OPTIMIZATION OF SALT FOG CONDITIONS FOR ORGANIC ZINC PAINTS

FINAL REPORT

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METRIC CONVERSION FACTORS*

To Convert from	To	Multiply by
	Length	
foot	meter (m)	0.3048
inch	millimeter (mm)	25.4
yard	meter (m)	0.9144
mile (statute)	kilometer (km)	1.609
	Area	
square foot	square meter (m^2)	0.0929
square inch	square centimeter (cm^2)	6.451
square yard	square meter (m^2)	0.8361
	Volume (Capacity)	
cubic foot	cubic meter (m^3)	0.02832
gallon (U.S. liquid)**	cubic meter (m^3)	0.003785
gallon (Can. liquid)**	cubic meter (m^3)	0.004546
ounce (U.S. liquid)	cubic centimeter (cm^3)	29.57
	Mass	
ounce-mass (avdp)	gram (g)	28.35
pound-mass (avdp)	kilogram (kg)	0.4536
ton (metric)	kilogram (kg)	1000
ton (short, 2000 lbm)	kilogram (kg)	907.2
	Mass per Volume	
pound-mass/cubic foot	kilogram/cubic meter (kg/m^3)	16.02
pound-mass/cubic yard	kilogram/cubic meter (kg/m^3)	0.5933
pound-mass/gallon (U.S.)**	kilogram/cubic meter (kg/m^3)	119.8
pound-mass/gallon (Can.)**	kilogram/cubic meter (kg/m^3)	99.78
	Temperature	
deg Celsius (C)	kelvin (K)	$t_K=(t_C+273.15)$
deg Fahrenheit (F)	kelvin (K)	$t_K=(t_F+459.67)/1.8$
deg Fahrenheit (F)	deg Celsius (C)	$t_C=(t_F-32)/1.8$

*The reference source for information on SI units and more exact conversion factors is "Metric Practice Guide" ASTM E 380.

**One U.S. gallon equals 0.8327 Canadian gallon.

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ABSTRACT

Although Louisiana has been testing and using organic zinc coatings since 1963, premature failures have occcurred on bridges within the state recently. These failures were not predicted by accelerated testing which included salt fog exposure. The results of this project show that while salt fog testing cannot directly predict the longevity of field performance, it is an excellent tool which should be used in accelerated testing.

Time lapses between coats of paint do occur on new construction projects; therefore, it was also an objective of this study to evaluate the overall performance of coating systems after primers were allowed to weather. Although adhesion testing did not correlate to primer weathering, visual inspection did show primer degradation on topcoated panels. Therefore, it is recommended that the topcoat be applied to all paint systems immediately after the primer has cured sufficiently.

IMPLEMENTATION STATEMENT

The Department is called to realize the importance of accelerated testing. Although salt fog exposure does not predict exact field performance, it is a valuable tool in determining the effectiveness of a coating system. It is recommended that the accelerated testing of coatings be continued using the salt fog chamber operating at conditions identical to those established in ASTM specification B117.

The researchers call for for the Department to place time restrictions on all segments of a coating job.

INTRODUCTION

At the time that this project was undertaken, some of the organic zinc paint systems that were being used were showing premature failures. These premature failures were not predicted by accelerated testing in a salt fog chamber. It was therefore imperative that the accelerated testing procedures be reevaluated to better predict the performance of coatings in the environment.

The effect that the weathering of primer before it was topcoated had on the overall performance of a coating system was unknown. This problem occurs on most of the new construction projects. Therefore, this aspect of painting was explored.

OBJECTIVE

The objective of this program was to review and develop accelerated testing mechanisms for organic zinc coatings. The study compared the weathering of organic zinc coatings at two outdoor exposures in the state with accelerated testing in a salt fog chamber under three different operating conditions.

Another objective of the study was to determine variances in perfomance that would occur after allowing the primer to weather for different periods of time before topcoating.

METHODOLOGY

Organic zinc coating systems were obtained from four coating manufacturers. The coating systems were being used by the state at the time this project started. Three zinc rich epoxy primers with their respective epoxy topcoats and a phenoxy organic zinc with a vinyl topcoat were used.

Each primer was applied to forty-five panels; fifteen were topcoated with their respective topcoats. One of these panels was retained as a reference. Two of the topcoated panels were placed at each of the two outdoor exposure sites. The remainder of the topcoated panels were reserved for salt fog testing.

The 30 untopcoated panels of each of the four tested systems were placed at the outdoor exposure sites. After one week of being exposed outdoors, three untopcoated panels for each system were taken from each site, topcoated, and returned to its exposure site. The same procedure was followed for the remaining untopcoated panels, except that the primer was exposed longer in each case. The exposure times were one month, three months, and six months.

All coats of paint were applied by conventional spray at a minimum dry film thickness of 3 mils in accordance with Section 811 of the Louisiana Standard Specifications for Roads and Bridges.

The Industrial 411 Salt Fog Chamber was operated at three different conditions. Three panels of each system were tested in each of the salt fog conditions.

Salt Fog condition "a" used for testing was the Louisiana Department of Transportation and Development specification LDH-TR (1011-74). The operating conditions were 135±8°F temperature, atomization pressure 15 ± 3 psi, 8 hours heating, 16 hours non-heating, and 18% salt concentration.

