[illegible] M-1609

DATE [illegible] April [illegible]

SUBJECT

Progress Report II

on

Use of Chaplets in Steel Castings

by

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FR-1609

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NAVY DEPARTMENT

Progress Report II

on

Use of Chaplets in Steel Castings

18-12 S.C.

NAVAL RESEARCH LABORATORY
ANACOSTIA STATION
WASHINGTON, D. C.

Number of Pages: Text: 8 Plates: 14

Authorization: BuEng. let. QP/Castings (6-19-Ds) of 13 July 1928.

Date of Test: February 1940.

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Distribution:
BuEng. and
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ABSTRACT

The influence of chaplets on the soundness and integrity of steel castings is studied using specimens prepared under carefully controlled laboratory conditions. Two sizes of bare, uncoated chaplets in each of three different styles were obtained from the same commercial firm which supplied the material of the initial work presented in Navy Report M-1561. Using different techniques both before and after coating the following surfaces were applied and tested: silver, silver-cadmium, cadmium, copper, and nickel plated; tin and aluminum dipped, calorized, and aluminum sprayed.

The influence of the various coatings was determined under varying conditions of preparation and storage. 1/4" and 3/16" stem diameter types were tested under identical conditions to determine their relative tendencies to fuse satisfactorily. A well dioxidized steel was used in testing a series of badly corroded specimens to determine if the condition of the steel might not be a contributing factor to poor chaplet reaction.

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AUTHORIZATION

1. The studies in steel castings were originally authorized by Bureau of Engineering letter QP/Castings (6-19-Ds) of 13 July 1928.

STATEMENT OF PROBLEM

2. The results of the initial investigation served to point to the need for further information on chaplet behavior in an effort to determine what variables were predominantly operative in causing faulty fusion. It was necessary to check the relative merits of the different styles and types and also to determine the influence of storage and handling. To do this it was necessary to control variables as closely as possible and as a result all specimens were prepared at this Laboratory.

KNOWN FACTS BEARING ON THE PROBLEM

3. From the previous work presented in Navy Report M-1561, the following conclusions were drawn:

(a) Many generally ignored factors operate jointly or individually in causing unsatisfactory operation of chaplets.

(b) More consideration should be given to the preparation and care of chaplet surfaces both before and after plating or processing.

(c) At the present time no information is available in the technical press to aid a foundryman in the judicious choice of chaplet material and coating.

(d) A good grade of low carbon steel is well chosen for chaplet material to be used in steel castings. A properly chosen alloyed or impregnated type can be very useful if employed with care and cognizance of its fusion characteristics.

(e) Threaded stem chaplets did not seem to present any added assurance of fusion and might, in some cases, be deleterious by presenting spaces at the root of the threads for the accumulation of gases. This type does serve to promote a keying action by fusion at the points. This would be an aid in getting the casting past a qualifying test, but without complete fusion at both base and point, the casting might fail in service.

(f) Alloyed chaplet material, in the form of silicon impregnated specimens, fuses readily, but might sometimes melt too prematurely for suitable core support. A certain amount of grain coarsening results in the casting for a small distance around the imbedded chaplet, due to the diffusion of silicon.

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The hardness increases markedly in this high silicon region, but the danger of any failure because of this is probably slight.

(g) The tin dipped series proved better than did the copper series. This was not in accord with the findings of a group of cooperating foundries, the copper series proving best in the estimation of these foundrymen.

(h) Fusion is greatly aided by carbon diffusion from the higher carbon base metal into the chaplet material at the interface. This diffusion lowers the melting point of the chaplet and promotes satisfactory fusion at a clean surface.

(i) The duplication of results attested to the suitability of the test procedure used.

(j) Regarding chaplet stem diameters, there appeared to be no tendency toward an increased fusion of the smaller size. This indicated that the latitude is sufficiently great for practical purposes.

4. The basic material, in the form of bare, uncoated, chaplets, was again donated by the Fanner Manufacturing Company. These were of the coarse thread, superstem, and plain stem styles of both 1/4" and 3/16" stem diameter. Plate 2 shows these together with a Reeder type which was not received in time for testing.

EXPERIMENTAL PROCEDURE

5. The work was laid out and chaplets prepared in such a way as to answer (or at least indicate a trend) the following questions:

(1) What, if any, is the influence of chaplet cleanliness before plating or dipping? Should the base material be sandblasted before coating, or would a simple electrocleaning treatment, as normally practiced, be sufficient to remove all deleterious surface scales or films?

(2) What would be the difference in efficiency between chaplets prepared under ideal conditions and kept in a desiccator and similar ones allowed to remain on the foundry floor free to collect dust and moisture?

(3) What would be the difference in fusion characteristics between the 1/4" and the 3/16" stem diameter types placed in identical metal sections and poured at the same metal temperature? Would the smaller show any marked advantage?

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(4) What would be the relative abilities of the various types of coatings to withstand the corrosion normally encountered in storage and use?

(5) What would be the influence, if any, of metal analysis and state of deoxidation of the fusion of badly corroded or unclean chaplets? In other words, could a certain amount of poor chaplet reaction be blamed on steel composition?

(6) What further evidence can be obtained regarding the effect of stem design?

(7) And lastly, what are the relative merits of different possible coatings weighed in the light of experimental and practical values?

6. To shed light on the above questions the bare chaplets as received from the manufacturer were treated in series as follows:

(1) 1/4" coarse thread style - sandblasted - electrocleaned, coated, and kept in desiccator until used.

(2) 1/4" coarse thread style - electrocleaned, coated and kept in desicator until used.

(3) 1/4" coarse thread style - sand blasted, electrocleaned, coated and left on the foundry floor free to dust and moisture.

(4) 1/4" plain stem style - sandblasted, electrocleaned, coated and kept in desiccator until used.

(5) 3/16" plain stem style treated same as (4)

(6) 1/4" superstem style treated same as (4), but placed in a washed green sand mold prior to drying and cast in a high silicon steel.

7. In treatments (1) to (5) inclusive the following coatings were employed - silver plate, silver-cadmium plate, cadmium plate, copper plate, nickel plate, tin dip, calorized, and aluminum dip. In treatment 6, however, the cadmium plated piece was eliminated on the basis of past behavior and an aluminum sprayed chaplet substituted.

8. The pouring procedure was identical to that outlined in Report M-1561 and the temperature of pouring 2900°F. This time, however, in the interests of constant conditions, the eight specimens shown in the figures were placed in a single mold. Two were equally spaced in the same relative position in each arm of the test piece that one had occupied in the earlier work. Plate 1 shows a photograph of the actual mold used in the experiments with the chaplets in place. This particular one was washed and dried whereas all other

series were poured in green sand molds. The analysis of the metal for the work of Plates 3 to 12 inclusive was C - 0.21%, Mn - 0.65%, Si - 0.34% while the series of Plates 13 and 14 were from a high silicon steel - C - 0.17%, Mn - 0.62%, and Si - 1.15%.

DISCUSSION OF RESULTS

9. From a comparison of Plates 3 and 5 there seems to be a trend in favor of the specimen being sandblasted before coating. Whether this is the influence of metal scale or some film built up during forming the chaplet stock, which is not removed by electrocleaning is not known, but it is certain that there exists a very noticeable difference in the appearance of the two surfaces. In the case of the tin dipped chaplet the fusion was better in the piece which was not sandblasted. Either extreme condition could prevail depending on the surface condition and previous treatment.

10. Plates 3 and 7 afford a comparison to be made between chaplets kept ideally clean and ones similarly prepared but exposed to conditions of foundry storage. It must be noted that these conditions were not nearly as aggravated as those usually encountered in the average foundry since they stood exposed only for a matter of 3 weeks and the foundry was not extremely dusty. However, there seems to be enough difference to indicate that cleanliness and care in storage are matters for attention. Several of the chaplets tarnished very noticeably in the time allowed.

