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NAVY DEPARTMENT

Report

on

Radiographic Tests

on

XF4U-1 Engine Mount, SAE 4340 Steel

NAVAL RESEARCH LABORATORY
ANACOSTIA STATION,
WASHINGTON, D. C.

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ABSTRACT

Prolonged contact between radiographic film and metallic intensifying screens often leads to blackened areas in the developed film. The effect is more noticeable the higher the speed of the film and seems to be due to the presence of moisture in the air rather than to the particular metal used as a screen. The use of paper or other organic spacing sheets between the foil and the film was found useless under conditions of high humidity and temperature and quite unnecessary when the film holder is kept moisture free by simple means described herein. X-ray diffraction patterns of commonly used tin coated radiographic foil showed presence of pure lead in the surface but comparative film marking tests showed little difference in the action of pure lead, antimonial lead or tin-coated lead. Comparative intensifying tests under gamma radiation also showed that these three materials had very nearly the same intensifying action. Tests were made using both x- and gamma rays which showed that the use of paper separators between the intensifying screens and films leads to a loss of radiographic sensitivity and definition.

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Prolonged contact between radiographic film and metallic intensifying screens often leads to blackened areas in the developed film. The effect is more noticeable the higher the speed of the film and seems to be due to the presence of moisture in the air rather than to the particular metal used as a screen. The use of paper or other organic spacing sheets between the foil and the film was found useless under conditions of high humidity and temperature and quite unnecessary when the film holder is kept moisture free by simple means described herein. X-ray diffraction patterns of commonly used tin coated radiographic foil showed presence of pure lead in the surface but comparative film marking tests showed little difference in the action of pure lead, antimonial lead or tin-coated lead. Comparative intensifying tests under gamma radiation also showed that these three materials had very nearly the same intensifying action. Tests were made using both x- and gamma rays which showed that the use of paper separators between the intensifying screens and films leads to a loss of radiographic sensitivity and definition.

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AUTHORIZATION.

1. The studies and experimental work described in this report form a part of a program of research on gamma radiography which was authorized by Bureau of Engineering Letter QP Radiography (7-31-DS) 19 September 1939 and QP Radiography (DW,DYs) (12-4-1940).

STATEMENT OF THE PROBLEM.

2. The objects of this work were: (a) the study of the type of defect produced in radiographs by the action of lead intensifying screens, this effect is commonly known as lead marking; and (b) the development of practical means for the elimination of this source of trouble. This work includes studies to determine the relative resistance of the commercially available radiographic films to lead marking, and the effects of modifying the material of the intensifying screens. In addition some experimental tests were made to show that there is a loss of radiographic sensitivity and definition when paper spacing sheets are used between the radiographic film and its intensifying screen. This practice has been employed to avoid film marking.

KNOWN FACTS BEARING ON THE PROBLEM.

3. From one point of view the action of metals by direct contact with the emulsion of a photographic film or plate has been known for perhaps 40 years or so as the Russell effect. Experimenters have been chiefly interested, however, in such matters because of a belief that perhaps various metals, even the common ones, gave off peculiar radiations which might be due to radioactivity in the metal itself, or due to secondary radiation produced in the metal by unknown causes. Recently the use of metal foils as intensifying screens in radiography has increased as the hardness of the x-radiation has been stepped up by use of higher voltage equipment and radioactive sources. In this region metallic intensifying screens while slow have certain advantages over the faster calcium tungstate intensifying screens used in lower voltage radiography. Metallic intensifying screens possess an advantage over the calcium tungstate screens in that higher definition is obtained in the radiograph. In such work the metallic intensifying screen is in intimate contact with the radiographic films and it is obviously important that the intensifying screen does not generate false or spurious effects in the emulsion of the radiographic film.

4. The cause of this action has engaged the curiosity, if not the sustained attention, of a number of investigators. As pointed out in a recent article by Reboul, (1) the effect was first noted in 1896 by R. Colsen (2) and studied more intensively by Russell (3) who found that a large number of metals had the ability to exert a photographic effect even when actually separated from the photographic emulsion for a slight distance by a non-metallic separating sheet. The order of activity for the different metals was placed as Mg, Cd, Zn, Ni, Al, Pb, Bi, Co, Sb.

This shows little relation to the atomic number or chemical properties. Russell explained the effect as being due to the formation of hydrogen peroxide of which the photographic emulsion is known to be a very sensitive detector and showed further that various non-metallic sheets, such as paper and cardboard, produced similar effects if these had been in contact with H_2O_2. How the latter is formed by the metal is not quite certain. One theory is that the metal by oxidation liberates atomic oxygen which unites with water, while another is that the metal, reacting with moisture, produces active hydrogen which combines with the oxygen of the air to form H_2O_2. Whichever mechanism is assumed, the presence of moisture is necessary for the effect. In recent work Reboul indicates that this explanation is not entirely complete and that there is reason to believe that the metals themselves emit radiations somewhat like very soft X-rays in quality. These radiations supplement the effect due to the interaction of metal and moisture.

