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EVALUATION OF MATERIALS FOR CAVITATION RESISTANCE

A Progress Report

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Engineering and Research Center
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16. ABSTRACT

Cavitation testing of potential protective coating materials that can be field-applied to steel and concrete surfaces is described. Performance of 71 coated specimens representing 21 classes of materials was evaluated in a Venturi-type cavitation apparatus which produces a mild to moderate cavitation environment. Only a few materials showed good cavitation resistance. A particular neoprene showed the best cavitation resistance of the materials tested. Another neoprene, a neoprene-urethane blend, a polyurethane, and a polysulfide showed satisfactory cavitation resistance in mild cavitation environments. Many epoxies, modified phenolics, epoxy polysulfides, epoxy polyamides, polysulfides, and other similar materials proved to have questionable or little cavitation resistance. Sharp edges and rough surfaces decreased the cavitation resistance of a test material.

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by

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Division of General Research
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Denver, Colorado

UNITED STATES DEPARTMENT OF THE INTERIOR * BUREAU OF RECLAMATION
Ellis L. Armstrong
Commissioner

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INTRODUCTION

Protection of steel and concrete against damage caused by cavitation is an important factor in the proper operation and maintenance of hydraulic structures. Because steel and concrete cannot always withstand the extreme forces of cavitation, it frequently becomes necessary to investigate different coating materials which possibly can withstand these forces and at the same time be field applied to the steel and concrete surfaces. It is for this reason that a cavitation test of protective coating materials for steel and concrete was initiated.

Since the degree of cavitation can vary from that which causes very little damage to the steel or concrete to that which causes major damage and even failure of that portion of the structure, a variety of coating materials have been tested for their resistance to cavitation damage. These tests are conducted for many hours in a Venturi-type apparatus with periodic evaluation of performance. The velocity through the throat is about 90 fps (27.4 mps) and produces a mild to moderate cavitation environment.

For readers of this report who are not familiar with cavitation phenomenon, excellent presentation is given by Rouse.[1]

MATERIALS

Some 71 different specimens were tested. The materials tested were divided into 21 categories: (1) neoprenes, (2) epoxy polyamides, (3) phenolic modified phenolic, (4) epoxy polysulfides, (5) sand-filled epoxy polyamides, (6) epoxies, (7) steel-filled epoxy polyamides, (8) sand-filled epoxy polysulfide, (9) sand-filled epoxy, (10) polysulfides, (11) polyurethanes, (12) epoxy modified phenolic, (13) coal-tar epoxy, (14) vinyls, (15) steel-filled epoxy, (16) polyester filled with chopped fiberglass, (17) epoxy polyurethane varnish, (18) neoprene-urethane rubber, (19) gum rubber, (20) chlorinated polyether, and (21) zinc.

Several of the sand- and steel-filled epoxy materials were applied with a trowel as mortars and then ground smooth. The majority of the materials were brush applied, and adhesives were used to bond rubber to the substrate. Two coatings were fusion applied and two polyurethane rubbers were vulcanized by the manufacturer.

TEST PROCEDURES

The materials for laboratory tests were applied to 3-1/2-inch (9.89-cm) by 10-inch (25.4-cm) steel and concrete substrates. The substrates were freshly sandblasted steel and concrete, cavitated concrete, and epoxy patched concrete and steel. Table 1 lists the types of material tested, type of specimen coated, method of application, surface preparation, and thickness.

In each case component mixing and coating application were as directed by the manufacturer.

Each of the laboratory specimens was tested in a Venturi-type apparatus shown in Figures 1 and 2. Velocity through the machine is about 90 fps (27.4 mps), producing a mild to moderate cavitation environment. The machine produces noticeable cavitation damage in good concrete in 3 hours of operation. It will destroy a good protective coating on steel, such as a six-coat vinyl resin system, in 7 hours. In the preliminary tests, no cavitation damage through 40 hours was considered good performance. Later, to obtain a wider spread in performance, 250 hours exposure was arbitrarily set as a maximum time for testing any one material. The few materials sustaining essentially no damage for this period were considered to have good performance under mild cavitation conditions and were scheduled for further testing in the field. In addition, two specimens were tested several hundred hours beyond this stopping point to evaluate fatigue and long-term performance.

TEST RESULTS

A summary of test results is shown in Table 1 in the Appendix. Figures 3 through 74 are a photographic record of each material's performance.

1. Neoprenes

Two different neoprenes were applied to eight steel and concrete specimens. Neoprene 1 was applied to Specimens No. 1, 5, 26, and 27. Specimen No. 1 showed failure after 42 hours. Specimens No. 5 and 26 performed good through 250 hours. Specimen No. 27 was tested only 28 hours showing no wear. See Figures 3 through 6.

Neoprene 2 showed excellent performance under these laboratory tests. Neoprene 2 is on Specimens No. 55,

[1] Engineering Hydraulics, edited by Hunter Rouse, John Wiley & Sons, Incorporated, N.Y., 1950.

61, 62, and 63. Specimen No. 63 which was applied over a welded stainless steel patch and was tested for 2,000 hours. The neoprene was still in excellent condition. See Figures 7 through 10.

2. Epoxy Polyamides

Eight specimens of epoxy polyamides were tested on concrete and steel substitutes. The specimens tested were No. 2, 2T, 3, 3T, 5T, 6T, 25, and 30. Specimen No. 2 failed after 70 hours, 2T failed after 63 hours, 3 failed after 14 hours, 3T failed after 49 hours, 5T failed after 7 hours, 6T failed after 7 hours, 16 failed after 21 hours, 25 failed after 71 hours, and 30 failed in 21 hours' testing. Specimens No. 2, 3, and 25 are the same epoxy polyamide; 5T and 6T are a second epoxy polyamide. See Table 1 for substrates and Figures 11 through 18 for types of failures.

3. Phenolic Modified Phenolic

Two specimens of phenolic modified phenolic were tested. These are Specimens No. 8 and 24. Both specimens failed in less than 21 hours. See Figures 19 and 20.

4. Epoxy Polysulfides

Six specimens coated with epoxy polysulfides were tested. The specimen numbers are 7, 7T, 9, 9T, 41, and 46. All these specimens were stopped after 7 to 14 hours' testing. See Table 1 and Figures 21 through 26 for exposure times and types of failure.

5. Sand-filled Epoxy Polyamides

Two specimens coated with sand-filled epoxy polyamides performed unsatisfactorily. Specimen No. 11T failed in 14 hours and Specimen No. 15T failed in 21 hours' testing. See Figures 27 and 28 for types of failure.

6. Epoxies

Some 18 specimens of steel and concrete substrates were coated with epoxies. The performances of the specimens varied from very poor to poor and showed failures in time tested from 1 hour to 53 hours. These specimen numbers are 12, 12T, 13T, 19, 19T, 22, 23, 28, 34T, 35, 36T, 37, 44, 56, 64, 65, 73, and 74. See Figures 29 through 46.

7. Steel-filled Epoxy Polyamides

Four steel-filled epoxy polyamide-coated specimens were tested. One of these materials, Specimen No. 31, gave good performance over 100 hours before failing at 117 hours. The other specimens failed in 7 to 21 hours. These are Specimens No. 32, 33, and 34-1 and Figures 47 through 50.

8. Sand-filled Epoxy Polysulfide

Specimen No. 42T, a sand-filled epoxy polysulfide applied to concrete failed in 7 hours' testing. See Figure 51.

9. Sand-filled Epoxy

Specimen No. 10T, a sand-filled epoxy applied to concrete failed in 14 hours' testing. See Figure 52.

10. Polysulfides

Two specimens coated with polysulfides were tested. The specimen numbers are 43 and 50. Specimen No. 43 was tested for 224 hours and showed little wear. Polysulfide Specimen No. 50 failed in less than 36 hours. Figures 53 and 54 show these polysulfides.

11. Polyurethanes

Polyurethanes were used to coat four steel and concrete specimens for test. The specimen numbers are 51, 51T, 52, and 60. Specimens No. 51, 51T, and 52 were vulcanized and did not prove satisfactory. Specimen No. 60 has given very good performance through 250 hours. This specimen was tested to failure which was 1,738 hours. See Figures 55 through 59 for types and times of failure.

12. Epoxy Modified Phenolic

Two specimens coated with epoxy modified phenolic were tested and proved unsatisfactory. The specimen numbers are 4 and 21. See Figures 60 and 61 for times of failure.

13. Coal-tar Epoxy

One coal-tar epoxy was applied to steel substrate. The coal-tar epoxy, Specimen No. 29, failed in 14 hours. See Figure 62 for type of failure.

14. Vinyls

Three vinyl-coated specimens were tested and found unsatisfactory. The specimen numbers are 47, 48, and 66. Specimens No. 47 and 48 are six-coat vinyl resin systems and No. 66 is a fused vinyl. See Figures 63, 64, and 65 for times of failures.

15. Steel-filled Epoxy

One steel-filled epoxy, Specimen No. 53, was applied on steel. It failed in 119 hours' testing. See Figure 66 for appearance.

16. Polyester Filled with Chopped Fiberglass

Specimen No. 54, polyester filled with chopped fiberglass was unsatisfactory as it failed in 38 hours. See Figure 67.

17. Epoxy Polyurethane Varnish

Specimen No. 68, epoxy polyurethane varnish applied to concrete substrate failed in 8 hours. See Figure 68 for details of failure.

18. Neoprene-urethene Rubber

Neoprene-urethene rubber, Specimen No. 69, applied on steel performed satisfactorily for 250 hours. See Figure 69.

19. Gum Rubber

Three specimens had gum rubber of three thicknesses bonded to them by an adhesive. These are Specimens No. 70, 1/16 inch (0.16 cm); 71, 1/8 inch (0.32 cm); and 72, 1/4 inch (0.63 cm) thick. The two thinner pieces of rubber had bond failures. Specimen No. 72 had delamination failure in 126 hours on one edge. See Figures 70, 71, and 72 for types of failure.

20. Chlorinated Polyether

Specimen No. 67, a fused chlorinated polyether over a welded stainless steel patch in the steel substrate, failed in 8 hours. Figure 73 shows the failure.

21. Zinc

One zinc-coated steel specimen was tested and gave poor performance. See Figure 74.

CONCLUSIONS

The following conclusions were drawn from these tests:

1. The ability of material to protect concrete or steel against cavitation depends upon selection of a suitable coating and also obtaining good workmanship in the application. Sharp corners or edges on the substrate to be protected should be bevelled, and a uniform, smooth-coated surface should be obtained for best resistance to the cavitation forces.

2. A liquid-applied neoprene, listed as Neoprene 2, showed excellent protection to steel and concrete substrates. One of four specimens was tested for 2,000 hours and was still in excellent condition. A second liquid-applied neoprene, listed as Neoprene 1, showed good protection to substrates. One of the four similar specimens tested had edge failure in 42 hours, while others did not show failure.

3. A particular polyurethane showed good protection to steel for nearly 1,700 hours, yet three other vulcanized polyurethanes failed after a several-hour exposure.

4. One sprayable neoprene-urethane blend demonstrated good performance for 250 hours with only minor pitting of the surface.

5. Many epoxies, modified phenolics, epoxy polysulfide, epoxy polyamides, polysulfides, and other similar materials proved to have questionable or little cavitation resistance.

APPLICATIONS

The results of these tests are applicable to many situations. Cavitation environments exist in some hydraulic machines and structures varying from mild to severe. Application of Neoprene 2 in conjunction with one or more of the surface repair and/or preparation techniques studied has reduced cavitation damage in turbines, outlet structures, and other hydraulic pressure systems. Field performance, to be reported separately, indicates that this material, Neoprene 2, is effective in protecting against damage in moderate to severe environments.

Table 1

SUMMARY OF RESULTS AND PERFORMANCE OF MATERIALS TESTED IN LABORATORY CAVITATION APPARATUS

Specimen No.	Material type	Coats and method of application	Thickness mils	Substrate	Surface preparation	Performance
1	Neoprene 1	4 Brush	*	Concrete	Sandblasted	After 1 hour, part of fourth coat peeled off; 7 hours, practically all of fourth coat peeled off; 35 hours, partial failure on one end; 42 hours, failure.
2	Epoxy polyamide	2 Trowel sanded smooth	*	Concrete	Sandblasted	After 7 hours, few pinpoint holes; 42 hours, increase in number of pinpoint holes; 63 hours, damage more pronounced; 70 hours, few cracks in middle, epoxy became loose.
2T	Epoxy polyamide	2 Trowel sanded smooth	*	Concrete	Repaired cavitation damage	After 1 hour, a few pinpoint holes; 35 hours, epoxy pitted off on top left corner and lower edge; 63 hours, a crack occurred on downstream side of specimen and pitted areas enlarged to failure.
3	Epoxy polyamide	1 Trowel	*	Concrete	Sandblasted	Failed in 14 hours. A poor finish may have caused early failure.
3T	Epoxy polyamide	1 Trowel	*	Concrete	Repaired cavitation damage	After 7 hours, a few pinpoint holes; 28 hours, slight enlargement and increase in pinpoint holes; 42 hours, epoxy chipped at upper end; 49 hours, epoxy failed.
4	Epoxy modified phenolic	2 Brush	*	Concrete	Sandblasted	After 7 hours, the epoxy failed.

* Thickness not measured.

Table 1 - Continued

Specimen No.	Material type	Coats and method of application	Thickness mils	Substrate	Surface preparation	Performance
5T	Epoxy polyamide	1 Brush	*	Concrete	Repaired cavitation damage	After 7 hours, failed.
5	Neoprene 1	4 Brush	*	Concrete	Sandblasted	After 253 hours, neoprene has performed satisfactorily.
6T	Epoxy polyamide	1 Brush	*	Concrete	Repaired cavitation damage	Failed after 7 hours testing.
7	Epoxy polysulfide	2 Brush	*	Concrete	Sandblasted	Failed after 7 hours.
7T	Epoxy polysulfide	2 Brush	*	Concrete	Repaired cavitation damage	Failed after 7 hours.
8	Phenolic modified phenolic	2 Brush	*	Concrete	Sandblasted	After 7 hours, a few pinpoint holes; failed in 14 hours.
9	Epoxy polysulfide	1 Brush	*	Concrete	Sandblasted	Failed after 7 hours testing.
9T	Epoxy polysulfide	1 Brush	*	Concrete	Repaired cavitation damage	Failed in 7 hours, 75 percent of epoxy eroded off.
10T	Sand-filled epoxy	1 Trowel	•	Concrete	Repaired cavitation damage	Developed many holes in first 7 hours of test. Failed in 21 hours.
11T	Sand-filled epoxy polyamide	1 Trowel	*	Concrete	Repaired cavitation damage	Many holes occurred in the first 7 hours of test. Failed in 14 hours test.

* Thickness not measured.

Table 1 - Continued

Specimen No.	Material type	Coats and method of application	Thickness mils	Substrate	Surface preparation	Performance
12	Epoxy	2 Trowel sanded smooth	*	Concrete	Sandblasted concrete	Ninety-five percent of finish coat peeled off in 7-hour testing.
12T	Epoxy	2 Trowel sanded smooth	*	Concrete	Repaired cavitation damage	Several pinpoint holes occurred in first 7 hours; the number increased by 21 hours; 35 hours, a large peeled-away area on one corner appeared; the peeled area enlarged causing failure at 42 hours.
13T	Epoxy	1 Trowel	*	Concrete	Repaired cavitation damage	A few pinpoint holes occurred in first 7 hours; a slight enlarging showed at 14 hours; epoxy failed at 28 hours.
15T	Sand-filled epoxy polyamide	1 Trowel	*	Concrete	Cavitation damage etched 50 percent HCl	Little change occurred in first 7 hours; many holes appeared in surface in next 7 hours; holes to concrete caused failure at 21 hours.
19	Epoxy	1 Trowel sanded smooth	*	Concrete	Sandblasted	A few pinpoint holes in first 7 hours; top edge showed pitting in 14 hours; and increased at 21 hours; 28 hours, concrete was exposed on top edge; failed at 50 hours from pitting and holes.

* Thickness not measured.

Table 1 - Continued

Specimen No.	Material type	Coats and method of application	Thickness mils	Substrate	Surface preparation	Performance
19T	Epoxy	1 Trowel sanded smooth	*	Concrete	Repaired cavitation damage	A few pinpoint holes occurred in first 7 hours; the holes had become more pronounced by 28 hours testing and enlarged by 36 hours; holes penetrated through to base specimen by 50 hours causing partial failure.
21	Epoxy modified phenolic	2 Brush	*	Steel	Sandblasted	Coating badly pitted after 7 hours testing; failed in 14 hours testing.
22	Epoxy	1 Trowel	*	Steel	Sandblasted	Sixty percent of epoxy eroded away in 24 hours of testing.
23	Epoxy	1 Trowel	*	Steel	Sandblasted	Number of pinpoint holes occurred in first 7 hours; increase in size and depth through 23 hours; a large hole developed in middle of specimen at 28 hours; failed at 35 hours.
24	Phenolic modified phenolic	2 Brush	*	Steel	Sandblasted	Pitting of top coat showed in first 14 hours; failed in 21 hours.
25	Epoxy polyamide	1 Trowel sanded smooth	*	Steel	Sandblasted	After 7, 14, and 21 hours little or no wear; a few pinpoint holes showed at 28 hours; at 50 hours pinhole holes were pronounced; at 71 hours enlarged in size and depth.
26	Neoprene 1	4 Brush Heat cure at 130° F, 24 hours	35-40	Steel	Sandblasted	Showed good performance through 250 hours testing.

Table 1 - Continued

Specimen No.	Material type	Coats and method of application	Thickness mils	Substrate	Surface preparation	Performance
27	Neoprene 1	5 Brush, cure 24 hours at 130° F	62-70	Steel	Sandblasted	No wear; after 35 hours test stopped.
28	Epoxy	1 Trowel	*	Steel	Sandblasted	Pinpoint holes occurred in first 17 hours; increased at 32 and 39 hours; enlarging at 46 hours; 53 hours, holes to steel causing failure.
29	Coal-tar epoxy	3 1 and 2 brushed 3 trowel	25-30	Steel	Sandblasted	Failed in 14 hours testing.
30	Epoxy polyamide	1 Trowel ground smooth	80-90	Steel	Sandblasted	Many holes developed in first 7 hours; increased in number in next 7 hours, and by 21 hours testing had enlarged to cause partial failure.
31	Steel-filled epoxy polyamide	1 Trowel ground smooth	70-80	Steel	Sandblasted	A number of holes occurred in first 7 hours; the next 14 hours showed small increases in size and depth. After 102 hours, holes had enlarged; at 117 hours the tests were stopped with partial failure.
32	Steel-filled epoxy polyamide	1 Trowel ground smooth	60-80	Steel	Sandblasted	A number of holes were evident after 8 hours testing; enlarged by 21 hours, causing partial failure.

* Thickness not measured.

Table 1 - Continued

Specimen No.	Material type	Coats and method of application	Thickness mils	Substrate	Surface preparation	Performance
33	Steel-filled epoxy polyamide	1 Trowel ground smooth	40-60	Steel	Sandblasted	A large hole appeared to steel in first 7 hours; many appeared at 14 hours; increased in size causing partial failure at 21 hours.
34-1	Steel-filled epoxy polyamide	1 Trowel ground smooth	*	Concrete	Sandblasted	Holes to base specimen caused failure in 7 hours.
34T	Epoxy	1 Brush	*	Concrete	Repaired cavitation damage	Slight deterioration showed after 1 hour testing; a large hole developed at 7 hours causing failure.
35	Epoxy	1 Brush	*	Steel	Sandblasted	After 7 hours testing only small pinpoint holes were visible; became more pronounced after 15 hours.
36T	Epoxy	1 Brush sanded smooth	*	Concrete	Repaired cavitation damage	No evidence of damage in first hour; coating tested only 7 hours.
37	Epoxy	1 Brush sanded smooth	*	Steel	Sandblasted	No evidence of damage after 7 hours testing; coating tested only 14 hours.

* Thickness not measured.

Table 1 - Continued

Specimen No.	Material type	Coats and method of application	Thickness mils	Substrate	Surface preparation	Performance
41	Epoxy polysulfide	2 Brush	*	Steel	Sandblasted	After 7 hours, a few pinpoint holes occurred; after 14 hours, a few new pinpoint holes occurred.
42T	Sand-filled epoxy polysulfide	1 ground smooth	*	Concrete	Sandblasted	Tested only 7 hours, appeared good.
43	Polysulfide	3 Brush	28	Steel	Sandblasted	Tested 224 hours and showed good performance.
44	Epoxy	2 Brush	*	Steel	Sandblasted	Tested only 7 hours, a few holes were visible.
46	Epoxy polysulfide	1 Trowel	*	Steel	Sandblasted	Showed large areas of damage after 7 hours.
47	Vinyl	6	12-14	Steel	Sandblasted	After 7 hours, a few pinpoint holes occurred in middle of specimen; at 15 hours an increase was visible: failed at 18 hours.
48	Vinyl	6	12-14	Steel	Sandblasted	No visual damage after 7 hours, test not continued.

* Thickness not measured.

Table 1 - Continued

Specimen No.	Material type	Coats and method of application	Thickness mils	Substrate	Surface preparation	Performance
50	Polysulfide	4	*	Concrete	Sandblasted	Top coat completely gone after 4 hours. One small break after 8 hours, two breaks after 12 hours, failed.
51	Polyurethane	Mfg. applied	*	Concrete	**	Slight lifting at one end; about 1/8 inch after 58 hours; about 3/4 inch after 74 hours; lifted to concrete on one end or peeled off a piece 1 by 3 inches after 82 hours. Peeled off a 3- by 4-inch area approximately after 98 hours. Failed.
51T	Polyurethane	Mfg. applied	*	Concrete	Cavitated area filled with epoxy before coating	Started to delaminate after 7 hours. Top coat 90 percent eroded after 9 hours. Damaged through to concrete, failed after 11 hours.
52	Polyurethane	Mfg. applied	*	Steel	Stainless weld repair	Two types of rubber, one tan and one blue-gray. Tan completely removed in 2.5 hours. Part of blue-gray eroded off.
53	Steel-filled epoxy	Epoxy in cut grooves sanded smooth	*	Steel	Grooves cut in steel	After 56 hours, several sizes of holes occurred; at 72 hours, only a slight increase in size; at 119 hours, holes have become large and through plastic steel to substrate causing failure.

* Thickness not measured.
** Not known.

Table 1 - Continued

Specimen No.	Material type	Coats and method of application	Thickness mils	Substrate	Surface preparation	Performance
54	Polyester filled with chopped fiberglass	Mfg. applied	*	Steel		After 38.5 hours, holes through to steel causing failure.
55	Neoprene 2	4 Brush	40-45	Steel	Groove cut in cold-rolled steel and stainless steel weld patch	After 63 hours, coating appeared excellent; after 252 hours the neoprene still appeared excellent.
56	Flexible epoxy patching compound	1 Trowel	*	Steel	Sandblasted	After 8 hours testing, 33 percent of the flexible epoxy had peeled off.
58	Zinc	1 Brush	2	Steel	Sandblasted	After 2 hours, damage through zinc to steel substrate causing failure.
60	Polyurethane	2 Brush	50-60	Steel	Sandblasted	No sign of deterioration after 7 hours; still no sign of deterioration at 176 hours; material appeared excellent after 250 hours; at 650 hours edge deterioration was visible; at 890 hours edge deteriorations enlarged; 1,200 hours, the edge deterioration continued to enlarge; at 1,506, edge deterioration was on all edges, at 1,738 hours, holes to steel in middle of coating. Test stopped.
61	Neoprene 2	14	65-70	Concrete	Epoxy mortar patched sandblasted	Appears excellent after 250 hours.

* Thickness not measured.

Table 1 - Continued

Specimen No.	Material type	Coats and method of application	Thickness mils	Substrate	Surface preparation	Performance
62	Neoprene 2	14	65-70	Steel	Plastic steel patch sandblasted	No damage after 124 hours. No damage after 251 hours.
63	Neoprene 2	14	65-70	Steel	Stainless weld repair sandblasted	No damage after 254 hours. No damage after 2,000 hours.
64	Epoxy	*	**	Steel	Stainless weld repair	Failed after 4 hours.
65	Epoxy	Mfg. applied fused coating	**	Steel	Stainless weld repair	One damage spot 1-1/4 inches by 1/2 inch to steel after 12 hours. One large damage area 3 inches by 3/4 inch to steel after 16 hours, failed.
66	Vinyl	Mfg. applied fused coating	**	Steel	Stainless weld repair	One large damaged area to steel, 3 inches by 3/4 inch after 8 hours.
67	Chlorinated polyether	Mfg. applied fused coating	**	Steel	Stainless weld repair	Cavitation damage showed up in the first 4 hours. Failed after 6 hours damaged areas 4 inches by 1 inch.
68	Epoxy polyurethane varnish	1	2-5	Concrete	Sandblasted	Cavitation damage was evident after 4 hours. Damage into the concrete 10 by 1-1/2 by 1/16 - 1/4 depth after 8 hours.

* Not known.
** Thickness not determined.