11. In plates 9 and 11 can be seen the relative influence of chaplet stem diameter. By paying special attention to the longitudinal sections cut lengthwise of the chaplet stem there is an overall better fusion of the smaller type. At the same time a glance at Plate 12 shows that probably a satisfactory amount of unmelted chaplet remains to support a core. However, the difference in fusion is slight as was shown to be the case in the initial work. It is fortunate that this latitude exists. What might be the case of metal poured markedly colder or hotter can only be postulated. The etched examples tend to show that the smaller chaplet does not disturb the grain structure as much as the larger one but this is no doubt unimportant.

12. To check the corrosion resisting characteristics of the various coatings specimens were placed outside the window and subjected to the changing climatic conditions of wind, rain, snow and sun. Also the series dried in place in the washed green sand mold gave further evidence. In general, and only from visual estimation, it can be said that the ability of the various coatings to prevent corrosion is about as indicated in the electromotive series of metals. That is in the order of decreasing resistance they could be placed aluminum, cadmium, tin, nickel, and copper with silicon impregnation in some position near the top of the list.

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13. It must be borne in mind that not only must a coating be corrosion resistant but it must also be continuous. A porous covering can be very deleterious because of rust or moisture accumulating on the unprotected portions. Thus the care and technique of preparation can play an important part, as well as the density of the coating.

14. It was thought that perhaps a certain amount of chaplet trouble might be the result of the chemistry of the steel poured around it. As a result a mold was prepared in green sand, painted heavily with a mold wash, chaplets placed in position, and the whole dried slowly in a core oven. This gave the chaplets an aggravated condition for corrosion and there was no doubt concerning the efficiency of the medium. Every porous spot rusted badly and certain of the specimens were completely covered. When used in a casting they would present the worst possible condition. A well-killed steel containing 1.15% Si (analysis above) was used for the casting and Plates 13 and 14 show the result. In spite of the apparently bad surface condition of the chaplets nearly every one fused satisfactorily. Also from Plate 14 it appears that silicon has diffused from the base metal into the chaplet stem. Such was found to be the case by micrographic analysis. No doubt a better deoxidizing practice would lead to less trouble from chaplets and internal chills. A high silicon heat was used because it was readily available from other work being done at the time and not because it was a particulrly practical commercial analysis. It should be representative of a well-deoxidized steel, however. Further work using special deoxidizers would be valuable..

15. The effect of the two extremes of stem design, i.e., the coarse thread and the plain stem type are portrayed in Plates 3 and 9. Under the conditions of these tests there is very little difference noticeable but this might be expected since the chaplets were handled under ideal conditions. Therefore, no accumulation of gases or dust would be able to collect in the depressions. In the plain stem type there was a tendency for the porous spots to localize at the junction of the stem and head of the chaplet whereas, while the same tendency is usually shown in all cases, there generally appears an increased number of holes near the base of the "V's" in the coarse thread type.

16. It was hoped that the experimental evidence might be conclusively in favor of one or more of the coatings tried. This would have allowed a classification into some definite order on the basis of practical operation. While the present work does not clear this issue up entirely the results do show very definitely in favor of certain ones over others

17. For example, it can readily be seen that the silver coated chaplets functioned very well under all the test conditions. It might not, however, be enough better than copper, nickel, or aluminum to merit its extra cost. This coating was tried on the basis of the absorbing power of silver for gases. It was thought that perhaps the coating would absorb such gases as seemed to be quite generally present at cast metal-

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chaplet interfaces. It is seen that a silver plated chaplet would function properly and would certainly present no problem by solution into the base metal.

18. In the interest of increased corrosion resistance a specimen was tried with a layer of silver covered by a layer of cadmium, the latter having excellent corrosion resistance. This would permit advantage to be taken of the gas absorbint power of silver and at the same time provide a corrosion resistant coating. This type was not satisfactory because of the influence of the cadmium which has a high vapor pressure and produces extensive blowholes as a result of its volatilization. In four of the tests this type was quite good but was not dependable as two cases showed up unsatisfactorily.

19. From these tests it appears that cadmium is not suitable as a chaplet or internal chill covering.

20. The copper plated series proved very satisfactory in all tests except the one employing the specimens which had been kept on the foundry floor to collect dust and moisture. From the standpoint of convenience and economy this type or the nickel plated type would be the best choice. Copper plated surfaces, if not carefully stored, will oxidize to a considerable extent and often because of the porous nature of the coating as plated some iron oxide will build up. However, with reasonable care in handling this should provide a satisfactory chaplet.

21. Like copper, nickel seems to give consistent and fully satisfactory results. The choice of chaplet material and cleanliness of surface, as well as stem diameter no doubt accounts for the failure of some nickel flashed internal chills to fuse properly. Perhaps a certain amount can be laid to the condition of the steel.

22. Contrary to the results of the work on the commercially plated specimens, the tine dipped chaplets were not consistently satisfactory. There is some reticence on the part of many foundrymen to use tin since they believe it to be deleterious to the steel. Lacking any definite data on the subject, it is impossible to say what the exact influence might be, but on the basis of general observations one is lead to believe that what small amount would be washed from chaplets would not seriously effect the physical properties of the casting. In trials at various foundries tin was not found as suitable for a coating as copper in regard to fusion characteristics.

23. Aluminum dipped and calorized chaplets were not sufficiently good to merit the extra expense in preparing. Aluminum dipping is not an easy matter and such a process has not been commercially developed. It would seem that the calorized (aluminum impregnated) chaplet would fuse rather readily in the manner of the silicon impregnated variety. However, such was not the case but the layer of aluminum rich iron was extremely thin. Further work on the aluminum impregnated variety will no doubt prove of value.

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24. Aluminum sprayed chaplets were prepared by thoroughly sand blasting and spraying with a metallizing gun. It is imperative in this instance that the base material be perfectly free of dirt or grease or the sprayed layer will not adhere. A trial was made with chaplets as received and not sandblasted but the sprayed metal would not adhere. Plates 13 and 14 show the nearly perfect fusion of the only specimen tried. While expensive and troublesome to prepare, this type may yet prove of practical importance. Because of its value as a powerful deoxidizer, this type would no doubt function equally as well in steels which were not fully killed. This type has excellent corrosion resisting properties as well.

SUMMARY AND CONCLUSION

25. The conclusions formed from this second part of the investigation are listed below. The general results of the initial work are included at the beginning of this report as "Known Facts Bearing on the Problem". These conclusions will not be restated here unless some modification is necessary.

26. The tin dipped series of this investigation did not give good fusion in every trial as was the case in the initial testing. More work will be necessary to definitely state a reason for this.

27. Copper and nickel plated chaplets proved consistently satisfactory and with the possible exception of tin, these would be the most economical and convenient to obtain.

28. The ideal manner of preparing chaplets would be to obtain a base material of satisfactory analysis, sandblast the surface prior to use, and then apply the coating desired. Stock supplies made up ahead of time would be perfectly satisfactory if the maximum care could be exercised in their storage and handling, paying careful attention to keeping them as free as possible of dust and moisture. In many instances, sandblasting might be unnecessary, but it is one way of being on the safe side and the surface is then in the best possible condition for receiving a plated, dipped, or sprayed coating.

29. Silver plated specimens included in this work appeared to be very satisfactory in all instances. The corrosion resistance of the silver is not as high as desirable and its cost might prohibit its general use. It would have to prove overwhelmingly better than any of the others to merit its added expense. From these tests it is safe to propose that other less expensive surfaces, if properly employed, would serve equally as well as silver. It might be added that any deleterious effects of the silver in not being appreciably soluble in steel would be inconsequential. In a finely dispersed form, steel is often improved by the presence of silver.

30. The difference between the fusion characteristics of the 3/16" and 1/4" stem diameters was slight with the smaller perhaps showing to somewhat the best advantage.

31. Chaplets stored in an open place on the foundry floor gave inferior fusion characteristics when compared to those kept ideally clean.

32. A consistent tendency was shown for porous areas around imbedded chaplets to segregate in internal angles and at sharp corners. The elimination of such places by streamlining chaplets would possibly be very advantageous.

RECOMMENDATIONS FOR FUTURE WORK

33. As time permits, it is planned to conduct tests, using the technique disclosed above, which may eventually lead to the development of some chaplet and internal chill coating meriting a recommendation above all others.

