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NAVY DEPARTMENT

FR-2233

Report on

The Suitability of a Black, Iron Oxide Coating for Chaplets and Internal Chills.

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ABSTRACT

A corrosion resistant black iron oxide coating applied to chaplets and internal chills shows that it compares favorably with the coatings of critical metals generally used. The method of processing which requires dipping the clean part in a hot salt bath is simple and inexpensive.

AUTHORIZATION

1. The study of coatings for chaplets and internal chills was authorized by the Bureau of Engineering letter QP/Castings (6-19-D6)` of 13 July 1928.

STATEMENT OF PROBLEM

2. The problem undertaken was to determine the suitability of a black oxide coating for use in replacing strategic materials such as tin, nickel and copper as a coating for chaplets and internal chills to be used in the manufacture of steel castings.

GENERAL CONSIDERATIONS

3. Chaplets are used to support the cores in the manufacture of castings and internal chills are often used in heavy sections of castings as a means of influencing temperature gradients so that proper feeding can be accomplished.

4. The usual material for chills and chaplets is wrought iron or cheap cold-rolled bar stock. Since they are placed in moist green sand molds and allowed to stand for several days; or dried in an oven, the surfaces rust unless some protective coating is provided. The coating also protects them from corrosion during handling and storage. The current methods of protection consist of plating the chaplet or chill with copper or nickel or dipping in hot tin.

5. This investigation was prompted by the following:

a. A War Production Board order limiting the use of tin as a chaplet coating material.

b. The strategic nature of copper, tin and nickel.

c. The adaptability of black oxide coating to metal objects for the general purpose of corrosion resistance, and,

d. The knowledge that cleanliness of chills and chaplet surface and freedom from porous oxidation and/or moisture are of greater importance than the nature of the coating, provided, of course, that the coating itself does not volatilize and cause gassiness in the steel.

KNOWN FACTS BEARING ON THE PROBLEM

6. NRL Report Nos. M-1561 and M-1609 described previous work on the surface preparation of internal chills and chaplets. The conclusions from these reports were as follows:

a. Many generally ignored factors operate jointly or individually in causing unsatisfactory behaviour of chaplets.

b. Threaded stem chaplets do not present any added assurance of fusion and may be deleterious by presenting spaces at the bottom of threads for the accumulation of gases. Also steel does not wet and flow into the sharp grooves.

c. Careful consideration should be given to the preparation and care of chaplet surfaces both before and after processing. The mill scale left in some cases after forming is capable of causing porosity in the casting.

d. Chaplets with highly alloyed surfaces fuse readily but may melt too quickly for suitable core support.

e. Gases occluded during electroplating can be detrimental.

f. Silicon impregenated chaplets fuse readily but lead to embrittlement of the parent metal at the interface.

g. Chaplets coated with copper, nickel, silver or tin are satisfactory if the surface is properly cleaned before coating.

h. Chaplets should be sandblasted or pickled prior to coating regardless of the type of coating used. If pickled they should be heat treated to remove any hydrogen which might be present.

i. Chills or chaplets with unclean surfaces do not perform satisfactorily. Dust, oil, or moisture which may be present, are particular sources of porosity in the castings. Careless handling is the rule rather than the exception and a little care in preparation and storage of chaplets and chills would save many castings.

j. Porous areas are prevalent in internal angles and at sharp corners and their elimination by streamlining the chills and chaplets is desirable.

k. The state of deoxidation of steel is important. A well deoxidized steel seems to be less vulnerable to defects

caused by rusty, dirty or poorly plated chills and chaplets, than is a steel deoxidized just enough to be satisfactory under average conditions.

1. Surface preparation before coating appears to be more important than the type of coating, provided, of course, that the coating itself does not volatilize or segregate to disadvantage and cause gassiness and/or poor properties in the casting.

7. The particular black oxide coating used for these experiments was applied by the Mitchell-Bradford Chemical Company of Bridgeport, Conn. and arrangements were made through Mr. William H. Price of that company. The process is know commercially by the trade name of "Black Magic" and the final liquid wax treatment is called "Witch's Dip". The chaplets were supplied by the Fanner Manufacturing Company of Cleveland, Ohio and by the Pennsylvania Foundry Supply Company of Philadelphia, Pa. The black oxide treatment of steel has been an accepted commercial process for several years for coating metal objects to protect them from corrosion. It is not a "plating" in that it is not dimensionally additive to the originally untreated chaplet or chill. It is a penetration from 0.0001 to 0.00015 of an inch in depth, produced by the formation of Fe_3O_4 when the chaplets or chills are immersed in a salt bath high in sodium hydroxide content. The bath is at a temperature of between 130°C. and 150°C. and the time of immersion is approximately fifteen minutes. After the chaplets and chills have been removed from the bath and rinsed thoroughly, they are immersed in a petroleum hydrocarbon liquid wax for final finish.

8. Hugo Krause in his book "Metal Coloring and Finishing" has described methods of forming the black oxide coating on steel. A method described in this book was tried at the Naval Research Laboratory with excellent results. This consisted of using a solution of 400 g. of NaOH in 600 cc. of water to which was added 10 g. of KNO_3 and 10 g. of $NaNO_2$. The solution was brought to a boil and a sand-blasted chaplet was immersed for ten minutes after which time the black coating was formed. The KNO_3 and $NaNO_2$ were added only as a source of oxygen which is necessary to the reaction. Other substances which evolve oxygen such as sodium perioxide could be used equally well. It is necessary to replace evaporated water from the solution as it is used. The precaution should be taken to keep the bath covered when not in use as CO_2 from the air will be absorbed by the bath to reduce the hydroxide concentration by forming a sodium carbonate. The addition of slaked lime to the bath will convert the sodium carbonate back to sodium hydroxide and remove the carbon dioxide as a calcium carbonate precipitate.

9. "Metal Coloring and Finishing" gives many methods which are ramifications of the one described above. These methods were obtained largely from German patents which have now expired.

EXPERIMENTAL PROCEDURE

10. Plates 1, 2 and 3 are photographs of the various designs of chaplets and chills which were tested.

11. Before being processed the chaplets and chills were thoroughly cleaned by sandblasting. Cleaning can also be accomplished by "pickling", if after the "pickling" operation they are heated to 550°F. to remove any hydrogen which may be present.

12. The chills and chaplets were placed in test molds as shown in Plates 4, 5 and 6. Chaplets coated with tin, aluminum and copper were included for comparison. Some of the smaller chills were tested in the barrel of a flanged casting. Plate 7 is a photograph of two sections cut from the casting through the center of the chills. The wall thickness through the barrel of the fitting in which the chills were placed is three-quarters inch. The steel used in casting these test molds was Navy Class B, containing about 0.25 percent carbon, 0.60 percent manganese and 0.40 percent silicon.

13. After the molds were poured the castings were cold sawed through the center of each chill or chaplet and etched with a hot fifty percent hydrochloric acid solution. The etching treatment outlines the chills and chaplets clearly in the specimen and any porosity present is apparent.

DISCUSSION OF RESULTS

14. Plates 8, 9 and 10 are photographs of sections through the center of one-inch long chaplets of the different designs and coating materials indicated. The chaplets with the black oxide treatment show as good fusion as do the copper plated or tin dipped types.

15. In all cases where grooved stem chaplets are used poor fusion results, and the plain stem types appear to be satisfactory.

16. The absence of cavities in the parent metal around the chaplets indicates that the black oxide coating does not volatilize and cause gassiness. This is even more clearly indicated in the case of the internal chills, to be discussed below.

17. The prevalence of cavities and lack of fusion at the internal angles, such as the places where the head joins the stem of the chaplet, indicate again in this work that streamlining chaplets is desirable, and any sharp internal corners are potential sources of trouble. Where the metal rises against the upper flathead of the chaplet and does not flow over it to any extent, lack of fusion is the combined result of chilling and the inability of the flowing stream to work away any gases which may be trapped.

18. Plate 11 shows similar results with chaplets of the type in Plate 1 and in these cases only black oxide coatings were tried. For some unknown reason the results were not particularly satisfactory as several cavities are present in the parent metal.

19. Plates 12 and 13 show the result of casting black oxide coated bar and coil chills in the barrel of a three-fourths inch thick valve body. Good fusion and lack of porosity indicate that the chills were satisfactory.

20. Plates 14, 15, 16, 17 and 18 show satisfactory behaviour for black oxide coated coil and bar chills in heavy sections. The specimens shown in these plates have been boiled in hot acid to bring out the fusion line more clearly and to etch away any metal that might be flowed over cavities during polishing.

21. Plate 18 is particularly interesting in that it shows an actual porosity within the chill itself. In such cases it could be expected that gas cavities might be present in the parent metal as a result of the gas in such cavities expanding under the increased temperature and forcing itself out into the molten metal. In the instances shown this was not the case and the chills gave good fusion.

22. One disadvantage of this coating, however, is that there are several iron oxide inclusions in the metal near the metal chill interface.

CONCLUSIONS AND RECOMMENDATIONS

23. The results of the present investigation substantiate those of former work in regard to the behaviour of chills and chaplets, and in addition indicate that a cheap, non-strategic black oxide of iron is satisfactory as a coating material. It resists normal oxidation satisfactorily and gives as good fusion characteristics as copper, tin, or nickel-coated types.

24. It is recommended that manufacturers treat a trial batch of chills and chaplets with a black oxide coating and have them tried in commercial practice, that Navy Yards or other foundries coat some in their shops and try them as an alternate to present methods which require strategic materials, if for any reason this becomes a problem or present coatings are not satisfactory.

This report has not as yet been approved by the Bureau concerned.