Table 1 - Continued

Specimen No.	Material type	Coats and method of application	Thickness mils	Substrate	Surface preparation	Performance
69	Neoprene-urethane blend	Sprayed Mfg. applied	50-60	Steel	-	One small void showing after 226 hours. Good performance after 250 hours.
70	Tan gum rubber (natural)	Rubber cement cured under steam pressure	1/16 inch	Steel	-	Bond failure during first 7 hours of test.
71	Tan gum rubber (natural)	Rubber cement cured under steam pressure	1/8 inch	Steel	-	Bond failure after 11 hours of test.
72	Tan gum rubber (natural)	Rubber cement cured under steam pressure	1/4 inch	Steel	-	Failed after 126 hours.
73	Epoxy resin	2 Mfg. applied	20-30	Steel	10 drill holes for damage area sandblasted	Four or five chips down the center about 3/8 inch diameter after 1 hour. Failed (damage down center a strip 8 by 1 and epoxy removed from drill holes) after 2 hours.
74	Epoxy resin	2 Troweled Mfg. applied	20-30	Concrete	Sandblasted	Two small breaks after 4 hours. Holes in coating to concrete after 8 hours. Cutting to concrete after 10 hours. Failed after 15 hours.

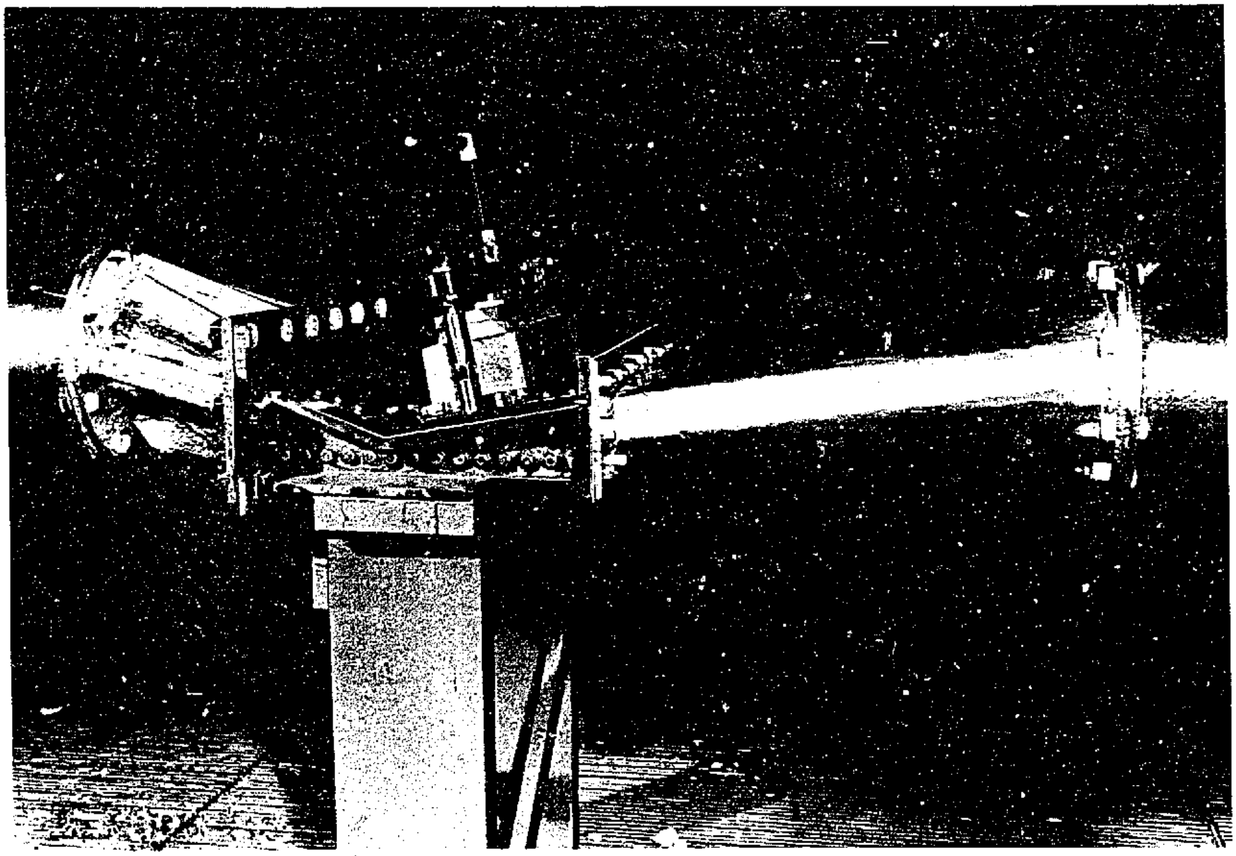


Figure 1. Venturi-type cavitation apparatus used for laboratory tests. Photo PX D-32396

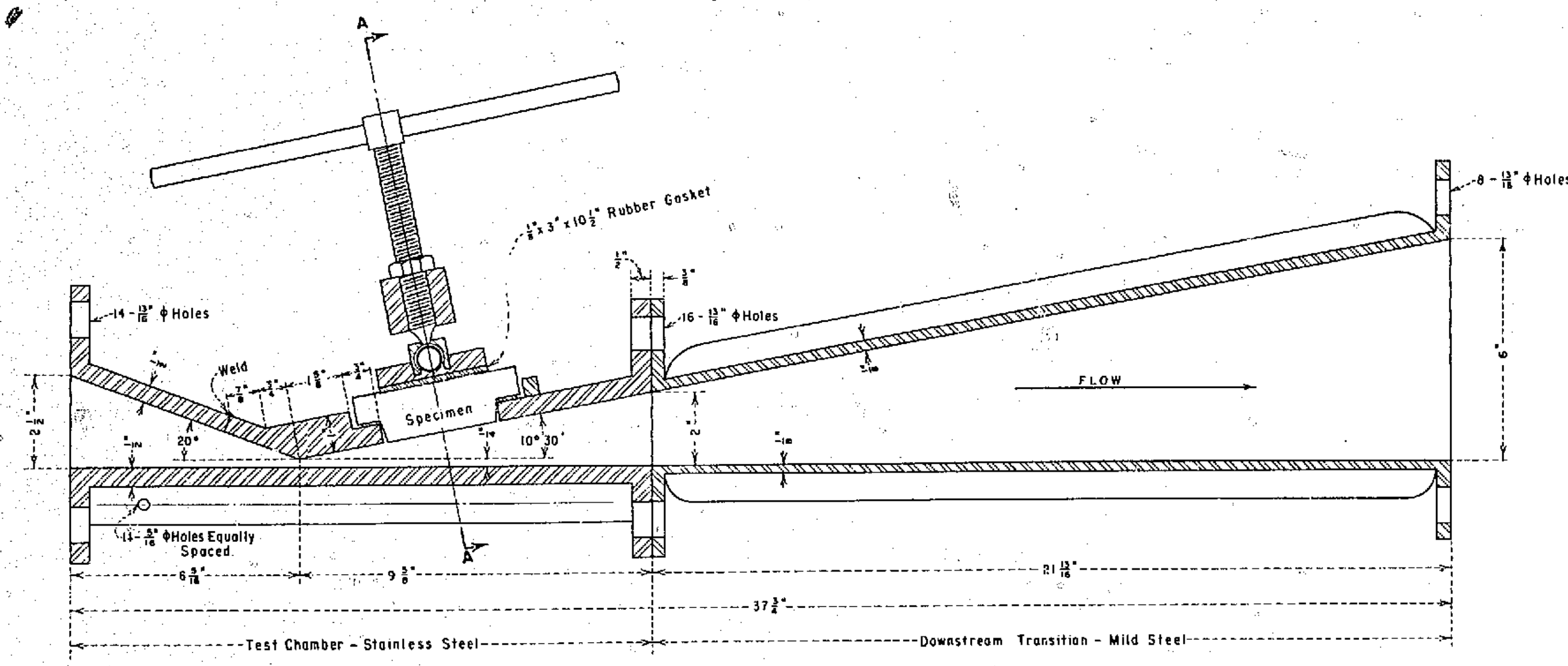


Figure 2. Test chamber and downstream transition.

A. Before exposure. Photo PX-D-67956

B. Peeling off of the protective coating from the edge caused failure after 42 hours. Photo PX-D-67957

Figure 3. Specimen No. 1—Neoprene 1.

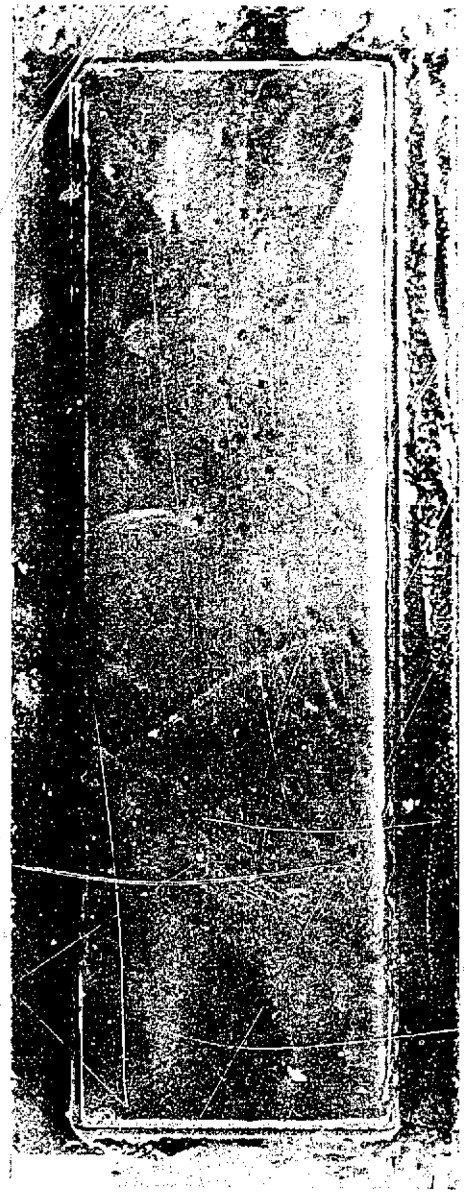


Figure 4. Specimen No. 5–Neoprene 1 before test. Photo PX-D-67945

Figure 5. Specimen No. 26—Neoprene 1 before testing. Photo PX-D-45752

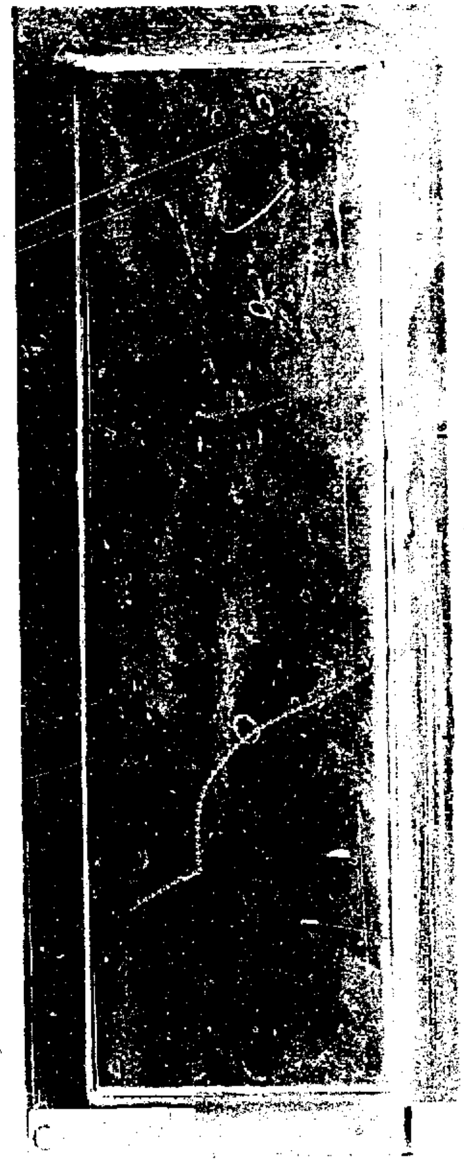


Figure 6. Specimen No. 27–Neoprene 1 rubber before testing. Photo PX-D-67947

Figure 7. Specimen No. 55—Neoprene 2 coating before test. Photo PX-D-67946

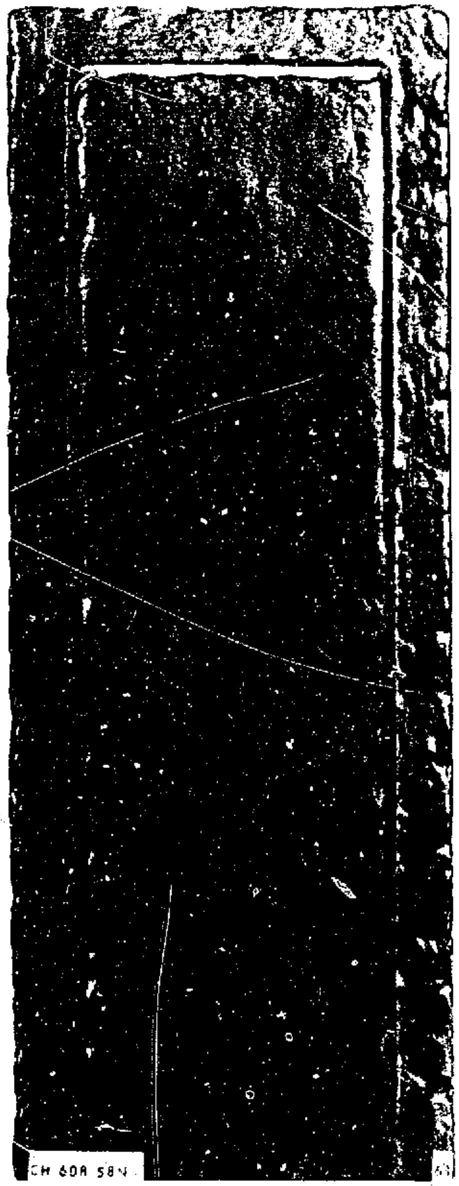


Figure 8. Specimen No. 61--Neoprene 2 coating over epoxy patches on a concrete substrate before test. Photo PX-D-67948

Figure 9. Specimen No. 62—Neoprene 2 coating over plastic steel patches on a steel substrate before test. Photo PX-D-67949

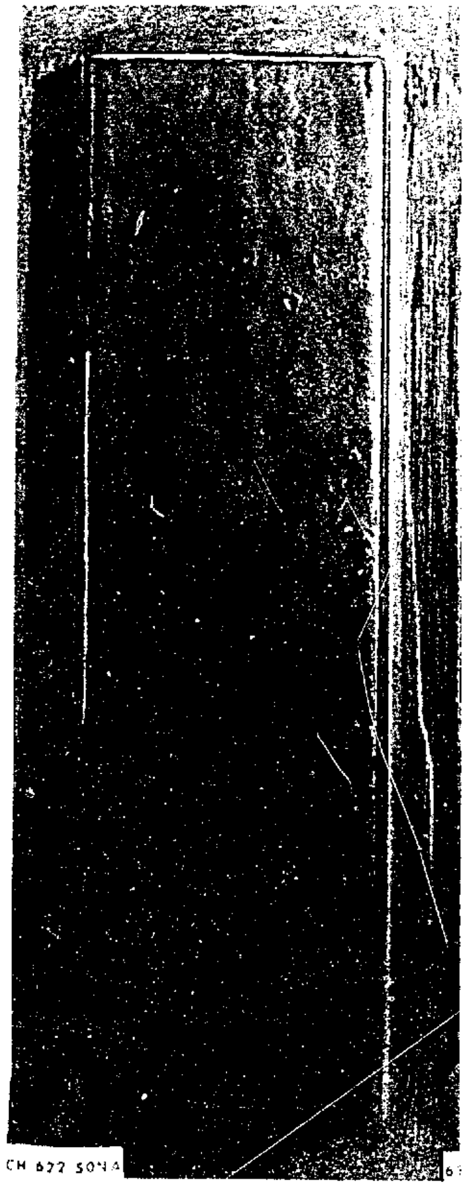


Figure 10. Specimen No. 63—Neoprene 2 coating over stainless steel welded patches before test. Photo PX-D-67950

A. Epoxy before test. Photo PX-D-25528

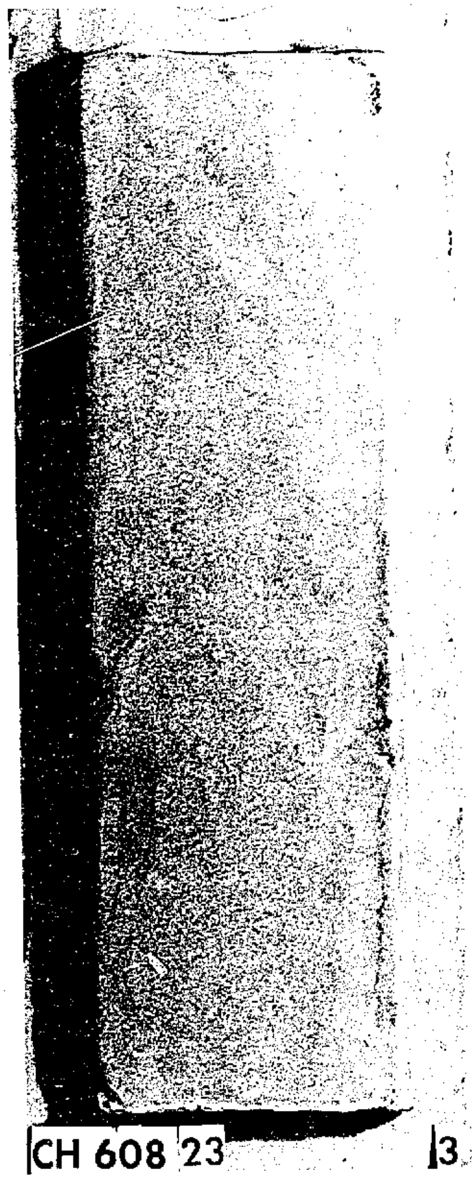
B. After 70 hours, scoured area in the middle of the specimen was enlarged, few cracks occurred in that vicinity and the epoxy became loose. Photo PX-D-67951

Figure 11. Specimen No. 2—Epoxy polyamide.

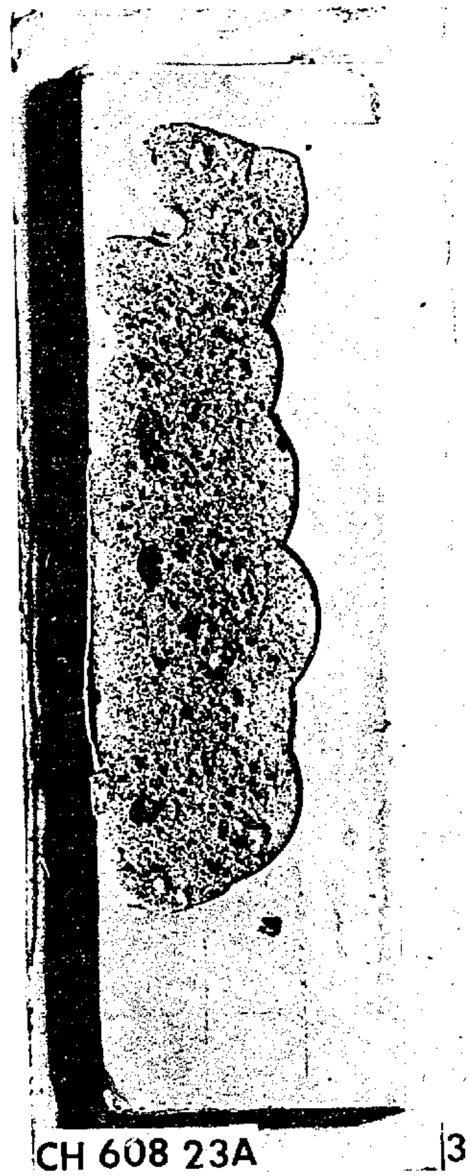
A. Epoxy before test. Photo PX-D-67952

B. After 63 hours, a crack occurred on the downstream side of the specimen, scouring in the middle of the specimen was more pronounced, and peeled areas enlarged. Photo PX-D-67953

Figure 12. Specimen No. 2T—Epoxy polyamide.

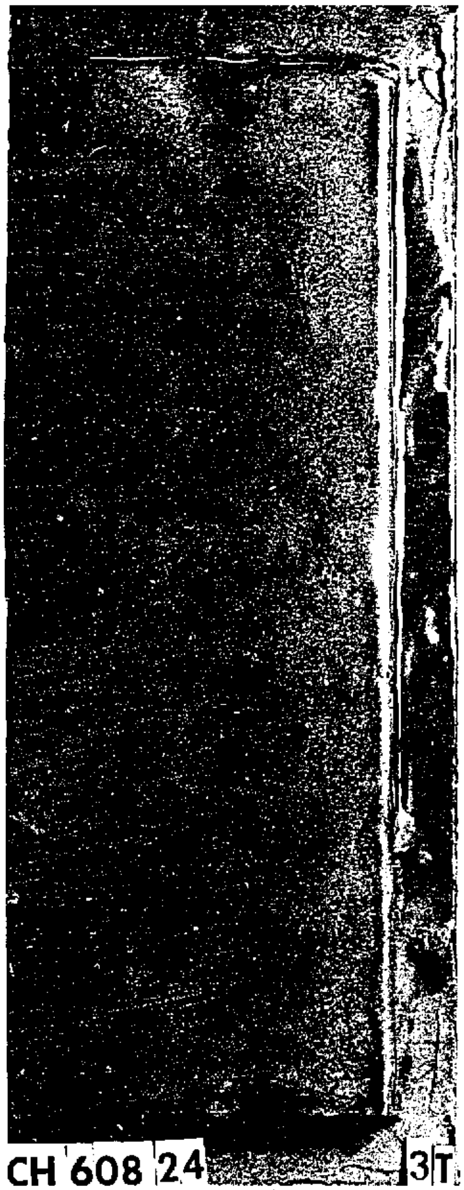


A. Epoxy polyamide before test. Photo PX-D-67954



B. After 14 hours, the epoxy failed as shown above. It is believed that a poorly finished surface caused early failure. Photo PX-D-67955

Figure 13. Specimen No. 3—Epoxy polyamide.



A. Epoxy polyamide before test. Photo PX-D-25532

B. After 49 hours, cavitation had chipped away a large area at the top and scoured the middle of the sanded fillet epoxy to failure. Photo PX-D-25534

Figure 14. Specimen No. 3T—Epoxy polyamide.

A. Before test. Photo PX-D-67958

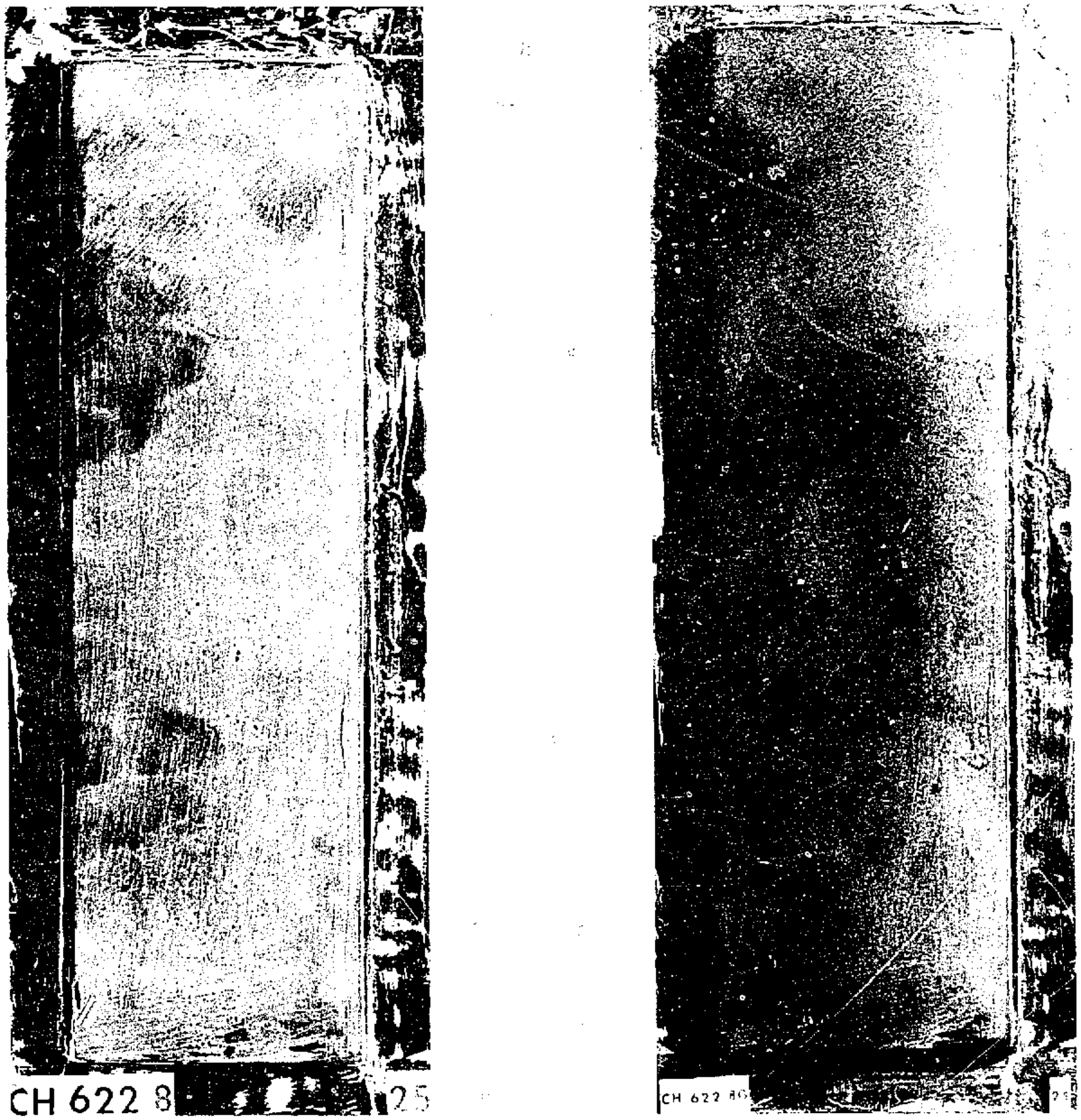
B. Failed after 7-hour test. Photo PX-D-67959

Figure 15. Specimen No. 5T—Epoxy polyamide.