34. More work is needed on the impregnated types since they will undoubtedly prove of value in many classes of work. The melting point of the surface layer can be varied by the choice of element and depth of the case. It is proposed to write to various companies operating the impregnating processes and ask their cooperation in preparing specimens as desired using their standard methods. Carburized, calorized, and silicon impregnated varieties will be tried.

35. The design of the chaplet will be varied to eliminate the sharp corners and internal angles and determine fully to what extent chaplet behavior can be improved by attention to this feature.

36. Since the work on chaplets is equally as applicable to internal chills, the development of a coating satisfactory in all respects will enable fundamental studies and subsequent calculations to be made on proper chill diameter-metal section ratios. By employing the accurate temperature measurements available at this Laboratory and varying pouring temperature, casting section, and chill diameter in a systematic order, many pertinent foundry questions can either be answered or simplified. Heretofore, lack of a suitable chill coating often interfered with the interpretation of results.

37. Aluminum sprayed surfaces will be tried in detail as it is felt that this should be an excellent type. Calorized cases also merit further study.

38. The state of deoxidation of the steel is a contributing factor to chaplet reaction. The well killed steel used in testing a series of badly corroded specimens fused the chaplets satisfactorily in spite of their very poor surface condition. More work along these lines will be of both practical and academic value.

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Plate 1 unavailable

(None in Archives copy. If and when one can be obtained, it will be taped in this place)

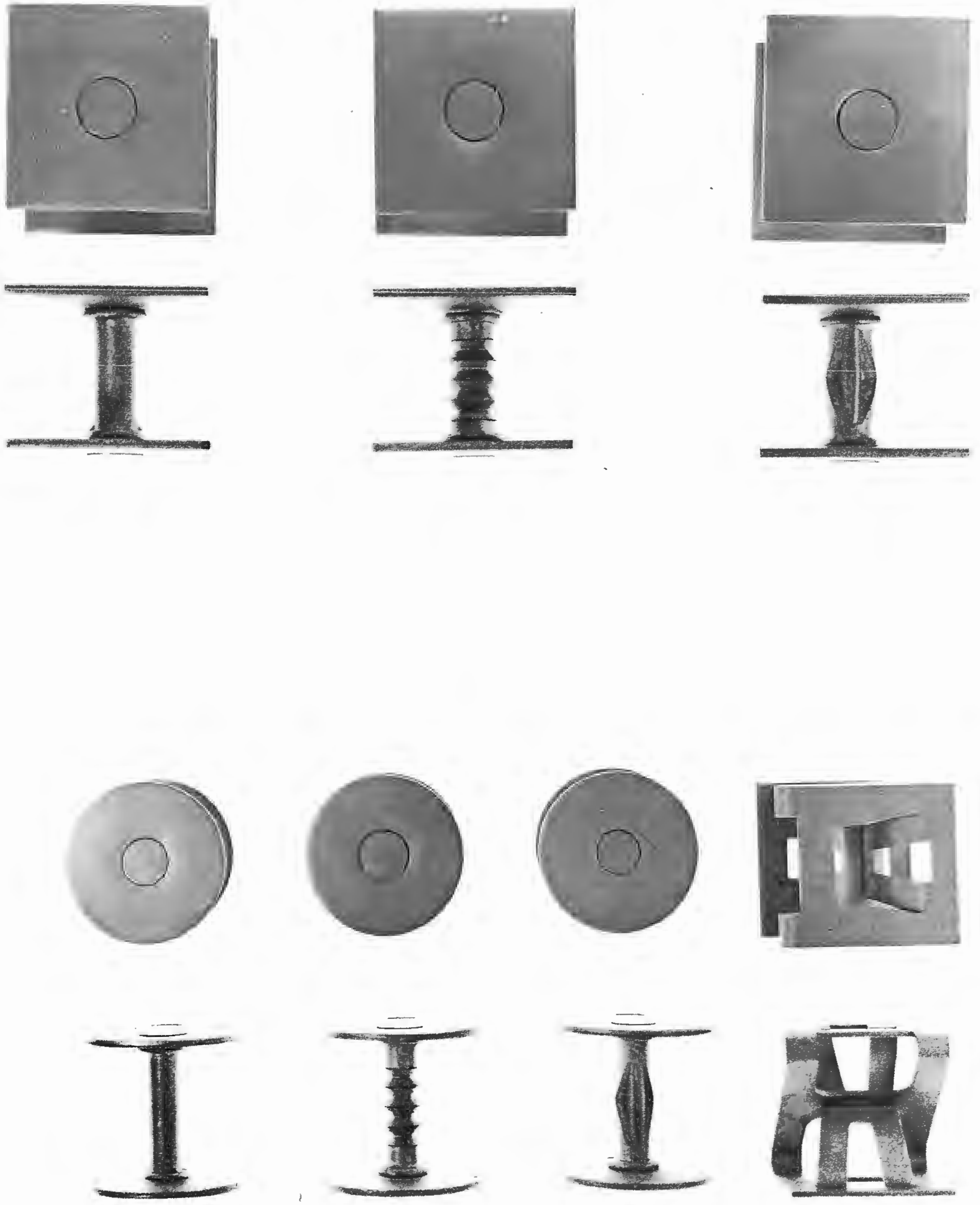
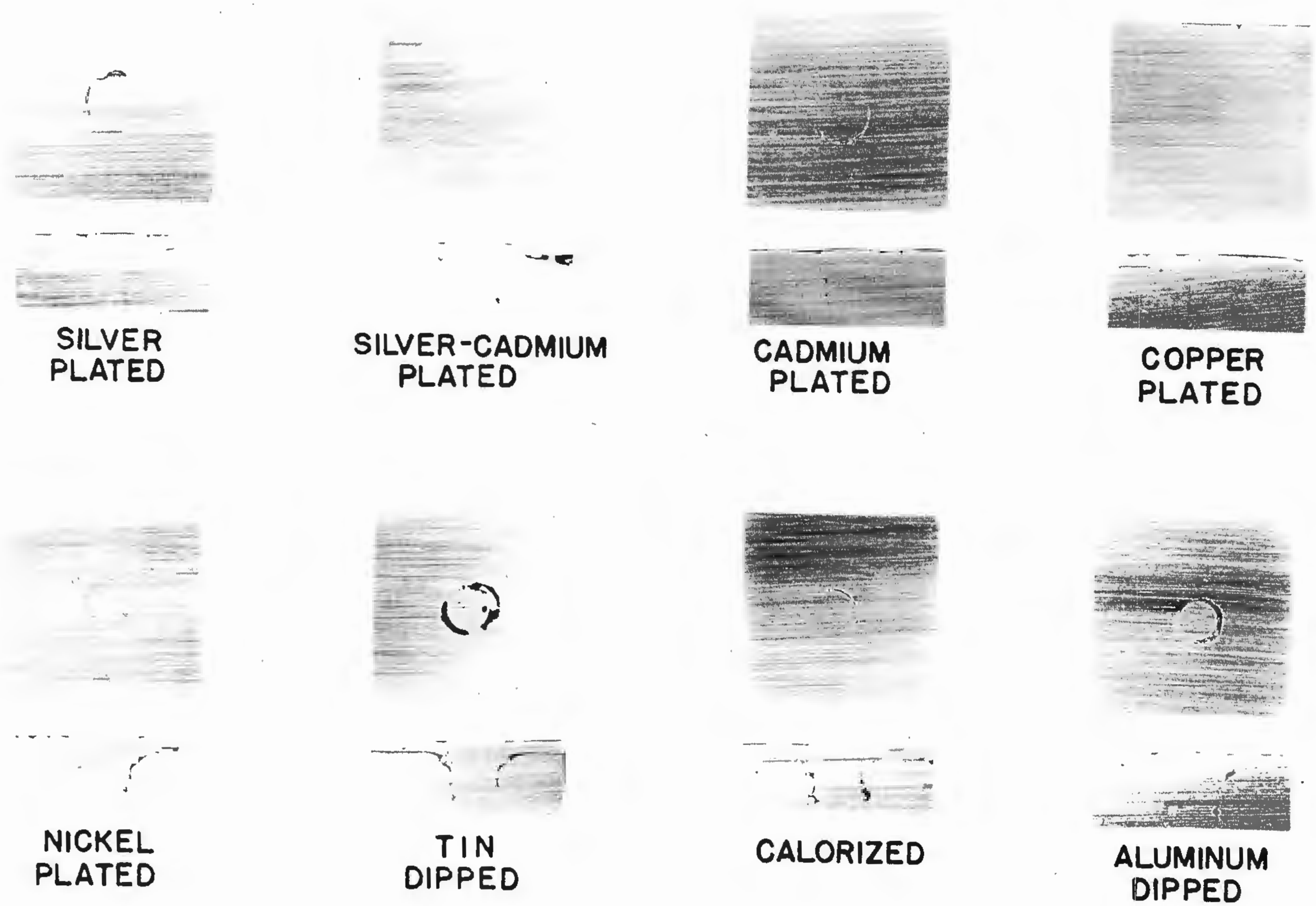
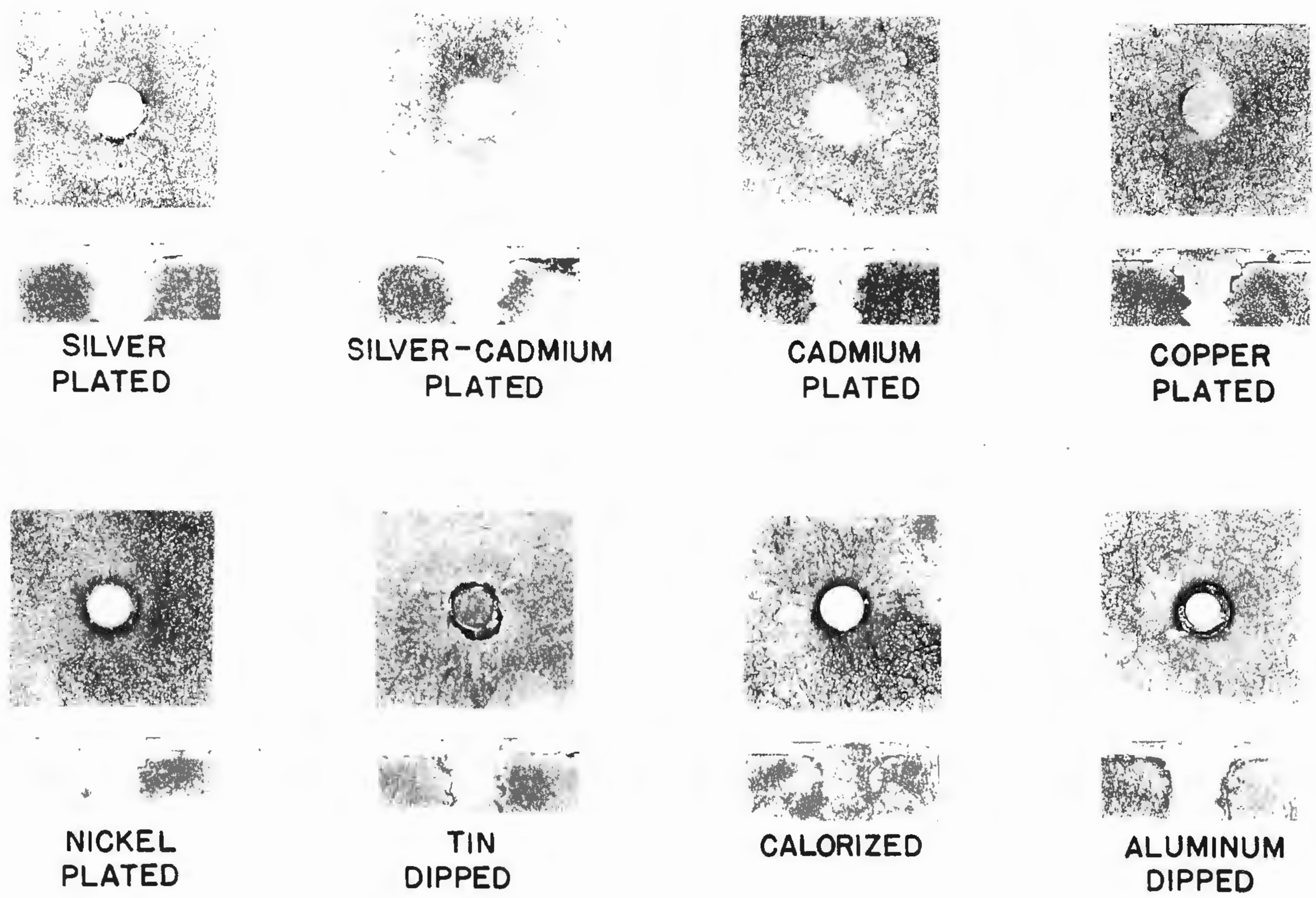