BIBLIOGRAPHY

1. Krause, Hugo, "Metal Coloring and Finishing", Chemical Publishing Company of New York, pp. 150-159.

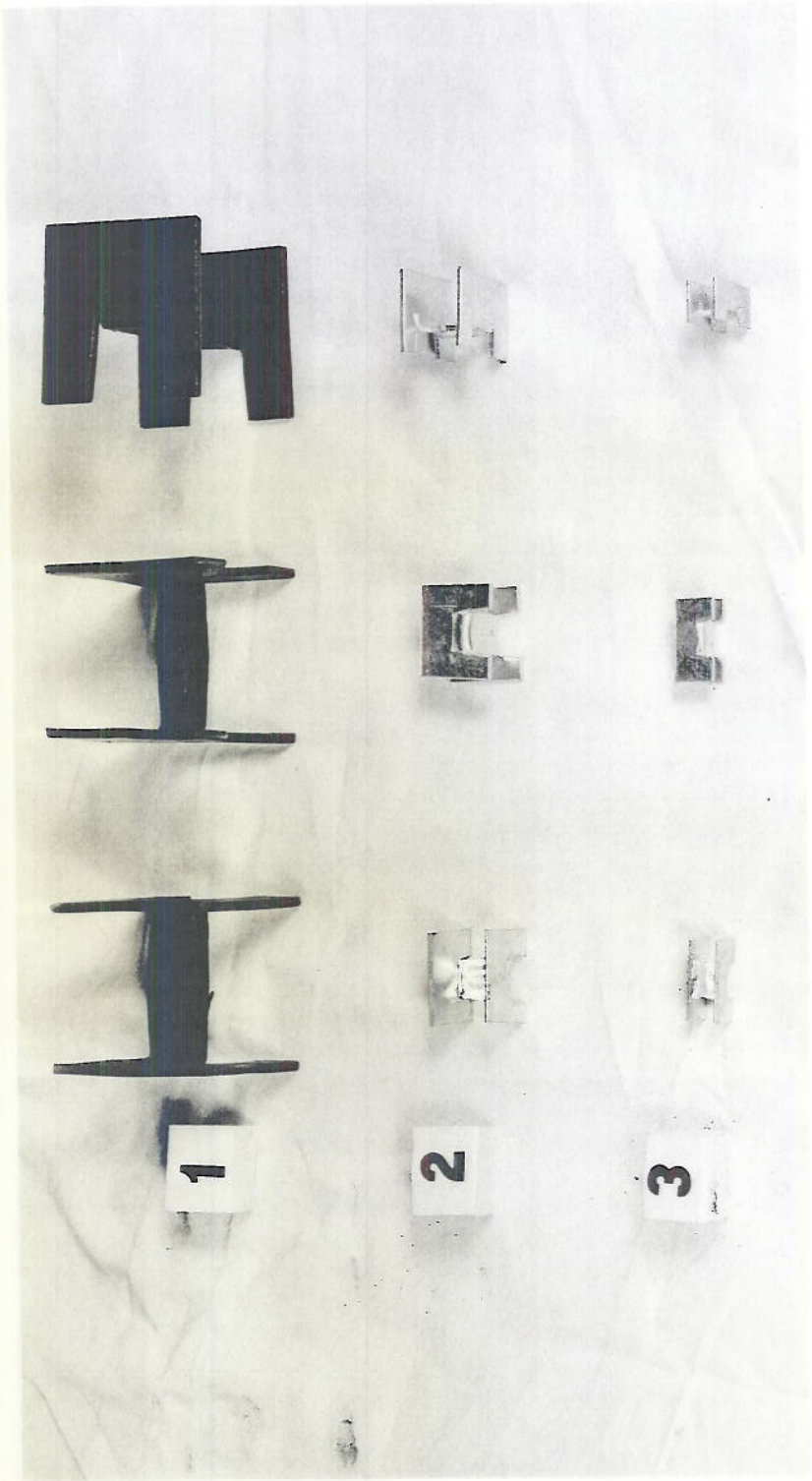


PLATE I

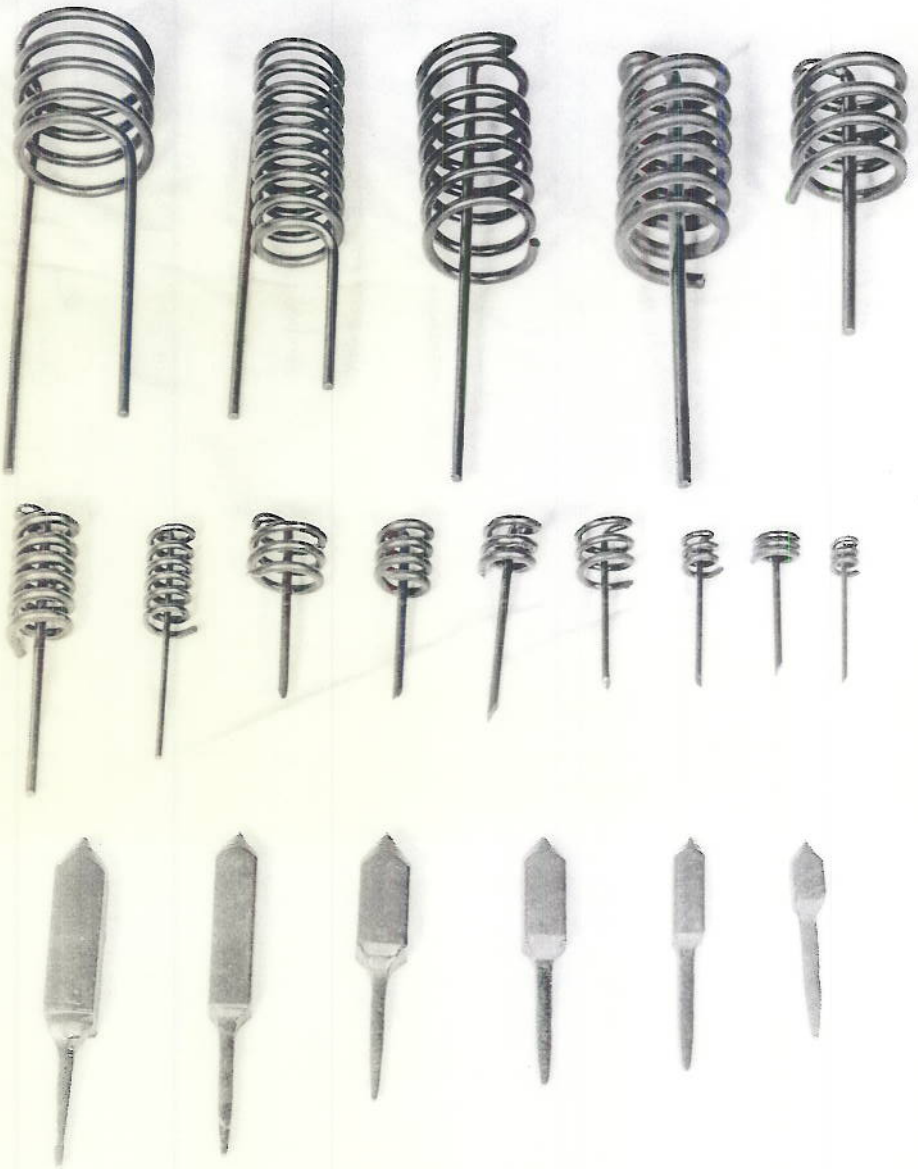
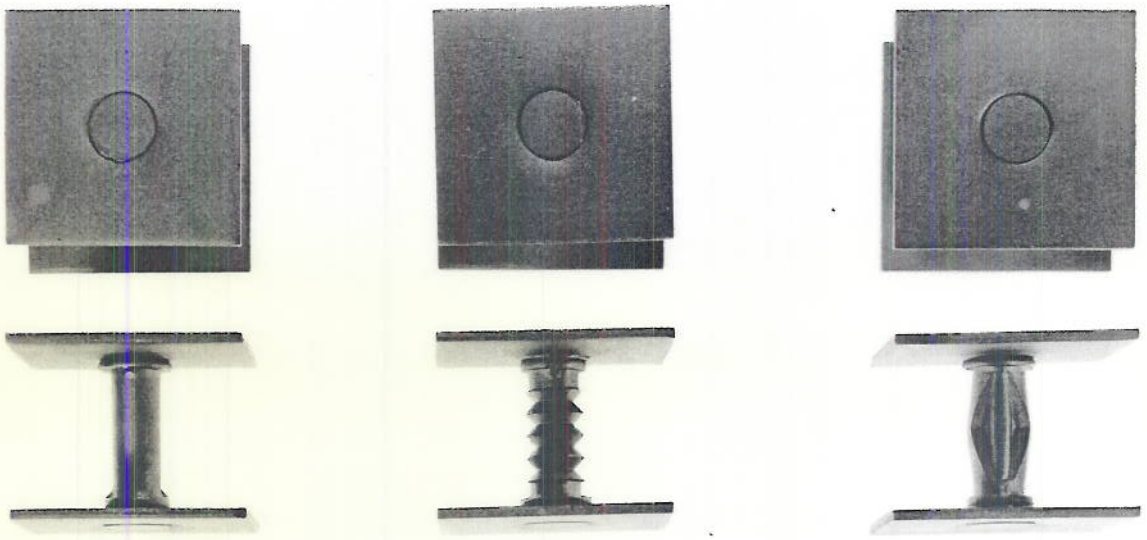