A. Before test. Photo PX-D-67960

B. Failed after 7-hour test. Photo PX-D-67961

Figure 16. Specimen No. 6T—Epoxy polyamide.

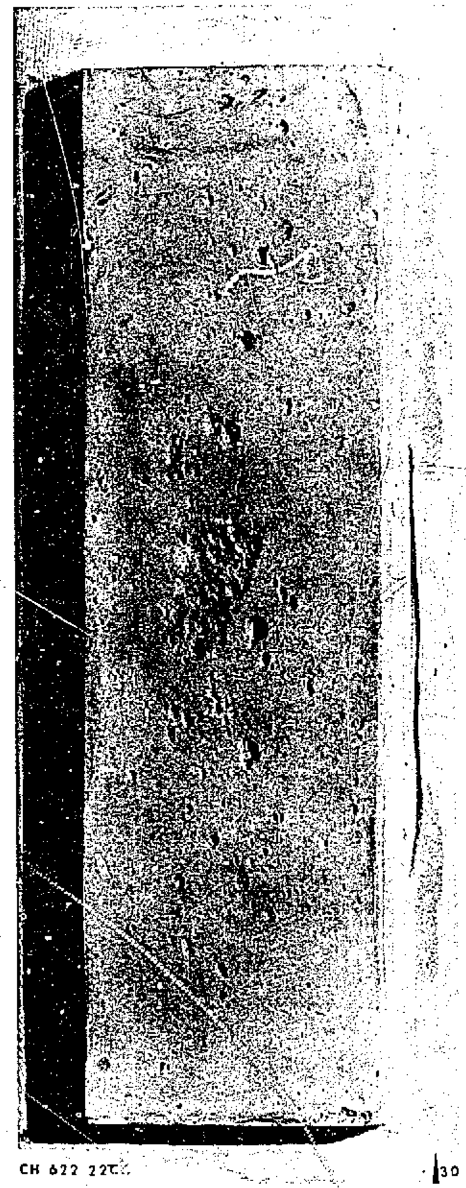


A. An epoxy polyamide before test. Photo PX-D-67962

B. After 71 hours, the epoxy showed pinpoint holes in the center of specimen. Photo PX-D-67963

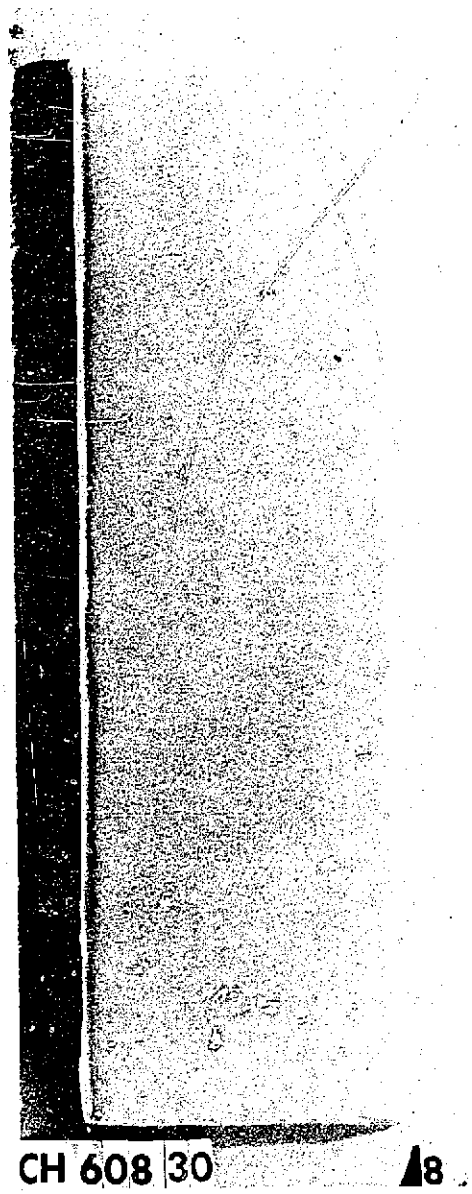
Figure 17. Specimen No. 25—Epoxy polyamide.

A. An epoxy polyamide before test. Photo PX-D-67964

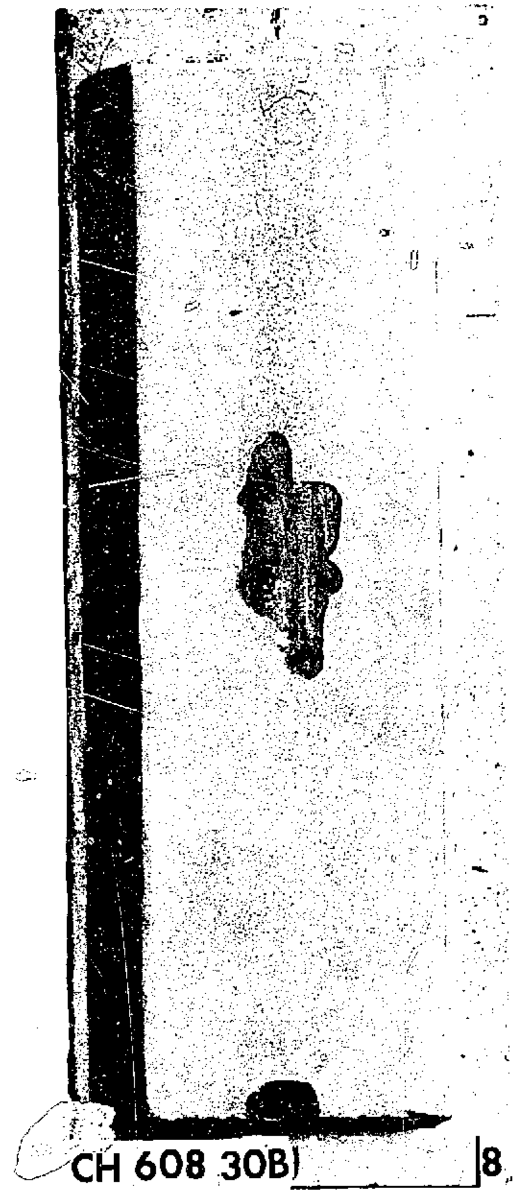


B. After 21 hours, the holes increased in size to cause partial failure of the coating. Photo PX-D-67965

Figure 18. Specimen No. 30—Epoxy polyamide.

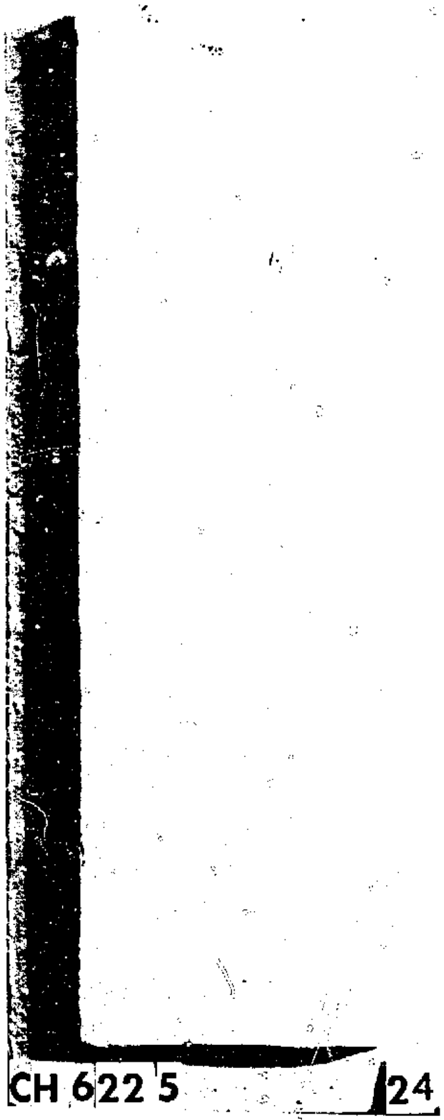


A. Phenolic modified phenolic before exposure. Photo PX-D-67966



B. The phenolic modified phenolic failed after 14 hours testing. Photo PX-D-67967

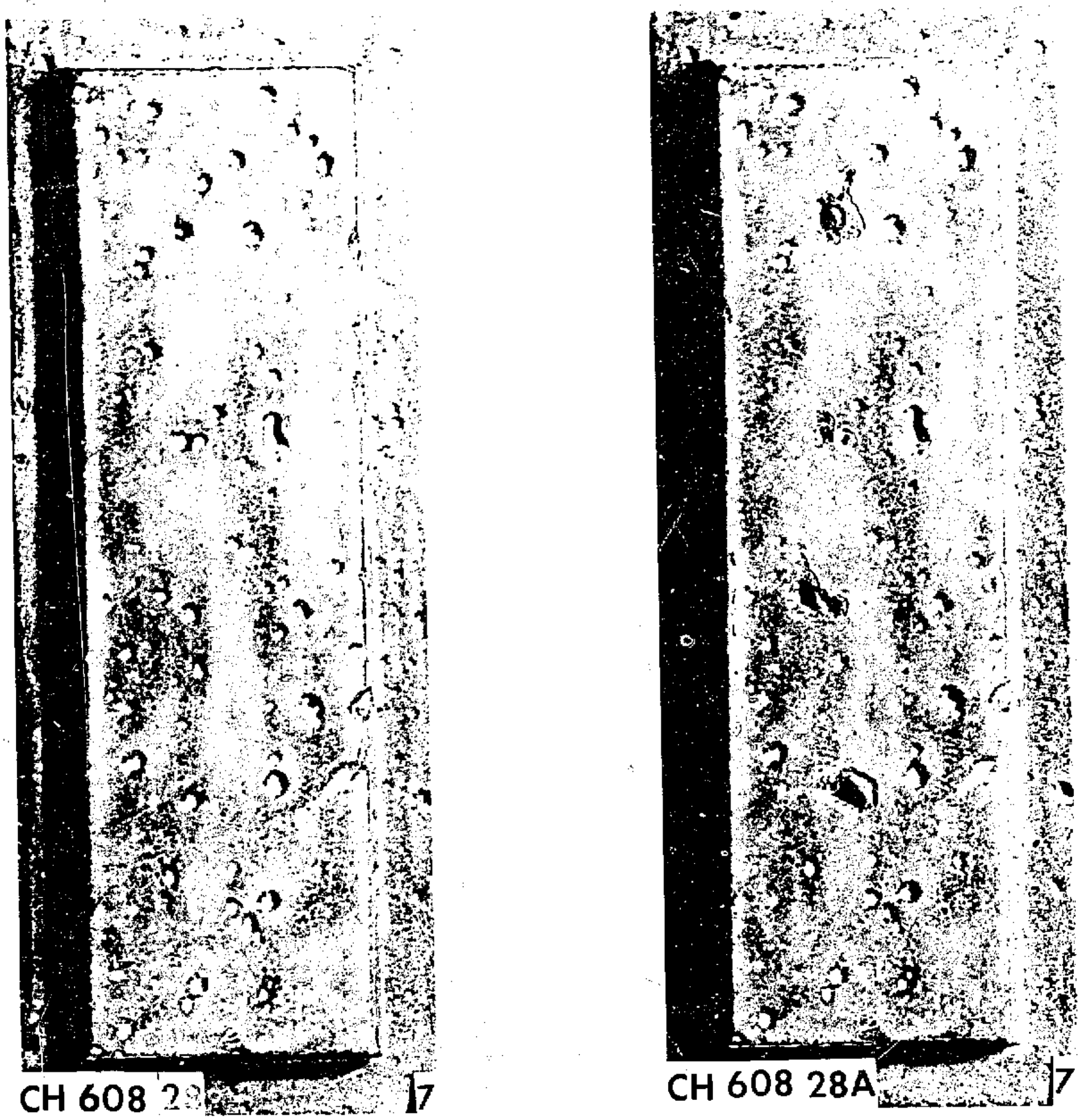
Figure 19. Specimen No. 8—Phenolic modified phenolic.



A. A phenolic modified phenolic before test. Photo PX-D-67968

B. After 21 hours, the damage had reached the base concrete specimen causing failure. Photo PX-D-67969

Figure 20. Specimen No. 24—Phenolic modified phenolic.



A. Epoxy before exposure. Photo PX-D-67970

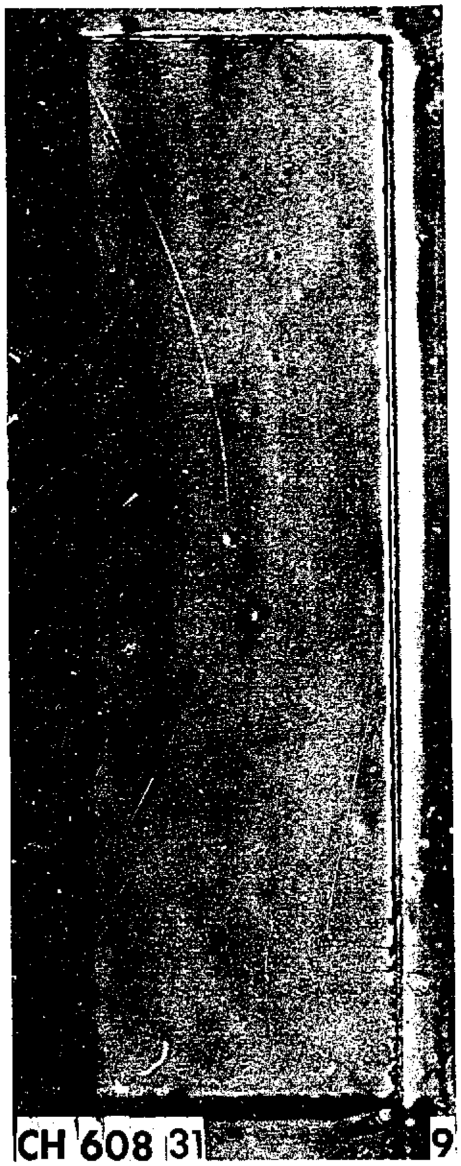
B. Epoxy failed after 7 hours of testing. Photo PX-D-67971

Figure 21. Specimen No. 7—Epoxy polysulfide.

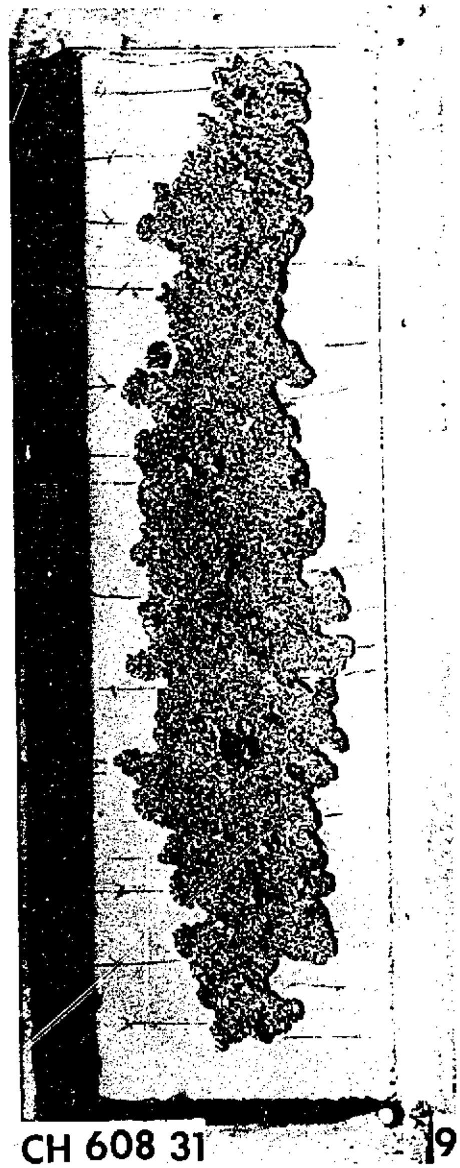
A. Epoxy before test. PX-D-67972

B. Epoxy failed after 7 hours of testing. PX-D-67973

Figure 22. Specimen No. 7T—Epoxy polysulfide.

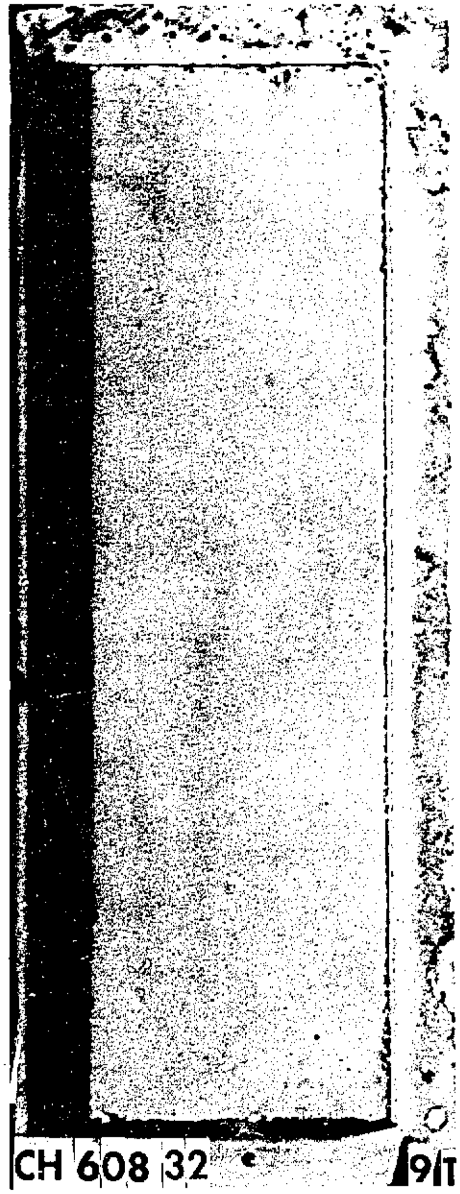


A. An epoxy crack sealer before test. Photo PX-D-67974



B. The epoxy crack sealer failed after 7 hours testing. Photo PX-D-67975

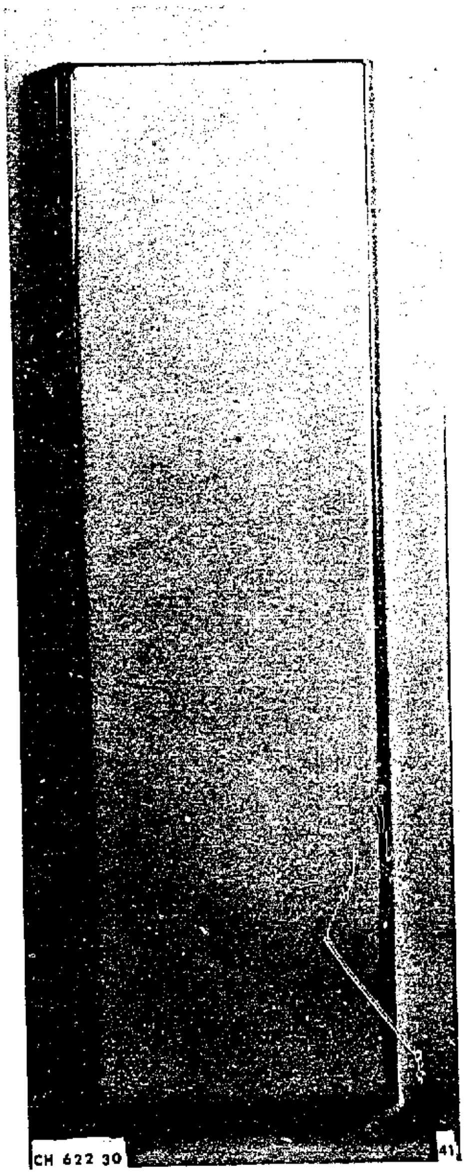
Figure 23. Specimen No. 9—Epoxy polysulfide.



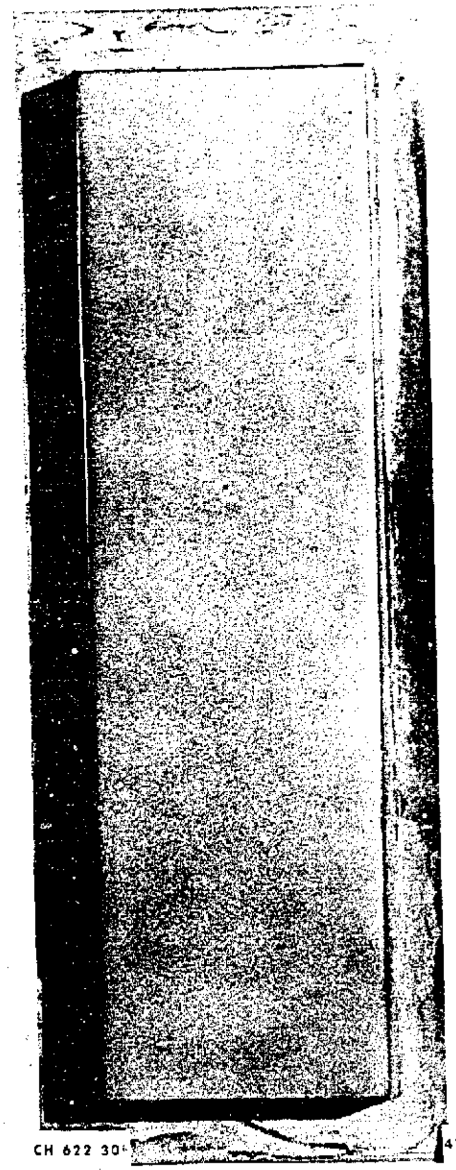
A. Epoxy polysulfide before exposure. Photo PX-D-67976

B. The epoxy was 75 percent damaged after 7 hours testing. Photo PX-D-67977

Figure 24. Specimen No. 9T—Epoxy polysulfide.

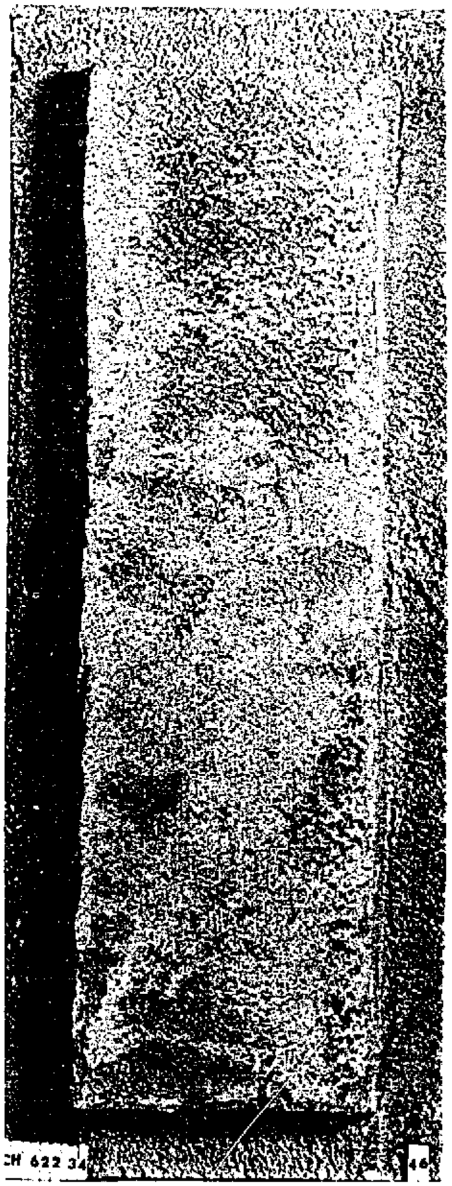


A. An epoxy polysulfide before exposure. Photo PX-D-67978

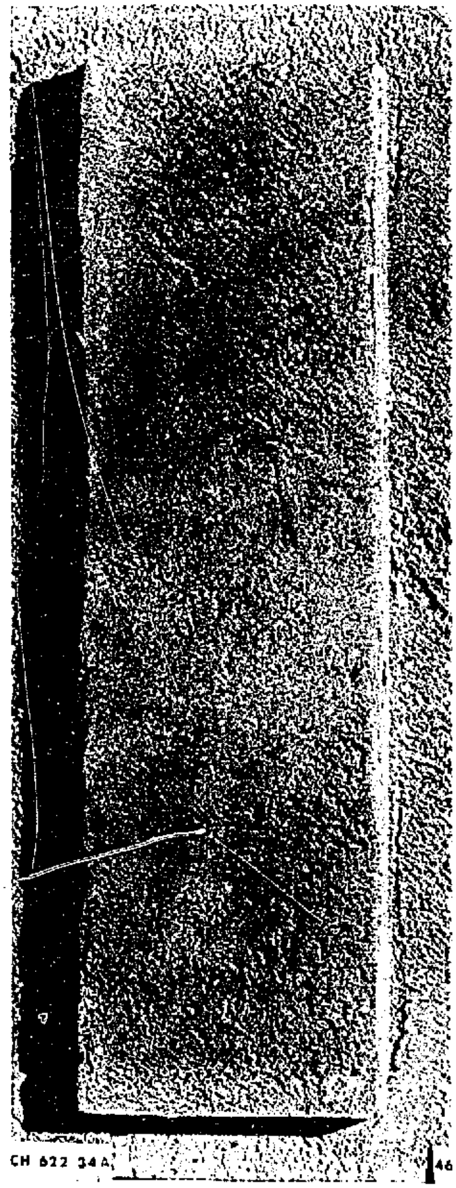


B. After 14 hours test, there appeared to be little change from 7 hours test. Some pinpoint holes occurred. Photo PX-D-67979

Figure 25. Specimen No. 41—Epoxy polysulfide.