5. These studies are valuable in that they suggest the main cause of the action but it is possible that the lead marking encountered in radiography is more complicated. It is barely possible that at times head foils may be used which contain traces of radioactive impurities. Over a period of time these could cause spurious markings also. Another source of trouble in radiography is uneven contact of the metallic intensifying screen with the emulsion of the film. This, however, is a mechanical difficulty which has to be overcome by proper care in preparing and loading radiographic exposure holders. A considerable amount of research on metallic intensifying screens and their proper use has been carried out by Seeman[4] and Tobey & Seeman[5] at the Eastman Kodak Research Laboratories. In their opinion, the lead marking is due to a reducing action which the lead exerts on the silver bromide during the oxidation of the metal. In support of this view they have observed that a lead surface, freshly cleaned by steel wool, will cause a fogging action while a lead foil that has been exposed to air for some time will not. While this observation is correct as far as it goes, it will be shown in this report that even uncleaned lead foils exert a fogging action when the humidity and temperature are high enough. Another source of trouble according to Tobey and Seeman, is a leadmarking which is due to the rubbing off of particles of lead on the photographic film and the consequent marking of the film in the development. To get around this source of trouble they have adopted the use of a "hard" lead (antimony lead) which they claim is giving satisfactory results. In the past, extensive use has been made of the tin coated lead foils, and on the whole these have been fairly satisfactory. One of the foils studied in the present work is of this kind and has been on the market for some time. It is stated, however, by Tobey and Seeman that a homogeneous metal intensifying screen is to be preferred to one of the coated variety because any variations in thickness of the plating will be likely to give rise to irregular absorption of electronic radiation at the surface of the foil which gives a mottled effect in the radiograph.

6. Somewhat different points of view on the desirability of a tin or other metal coating on lead intensifying screens have been taken. It is believed by some (6) that the tin coating offers protection of the film against direct contact with pure lead, which is assumed to be the cause of the lead marking. It is believed that a perfect coating of tin will insure against lead marking while with an imperfect coating, enough lead will show through the surface to give lead marks in spots. An attempt has been made in the course of this work to determine how correct this point of view may be, and the results will be discussed further on.

7. Passing mention may be made of two more types of film markings which also are not the direct interest of this report. One is a type of marking due to pressure which has partially desensitized the emulsion. The other is a type of marking due to deep scratches in the intensifying screen. Both of these are easily avoided by proper care and use of the exposure holders.

8. To prevent lead marking, some Naval radiographers have resorted to placing a sheet of paper between the intensifying screen and the film. This simple expedient would be ideal if there were not certain good reasons against its adoption. The intensifying action of a metallic screen is due mainly (85%) to the emission of electrons from the surface of the metal.[4] The emitted electrons have a range of velocities depending on the thickness of metal traversed before emergence. Some of these would have sufficient speed to penetrate a film of air or paper of appreciable thickness while others are so slow that they are stopped by a thin film of air. Consequently, the introduction of a sheet of paper between the intensifying screen and the film does two things: (a) a considerable fraction of the electrones are prevented from reaching the emulsion, and (b) an electron radiograph of the structure of the paper is impressed on the emulsion. Such impressions have actually been observed. In the course of this work an attempt will be made to ascertain to what extent a film may be protected against lead marking by the use of thin sheets of organic material such as paper and cellophane.

9. Other methods of obviating the difficulties due to lead marking have been considered and tried. These will be discussed in a subsequent section of this report.

EXPERIMENTAL PROCEDURE.

10. The tests described in this report were started in the late fall when the humidity and average room temperature were both low. The first tests attempted to determine how long it would take under these conditions to produce lead markings in loaded exposure holders stored in a laboratory room, and subjected to a variation in temperature between 25°C. during the day, and 10°C. during the night. In order to study the effect of three different kinds of foil at the same time, special cardboard sheets were prepared on which three parallel strips of foil were cemented. The arrangement and kinds of test foils are shown in Plate I. All experiments were carried out on 5" X 7" films; and three kinds of commercial radiographic

film were used because, as mentioned before, a difference in ability to withstand lead marking had been noticed in practical use of several brands of film.

11. In these tests, six Eastman cardboard exposure holders were loaded so that each holder held one test film placed with one face in direct contact with the foil test card and its other face covered with its black paper wrapping. The foils on the test card were cleaned with cotton soaked with alcohol, dry cotton, and then dried. Two films of each of three brands were used. Storage tests of 24 hours, 72 hours, 10 days, and 2 months were made. The films were developed in Eastman Tank developed with 20 mg. potassium iodide per liter added to double the length of time given by the Eastman X-Ray development chart. This is the procedure ordinarily used for developing gamma radiographs. Several blank films of each brand were developed along with the test films to serve as a comparison and to insure against misinterpretation of defects in the film stock. The results of these preliminary tests are given in Table I, which shows, in general, that during the winter months loaded holders can be stored for as long as 10 days without any action of the lead on the emulsion, but that continued storage will eventually cause this effect.

12. Tests of this kind were obviously too slow and time-consuming to be very useful in this work. Since it is known that lead marking troubles are more prevalent during summer months than in the winter, an accelerated test was devised which would not only simulate the worst humid summer conditions but would be even more drastic in accelerating the action of the lead strips on the emulsion. This test consisted of storing the test holders in a small sealed laboratory oven together with a pan of water to keep the air saturated with water vapor. The temperature regulator on the oven was adjusted so that for 8 hours of each day the temperature was about 40° C. (104°F), and at the end of the period the power was cut off and the oven cooled to room temperature during the night. This would tend to produce supersaturation of the air in the test chamber and the precipitation of moisture in the film holders.