PLATE 2

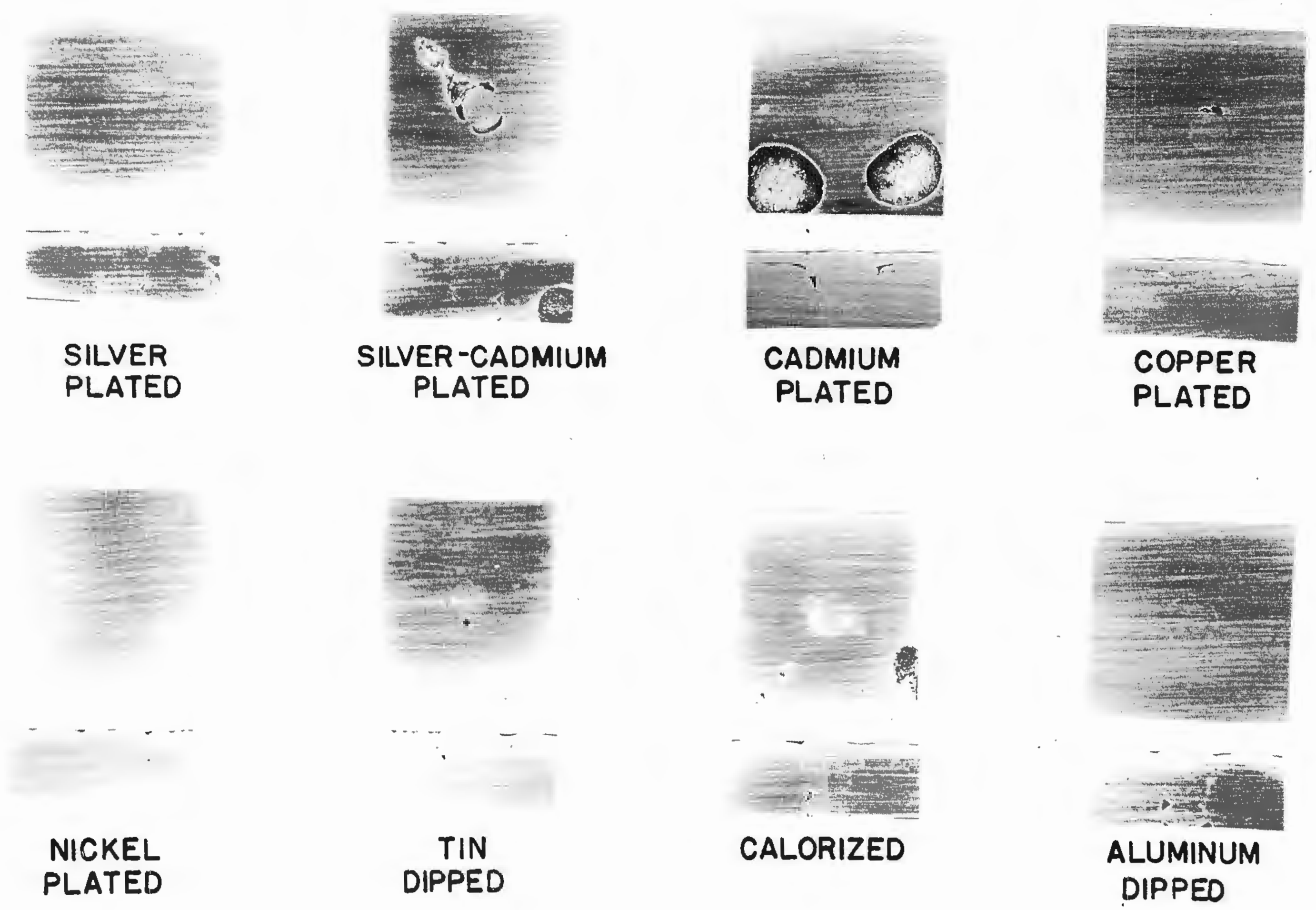


INFLUENCE OF SURFACE COAT ON 1/4" X 1" X 1-1/4" SQ. HD. THREADED STEM CHAPLET—SANDBLASTED BEFORE COATING AND KEPT IN DESSICATOR