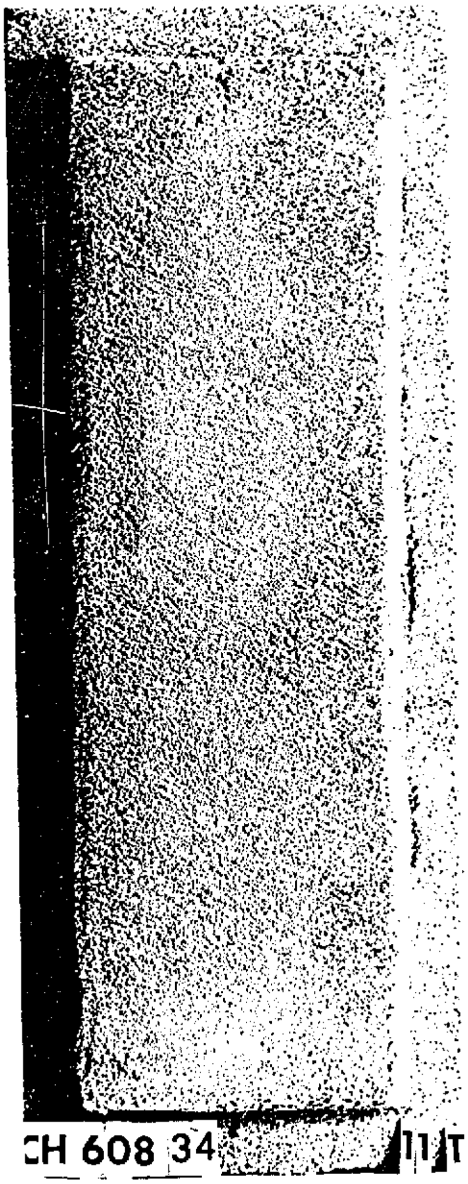


A. An epoxy polysulfide before test. Photo PX-D-67980

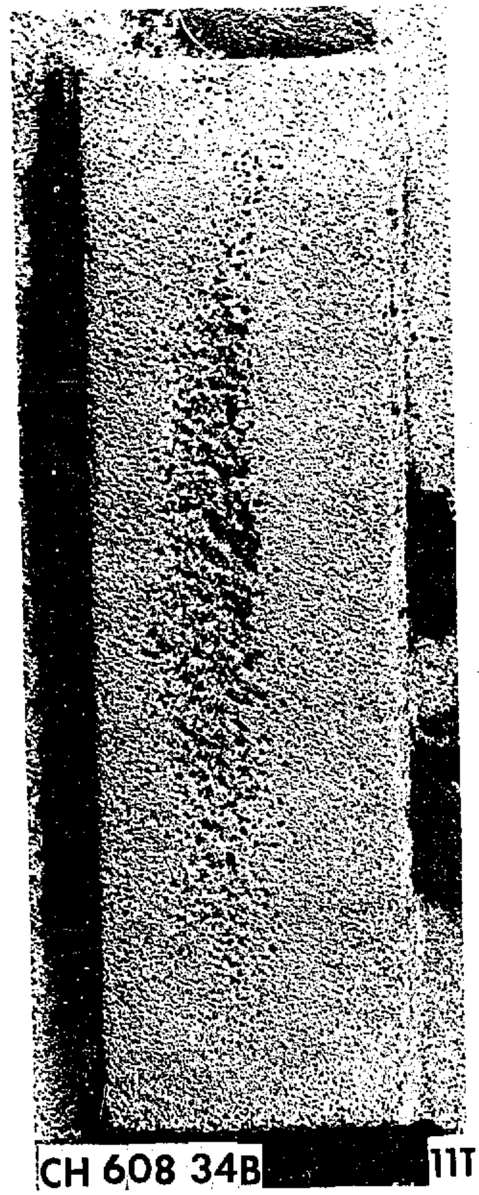


B. After 7 hours, many holes were visible causing partial failure of the epoxy polysulfide. Photo PX-D-67981

Figure 26. Specimen No. 46—Epoxy polysulfide.

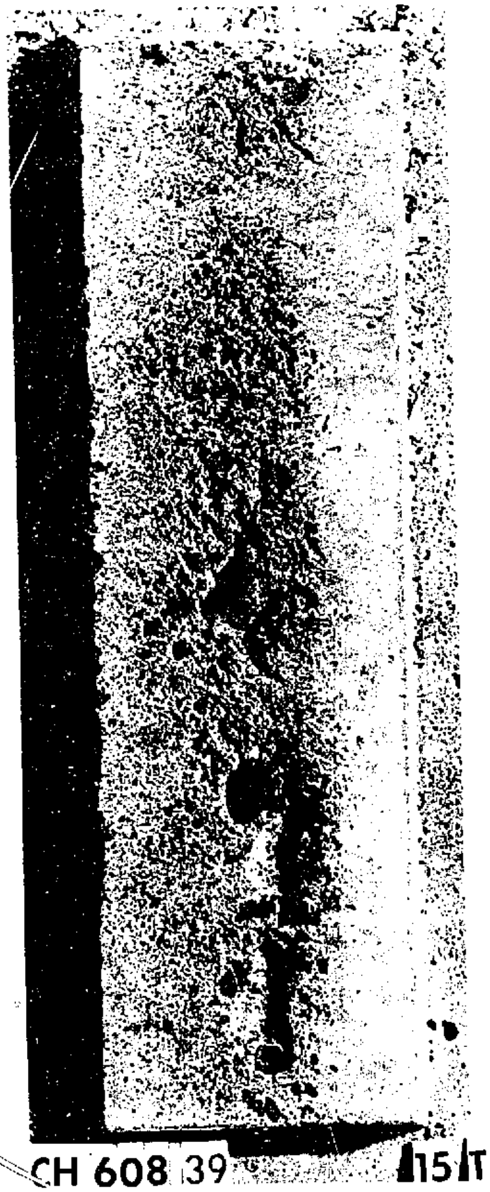


A. A sandfilled epoxy before testing. Photo PX-D-67982

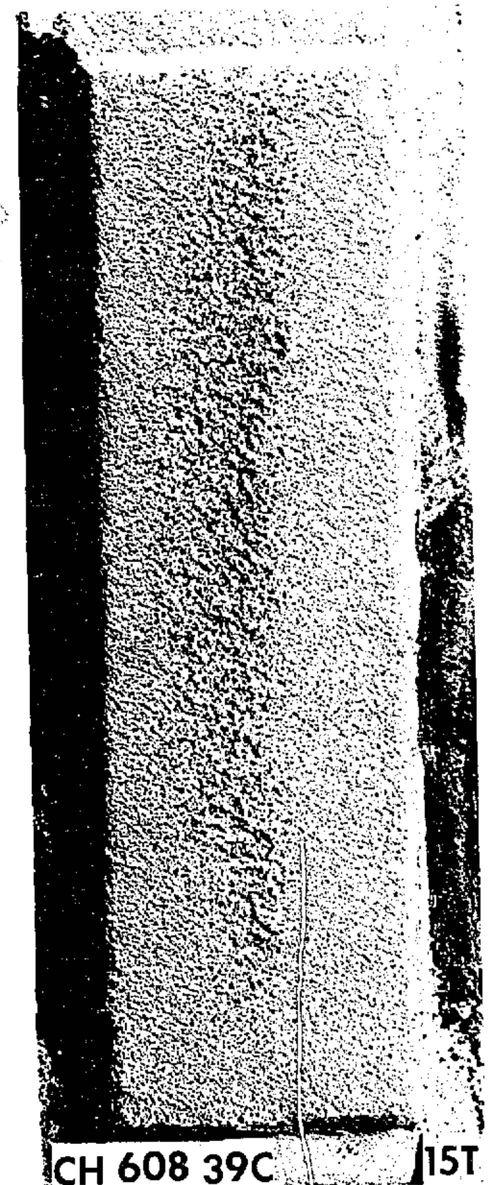


B. After 14 hours, the holes had enlarged and were through to the concrete causing failure of the sand-filled epoxy. Photo PX-D-67983

Figure 27. Specimen No. 11T—Sand-filled epoxy polyamide.

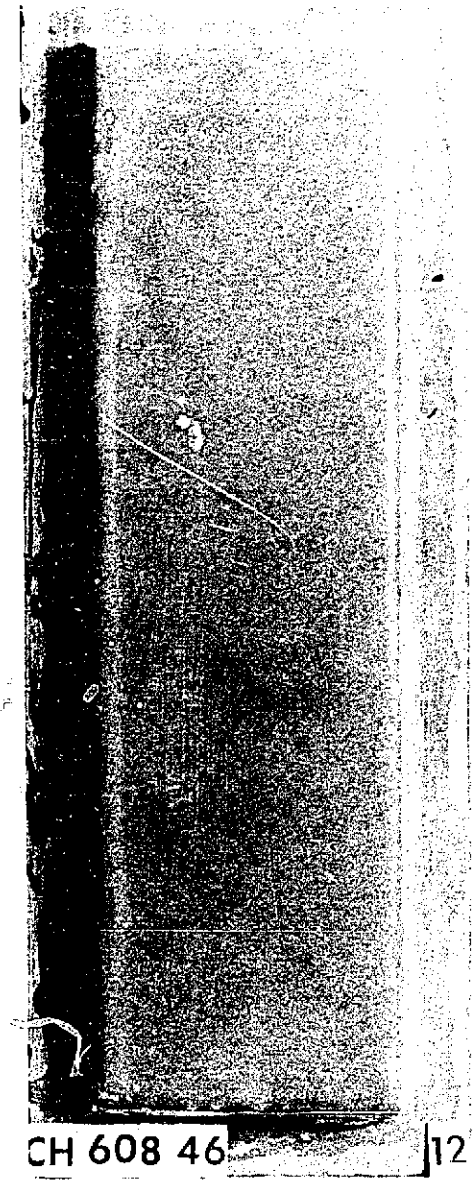


A. A sand-filled epoxy polyamide before test. Photo PX-D-67984



B. The holes have reached the base concrete causing failure after 21 hours testing. Photo PX-D-67985

Figure 28. Specimen No. 15T—Sand-filled epoxy polyamide.



A. Epoxy resin before exposure. Photo PX-D-67986

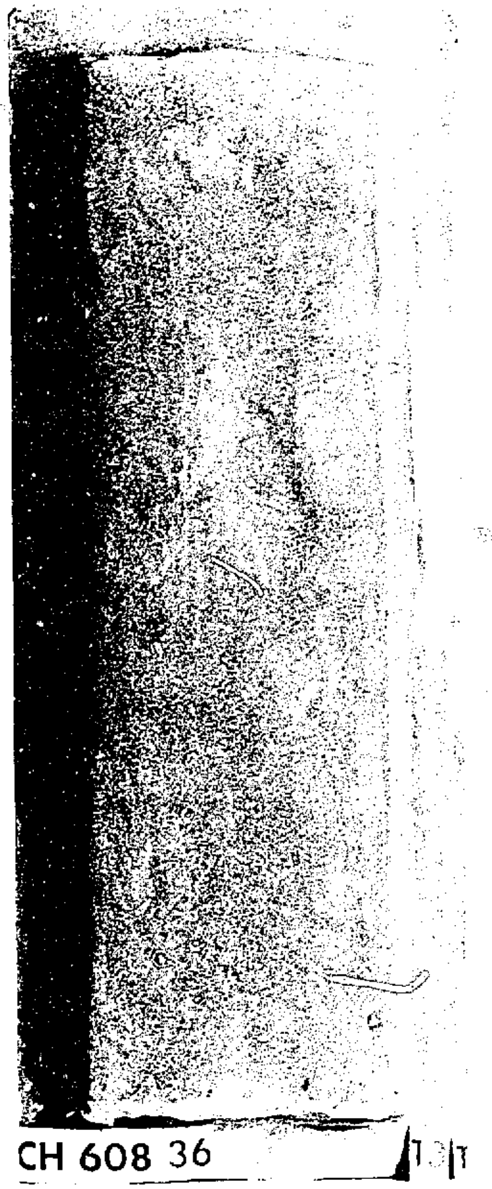
B. After 7 hours testing 95 percent of the finish coat was peeled off. Photo PX-D-67987

Figure 29. Specimen No. 12—Epoxy.

A. Epoxy resin before test. Photo PX-D-67988

B. The size of the damage area enlarged causing failure of the epoxy resin after 42 hours testing. Photo PX-D-67989

Figure 30. Specimen No. 12T—Epoxy.

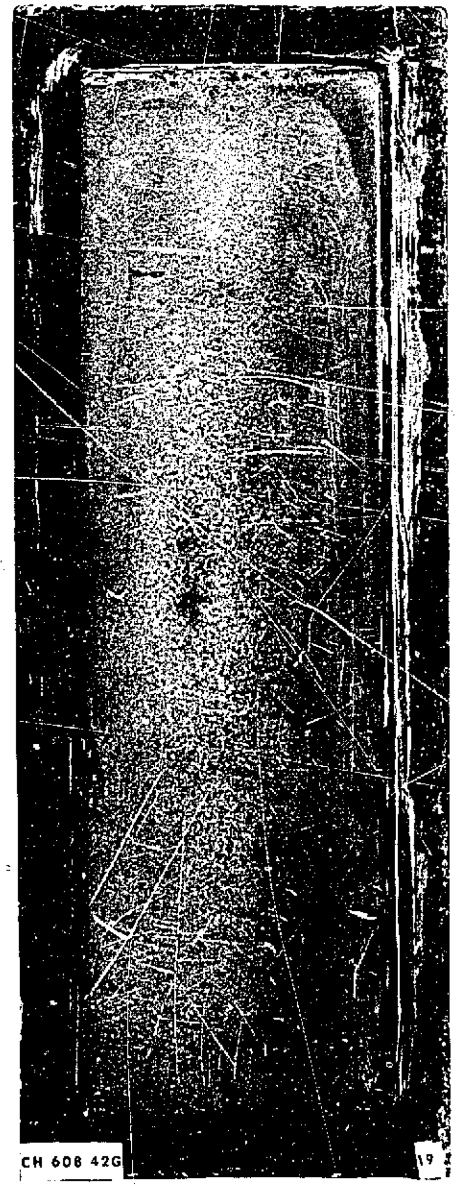


A. Epoxy before test. Photo PX-D-67990

B. After 21 hours, epoxy failed at 28 hours. Photo PX-D-67991

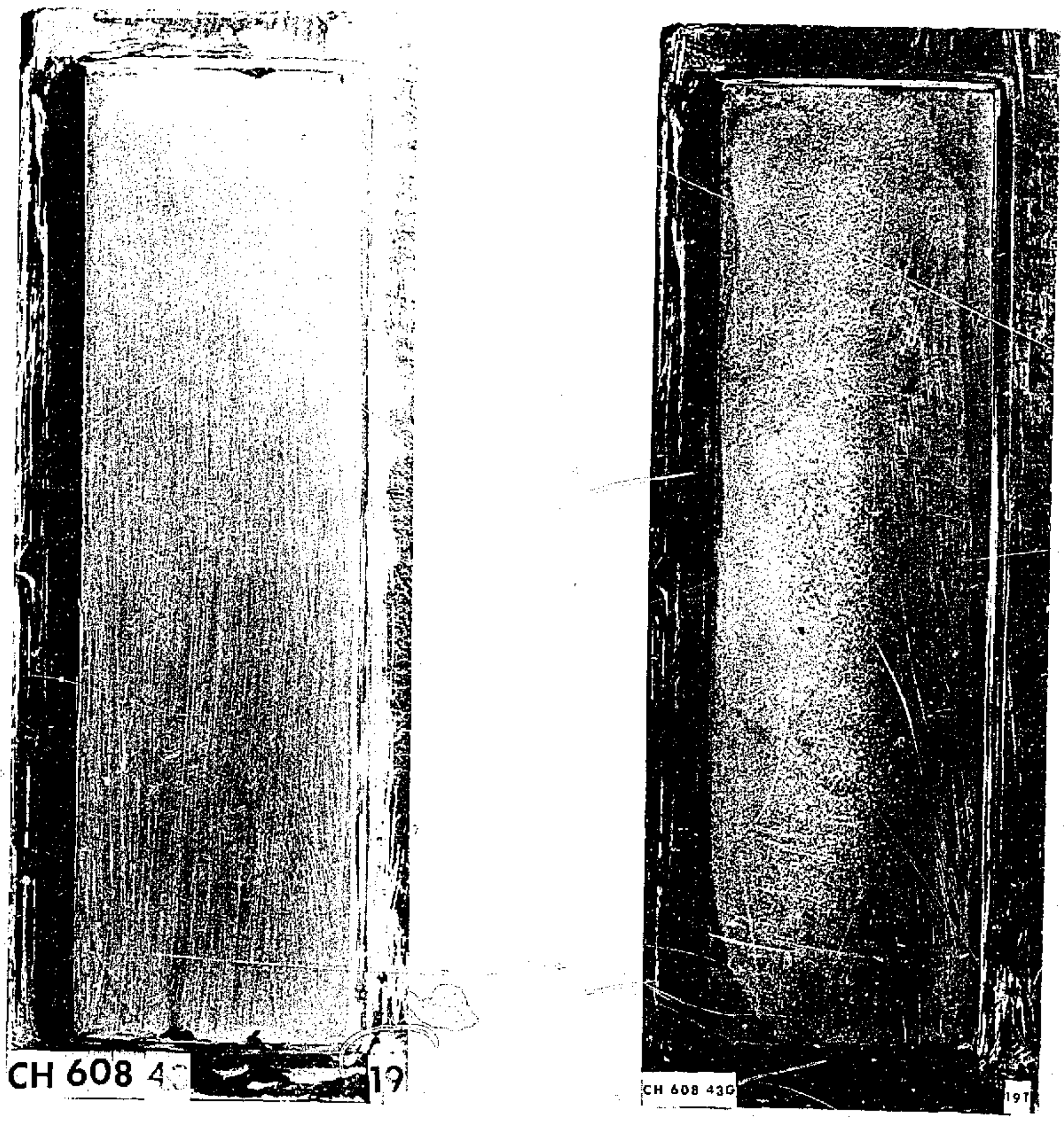
Figure 31. Specimen No. 13T—Epoxy.

A. A trowel-on epoxy that was ground smooth, before testing. Photo PX-D-67992



B. After 50 hours, damage has continued to the base specimen causing partial failure. Photo PX-D-67993

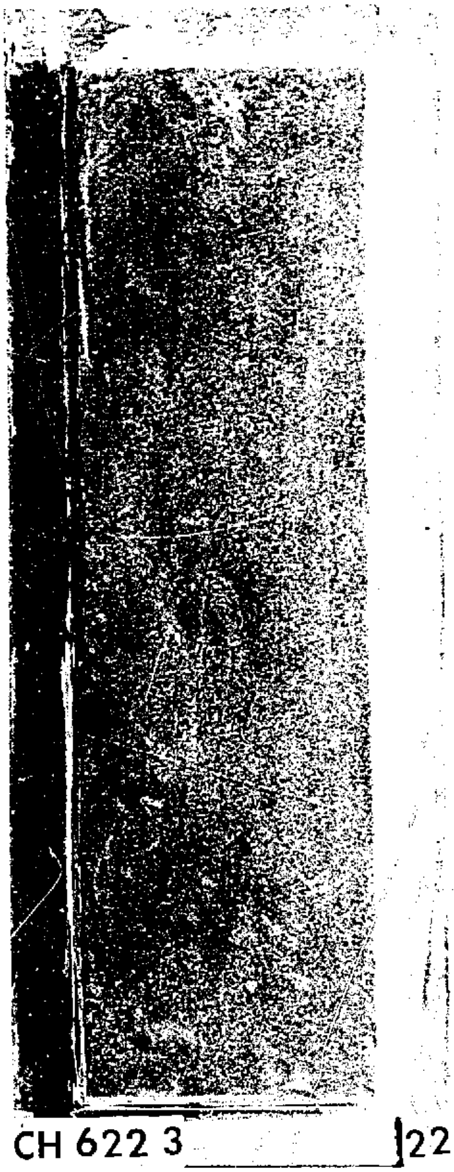
Figure 32. Specimen No. 19—Epoxy.



A. A trowel on epoxy that was ground smooth, before testing. Photo PX-D-67994

B. After 50 hours, the holes had cut through to base specimen, resulting in partial failure. Photo PX-D-67995

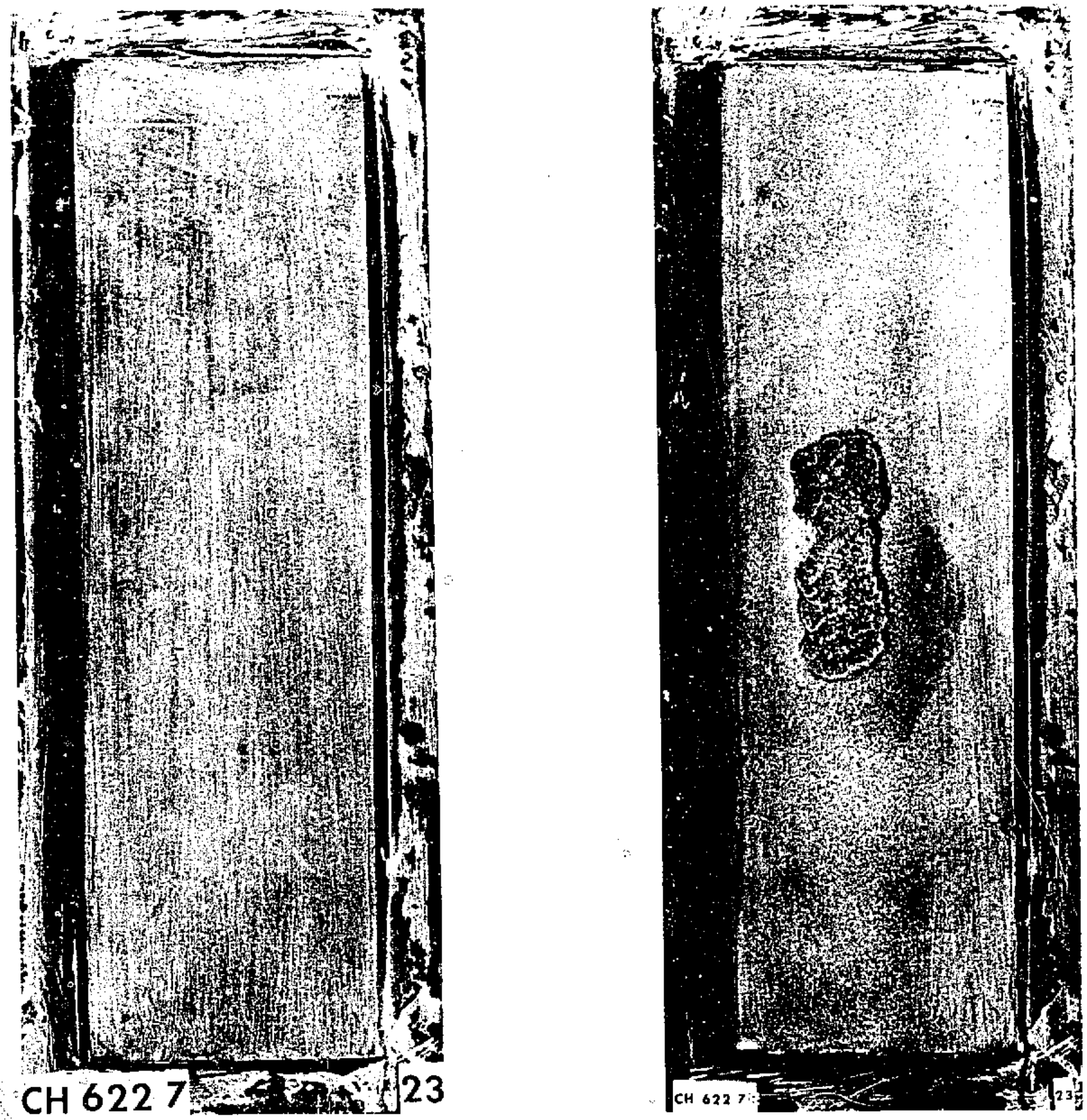
Figure 33. Specimen No. 19T—Epoxy.



