

IOWA STATE HIGHWAY COMMISSION
Materials Department
SPECIAL INVESTIGATIONS

Research Project
R-242
Final Report

Evaluation of Concrete
Sealers for use on Bridge
Pier Tops and Abutments

November, 1971

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OF

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EVALUATION OF CONCRETE SEALERS FOR USE
ON BRIDGE PIER TOPS AND ABUTMENTS

November 1971

By:

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INTRODUCTION

Many reports have been written concerning investigations of concrete sealants. The primary concern of most investigators is the protection of bridge decks from de-icing chemicals which cause surface scaling and, when allowed to permeate to reinforcing steel, result in deep spalling and general concrete deterioration.

It has been the conclusion of the majority of these reports that few proprietary products can afford the protection provided by regular linseed oil treatments. Epoxy resins have generally performed well in laboratory investigations, however, they are usually a coating rather than a sealant and provide an objectionable smooth surface. An exception to this is the penetrating epoxy sealants. There appears to be conflicting evidence concerning chlorinated rubber compounds. (1, 2)

As a result of the many investigations conducted in this area, the standard practice of treating bridge decks in Iowa consists of applying a boiled linseed oil solution at regular intervals.

The problem of protecting abutments and pier tops from salt solutions entails a significantly different approach than the problem of protecting bridge decks. The epoxy resins become eligible as a protective material since one need not be concerned with slipperiness or its abrasive characteristics. Protection with linseed oil at regular intervals would prove bothersome because of the inaccessibility of pier tops after the deck is placed.

One significant factor associated with the scaling and spalling of concrete surfaces, is the quality of aggregates incorporated into the concrete. While specifications limit the amount of shale

or other deleterious material contained in an aggregate, it is also recognized that an aggregate containing an amount of shale close to the specification limit will have a greater tendency to produce concrete susceptible to the scaling and "pop-outs" than an aggregate relatively free of these materials. For a concrete sealer to be effective it must have the capability of protecting any concrete containing a limited amount of deleterious particles.

It should be stated here that because of the limited size of concrete test specimens used in a laboratory investigation, variable results may be obtained if the coarse aggregate contains particles of shale, unsound chert, or other deleterious materials. It is highly unlikely that each specimen would contain the same amount of deleterious particles located in the same relative position. When the variable under study is a concrete sealer, every effort should be made to have the specimens being sealed as uniform as possible, and for this reason the coarse aggregate used is generally of a uniform high quality.

Because of the larger number of particles in the fine aggregate the chance of a uniform distribution of deleterious particles within this fraction is quite good and specimens may be prepared to evaluate the sealers in terms of the protection they will afford concrete containing something other than the highest quality aggregates available.

PURPOSE AND SCOPE

The primary purpose of this investigation was to evaluate various commercial products in terms of their ability to prevent concrete scaling of bridge abutments and pier tops which are subject to

to salt water deterioration.

Inquiries were sent to 10 companies inviting them to submit products to be evaluated in this study. A total of 16 sealers were submitted for study by 10 companies. Some products were sealers only and some were to be used as a combination curing material and sealer.

The participating companies were required to provide complete instructions concerning the use of their materials including concrete curing, application rates, etc. If a range of application rates was provided, the heaviest coverage was applied to the specimens. One company chose to submit four chlorinated rubber compounds for evaluation (2 clear sealers, 2 white pigmented cure-seal materials) however, only the two compounds with the highest solids content were evaluated (1 clear sealer, 1 white pigmented cure-seal material.)

MATERIALS AND SPECIMEN PREPARATION

The concrete used in all of the specimens was a structural C-5 mix commonly used in structures throughout the state. The mix proportions are as follows:

	<u>Approx. Dry Wt. per Cubic Yard</u>
Cement (Pounds)	650
Fine Aggregate (Pounds)	1576
Coarse Aggregate (Pounds)	1290
Air Content	6 ± 1%
Slump	2 ± 1/2 in.

The cement was a laboratory blend of seven Type I cements. A commercially available neutralized vinsol resin was used to obtain the air content.

The coarse aggregate used was a clean, uniformly graded limestone from Fort Dodge, all passing the 1 in. sieve.

Two sources of fine aggregate were used, both of which complied with current Iowa State Highway Commission specifications. The first series of specimens contained a fine aggregate from Ames containing approximately 0.8% shale. The second series of specimens contained a relatively shale free fine aggregate from West Des Moines, with a shale content of 0.1%.

Two types of concrete specimens were prepared to evaluate the sealers under study: (1) curved specimens to hold salt water when undergoing freezing and thawing tests and (2) flat specimens which could be placed in outdoor storage to measure the long term effects of weathering and sunlight on the sealer. (Fig. 1)

All specimens were cast in a mold 12" x 12" x 2-1/2". The outdoor weathering specimen, after vibration compaction, was wood float finished even with the top of the form. The freeze-thaw specimens were molded similar to those in a recent Pennsylvania study⁽²⁾ in that a 1 in. wall was formed on two parallel edges as the center of the slab was contoured to produce areas of the slab subject to both immersion and surface-liquid contact. The freeze-thaw specimens were constructed by vibration, utilizing a curved steel and brass form. After forming the slabs were set aside and later given a wood float finish to yield a uniform surface on all specimens.

After casting, all specimens were cured with plastic film, except those on which a combination cure-seal material was to be applied.

After 20 hours the specimens were removed from the molds and placed in the moist room for 14 days. After moist curing, the specimens were air dried for at least 5 days prior to the application of the sealer.

Two white pigmented, chlorinated rubber curing compounds were evaluated in this study. These materials were sprayed on the specimens after the moisture sheen from finishing had disappeared. After 20 hours, these specimens were also moist cured and air dried together with the other specimens.

Upon completion of the air drying period, the sealers were brushed on the specimens at the rates recommended by the manufacturer. After application of the sealers, the specimens were air dried an additional 7 days to allow the sealer to properly cure, before undergoing the freeze-thaw testing. The specimens to which curing compound was applied were air dried during the same period. Control specimens, to which no sealer was applied, were prepared and cured in a manner identical to specimens to which a sealer was applied.

For each sealer investigated, a total of 6 specimens were prepared; 1 outdoor storage and 2 freeze-thaw specimens containing a shale free fine aggregate and 1 outdoor storage and 2 freeze-thaw specimens containing the shale bearing fine aggregate.

For the sealers evaluated in this report, a total of 64 freeze-thaw specimens and 32 outdoor weathering specimens were prepared.

A tabulation of the sealers submitted for evaluation is shown in Table I.

TESTING PROCEDURE

After allowing the sealers to cure, 300 ml. of a 5% calcium chloride solution was placed on each freeze-thaw specimen. Each afternoon the specimens were placed in a freeze room maintained at -20°F., and thawed in laboratory air the following day. During the first 30 cycles of freeze and thaw tests, one freeze-thaw cycle per day was maintained. Thereafter, to expedite the testing phase, two freeze-thaw cycles were obtained per day by thawing 2-1/2 hours in circulating laboratory air, freezing 2-1/2 hours, thawing 2-1/2 hours and finally freezing overnight.

At the end of every 10 cycles the specimens were rinsed with clean tap water, wire brushed, and a fresh salt solution placed on the specimen.

After 10, 20, 40, 70 and 100 cycles the specimens were air dried, photographed and rated by a three man panel in accordance with the following system:

<u>Rating Number</u>	<u>Description</u>
0	No Scale
1	Slight Scale
2	Slight to Moderate Scale
3	Moderate Scale
4	Moderate to Heavy Scale
5	Heavy Scale

This procedure was followed for 100 freeze-thaw cycles or until the specimen developed leaks.

DISCUSSION OF TEST RESULTS

A summary of test results is shown in Tables II and III and Figures 2 - 17.

Only the penetrating epoxy-polysulfide sealer (Product No. 3) and an epoxy sealer (Product No. 16) provided adequate protection on all specimens. No scaling had occurred regardless of the quality of the fine aggregate used in the concrete.

As was expected, the sealers that were only a surface coating generally provided more protection from scaling to the concrete containing the shale-free fine aggregate. The freezing of the moisture within the shale particles near the surface of the specimen ruptures the sealer, thereby allowing the salt solution to reach the underlying concrete. After this barrier has been broken, the remaining sealer comes off quite rapidly; leaving the concrete unprotected. An exception to this occurred with Product No. 16 which is a surface coating material rather than a penetrating material. A very heavy coating of this material was applied which, apparently possessed a film of sufficient strength to resist the expansive pressures produced by the shale particles.

It is logical to assume that the shale in the fine aggregate directly under the surface, contained little or no moisture after the specimen had been air dried, and that part of the water migrating from the center of the specimen to the cold surface during freezing, entered the shale particles causing them to expand. It follows that if the foregoing assumption is correct, the penetrating epoxy effectively waterproofs these shale particles preventing the

re-entry of water during the freeze cycle.

To illustrate the damaging effect of moisture within the shale during freezing, ten pieces of shale from the same source as the shale bearing fine aggregate were subjected to two freeze-thaw cycles in a dry condition, and a saturated surface dry condition. Figures 18 and 19 show the breakdown of the saturated particles, and the almost complete immunity of the dry particles. Figure 20 shows the effect after ten pieces of dry shale were coated with the penetrating epoxy, immersed in water for 24 hours and subjected to two freeze-thaw cycles.

The chlorinated rubber compounds performed poorly on almost all specimens regardless as to whether they were used as a curing material or later as a sealer.

A 50% distilled tall oil, 50% kerosene solution provided protection to specimens comparable to the boiled linseed oil solution. The three component penetrating epoxy (Product No. 15) provided protection similar to the tall oil and linseed oil solutions.

After 1-1/2 years of natural weathering, all sealers on the outdoor storage specimens appear intact.

SCALING MECHANISM

The most severe scaling that occurred in the majority of test specimens was at the interface between the salt solution and the air (Fig. 21). While it is beyond the scope of this study to investigate the exact mechanism associated with this type of deterioration,

it may be assumed that it is caused by evaporation of water from the salt solution, thereby permitting salt crystallization at this interface area. This type of scaling has been reported where concrete is exposed to sea water(3).

CONCLUSIONS

1. The penetrating epoxy-polysulfide sealer and one epoxy sealer afforded the most protection of all the sealers studied regardless of aggregate quality.
2. Surface coating materials generally provided more protection to concrete containing shale-free aggregates than to concrete containing shale bearing aggregates.
3. The three component penetrating epoxy, distilled tall oil and boiled linseed oil provided as much, and usually more, protection to concrete as any surface sealer studied, except the penetrating epoxy-polysulfide and one epoxy sealer.
4. Chlorinated rubber compounds provided little protection to concrete regardless of aggregate quality.