Condition "b" was the ASTM condition, ASTM-B117. The operating conditions were 95°+2°-3°F temperature, atomization and fog gravity as specified (1.0-2.0 ml/hr collected over 16 hr. run), pH 6.5-7.2 and salt concentration 5 ± 1 wt.%.

Condition "c" was the same as "b" but the spray was in operation 8 hours and off 16 hours.

The systems were allowed to remain in the salt fog cabinet until they showed signs of failure. The coatings were evaluated for rusting, blistering, undercutting or delamination. If any of the above conditions existed the coating system failed.

After every four weeks in the salt fog, adhesion tests were conducted using an Elcometer Adhesion Tester Model 106 according to the manufacturer's operating instructions. The authors were aware of the questioned reliability of the Elcometer adhesion tester; however, the test method was deemed more appropriate for this research than any of the other practiced adhesion test methods. Adhesion values were not used for determining failure, rather they were used only for comparisons.

Each of the two outdoor sites was deemed a harsh test for coatings, based on early paint failures at the locations. One site was on the U.S. 11 bridge over Lake Pontchartrain. The other site was the U.S. 167 bridge over the Wax Lake Outlet Channel. Panels were wired to the bridges at both locations in a position where they achieved the maximum southern exposure. The positions were selected to avoid road contamination and splash zone effects.

Elcometer adhesion tests were performed on the panels at the outdoor sites at exposures of three months, 6 months, one year and thereafter in periods of six month intervals.

Periodic visual examination of the panels was conducted for excessive rusting, blistering, undercutting, delamination, or excessive chalking.

DISCUSSION OF RESULTS

When testing under condition "a", all of the systems failed after four weeks' exposure. All of the systems failed under conditions "b" and "c" after twelve weeks' exposure.

As shown in Table I,* system "W", "X" and "Z" failed only by undercutting at the scribe, whereas, system "Y" failed by blistering and undercutting.

After testing under all salt fog conditions, the coatings exhibited no chalking and the color was almost identical to the reference panels.

Examination of the panels that were placed at the two outdoor exposure sites showed that the Wax Lake Outlet site was much more of a corrosive environment than was the Lake Pontchartrain site. The panels placed at the Wax Lake Outlet site showed more rusting and chalking than the panels placed at the Lake Pontchartrain site.

After three years' exposure, none of the systems failed at either location. Some rust near the scribes was evident. All four systems were chalking and there was a significant difference in color as compared to the reference panels. None of the panels delaminated as was expected.

The panels that were tested in the salt fog chamber did not have the same appearance as did the panels that were placed in outdoor exposures. The modes of failure in the salt fog chamber were undercutting at the scribe and blistering. The panels at the outdoor exposure were chalking heavily, but showed no undercutting or blistering.

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*All tables & figures located on pages 11-28

The adhesion tests showed that the coating adhesion fluctuated. The coating adhesion did not decrease through time as was expected.

Figure I shows the adhesion test results as related to time for system "W" for each three salt fog conditions. During condition "a" there is a steady rise in adhesion. Conditions "b" and "c" show cyclic behavior of increased adhesion and decreased adhesion.

All of the other systems show the same behavior as shown in Figures II, III, and IV.

As shown in Figures 5, 6, 7, and 8, the coating adhesion showed a cyclic behavior similar to that which occurred during the salt fog testing. Except for system "X", the coatings did not attain their maximum adhesion until they were exposed for approximately one year.

The adhesion data for systems from salt fog testing were not the same as the data obtained from the outdoor exposure sites. However, the adhesion cycle patterns were somewhat similar when comparing the salt fog data with the outdoor exposure data.

After three years of outdoor weathering, all of the panels were inspected visually and adhesion tests were run on the different coatings.

Visual inspection of the panels before and after they were subjected to three years of outdoor exposure showed no appreciable difference in any of the panels of a system.

The adhesion tests on the coatings showed different results for each system. As shown in Table II for system "W" at the Lake Pontchartrain site, the maximum initial adhesion was after 6 months exposure of the primer. The maximum final adhesion was on the coatings that were applied after a one month exposure of the primer. At the Wax

Lake Outlet site, maximum initial adhesion occurred after a one month exposure of the primer and final adhesion was best on the panels on which the primer was exposed for six months.

Table III shows that on system "X" at the Lake Pontchartrain site, the maximum initial adhesion occurred after the primer had been exposed one week and the maximum final adhesion occurred on primer exposed one month. At the Wax Lake Outlet site, maximum initial adhesion was after one week and the maximum final adhesion occurred after a three month exposure.

As shown in Tables IV and V, systems "Y" and "Z" performed in a similar manner.

CONCLUSIONS

The inconsistency in the data that this project produced, confirms the belief that salt fog exposure testing alone cannot accurately predict the performance of coatings in the field, because failure modes of the salt fog chamber and outdoor exposure differ. However, salt fog testing does aid in predicting the field performance of a coating. The fluctuating behavior of coating adhesion that occurred under salt fog conditions "b" and "c" were similar to the adhesion patterns exhibited by the coating, exposed at the two different outdoor sites. Therefore, some of the same stresses coatings undergo in the field can be duplicated in a salt fog chamber.

