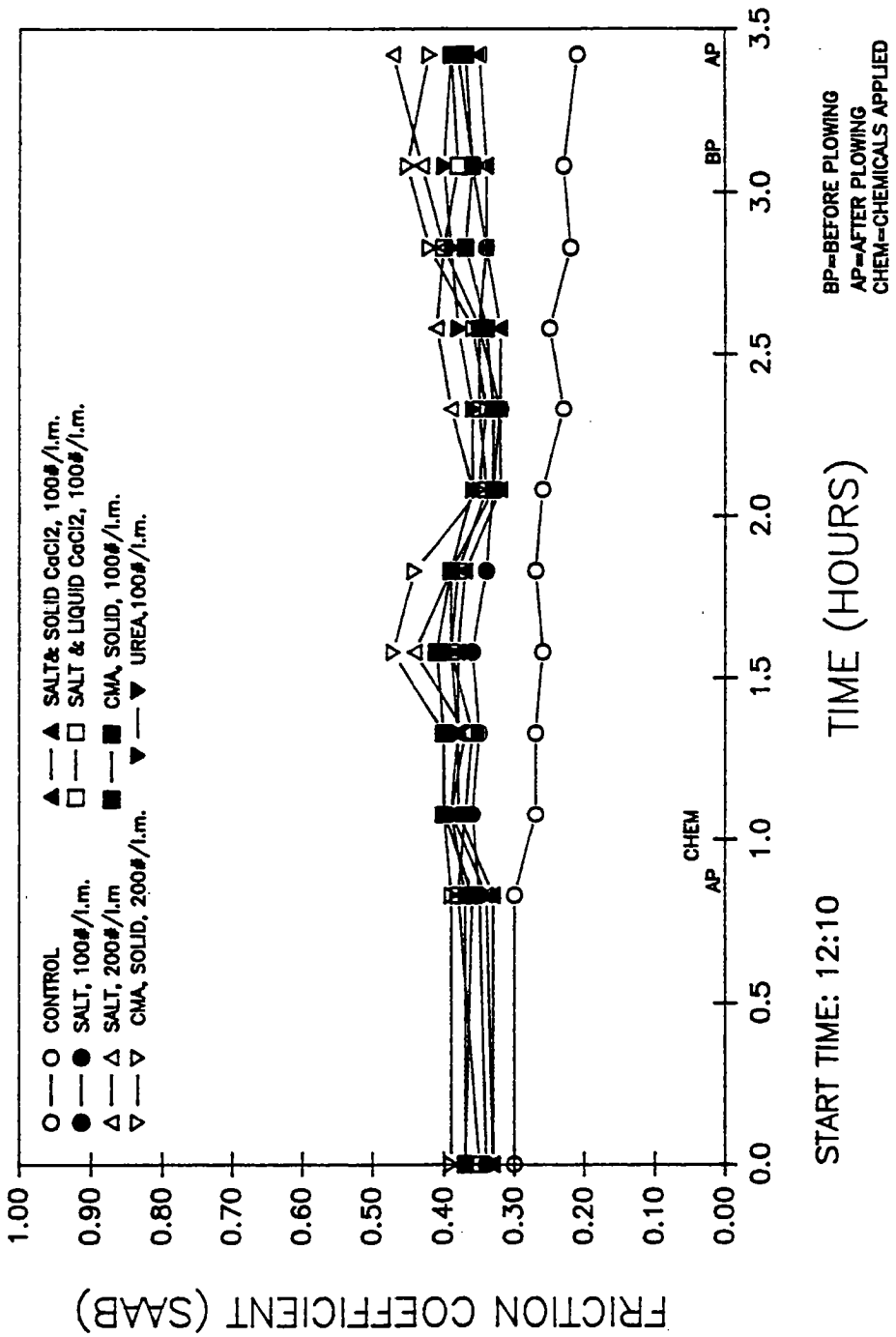
Friction Values --- 01-30-92 --- Liquids.



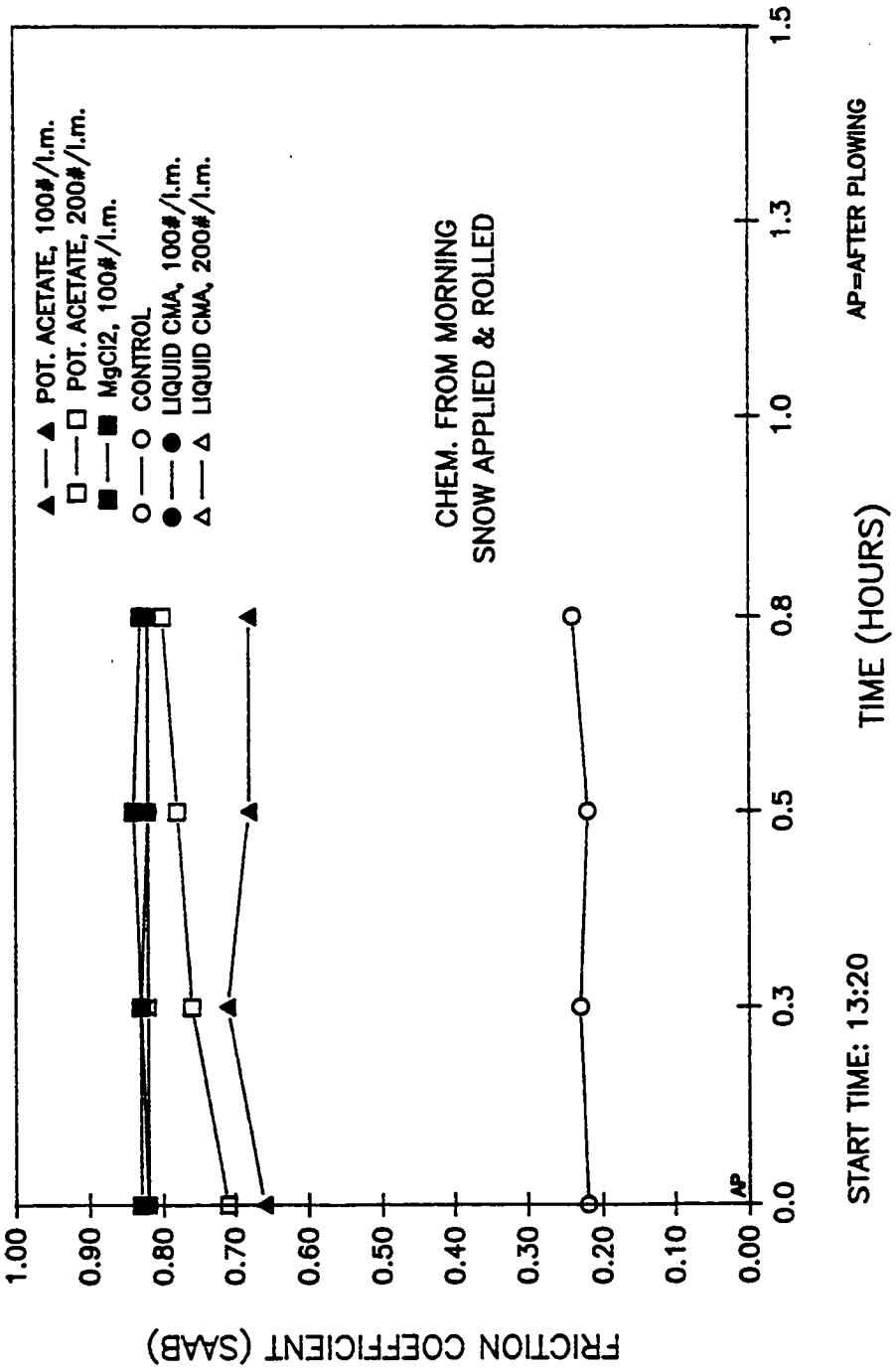
Friction Values --- 01-30-92 --- Solids.



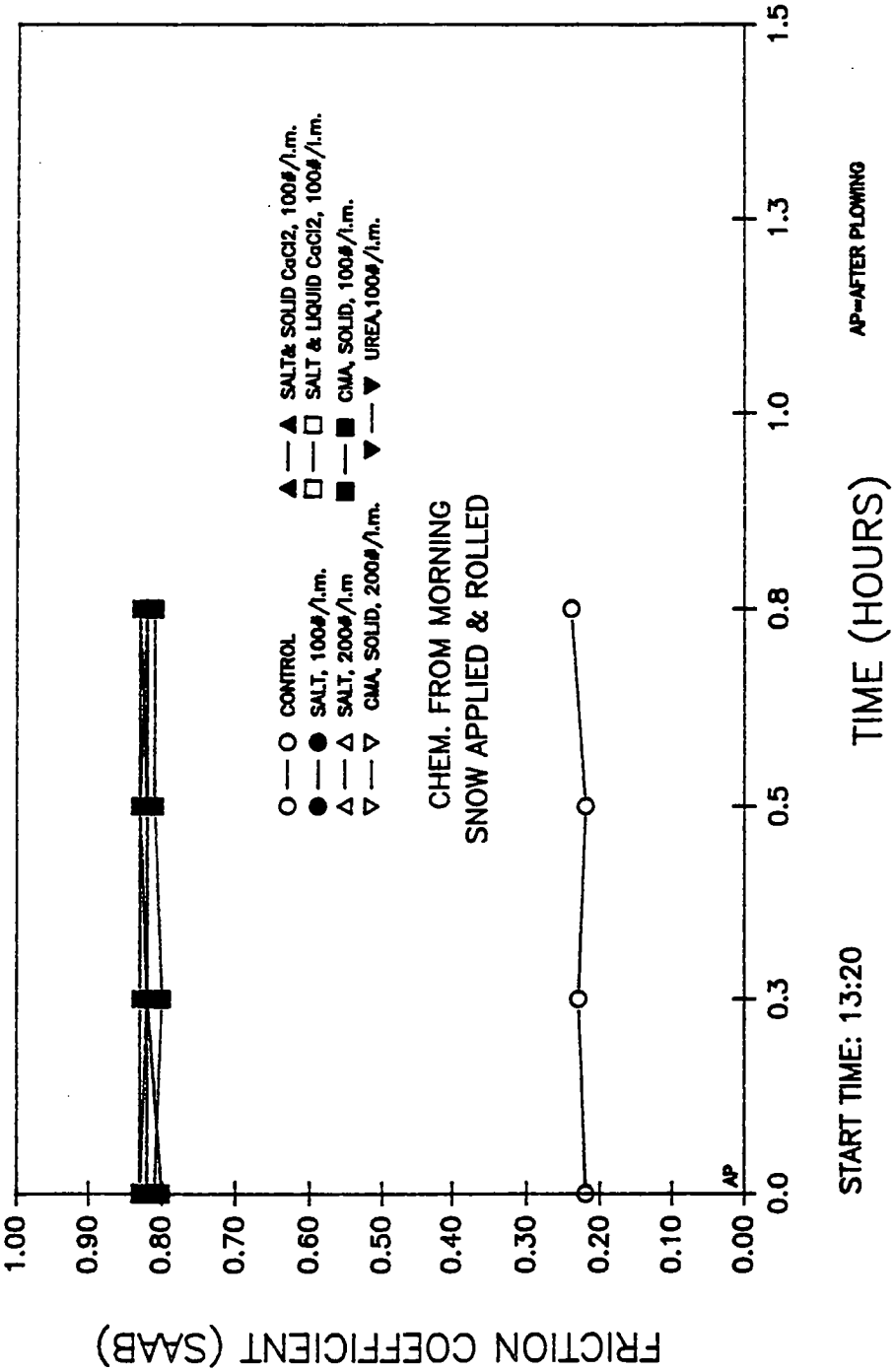
Friction Values --- 01-31-92 --- Liquids.



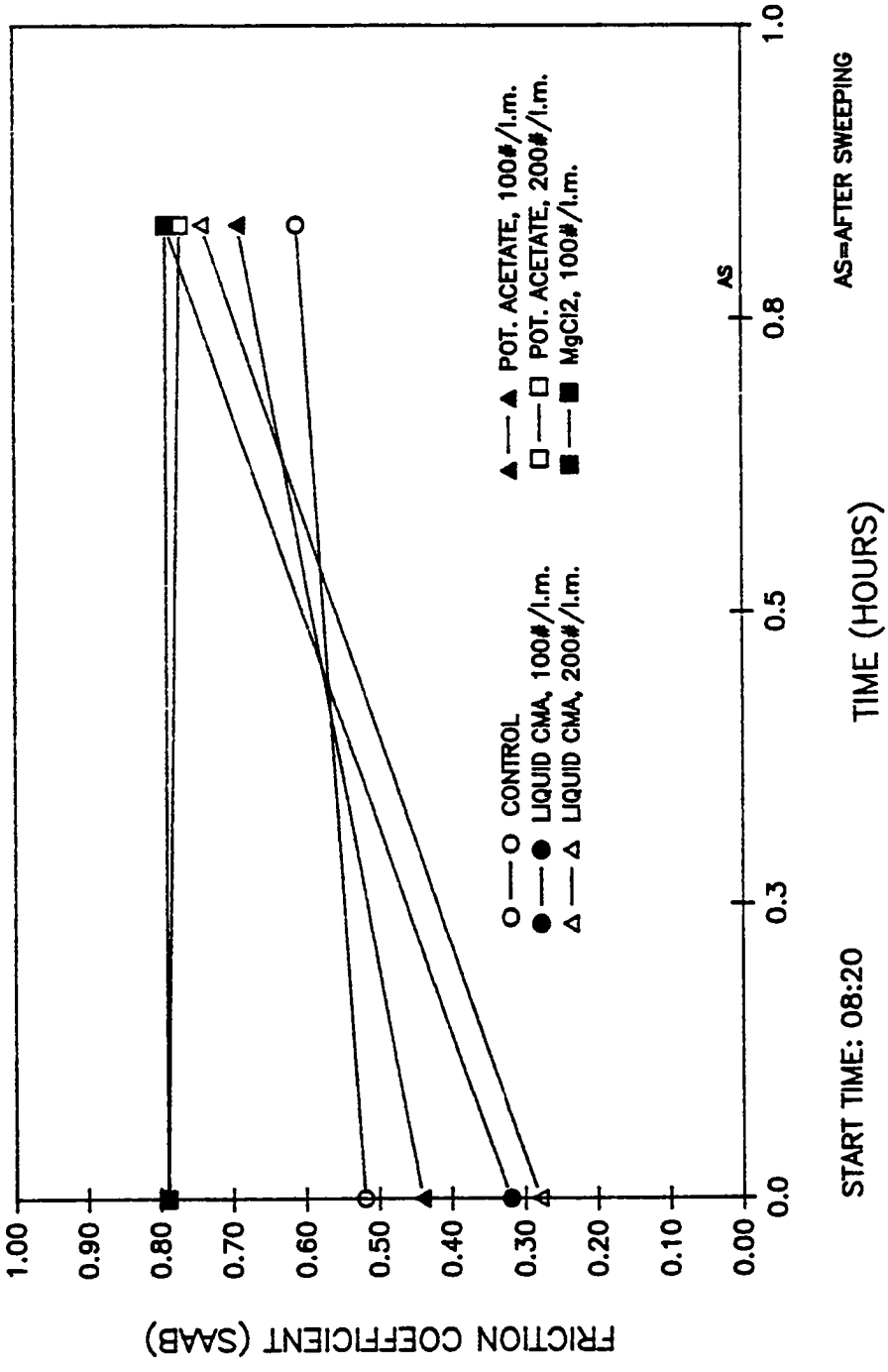
Friction Values --- 01-31-92 --- Solids.



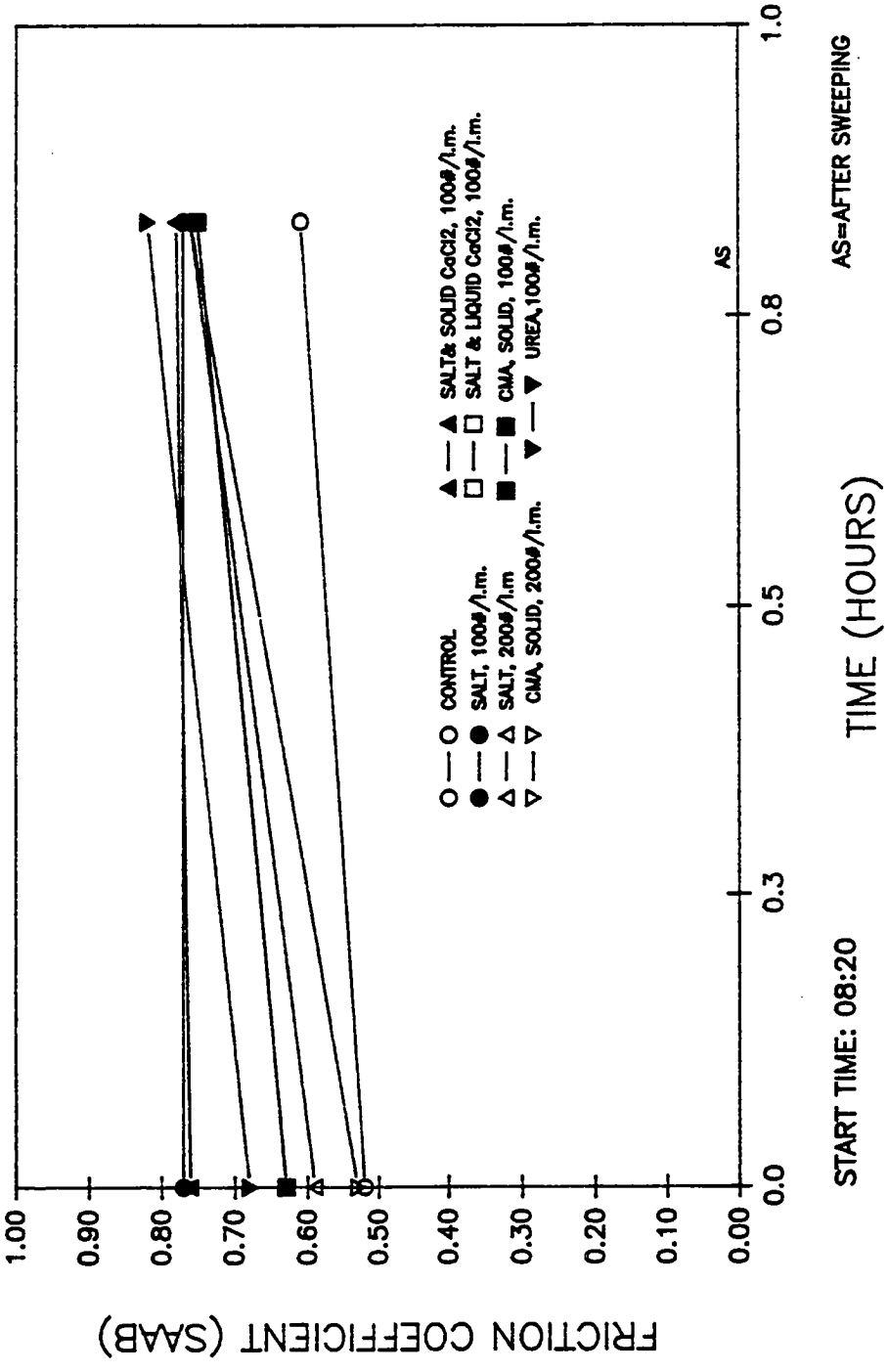
Friction Values --- 02-03-92 --- Liquids.



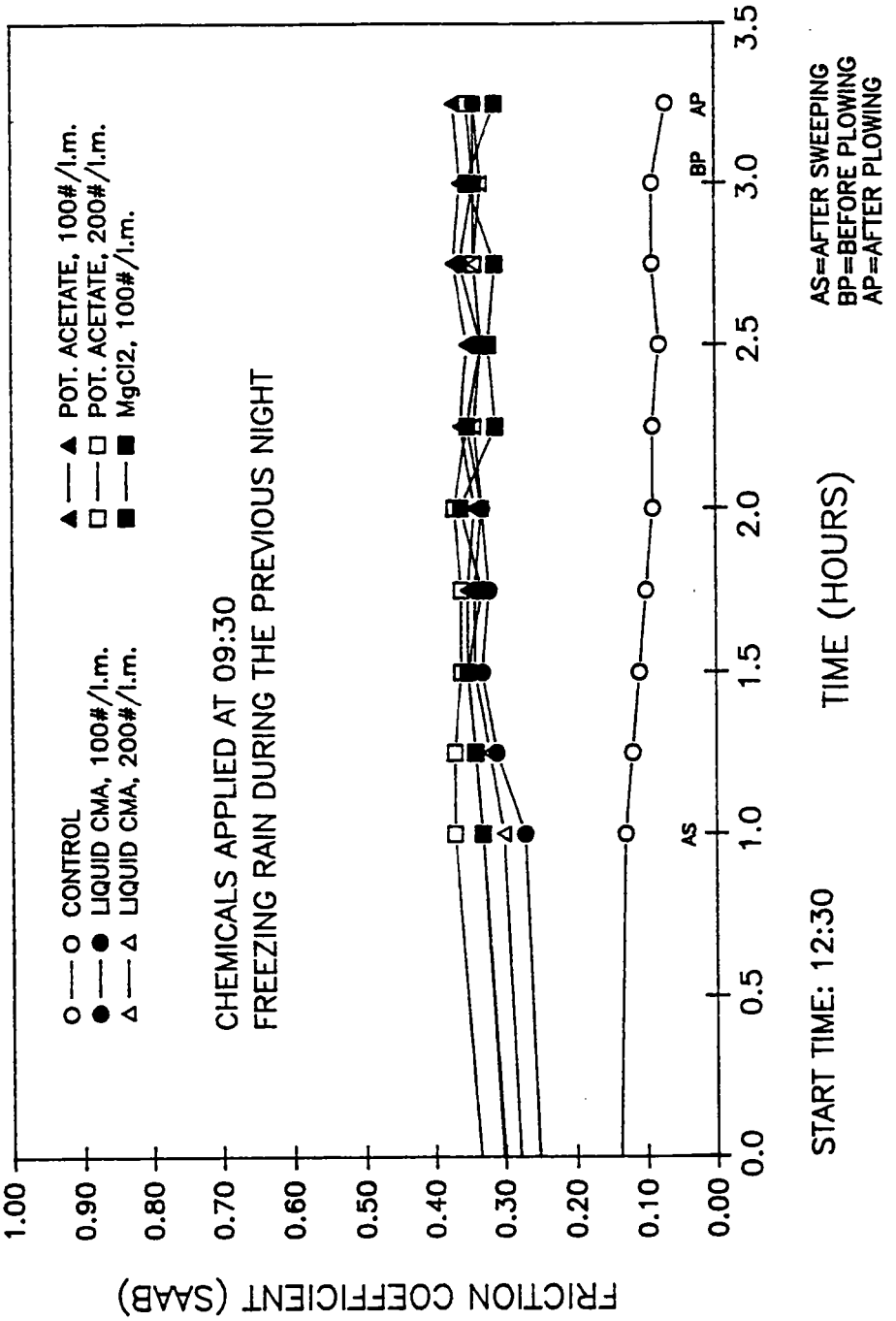
Friction Values --- 02-03-92 --- Solids.