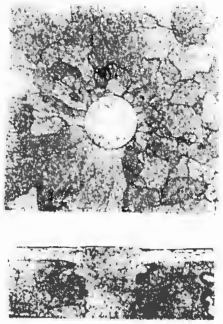


INFLUENCE OF SURFACE COAT ON 1/4"X 1"X 1-1/4" SQ. HD.
THREADED STEM CHAPLET — SANDBLASTED BEFORE COATING
AND KEPT IN DESSICATOR
ETCHED WITH 3% NITAL

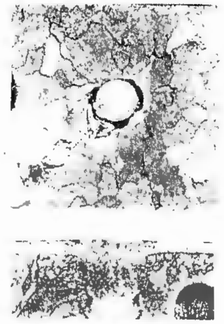
PLATE 4



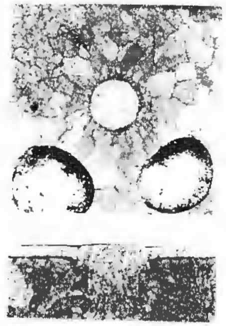
INFLUENCE OF SURFACE COAT ON 1/4" X 1" X 1-1/4" SQ. HD. THREADED STEM CHAPLET — PREPARED AS RECEIVED AND KEPT IN DESSICATOR



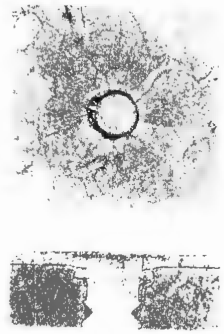
SILVER
PLATED



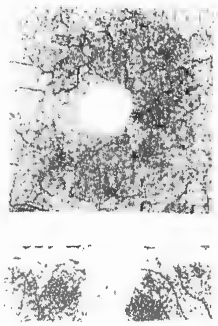
SILVER-CADMIUM
PLATED



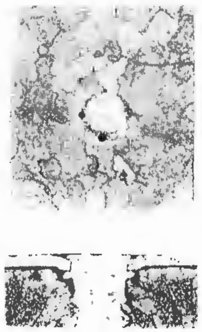