Although no consistent performance pattern was established in allowing different elapsed times between topcoating and primer, degradation of the primer did occur after leaving the primer uncoated for a prolonged period. This degradation of the primer does affect the primer's overall effectiveness by permitting the zinc in the coating to oxidize in the atmosphere rather than galvanically protecting the steel. The longer the primer was exposed to the atmosphere, the more atmospheric contaminants deposited on the panels. When these panels were subsequently topcoated, extreme care was taken to thoroughly clean the primer. The same extent of cleaning would not be practical on a highway structure.

The adhesion data did not support the above conclusions concerning primer exposure, rather in most cases, coating adhesion was higher for those primers which were exposed for periods longer than one week. However, these higher coating adhesions could be the result of adhesion fluctuation that was observed in all of the outdoor exposure tests.

RECOMMENDATIONS

Accelerated testing is a necessity in the evaluation of coating systems. This project has shown that a salt fog chamber cannot duplicate field environments for coatings. However, it has shown that the salt fog chamber can be a useful tool in the evaluation of coatings.

The failure modes of salt fog conditions "a" and "b" were identical. However, condition "b" caused the same type of fluctuating adhesion stresses that were observed in the outdoor exposures; therefore, it is recommended that coating systems be tested in the salt fog chamber operating at condition "b" (ASTM B117) and each new system be required to perform satisfactorily for 1500 hours of exposure.

It is also recommended that organic zinc primers should be topcoated immediately after the primer has cured sufficiently to prevent degradation and contamination of the primer, thereby enabling the primer and topcoat to protect the steel as intended.

APPENDIX A

List of Tables

TABLE I

SALT FOG TESTING FAILURE MODES

System	Condition	Description
W	a	Undercutting
	b	Undercutting
	c	Undercutting
X	a	Undercutting
	b	Undercutting
	c	Undercutting
Y	a	Blistering
	b	Blistering and Undercutting
	c	Blistering
Z	a	Undercutting
	b	Undercutting
	c	Undercutting

TABLE II

ORGANIC ZINC SYSTEM "W" EXPOSED PRIMER PERFORMANCE

Lake Pontchartrain Location

Primer Exposed	Adhesion after topcoating, psi	Final Adhesion, psi
1 week	400	292
1 month	358	358
3 months	325	317
6 months	408	300

Wax Lake Outlet Location

1 week	400	675
1 month	433	550
3 months	358	458
6 months	342	750

TABLE III

ORGANIC ZINC SYSTEM "X" EXPOSED PRIMER PERFORMANCE

Lake Pontchartrain Location

Primer Exposed	Adhesion after Topcoating, psi	Final Adhesion, psi
1 week	700	350
1 month	517	383
3 months	483	233
6 months	550	283

Wax Lake Outlet Location

Primer Exposed	Adhesion after Topcoating, psi	Final Adhesion, psi
1 week	650	250
1 month	558	275
3 months	442	483
6 months	467	258

TABLE IV

ORGANIC ZINC SYSTEM "Y" EXPOSED PRIMER PERFORMANCE

Primer Exposed	Adhesion after Topcoating, psi	Final Adhesion, psi
Lake Pontchartrain Location		
1 week	500	333
1 month	542	417
3 months	458	458
6 months	533	400
Wax Lake Outlet Location		
1 week	475	333
1 month	500	333
3 months	575	375
6 months	483	567

TABLE V

ORGANIC ZINC SYSTEM "Z" EXPOSED PRIMER PERFORMANCE

Lake Pontchartrain Location

Primer Exposed	Adhesion after Topcoating, psi	Final Adhesion, psi
1 week	325	375
1 month	317	333
3 months	367	358
6 months	517	342

Wax Lake Outlet Location

Primer Exposed	Adhesion after Topcoating, psi	Final Adhesion, psi
1 week	300	325
1 month	308	308
3 months	433	375
6 months	558	391

APPENDIX B

List of Figures

Figure 1
Salt Fog Testing
Organic Zinc System "W"