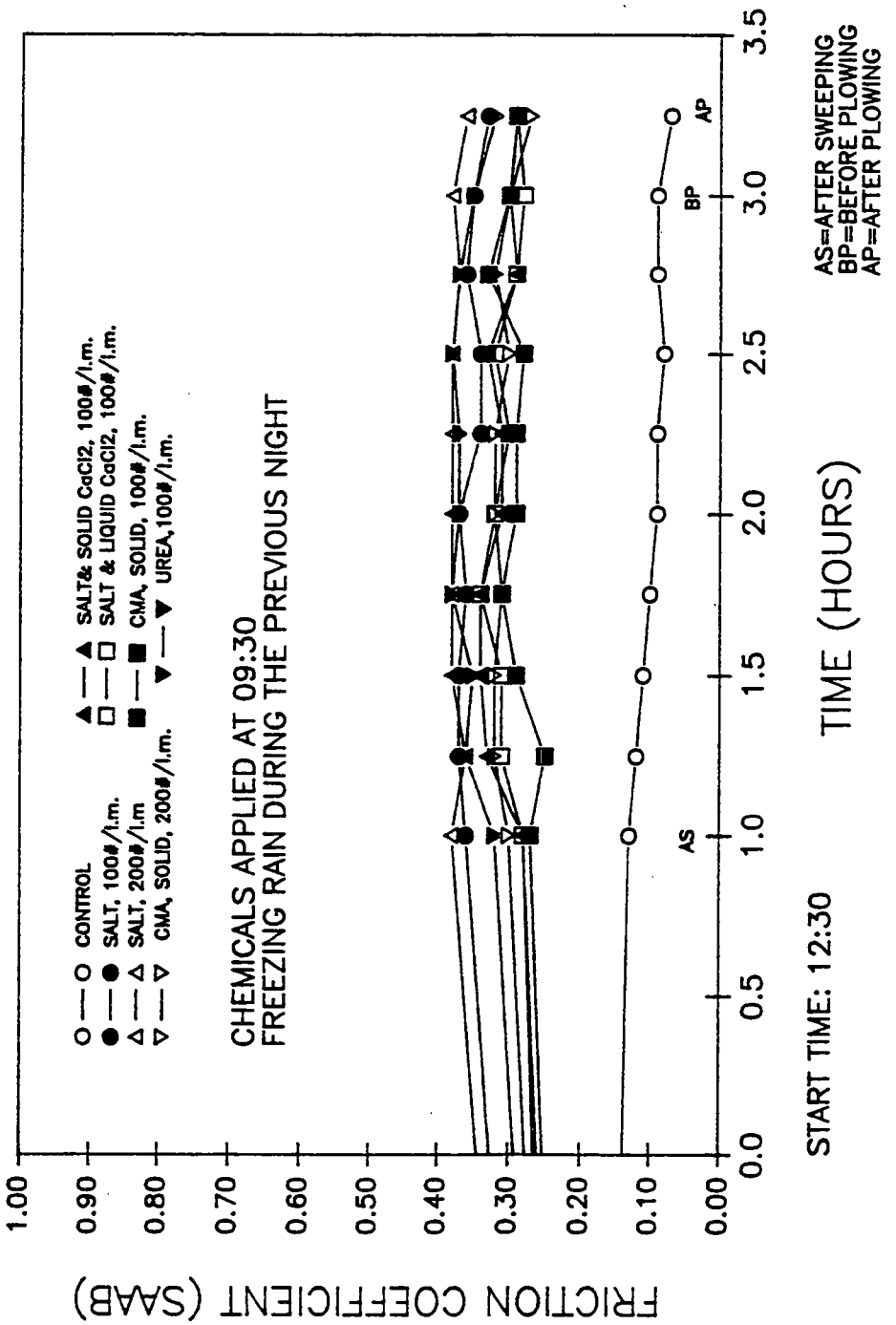
Friction Values --- 02-05-92 --- Liquids.



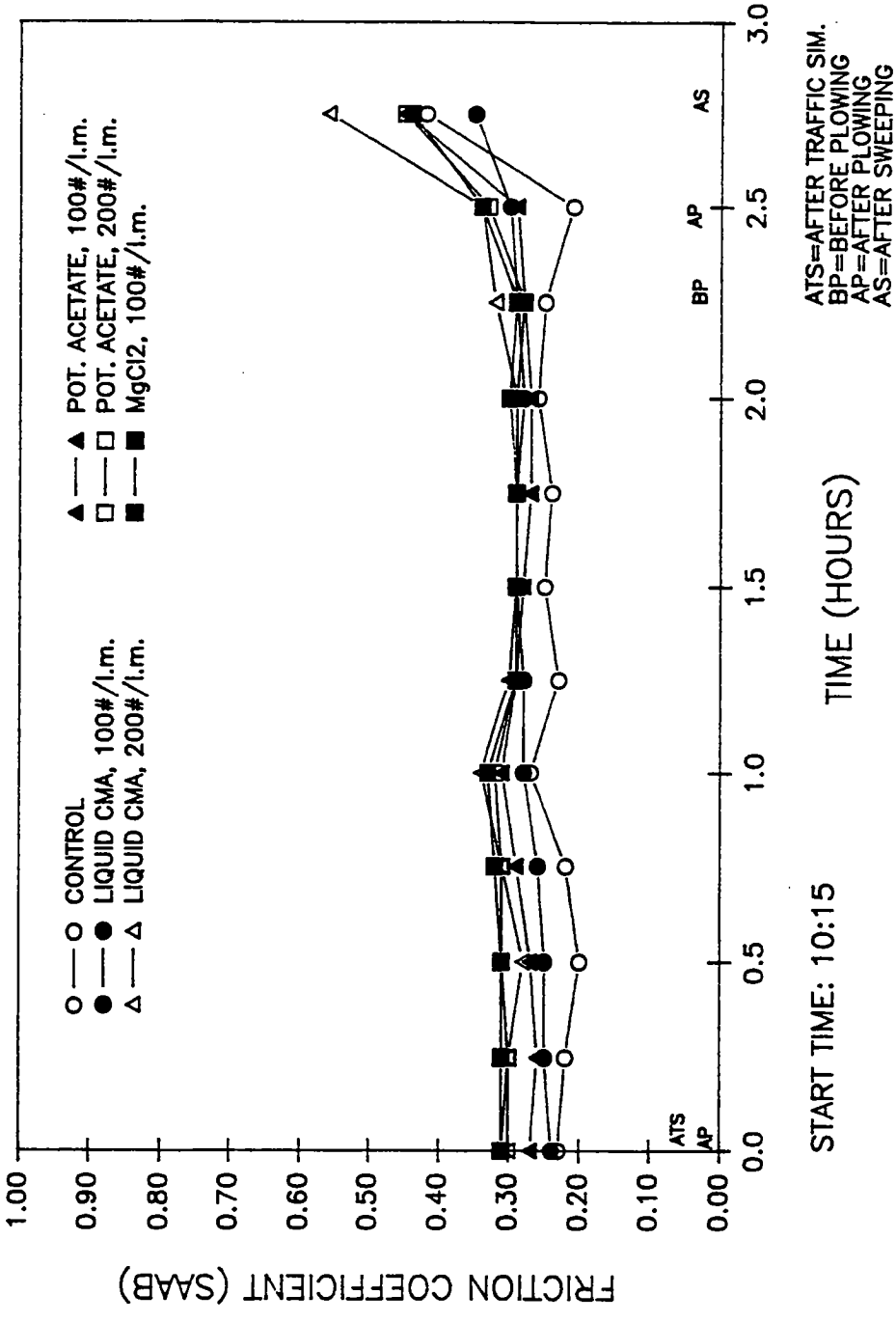
Friction Values --- 02-05-92 --- Solids.



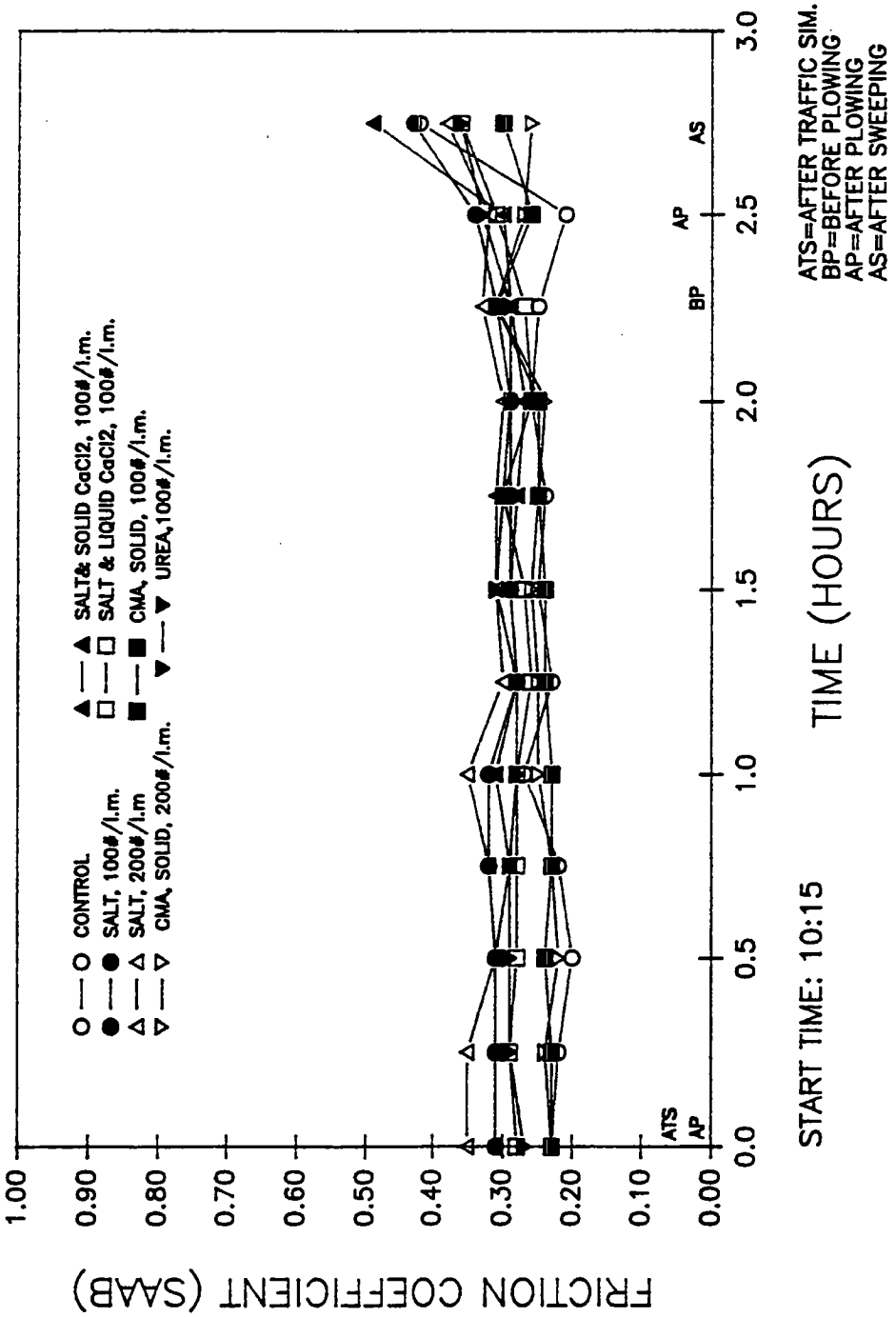
Friction Values --- 02-06-92 --- Liquids.



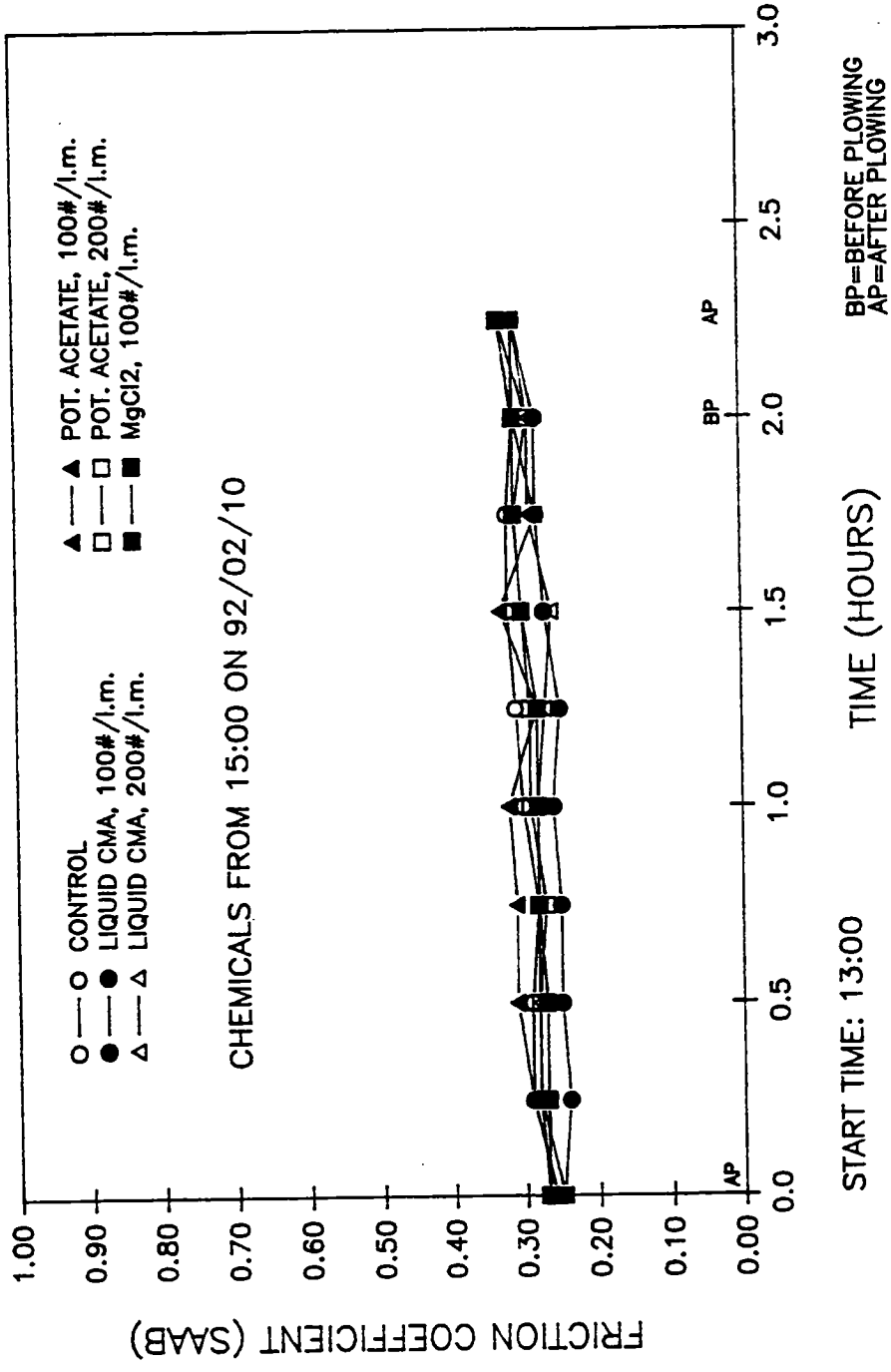
Friction Values --- 02-06-92 --- Solids.



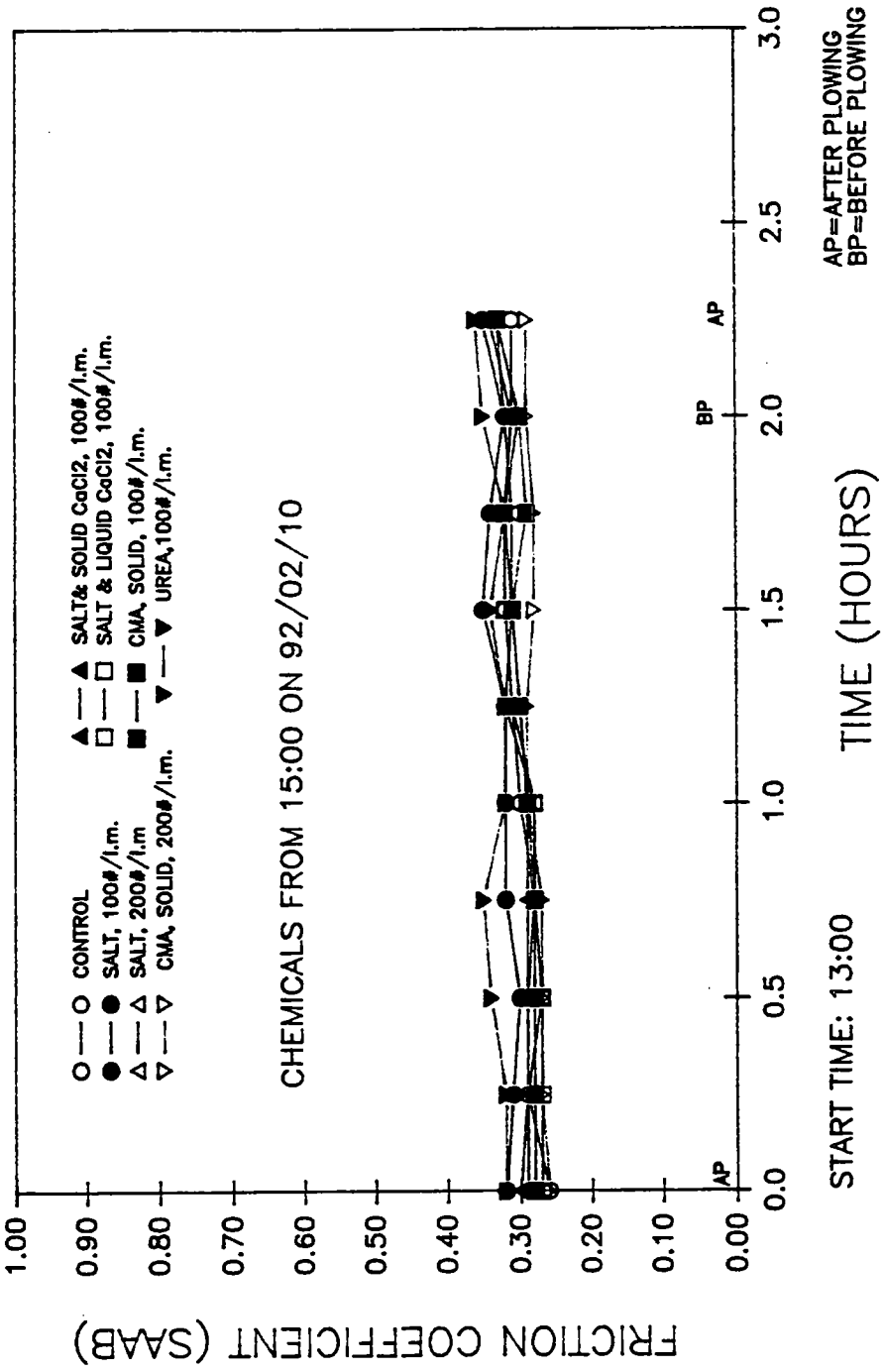
Friction Values --- 02-10-92 --- Liquids.



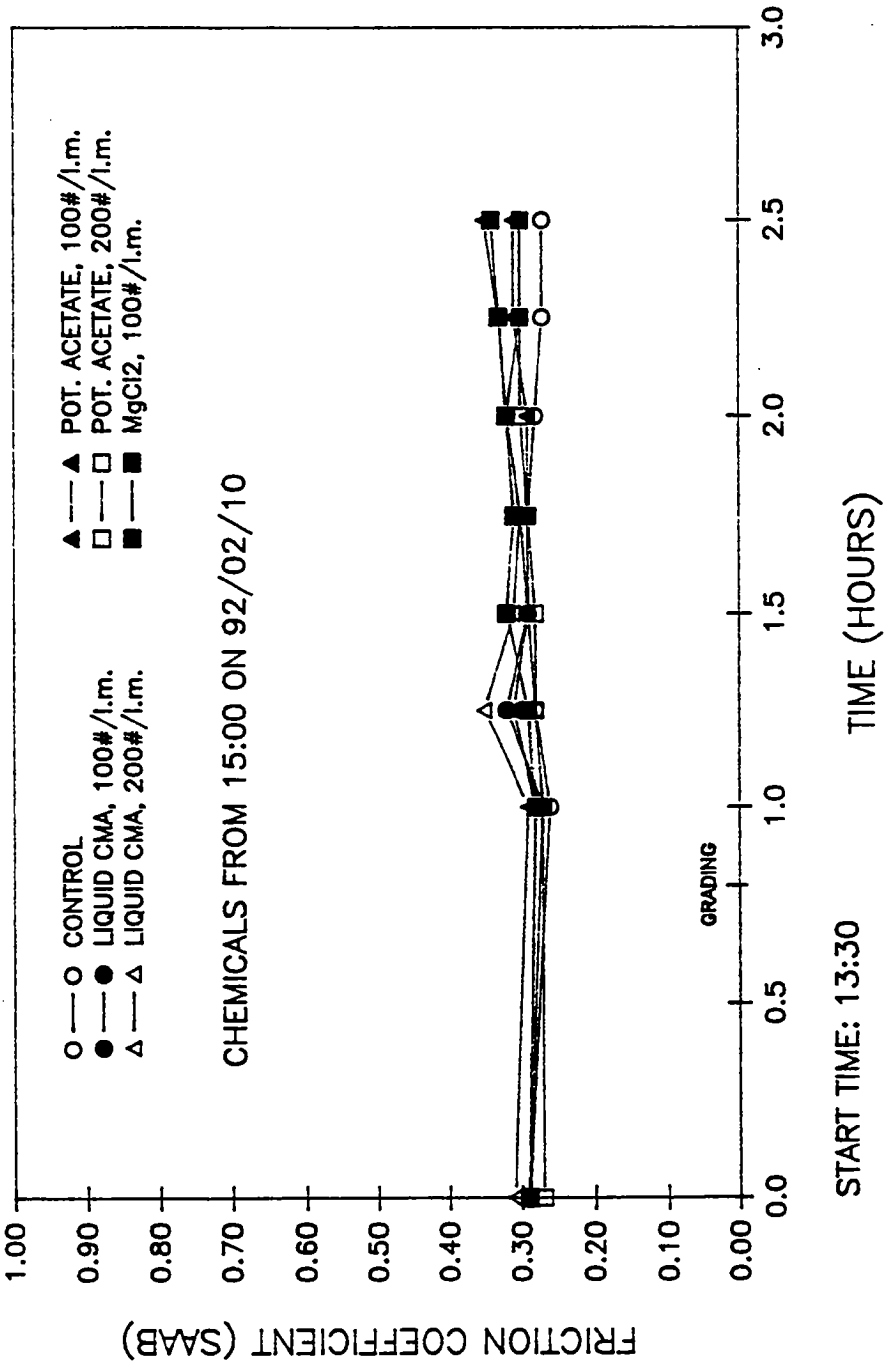
Friction Values --- 02-10-92 --- Solids.



