

12 December 1941

NRL Report No. P-1820

NAVY DEPARTMENT

Report

on

The Evaluation of Six Experimental
Anti-Fouling Coatings

Submitted by

The Goodyear Tire and Rubber Company

NAVAL RESEARCH LABORATORY
ANACOSTIA STATION
WASHINGTON, D. C.

Number of Pages: Text - 8 Plates - 17

Authorization: Bureau of Aeronautics Project Order 32-40 of 29 June 1939.

Date of Test: January 1941 to July 1941.

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AUTHORIZATION FOR TEST

1. This problem was authorized by Bureau of Aeronautics Project Order 32-40 of 29 June 1939, which provided for the evaluation of anti-fouling materials developed by cooperating laboratories along with experimental products originating in this Laboratory.

OBJECT OF TEST

2. The object of this test is to determine the value of six experimental anti-fouling paints for the protection of flying boat hull bottoms. The six samples were submitted by the Goodyear Tire and Rubber Company of Akron, Ohio.

ABSTRACT OF TEST

3. The general physical properties of these materials were studied as well as their anti-fouling qualities. The usual tests for weathering (durability), resistance to abrasion, and their adhesion and toughness were made. To evaluate their anti-fouling properties, panels were prepared in triplicate and sent to Miami, Guantanamo Bay, and San Juan for submarine exposure in media conducive to the rapid growth of various types of marine life.

Conclusions

(a) The general anti-fouling properties of the subject materials do not compare favorably with standard materials currently in use.

(b) The weathering characteristics of the test materials are inferior to standard products now in use for the protection of flying boat hull bottoms.

Recommendations

(a) Since the subject materials under test were purely experimental materials, and since they show little or no promise of possessing advantages superior to a standard product, it is recommended that they be excluded from any experimental service tests contemplated by the Bureau.

MATERIALS UNDER TEST

4. The materials under test consisted of six experimental anti-fouling coatings prepared by the Goodyear Tire and Rubber Company of Akron, Ohio. Wet samples of the paints were not submitted to this Laboratory, but anodized aluminum panels were shipped to the Goodyear laboratory where they were coated with the test paints. The panels were subsequently returned to the Naval Research Laboratory for their final evaluation.

5. In order to thoroughly evaluate both the anti-fouling and physical properties of these coatings, a total of six panels was prepared for each separate formulation. Each group of six consisted of the following:

3 panels size 7 x 12"
1 panel size 1-1/2 x 6"
1 panel size 4 x 4"
1 panel size 4 x 12"

The panels of each set were numbered identically and the sets carried the serial numbers 70 to 75, inclusive. Since all exposure panels are sent out to the exposure stations in groups of twenty, this series was included in a larger group which carried as a control a panel finished in the standard Naval aircraft system of one coat of P-27b-2 primer followed by two top coats of aluminized Silosyn. This control panel was assigned the serial number 81.

6. The unfinished panels were prepared in this Laboratory. They were cut from 24ST aluminum alloy sheet .064" in thickness, after which they were anodized by the standard chromic acid process before shipment to the Goodyear laboratory. The entire paint system on each panel was produced and applied by the manufacturer, after which the finished panels were returned for test.

METHOD OF TEST

(a) Submarine Exposure

7. The Bureau arranged with the Naval Air Stations at San Juan, Puerto Rico, and at Guantanamo Bay, Cuba, to expose panels and to examine them and submit reports on their condition at the end of each month. The Laboratory made a contract with the Sub-Tropical Testing Service at Miami, Florida, to conduct similar tests at their station. Triplicate panels of each material studied were prepared as described above, and one panel of the same material was exposed at each of these three stations. The monthly reports from each station were returned to the Naval Research Laboratory (those from the Naval Air Stations by way of the Bureau of Aeronautics) where they were assembled and correlated with each other and with other exposure data pertinent to the value of the paint.

8. The Florida test station of the Sub-Tropical Testing Service is located about 15 miles south of Miami in a small inlet at Tahiti Beach. Their racks are extended several hundred yards into the Bay and the panels

are suspended from these racks to a depth of about 4 feet below low tide. They are allowed to swing freely from wire ropes so that no one side receives different exposure conditions from the other. The length of their suspending chain does not permit them to strike the sides of beams supporting the racks. The panels are insulated from their supports by means of rubber gaskets.

9. The racks at Guantanamo Bay are placed off shore sufficiently to insure that the panels remain submerged even at low tide. The panels are so situated in the racks that one side always faces seaward with the other side facing directly toward the shore. This does not permit a swaying of the panel and there is invariably a difference between the two faces of the panels exposed at this station.

10. At San Juan an entire series of panels is fastened to a large metal frame which is submerged in a horizontal position beneath the surface. Here too the panels are rigidly fixed, and there is always a wide difference between the top and bottom sides. Of special interest is the fact that specimens exposed at San Juan foul much more rapidly than duplicate panels at Miami and Guantanamo.

11. In recording and reporting the changes occurring on the surface of these paint films, the Service at Miami employs a standard form in which the extent of the change in amount of marine growth is indicated. The Air Stations make photographs of the panels which are submitted along with a report consisting of an extremely brief comment as to the condition of the films and panels themselves. The photographs are extremely valuable in judging the nature and extent of the fouling.

(b) Abrasion Resistance.

12. For determining the abrasion resistance of the experimental formulations, an abrasion meter of a type described by Martin⁽¹⁾ was used. This apparatus was recently described in detail in Naval Research Laboratory Report #P-1740 on "A Study of Organic Coatings for the Camouflage of Fleet Aircraft," dated 22 May 1941. The films of experimental materials prepared on the 4" x 4" aluminum alloy panels were used for this test. The amount of abrasive was measured which was required to abrade through the film to the metal when the abrasive was allowed to strike the surface of the coated panel at an angle of 45° and under a carefully controlled pressure. The thickness of the film was measured with a micrometer and the specific abrasion resistance was reported in grams per mil as the ratio of the weight of abrasive to the thickness of the film. A minimum of four measurements was made on each panel, all of which checked within designated limits.

(c) Wet Abrasion Resistance.

13. The abrasion resistance of the same material after the film had been soaked in water for 24 hours was measured in a similar manner. The panels containing the films were placed in a pan of distilled water where they were allowed to remain for 24 hours. Upon removal, adhering water was rapidly absorbed with blotting paper and the painted surfaces were further

(1) Abrasion Test - Martin, "Lacquer in Synthetic Enamel Finishes," p. 263, D. Van Nostrand Company.

dried by means of a blast of compressed air. The abrasion resistance was then determined immediately before the film had an opportunity to give up any appreciable amount of absorbed water.

(d) Weathering.

14. To determine the outdoor durability of the materials under investigation, the 4 x 12" panels were exposed on a roof at an angle of 45° facing south, which is generally accepted as the most reliable measure of their durable qualities. A minimum exposure time of 2 months during the summer and of 4 months during the winter is required to tentatively establish the quality of any product. At the conclusion of these exposure tests, a record was made of various qualities of the film such as loss of gloss, color retention, adhesion, chalking, checking, and general condition and appearance of the film.

(e) Adhesion.