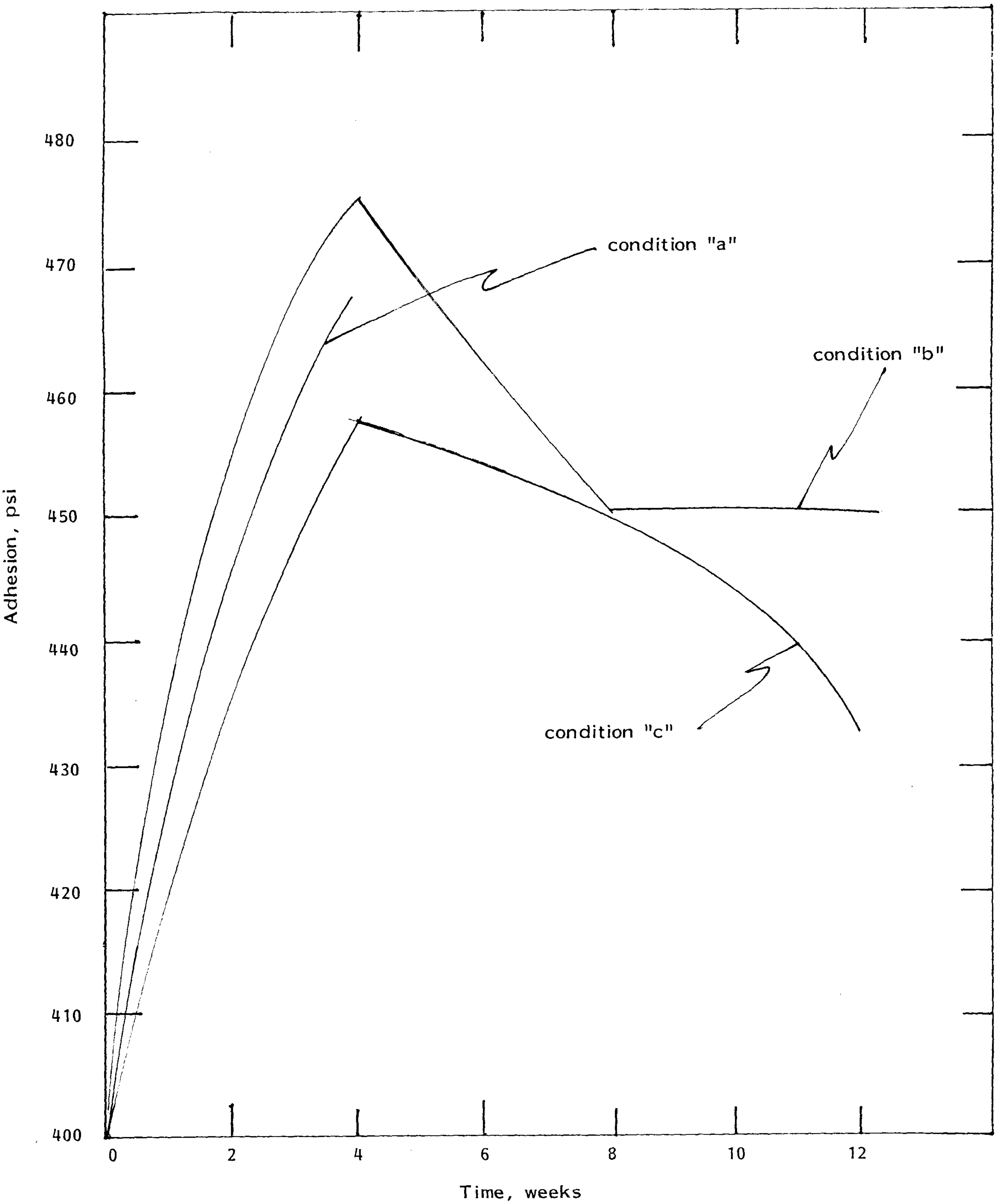

Figure 2
Salt Fog Testing
Organic Zinc System "X"