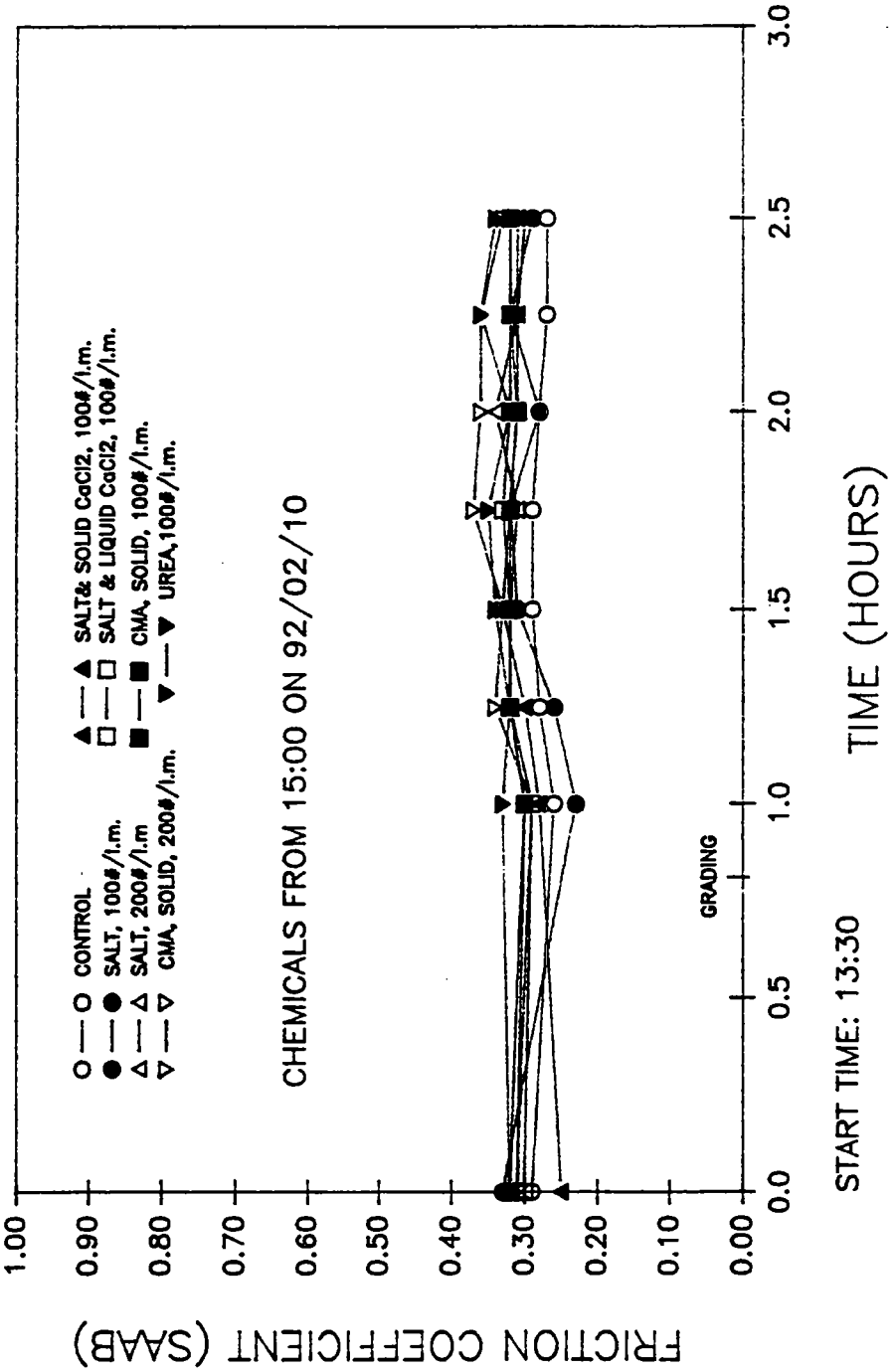
Friction Values --- 02-11-92 --- Liquids.



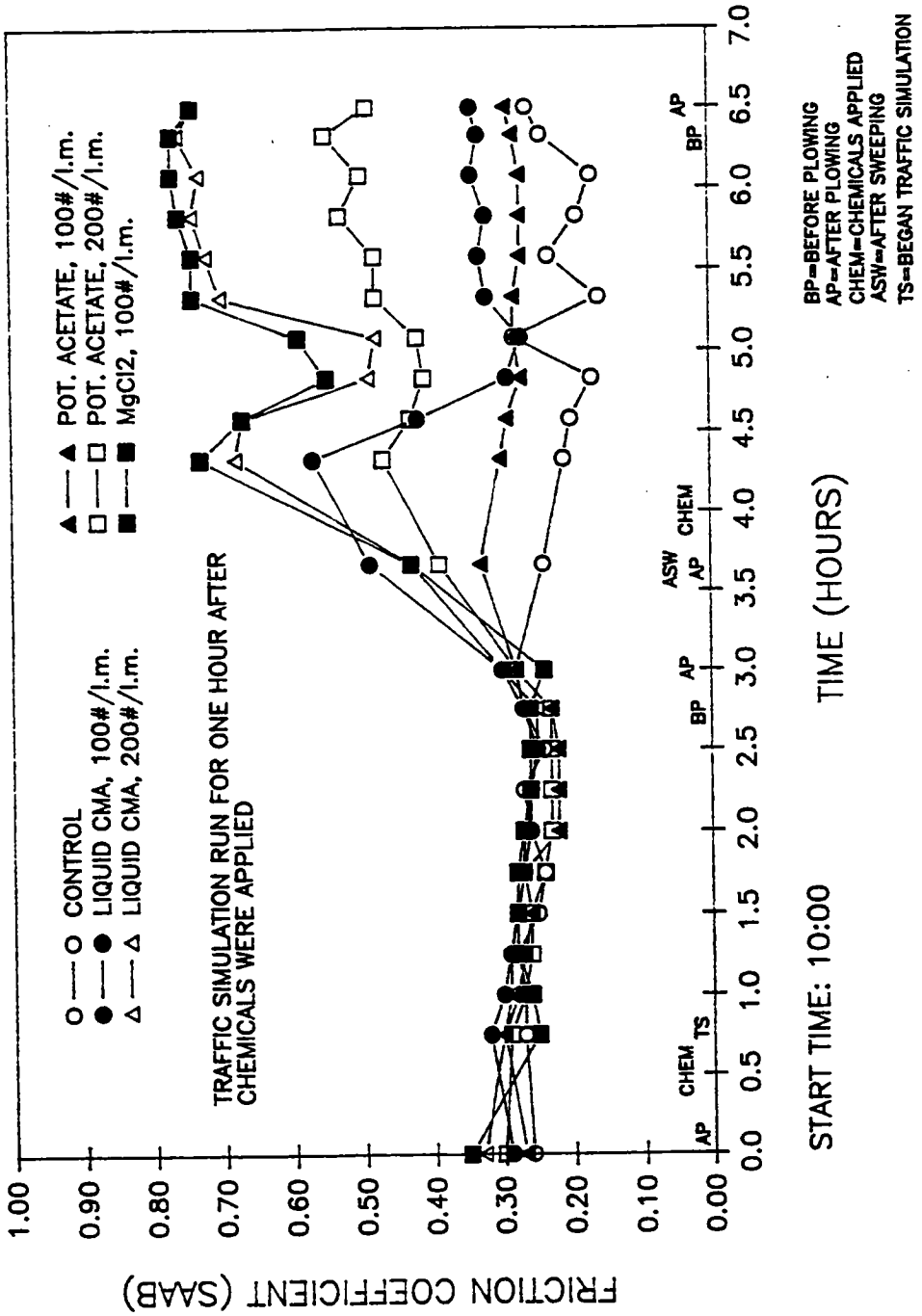
Friction Values --- 02-11-92 --- Solids.



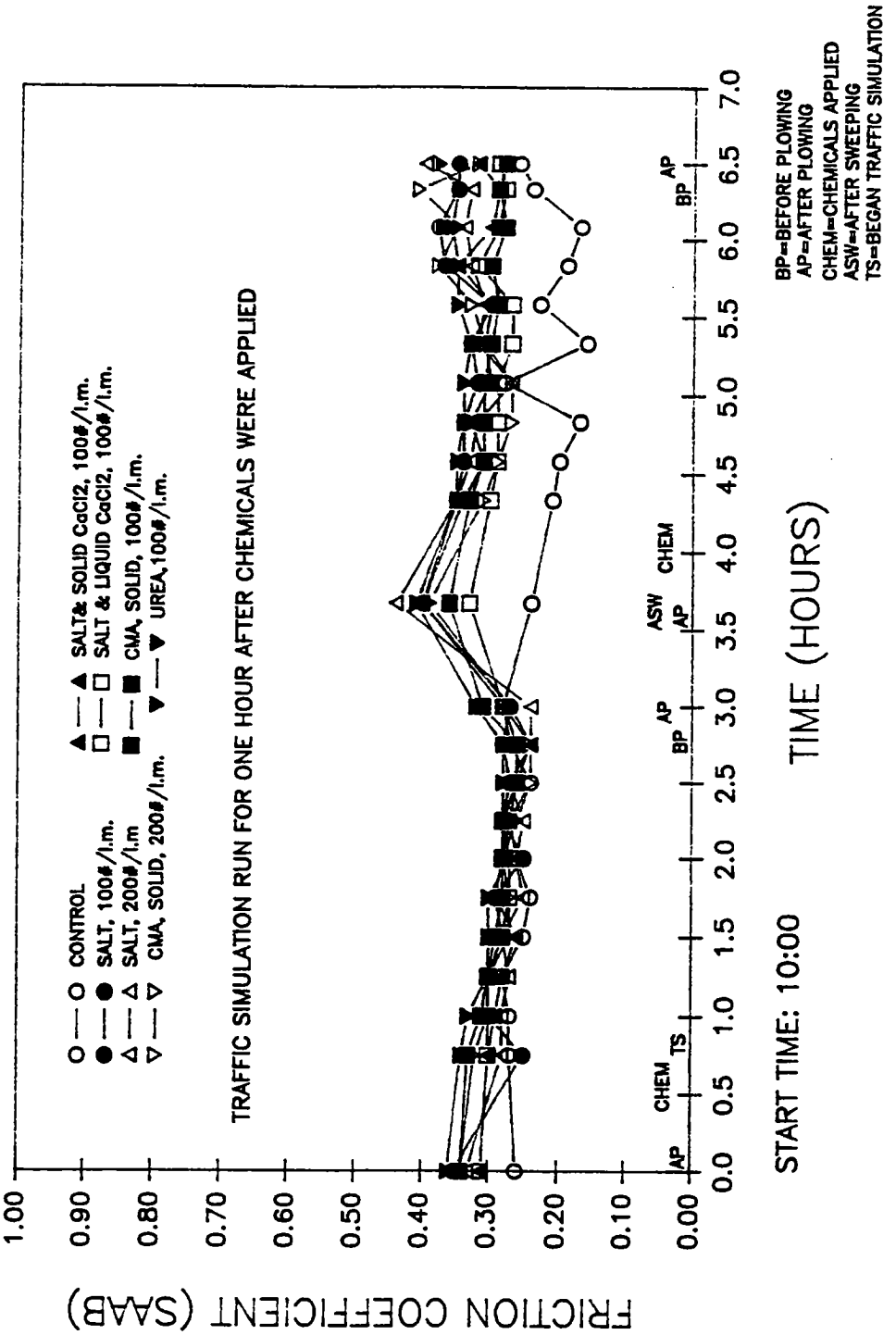
Friction Values --- 02-12-92 --- Liquids.



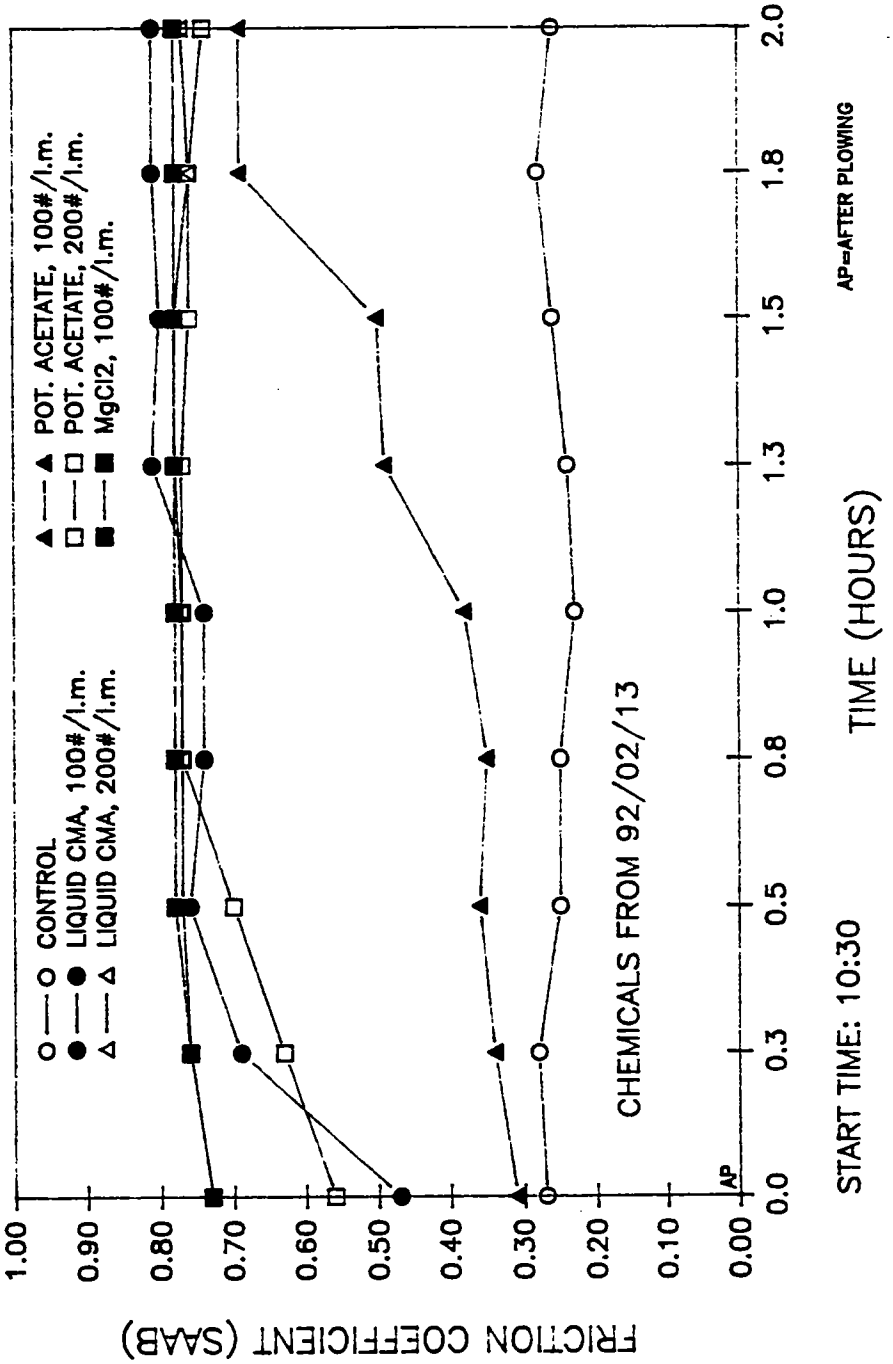
Friction Values --- 02-12-92 --- Solids.



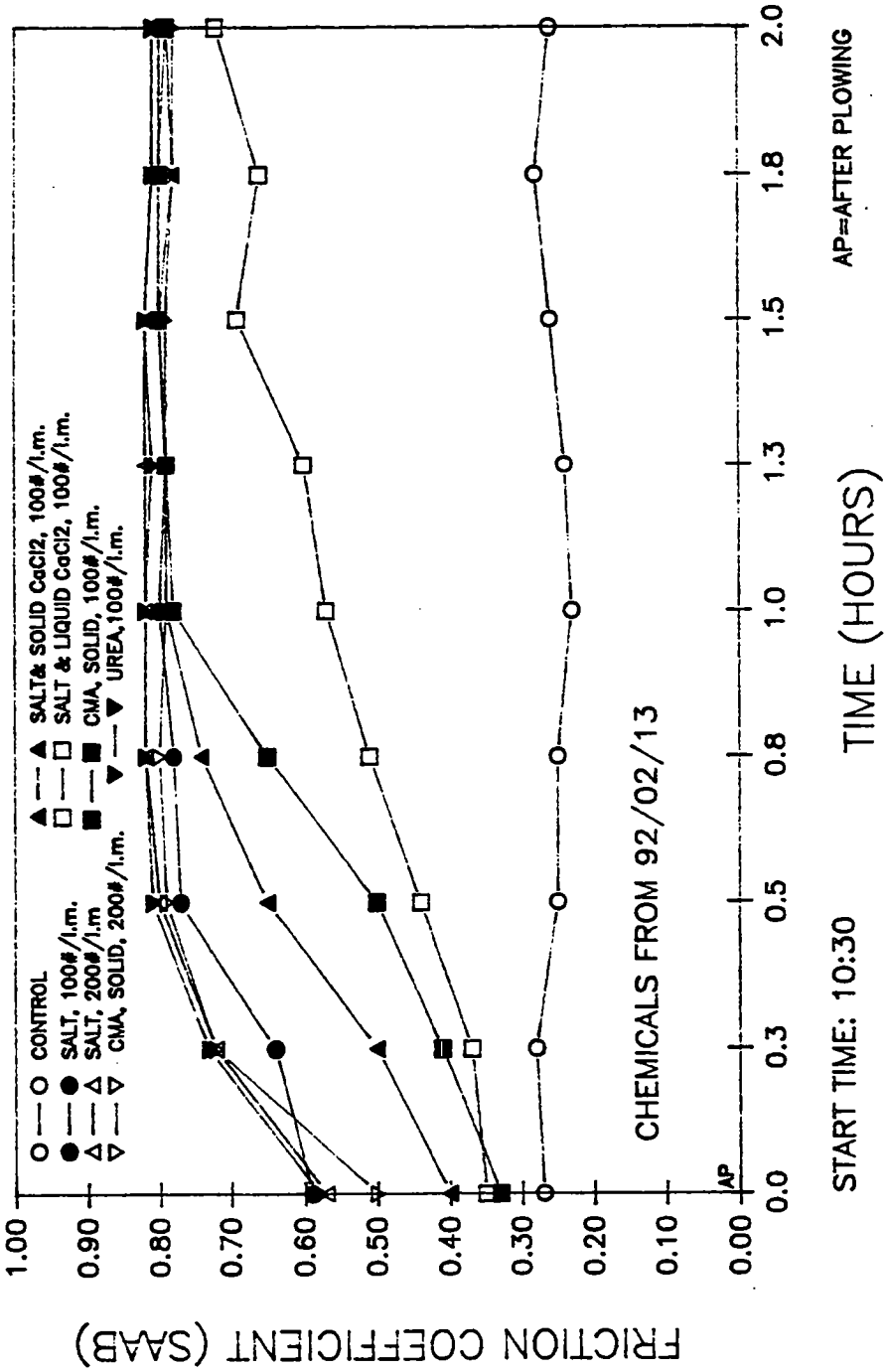
Friction Values --- 02-13-92 --- Liquids.



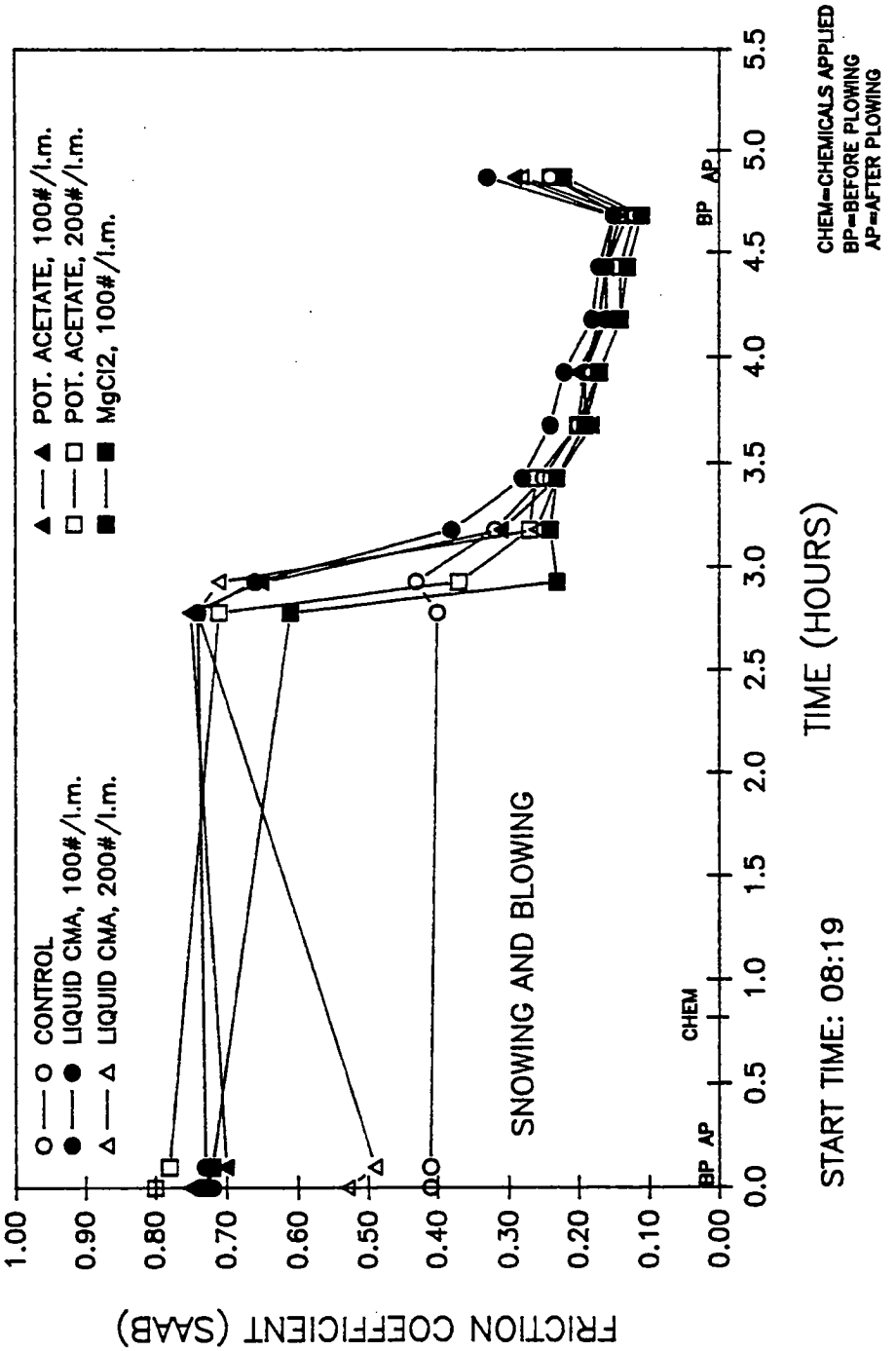
Friction Values --- 02-13-92 --- Solids.