15. Quantitative methods for the measurement of adhesion are entirely lacking. A qualitative test for establishing the relative adhesive qualities of protective coatings consists simply of scraping the coating from the metal surface by means of a knife, fingernail or some other hard object. The relative ease with which several coatings may be removed is the only semi-reliable measure of their adhesion. The adherence of the best films is recorded as excellent, and then in descending quality they are rated as very good, good, fair, poor, and unsatisfactory. Aircraft coatings should rate good or better because of the tremendous drag occurring on hull bottoms during take-off or landing operations. When testing films of the kind studied herein, care should be exercised to rate adherence of the top coats to the primer as well as the adhesion of the entire system to the metal beneath.

(f) Gloss.

16. In the description of the various experimental coatings studied in this report, the degree of gloss has a double significance. Under present conditions all Fleet aircraft are finished with non-specular organic coatings and no finish devised for a hull bottom should exceed the limit of gloss specified for this type of product. Secondly, the decrease in gloss of an exposed panel is a direct measure of the weathering characteristics of the film. The poor quality films become dull and chalk the most rapidly. For measuring gloss as described in these experiments, a Gardner 60° glossmeter was used.

(g) Film Permeability.

17. No actual permeability measurements were made using free films in an atmosphere of carefully controlled conditions of temperature and humidity. However, a good indication of the relative permeability of each film was obtained by measuring the amount of zinc yellow that passed from the priming coat through the top coat and into solution when finished panels were submerged in artificial sea water. The 1-1/2 x 6" panels were placed on a

machine which lowered the panels into a glass container of artificial sea water (Navy standard) where they were allowed to remain for 5 minutes. The apparatus then automatically removed the panels into the air where they remained for 10 minutes before the cycle was repeated. This experiment was originally set up to obtain some idea of the effect of the alternate wetting and drying of the film and the subsequent effect on the aluminum metal beneath. It was noticed after the experiment had proceeded for a short while that the characteristic color of zinc yellow was imparted to the solutions and they were then analyzed for chromate ion, which was then converted into terms of zinc yellow.

DATA RECORDED DURING TEST

(a) Submarine Exposure.

18. The monthly progress of the marine encrustation on the panels as reported by each exposure station is recorded in Table I. The notes describing panel condition at San Juan and at Guantanamo Bay are self-explanatory. The key to the system employed at Miami is as follows:

No change	- Gd
Very slight	- x
Definite	- xx
Medium	- xxx
Bad	- xxxx
Very bad	- xxxx-x

At the end of the exposure periods (six months at Miami and Guantanamo Bay, four months at San Juan), the panels were returned. Immediately upon arrival a photograph was made of each panel, after which the panel was scrubbed with water and a medium stiff brush to remove all loosely adhering mud and scum. A second photograph was made showing the condition of the panel due to the presence of strongly adhering tubeworms and barnacles. Figures 1, Plates 1 to 7, show the unwashed panels on their return from Miami. Figures 2, Plates 1 to 7, are the same panels after having been scrubbed. Plates 8 to 14 are duplicate panels exposed at Guantanamo Bay, and Plates 15 to 18 are a triplicate set exposed at San Juan. However, in this last group, none of the panels were scrubbed as it was desired to retain one set in their original condition.

(b) Abrasion Resistance

19. The data pertaining to the abrasion resistance of the subject materials are recorded in Table II.

Table II

Abrasion Resistance of Goodyear Anti-Fouling Coatings

Serial Number	Dry Film			Wet Film - 24 hours' soak		
	Average Wt. of Abrasive	Film Thickness in Mils	Specific Abrasion Wt/Thickness	Average Wt. of Abrasive	Film Thickness in Mils	Specific Abrasion Wt/Thickness
70	29.6	1.5	13.1	6.9	1.5	4.6
71	15.3	1.1	13.9	5.4	1.1	4.9
72	17.2	0.7	24.6	6.5	0.7	9.3
73	63.0	0.7	90.0	25.5	0.7	36.4
74	18.3	0.9	20.3	28.4	0.9	31.6
75	20.5	0.9	22.8	24.5	0.9	27.2
81	10.7	0.4	26.7	7.5	0.4	18.8

(c) Weathering Characteristics.

20. The physical properties of the subject materials after five months' outside exposure are listed in Table III.

Table III

Serial Number	Gloss in Mils			Color Retention	Adhesion	Chalking	Checking
	Initial	2 Mo.	5 Mo.				
70	68	1	3	Poor. Darkened.	Extremely poor.	Slight	None
71	48	1	3	" "	" "	"	"
72	69	1	1	" "	" "	"	Considerable on edges.
73	95	60	65	Fair. Faded.	" "	"	Bad
74	65	1	1	Poor. Mottled.	" "	Severe	Considerable
75	65	1	2	" "	Completely unsatisfactory	"	"
81	65	45	24	Good.	Good.	None.	None

(d) Film Permeability.

21. The amounts of zinc yellow going into solution are given in Table IV. The condition of the metal after the complete removal of the film is noted.

Table IV

Solution Tendency of Zinc Yellow in Priming Coats

<u>Serial Number</u>	<u>pH</u>	<u>Mgs. of Zn Yellow</u>	<u>Condition of Al after Removal of Film</u>
70	6.7	4.99	Unaffected
71	6.9	7.10	"
72	6.8	6.77	"
73	6.4	1.46	"
74	6.5	4.28	"
75	6.7	5.08	"
81	6.5	1.74	"

DISCUSSION

(a) Anti-Fouling Properties.

22. It has long been recognized that fouling conditions prevailing in different areas vary widely from place to place. That fact is easily recognized from the condition of identical panels exposed at the three different points described in this report. Panels exposed at San Juan are fouled after four months to about the same extent as duplicate panels at Miami at the end of six months. Those exposed at Guantanamo Bay do not foul as badly as identical compositions at Miami. However, there is one condition that does exist which gives credence to the reliability of these tests, namely, the same relative difference exists between similar panels exposed at all three points. This indicates that the merit of each individual material is well established relative to the control, no matter where it is exposed.

23. From an examination of Table II, it becomes evident that the experimental coatings performed fairly well for the first two months of exposure. Thereafter the marine growth was no longer affected by the presence of the anti-fouling coating and it even forms faster than on the control panel. This indicates that all of the poisonous constituents originally present have been spent, and that the initial inhibitive qualities have been lost. After two months have elapsed, the standard product is much more desirable as a finish for hull bottoms. The experimental coatings do appear superior to the control for the prevention of oysters and sponge growth, which are unusually heavy in this instance.

(b) Corrosion Resistance.

24. Again referring to Table I, attention is invited to the protection from corrosion offered by the paints whose serial numbers are 72 and 73. The remaining experimental compositions are comparable with the control. It should be added that in this particular instance the corrosion on the control panel is greatly in excess of that usually encountered by the use of this product.

(c) Abrasion Resistance.