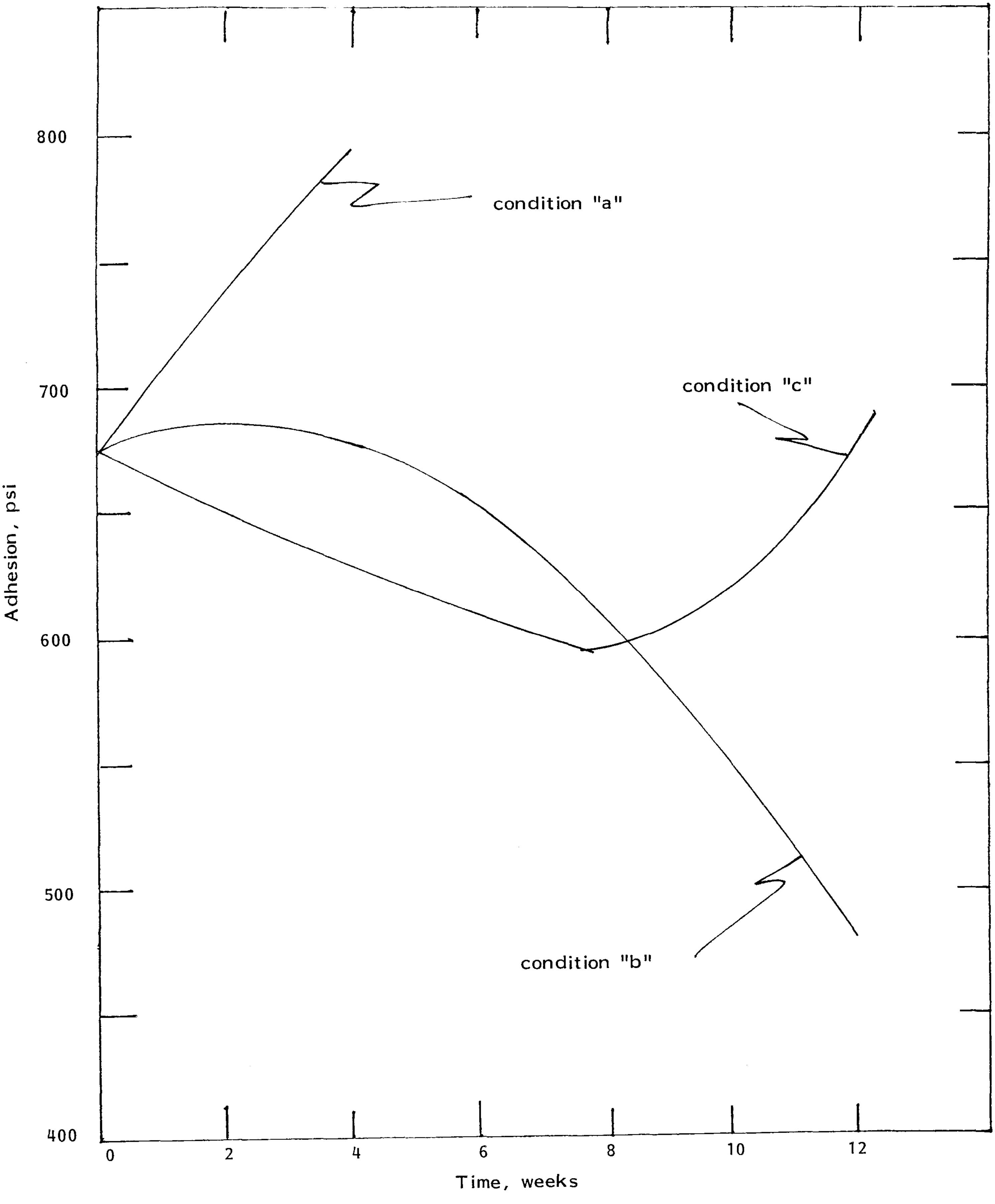

Figure 3
Salt Fog Testing
Organic Zinc System "Y"

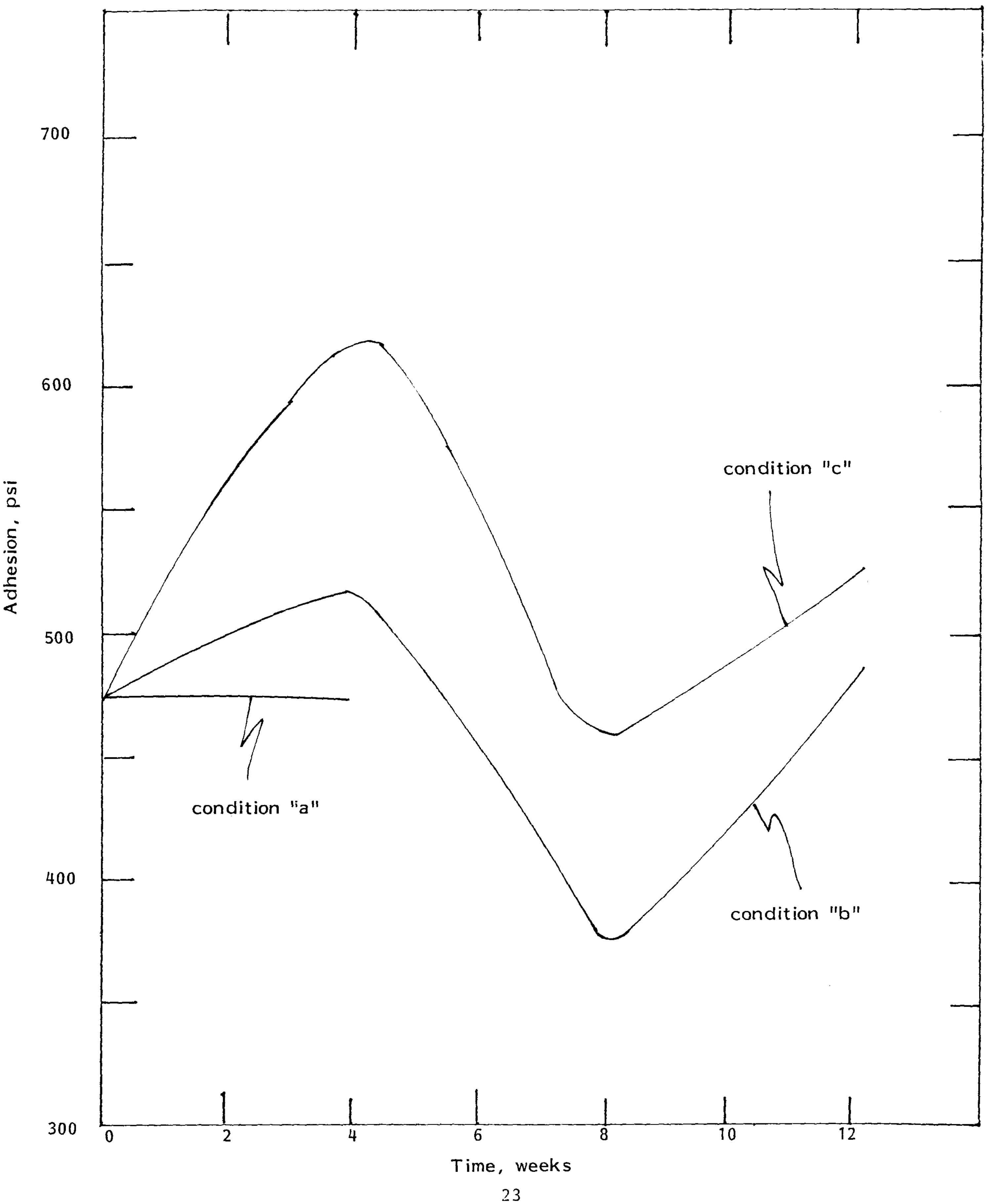

Figure 4
Salt Fog Testing
Organic Zinc System "Z"