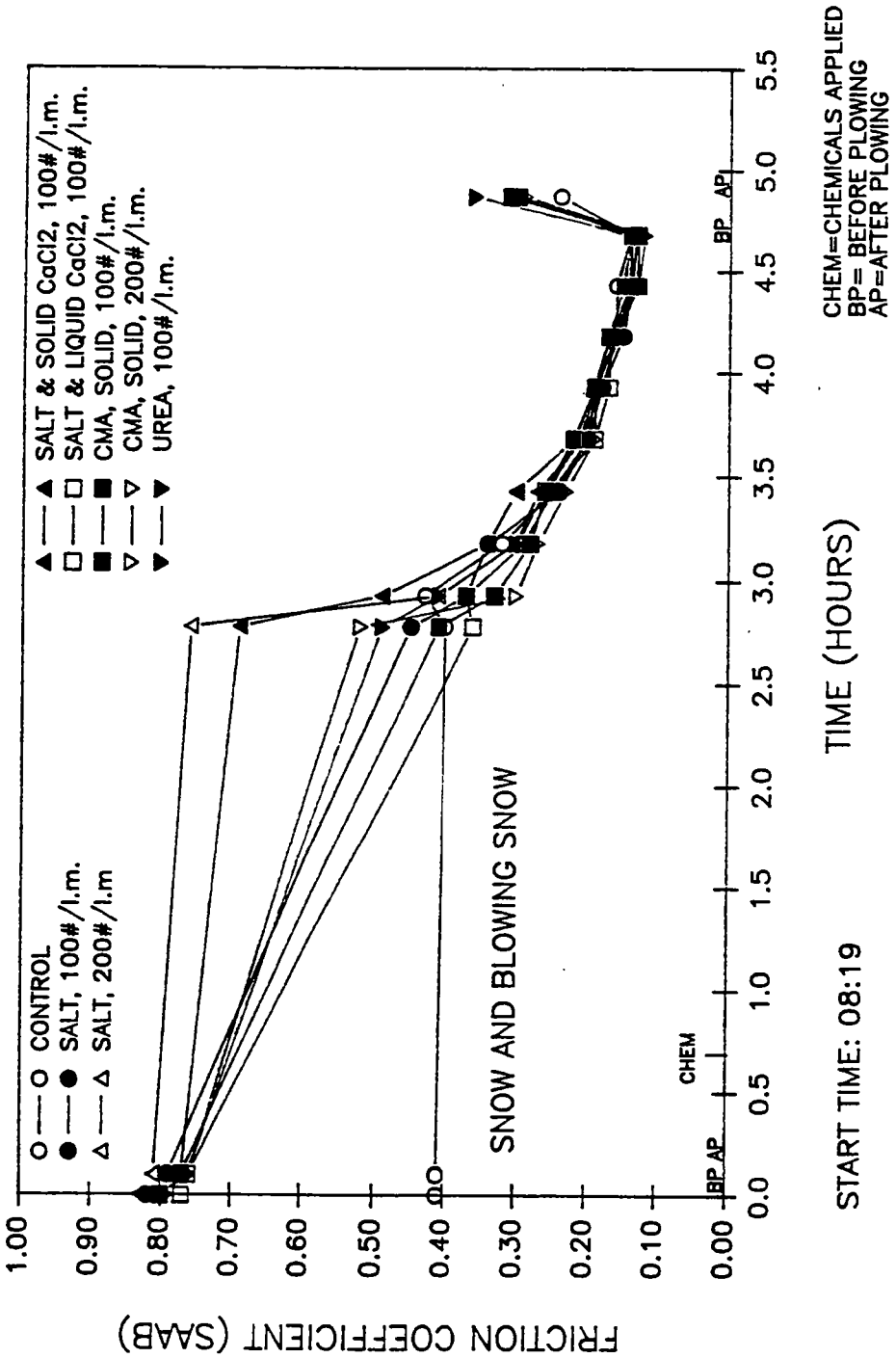
Friction Values --- 02-14-92 --- Liquids.



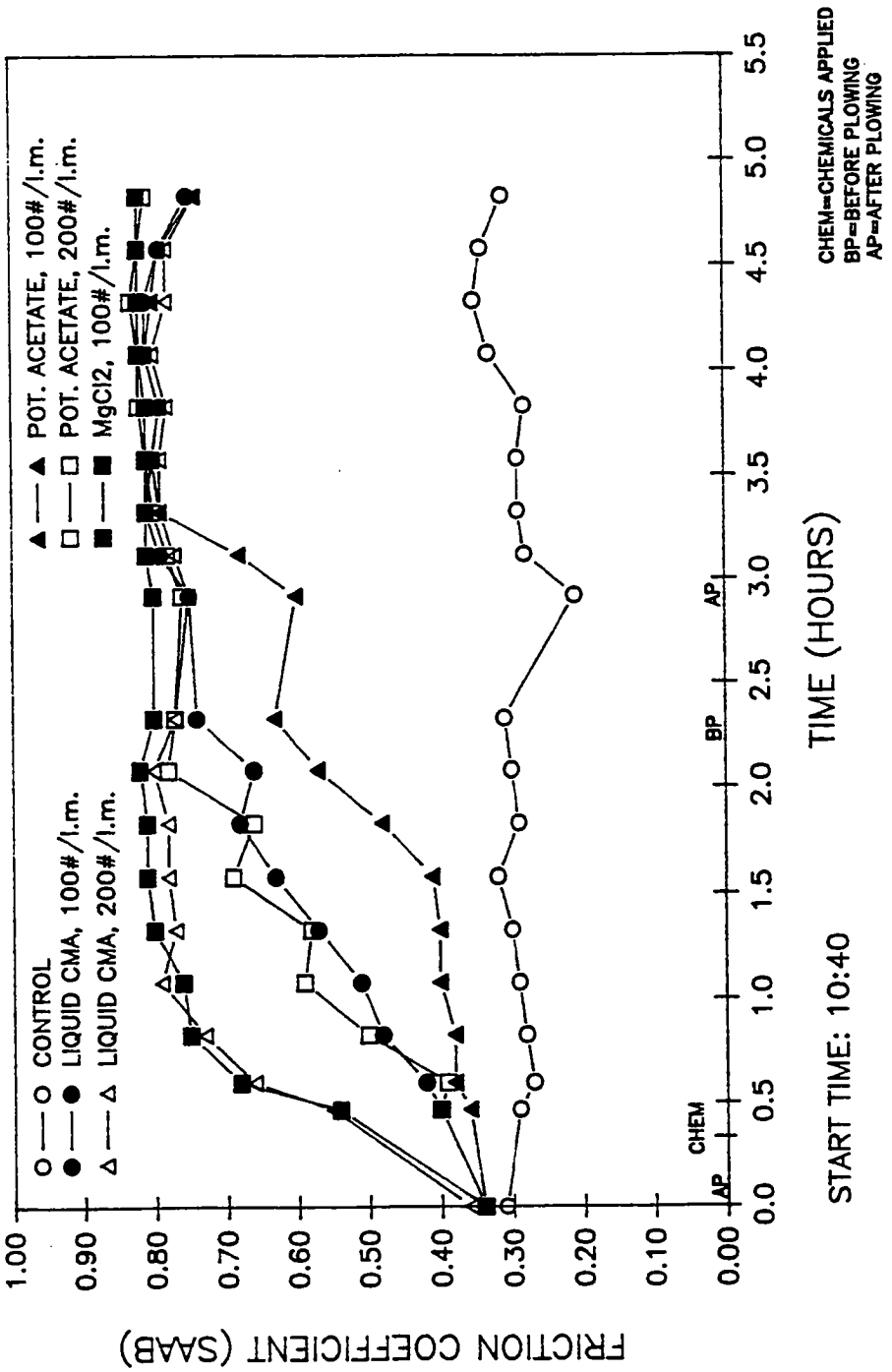
Friction Values --- 02-14-92 --- Solids.



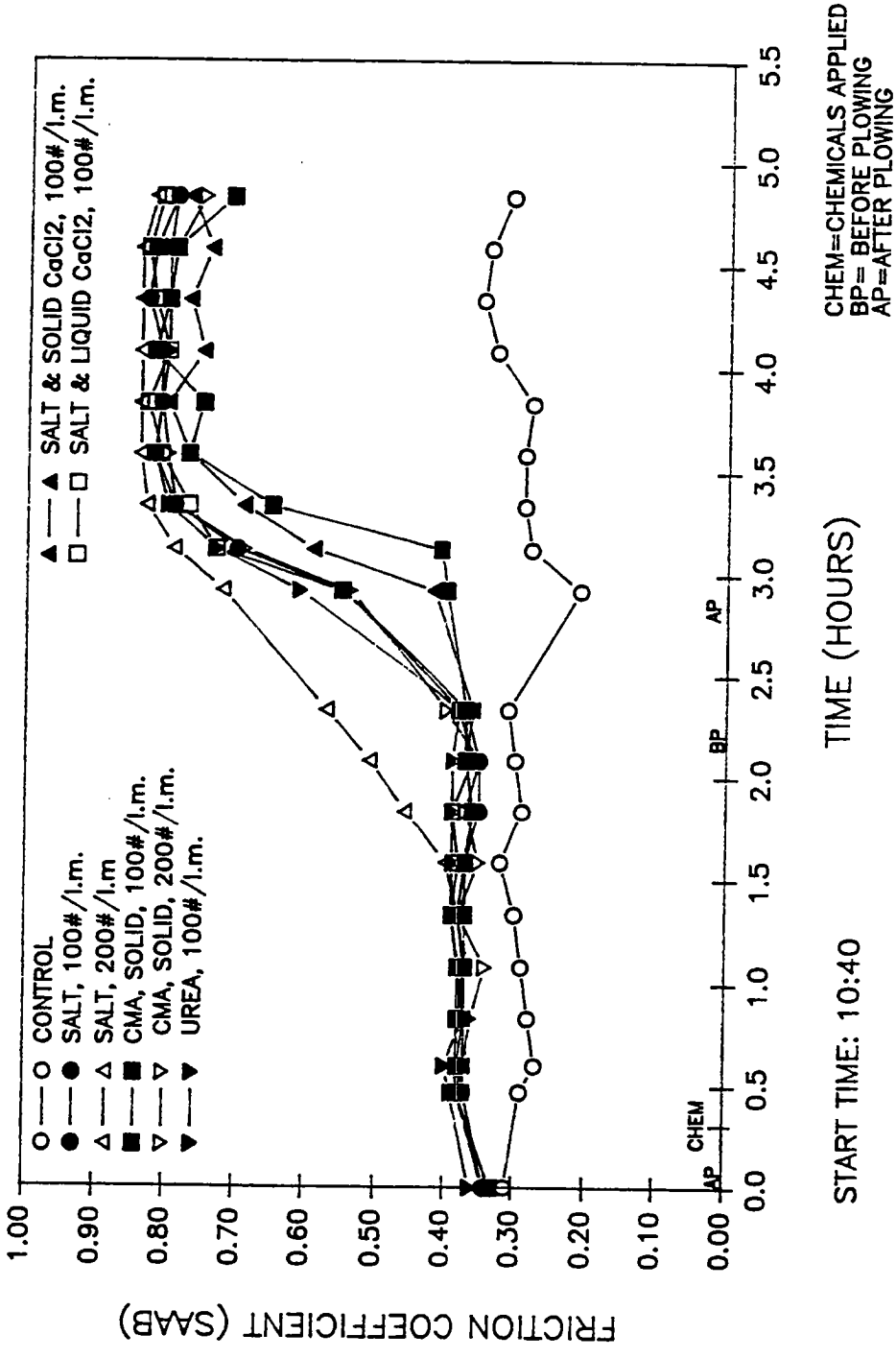
Friction Values --- 02-20-92 --- Liquids.



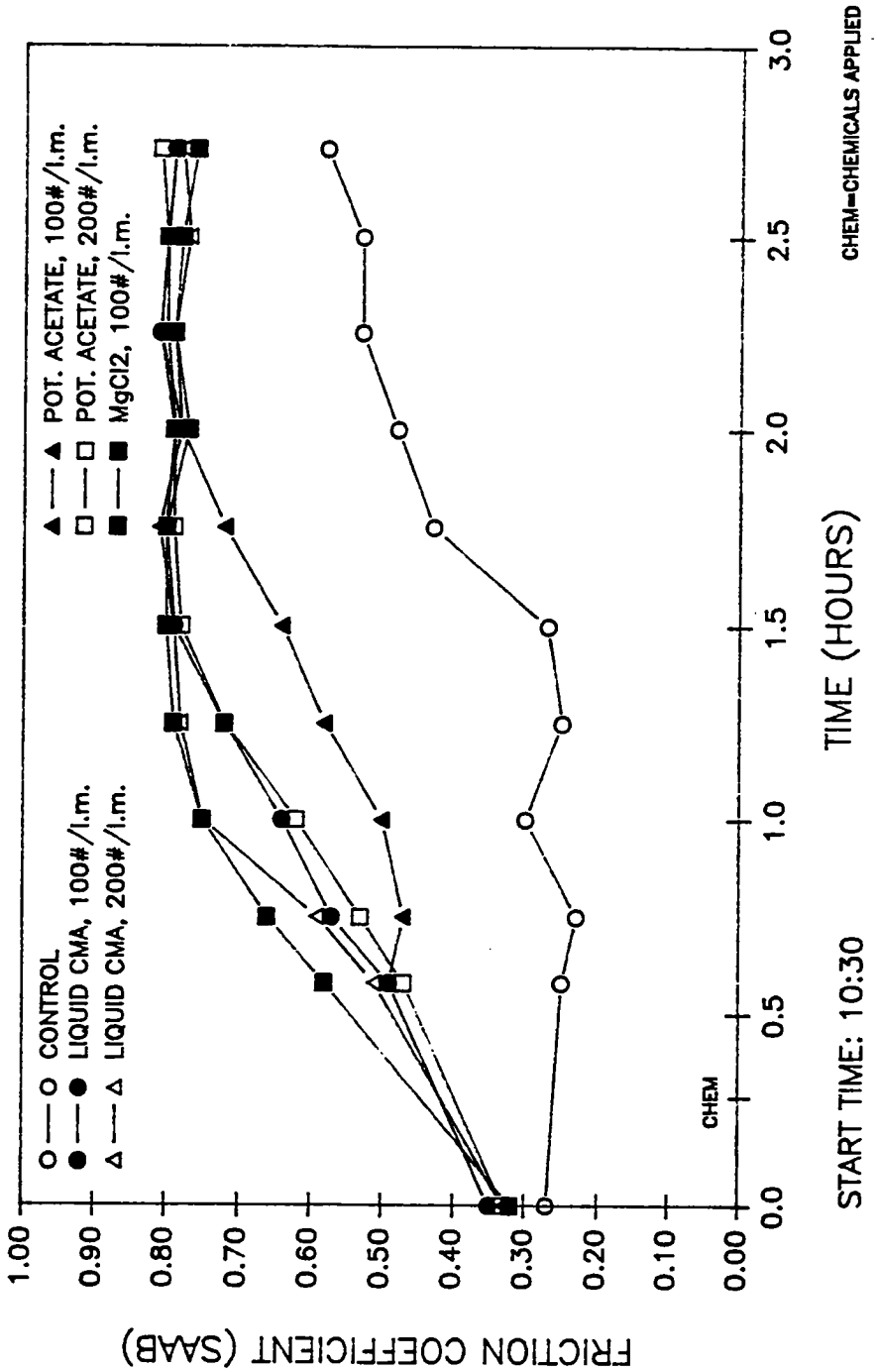
Friction Values --- 02-20-92 --- Solids.



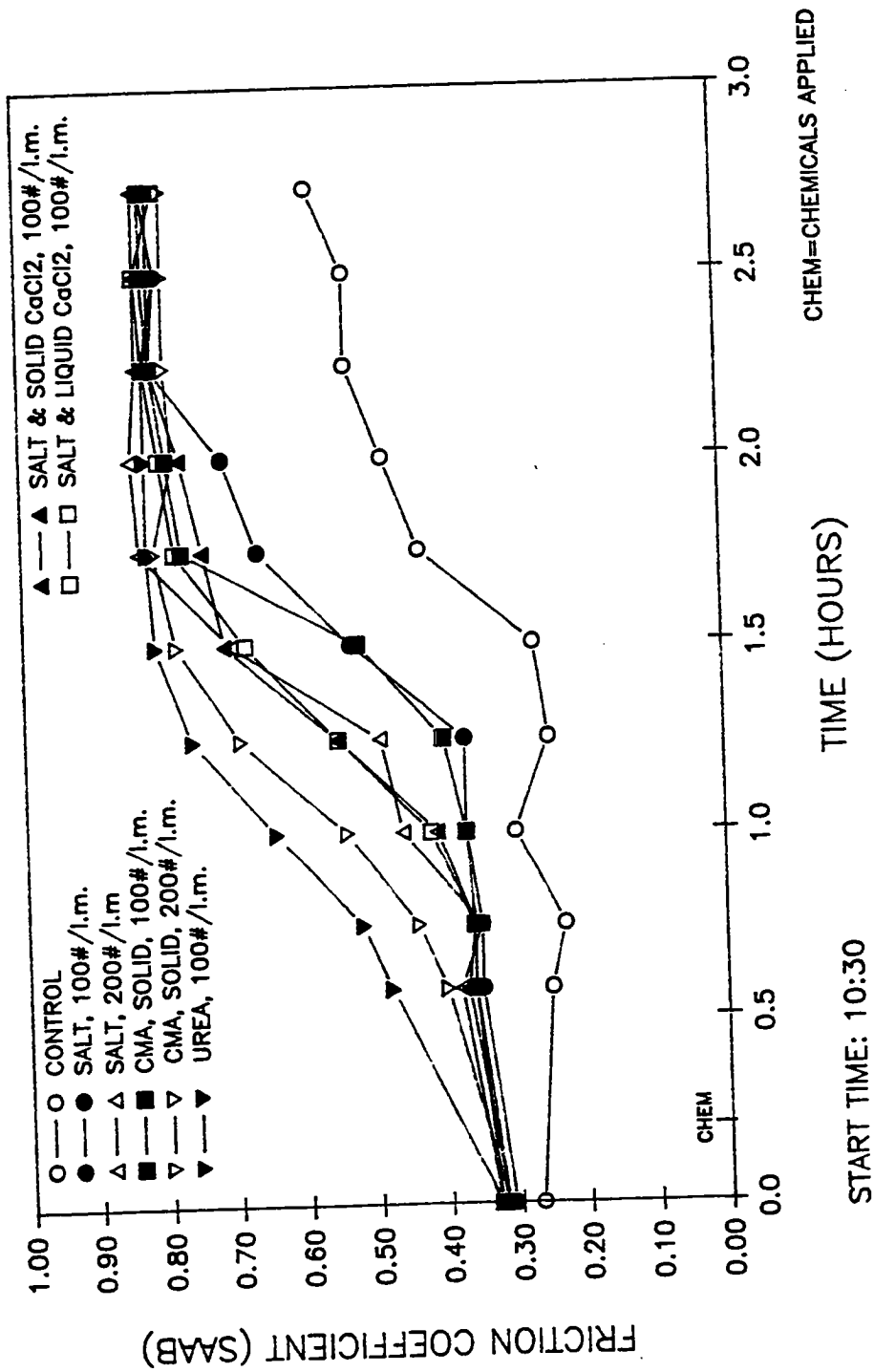
Friction Values --- 02-24-92 --- Liquids.



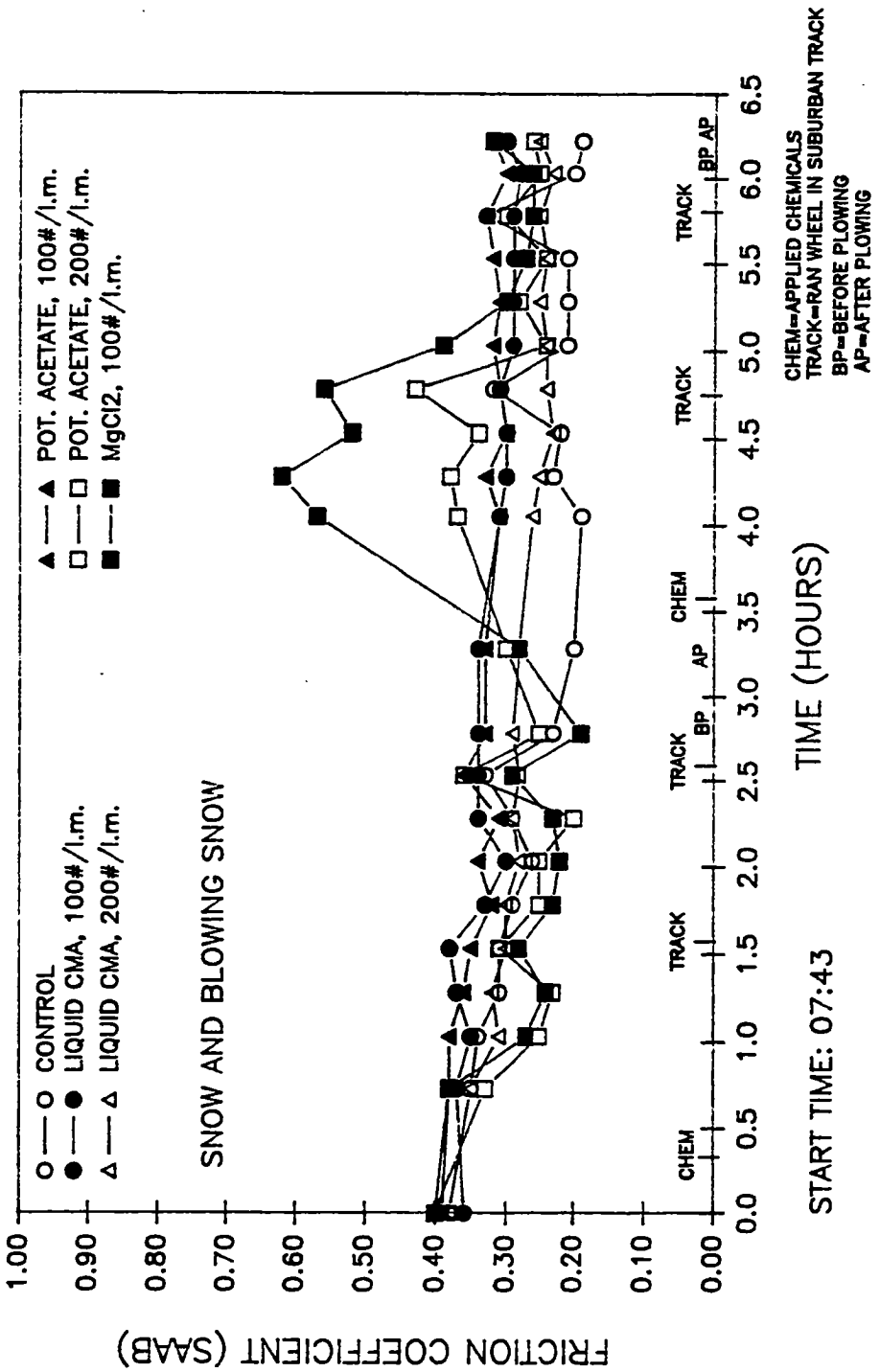
Friction Values --- 02-24-92 --- Solids.