References

- (1) Brink, Russell, Grieb, W.E. and Woolf, D. O. "Resistance of Concrete Slabs Exposed as Bridge Decks to Scaling Caused by De-Icing Agents". Highway Research Record 196, 1967.
- (2) Stewart, P. D., Shaffer, R. K. "Investigation of Concrete Protective Sealants and Curing Compounds". Highway Research Record 268, 1969.
- (3) Hollister, S. C. "Behavior of Concrete Exposed to Sea Water". ASTM Proceedings, Vol. 23, 1923.

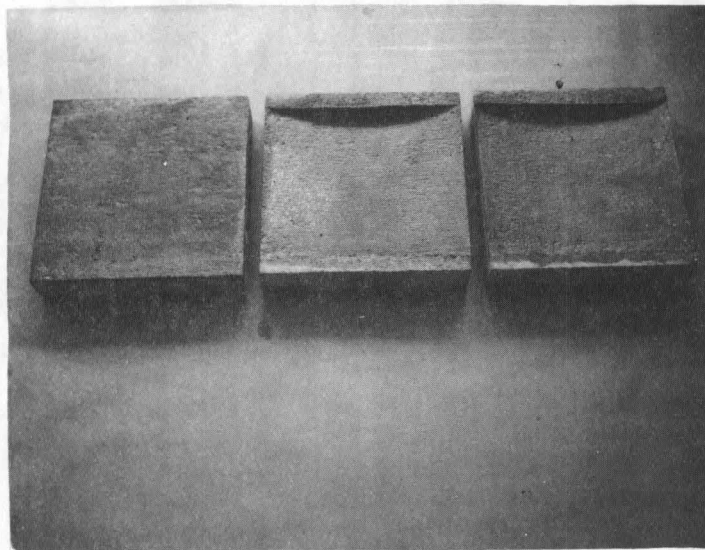


Fig. 1
Typical Specimens After Sealer Application

TABLE I

Sealers Submitted for Evaluation

<u>Product Number</u>	<u>Product Description</u>
1.	White pigmented chlorinated rubber curing compound, 27% solids.
2.	Clear chlorinated rubber, 29% solids.
3.	Two component penetrating polysulfide-epoxy resin, 50% solids.
4.	Two component epoxy resin surface coating.
5.	Clear epoxy chlorinated polymer.
6.	Two component epoxy bonding agent.
7.	Clear chlorinated rubber, 20% solids.
8.	White pigmented chlorinated rubber curing compound, 22% solids.
9.	Clear chlorinated rubber, 26% solids.
10.	White pigmented chlorinated rubber curing compound, 38% solids.
11.	Acrylic polymer resin.
12.	Two component epoxy resin surface coating.
13.	50% distilled tall oil, 50% kerosene.
14.	50% boiled linseed oil, 50% kerosene.
15.	Three component penetrating epoxy sealer.
16.	Two component epoxy sealer.
17.	Two component epoxy sealer.
Control	No sealer applied.

TABLE II
PRODUCT EVALUATIONS
SHALE FREE FINE AGGREGATE

Product Number	Application Rate Sq. Ft. per Gal.	Specimen Numbers	Av. Specimen Rating at Cycle No.				
			10	20	40	70	100
1	200	73 & 74	0	1	3	4	5
2	2 Coats of 200	134 & 135	1	2	2	2	3
3	80	40 & 41	0	0	0	0	0
4	1st Coat 275, 2nd & 3rd Coat 400	104 & 105	-	-	-	-	1
5		48 & 49	0	0	0	1	2
6		50 & 51	0	0	0	0	1
7*	---	-----	-	-	-	-	-
8*	---	-----	-	-	-	-	-
9	400	53 & 54	0	0	2	3	3
10	400	71 & 72	0	1	1	3	4
11	200	56 & 57	0	0	1	1	2
12	300*****	60 & 61	0	1	1	1	2
13	300**	62 & 63	0	0	1	1	1
14	300**	64 & 65	0	0	0	1	1
15	162	AZ1-4-1 & 2	0	0	0	0	0
16	90****	AZ1-5-1 & 2	0	0	0	0	0
17	135	AZ1-6-1 & 2	0	0	0	0	0
Control	No Sealer Applied	36 & 37	1	1	1	2	3

Note: * - No tests performed.

** - Mixed 50-50 with kerosene before applying to specimen.

**** - Recommended at 30 sq. ft. per gal. (Could not keep on specimen without ponding).

***** - 20% lacquer thinner added to mixture before applying to specimens.

TABLE III
PRODUCT EVALUATIONS
SHALE BEARING FINE AGGREGATE

Product Number	Application Rate Sq. Ft. per Gal.	Specimen Numbers	Av. Specimen Rating at Cycle No.				
			10	20	40	70	100
1***	200	25 & 26	0	2	3	5	5
2	2 Coats at 200	131 & 132	1	2	3	3	3
3	80	15 & 16	0	0	0	0	0
4	1st Coat 275, 2nd & 3rd Coat 400	101 & 102	-	-	-	-	3
5	300	3 & 4	0	0	1	2	3
6	103	21 & 22	0	1	1	2	4
7*	---	-----	-	-	-	-	-
8*	---	-----	-	-	-	-	-
9	400	7 & 8	0	0	1	1	1
10***	400	28 & 29	0	1	3	4	5
11	200	9 & 10	0	0	1	1	1
12	300	13 & 14	0	1	1	2	4
13	300**	113 & 114	0	1	1	1	1
14	300**	110 & 111	1	1	1	1	1
15	162	116 & 117	0	1	1	1	1
16	90****	119 & 120	0	0	0	0	0
17	135	122 & 123	1	1	1	1	1
Control	No Sealer Applied	31 & 32	0	3	3	4	5

Note: * - No tests performed.
 ** - Mixed 50-50 with kerosene before applying to specimen.
 *** - Specimens retired at 90 cycles (specimens leaking).
 **** - Recommended at 30 sq. ft. per gal. (Could not keep on specimen without ponding).