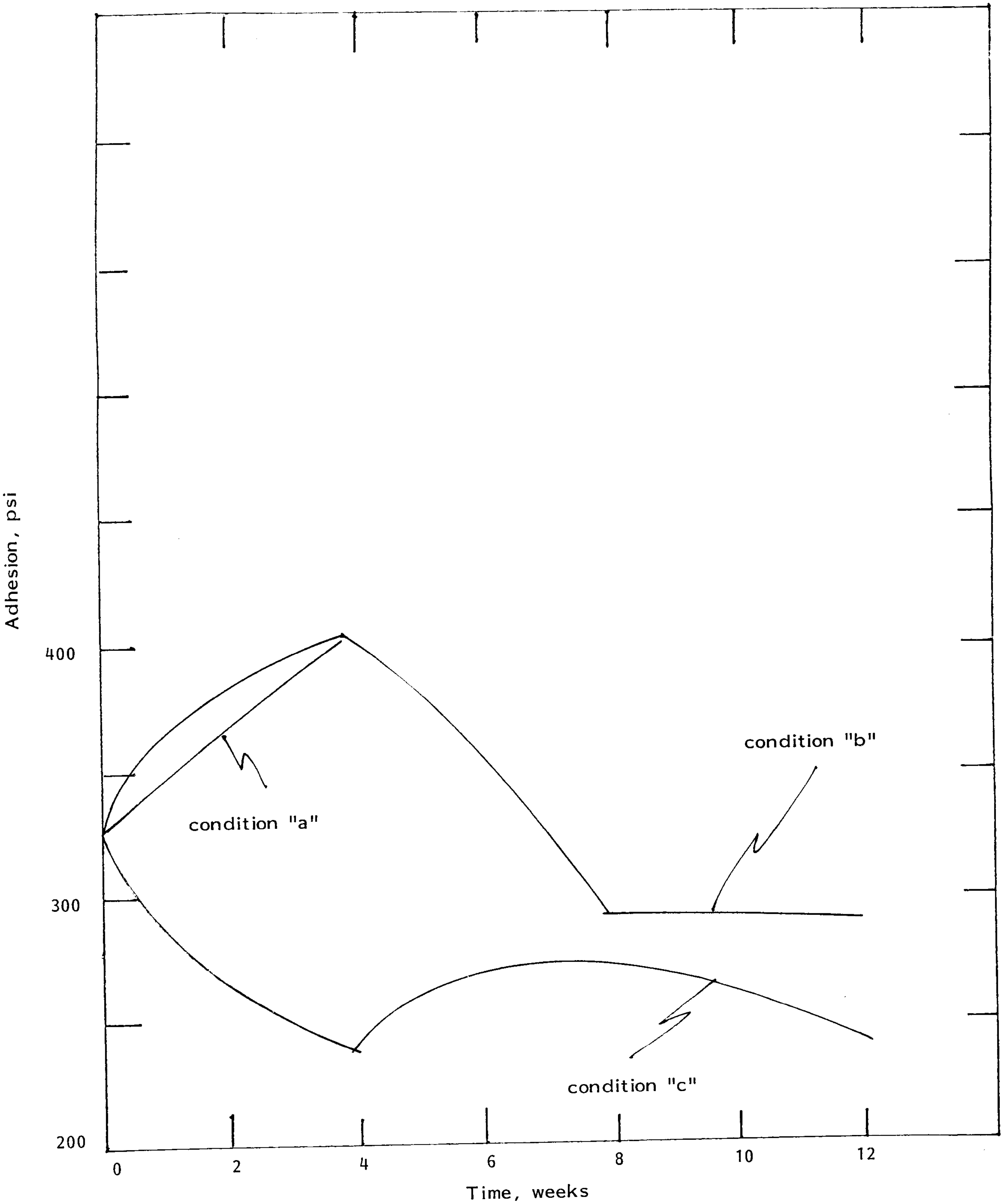

Figure 5
Outdoor Locations
Organic Zinc System "W"