13. The time of the first accelerated test was 5 days duration. It was found that under these drastic conditions, severe lead marking resulted and the severity of the marking was far greater than that obtained by weeks of storage under ordinary conditions. In these tests, the number of holders used was usually 6 to 12. At least three pairs of films of each particular brand were used. In some of the tests, arrangements were made to test the effectiveness of thin organic sheets as preventatives of lead marking. These showed results of little promise. Later tests were made on preventing the lead marking by use of sealed containers and also sealed containers with drying agents to absorb residual moisture in the sealed package. In addition, some of the accelerated tests were performed on foils other than the three illustrated in Plate I such as lead antimony foil, gold plated foil, etc.

14. The various experiments are listed in Table 2. With the exception of experiments (c) and (m), the tests were of the accelerated type. The general results obtained in each of the experiments are also given in the table.

15. Tests (a) and (c) have already been mentioned briefly. Tests (a) and (b) showed that the 5 day accelerated type of test would bring about very decided marking of test films and indicated also the relative severity with which this occurred for the three types studied. Test (g), which is the same as test (a), except that the time was three days, showed similar results. In it was noted that the air space created by the method of folding and closing the radiographic exposure holder formed a moisture pocket which caused blackening directly beneath the air space.

16. Tests (c) and (d) were made to test the protective action of lens paper and cellophane sheets between the lead foils and the films during accelerated test. Since the results were not encouraging, test (e) was made to study the protective action of lens paper at room temperature. In general, tests (c) and (g) showed that over periods of several days organic separators between the lead foil and film gave little or no protective action.

17. Since humidity had been found to promote the marking action, the next experiments (h) and (l) were made to test various schemes for eliminating moisture from the radiographic exposure holder. The first and simplest means tried were rubber envelopes and wax paper envelopes in which the exposure holders themselves had been previously stored in a large dessicator to remove moisture from the cardboard and paper parts. When these sealed holders underwent the 5 day accelerated tests, a great improvement over an unsealed holder was apparent at once. The two methods of sealing the exposure holders are shown in Plate 5. Plates 6 and 7 show test films which compare results for protected and unprotected holders. Even in the sealed holders, a slight amount of action takes place between the foil and the film. This indicated that perhaps some moisture was still contained in the sealed container or that some air could still diffuse through the protective wrappings.

18. Attention was then turned to obtaining some form of drying agent that could be conveniently enclosed in a radiographic exposure pack. It was decided to try to mount a commercial drying agent such as potassium perchlorate in a small rectangular holder which could be placed within the pack. The first attempts consisted in placing the drier between pieces of corrugated cardboard and between pieces of wire netting of sufficiently fine mesh. Experiment (i) of Table 2 was carried out to test the protective action of these drier inserts. It was found that the various forms of driers were about equally effective and that it was necessary to seal drier and exposure holder in an airtight container to get full protective action.

19. Since the mounted drying packs tried in the above experiment were somewhat bulky, usually at least a quarter inch in thickness, and not any too flexible, a blotter type drier was devised. This was made by soaking 5 x 7" sheets of asbestos paper in concentrated potassium perchlorate solution and drying these between metal sheets at a temperature of 250° C. While this treatment is not sufficient to completely renovate the perchlorate, the blotter strips prepared in this way were found to have considerable absorptive power when left out of the dessicator. Stored in dessicators these blotters can be kept available for use as needed. A test was made using the accelerated type of test (Experiment h, Table D1) and sealed holders containing these blotters in addition to the test exposure holders. It was found that this arrangement gave satisfactory protection.

20. Although it was apparent from the tests that the chief cause of any action of the metal foils on the films was moisture, there still remained the possibility of improving matters by the proper choice of metal foil. It was decided to make some comparisons between the tin coated radiographic foil commonly used and several foils other than those used on the test cards described in Plate 1. Test cards were made up on which the tin coated foil was mounted adjacent to pure tin, lead antimony foil, and lead on which gold had been plated. These cards were loaded together with radiographic films in exposure holders and subjected to the 5 day accelerated marking test (Experiment J, Table 2). In general it was found that aside from small intense markings due to specks of impurities in the foils, these metals had about the same marking action. The fact that pure tin sheet gave no improvement over the tin coated radiographic foil is to be expected since these surfaces were essentially the same.

21. As mentioned earlier in this report, it has been assumed that the presence of pure lead in the surface of the intensifying foil is a source of trouble. To see if any lead is actually present in the surface of the tin coated radiograph, some x-ray diffraction patterns were made (using the Seaman Bolin method, FeK. radiation) of test strips of pure tin, pure lead, and tin coated lead. The diffraction patterns observed are shown in Plate 9. They show that a small amount of metallic lead is actually present in the surface of the tin coated radiographic foil. In view of the other tests performed, however, it is doubtful whether this small amount of lead exerts any harmful effect on the radiographic film.