25. With the exception of coating number 73, the specific abrasion resistance of the experimental products does not compare favorably with the standard. This is particularly true for the dried films before they have been soaked in water. However, the total amount of abrasive required to abrade through the experimental coatings is considerably greater than that required for the standard. This would point to the fact that a hull bottom finished with the test films would actually withstand more abrasive abuse than the standard. This is attributable to the fact that a much heavier film of the test materials is necessarily applied, since this particular control forms the thinnest film of all coatings currently applicable to aircraft hull bottoms. As far as abrasion resistance is concerned, it may be concluded that paints 73 to 75 are equal or superior to the control, while 70 to 72 are decidedly inferior.

(d) Durability.

26. Table III presents a fair measure of the outdoor durability of the test materials when exposed for five months on the roof. Their outstanding failure perhaps is their utter lack of adhesion after exposure. The films appear to have surrendered all of their original adhesive qualities and could be removed by the rough edge of a coin in the form of a fine powder. With respect to their weathering characteristics, all the test materials fall far short of the standard, with paint number 73 showing the best qualities of the group.

(e) Film Permeability.

27. The amount of zinc yellow which permeates from the primer through the protective films and into the solution surrounding a submerged panel is expressed in Table IV. Here again, paint number 73 is the most outstanding, being the only one which compares favorably with the standard.

CONCLUSIONS

28. The general anti-fouling properties of the subject materials do not compare favorably with standard materials currently in use.

29. The weathering characteristics of the test materials are inferior to standard products now in use for the protection of flying boat hull bottoms.

RECOMMENDATIONS

30. Since the subject materials under test were purely experimental materials, and since they show little or no promise of possessing advantages superior to a standard product, it is recommended that they be excluded from any experimental service tests contemplated by the Bureau.