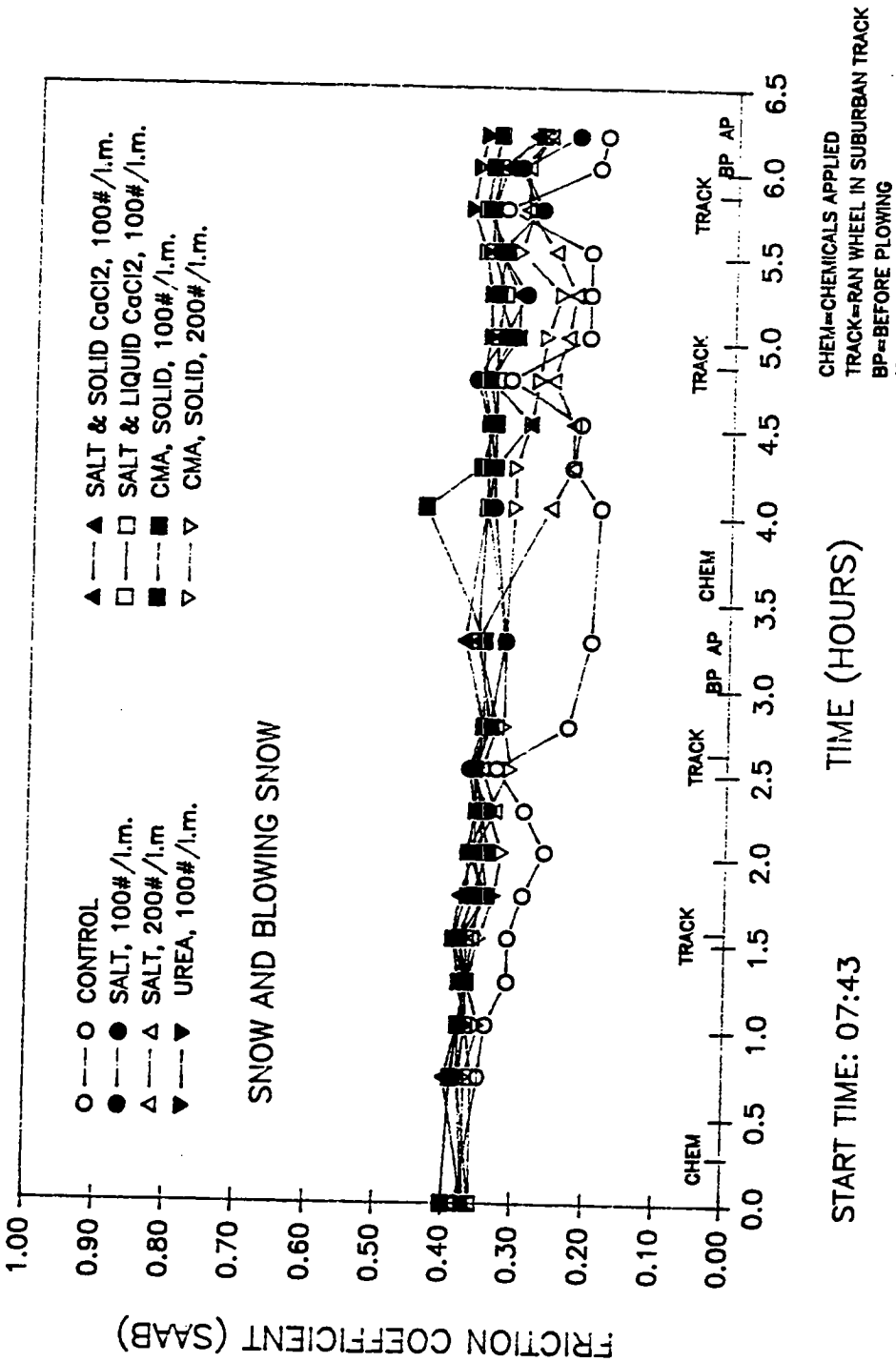
Friction Values --- 02-25-92 --- Liquids.



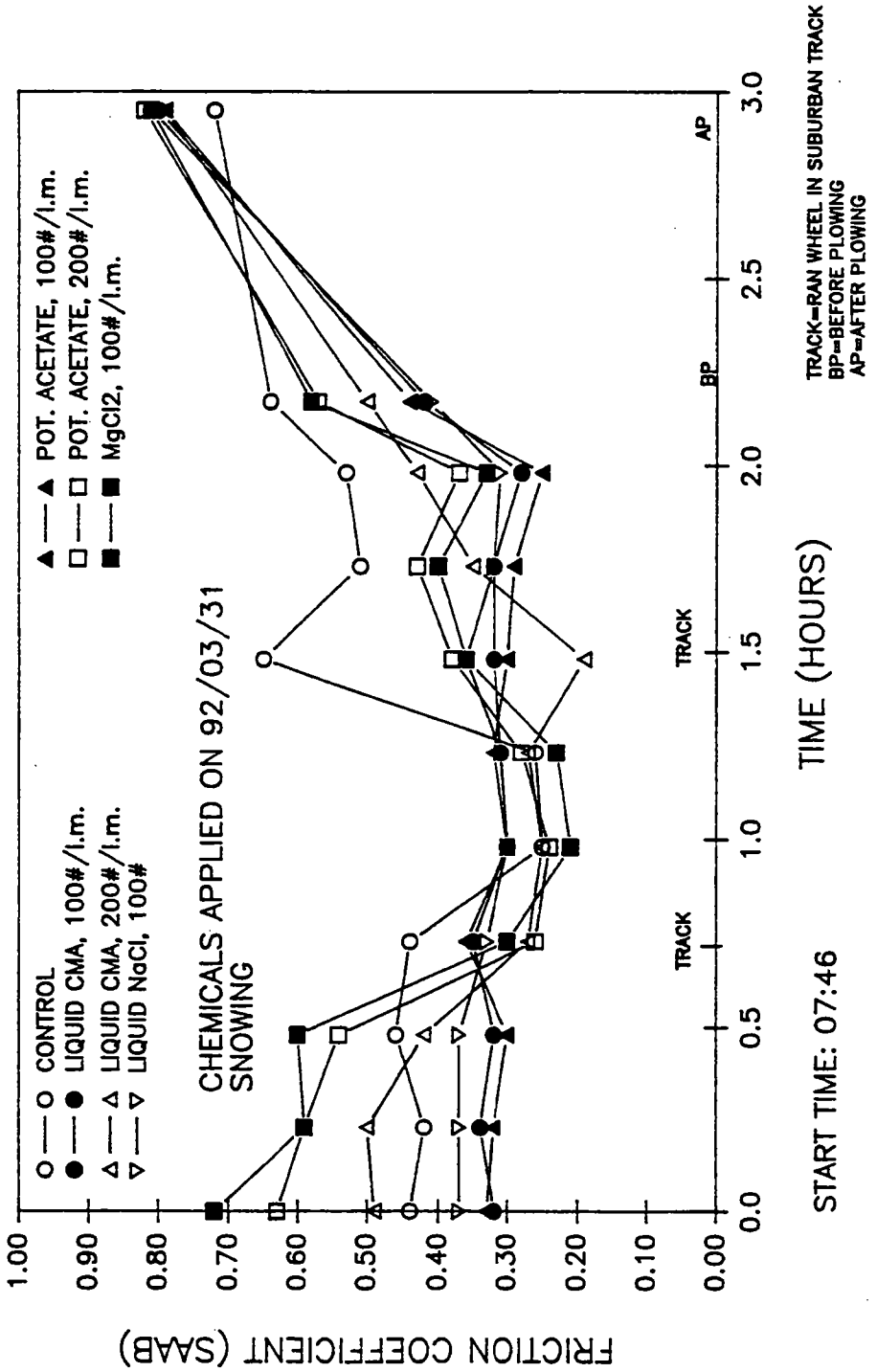
Friction Values --- 02-25-92 --- Solids.



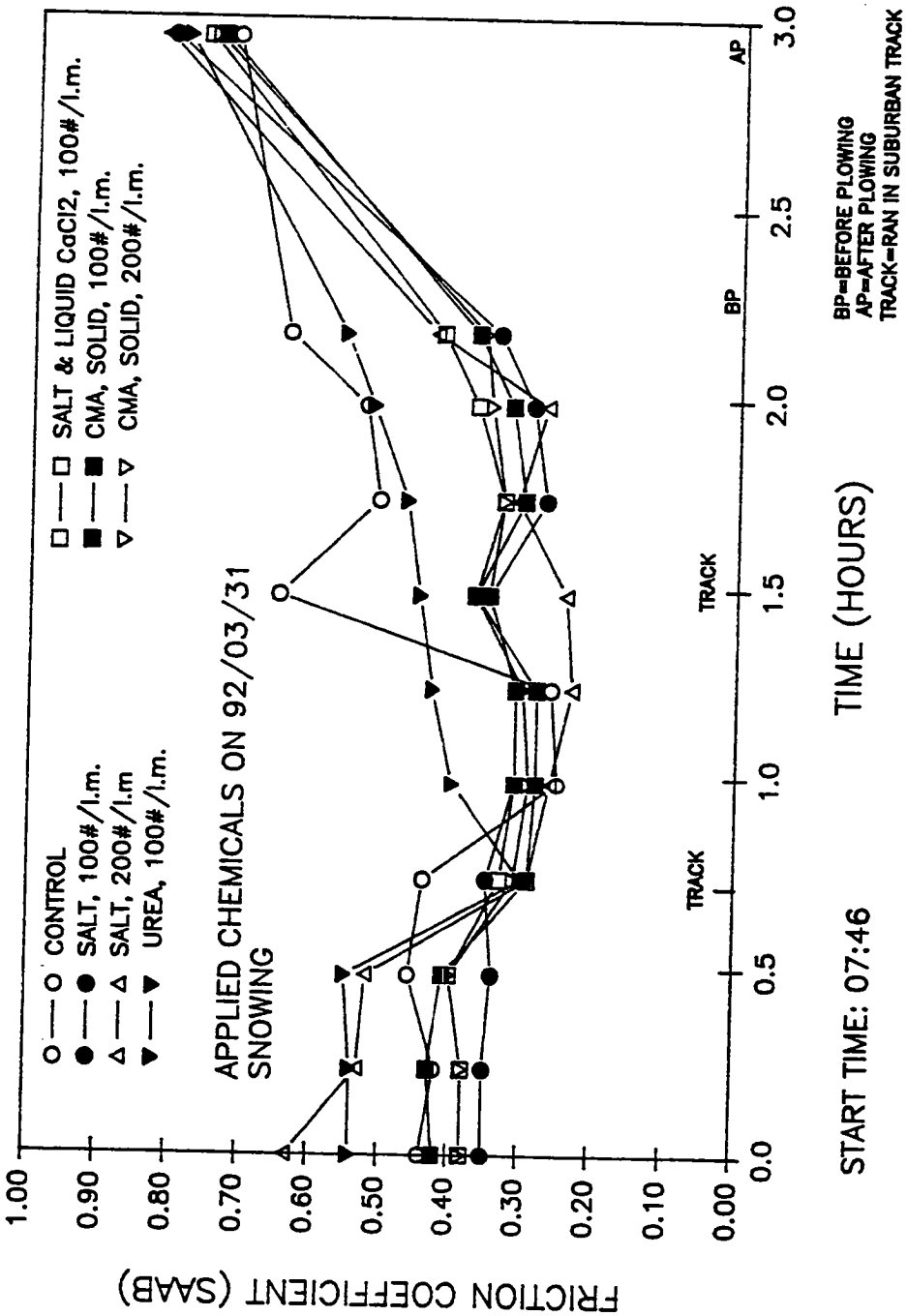
Friction Values --- 03-09-92 --- Liquids.



Friction Values --- 03-09-92 --- Solids.



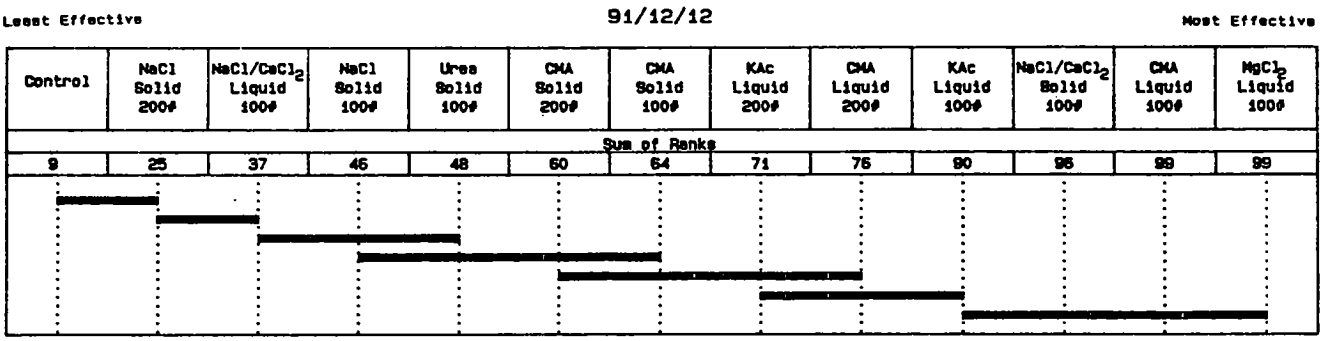
Friction Values --- 04-01-92 --- Liquids.



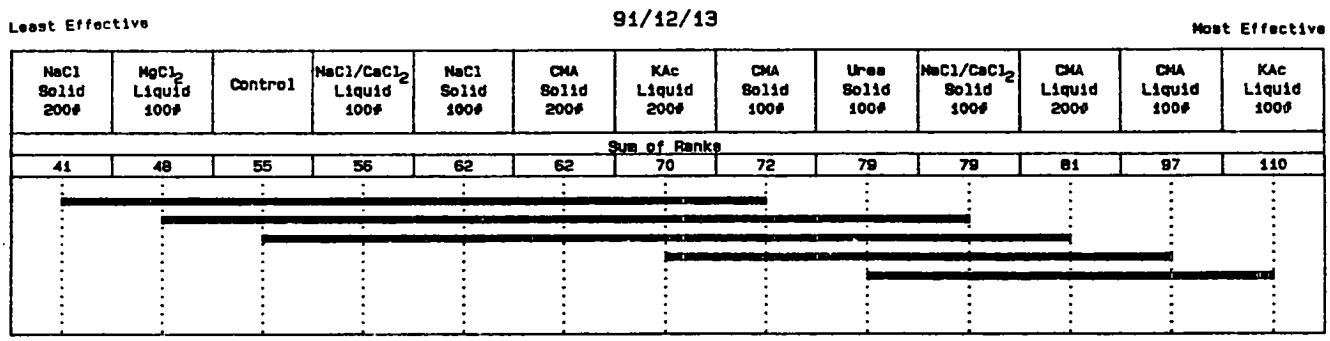
Friction Values --- 04-01-92 --- Solids.

APPENDIX D

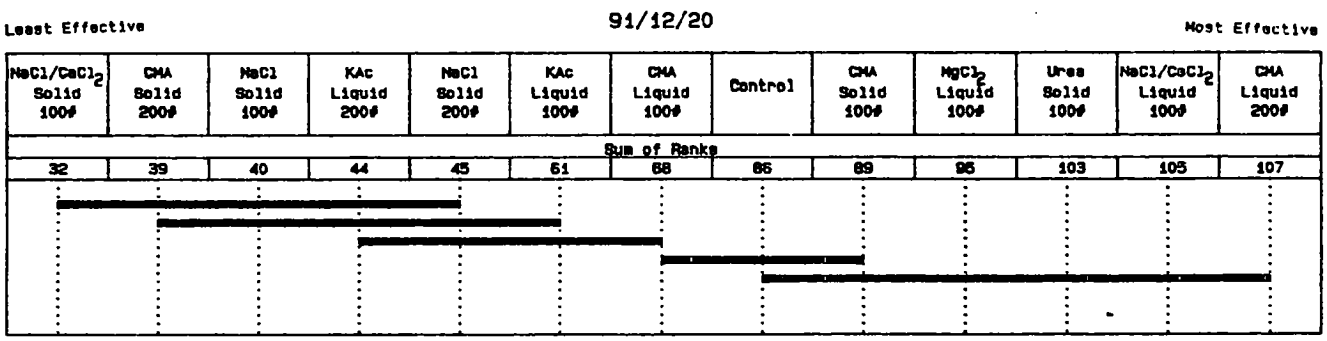
Friedman Results - Individual Tests



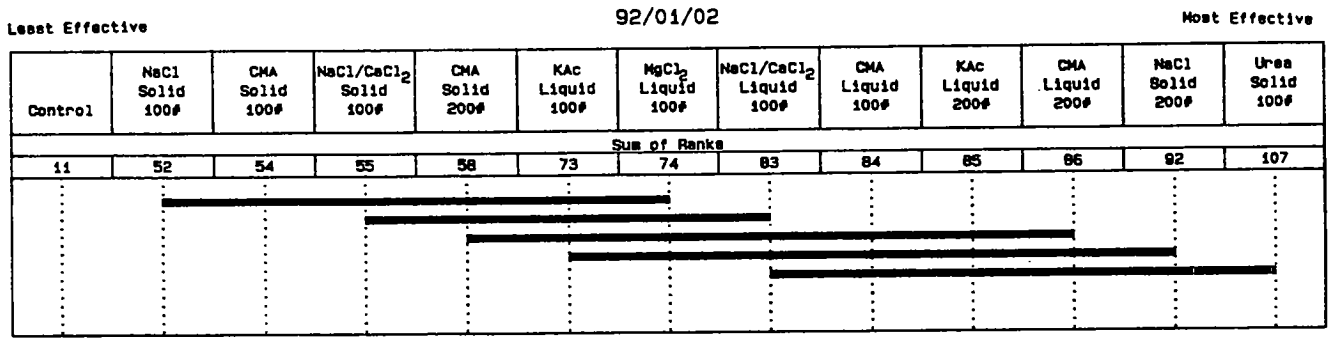
Friedman Results --- 12-12-91.



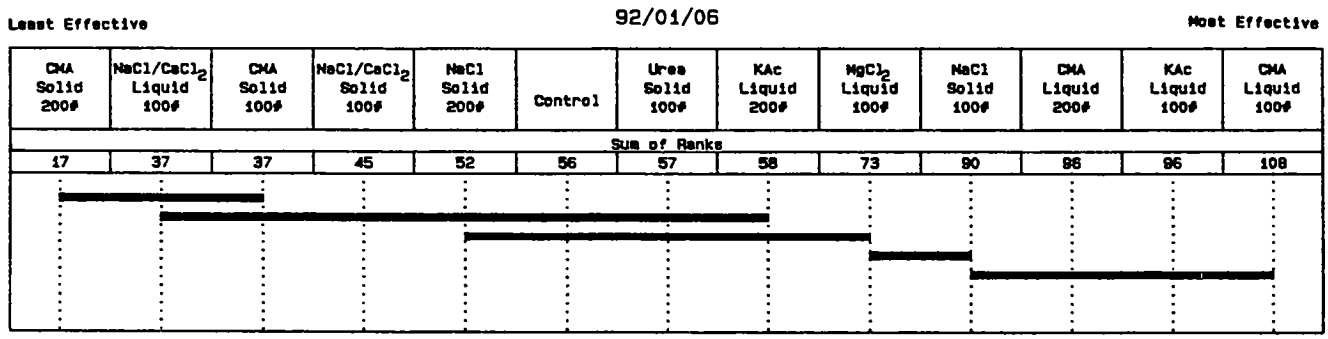
Friedman Results --- 12-13-91.



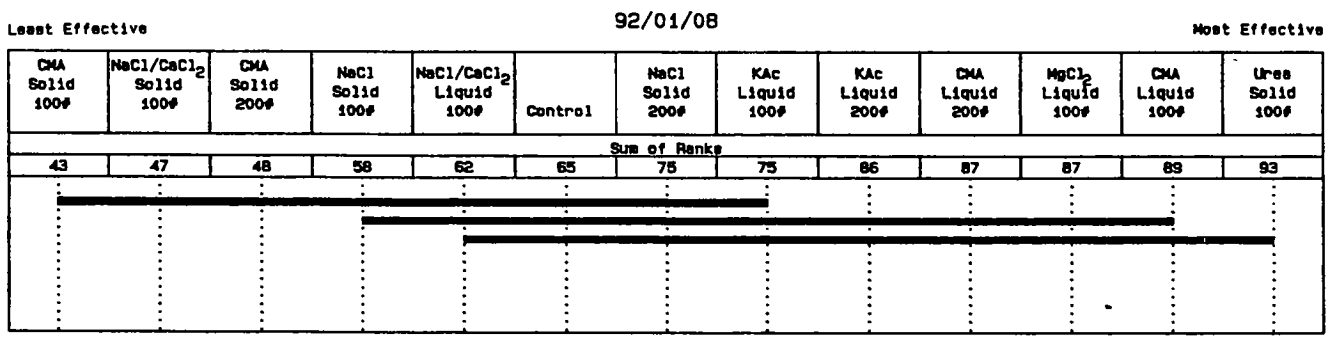
Friedman Results --- 12-20-91.