22. In view of the fact that lead antimony foil has recently been advocated for use as gamma ray intensifying screens, it was considered worth while to make some direct comparison of the intensifying action of lead antimony, tin coated lead, radiographic foil and pure lead sheet. The thicknesses of these foils were 0.014; 0.008; and 0.010 in. respectively. To compare the action of these foils, they were cut into strips about 3 1/2" x 5" and after cleaning and drying were placed in pairs between two films (Eastman Ultra Speed Blue Brand) in a radiographic exposure holder. Upon the tube side of each exposure holder was placed a steel bar 3/8" thickness and 1 1/2 inch width, carrying two 3 4 in. holes which would lie directly over the center of each of the two test foils. Thus a number of pairs of foils could be compared directly for their effectiveness as either front or back intensifying screens.

23. The loaded exposure holders were then exposed to 25 mg. of radium for 15 hours at 28 inches source to film distance. The holders were then unloaded and the films processed in Eastman X-ray developer in standard procedure. In Plate 10 are shown the front films obtained in comparing the three sets; tin coated lead, lead antimony, tin coated lead, pure lead, and lead antimony and pure lead. On the films are shown the measured densities for points within and adjacent to the 3/4 holes in the steel object plate. It may be noted that there is very little difference in the intensifying action of these foils. Also the general qulaity of the film areas does not show by unevenness of intensification which of the three films is to be preferred. It is possible that the samples of tin coated foil used here possessed a uniform coating. The front film was chosen for illustration and comparison because of small differences in thickness of the three foils which alone might give slight differences in densities on the back films. It was decided pertinent to study the action of paper separators on the radiographic sensitivity and definition in connection with this investigation. First attempts to show that their use in gamma radiograph seriously affected the definition of the radiograph were not very encouraging; the loss in density of the film not being very great and the apparent definition about the same. It was decided to test the definition by using penetrameters having a latitude of hole sizes and a thickness around the limit of sensitivity. It was found that the thickness sensitivity of the gamma radiograph was not seriously affected by the presence of a paper spacer in the cassette, but that the least diameter of hole in the penetrameter just visible was increased thereby. The technique followed was comparative and quite similar to that used for preparing Plate 10 except that a single intensifying sheet half covered with paper was employed. Identical penetrameters were placed on the steel test bar to either side of the center, one above film covered by paper, the other above film in direct contact with foil. The loaded cassettes were exposed to both gamma rays and x-rays. In the case of the latter the effect of the paper spacing sheets on the penetrameter hole sensitivity is quite evident and could perhaps be retained in a reproduced copy of the original. In the case of the gamma radiograph the effect is evident but an attempt to reproduce it in copy was not successful. For this reason no plate illustrating these results was prepared, and in place the actual radiographs taken will be enclosed in the signature and file copies of this report.

DISCUSSION OF RESULTS OBTAINED

24. The experimental work has shown that there is a definite undesired effect of the metallic surface of the intensifying screen commonly used in gamma radiography on the emulsion of the radiographic film. The effect of a sufficiently prolonged contact between foil and film is a fogging or blackening of the developed radiograph. This fogging may take place in irregular patches on the film (as shown in Plate 8) or it may be simply a uniform fogging over the entire film. It has been shown in this work that under conditions of low humidity and moderate temperature the effect is negligible for the usual exposure times for radiographs. The effect, however, will become quite noticeable even under favorable climatic conditions if the metal foils and films are kept in contact for several weeks. Actually, there is little

reason for keeping exposure holders loaded for such lengths of time before use or development.

25. These studies have shown that when the humidity of the air around radiographic exposure holders is increased considerably, the action of the metallic foil on the film is accelerated indicating that moisture is the prime factor that determines the amount of marking a film receiver. The subsequent attempts to exclude moisture from exposure holder by devising sealed packs, and sealed packs containing a drying agent, showed that the fogging action of the foils can be reduced decidedly, even under adverse conditions of temperature and humidity.

26. An objection may be made that the conditions of temperature and humidity employed in the accelerated tests are seldom met in practice except perhaps in the tropics. This is true, and it may be emphasized that this type of test was chosen primarily to bring about definite effects in reasonable lengths of time and not to duplicate some possible practical situation. The preliminary experiments in this work showed that these effects could be brought about under ordinary room conditions over much longer times.

27. The experiments have shown the importance of using dry exposure holders and have also shown that internal air spaces in the exposure holders can broduce desired blackened areas on the radiographic film.

28. In eliminating the effect of moisture in the exposure holder by sealing, the question naturally arises as to whether the reduction of moisture in the film emulsion may adversely affect the sensitivity. However, it appears certain that the presence of moisture decreased rather than increased the sensitivity of the emulsion; thus it is advantageous to use as dry a film as possible.

29. From the results obtained in the accelerated test, it seems that there is little to be gained by the use of paper and other organic sheets between the radiographic foil and film. Even under climatic conditions less drastic, the use of paper did not give any definite protection; however, the use of paper separators has been tried elsewhere and even advocated. Before the use of such means to prevent film marking is discouraged, it may be recalled that in the cases of foils having surface impurities, such methods may allow continued use of such foil while otherwise it would be necessary to discard it. This slight advantage is probably offset by a decrease in intensifying effect and the tendency of the paper to absorb moisture and thereby hasten action between the foil and the film.