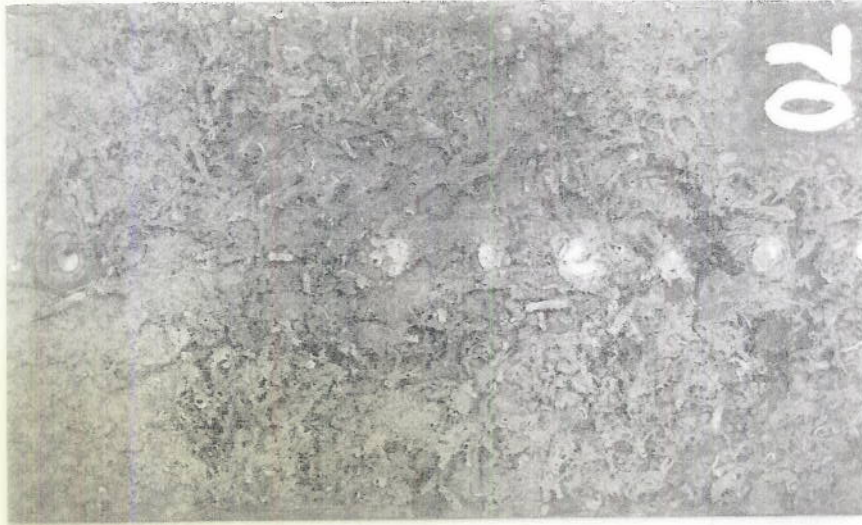


FIG. 1

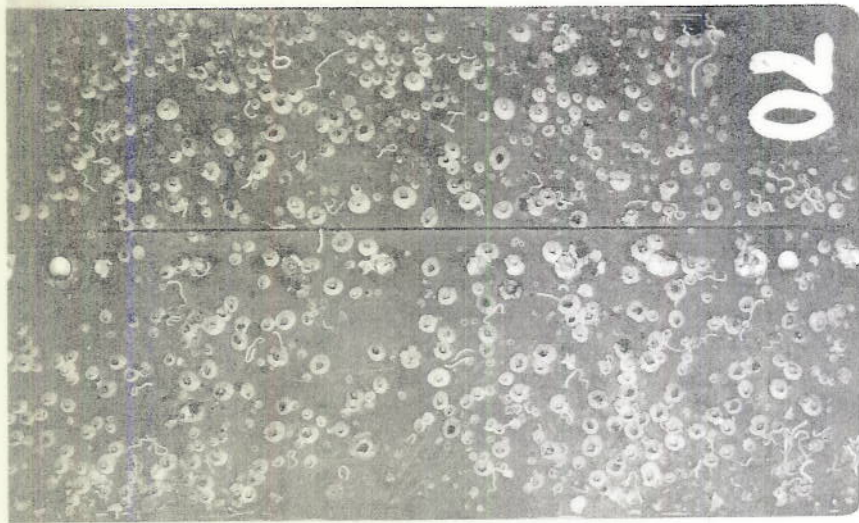


FIG. 2



FIG. 1

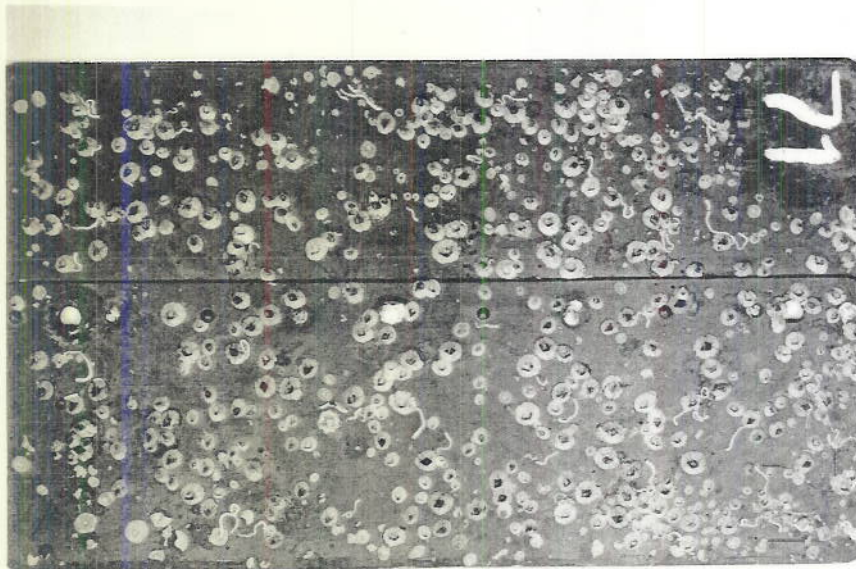


FIG. 2



FIG. 1

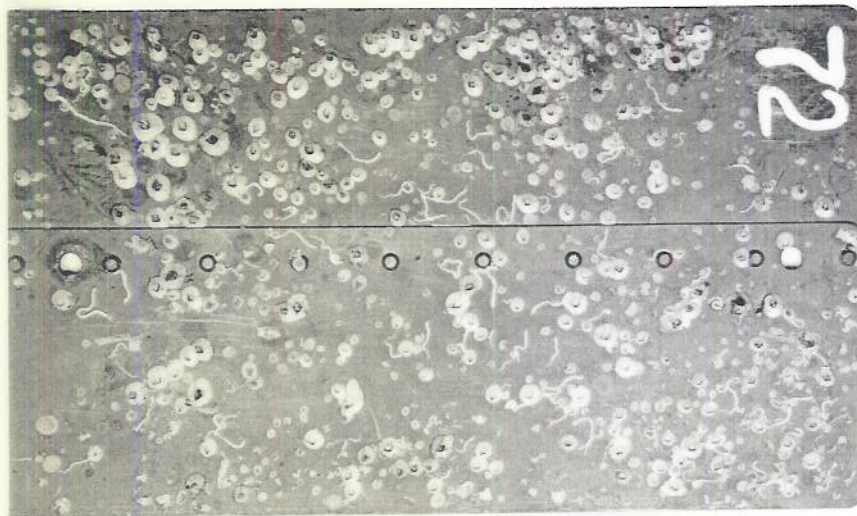


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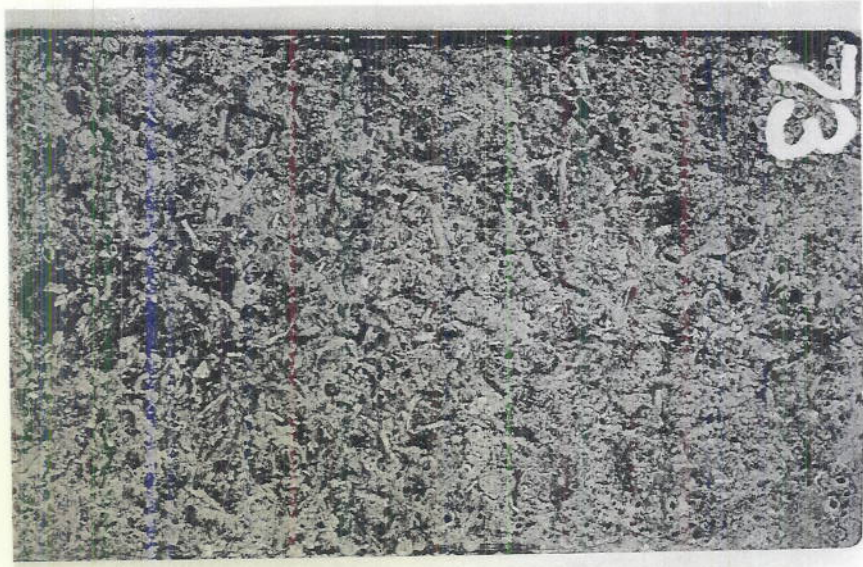