CADMIUM
PLATED



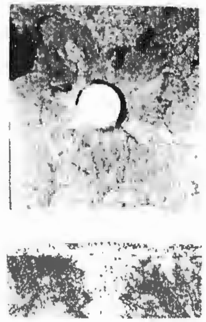
COPPER
PLATED



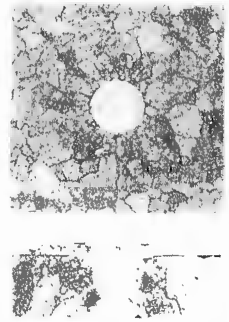
NICKEL
PLATED



TIN
DIPPED



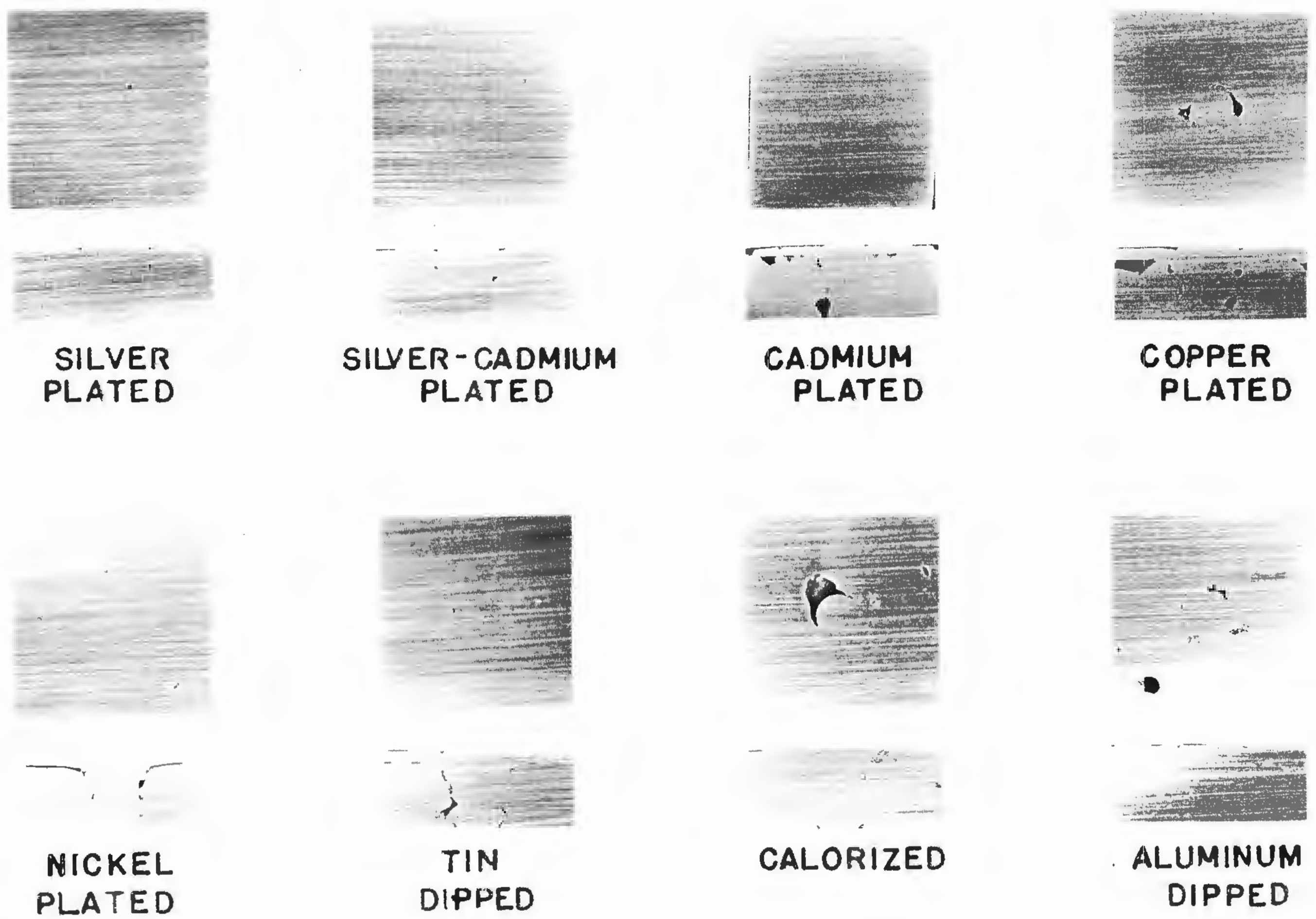
CALORIZED



ALUMINUM
DIPPED

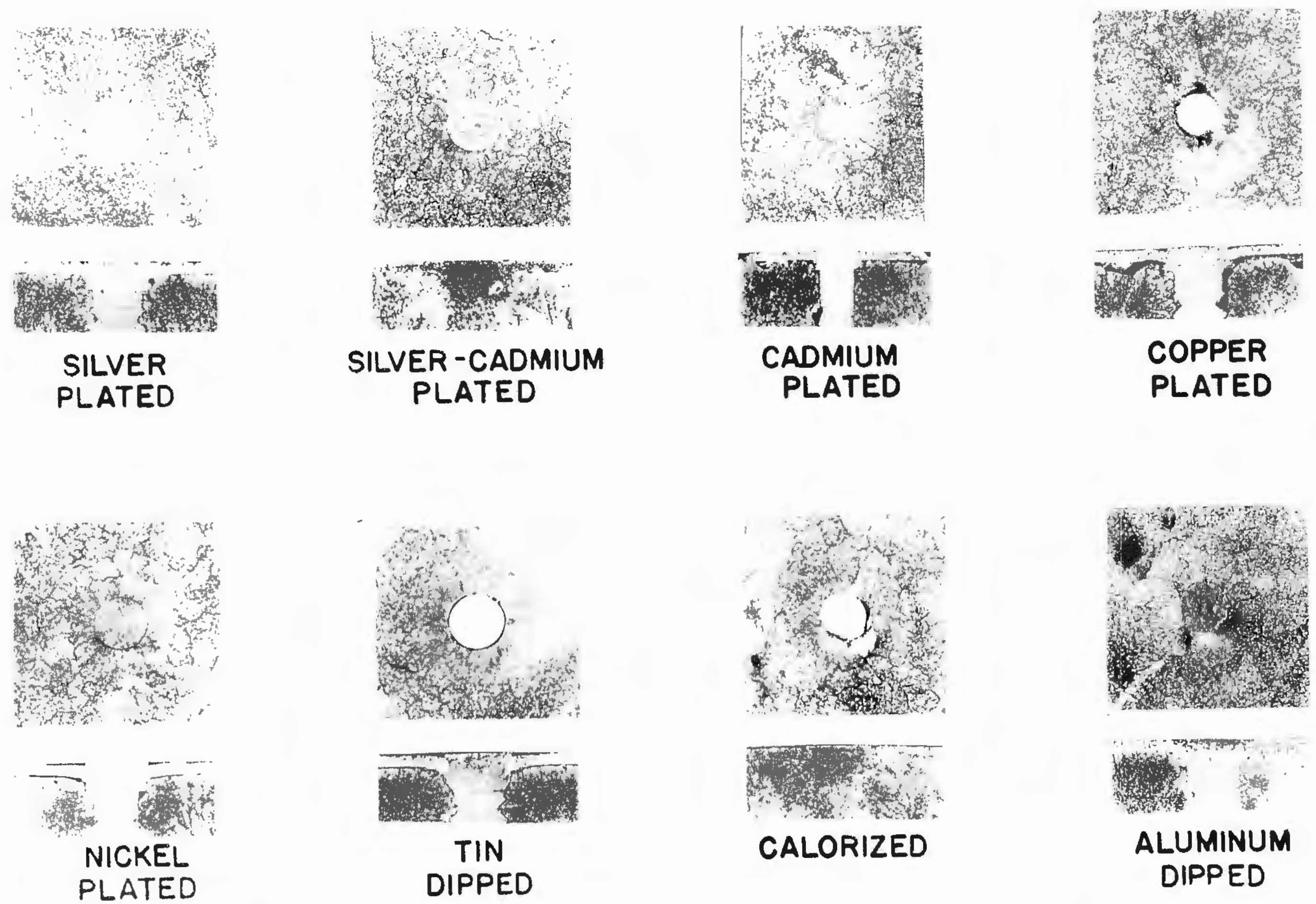
INFLUENCE OF SURFACE COAT ON 1/4"X 1/4"X 1-1/4" SQ. HD.
THREADED STEM CHAPLET—PREPARED AS RECEIVED
AND KEPT IN DESSICATOR
ETCHED IN 3% NITAL

PLATE 6

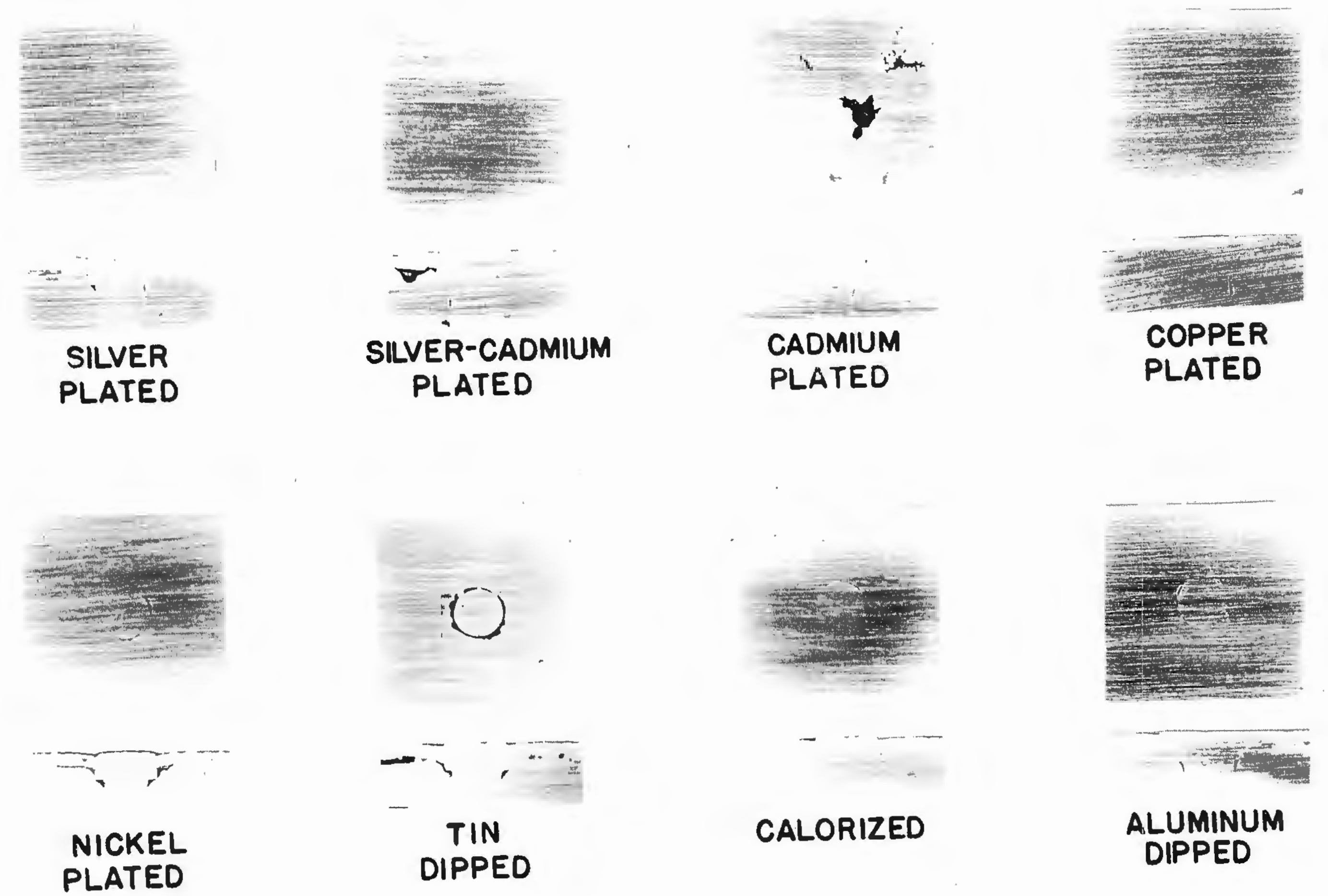


INFLUENCE OF SURFACE COAT ON 1/4" X 1" X 1-1/4" SQ. HD. THREADED STEM CHAPLET -- SANDBLASTED BEFORE COATING AND KEPT IN FOUNDRY