30. The particular type of lead marking tests adopted in this work showed that a number of different radiographic metal foils gave about the same action between the radiographic film and foil. Some minor differences were noted; in general, it was found that pure or nearly pure lead sheet gave slightly more pronounced marking than the commercial tin coated foil.

This difference was not large enough or even definite enough throughout to enable us to say that the presence of pure lead particles or areas in the surface of the commercial tin coated foil is the cause of "lead marking". Furthermore, the accelerated tests made did not show any difference in behavior between the tin coated foil and the recently advocated lead-antimony foil. As pointed out be Seeman, there are probably radiographic reasons for preferring the use of a homogeneous foil. The tests performed in this investigation are mainly to determine the effect produced on the film by the metallic sheet without the help of x- or gamma radiation. The intensifying effect of an uneven or incomplete metallic coating on the intensifying screen may reveal itself in further markings in a radiograph not due to the chemical action between the foil and the film. As the results of these tests show, there will be as much chemical action between film and foil when using lead-antimony as when using the tin-coated foils. On this basis it would seem that the radiographic intensifying action alone will determine the choice of a metallic foil. The experiments carried out to compare the intensifying action of pure lead, lead-antimony, tin-coated lead (Plate 10), however, failed to show that any positive improvement is to be gained by using either lead or lead-antimony instead of the tin-coated radiographic foil. In fairness it must be said that the tin-coated lead used in these tests may have been very uniform in structure and thus failed to show up the mottling effect due to uneven intensification which the use of homogeneous metal intensifying screen is intended to obviate.

31. The gamma and x - radiographs showing the effect of using paper spacers between the film and paper may be discussed briefly. In the gamma radiograph it may be noted that the penetrameter images are very faint. The difference in density of the two sides of the radiograph is appreciable and in itself is a good point against the use of paper. Penetrameter holes can just be seen on the side not covered by paper and not with any certainty on the side covered by paper, even though the penetrameter holes were of fair size. In the x - radiograph the penetrameter edges may be seen more distinctly but the hole sizes were deliberately chosen much smaller. It may be noted that the images of the penetrameter holes on the "uncovered" side are smaller and sharp compared to those on the covered side. It can be distinctly seen that the effect of the paper spacer is to spread the apparent size as well as reduce the intensity of the hole image. On the covered side only two of the three holes may be seen. The general decrease in film density caused by the paper spacer is in this case even greater than in the gamma radiograph.

32. In conclusion it can be said that the work described in this report has shown that it is essential that the exposure holder and film be free from moisture. If steps are taken to prevent this, there will be little or no action of a chemical nature between the radiographic film and the intensifying foil even though they are in direct mechanical contact. All that is necessary in this procedure is:

(a) to use exposure holders that have been dried or freed from moisture by storage in a dessicator or drying box.

(b) to load these with film without introducing dampness through wet hands, etc.

(c) to seal these holders in simple wax paper or rubber containers without an additional drier (as climatic conditions may indicate).

33. A simple and convenient method of introducing a drying agent has been described above.

SUMMARY

34. On prolonged contact between radiographic film with metallic intensifying screens there is an interaction between them which causes a blackening of the film on development. It was found that commercial films are susceptible in various degrees; a slow film is less apt to show foil marking than a fast film. This action is favored and hastened by the presence of moisture. An accelerated form of experimental test was devised for testing films and foils. The use of paper or other organic spacers between the foil and film to prevent lead marking was found to be without value when conditions of high humidity prevailed and quite unnecessary when the film holder is kept dry as possible by simple and effective means which have been described herein. X-ray examination of commonly used tin-coated radiographic foil showed presence of free lead in the surface but comparative film marking tests showed little difference in the lead marking action of pure lead, antimonial lead, or the tin-coated lead foil. The primary cause of lead marking of the kind studied seems to be the presence of moisture. A study of various common metallic intensifying screens showed there is little reason to prefer one to the other. Pure lead, antimonial lead and tin-coated radiographic lead gave about the same intensifying action on direct comparison tests.

35. Radiographic tests made employing both x- and gamma rays have shown that there is an appreciable loss in density in the radiograph as well as radiographic definition when paper sheets are interposed between intensifying foil and film.

RECOMMENDATIONS

1. In case gamma radiography is carried out under conditions where the air is fairly dry and temperature not much above 20° C, it is possible to use radiographic film in direct contact with radiographic lead intensifying screens provided the exposure holder itself is dry and no moisture is introduced during loading. Holders should not remain loaded more than three days however.

2. Under conditions of high humidity, such as encountered in tropical climate or in damp industrial locations, it may be necessary to seal the dry loaded exposure holder in a wax or rubber envelope together with a simple drying device described herein. The use of paper or other organic sheets between the films and the metal foils is not recommended under these conditions.

3. The use of paper spacing sheets between film and intensifying screen leads to a loss of radiographic density and definition and is not recommended even under ordinary conditions.