PLATE 2



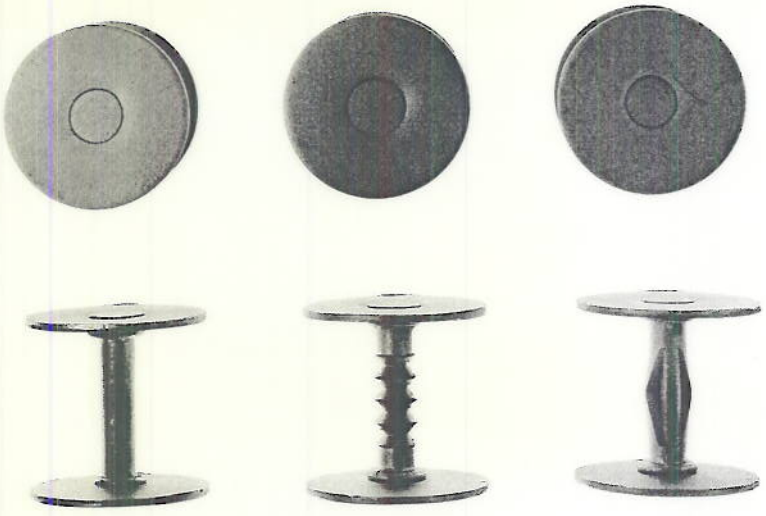


PLATE 3

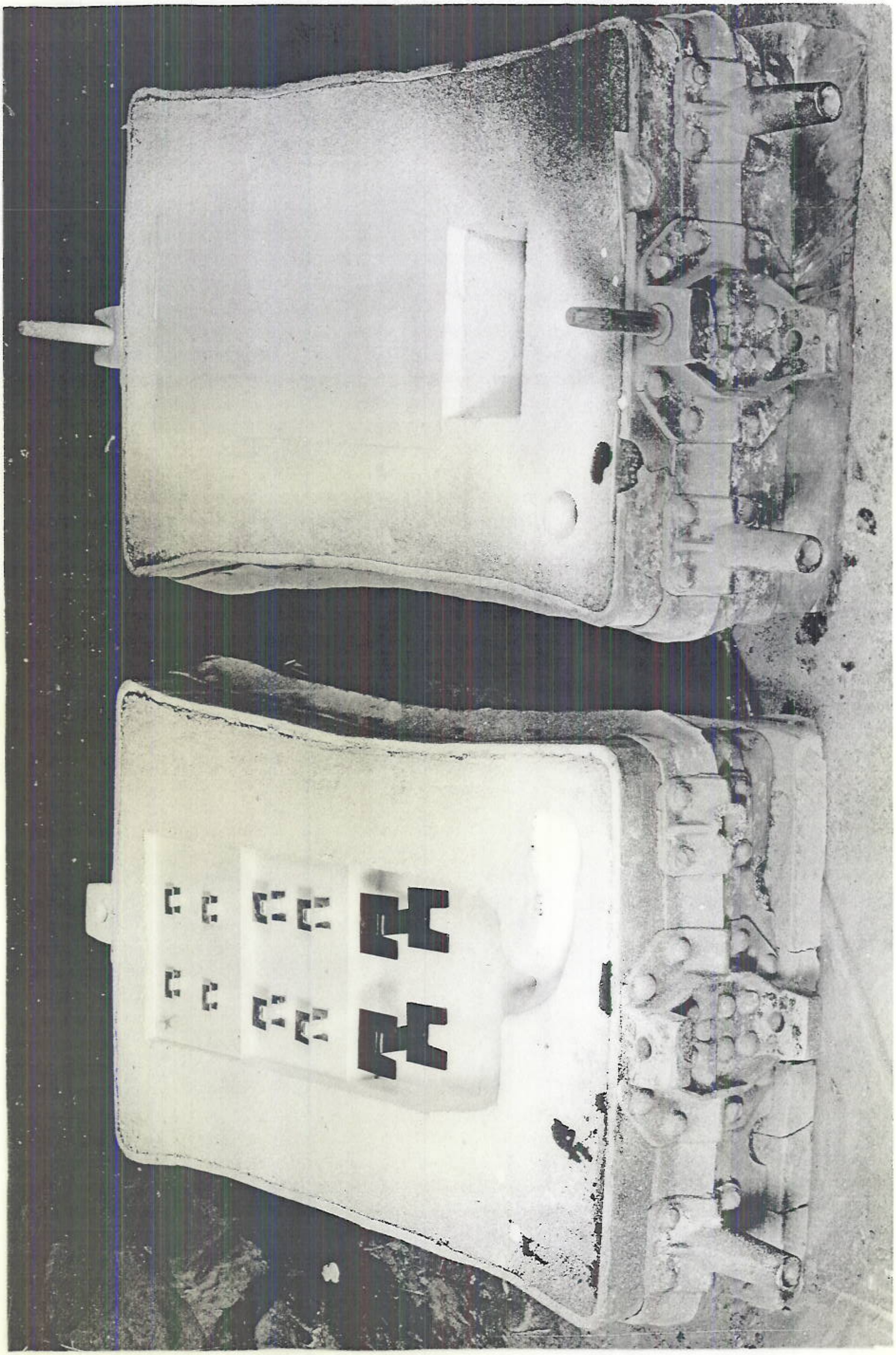
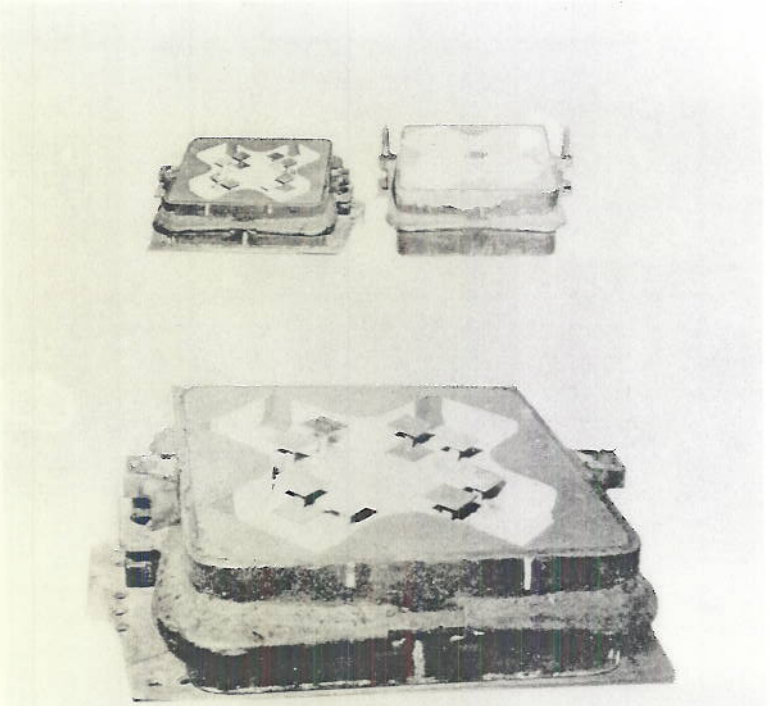