FIG. 1

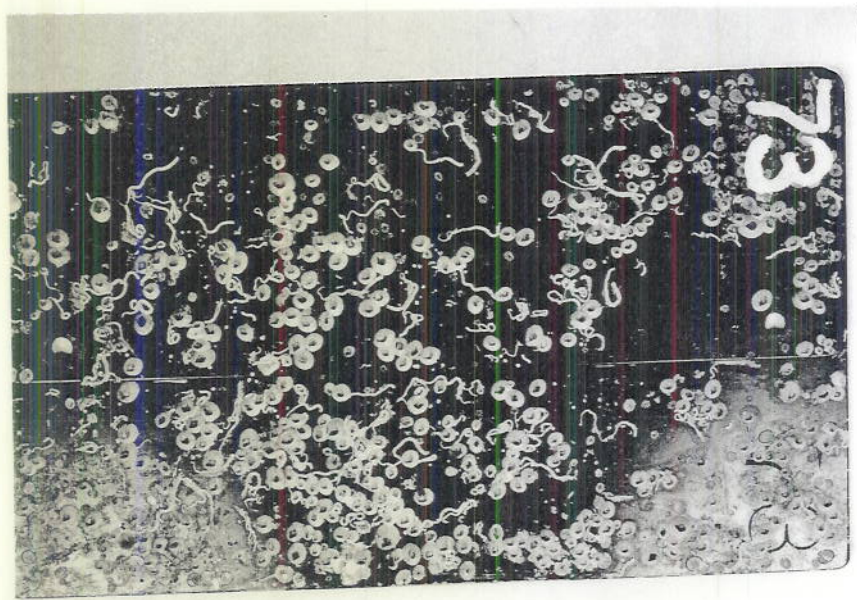


FIG. 2



FIG. 1

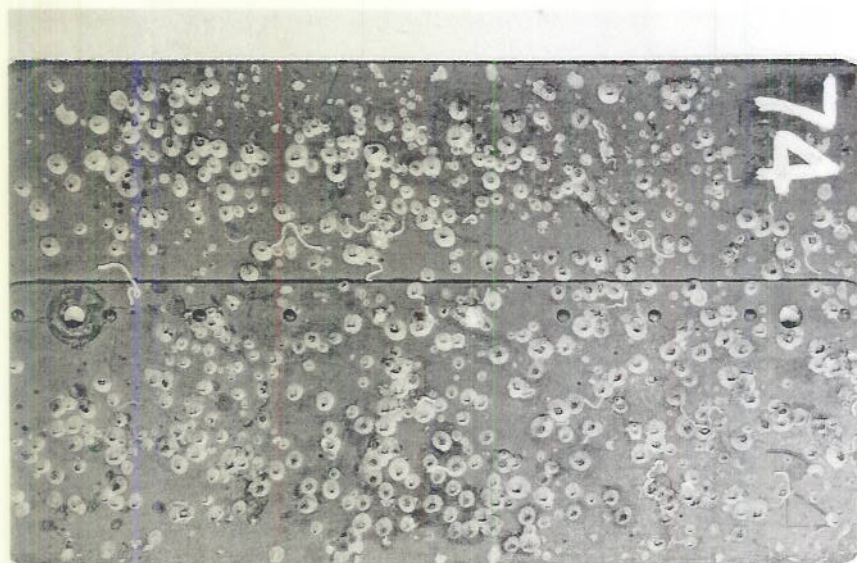


FIG. 2



FIG. 1

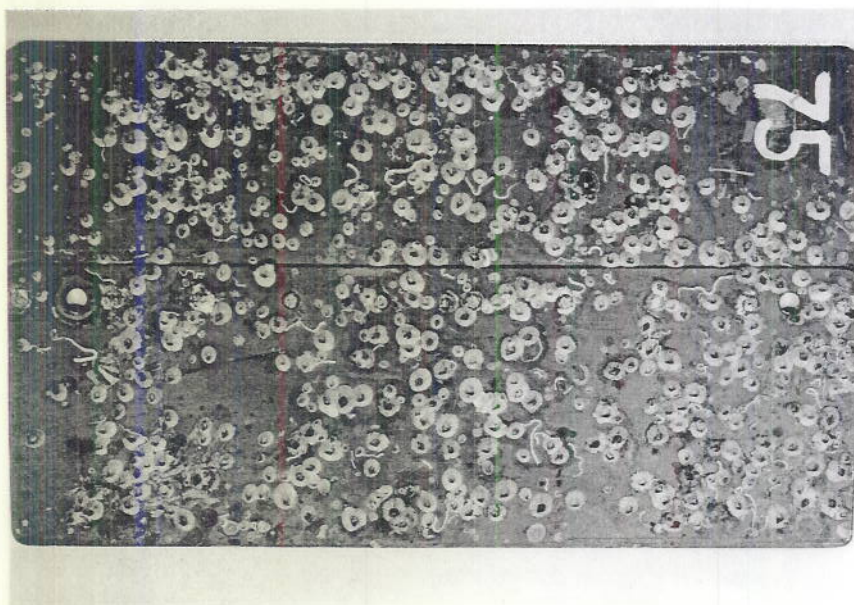


FIG. 2



FIG. 1

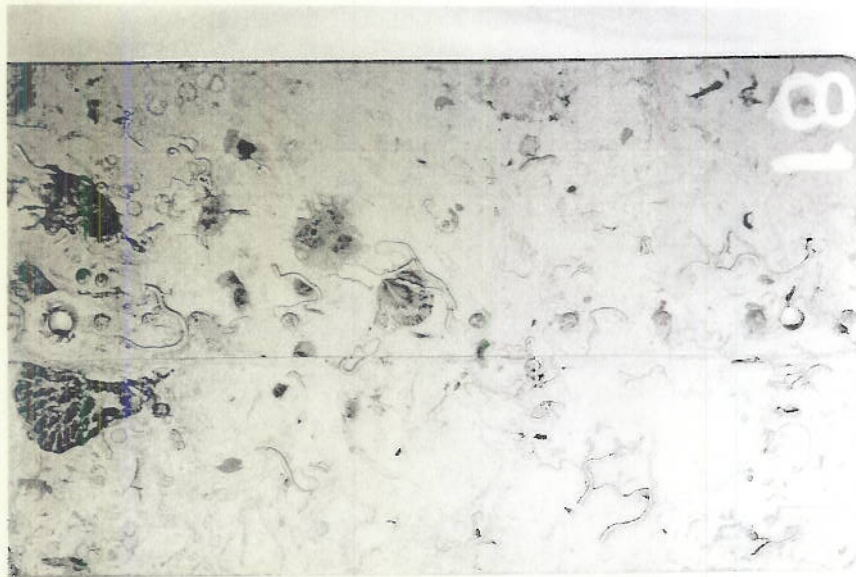


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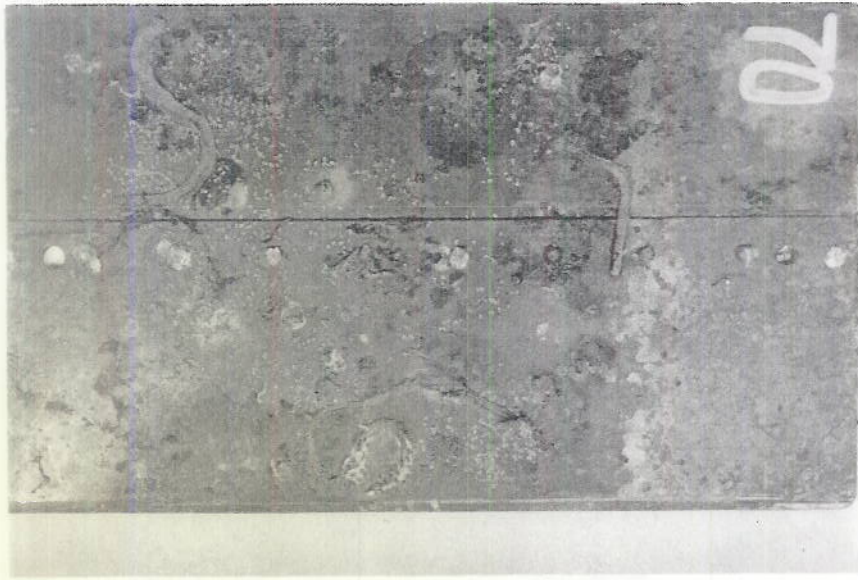


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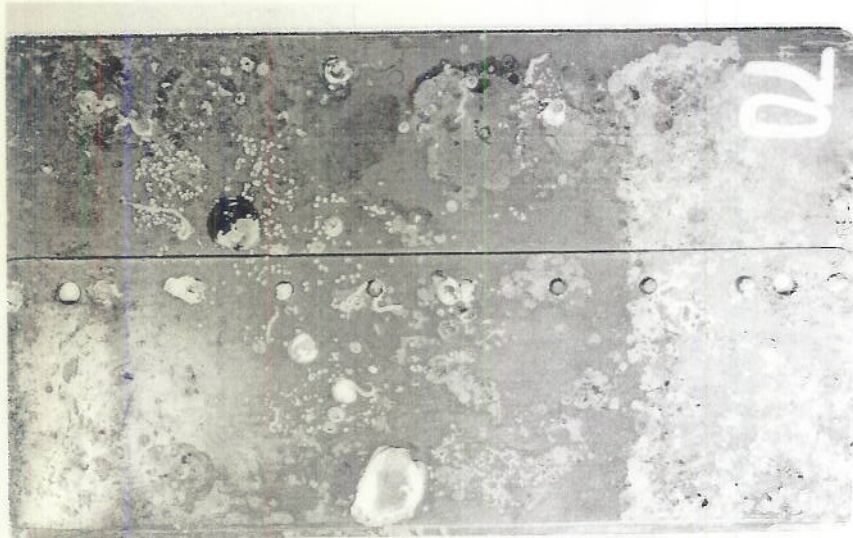


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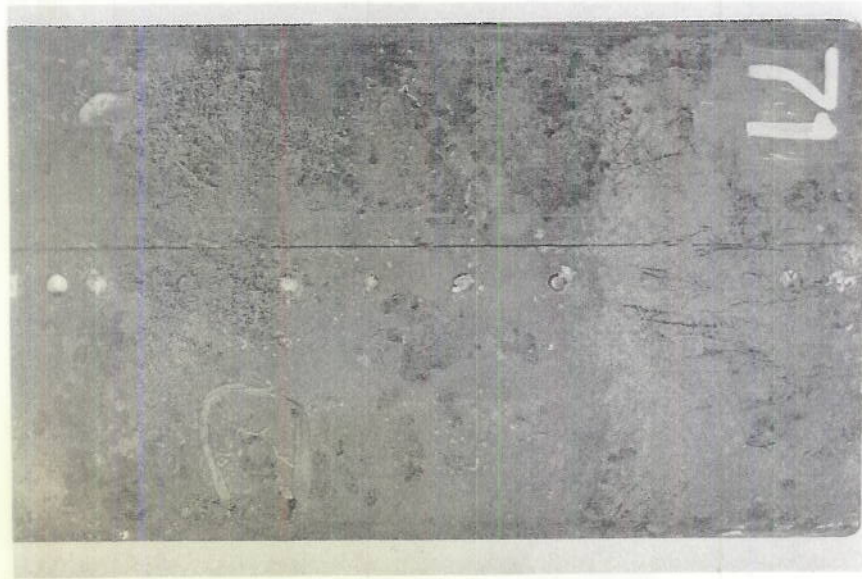