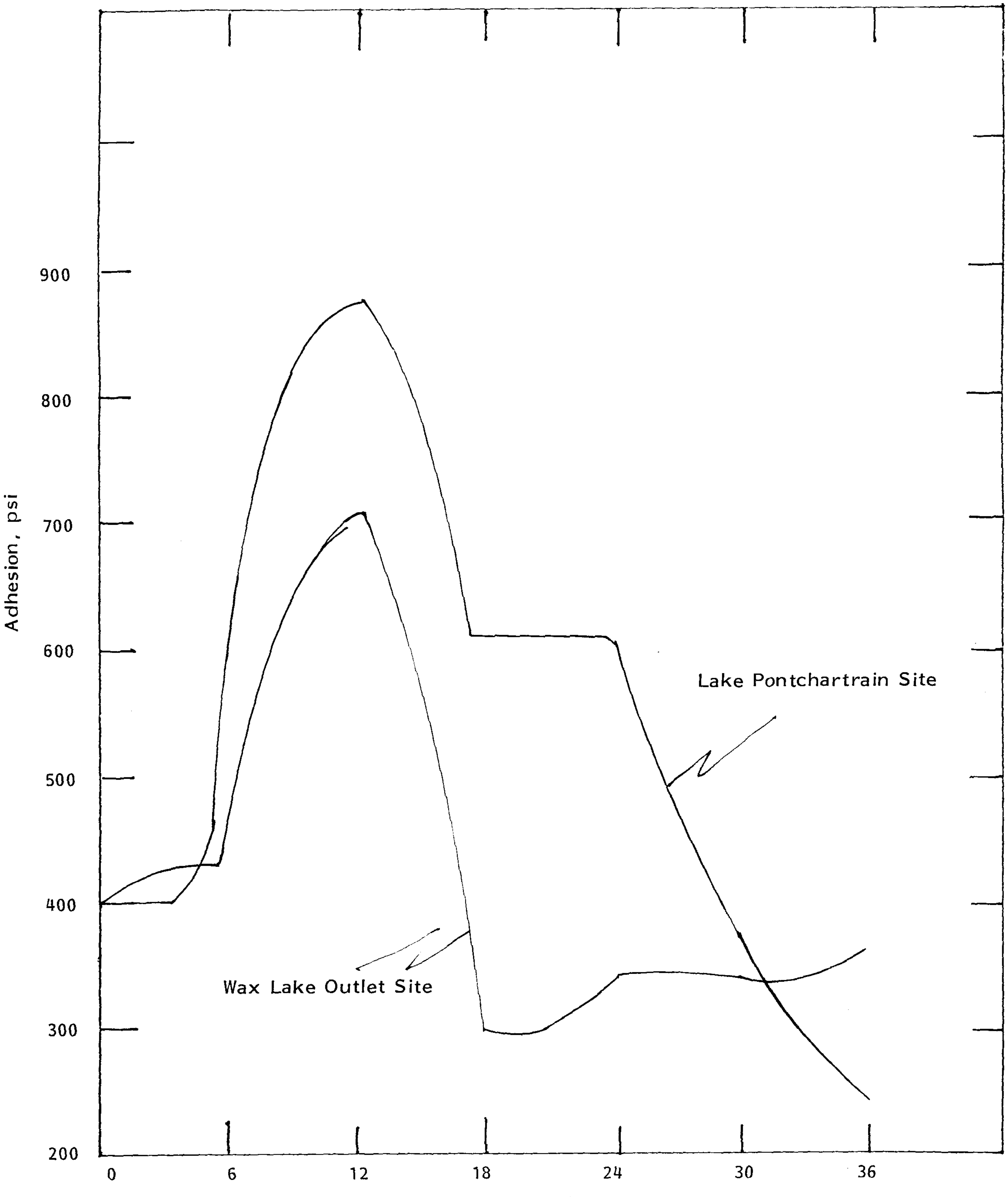

Figure 6
Outdoor Locations
Organic Zinc System "X"