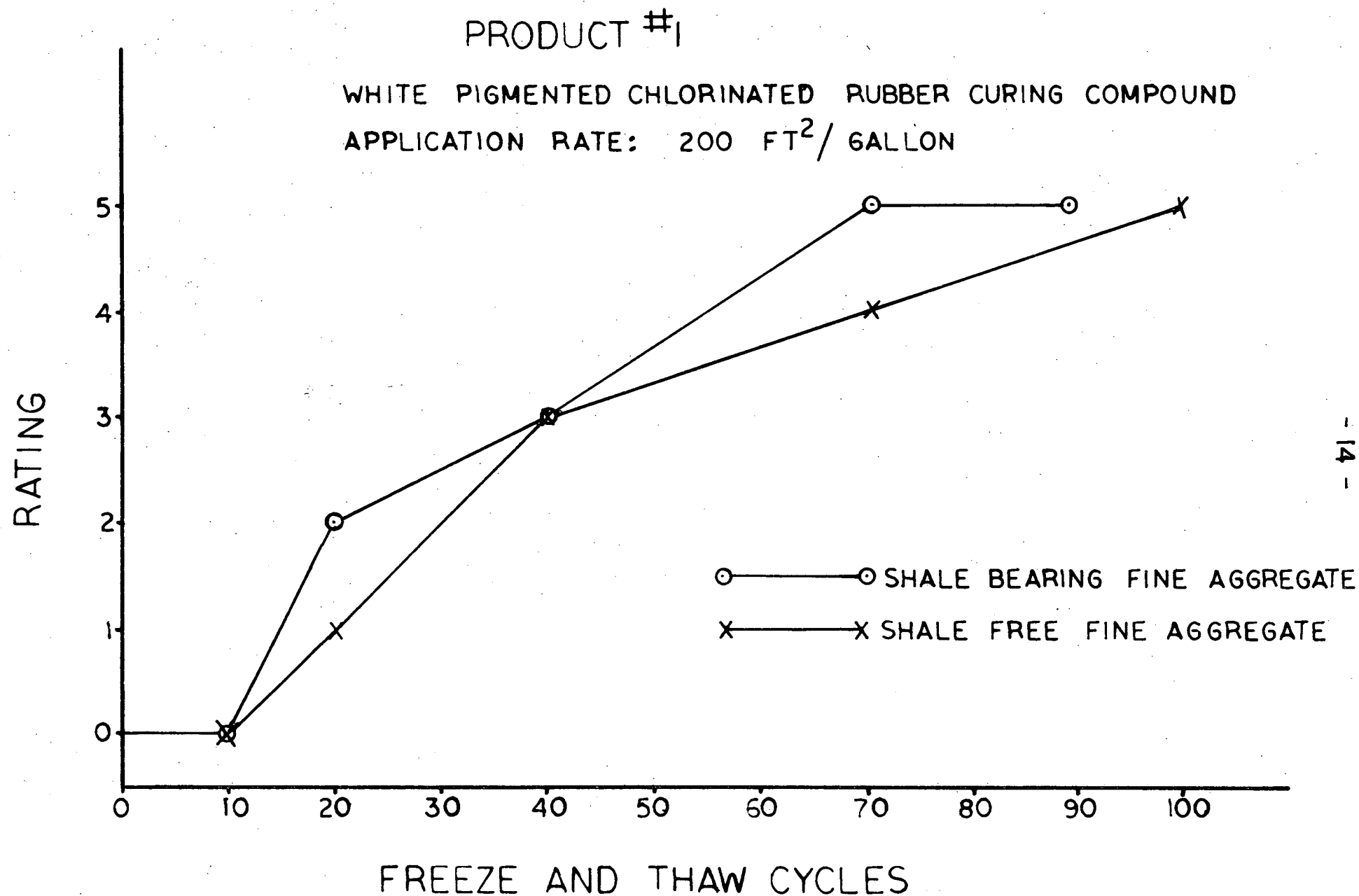


FIGURE-2

PRODUCT #2

CHLORINATED RUBBER SEALER
APPLICATION RATE: 400 FT²/GALLON

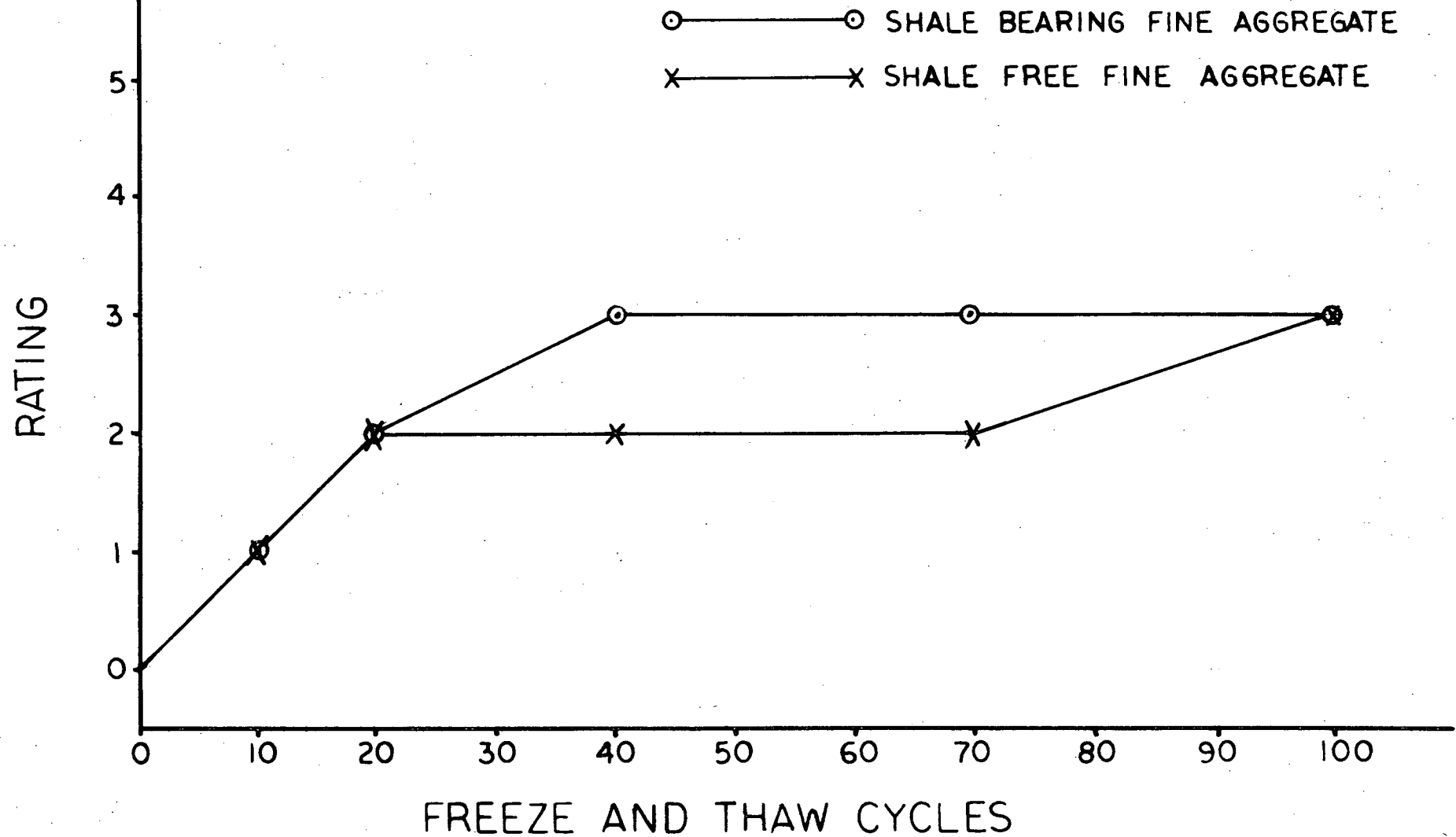


FIGURE - 3

PRODUCT #3

PENETRATING POLYSULFIDE / EPOXY RESIN
APPLICATION RATE: 80 FT² / GALLON

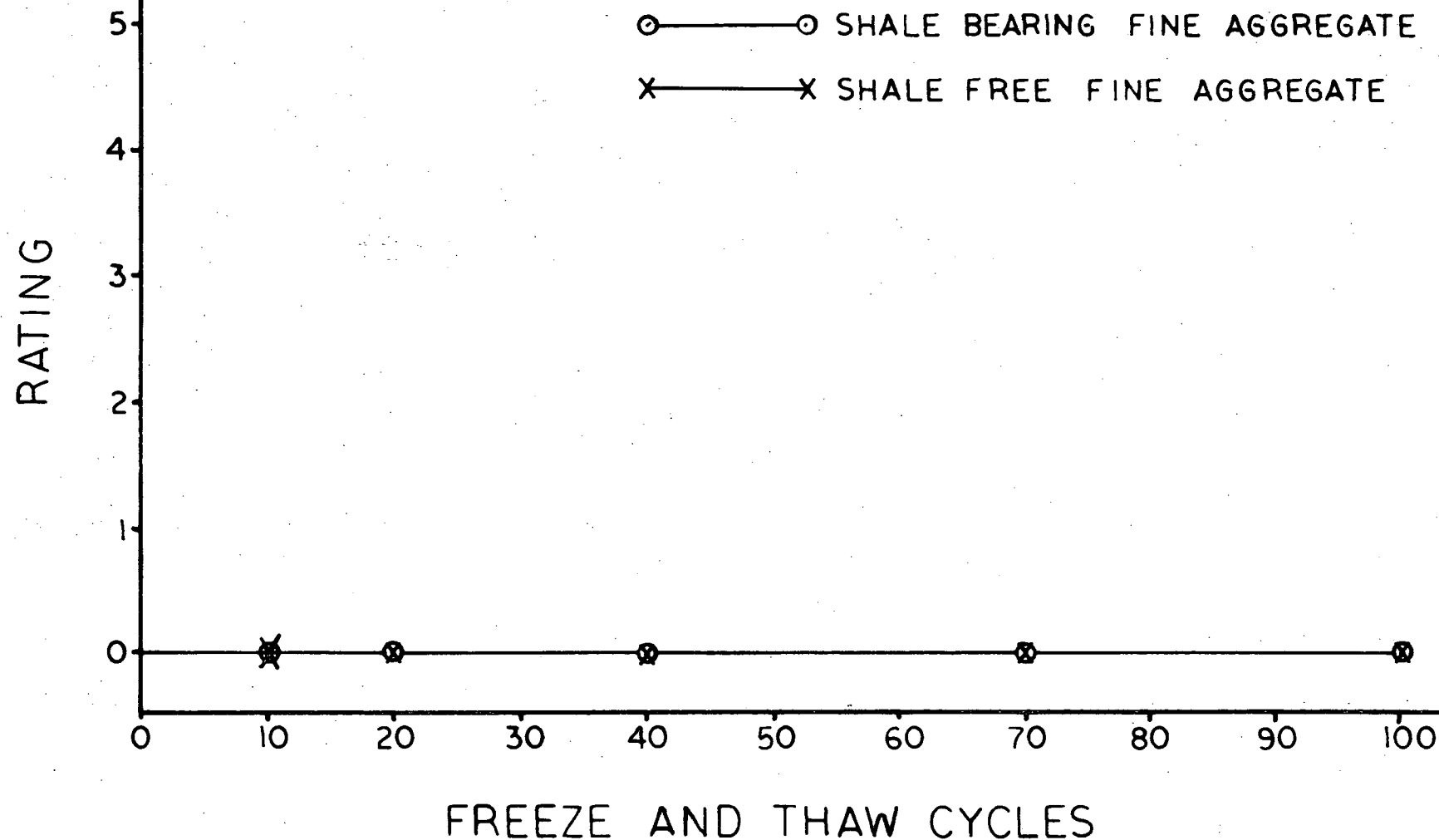


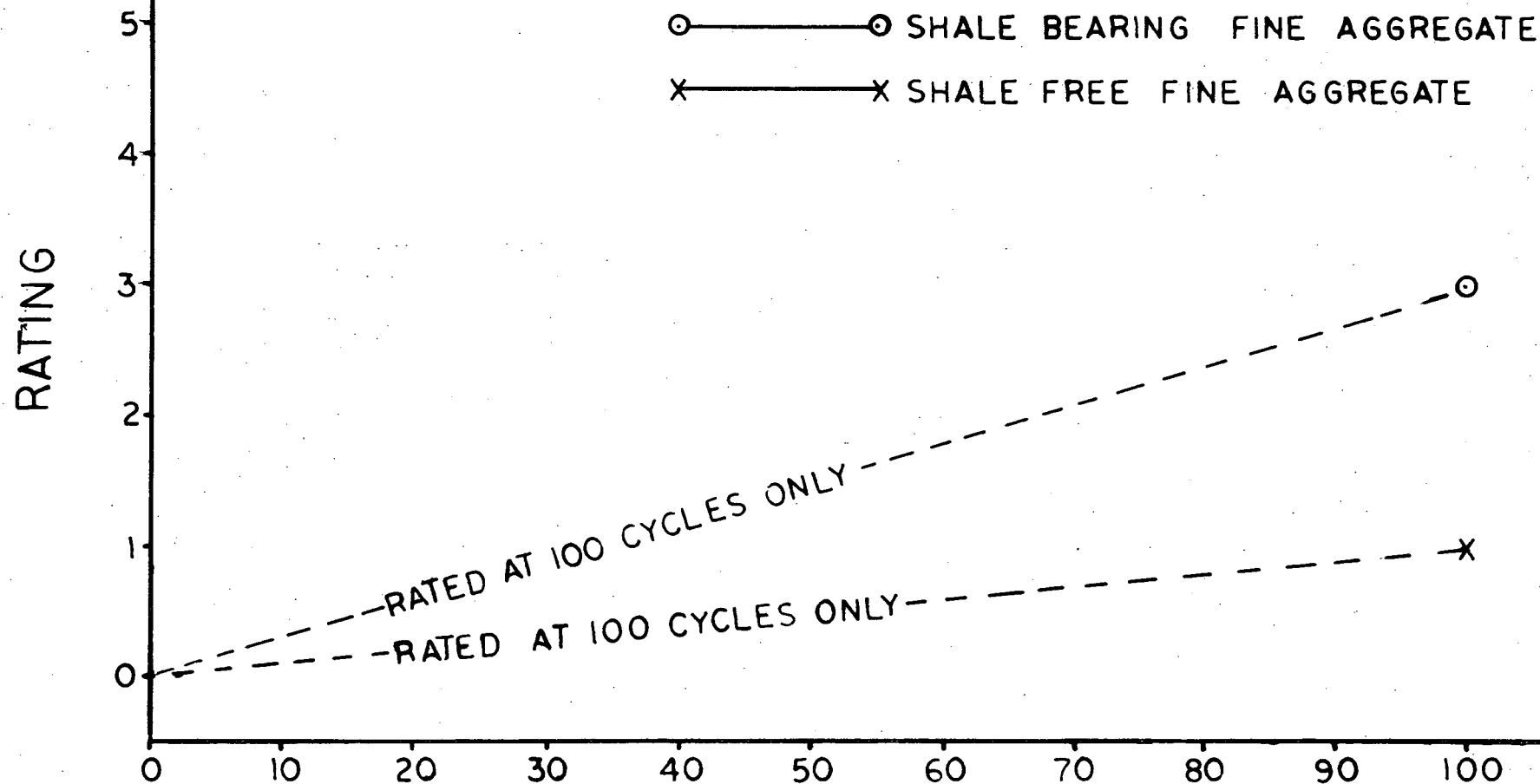