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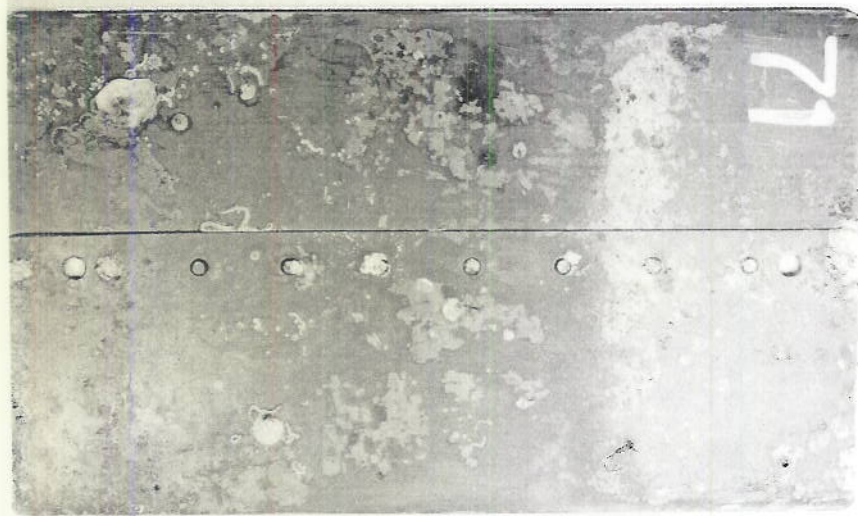


FIG. 2



FIG. 1



FIG. 2



FIG. 1

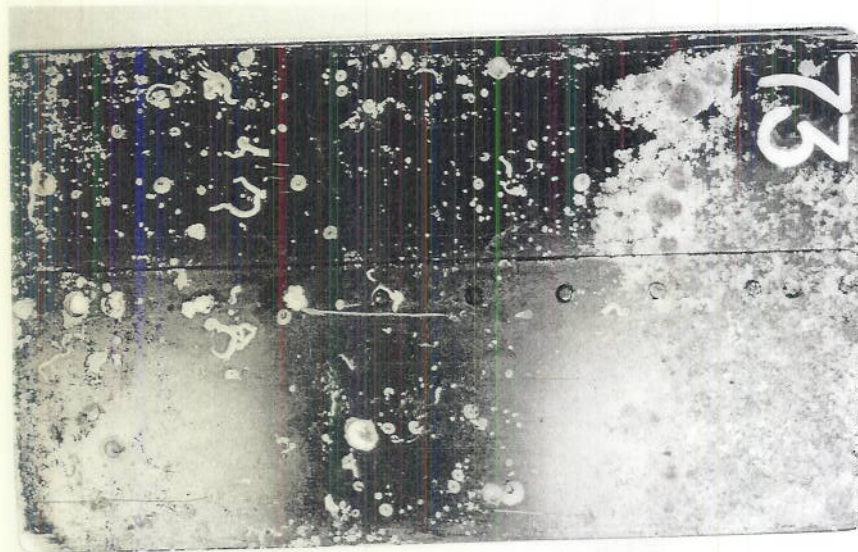


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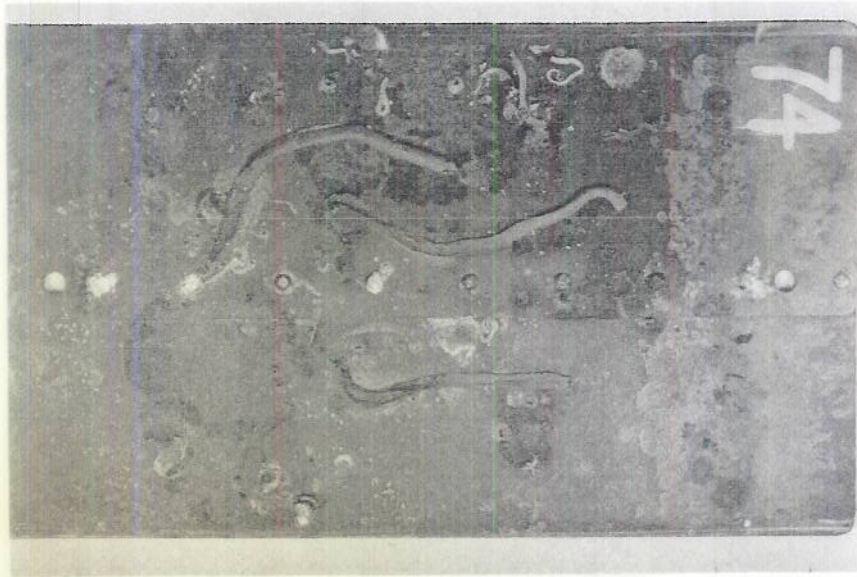