PLATE 7

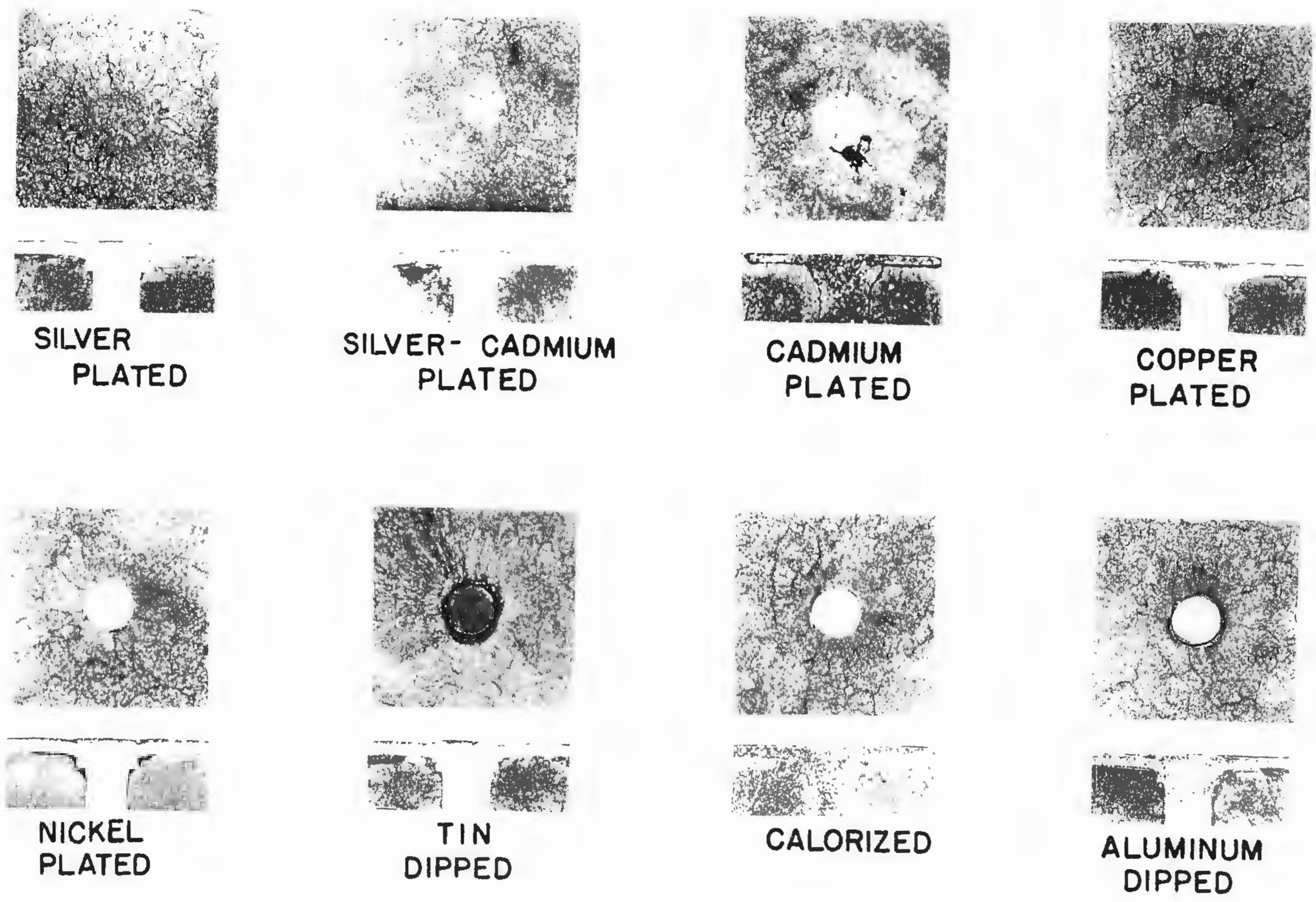


INFLUENCE OF SURFACE COAT ON 1/4" X 1/4" X 1-1/4" SQ. HD. THREADED STEM CHAPLET— SANDBLASTED BEFORE COATING AND KEPT IN FOUNDRY
ETCHED IN 3% NITAL



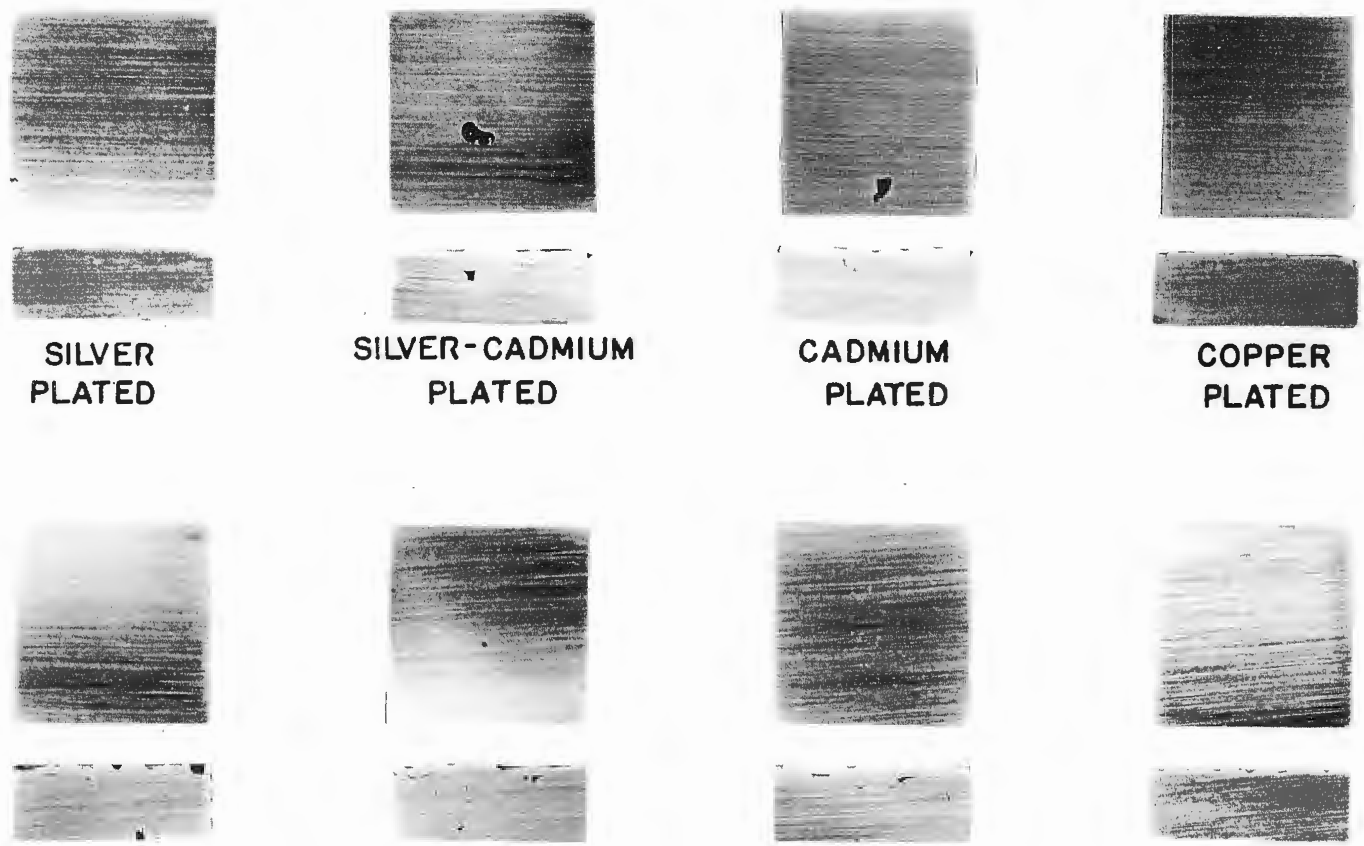
INFLUENCE OF SURFACE COAT ON 1/4"X 1"X 1-1/4" SQ.HD. PLAIN STEM CHAPLET—SANDBLASTED BEFORE COATING AND KEPT IN DESSICATOR