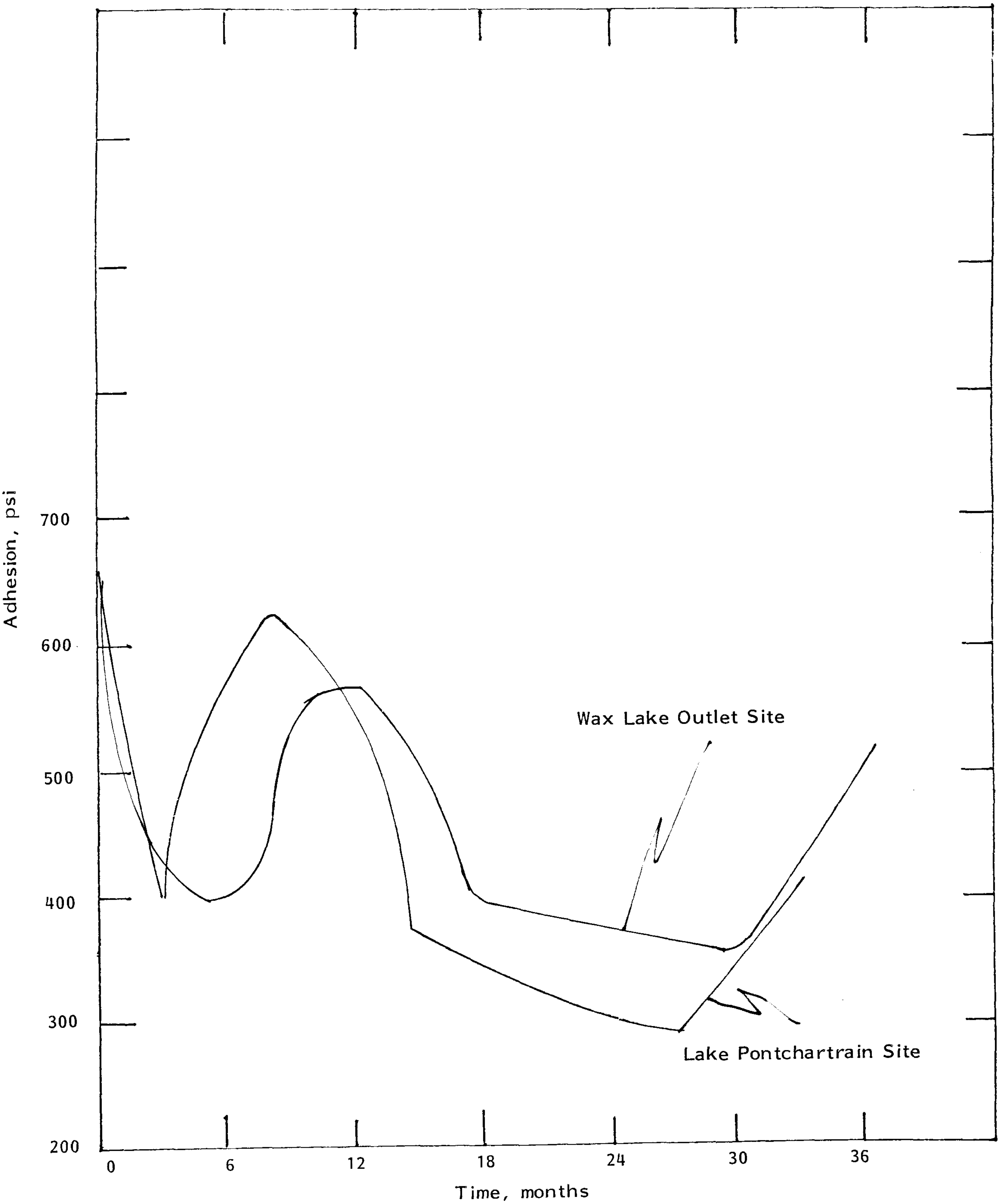

Figure 7
Outdoor Locations
Organic Zinc System "Y"

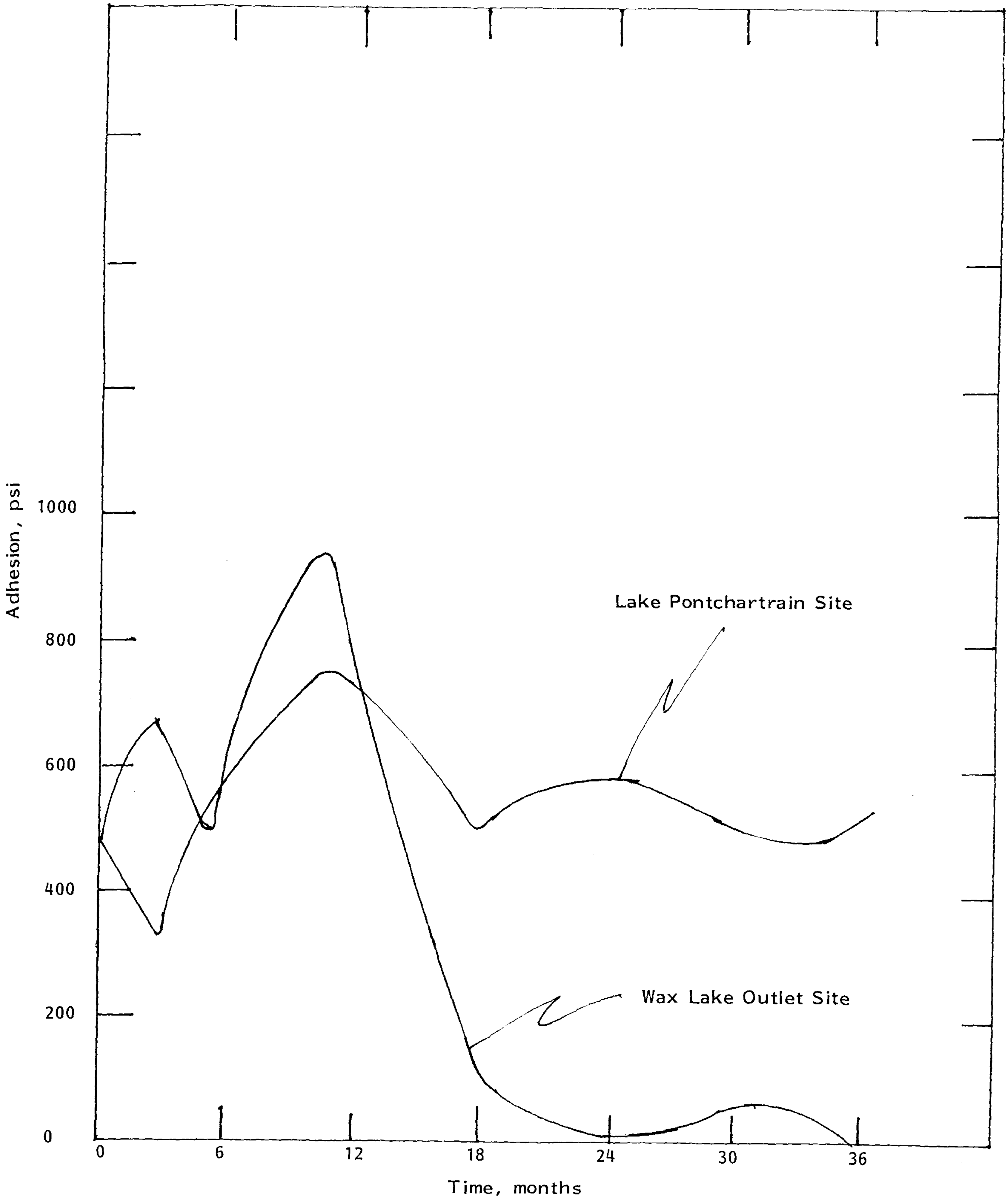

Figure 8
Outdoor Locations
Organic Zinc System "Z"