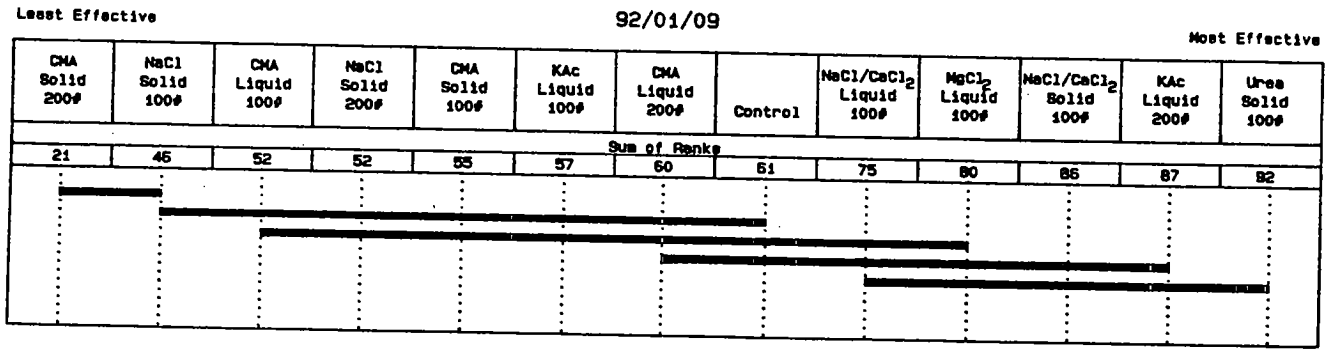
Friedman Results --- 01-02-92.



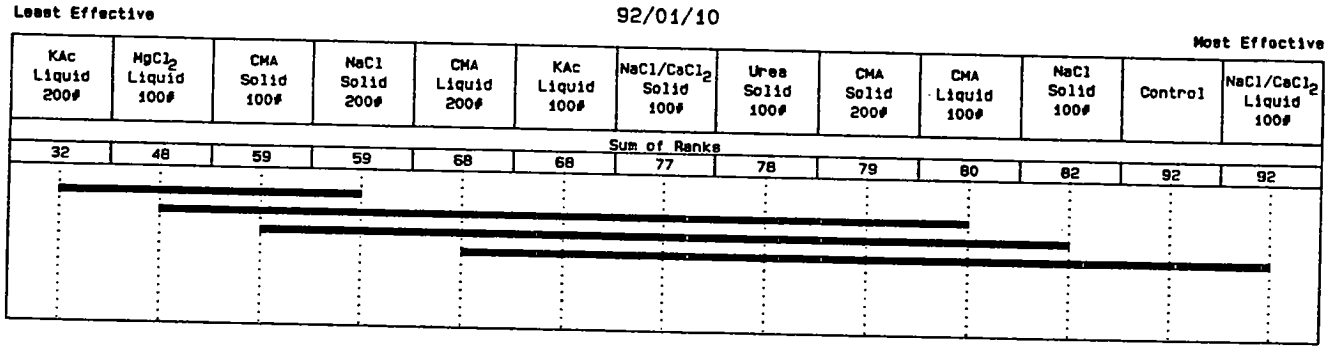
Friedman Results --- 01-06-92.



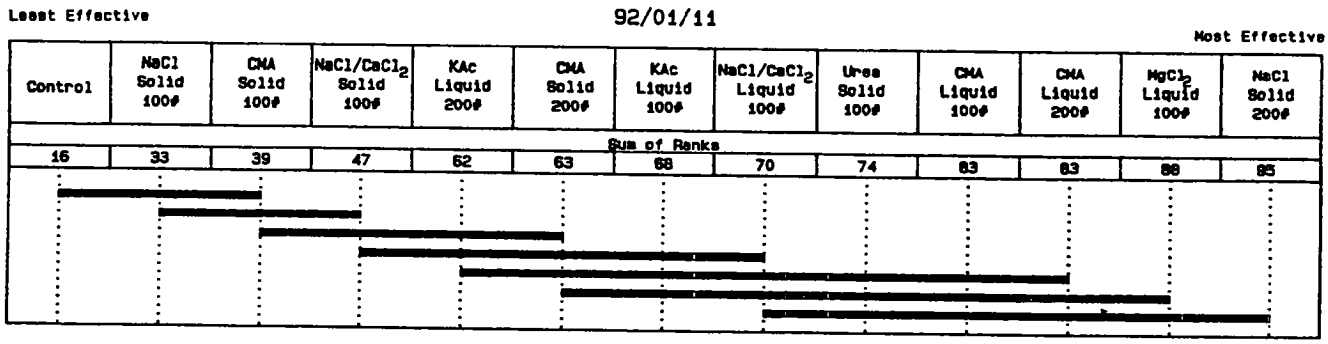
Friedman Results --- 01-08-92.



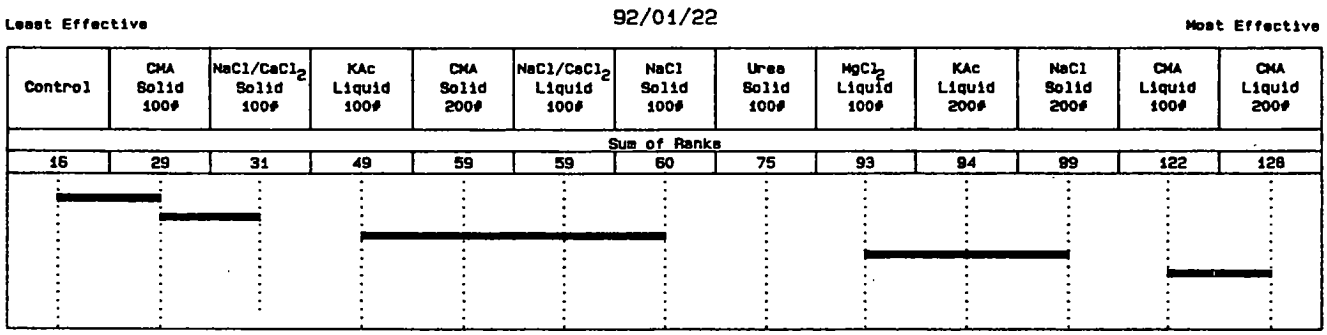
Friedman Results --- 01-09-92.



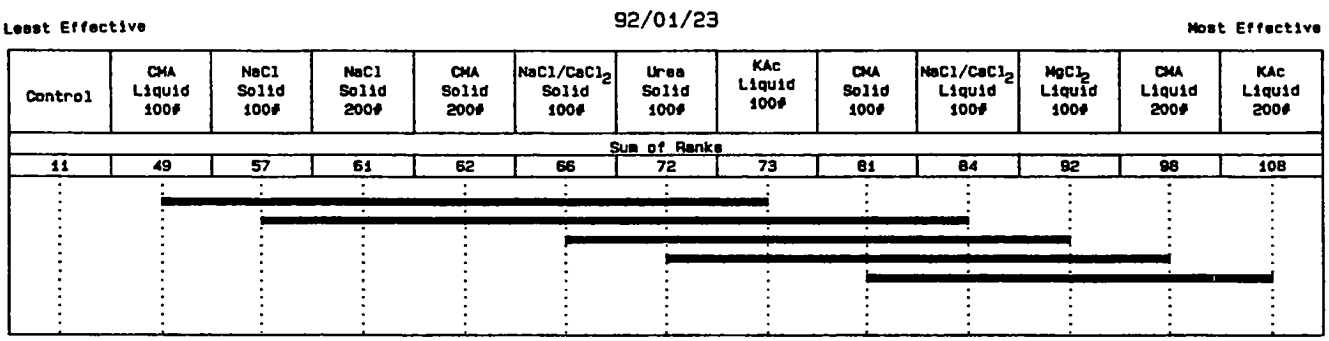
Friedman Results --- 01-10-92.



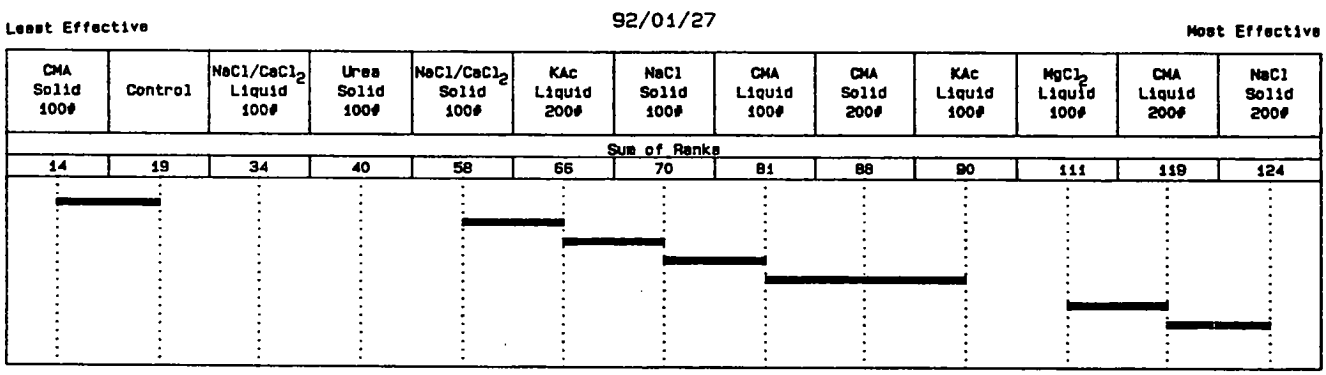
Friedman Results --- 01-11-92.



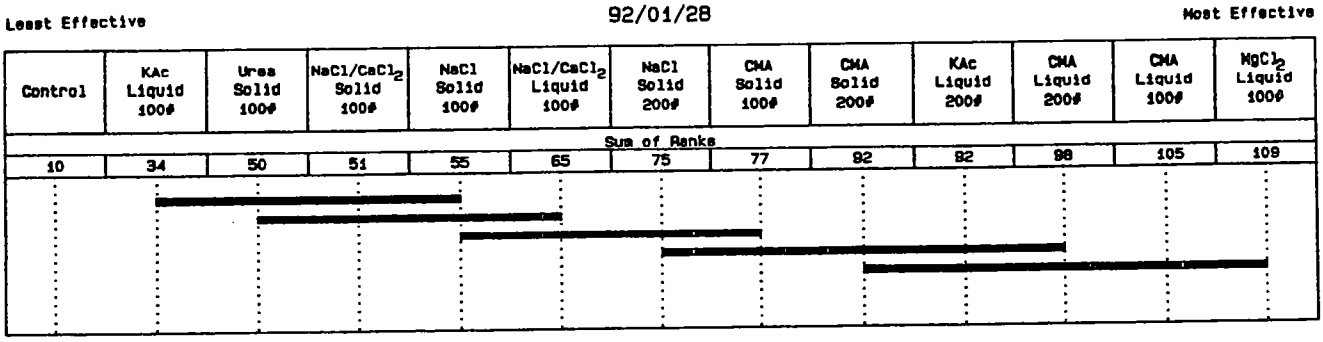
Friedman Results --- 01-22-92.



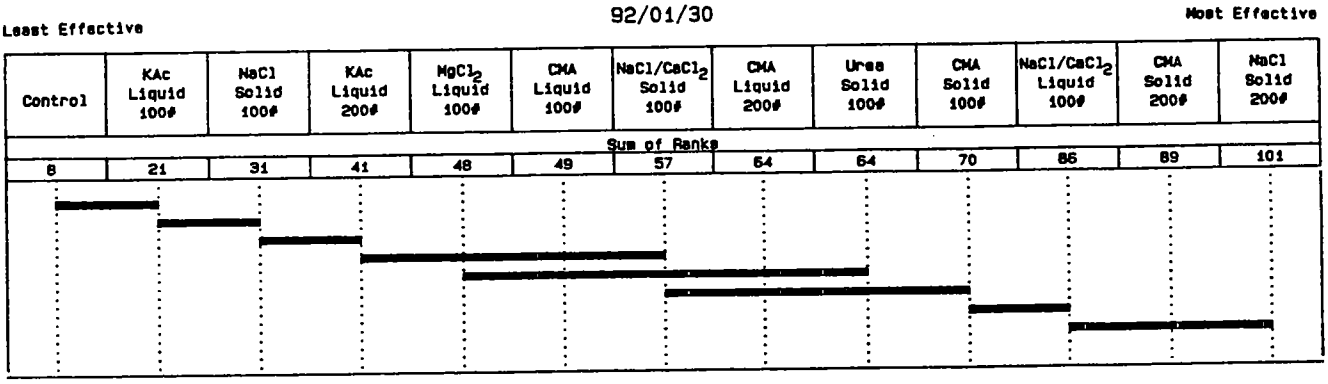
Friedman Results --- 01-23-92.



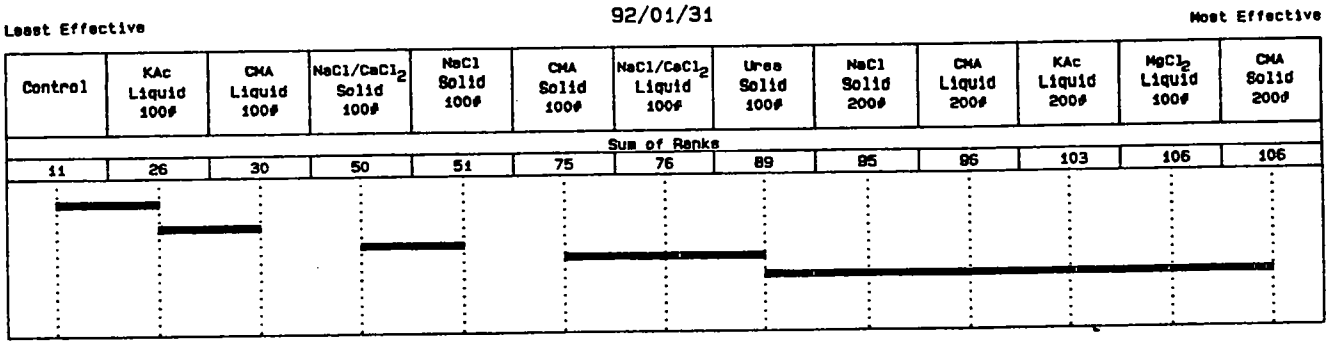
Friedman Results --- 01-27-92.



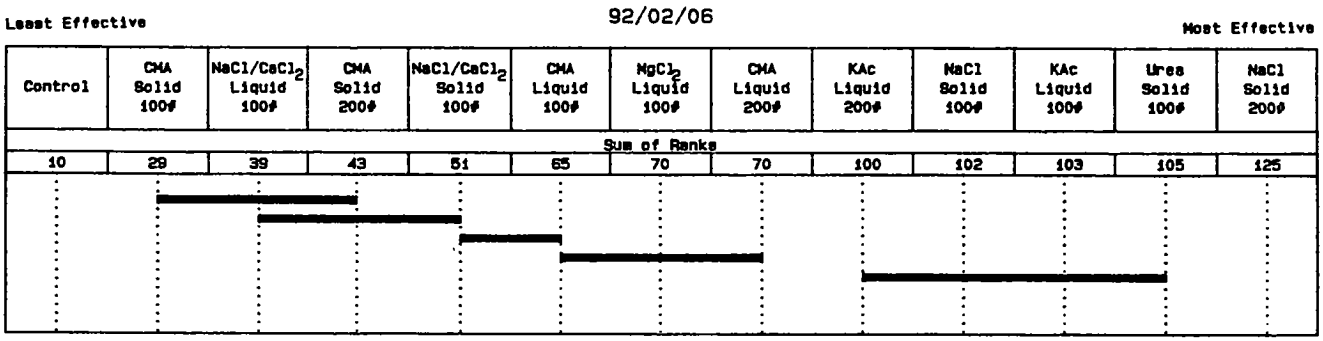
Friedman Results --- 01-28-92.



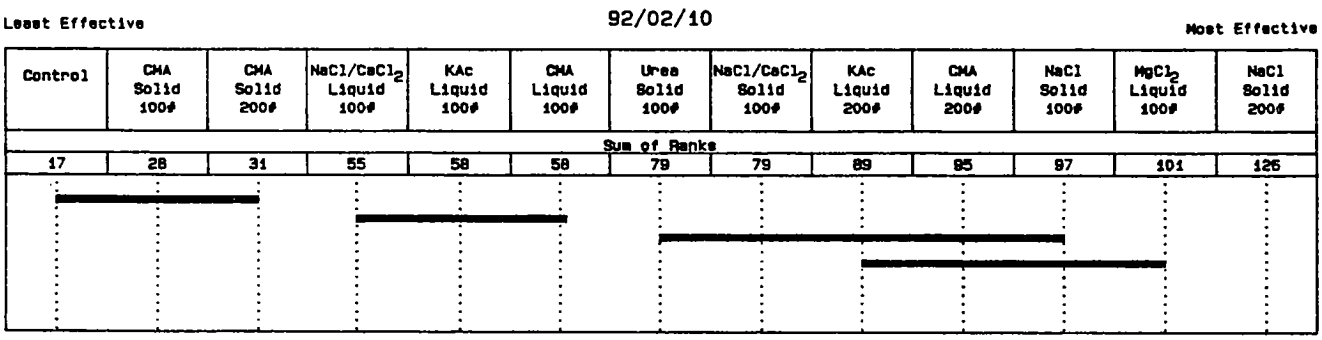
Friedman Results --- 01-30-92.



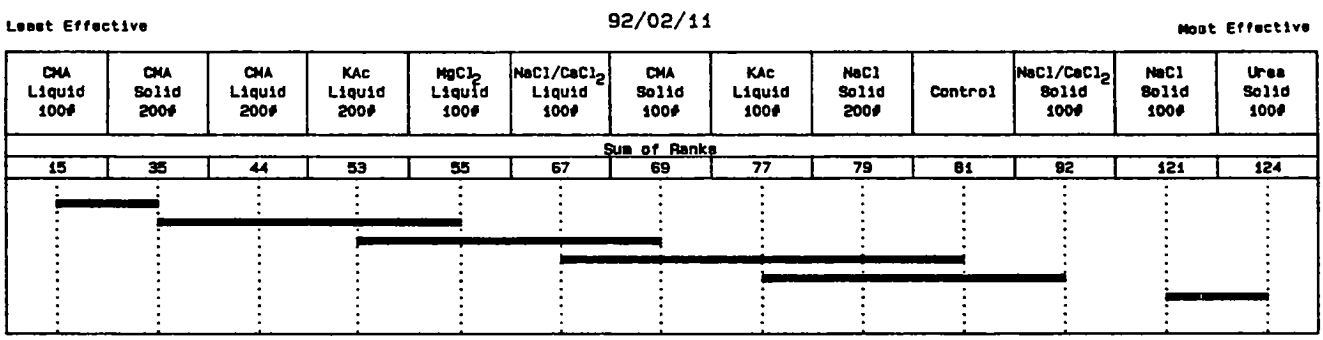
Friedman Results --- 01-31-92.



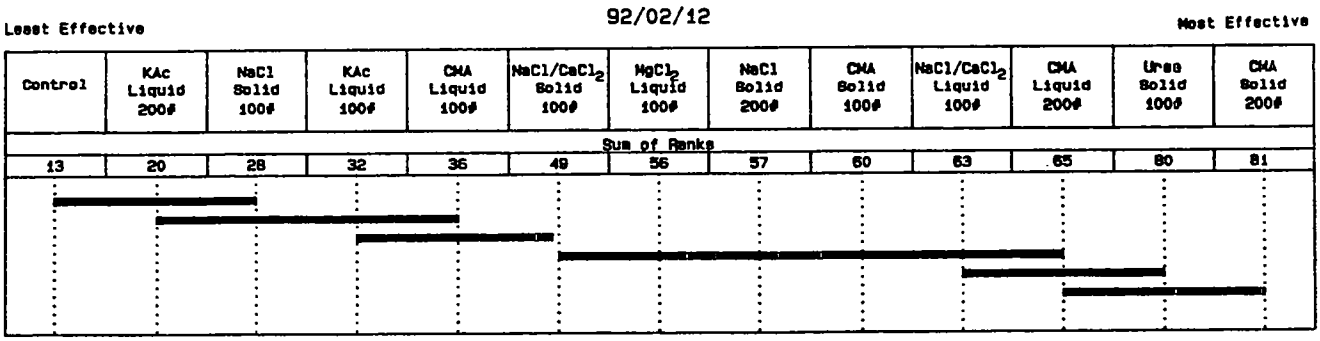
Friedman Results --- 02-06-92.



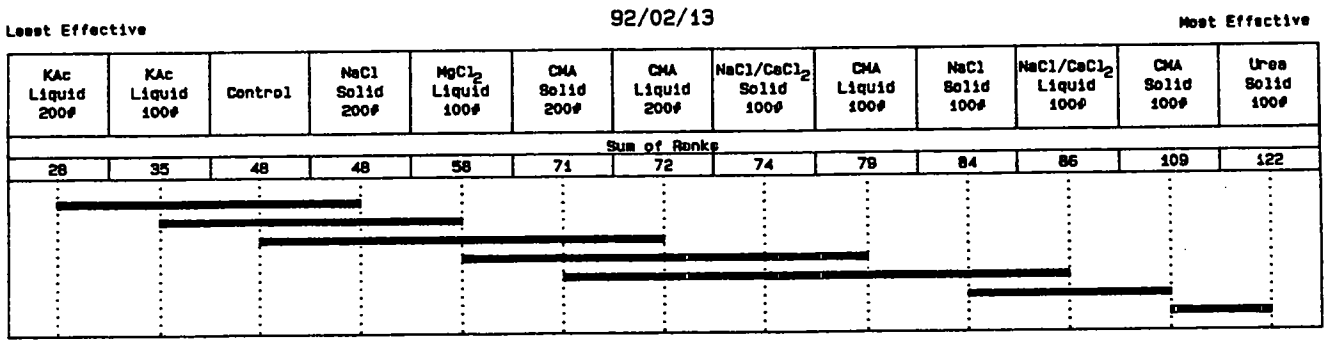
Friedman Results --- 02-10-92.



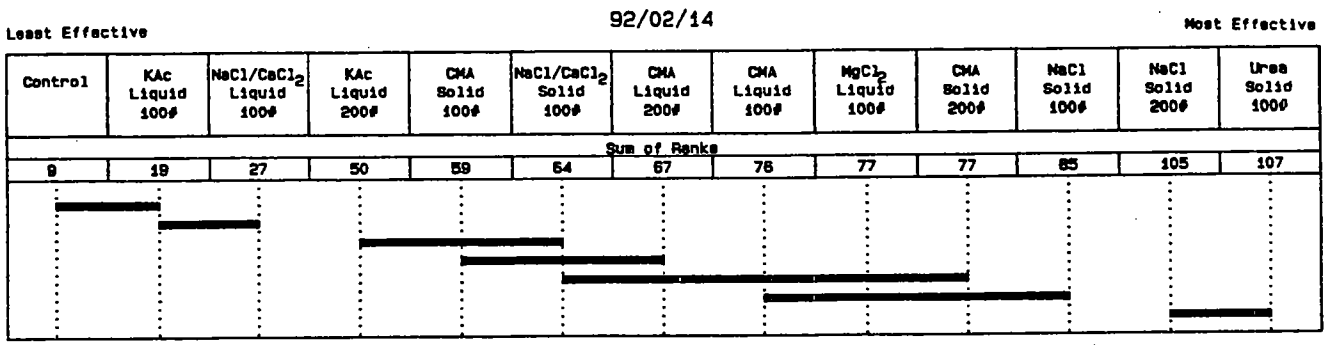
Friedman Results --- 02-11-92.