FIG. 1

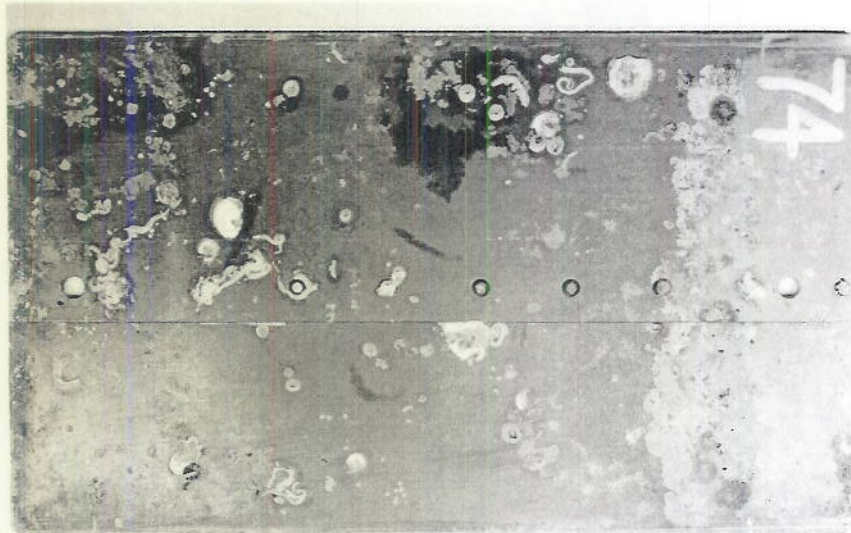


FIG. 2

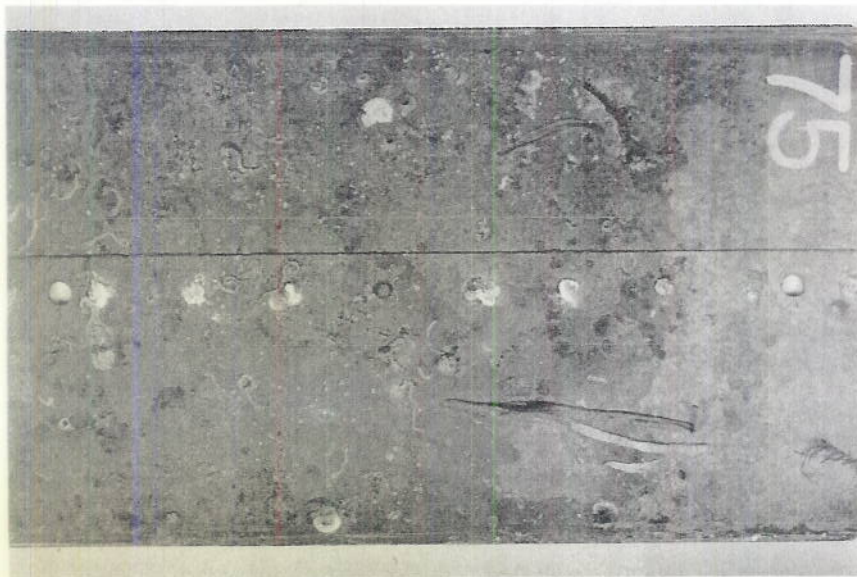


FIG. 1

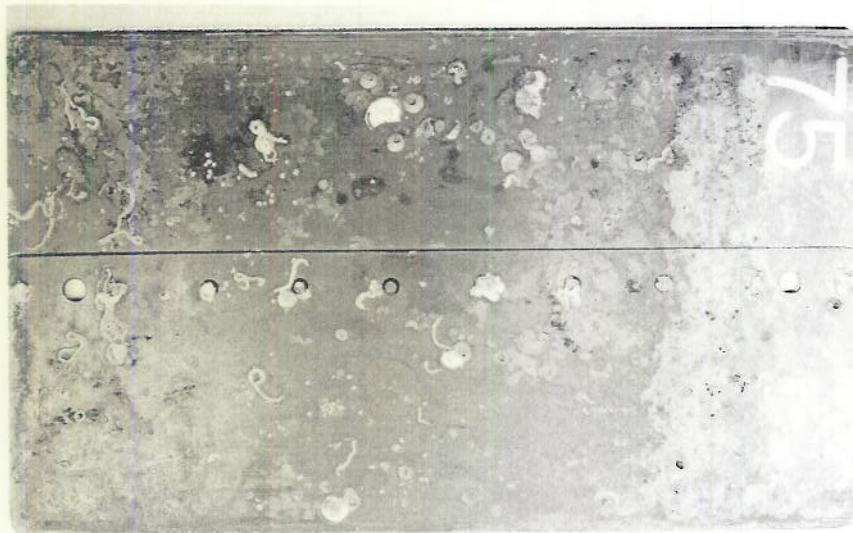


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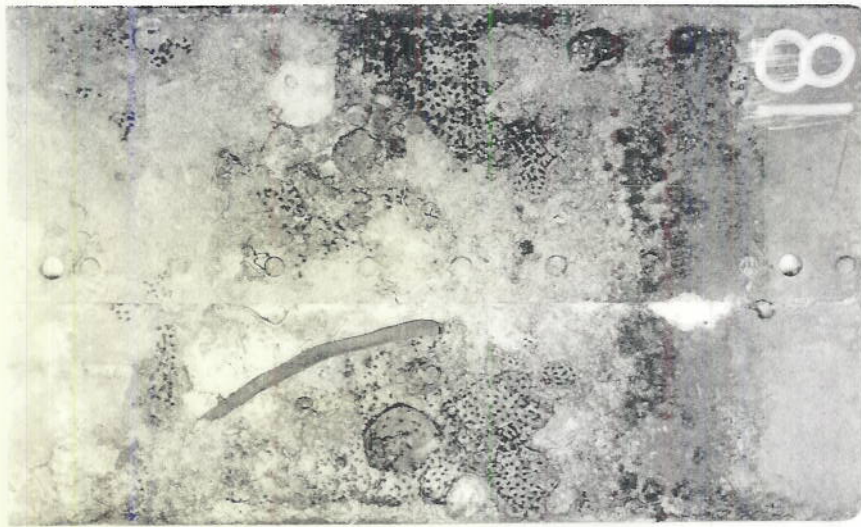


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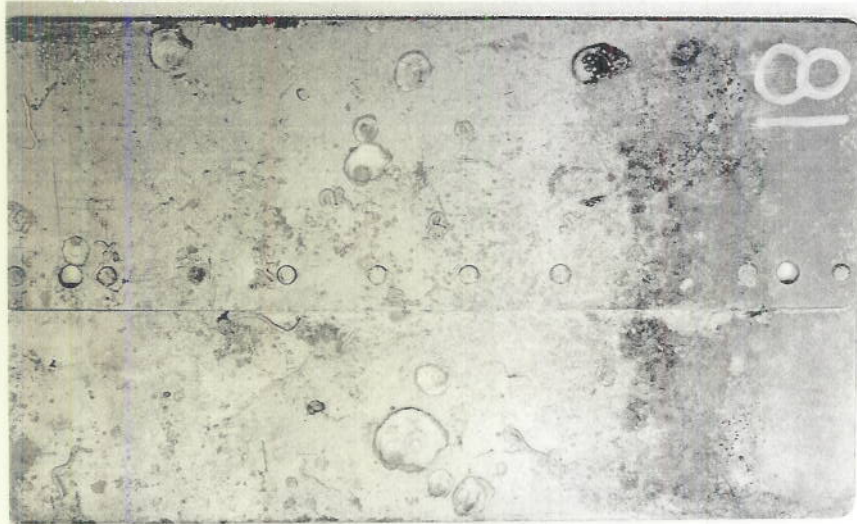


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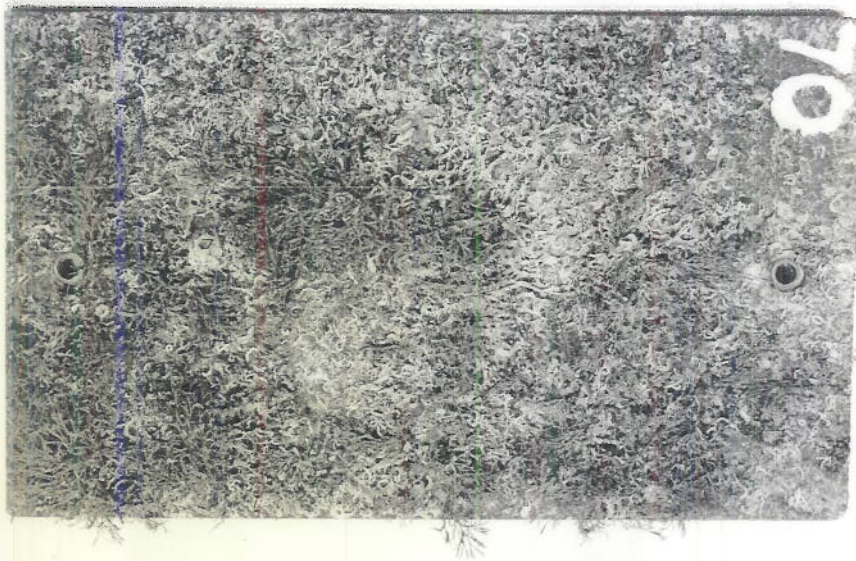