FIGURE - 4

PRODUCT #4

EPOXY RESIN SURFACE COATING

APPLICATION RATE: 1ST COAT - 275 FT²/GALLON

2ND COAT - 400 FT²/GALLON



FREEZE AND THAW CYCLES
FIGURE - 5

PRODUCT #5

CLEAR EPOXY CHLORINATED POLYMER
APPLICATION RATE: 300 FT² / GALLON

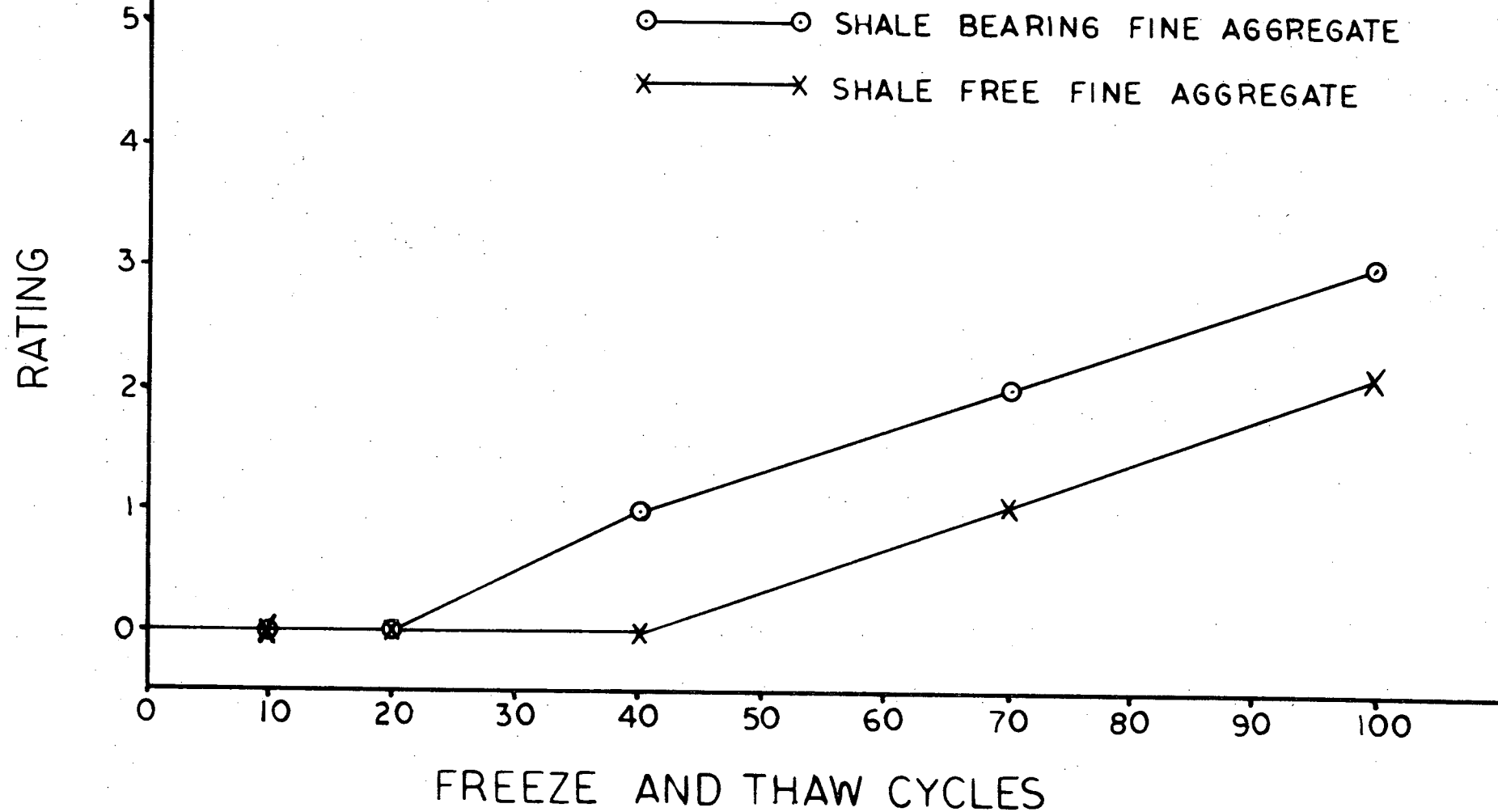
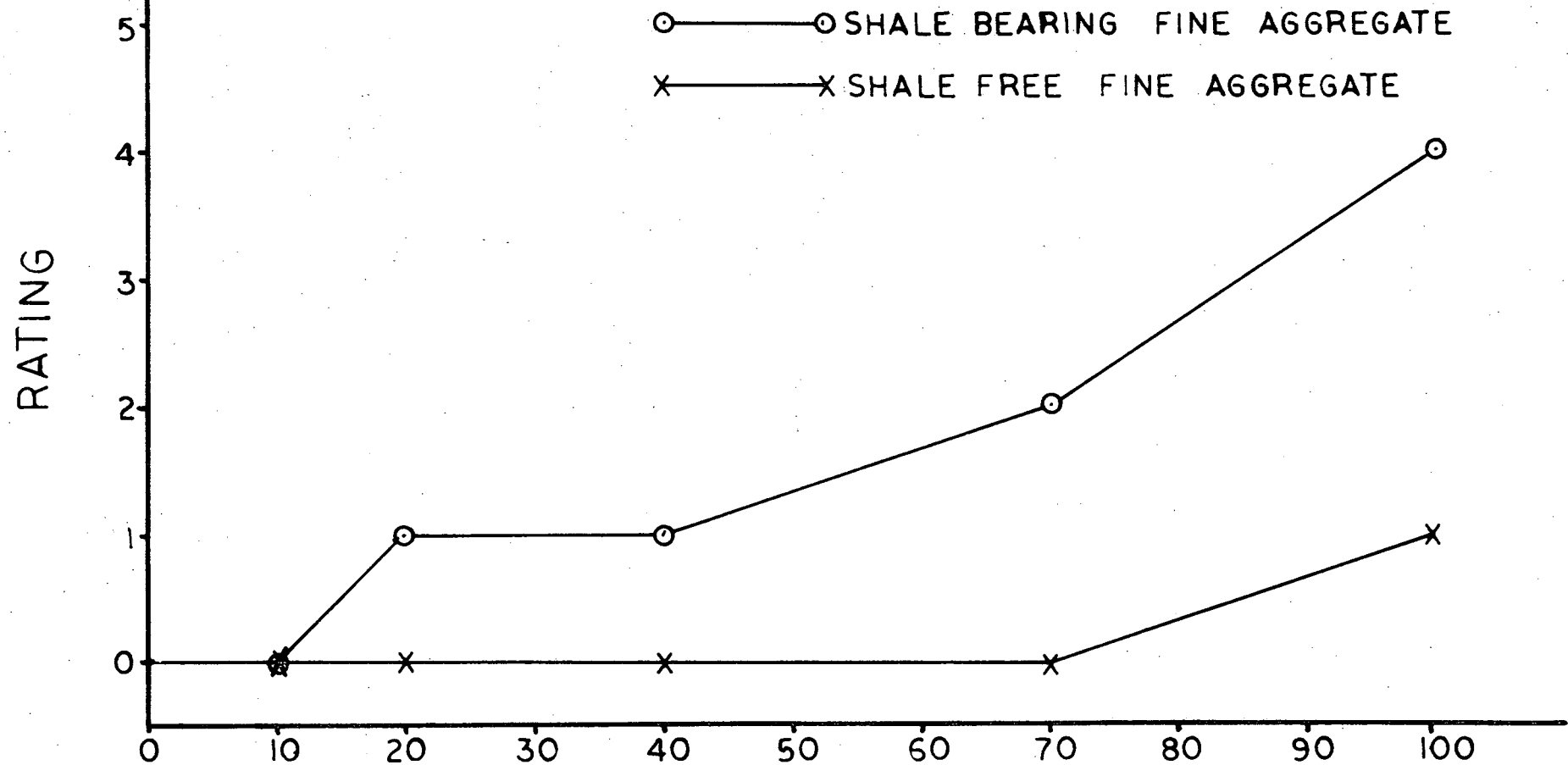