PLATE 4

PLATE 5



WASHED GREEN SAND MOLD
DRIED WITH CHAPLETS IN PLACE

PLATE 6

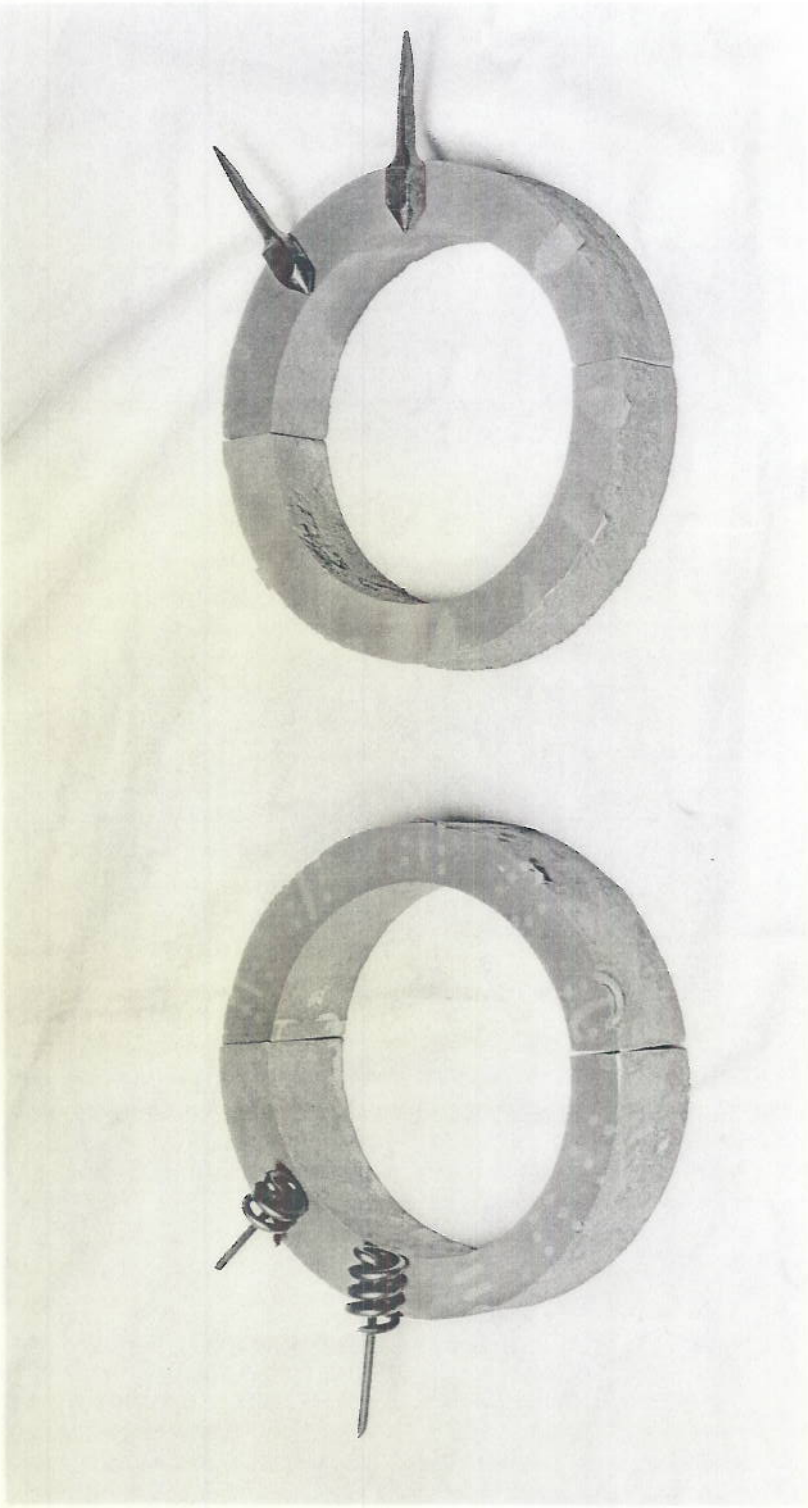
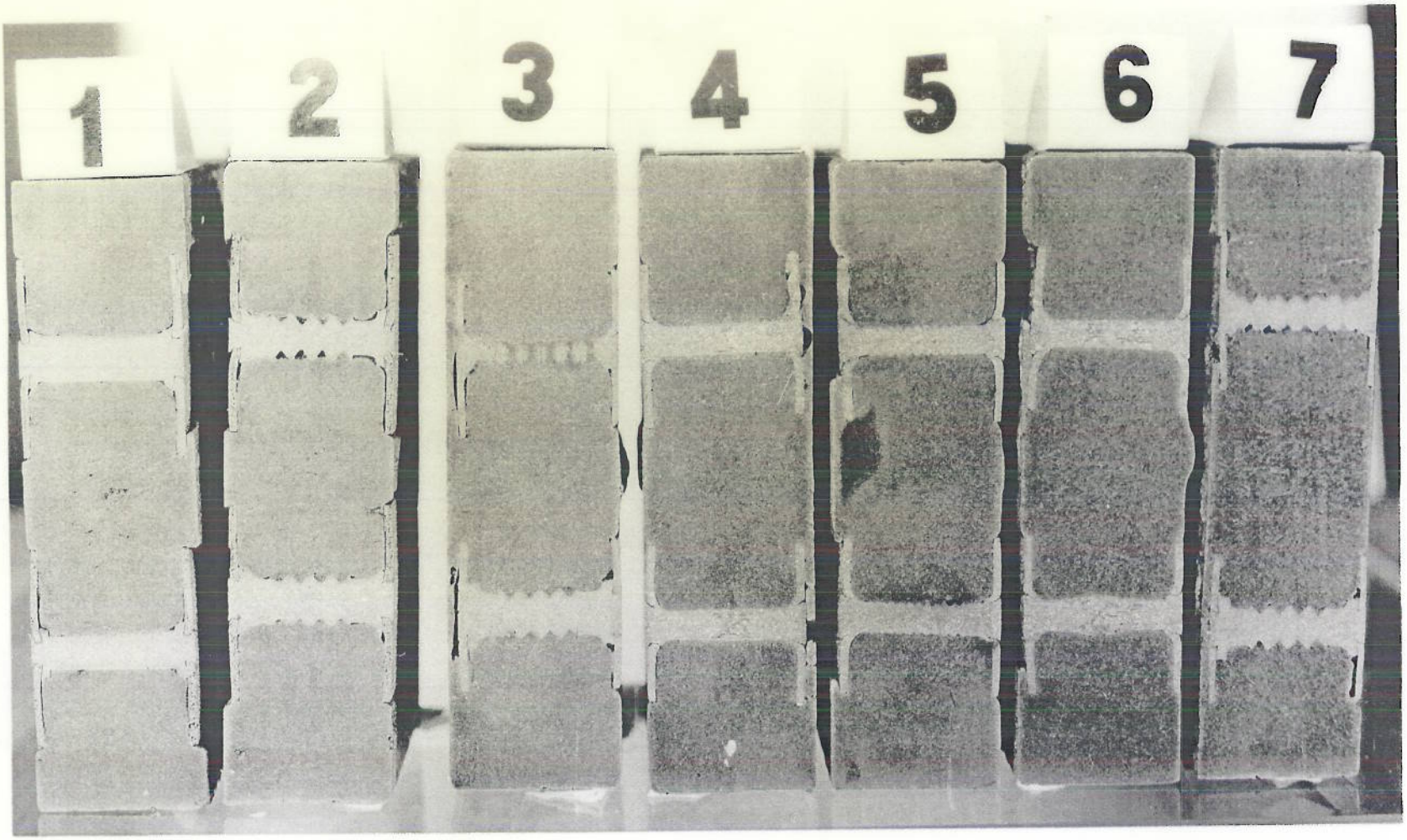
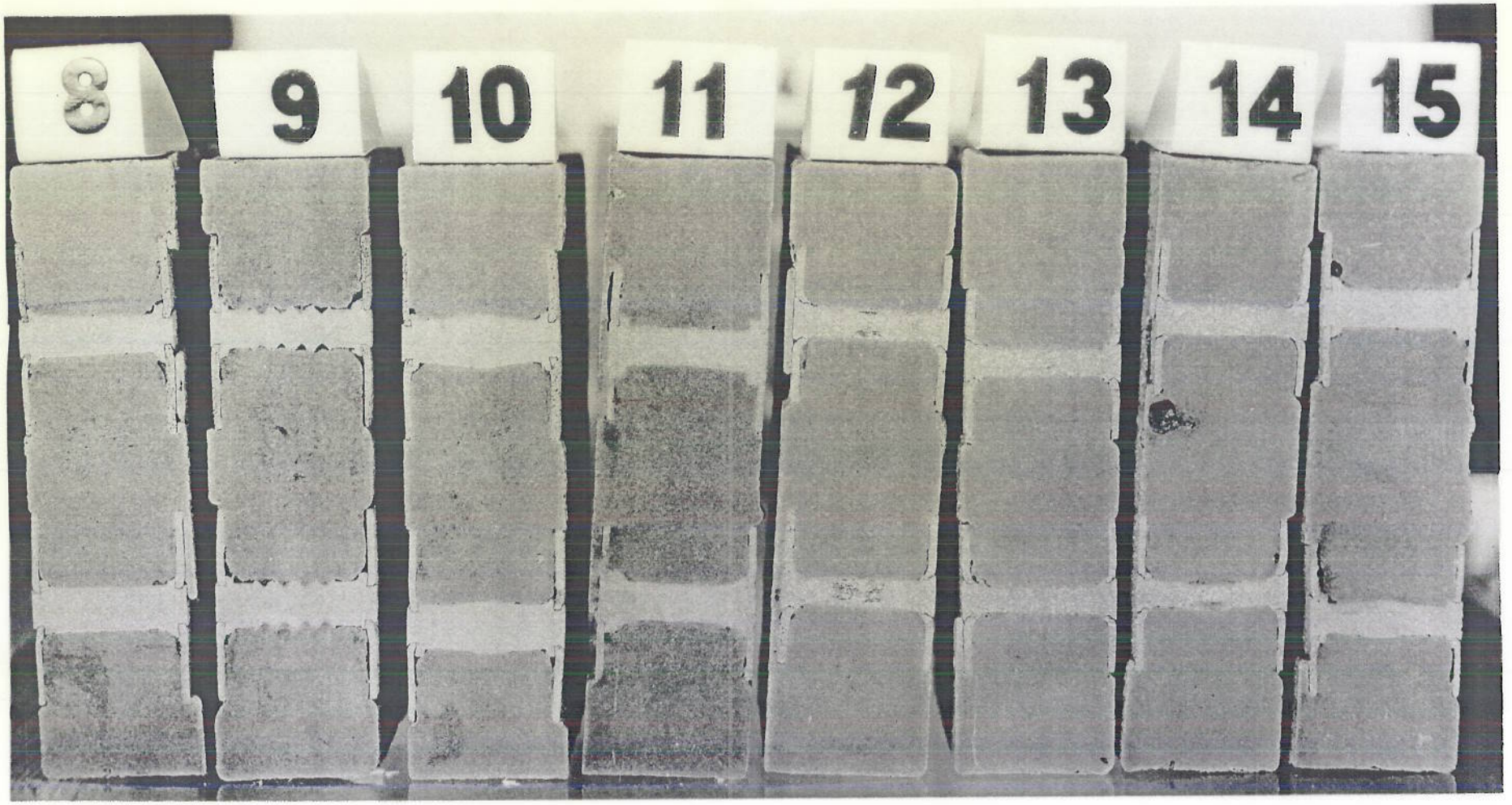


PLATE 7



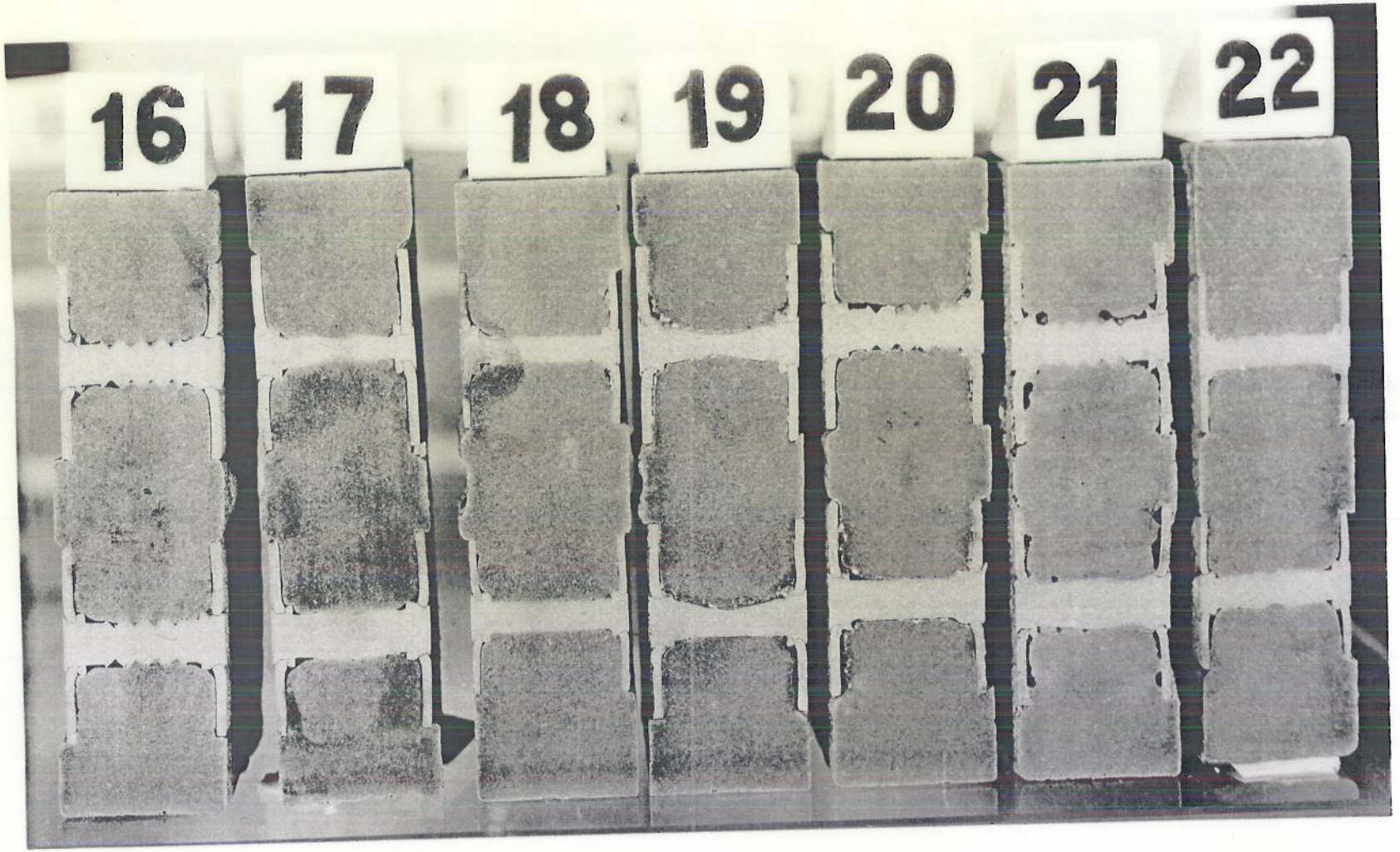
1-$\frac{1}{4}$" D PLAIN STEM BLACK OXIDE TREATMENT
2-$\frac{1}{4}$" D GROOVED STEM BLACK OXIDE TREATMENT
3-$\frac{1}{4}$" D GROOVED STEM COPPER PLATED
4-3/16"D PLAIN STEM BLACK OXIDE TREATMENT
5-3/16"D GROOVED STEM BLACK OXIDE TREATMENT
6-3/16"D PATENT STEM BLACK OXIDE TREATMENT
7-3/16"D and $\frac{1}{4}$"D GROOVED STEM TIN DIPPED