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Table 1

Results of Room Temperature Lead Marking Tests
of 1, 3, 10 and 60 Days Duration

Duration in Days	Film No.	Film Make	Lead Marking	Remarks
1	1	Eastman US	No	-
"	2	"	"	-
"	3	Agfa	?	Not definitely lead marked.
"	4	"	No	-
"	5	DuPont	"	-
"	6	"	"	-
3	1	Eastman	No	-
"	2	"	"	-
"	3	Agfa	No	-
"	4	"	"	-
"	5	DuPont	No	-
"	6	"	"	-
10	1	Eastman	Yes	Noted only on pure lead strip.
"	2	"	"	On pure lead and very faint on others.
"	3	Agfa	No	-
"	4	"	"	-
"	5	DuPont	Yes	Faintly marked by x-ray foil.
"	6	"	"	Definitely.
60	1	Eastman	Yes	Faintly marked by all three foils.
"	2	"	"	Strongly marked at edges of strips.
"	3	Agfa	Yes	Faintly marked by all three foils.
"	4	"	"	Faintly marked by all three foils.
"	5	DuPont	Yes	Faintly marked, least on G. E. x-ray.
"	6	"	"	Lead, most on pure lead strip.

Table 2

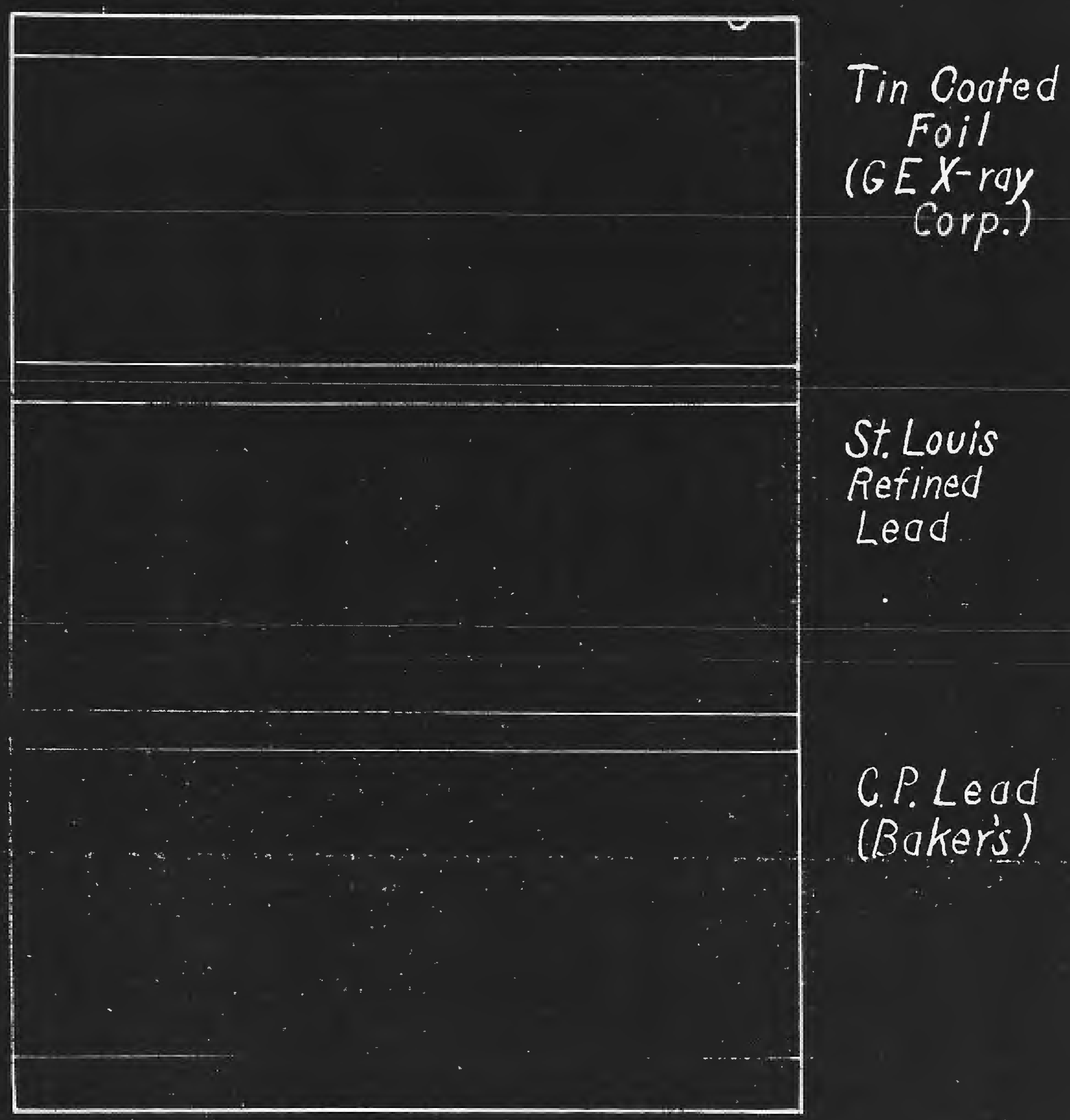
Experiments Carried Out to Study Lead Marking under Accelerated Test Conditions