FIGURE - 6

PRODUCT #6

EPOXY RESIN BONDING AGENT

APPLICATION RATE: 103 FT²/GALLON

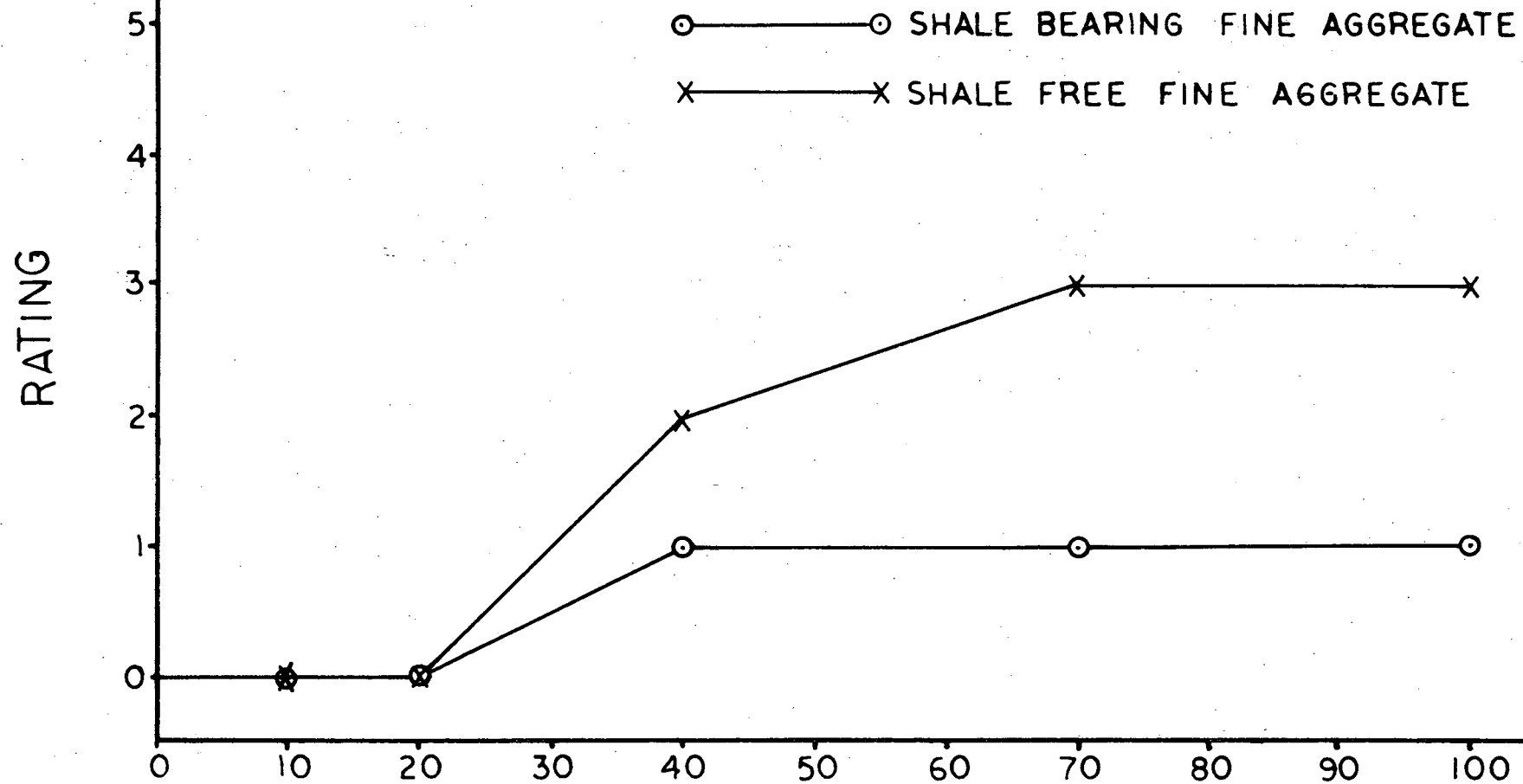


FREEZE AND THAW CYCLES

FIGURE - 7

PRODUCT #9

CHLORINATED RUBBER SEALER
APPLICATION RATE: 400 FT²/GALLON

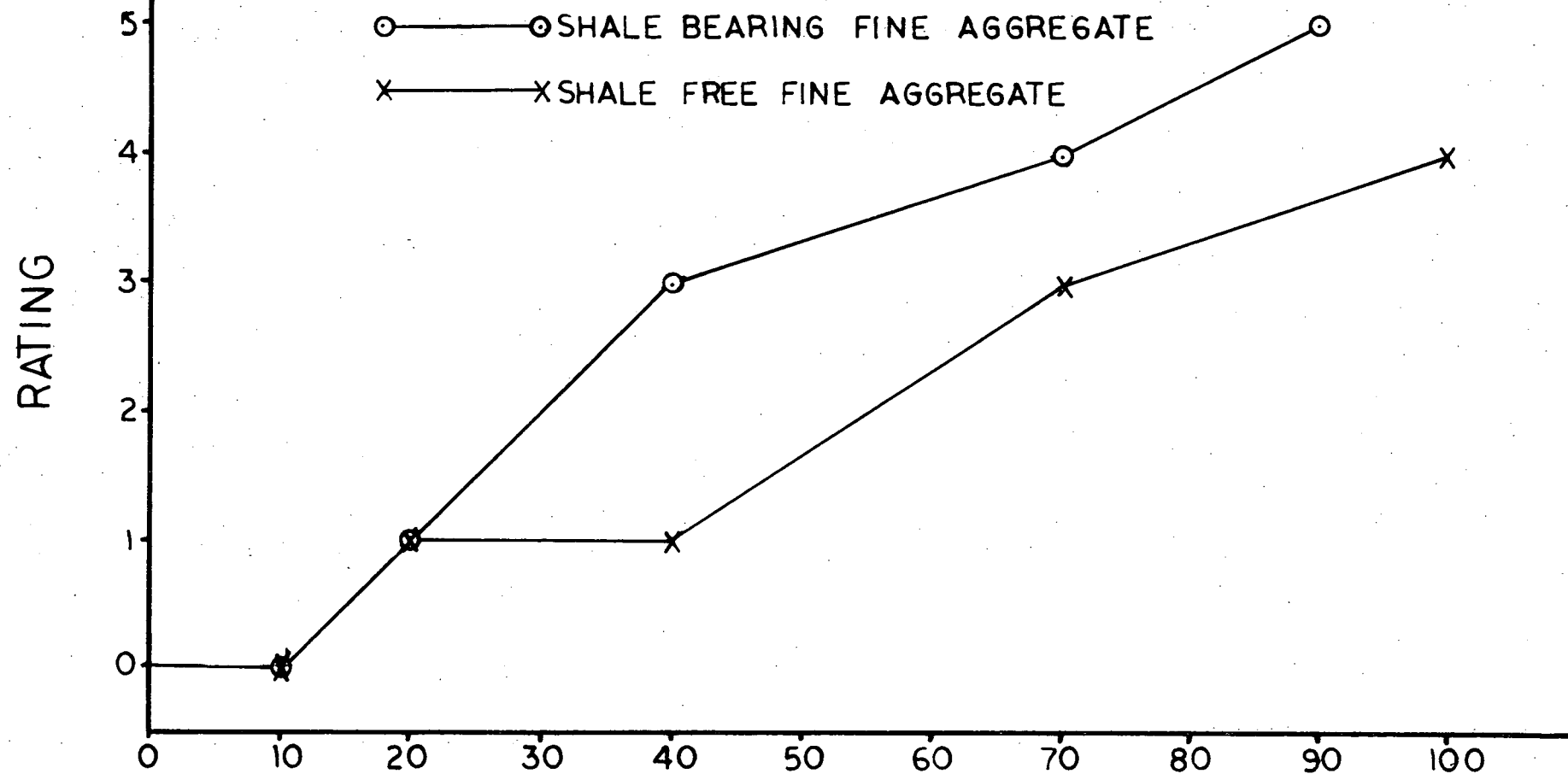


FREEZE AND THAW CYCLES
FIGURE - 8

PRODUCT #10

WHITE PIGMENTED CHLORINATED CURING COMPOUND