PLATE 9



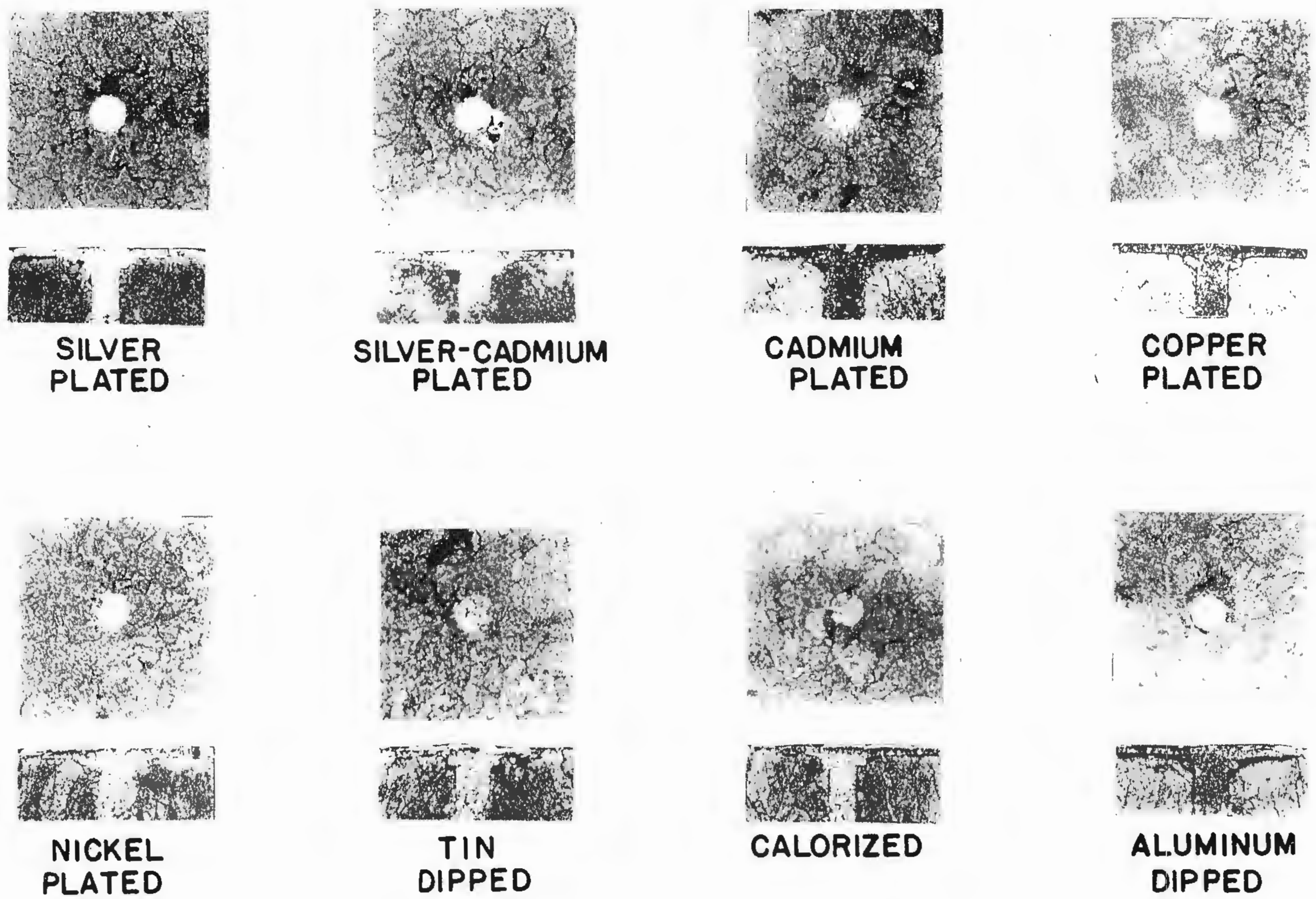
INFLUENCE OF SURFACE COAT ON 1/4" X 1/4" X 1-1/4" SQ. HD. PLAIN STEM CHAPLET—SANDBLASTED BEFORE COATING AND KEPT IN DESSICATOR

ETCHED IN 3% NITAL



INFLUENCE OF SURFACE COAT ON 3/16"X 1".X 1" RD. HD. PLAIN. STEM CHAPLET - SANDBLASTED BEFORE COATING AND KEPT IN A DESSICATOR

PLATE 11

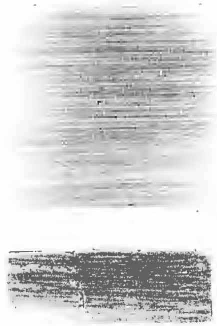


INFLUENCE OF SURFACE COAT ON 3/16"X1"X1" RD. HD.
PLAIN STEM CHAPLET—SANDBLASTED BEFORE COATING
AND KEPT IN DESSICATOR
ETCHED WITH 3% NITAL

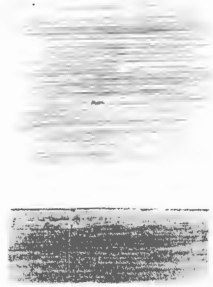
PLATE 12

SILVER PLATED

SILVER-CADMIUM PLATED

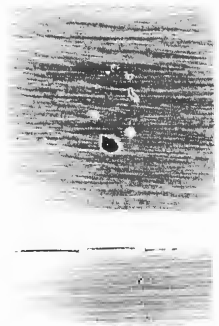


COPPER PLATED



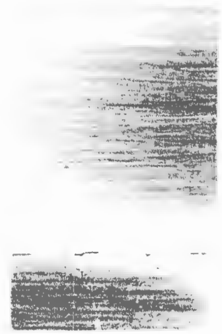
NICKEL PLATED

TIN DIPPED



CALORIZED

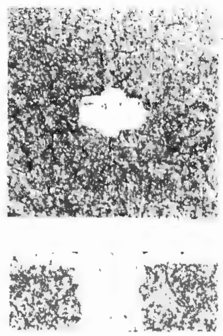
ALUMINUM DIPPED



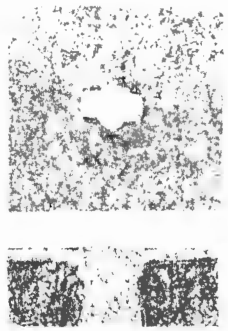
ALUMINUM SPRAYED

INFLUENCE OF SURFACE COAT ON 1/4" X 1" X 1-1/4" SQ. HD. SUPER-STEM CHAPLET- SANDLASTED BEFORE COATING AND PLACED IN WASHED GREEN SAND MOLD PRIOR TO DRYING

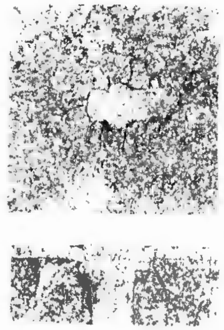
PLATE 13



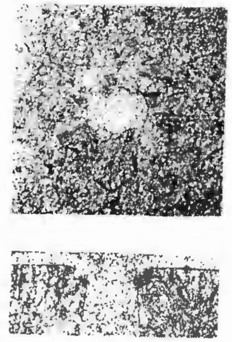
SILVER
PLATED



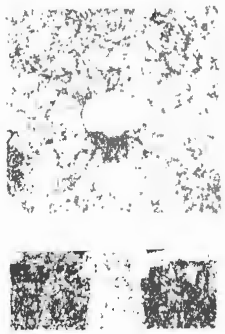
SILVER-CADMIUM
PLATED



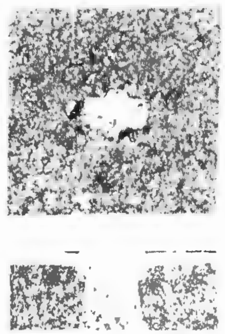
COPPER
PLATED



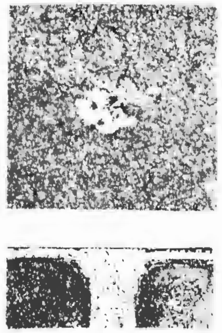
NICKEL
PLATED



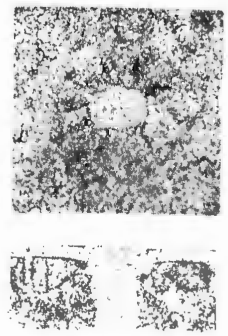
TIN
DIPPED



CALORIZED



ALUMINUM
DIPPED



ALUMINUM
SPRAYED

INFLUENCE OF SURFACE COAT ON 1/4"X 1"X 1-1/4" SQ. HD.
SUPER-STEM CHAPLET— SANDBLASTED BEFORE COATING
AND PLACED IN WASHED GREEN SAND
MOLD PRIOR TO DRYING
ETCHED WITH 3% NITAL

PLATE 14