A. Epoxy before test. Photo PX-D-67996

B. 60 percent of the coating is eroded from the base steel specimen after 24 hours testing. Photo PX-D-67997

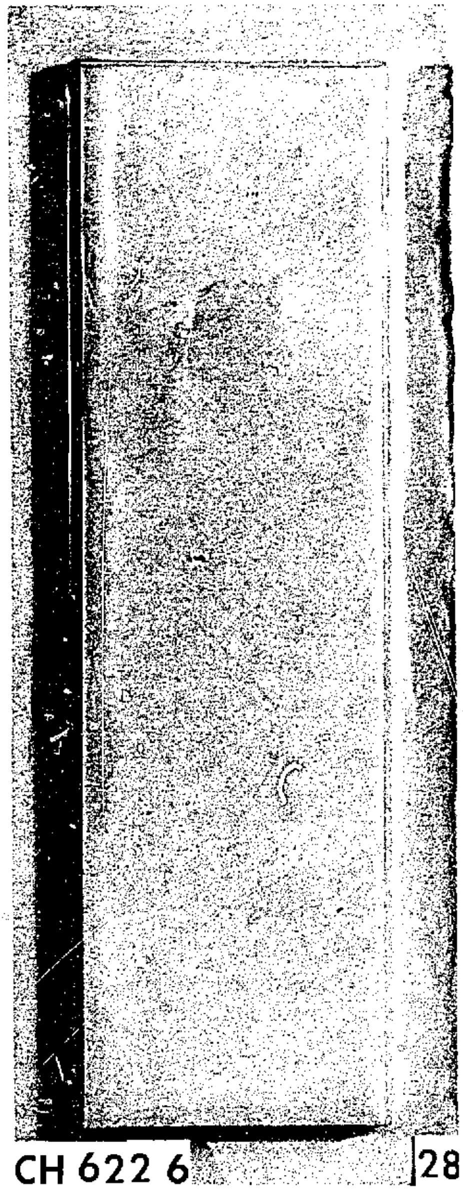
Figure 34. Specimen No. 22—Epoxy.



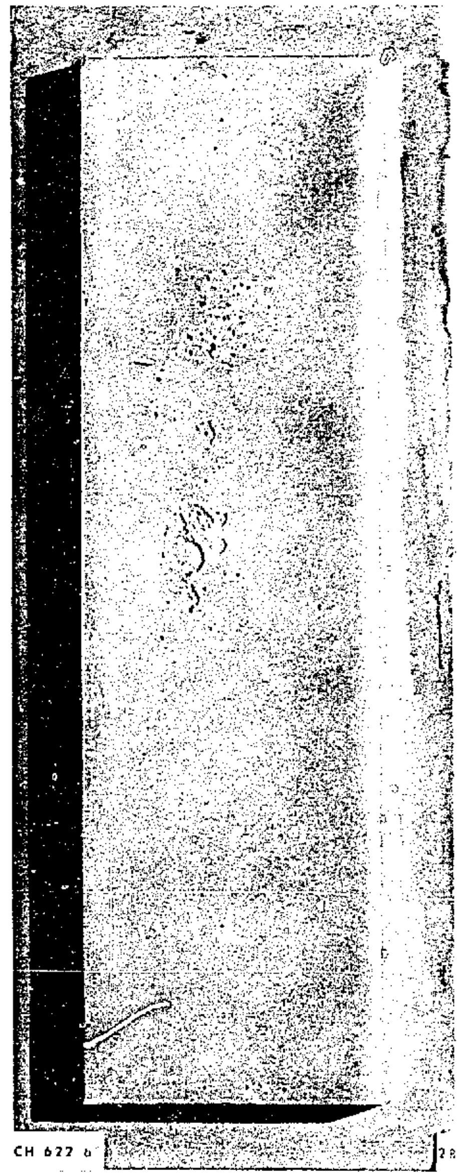
A. Epoxy coating before test. Photo PX-D-67998

B. After 35 hours, the epoxy showed failure. Photo PX-D-67999

Figure 35. Specimen No. 23—Epoxy.

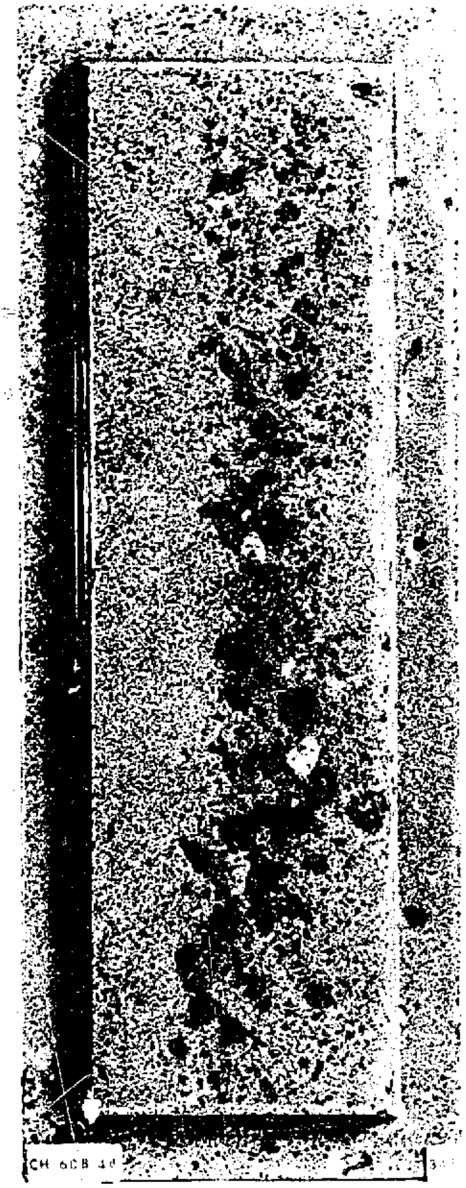


A. Epoxy before testing. Photo PX-D-68000



B. After 53 hours, pinpoint holes occurred on the coating surface particularly in a spilled area, and increased in size until they caused failure. Photo PX-D-68001

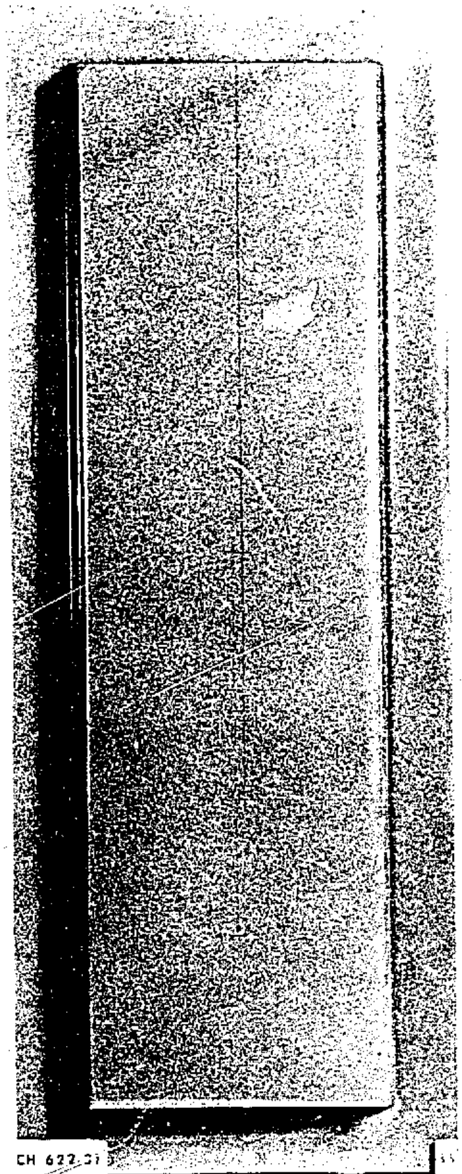
Figure 36. Specimen No. 28—Epoxy.



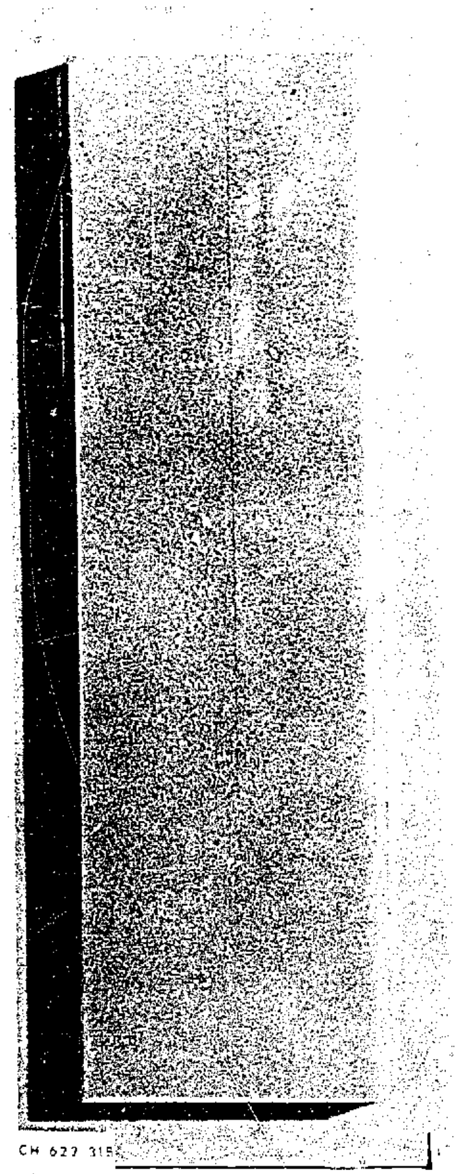
A. Epoxy resins before test. Photo PX-D-68002

B. After 7 hours, the epoxy resin failed from severe damage. Photo PX-D-68003

Figure 37. Specimen No. 34T—Epoxy.



A. Epoxy resin before test. Photo PX-D-68004



B. After 15 hours, holes had become evident. Photo PX-D-68005

Figure 38. Specimen No. 35—Epoxy.

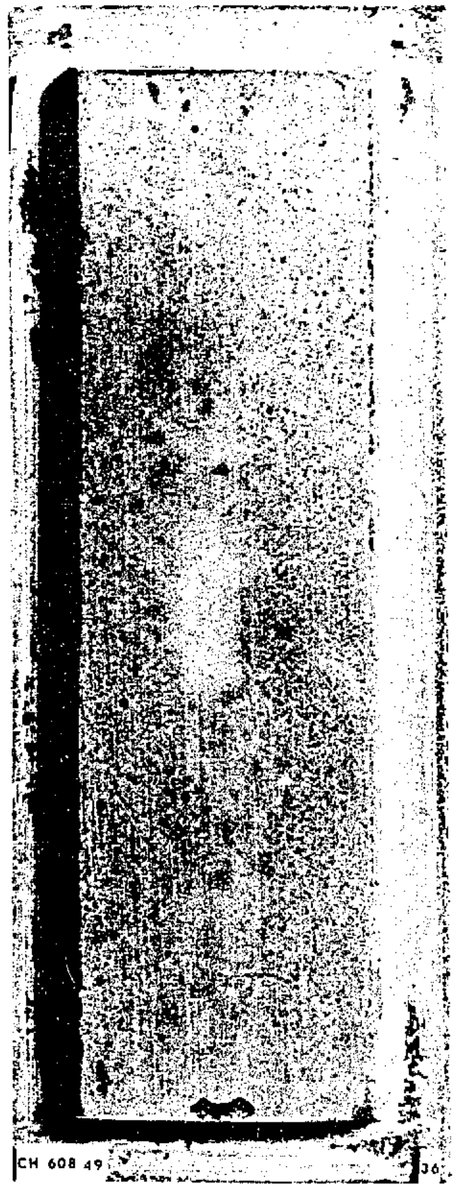


Figure 39. Specimen No. 36T—Epoxy resin before test. Photo PX-D-68006

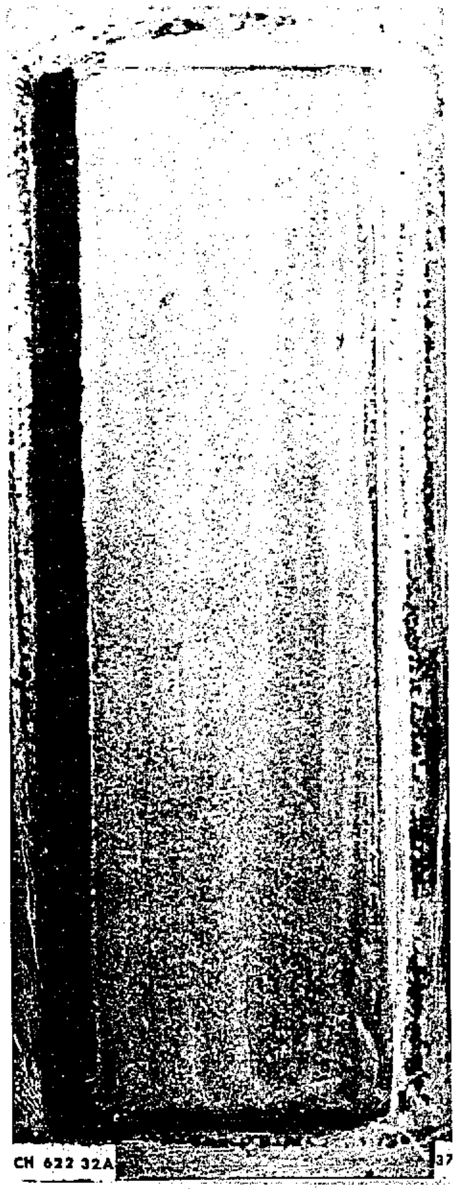


Figure 40. Specimen No. 37—Epoxy before exposure. Photo PX-D-68007

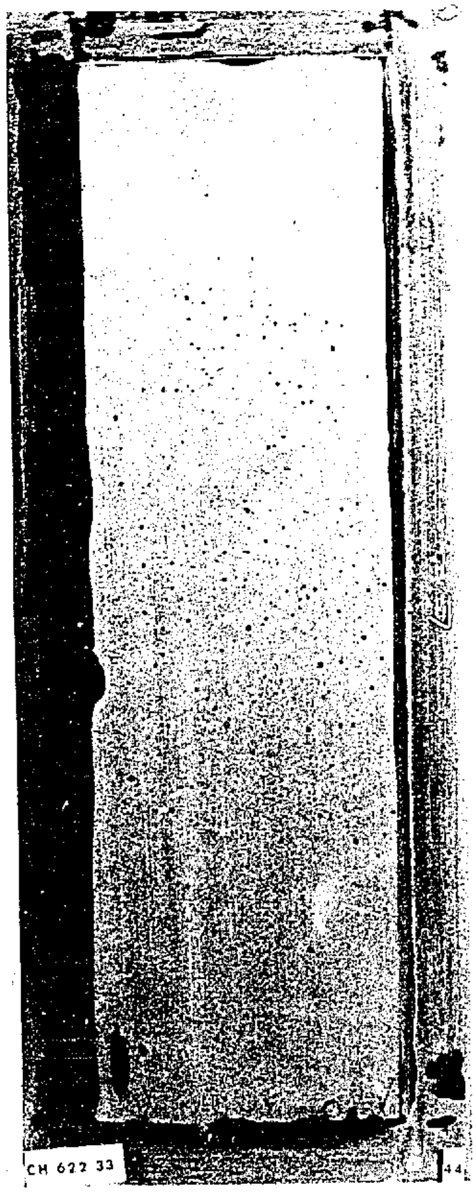
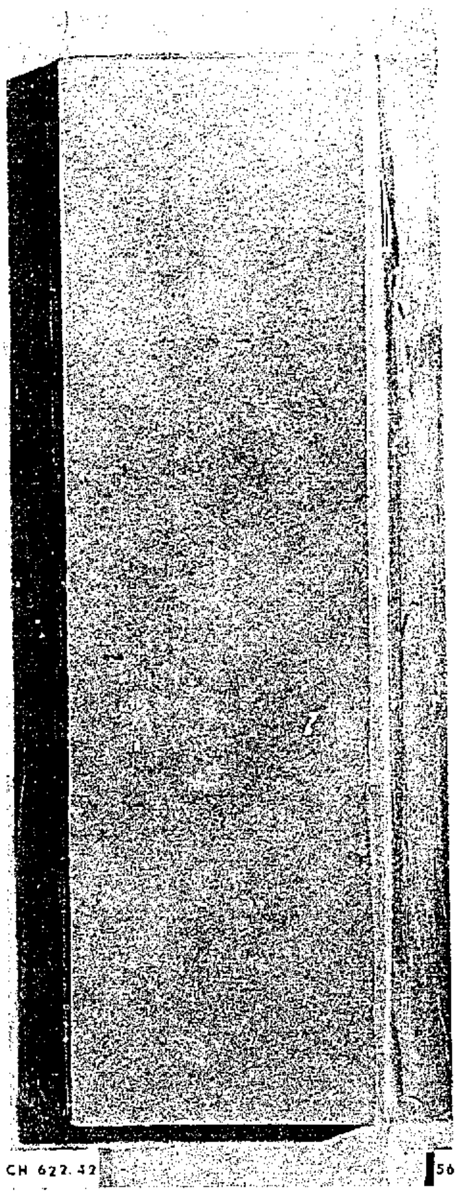
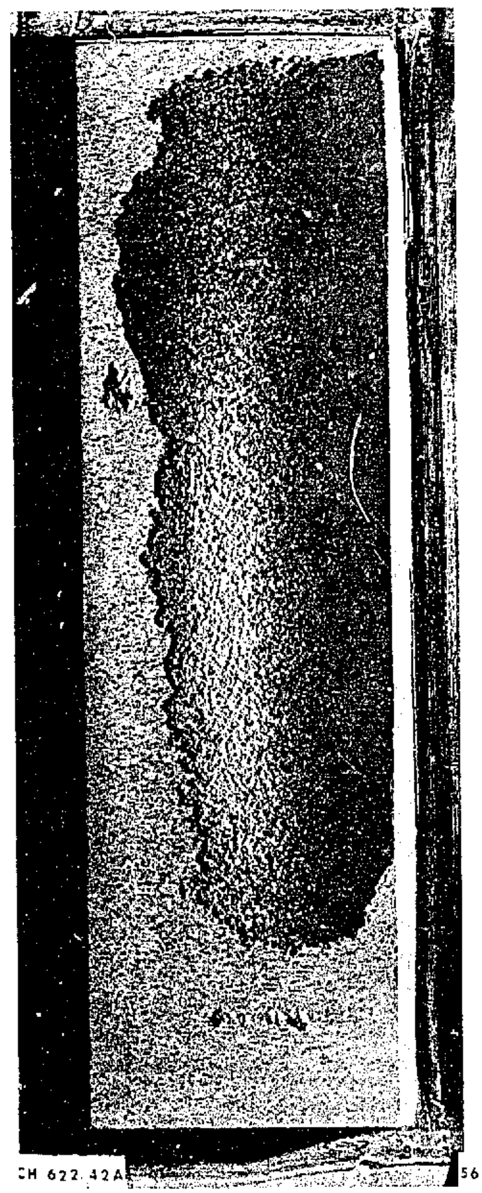


Figure 41. Specimen No. 44—Epoxy before test. Photo PX-D-68008

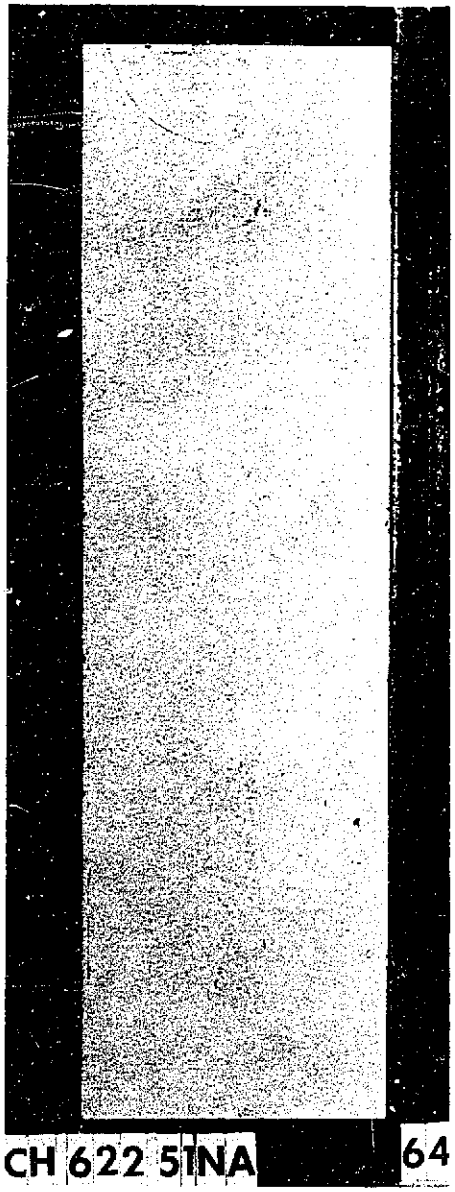


A. Flexible epoxy before test. Photo PX-D-68009

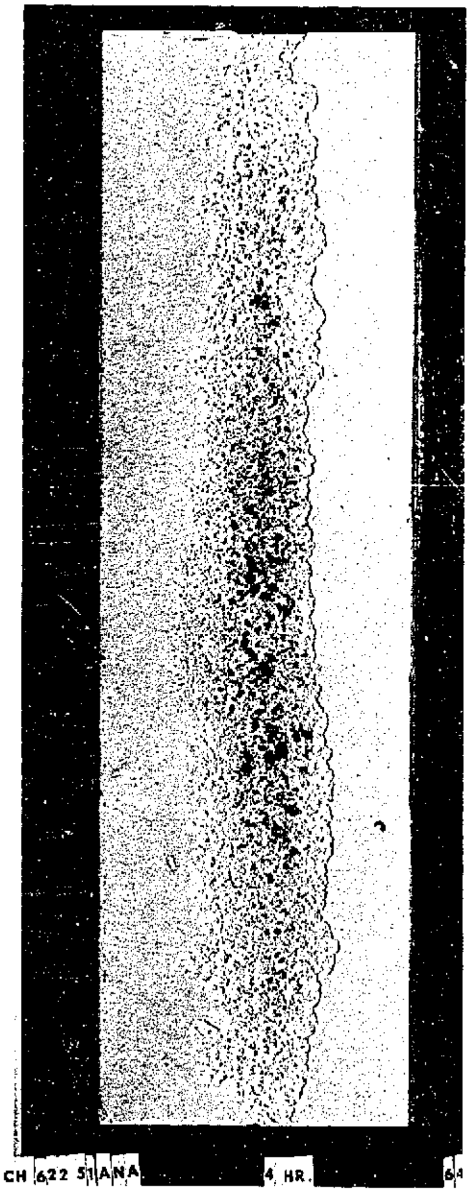


B. After 8 hours, 33 percent of the flexible epoxy had peeled off. Photo PX-D-68010

Figure 42. Specimen No. 56—Flexible epoxy patching compound.

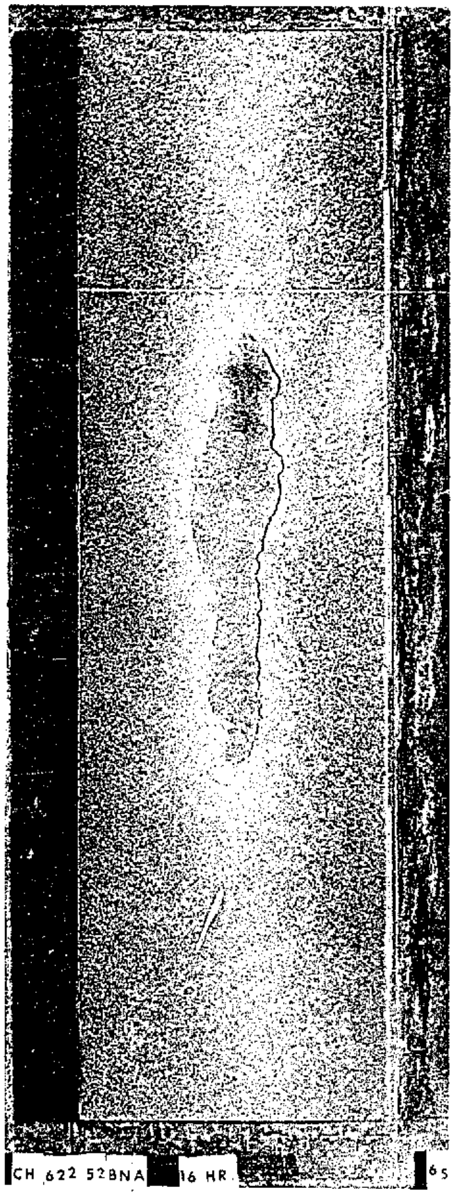


A. Epoxy over stainless weld patches on steel, before test. Photo PX-D-68011

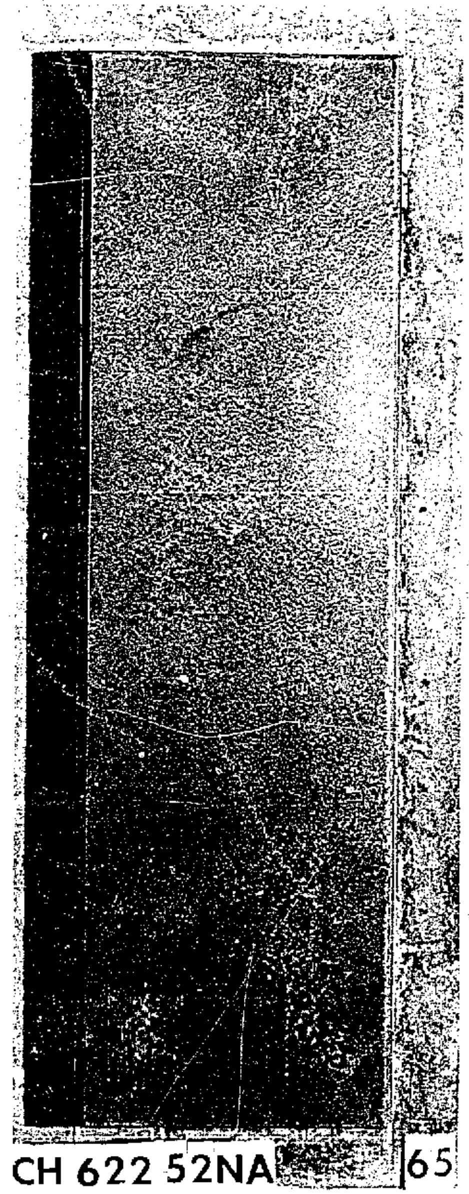


B. After 4 hours, the epoxy was eroded away to the steel in the middle of the specimen. Photo PX-D-68012

Figure 43. Specimen No. 64—Epoxy.