APPLICATION RATE: 400 FT²/GALLON

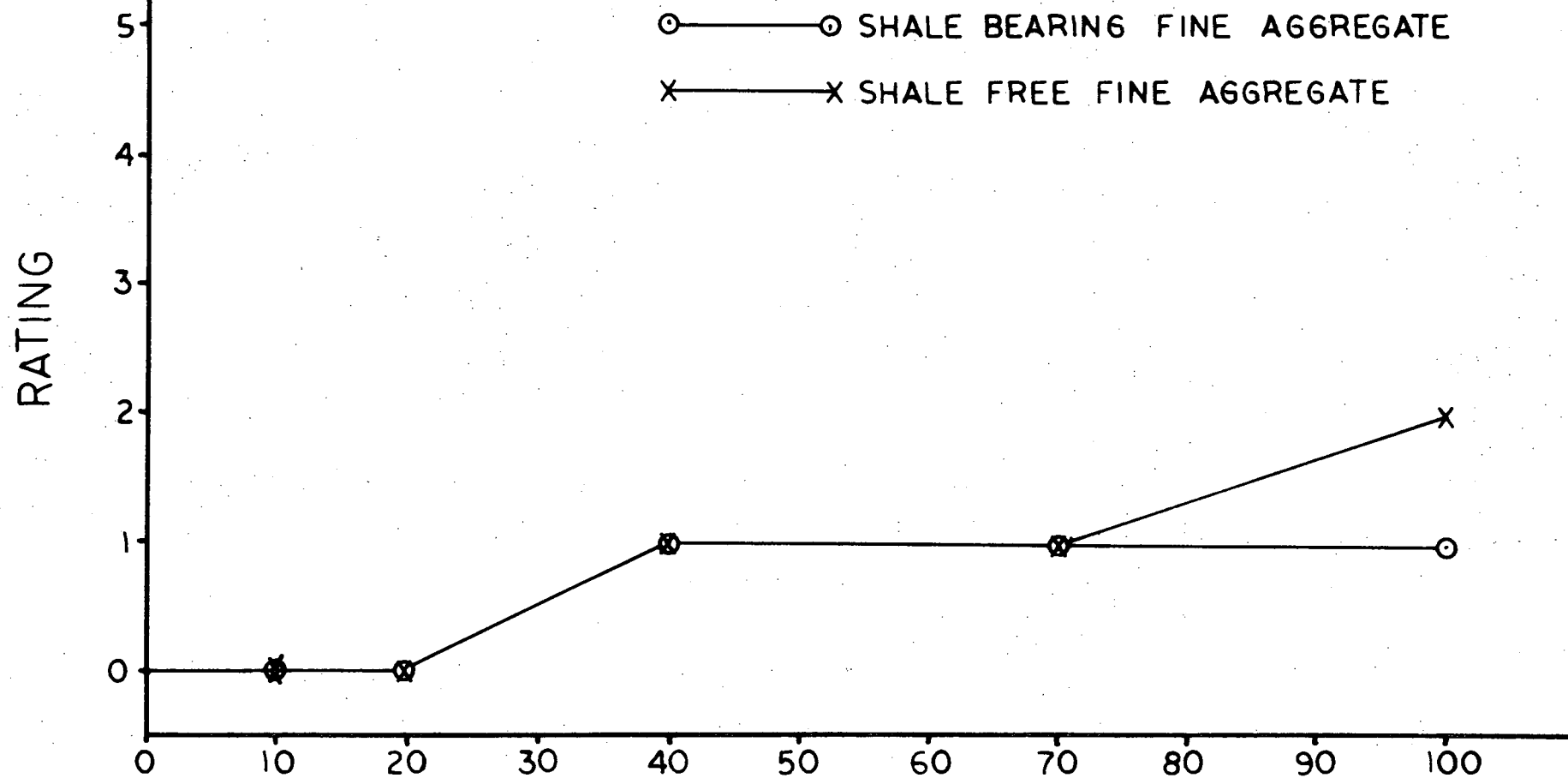


FREEZE AND THAW CYCLES
FIGURE - 9

PRODUCT #11

ACRYLIC POLYMER RESIN

APPLICATION RATE: 200 FT²/GALLON



FREEZE AND THAW CYCLES
FIGURE - 10

PRODUCT #12

EPOXY RESIN SURFACE COATING
APPLICATION RATE: 300 FT²/GALLON

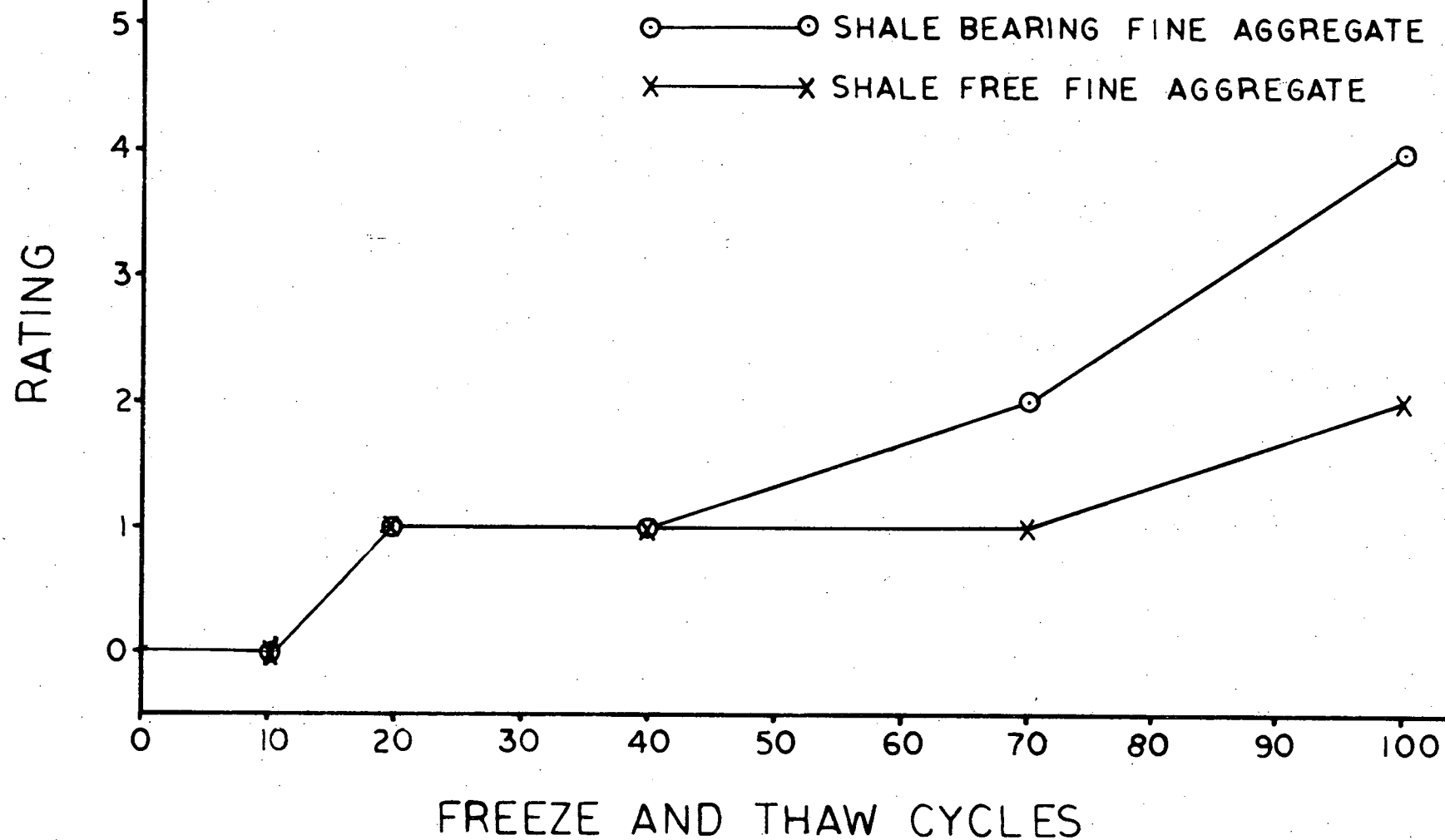
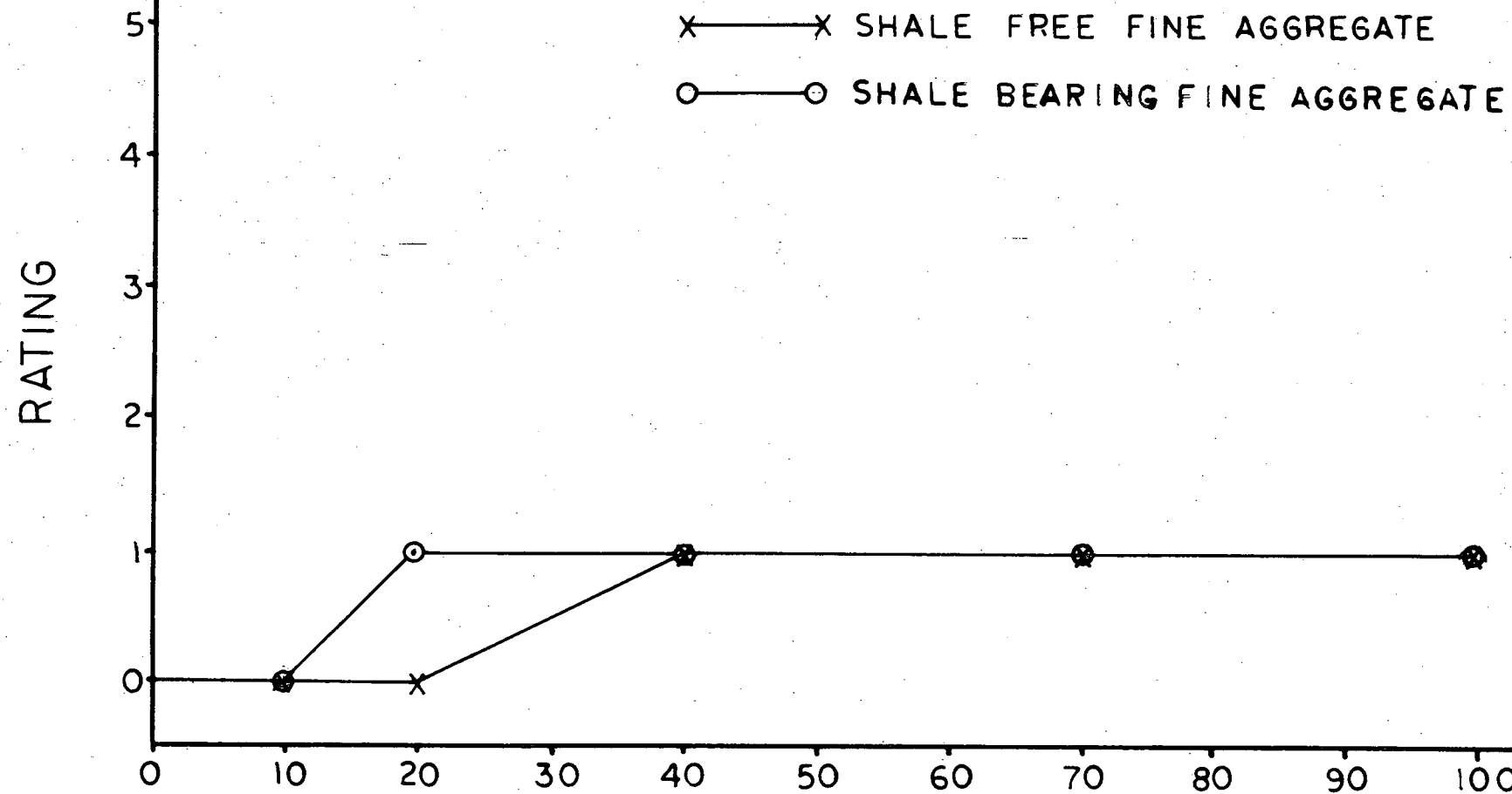