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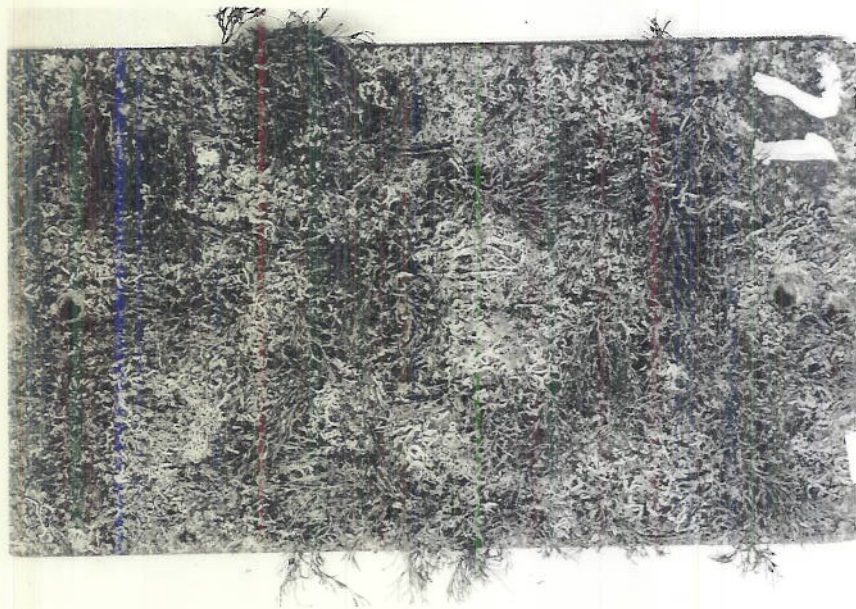


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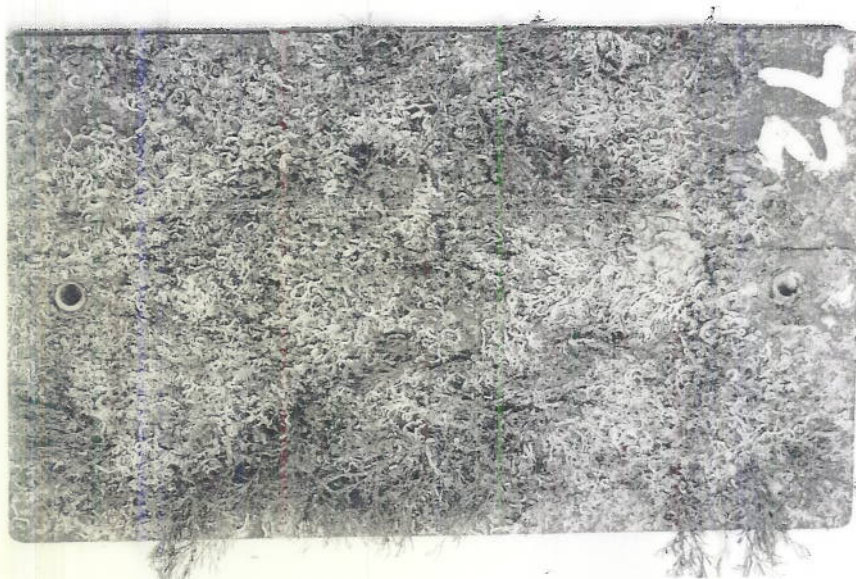


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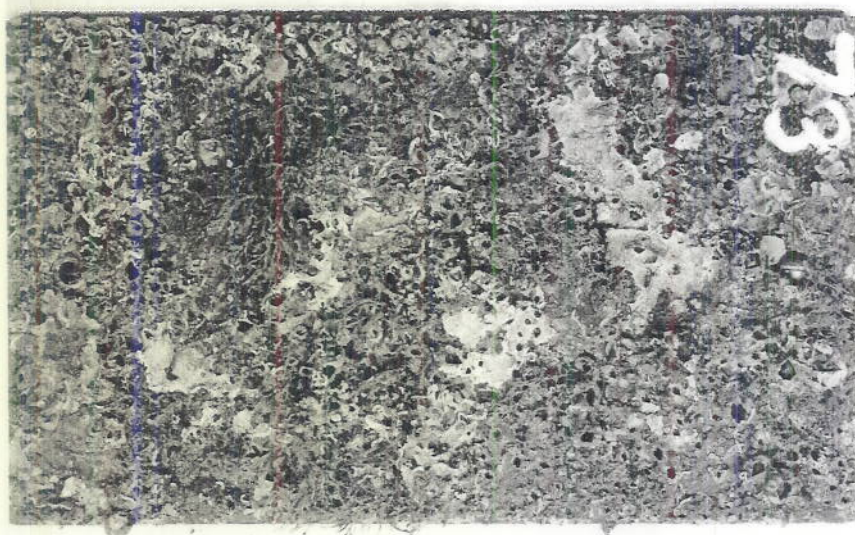


FIG. 2

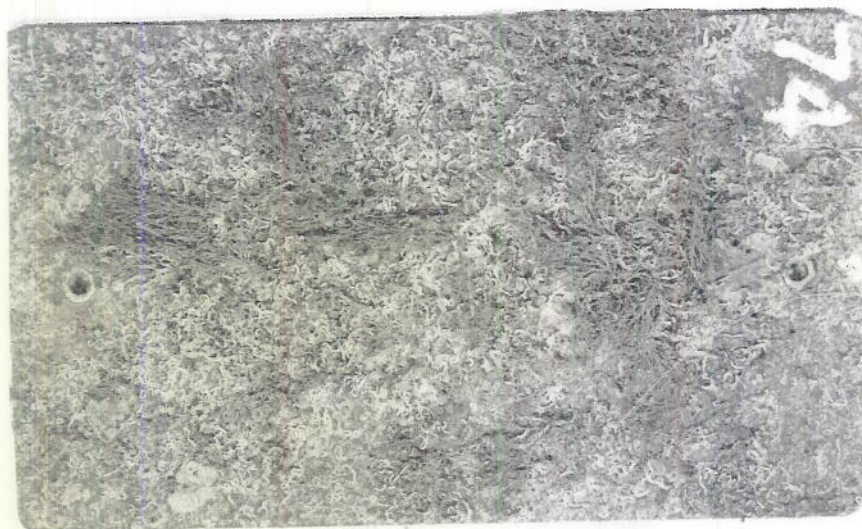


FIG. 1

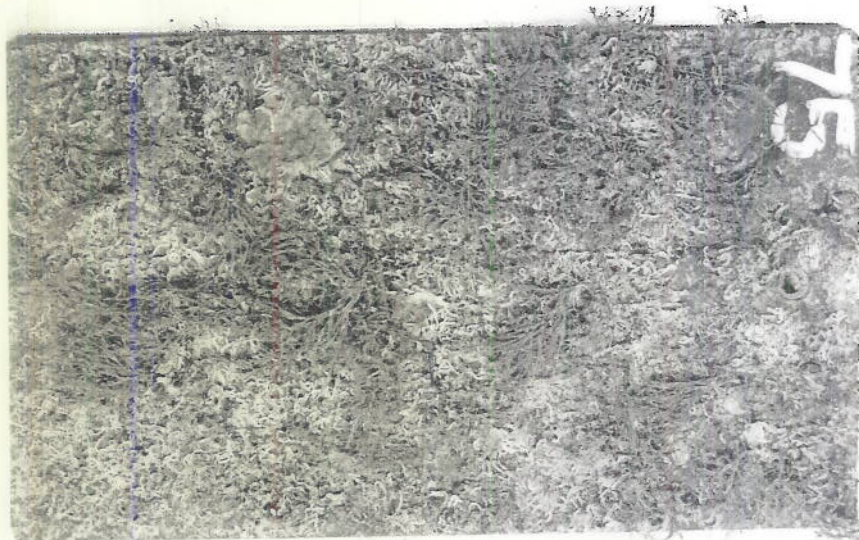


FIG. 2