PLATE 8



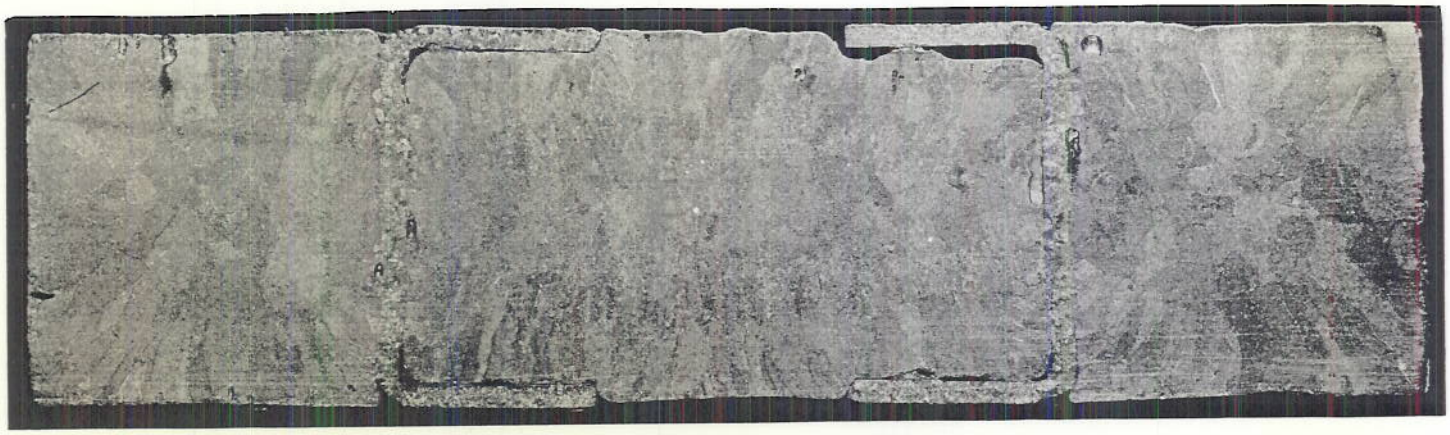
8-$\frac{1}{4}$" D PLAIN STEM BLACK OXIDE TREATMENT
9-$\frac{1}{4}$" D GROOVED STEM BLACK OXIDE TREATMENT
10-$\frac{1}{4}$" D PATENT STEM BLACK OXIDE TREATMENT
11-$\frac{1}{4}$" D PATENT STEM COPPER PLATED
12-3/16"D PLAIN STEM BLACK OXIDE TREATMENT
13-3/16"D GROOVED STEM BLACK OXIDE TREATMENT
14-3/16"D PATENT STEM BLACK OXIDE TREATMENT
15-$\frac{1}{4}$" D and 3/16"D PATENT STEM TIN DIPPED

PLATE 9



16-$\frac{1}{4}$" D GROOVED STEM-SANDBLASTED BEFORE PLACING IN MOLD
17-$\frac{1}{4}$" D PATENT STEM SANDBLASTED BEFORE PLACING IN MOLD
18-3/16" D PLAIN STEM SANDBLASTING BEFIRE PLACING IN MOLD
19-$\frac{1}{4}$" D PATENT STEM ALUMINUM SPRAYED
20-$\frac{1}{4}$" D GROOVED AND $\frac{1}{4}$"D PLAIN STEM -ALUMINUM SPRAYED
21-$\frac{1}{4}$" D GROOVED AND $\frac{1}{4}$"D PATENT STEM-ALUMINUM SPRAYED
22-3/16" D PATENTED STEM SANDBLASTED BEFORE PLACING IN MOLD

PLATE 10



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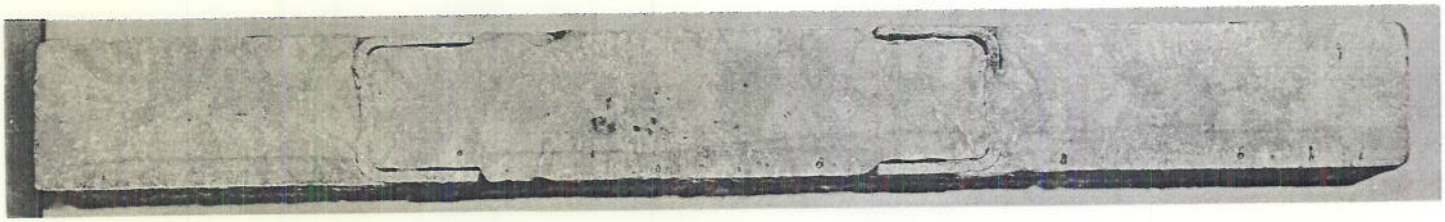

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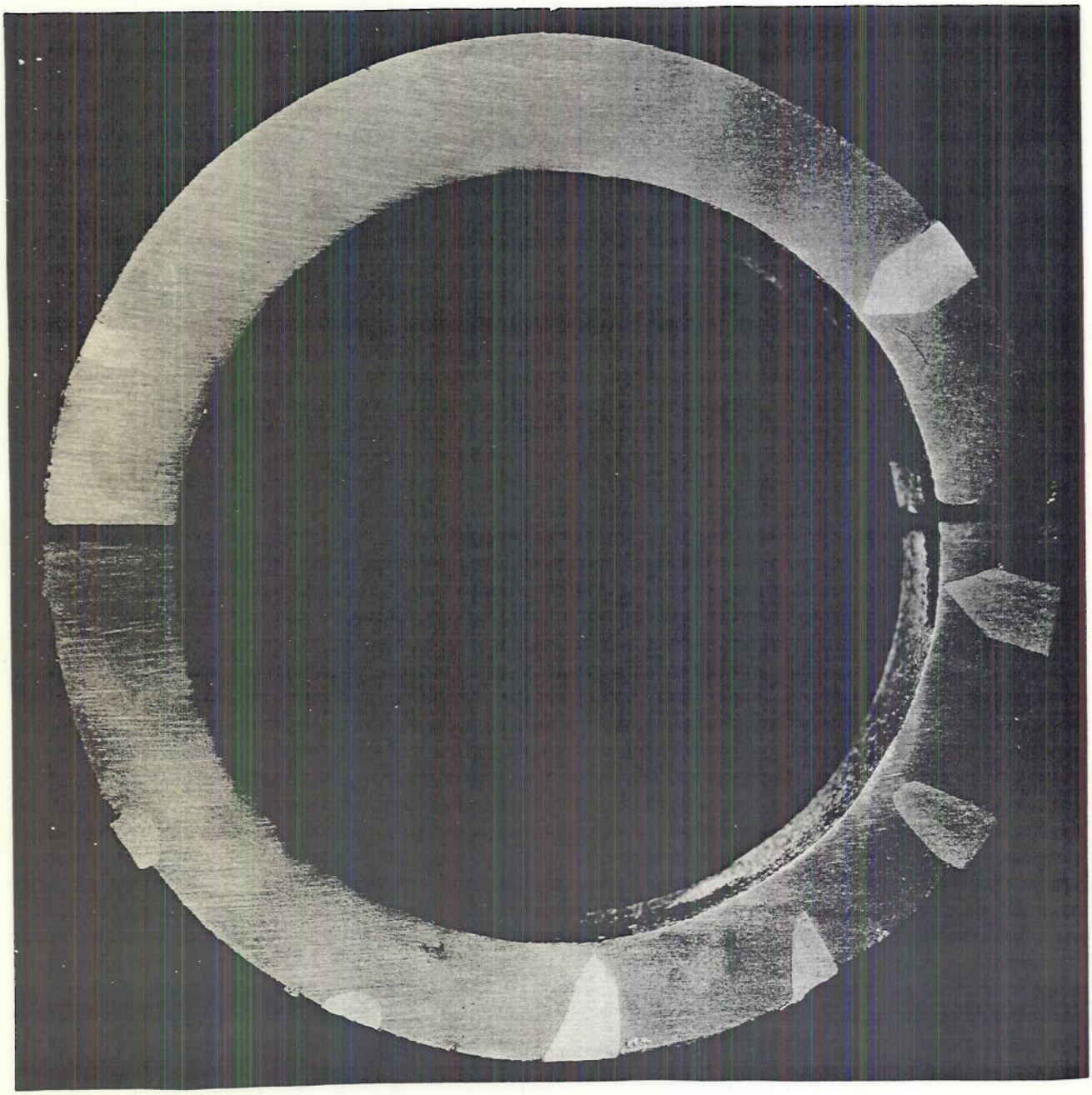
PLATE II