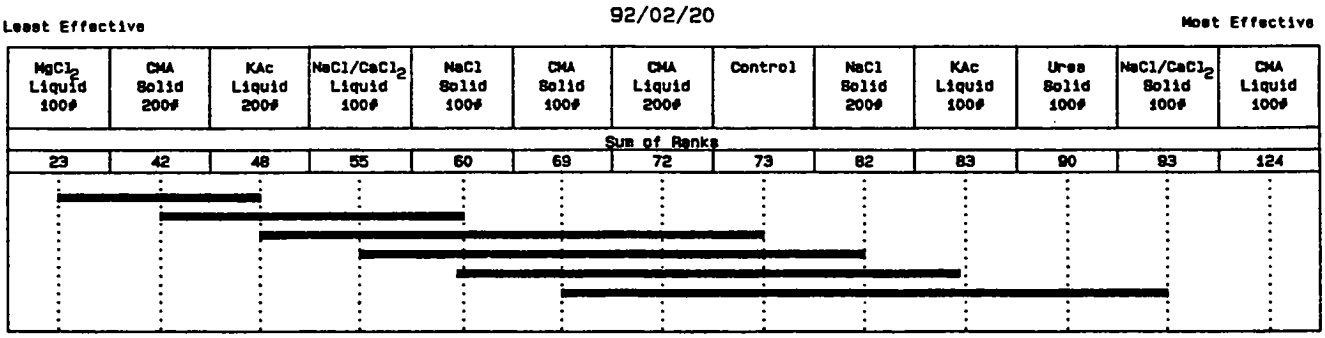
Friedman Results --- 02-12-92.



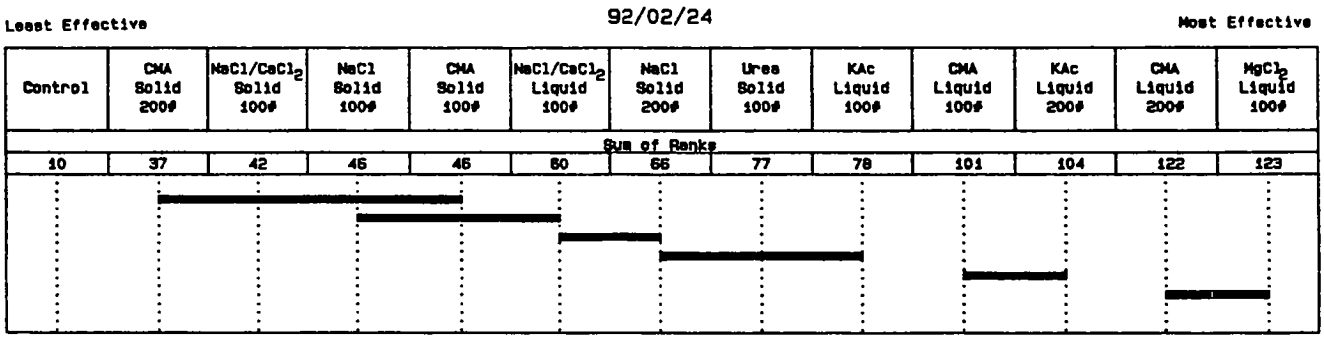
Friedman Results --- 02-13-92.



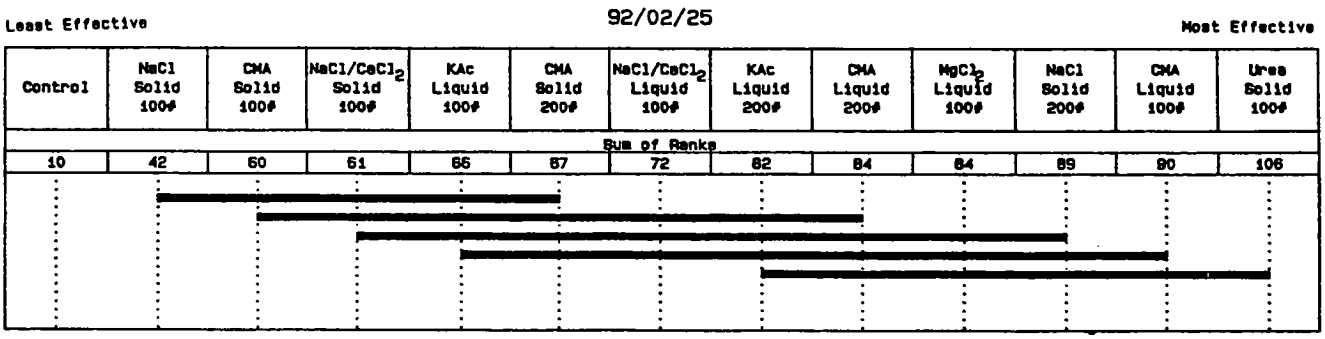
Friedman Results --- 02-14-92.



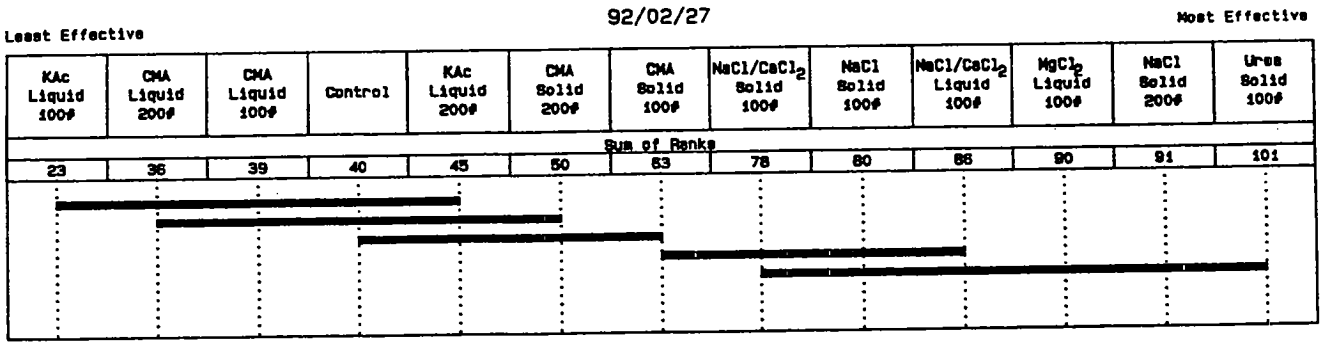
Friedman Results --- 02-20-92.



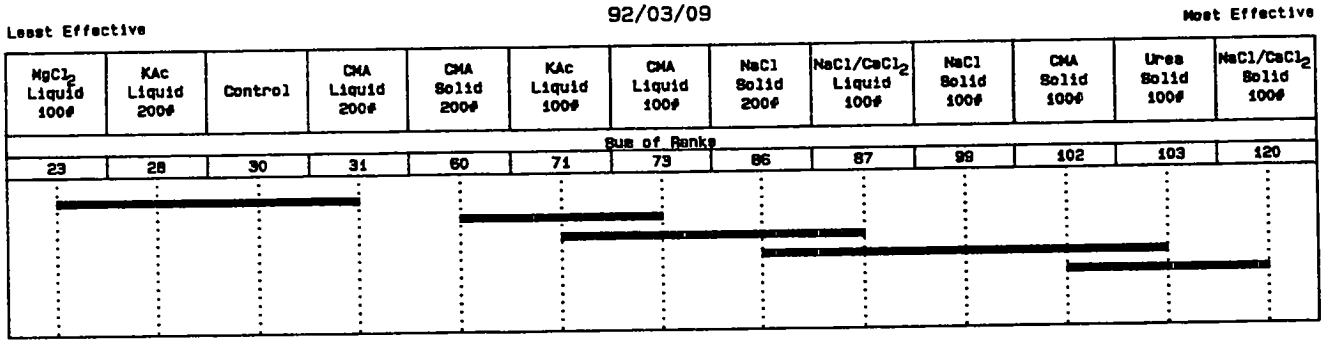
Friedman Results --- 02-24-92.



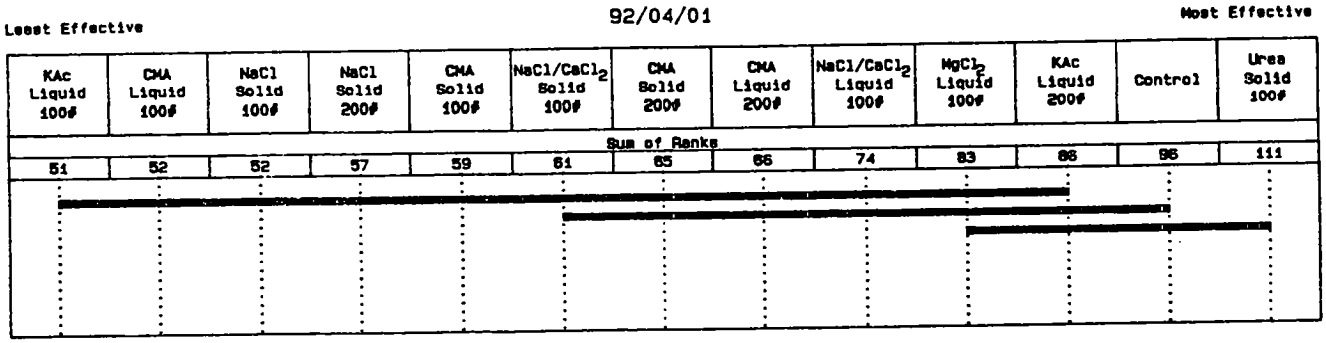
Friedman Results --- 02-25-92.



Friedman Results --- 02-27-92.



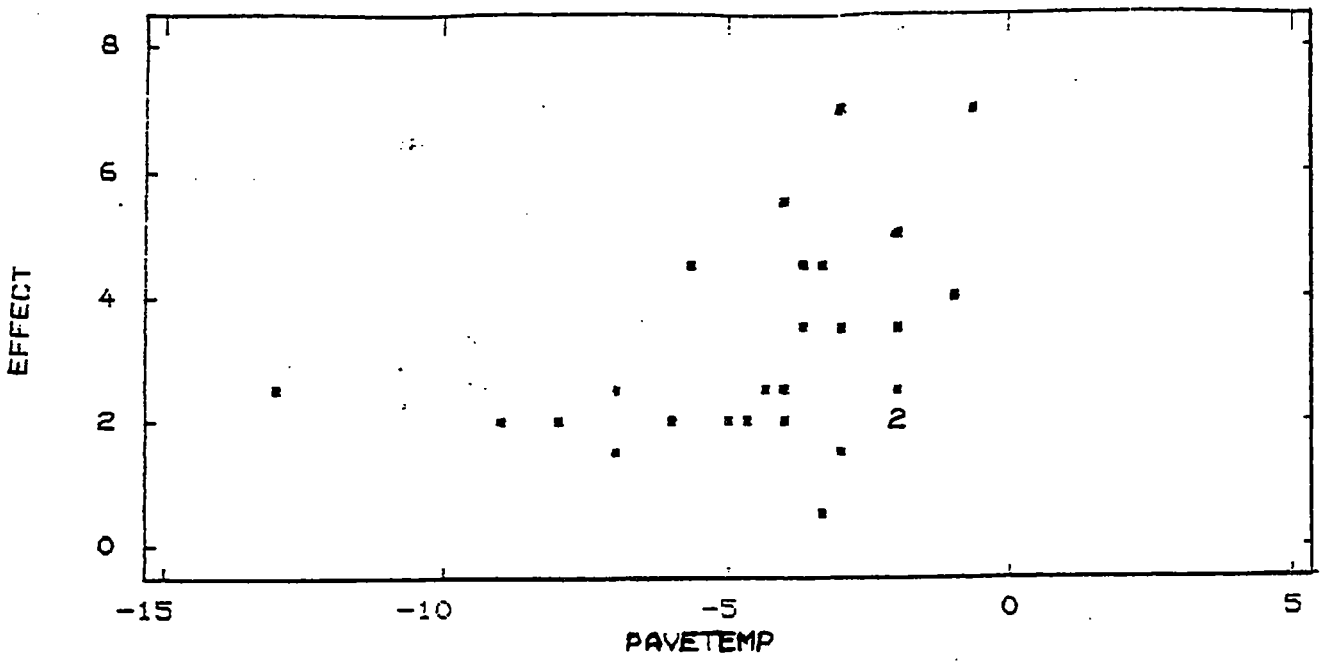
Friedman Results --- 03-09-92.



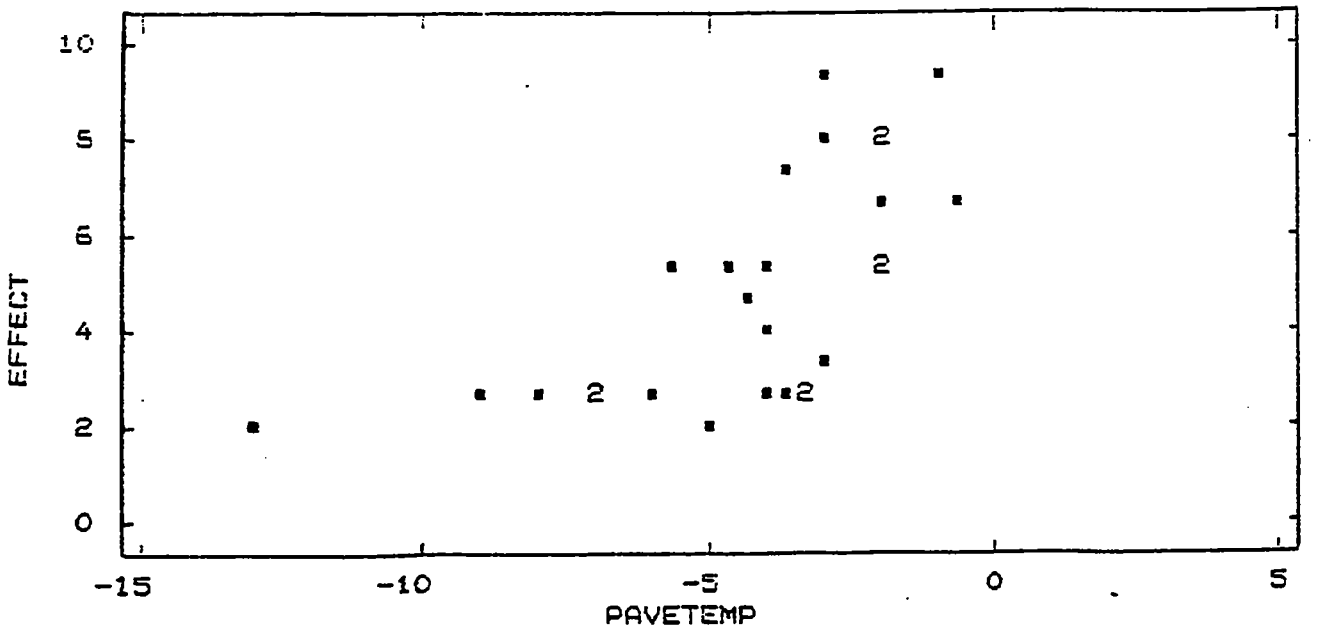
Friedman Results --- 04-01-92.

APPENDIX E

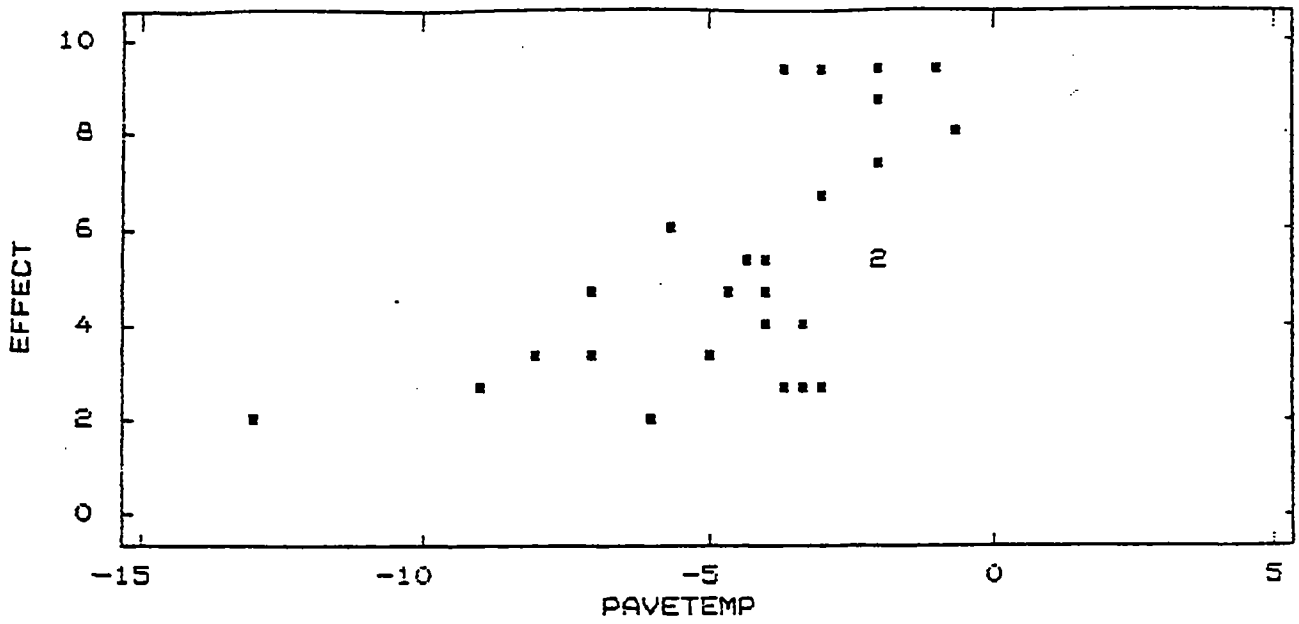
Meteorological Parameters vs *Effect* Plots



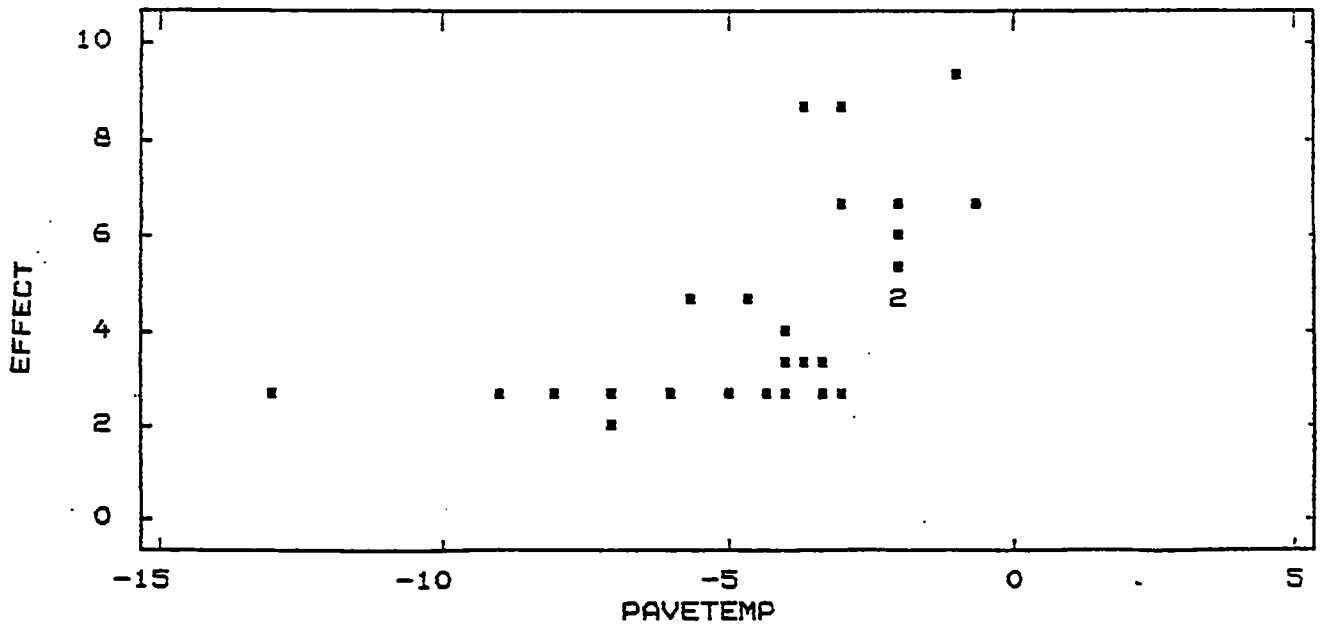
Pavement Temperature - *Effect* Relationship for 27 tests --- Test Section 1.



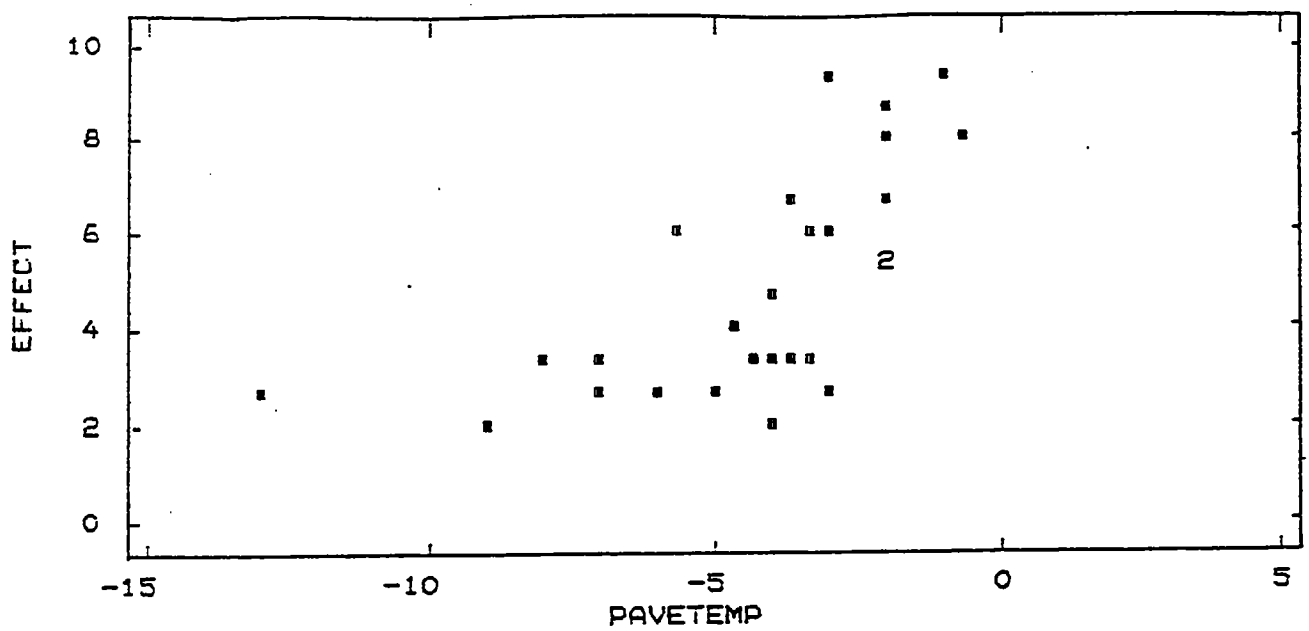
Pavement Temperature - *Effect* Relationship for 27 tests --- Test Section 2.