Expt. No.	Nature	Film Make	General Conclusions
(a)	Accelerated test 5 days 40° C.	Eastman U.S.	Faint marking by all three foils
		DuPont	Noticeably marked " " "
		Agfa	Film in good condition
(b)	" " "	Eastman U.S.	Marked by all foils. Most by pure lead.
		DuPont	" " "
		Agfa	Faintly marked.
(c)	Accelerated test as in (a) using lens paper between foils and film.	Eastman U.S.	Films marked in all cases.
		DuPont	Sticking of paper to film observed.
		Agfa	Effect of moisture from paper backing also noted.
(d)	Accelerated test of 25-30° C. (4 days) to test effectiveness of cellophane and filter paper.	Eastman U.S. DuPont Agfa	Films all marked. Lens paper not good protection under humid conditions. Cellophane causes marks and sticks to film.
(e)	Room temperature storage tests at 20-22° C. to study effect of lens paper. Time - 11 days.	"	Lens paper of little protection for 11-day period. Agfa films much less affected than others in these tests.
(f)	Test similar to (c) except for shortening time to 4 days.	"	Slight protective action found with DuPont, negligible effect on other films.
(g)	Accelerated test 3 days 40° C. Conditions as in (a).	"	All films showed marking and effect of "pocket" in film holder paper definitely shown.
(h)	Accelerated test. 5 days 40° C. using film holders protected against moisture in various ways.	"	Eastman, DuPont and Agfa films in holders sealed in rubber sheeting showed very little marking. Likewise for holders sealed in wax containers. Unprotected holders gave badly marked films.

(Continued)

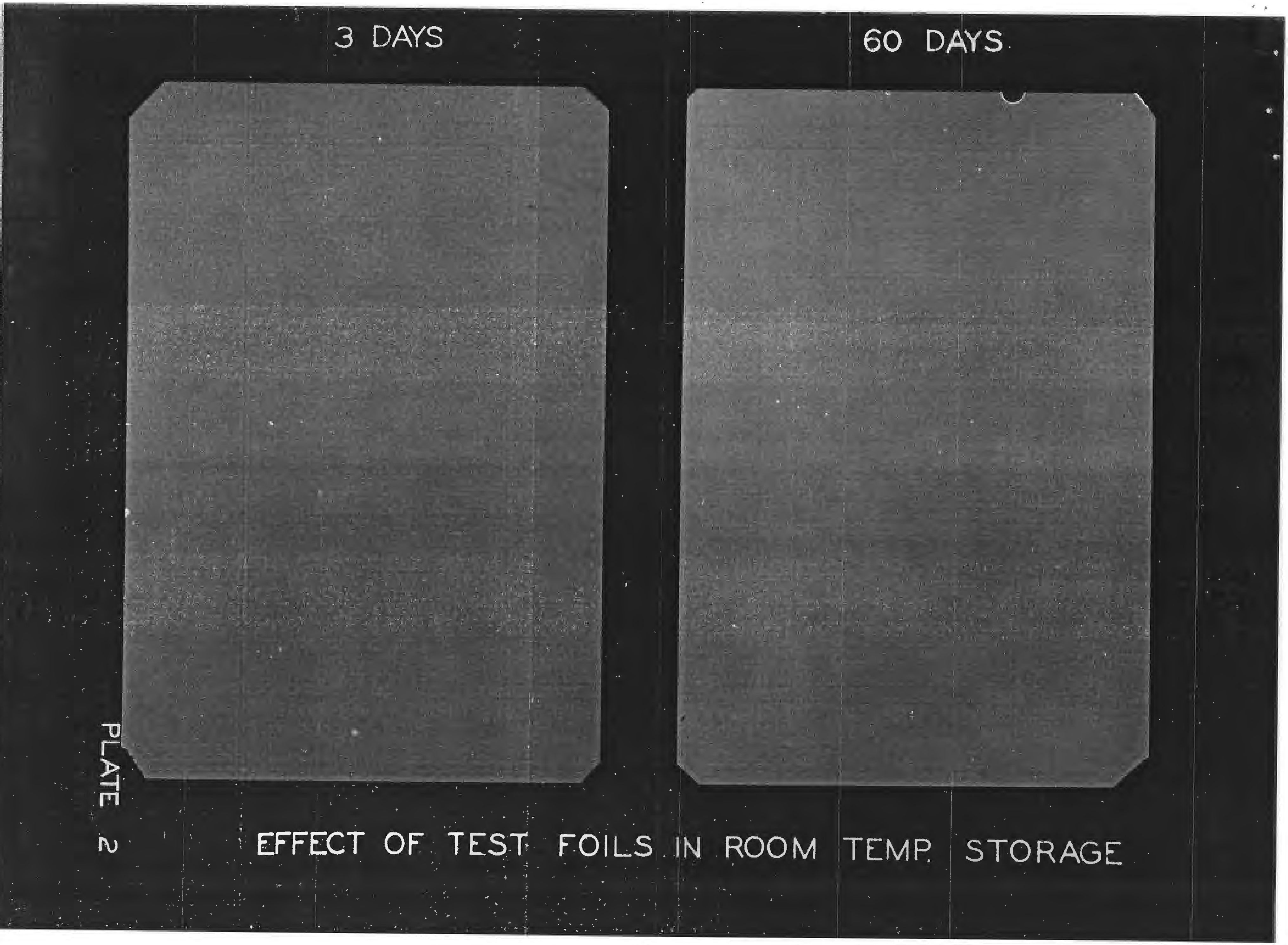
Table 2
(CONTINUED)