FIGURE-11

PRODUCT #13

50% DISTILLED TALL OIL, 50% KEROSENE

APPLICATION RATE: 300 FT²/GALLON



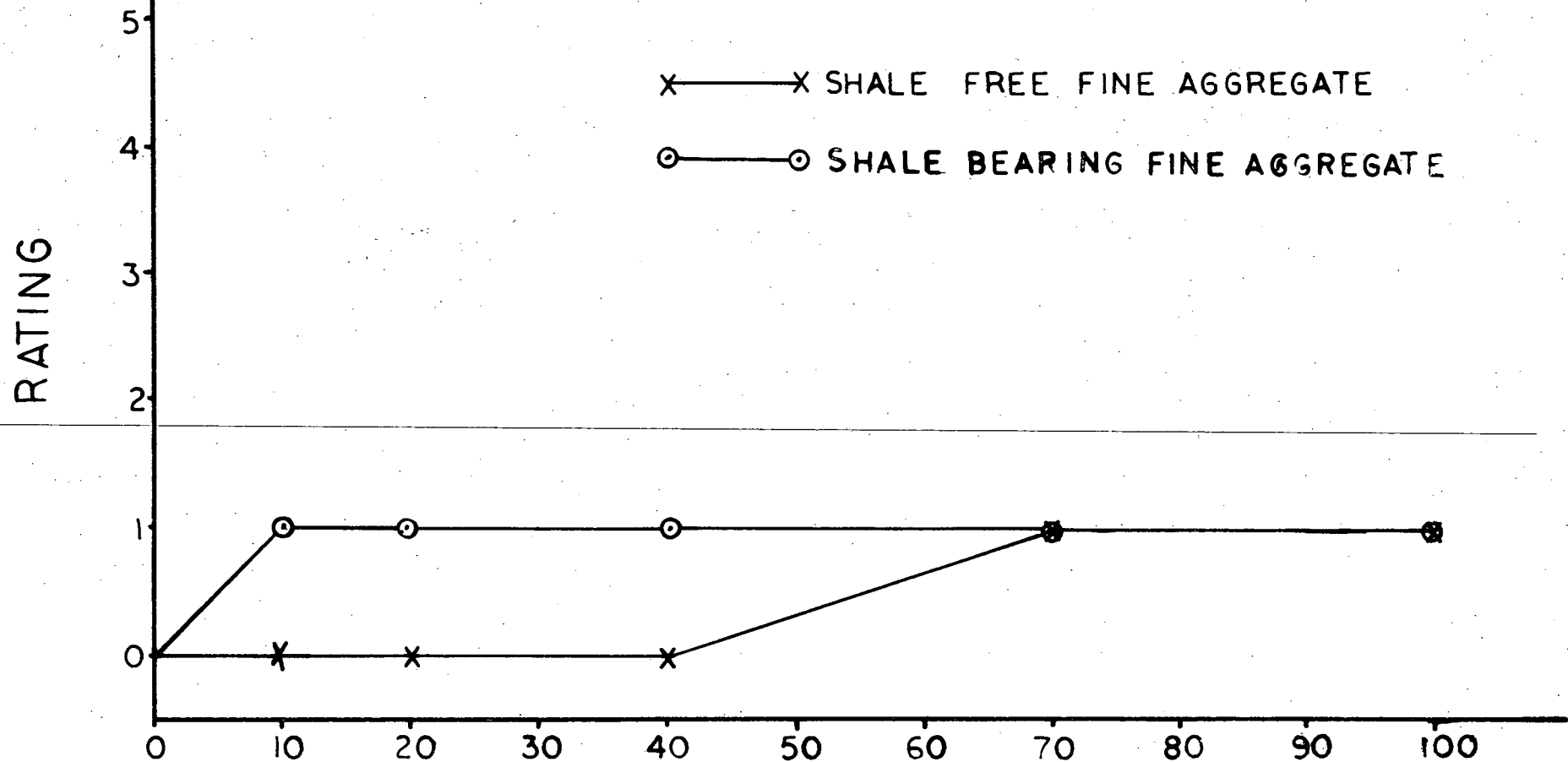
FREEZE AND THAW CYCLES

FIGURE - 12

PRODUCT #14

50% BOILED LINSEED OIL, 50% KEROSENE

APPLICATION RATE: 300 FT² / GALLON



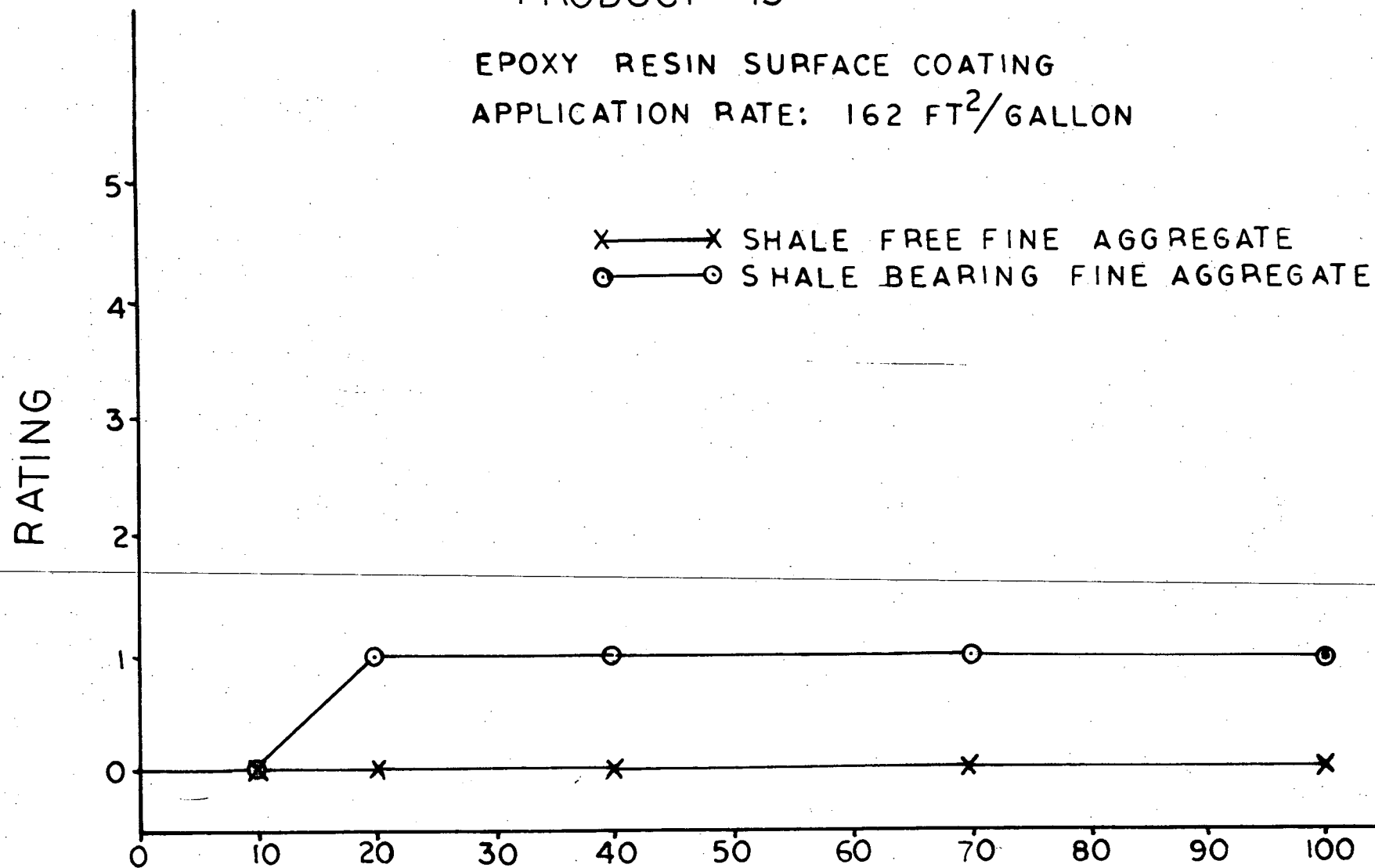
FREEZE AND THAW CYCLES

FIGURE - 13

PRODUCT #15

EPOXY RESIN SURFACE COATING

APPLICATION RATE: 162 FT²/GALLON



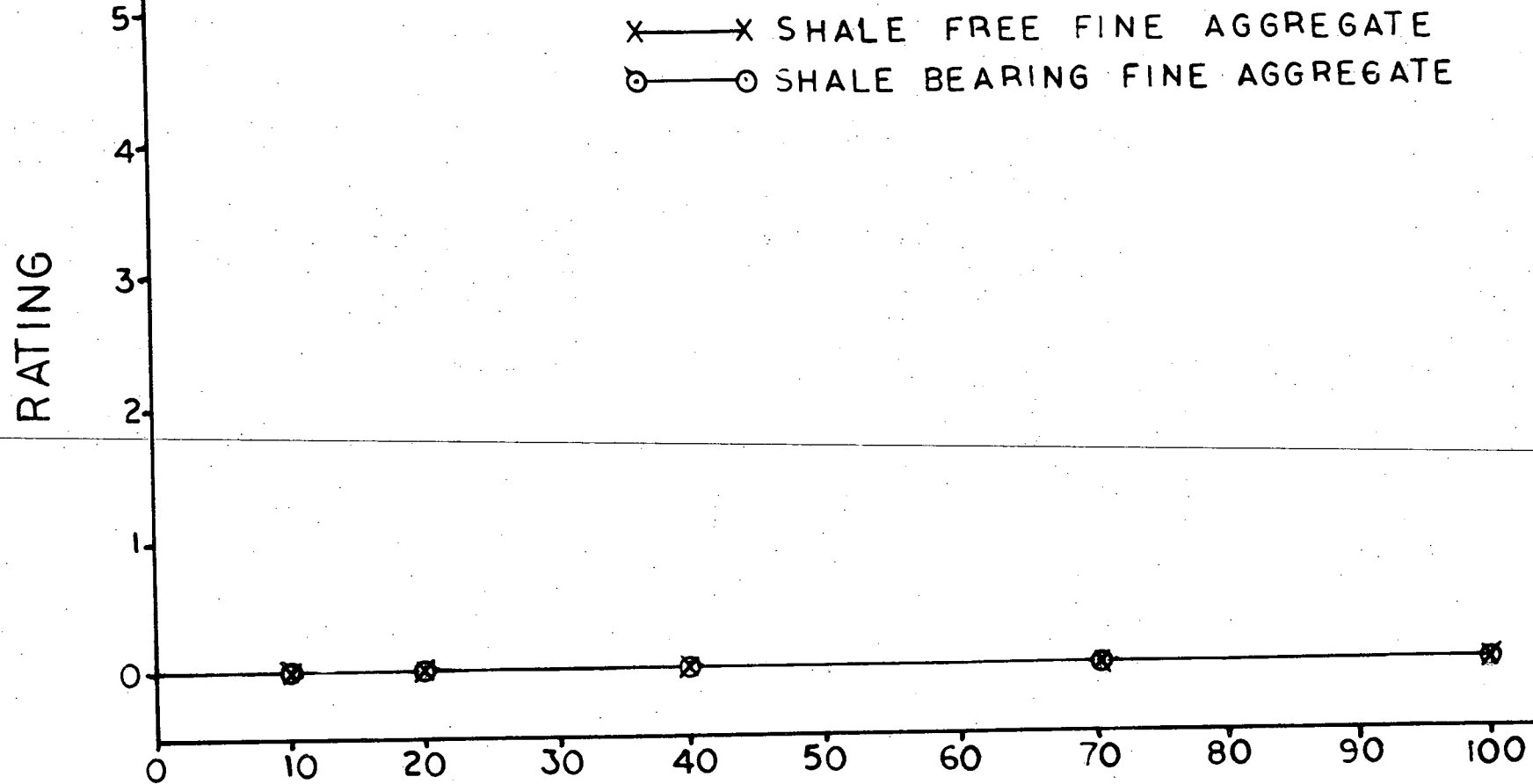
FREEZE AND THAW CYCLES

FIGURE-14

PRODUCT #16

EPOXY RESIN SURFACE COATING

APPLICATION RATE: 90 FT²/GALLON

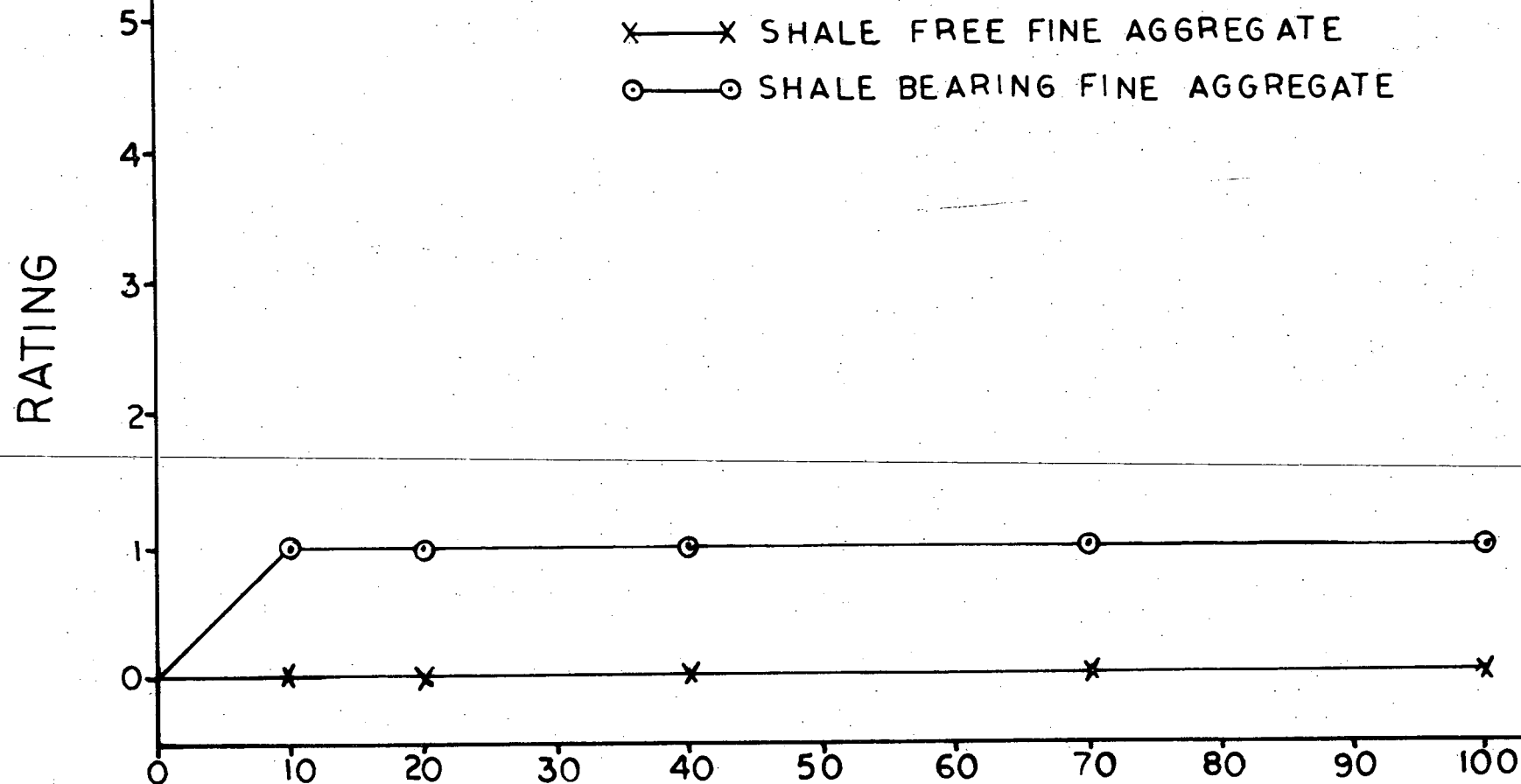


FREEZE AND THAW CYCLES
FIGURE-15

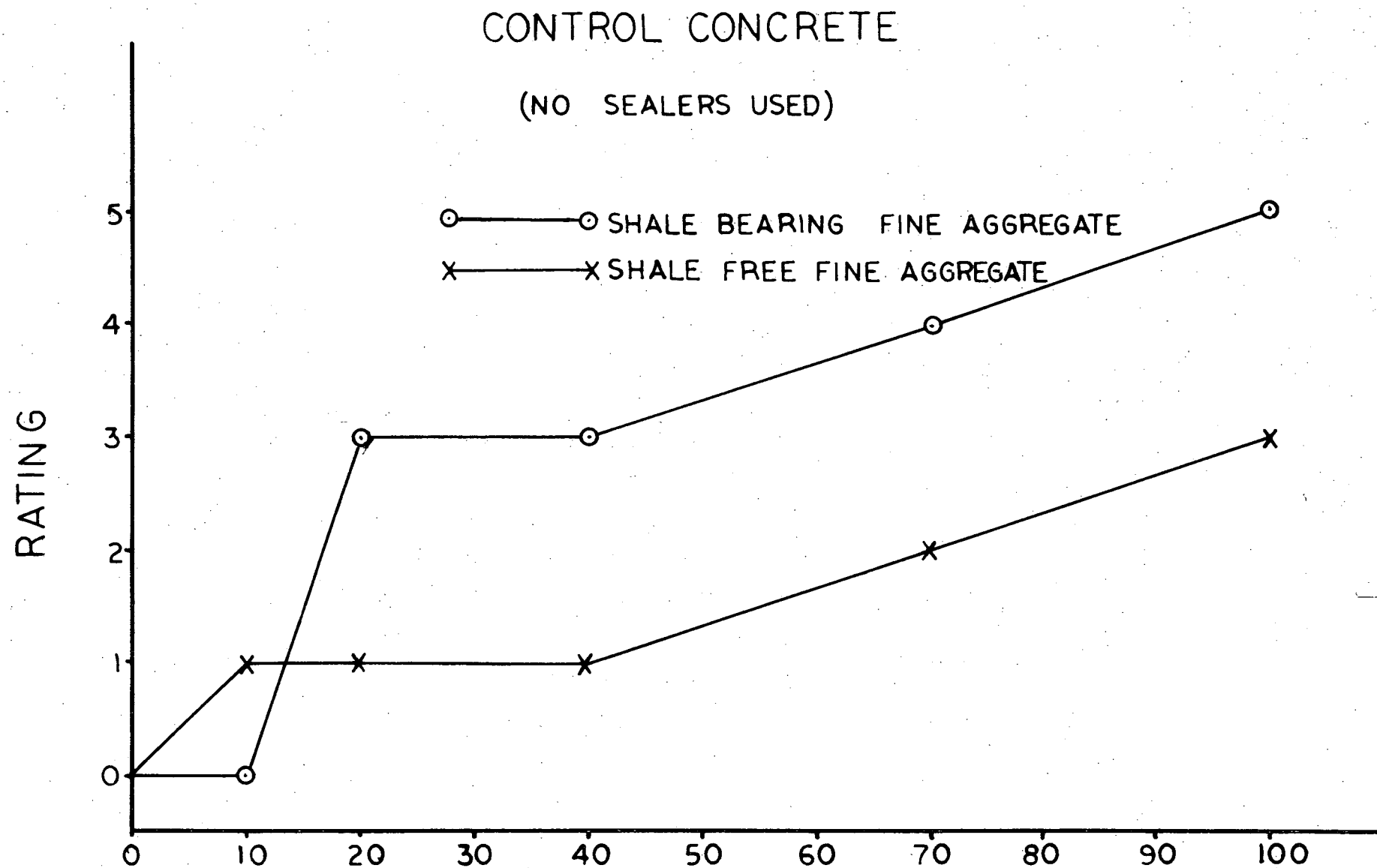