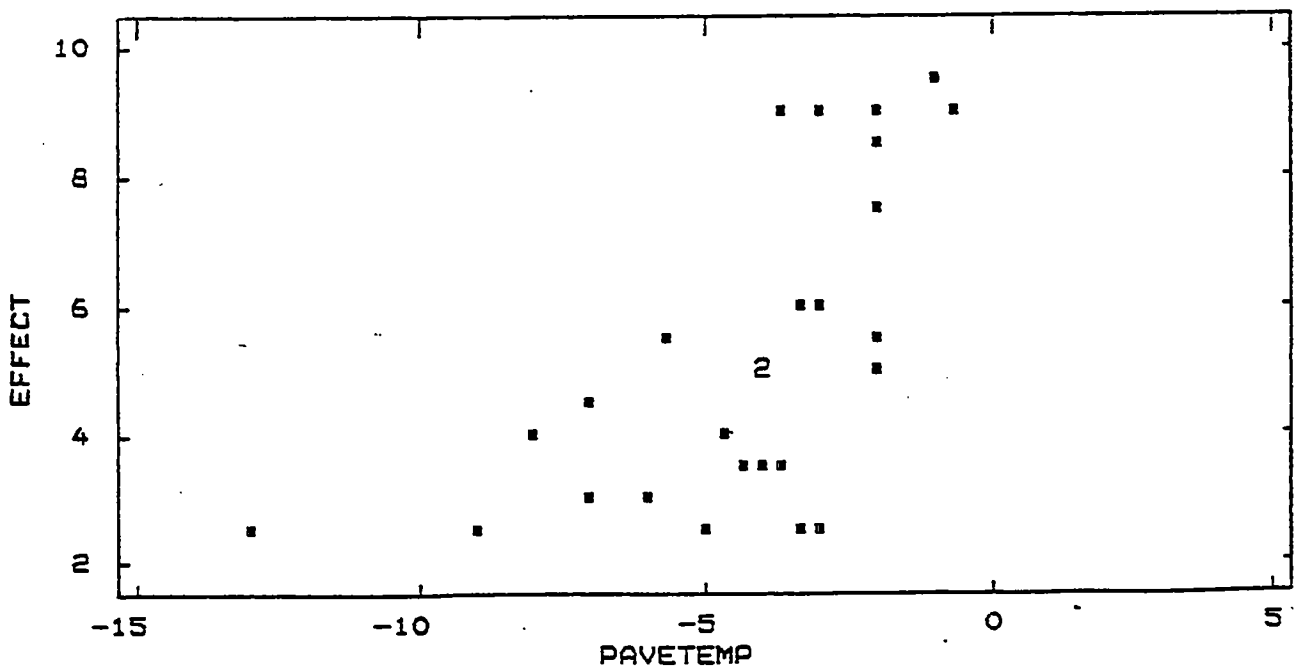
Pavement Temperature - *Effect* Relationship for 27 tests --- Test Section 3.



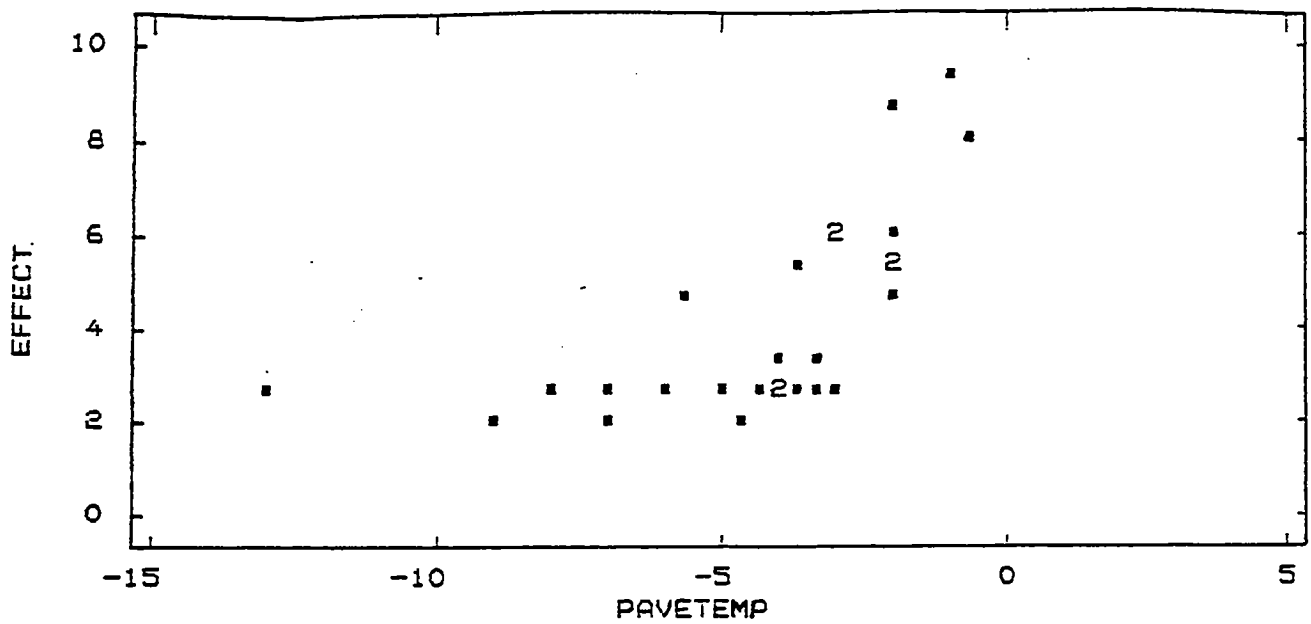
Pavement Temperature - *Effect* Relationship for 27 tests --- Test Section 4.



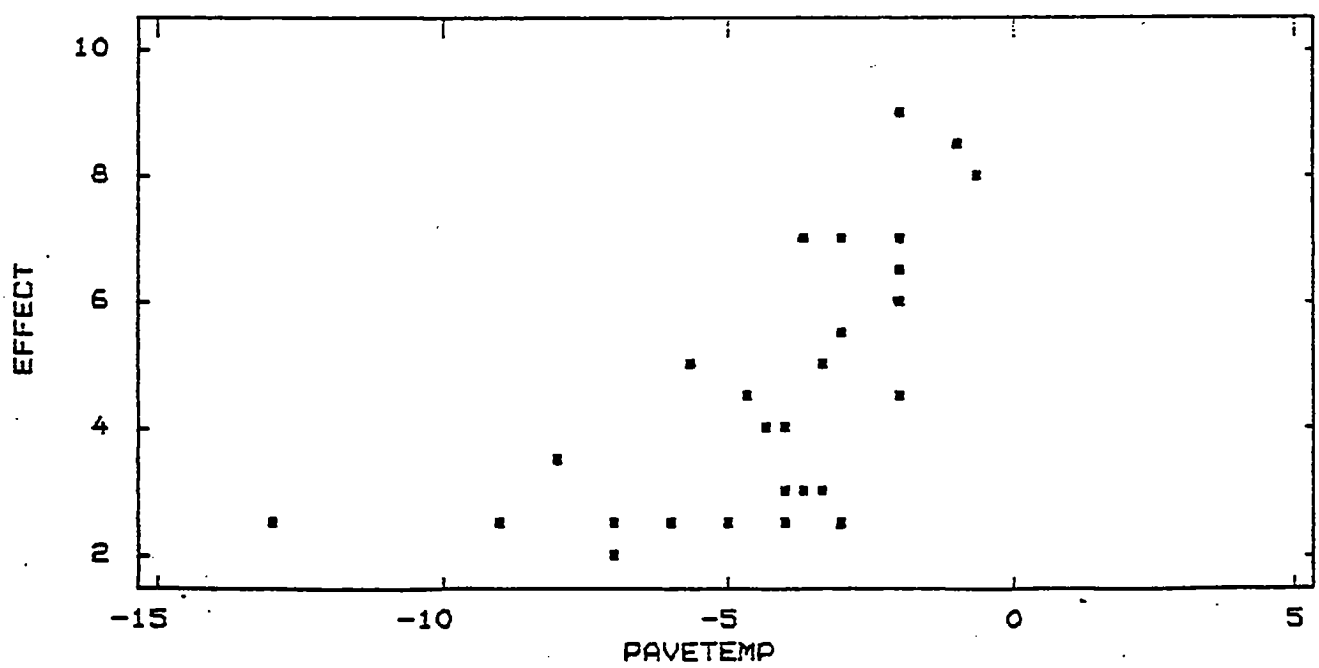
Pavement Temperature - *Effect* Relationship for 27 tests --- Test Section 5.



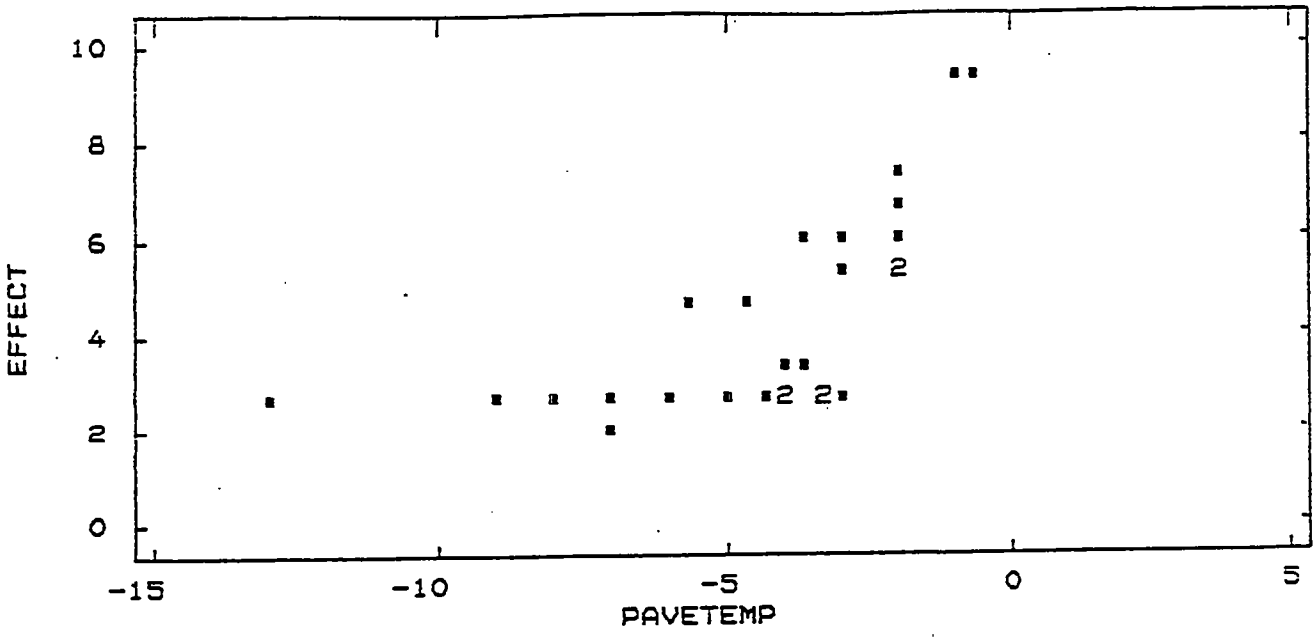
Pavement Temperature - *Effect* Relationship for 27 tests --- Test Section 6.



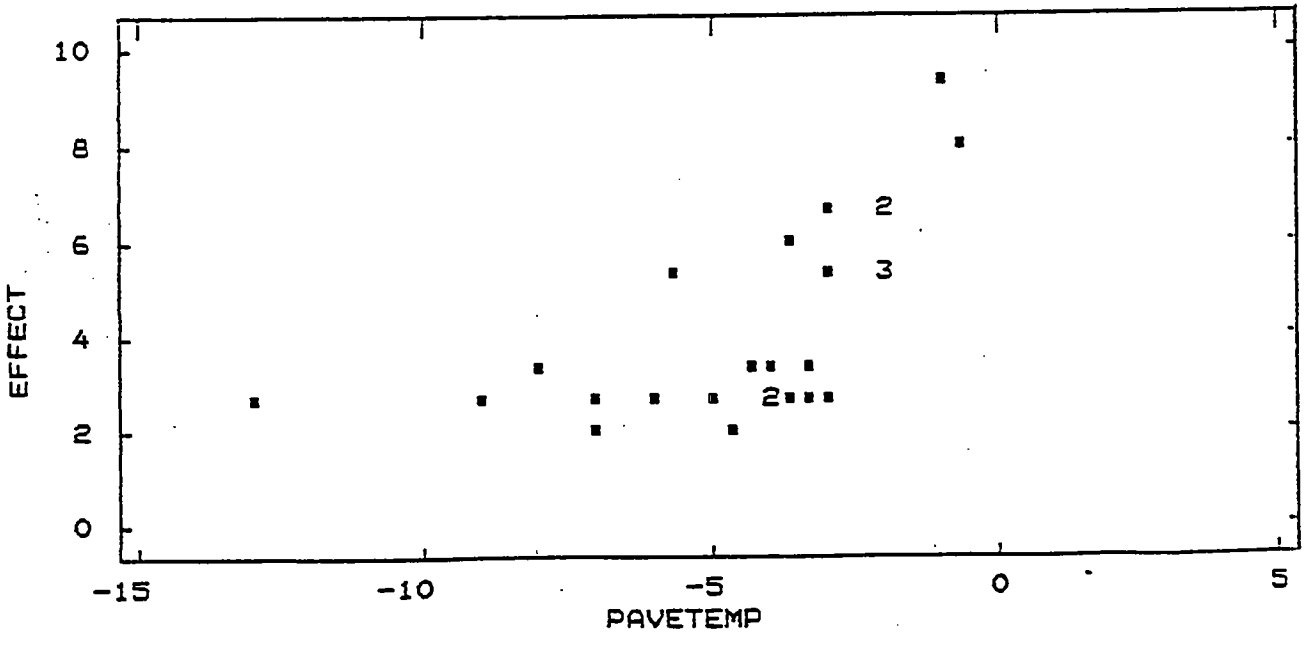
Pavement Temperature - *Effect* Relationship for 27 tests --- Test Section 7.



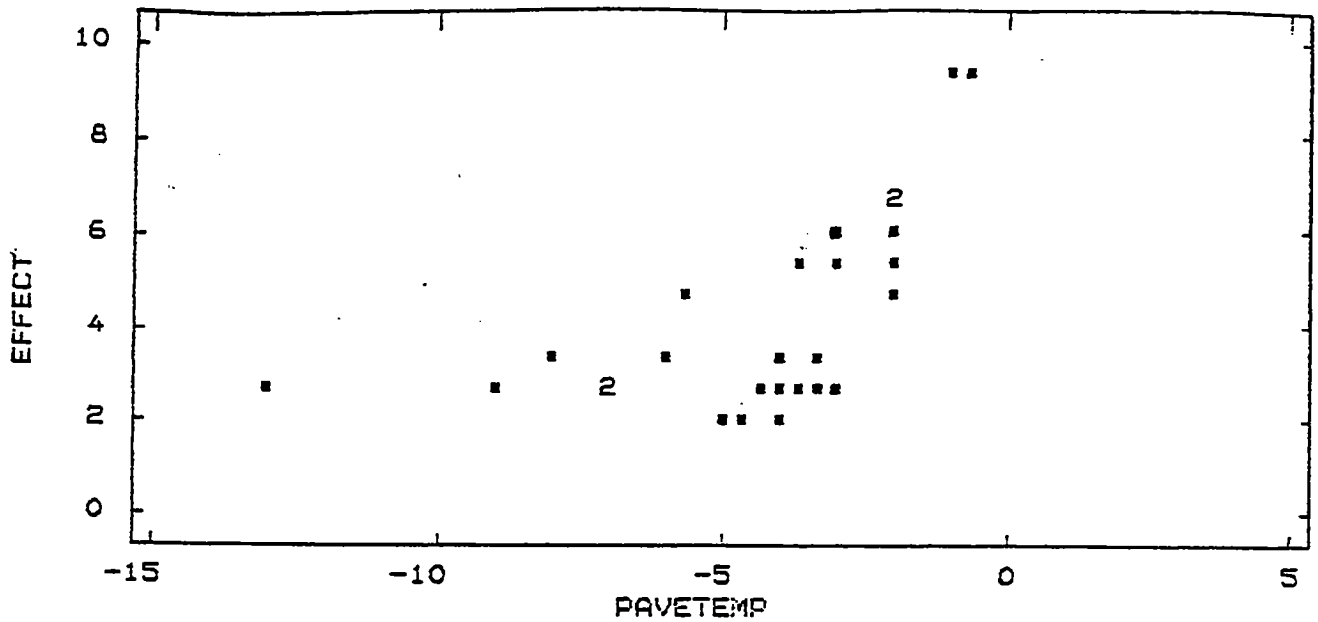
Pavement Temperature - *Effect* Relationship for 27 tests --- Test Section 8.



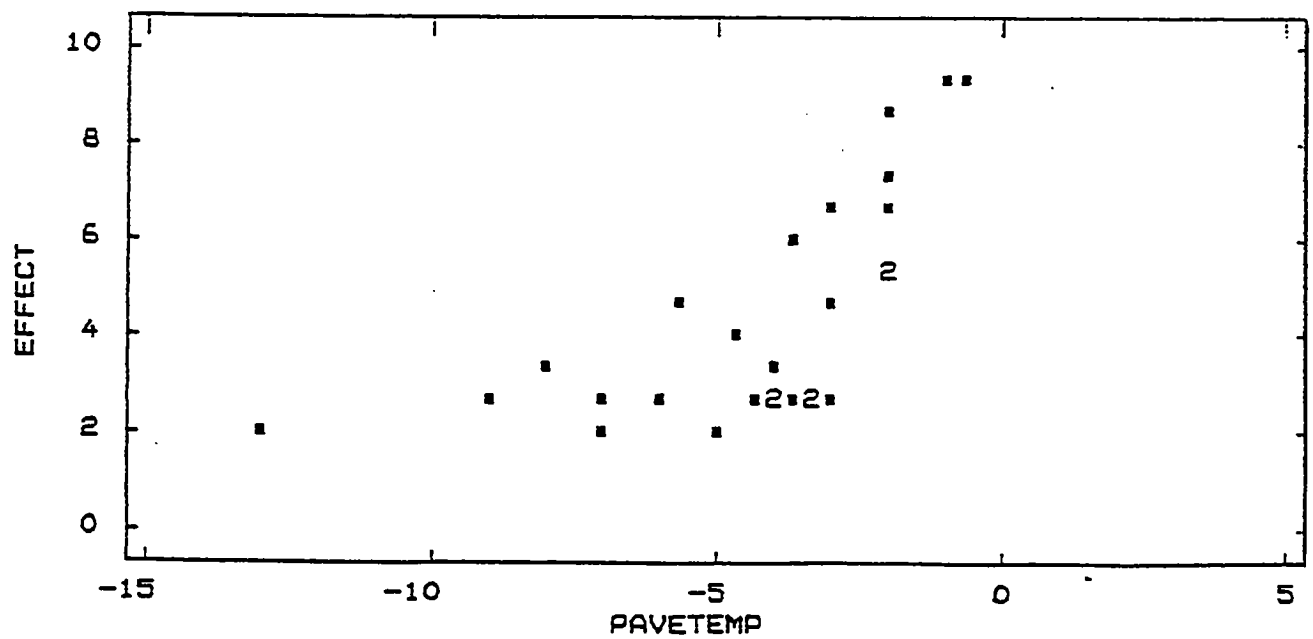
Pavement Temperature - *Effect* Relationship for 27 tests --- Test Section 9.



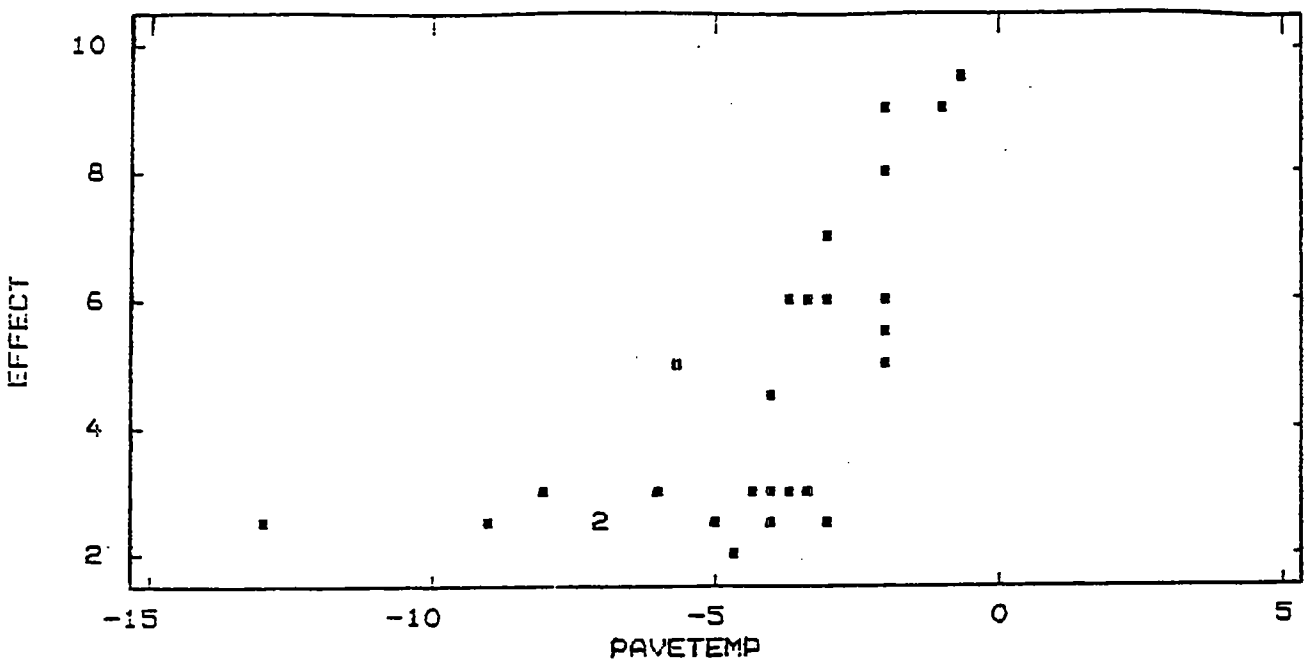
Pavement Temperature - *Effect* Relationship for 27 tests --- Test Section 10.



Pavement Temperature - *Effect* Relationship for 27 tests --- Test Section 11.



Pavement Temperature - *Effect* Relationship for 27 tests --- Test Section 12.



Pavement Temperature - *Effect* Relationship for 27 tests --- Test Section 13.

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