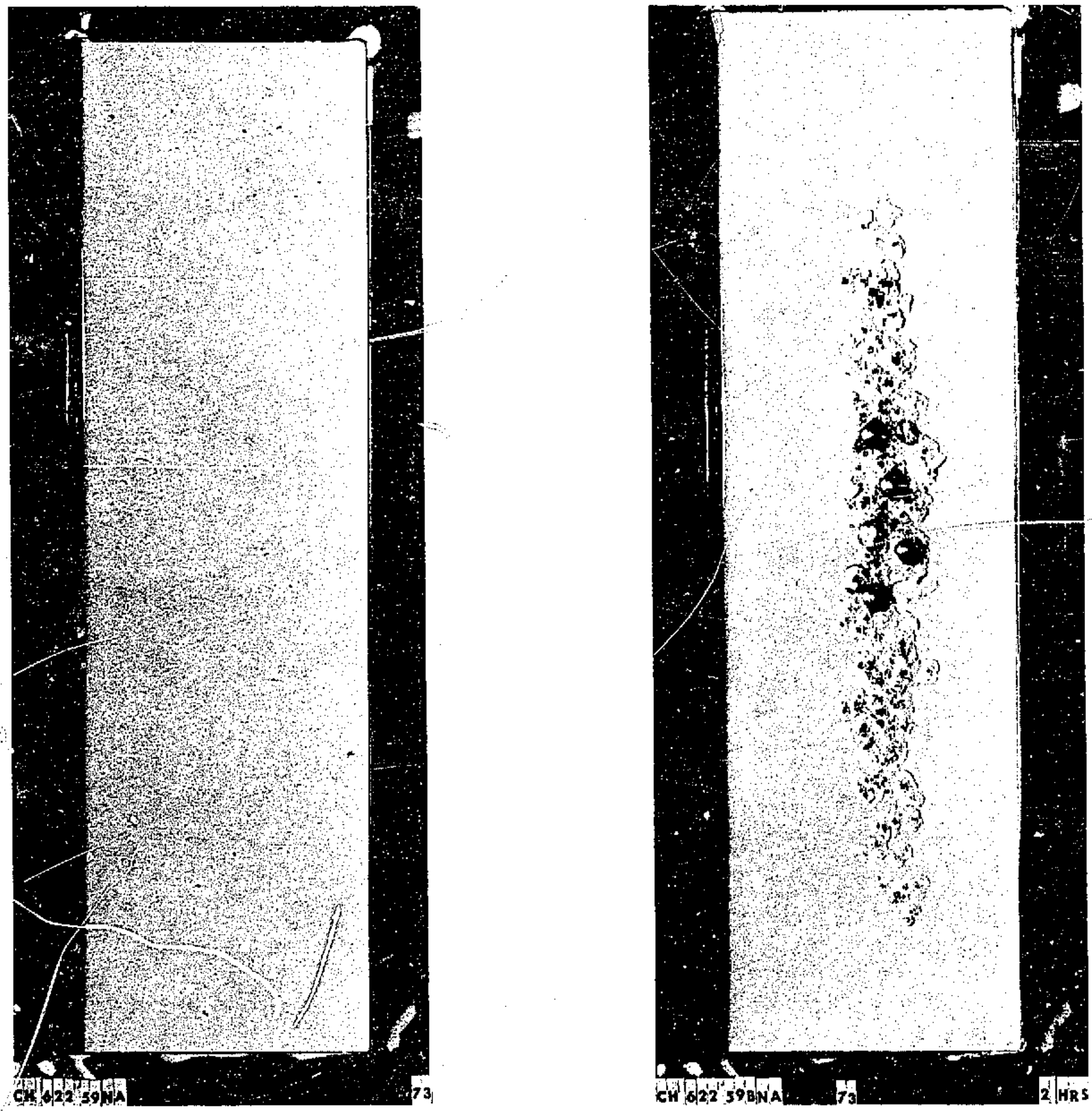


A. Fused epoxy coating over stainless steel weld patches on steel substrate, before test. Photo PX-D-68013



B. After 16 hours, the hole in the epoxy coating had enlarged to 4-1/2 by 1 inches and caused failure of the coating. Photo PX-D-68014

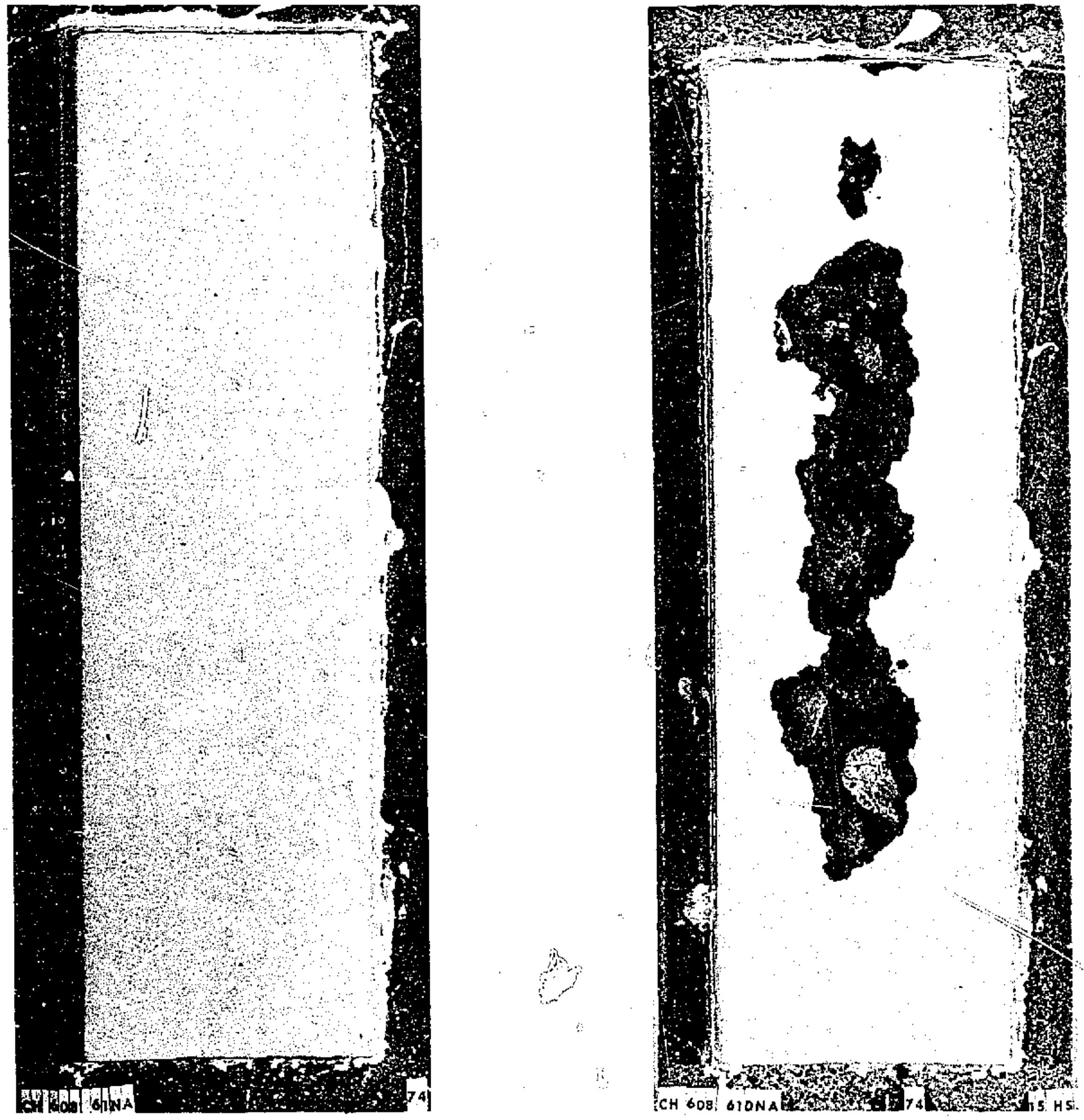
Figure 44. Specimen No. 65—Epoxy.



A. Epoxy coating over steel substrate which had several 1/8-inch holes, 1/8 inch deep drilled in it before test. Photo PX-D-68015

B. After 2 hours of testing, holes in the middle of the specimen to steel caused failure of the epoxy coating. Photo PX-D-68016

Figure 45. Specimen No. 73—Epoxy.

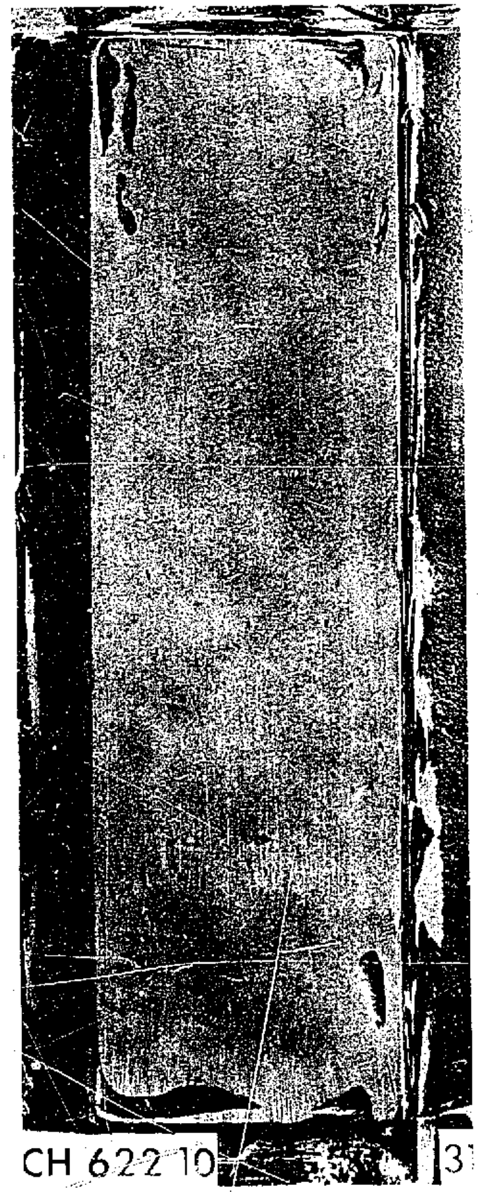


A. Epoxy on concrete substrate before test. Photo PX-D-68017

B. After 15 hours, a long damaged area to concrete developed down the middle of the specimen causing failure of the coating. Photo PX-D-68018

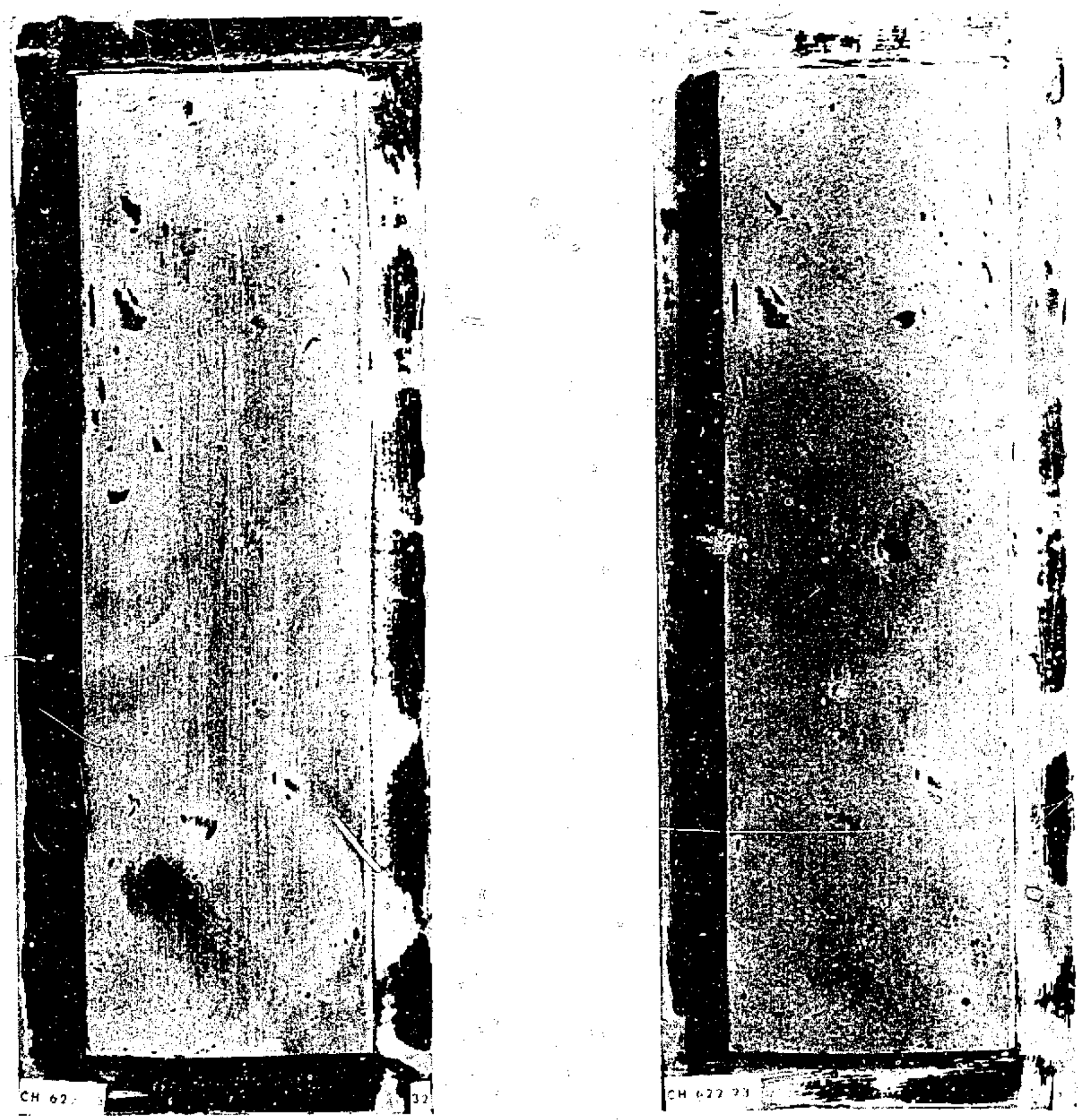
Figure 46. Specimen No. 74—Epoxy.

A. Steel-filled epoxy polyamide before test, surface ground, but a few holes remained. Photo PX-D-45758



B. After 117 hours testing, holes nearly to base specimen had caused partial failure. Photo PX-D-45759

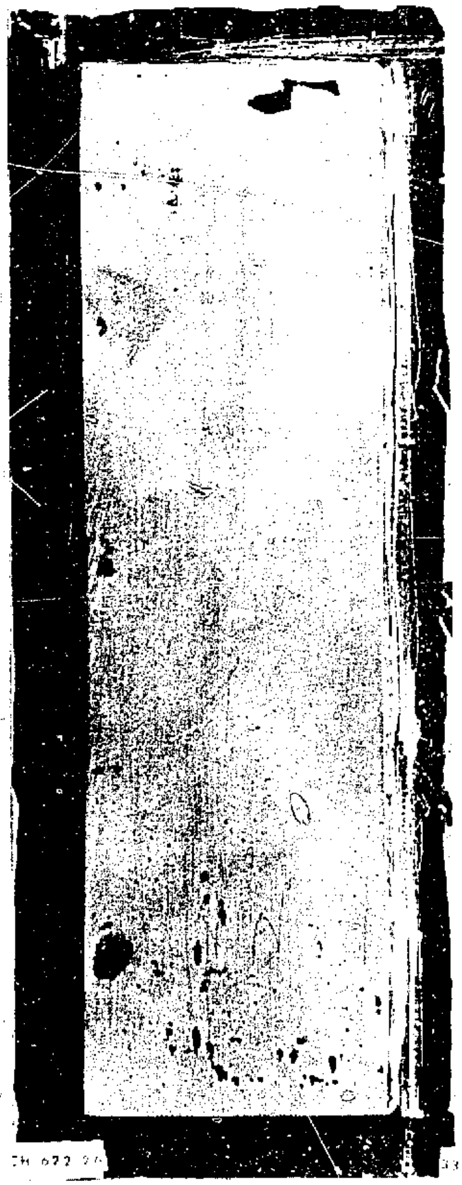
Figure 47. Specimen No. 31—Steel-filled epoxy polyamide.



A. A steel-filled epoxy polyamide before test. Photo PX-D-68019

B. After 21 hours of testing, there was evidence of partial failure from the holes enlarging. Photo PX-D-68020

Figure 48. Specimen No. 32—Steel-filled epoxy polyamide.



A. A steel-filled epoxy polyamide before exposure. Photo PX-D-68021

B. The holes continued to increase in size and number causing partial failure after 21 hours. Photo PX-D-68022

Figure 49. Specimen No. 33—Steel-filled epoxy polyamide.

A. An epoxy polyamide before test. Photo PX-D-68023

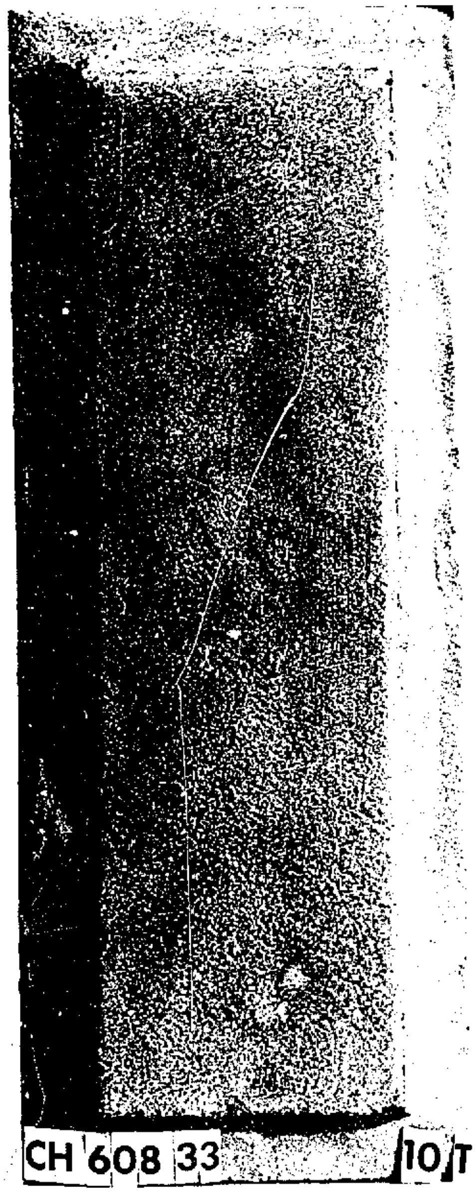
B. After 7 hours the coating had failed from severe damage. Photo PX-D-68024

Figure 50. Specimen No. 34-1—Steel-filled epoxy polyamide.

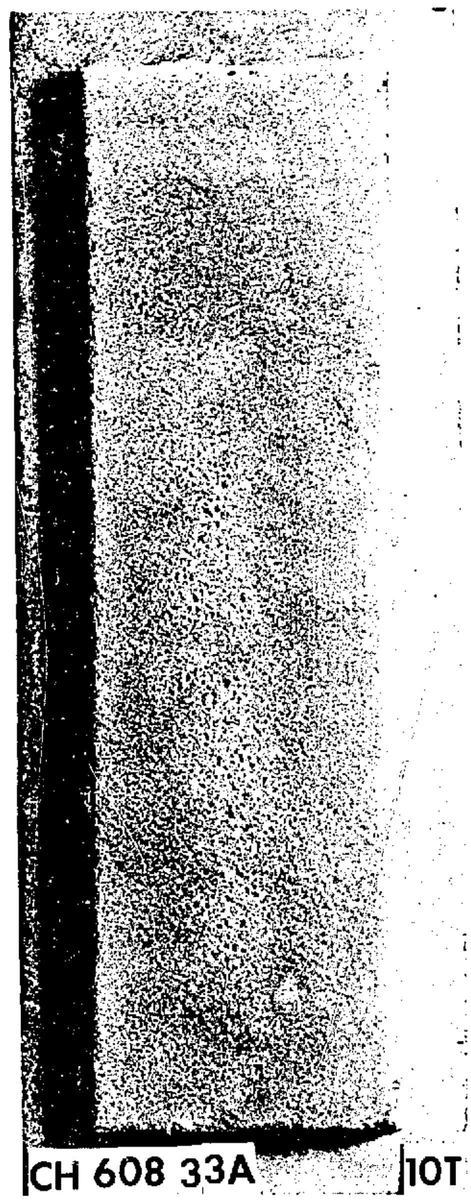
A. Sand-filled epoxy polysulfide before test. Photo PX-D-68025

B. Sand-filled epoxy polysulfide after 7 hours test. Photo PX-D-68026

Figure 51. Specimen No. 42T—Sand-filled epoxy polysulfide.



A. A sand-filled epoxy before exposure. Photo PX-D-25530



B. The epoxy developed many holes in the center of the specimen after 7 hours testing, and failed in 21 hours. Photo PX-D-68027

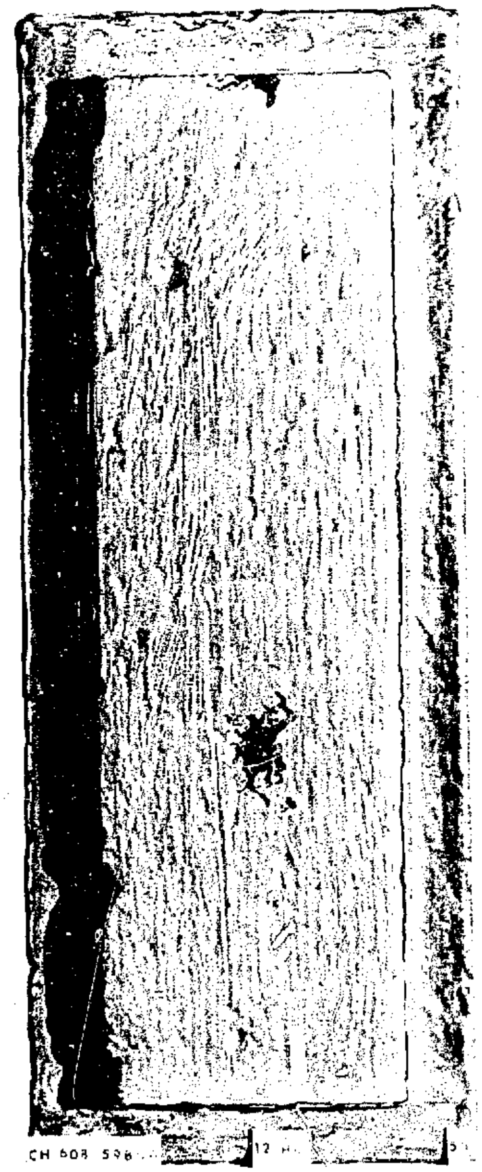
Figure 52. Specimen No. 10T—Sand-filled epoxy.

A. A polysulfide before exposure. Photo PX-D-45754

B. After 224 hours, the polysulfide rubber showed little wear. Photo PX-D-45755

Figure 53. Specimen No. 43—Polysulfide.