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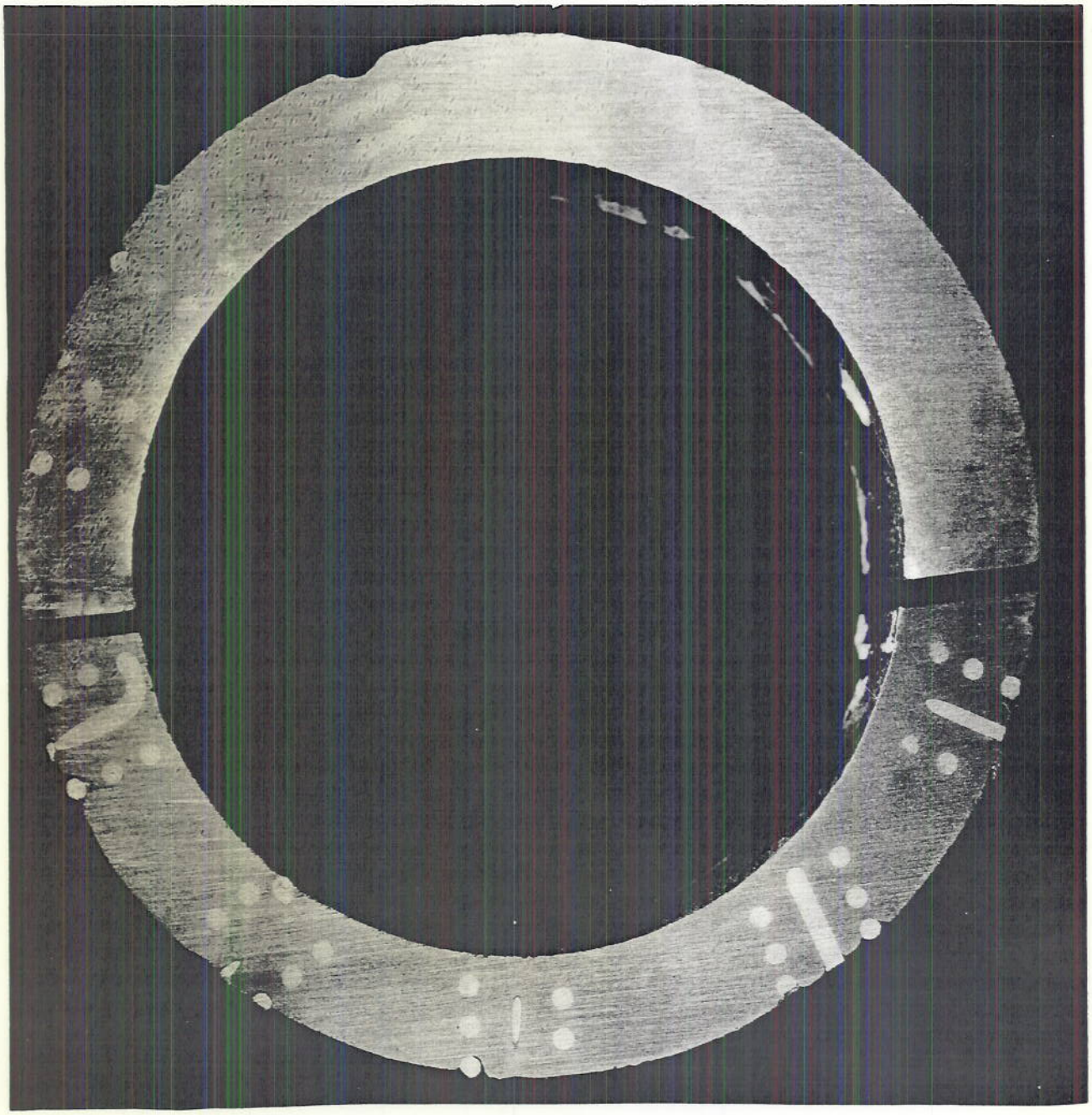

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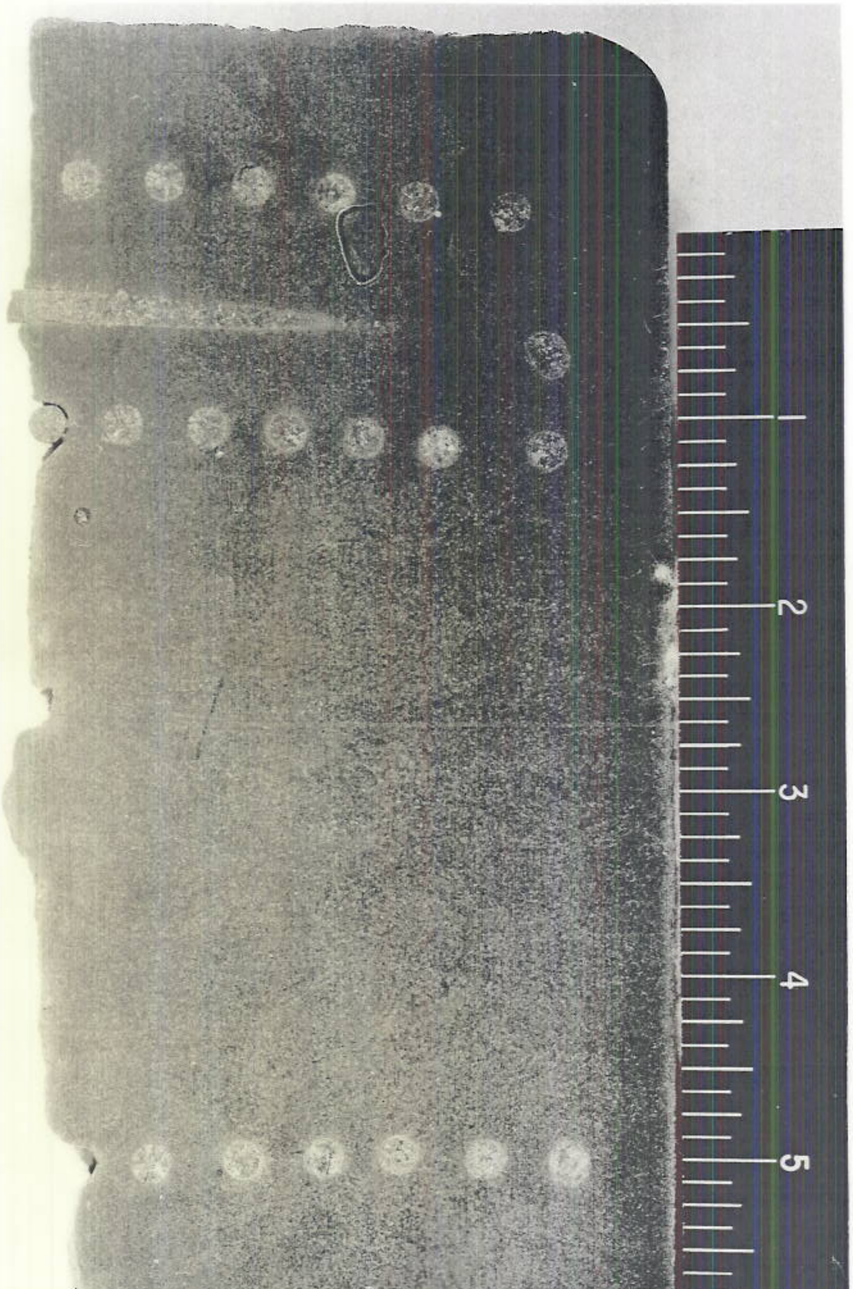

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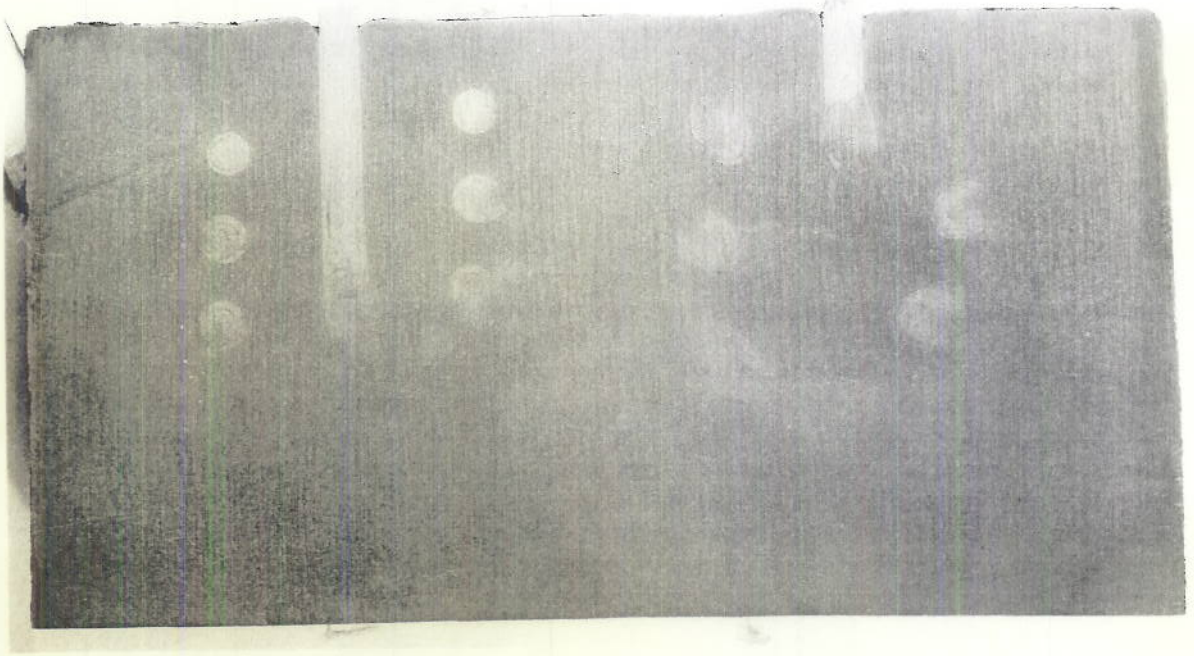