PRODUCT #17

EPOXY RESIN SURFACE COATING

APPLICATION RATE: 135 FT²/GALLON



FREEZE AND THAW CYCLES
FIGURE-16



FREEZE AND THAW CYCLES
FIGURE-17

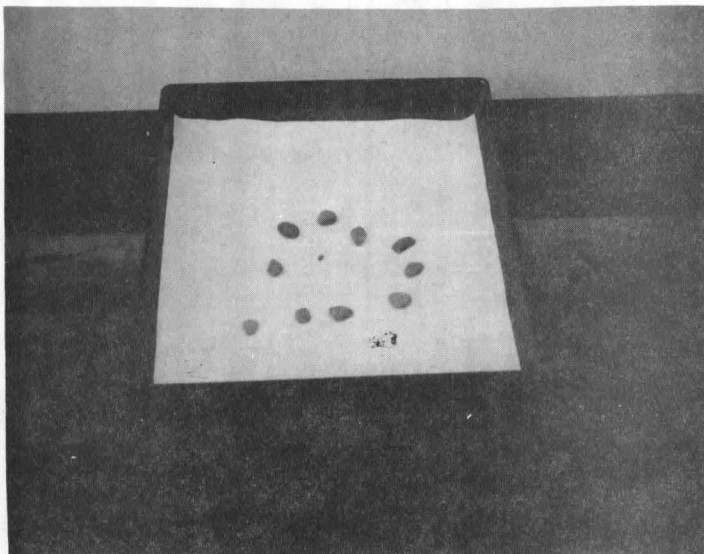


Fig. 18
10 Pieces of Dry Shale After
2 Freeze & Thaw Cycles

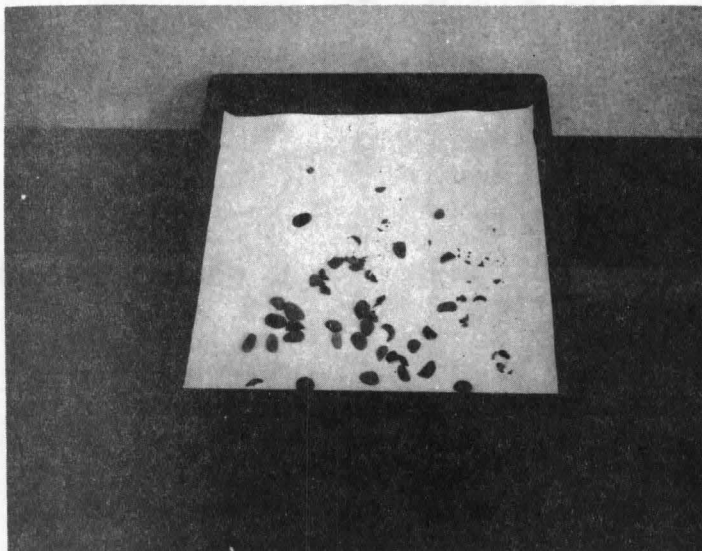


Fig. 19
10 Pieces of Saturated
Shale After
2 Freeze & Thaw Cycles

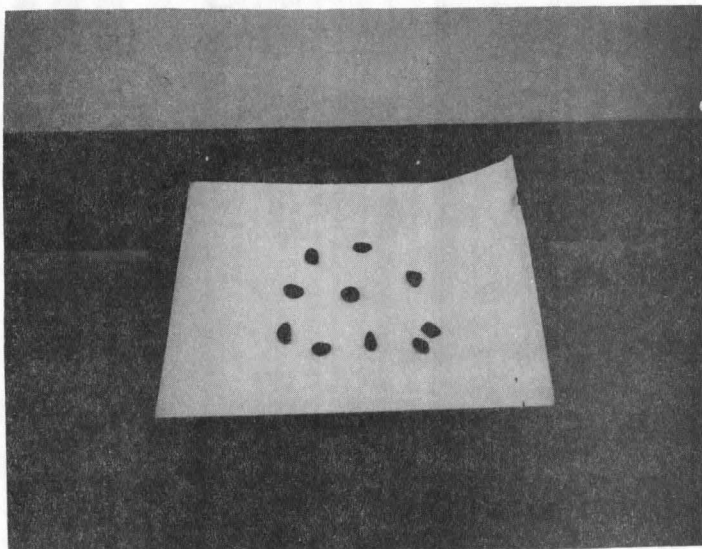


Fig. 20
10 Pieces of Dry Shale Coated
With Penetrating Epoxy Which
Were Immersed in Water And
Subjected to 2 Freeze & Thaw
Cycles

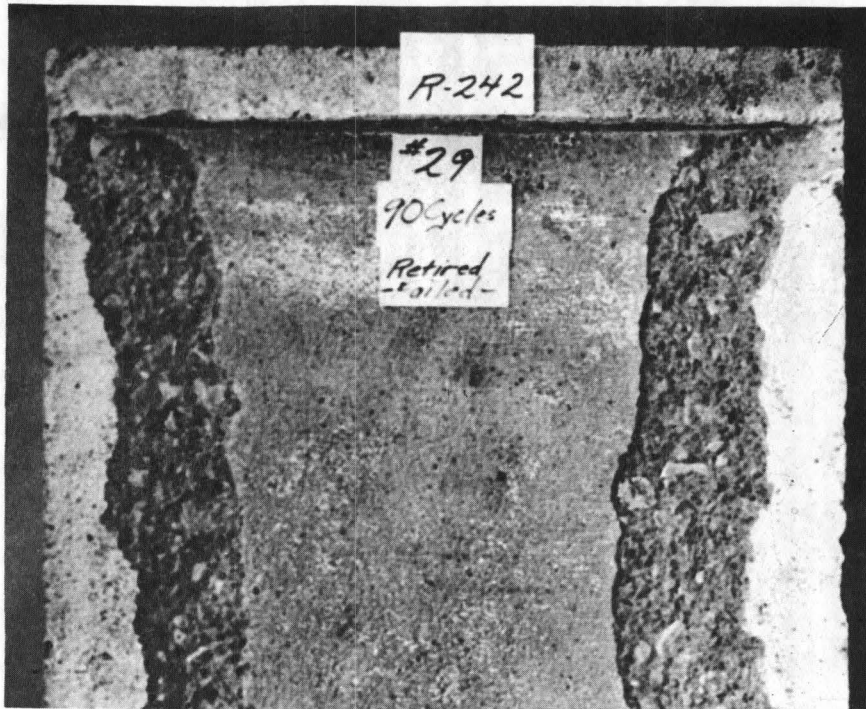


Fig. 21
Specimen Showing Severe Scaling at
Interface Between the Salt Solution and the Air