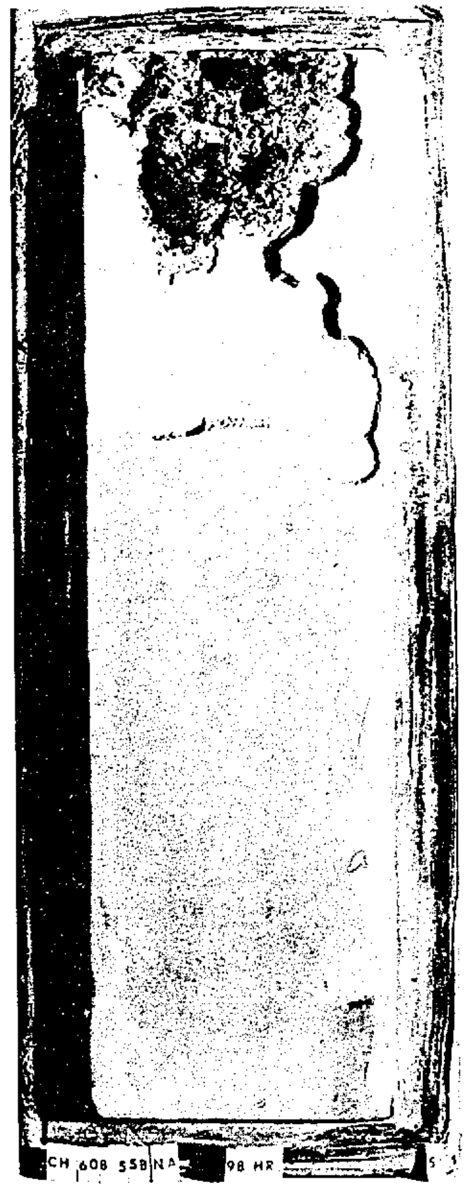
A. Polysulfide coating before test. Photo PX-D-68028



B. After 12 hours, two holes have developed to concrete causing failure of coating. Photo PX-D-68029

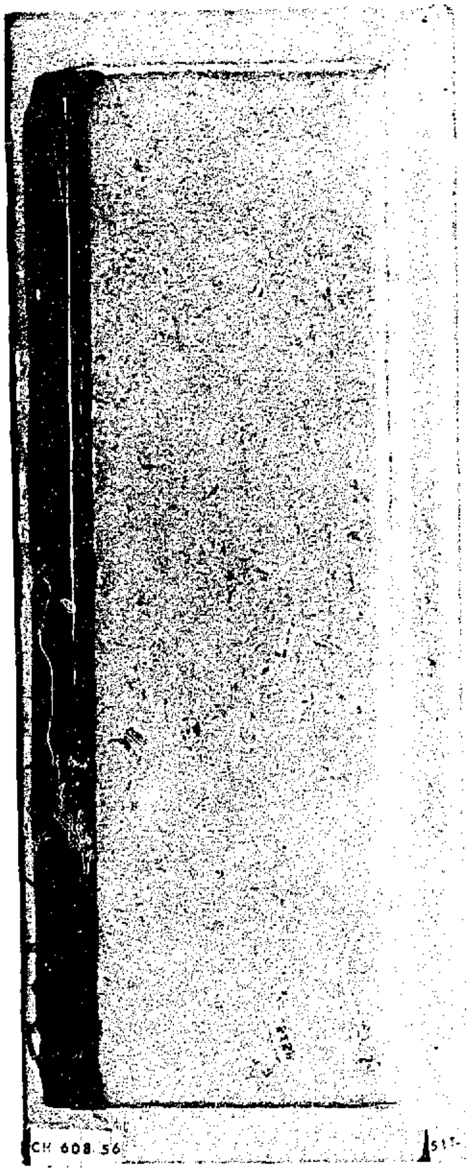
Figure 54. Specimen No. 50—Polysulfide.

A. A polyurethane on concrete before test. Photo PX-D-68030



B. After 98 hours, the rubber coating continued to peel from top end, failure of the rubber coating. Photo PX-D-68031

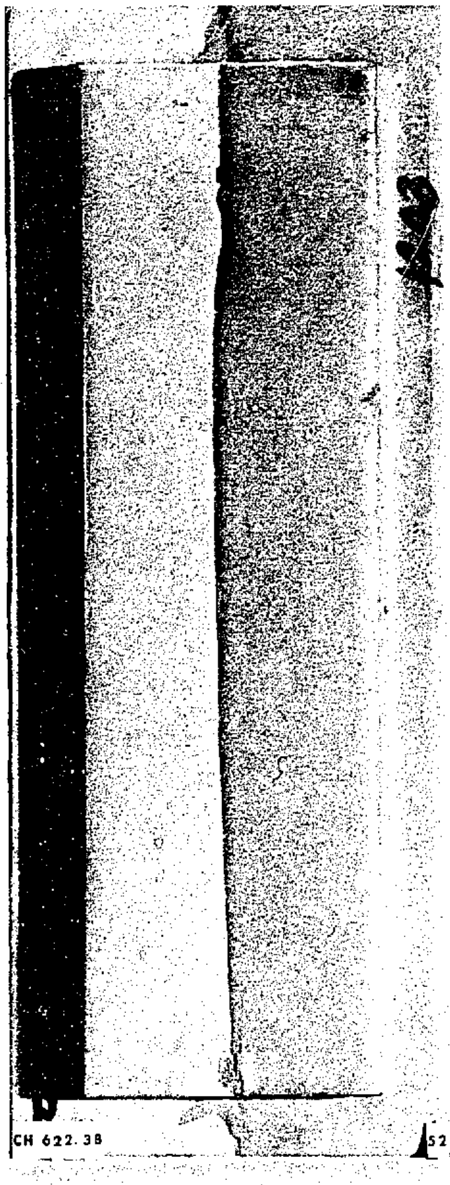
Figure 55. Specimen No. 51—Polyurethane.



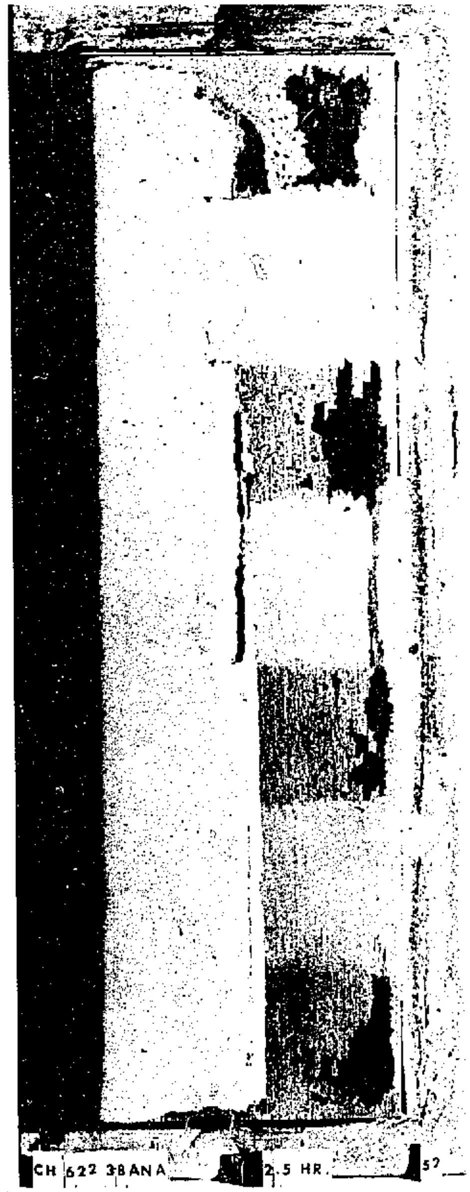
A. A polyurethane before test. Photo PX-D-68032

B. After 11 hours, large holes developed to base concrete causing failure of the rubber coating. Photo PX-D-68033

Figure 56. Specimen No. 51T—Polyurethane.



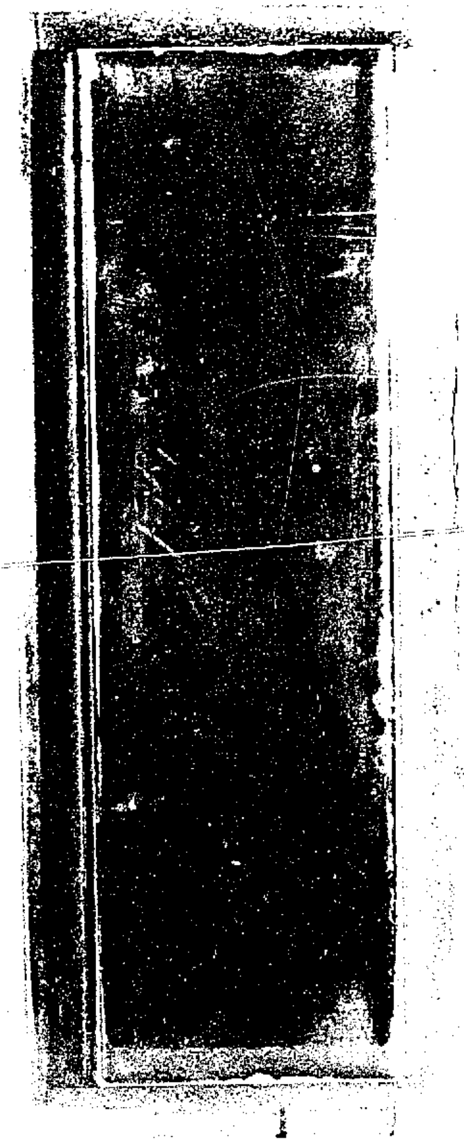
A. Two rubber coatings, one on the left half and the other on the right half before test. Photo PX-D-68034



B. The rubber coating on the right completely failed in 2.5 hours. Photo PX-D-68035

Figure 57. Specimen No. 52—Polyurethane.

A. Polyurethane before test. Photo PX-D-68036



B. After 650 hours testing, deterioration to the top and bottom edges had occurred. One damaged corner from storage before restarting of specimen which had been testing 250 hours. Photo PX-D-68037

Figure 58. Specimen No. 60—Polyurethane.

A. After 1,200 hours, the damaged edges area increased in size. Photo PX-D-68038

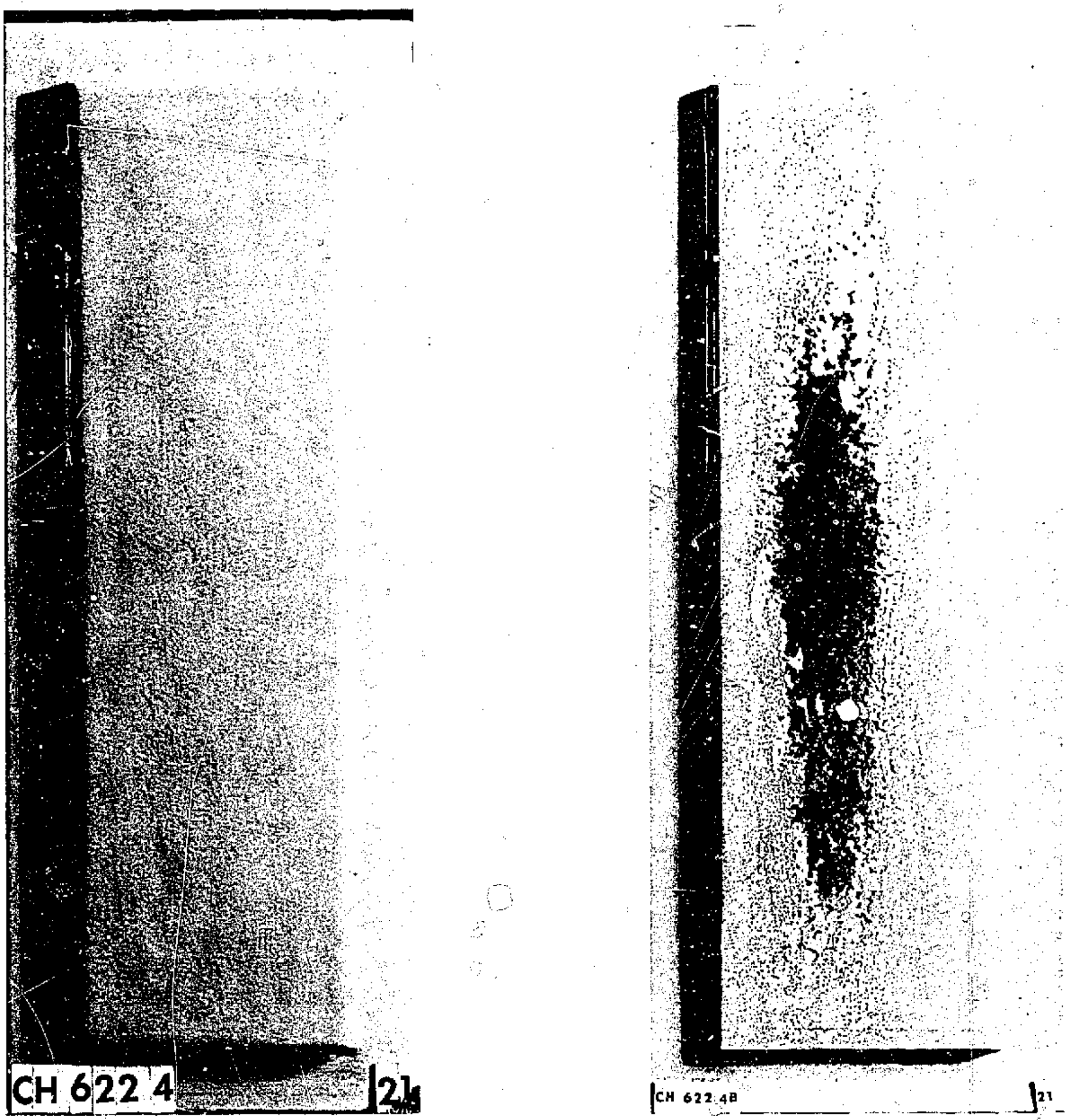
B. After 1,738 hours, damage in the upper center of the coating to the base steel specimen occurred and test was stopped. Photo PX-D-68039

Figure 59. Specimen No. 60—Polyurethane.

A. Epoxy modified phenolic before test. Photo PX-D-68040

B. After 7 hours, the epoxy modified phenolic failed. Photo PX-D-68041

Figure 60. Specimen No. 4—Epoxy modified phenolic.



A. Epoxy modified phenolic before exposure. Photo PX-D-68042

B. The epoxy modified phenolic had peeled from the steel and failed after 14 hours testing. Photo PX-D-68043

Figure 61. Specimen No. 21—Epoxy modified phenolic.

A. Coal-tar epoxy before exposure. Photo PX-D-32116

B. The coal-tar epoxy was damaged to base specimen and failure after 14 hours testing. Photo PX-D-32117

Figure 62. Specimen No. 29—Coal-tar epoxy.

Figure 63. Specimen No. 47–Vinyl (VR-6 with aluminum seal coat) before test. Photo PX-D-68045

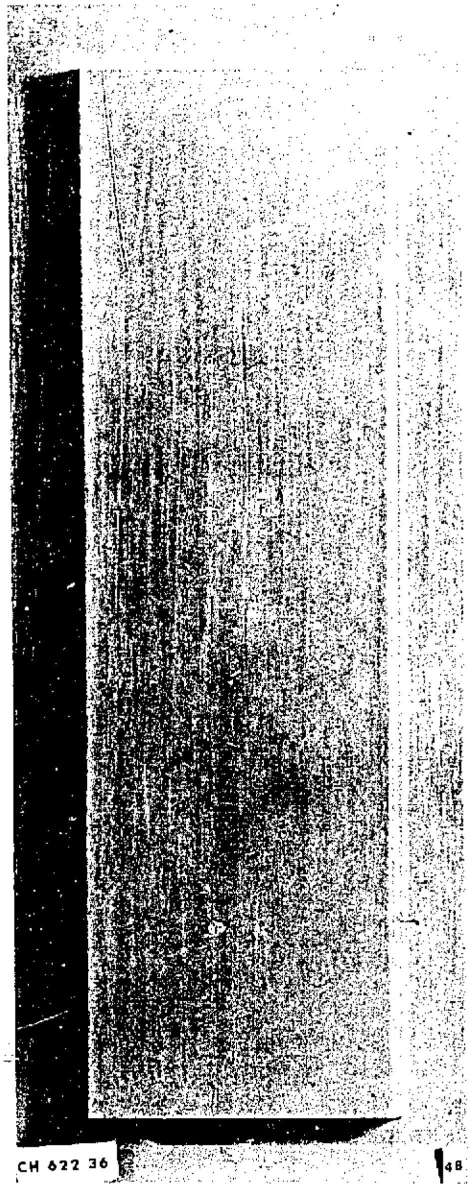
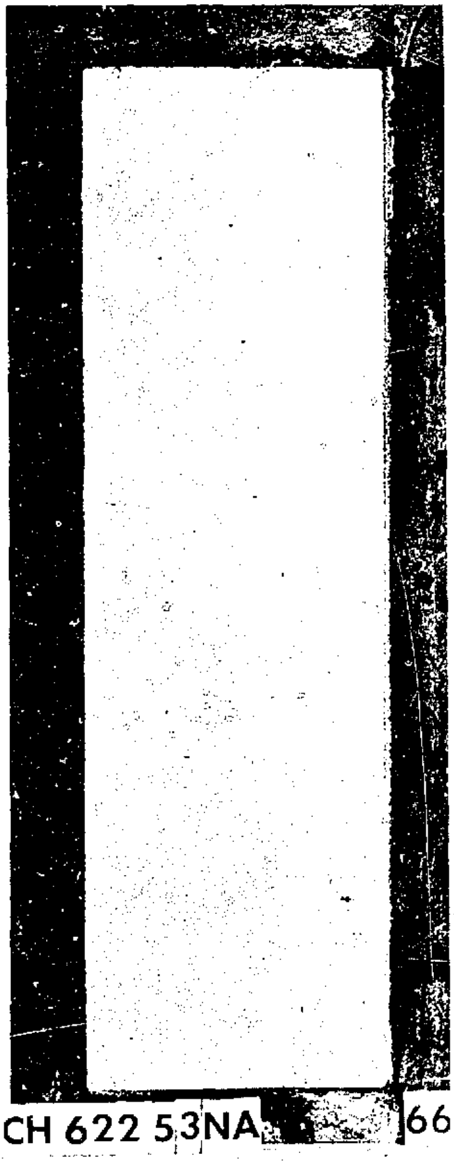
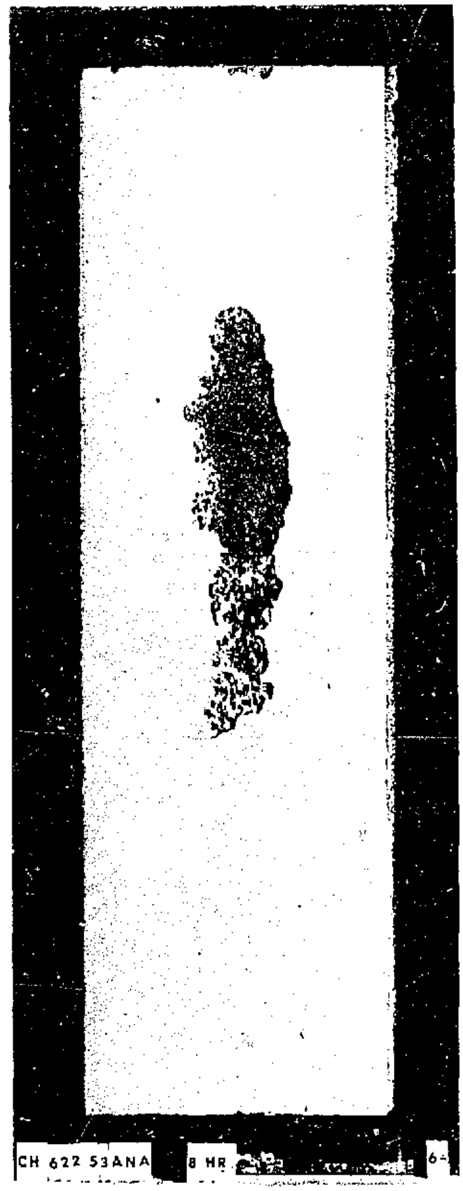


Figure 64. Specimen No. 48—Vinyl coating (VR-6 with a gray seal coat) before exposure. Photo PX-D-68046

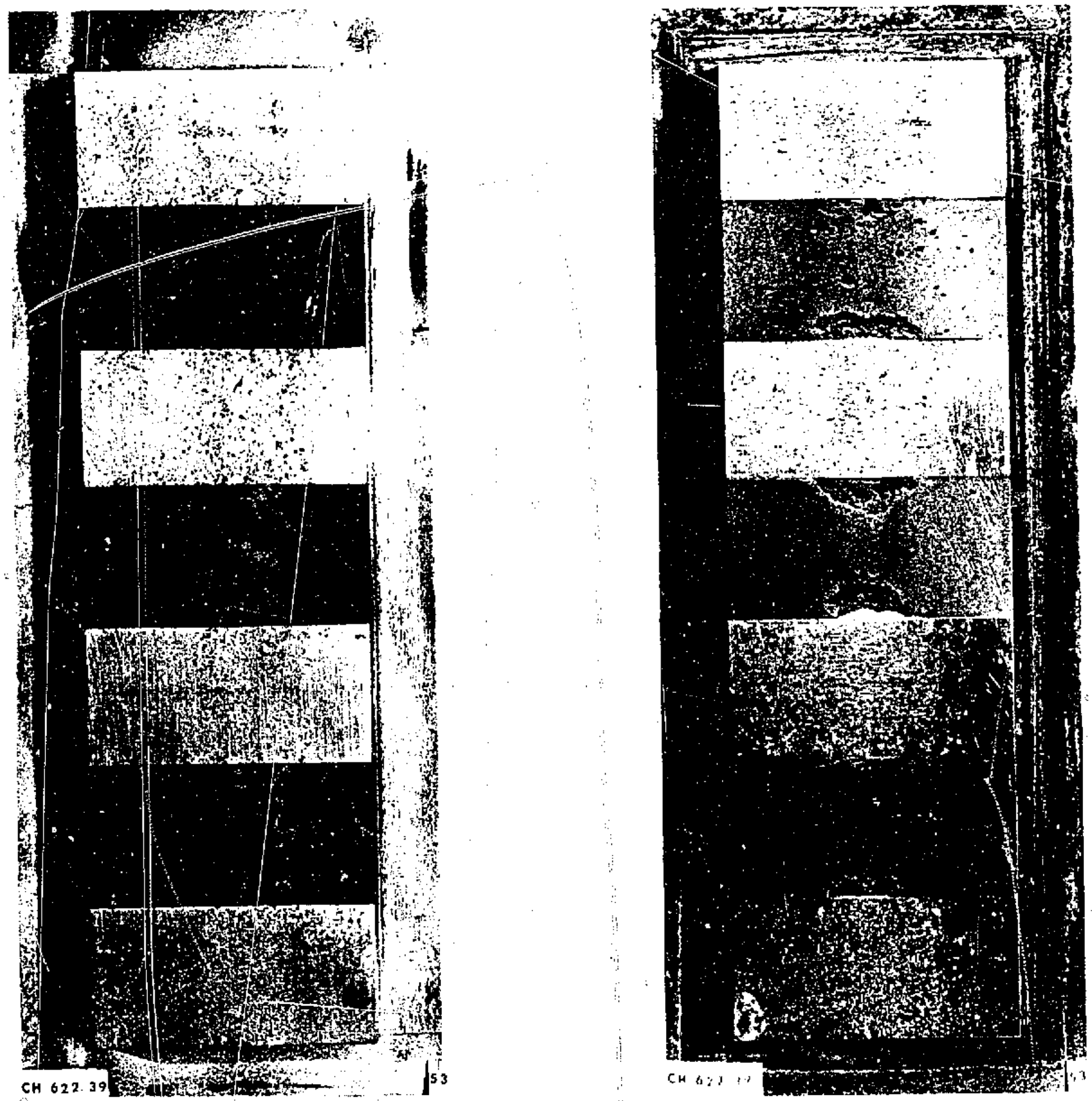


A. Fused vinyl before exposure. Photo PX-D-68047



B. After 8 hours, a hole 4 by 1 inches to steel was evident through the fused vinyl coating causing failure. Photo PX-D-68048

Figure 65. Specimen No. 66—Vinyl.



A. Plastic steel in cut areas before test. Photo PX-D-68049

B. After 119 hours, holes became large and deep causing failure of the plastic steel. Photo PX-D-68050

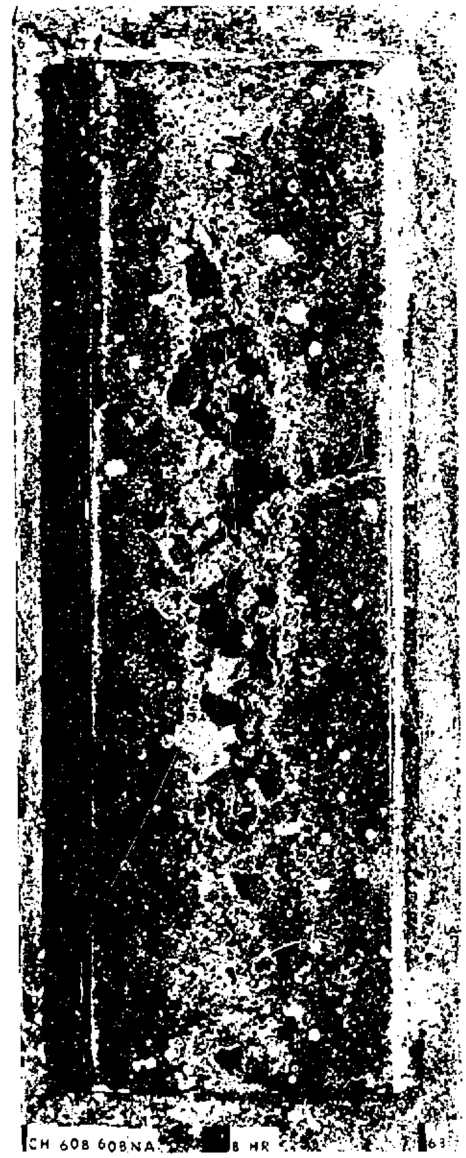
Figure 66. Specimen No. 53—Steel-filled epoxy.