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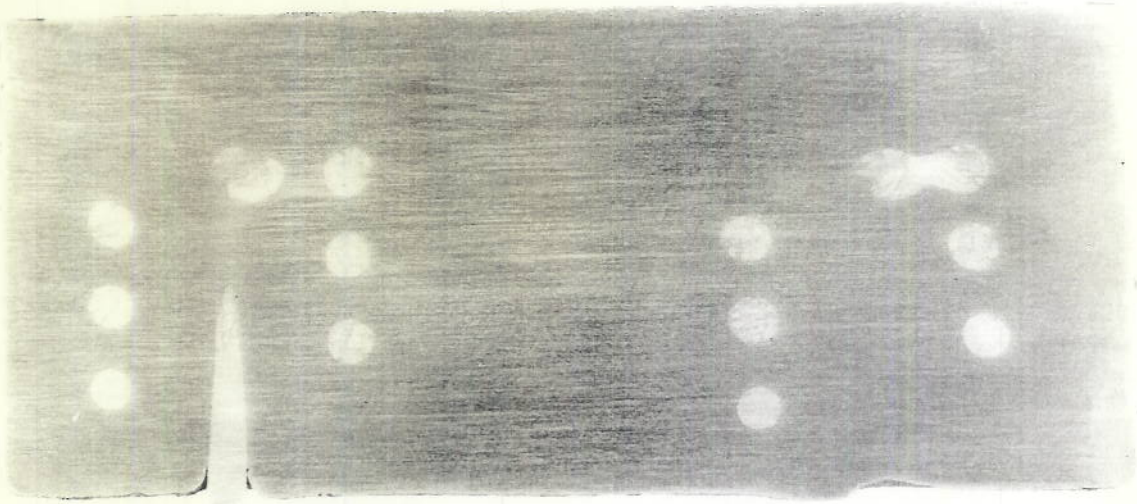

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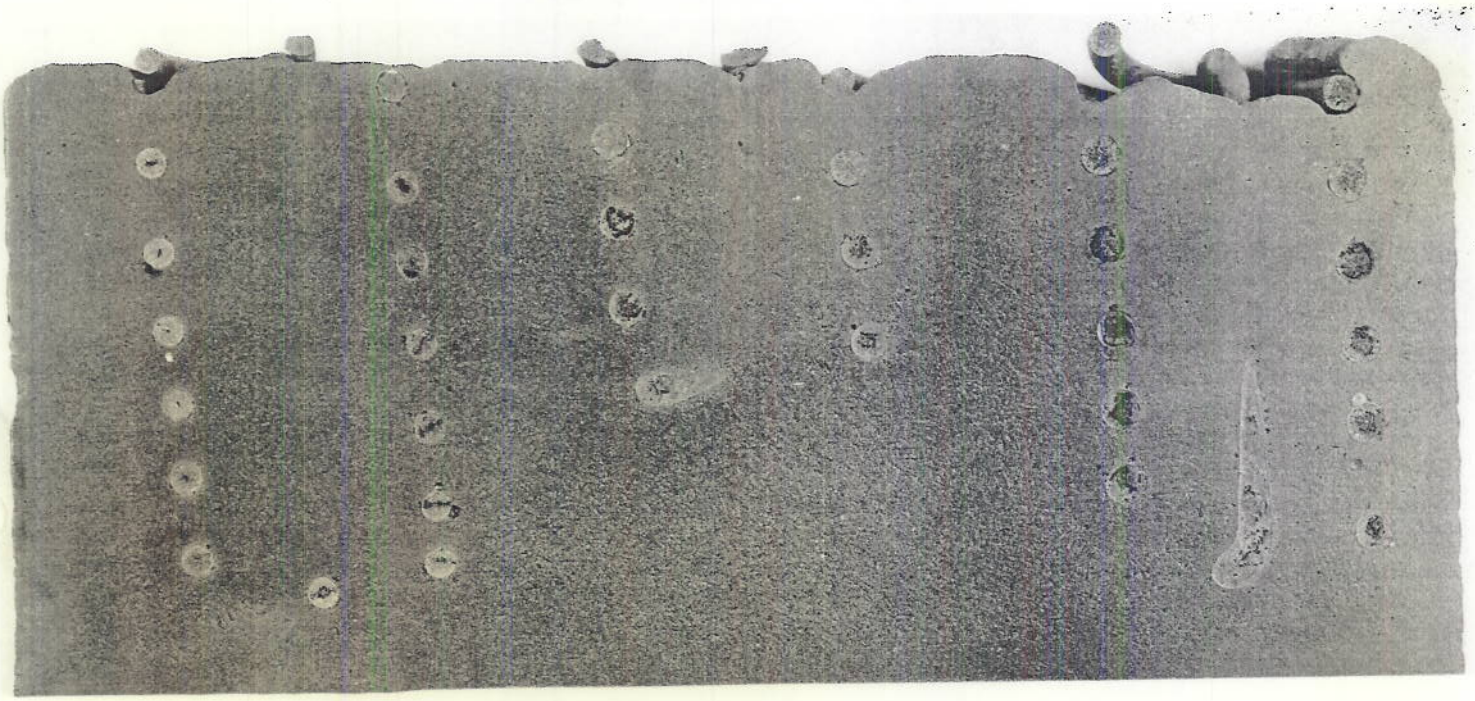
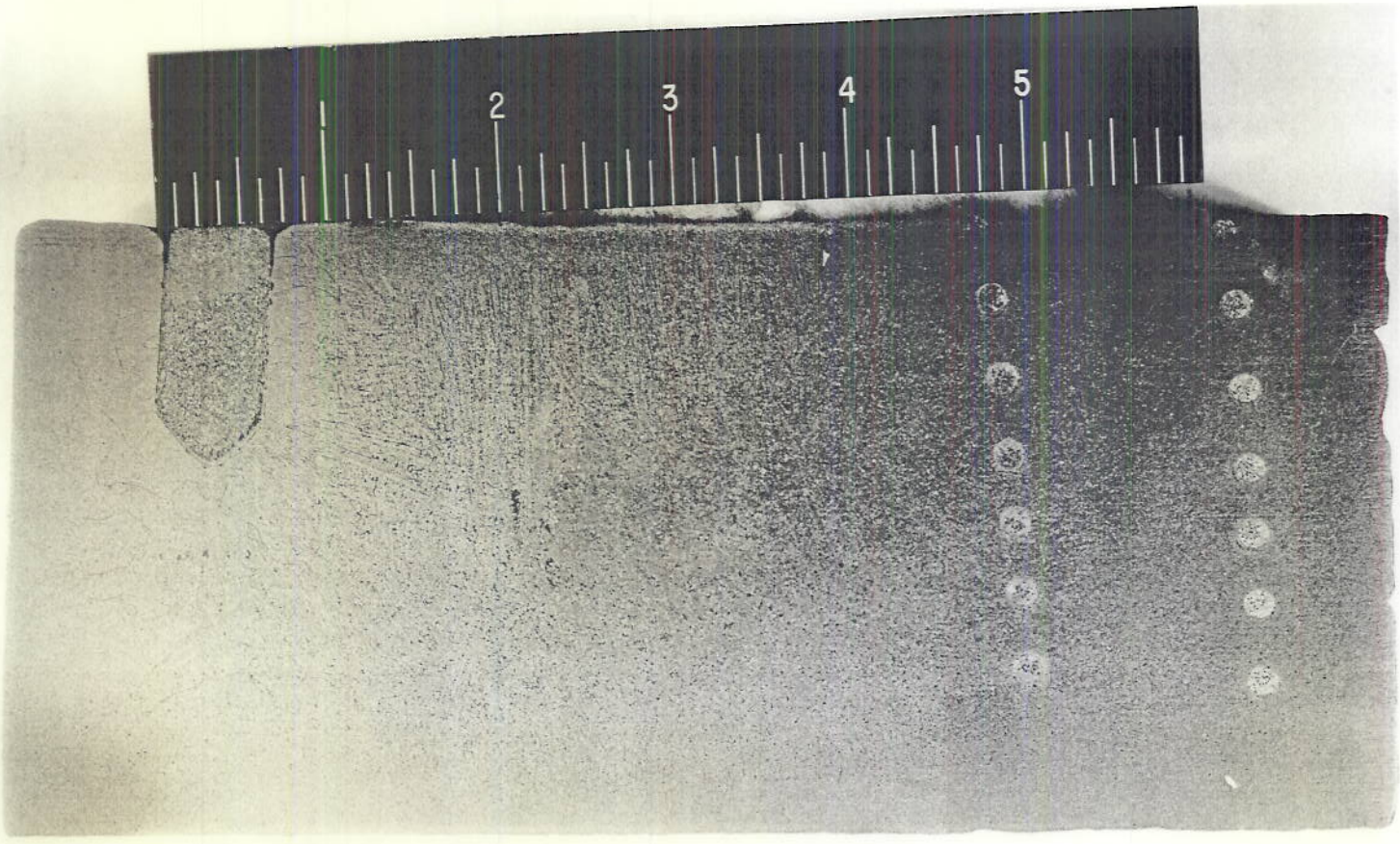
PLATE 15





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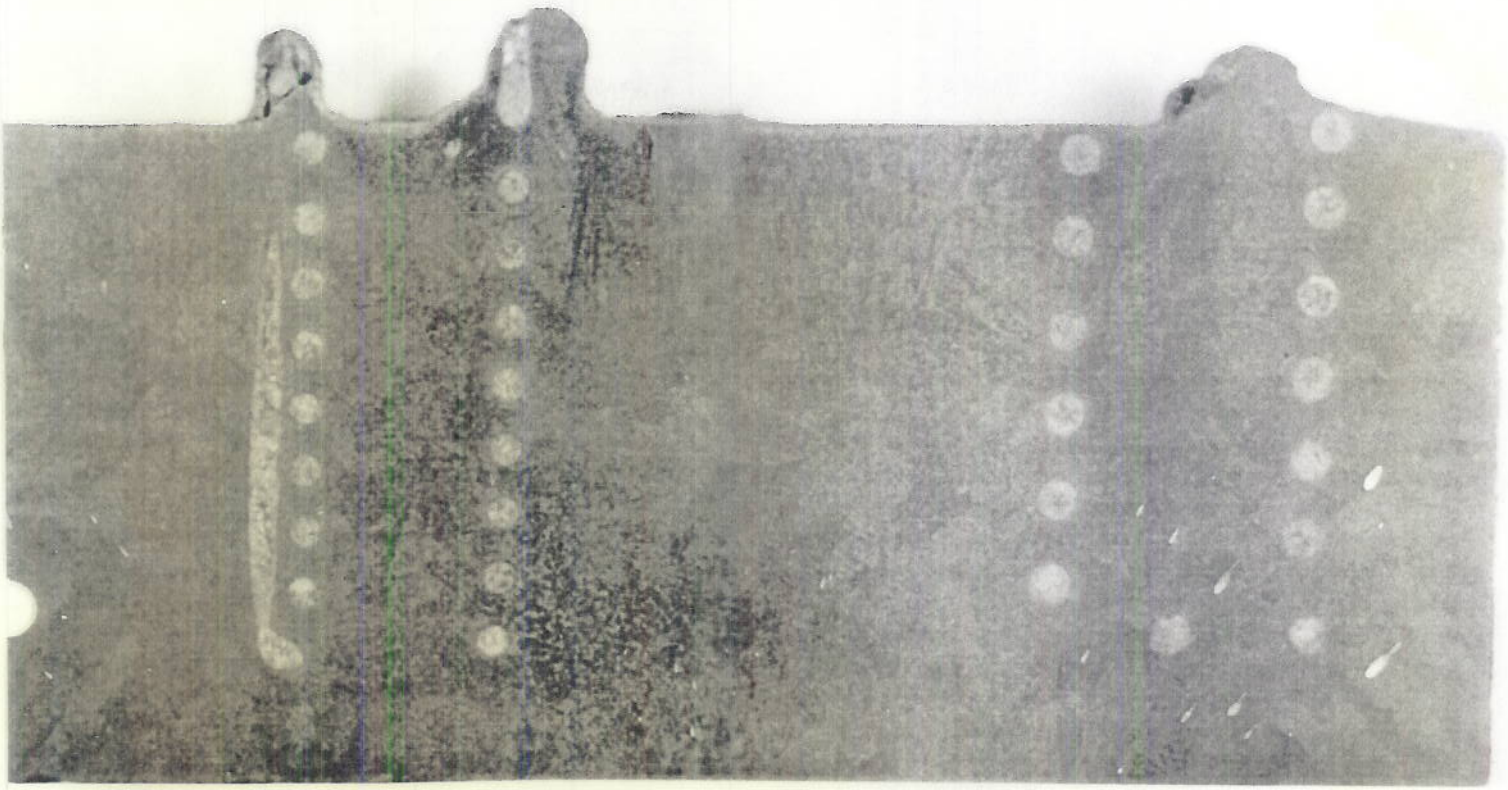

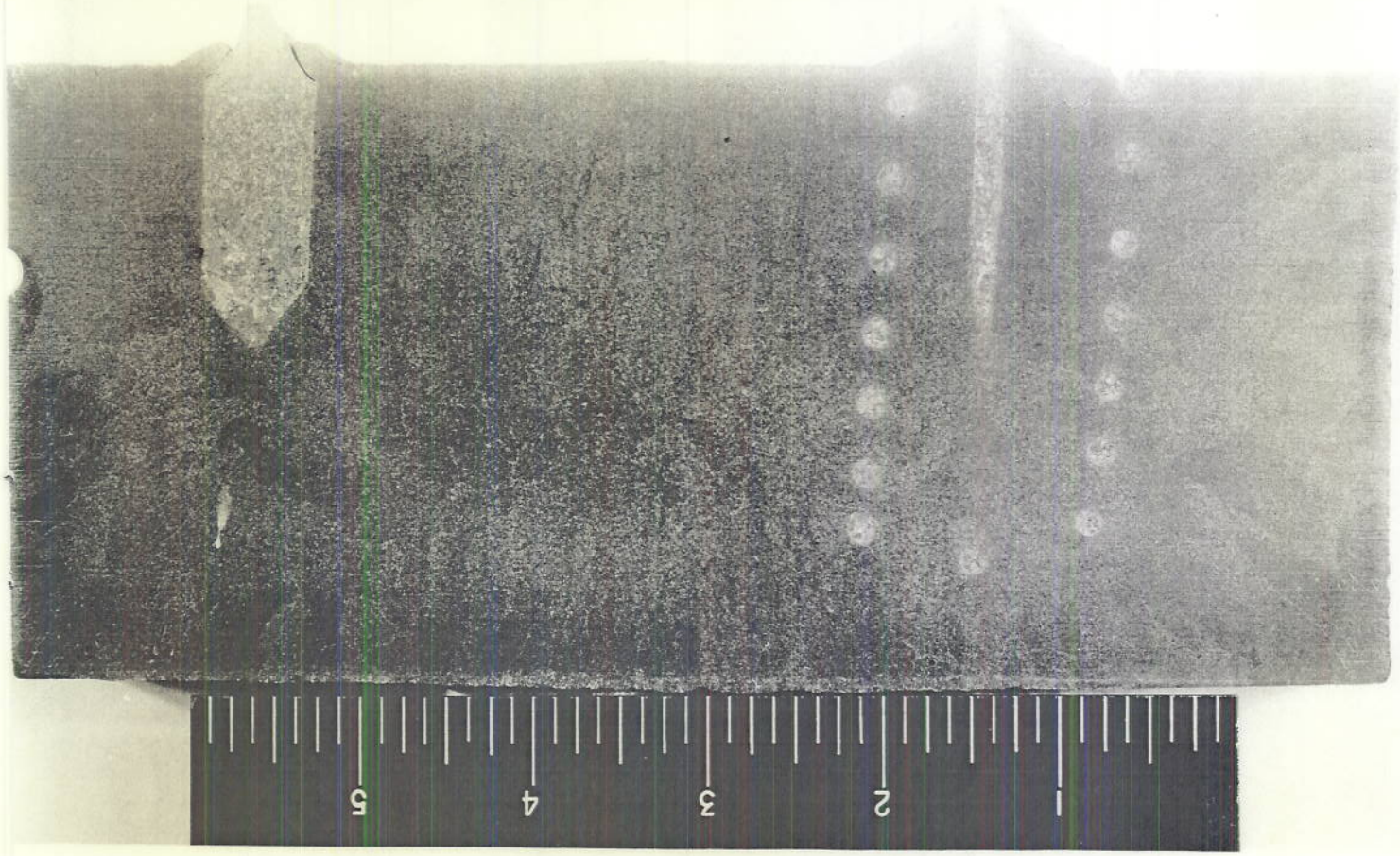

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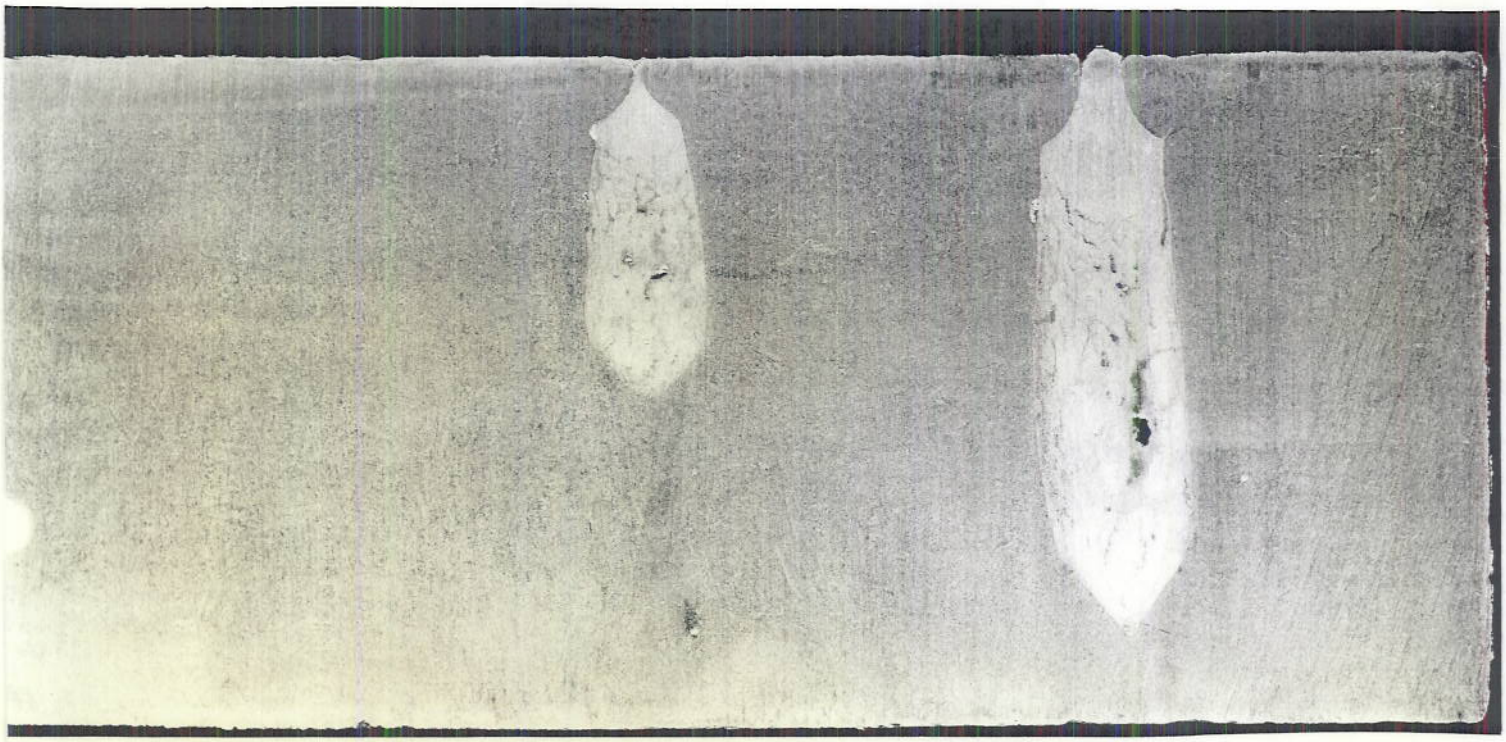

PLATE 18