A. Polyester filled with chopped fiberglass before test. Photo PX-D-68051

B. After 38.5 hours, the holes cut through to the steel causing failure. Photo PX-D-68052

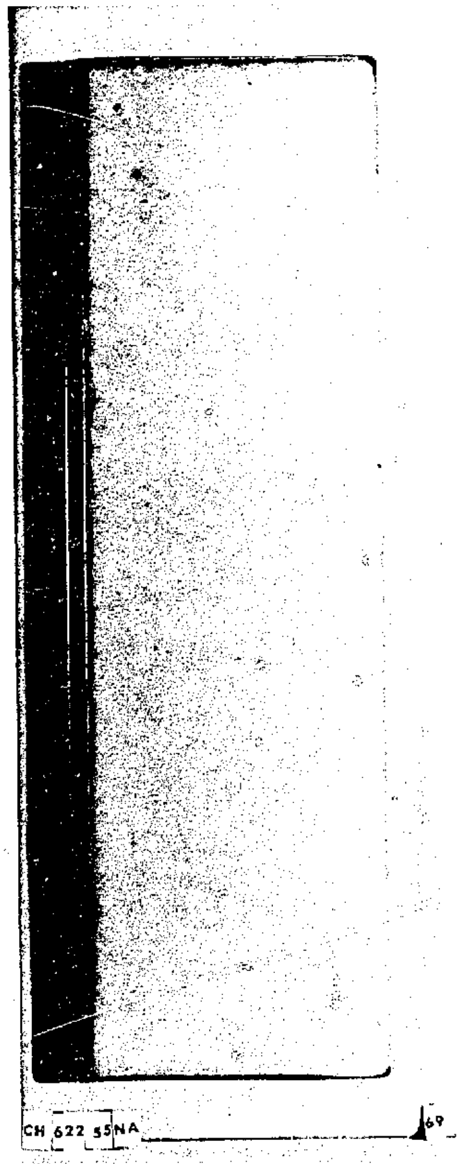
Figure 67. Specimen No. 54—Polyester filled with chopped fiberglass.

A. Epoxy polyurethane varnish on concrete substrate, before exposure. Photo PX-D-68053

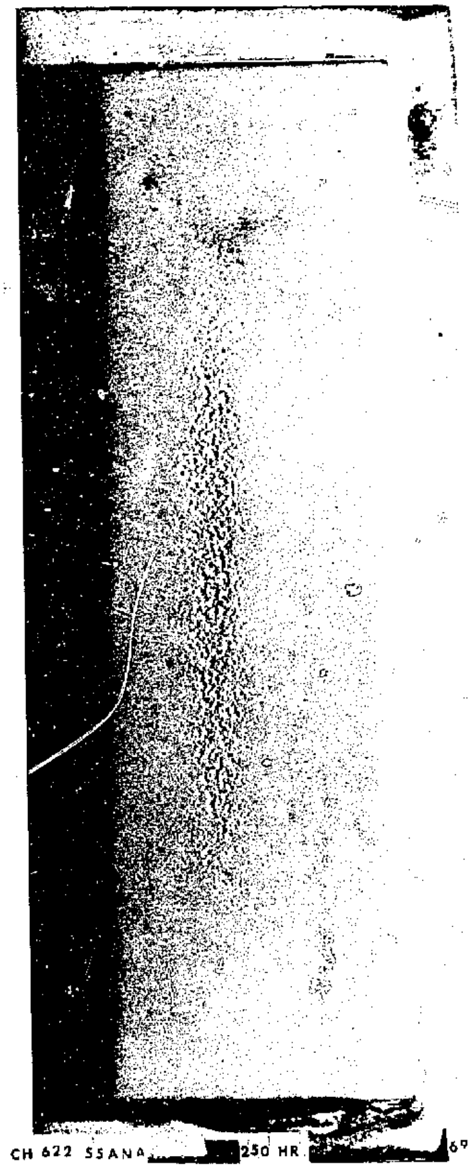


B. After 8 hours testing, the polyurethane varnish was pitted away in the middle of the specimen causing failure. Photo PX-D-68054

Figure 68. Specimen No. 68—Epoxy polyurethane varnish.

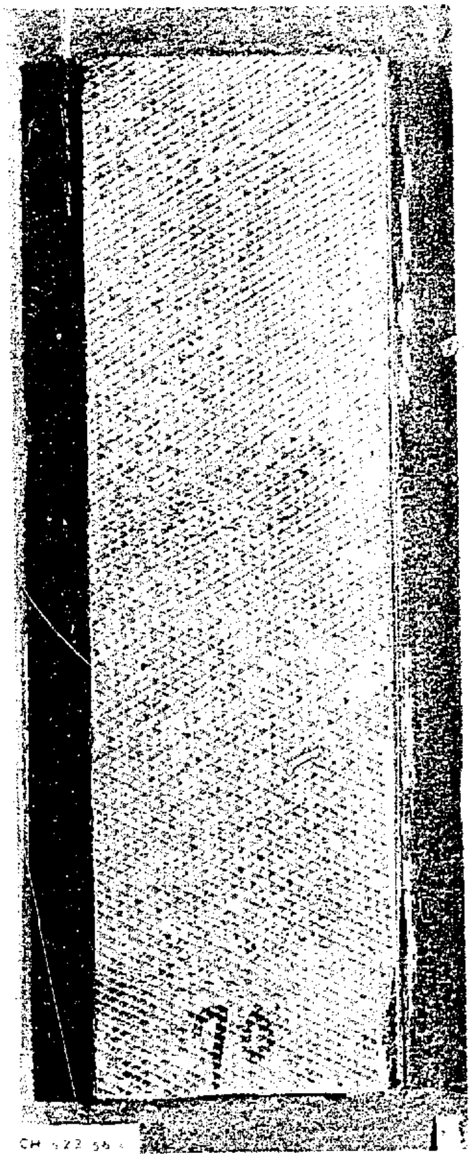


A. Sprayable neoprene-urethane coating on steel before test. Photo PX-D-68055

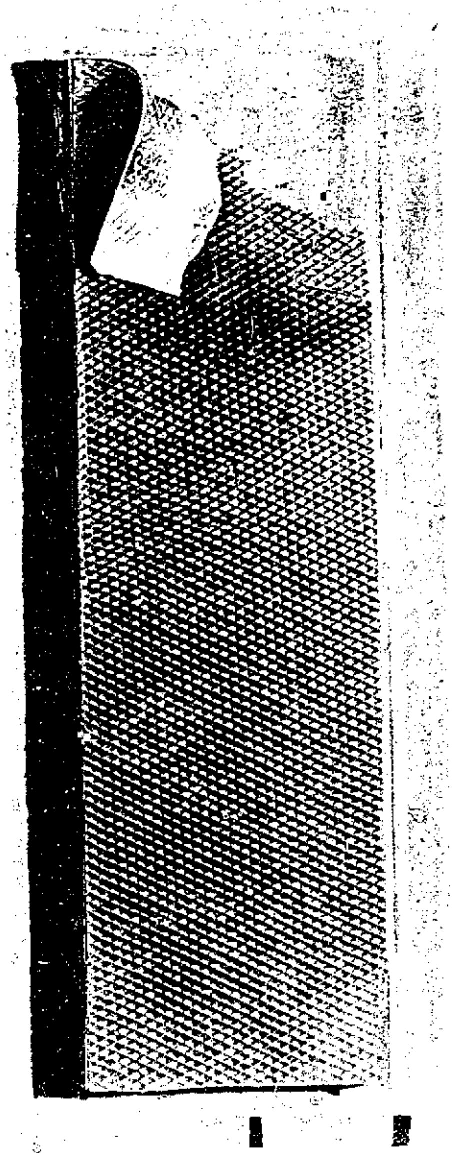


B. After 250 hours, the coating developed some pinpoint holes in the surface. Photo PX-D-68056

Figure 69. Specimen No. 69—Neoprene-urethane rubber.

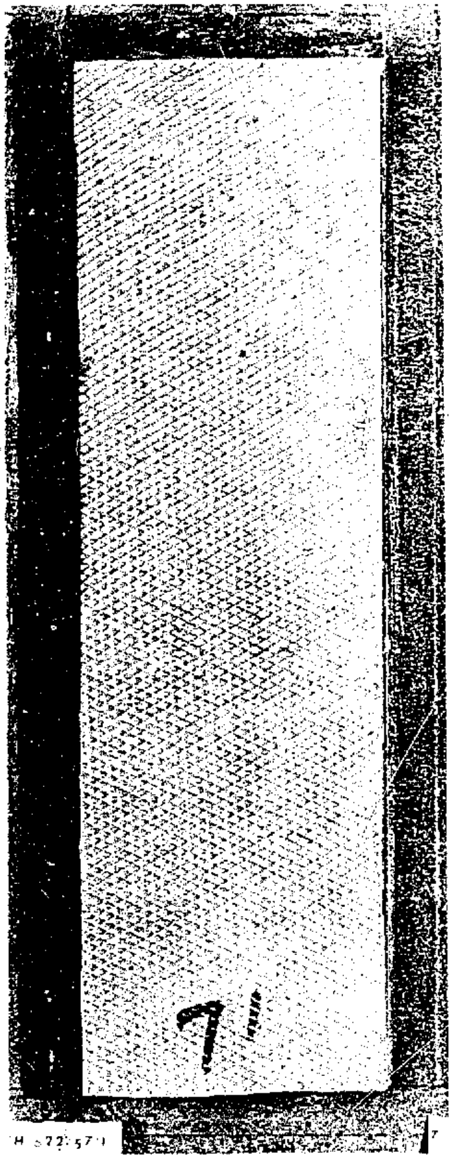


A. Tan gum rubber 1/16 inch thick on steel substrate before test. Photo PX-D-68057



B. After 7 hours of testing, there was a bond failure between adhesive steel and rubber. Photo PX-D-68058

Figure 70. Specimen No. 70—Gum rubber.

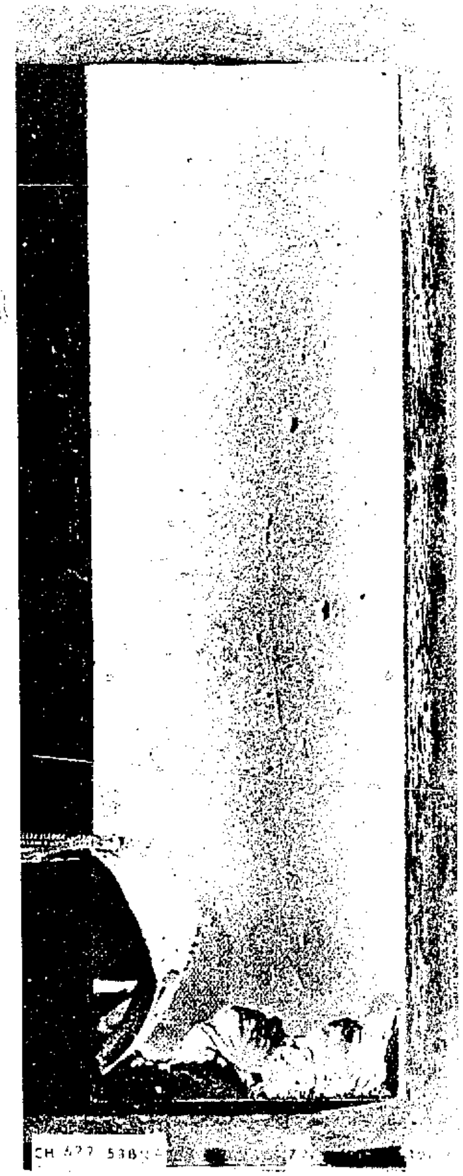


A. Tan gum rubber one-eighth inch thick on steel substrate before test. Photo PX-D-68059

B. After 11 hours of testing bond failure between steel, adhesive and rubber occurred. Photo PX-D-68060

Figure 71. Specimen No. 71—Gum rubber.

A. Tan gum rubber one-fourth inch thick on steel substrate before test. Photo PX-D-68061



B. After 126 hours of testing, bond, delimination and peel caused the failure of this gum rubber. Flap shown raised and clamped to illustrate disbond and tearing. Photo PX-D-68062

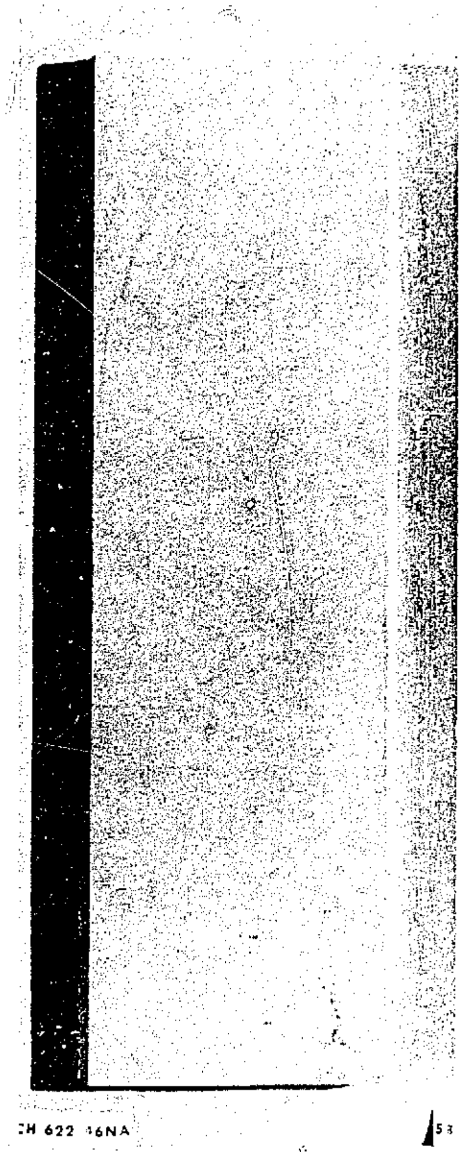
Figure -2. Specimen No. 72—Gum rubber.

A. Coating over stainless weld patches before test. Photo PX-D-68063

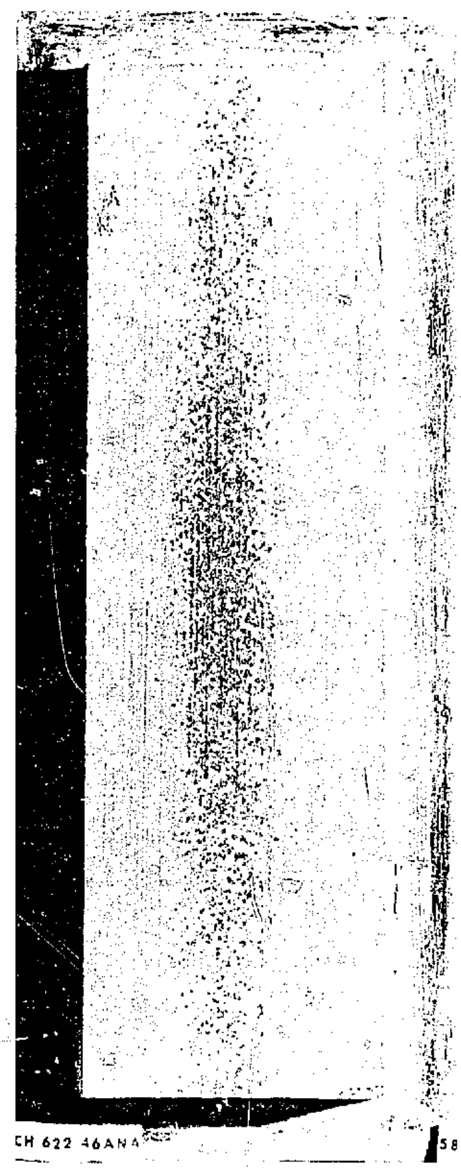
B. After 6 hours, the holes became one long eroded area down the middle of the specimen, 4 by 1 inches. Photo PX-D-68064

Figure 73. Specimen No. 67—Chlorinated polyether.

GPO 832-874



A. Zinc before test. Photo PX-D-68065



B. After 2 hours, damaged through zinc to steel causing failure. Photo PX-D-68066

Figure 74. Specimen No. 58—Zinc.

7-1750 (1-70)
Bureau of Reclamation

CONVERSION FACTORS--BRITISH TO METRIC UNITS OF MEASUREMENT

The following conversion factors adopted by the Bureau of Reclamation are those published by the American Society for Testing and Materials (ASTM Metric Practice Guide, E 380-68) except that additional factors (*) commonly used in the Bureau have been added. Further discussion of definitions of quantities and units is given in the ASTM Metric Practice Guide.

The metric units and conversion factors adopted by the ASTM are based on the "International System of Units" (designated SI for Systeme International d'Unites), fixed by the International Committee for Weights and Measures; this system is also known as the Giorgi or MKSA (meter-kilogram (mass)-second-ampere) system. This system has been adopted by the International Organization for Standardization in ISO Recommendation R-31.

The metric technical unit of force is the kilogram-force; this is the force which, when applied to a body having a mass of 1 kg, gives it an acceleration of 9.80665 m/sec/sec, the standard acceleration of free fall toward the earth's center for sea level at 45 deg latitude. The metric unit of force in SI units is the newton (N), which is defined as that force which, when applied to a body having a mass of 1 kg, gives it an acceleration of 1 m/sec/sec. These units must be distinguished from the (inconstant) local weight of a body having a mass of 1 kg; that is, the weight of a body is that force with which a body is attracted to the earth and is equal to the mass of a body multiplied by the acceleration due to gravity. However, because it is general practice to use "pound" rather than the technically correct term "pound-force," the term "kilogram" (or derived mass unit) has been used in this guide instead of "kilogram-force" in expressing the conversion factors for forces. The newton unit of force will find increasing use, and is essential in SI units.

Where approximate or nominal English units are used to express a value or range of values, the converted metric units in parentheses are also approximate or nominal. Where precise English units are used, the converted metric units are expressed as equally significant values.

Table I

QUANTITIES AND UNITS OF SPACE

Multiply	By	To obtain
LENGTH		
Mil	25.4 (exactly)	Micron
Inches	25.4 (exactly)	Millimeters
	2.54 (exactly)*	Centimeters
Feet	30.48 (exactly)	Centimeters
	0.3048 (exactly)*	Meters
	0.0003048 (exactly)*	Kilometers
Yards	0.9144 (exactly)	Meters
Miles (statute)	1,609.344 (exactly)*	Meters
	1.609344 (exactly)	Kilometers
AREA		
Square inches	6.4516 (exactly)	Square centimeters
Square feet	929.03*	Square centimeters
	0.092903	Square meters
Square yards	0.836127	Square meters
Acres	0.40469*	Hectares
	4,046.9*	Square meters
	0.0040469*	Square kilometers
Square miles	2.58999	Square kilometers
VOLUME		
Cubic inches	16.3871	Cubic centimeters
Cubic feet	0.0283168	Cubic meters
Cubic yards	0.764555	Cubic meters
CAPACITY		
Fluid ounces (U.S.)	29.5737	Cubic centimeters
	29.5729	Milliliters
Liquid pints (U.S.)	0.473179	Cubic decimeters
	0.473166	Liters
Quarts (U.S.)	946.358*	Cubic centimeters
	0.946331*	Liters
Gallons (U.S.)	3,785.43*	Cubic centimeters
	3.78543	Cubic decimeters
	3.78533	Liters
	0.00378543*	Cubic meters
Gallons (U.K.)	4.54609	Cubic decimeters
	4.54596	Liters
Cubic feet	28.3160	Liters
Cubic yards	764.55*	Liters
Acre-feet	1,233.5*	Cubic meters
	1,233,500*	Liters

REC-OCE-70-51

EVALUATION OF MATERIALS FOR CAVITATION RESISTANCE

A Progress Report

F. E. Causey
Engineering and Research Center
Bureau of Reclamation

October 1970

Table II

QUANTITIES AND UNITS OF MECHANICS

Multiply	By	To obtain
MASS		
Grains (1/7,000 lb)	64.79891 (exactly)	Milligrams
Troy ounces (480 grains)	31.1035	Grams
Ounces (avdp)	28.3495	Grams
Pounds (avdp)	0.45359237 (exactly)	Kilograms
Short tons (2,000 lb)	907.185	Kilograms
	0.907185	Metric tons
Long tons (2,240 lb)	1,016.05	Kilograms
FORCE/AREA		
Pounds per square inch	0.070307	Kilograms per square centimeter
	0.689476	Newtons per square centimeter
Pounds per square foot	4.88243	Kilograms per square meter
	47.8803	Newtons per square meter
MASS/VOLUME (DENSITY)		
Ounces per cubic inch	1.72999	Grams per cubic centimeter
Pounds per cubic foot	16.0185	Kilograms per cubic meter
	0.0160185	Grams per cubic centimeter
Tons (long) per cubic yard	[illegible].329[illegible]4	Grams per cubic centimeter
MASS/CAPACITY		
Ounces per gallon (U.S.)	7.4893	Grams per liter
Ounces per gallon (U.K.)	6.2362	Grams per liter
Pounds per gallon (U.S.)	119.829	Grams per liter
Pounds per gallon (U.K.)	99.779	Grams per liter
BENDING MOMENT OR TORQUE		
Inch-pounds	0.011521	Meter-kilograms
	1.12985 x 10^5	Centimeter-dynes
Foot-pounds	0.138255	Meter-kilograms
	1.35582 x 10^7	Centimeter-dynes
Foot-pounds per inch	5.4431	Centimeter-kilograms per centimeter
Ounce-inches	72.008	Gram-centimeters
VELOCITY		
Feet per second	30.48 (exactly)	Centimeters per second
	0.3048 (exactly)*	Meters per second
Feet per year	0.965873 x 10^{-6}*	Centimeters per second
Miles per hour	1.609344 (exactly)	Kilometers per hour
	0.44704 (exactly)	Meters per second
ACCELERATION*		
Feet per second^2	0.3048*	Meters per second^2
FLOW		
Cubic feet per second (second-feet)	0.028317*	Cubic meters per second
Cubic feet per minute	0.4719	Liters per second
Gallons (U.S.) per minute	0.06309	Liters per second
FORCE*		
Pounds	0.453592*	Kilograms
	4.4482*	Newtons
	4.4482 x 10^{-5}*	Dynes
WORK AND ENERGY*		
British thermal units (Btu)	0.252*	Kilogram calories
	1,055.06	Joules
Btu per pound	2.326 (exactly)	Joules per gram
Foot-pounds	1.35582*	Joules
POWER		
Horsepower	745.700	Watts
Btu per hour	0.293071	Watts
Foot-pounds per second	1.35582	Watts
HEAT TRANSFER		
Btu in./hr ft^2 deg F (k, thermal conductivity)	1.442	Milliwatts/cm deg C
	0.1240	Kg cal/hr m deg C
Btu ft/hr ft^2 deg F	1.4880*	Kg cal m/hr m^2 deg C
Btu/hr ft^2 deg F (C, thermal conductance)	0.568	Milliwatts/cm^2 deg C
	4.882	Kg cal/hr m^2 deg C
Deg F hr ft^2/Btu (R, thermal resistance)	1.761	Deg C cm^2/milliwatt
Btu/lb deg F (c, heat capacity)	4.1868	J/g deg C
Btu/lb deg F	1.000*	Cal/gram deg C
Ft^2/hr (thermal diffusivity)	0.2581	Cm^2/sec
	0.09290*	M^2/hr
WATER VAPOR TRANSMISSION		
Grains/hr ft^2 (water vapor transmission)	16.7	Grams/24 hr m^2
Perms (permeance)	0.659	Metric perms
Perm-inches (permeability)	1.67	Metric perm-centimeters

Table III

OTHER QUANTITIES AND UNITS

Multiply	By	To obtain
Cubic feet per square foot per day (seepage)	304.8*	Liters per square meter per day
Pound-seconds per square foot (viscosity)	4.8824*	Kilogram second per square meter
Square feet per second (viscosity)	0.092903*	Square meters per second
Fahrenheit degrees (change)*	5/9 exactly	Celsius or Kelvin degrees (change)*
Volts per mil	0.03937	Kilovolts per millimeter
Lumens per square foot (foot-candles)	10.764	Lumens per square meter
Ohm-circular mils per foot	0.001662	Ohm-square millimeters per meter
Millicuries per cubic foot	35.3147*	Millicuries per cubic meter
Milliamps per square foot	10.7639*	Milliamps per square meter
Gallons per square yard	4.527219*	Liters per square meter
Pounds per inch	0.17858*	Kilograms per centimeter

ABSTRACT

Cavitation testing of potential protective coating materials that can be field-applied to steel and concrete surfaces is described. Performance of 71 coated specimens representing 21 classes of materials was evaluated in a Venturi-type cavitation apparatus which produces a mild to moderate cavitation environment. Only a few materials showed good cavitation resistance. A particular neoprene showed the best cavitation resistance of the materials tested. Another neoprene, a neoprene-urethane blend, a polyurethane, and a polysulfide showed satisfactory cavitation resistance in mild cavitation environments. Many epoxies, modified phenolics, epoxy polysulfides, epoxy polyamides, polysulfides, and other similar materials proved to have questionable or little cavitation resistance. Sharp edges and rough surfaces decreased the cavitation resistance of a test material.

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REC-OCE-70-51
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Bur Reclam Rep REC-OCE-70-51, Div Gen Res, Oct 1970. Bureau of Reclamation, Denver, 88 p, 71 fig, 1 tab, 1 ref, append

DESCRIPTORS—/ concretes/ steel/ rubber/ mortar/ plastics/ epoxy resins/ coatings/ water/ exposure/ laboratory tests/ adhesion/ performance/ cavitation/ *protective coatings/ materials testing/ evaluation
IDENTIFIERS—/ *cavitation resistance/ Venturi-type apparatus/ neoprene/ polyamides/ polysulfides/ vinyl resins/ phenolic coatings

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