Expt. No.	Nature	Film Make	General Conclusions
(i)	Tests as in (h) with various drying agents enclosed in sealed exposure holders.	Eastman U.S. DuPont Agfa	Several methods of using drying agents in holders were tried and found about equally effective. Blotter-type of drier insert easiest to make and use.
(j)	Accelerated test 6 days 40° C. to study effect of Au plated foils, Pb Sb foil in sealed and unsealed holder.	"	Tests on sealed holders show little or no difference in action between G. E. Sn-coated foil and Pb-Sb foil. Au plating gave no definite improvement.
(k)	5-day 40° C. accelerated test to study asbestos anhydrone drying agent.	"	Anhydrone blotter driers in sealed packs give very good protection.
(l)	Special test to compare marking action of pure Sn and G. E. foil.	"	Tests indicate that pure Sn sheet marks about same way as G. E. foil.



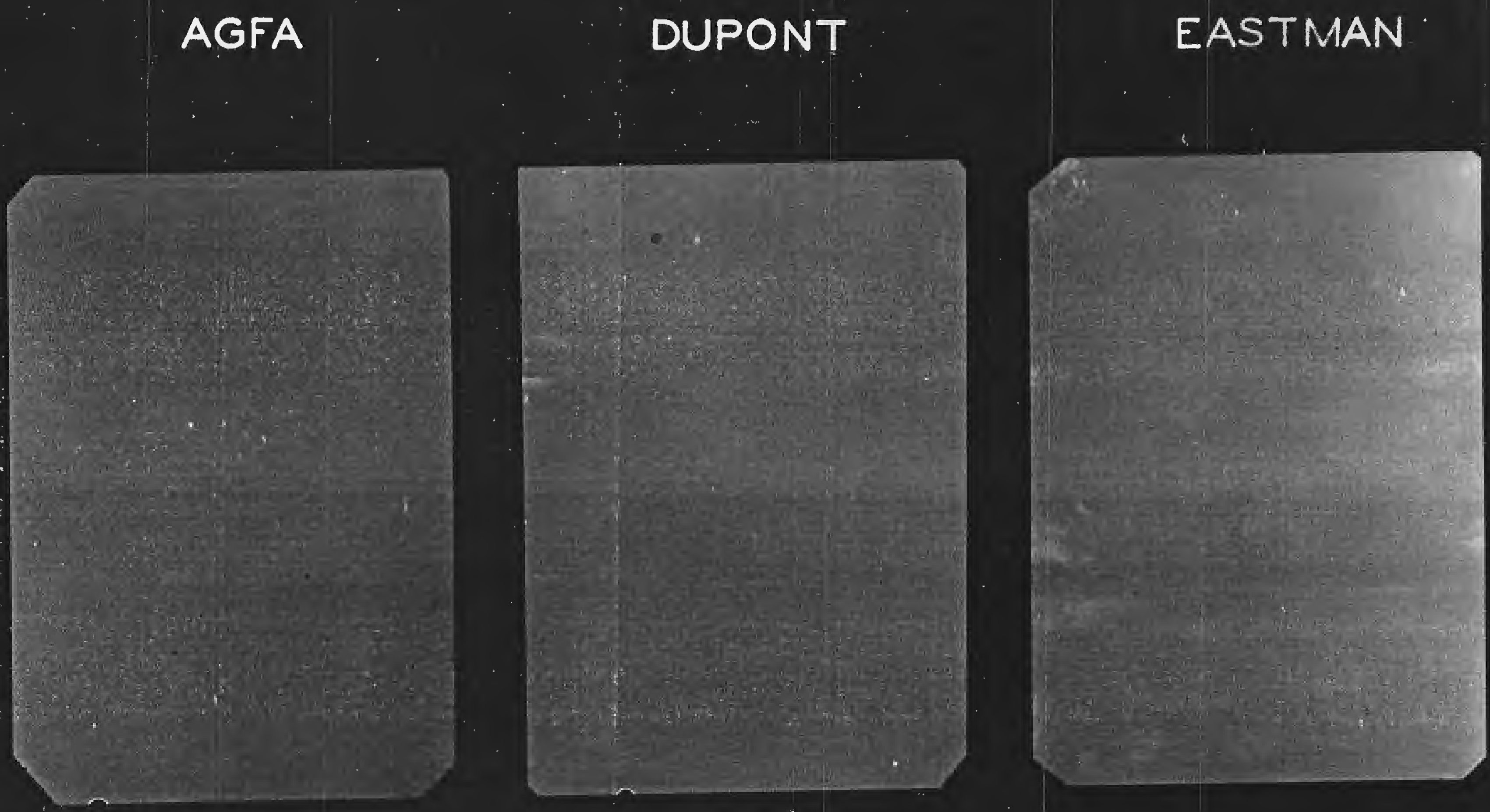
Mounting of Intensifying Foils on Test Cards

PLATE 1



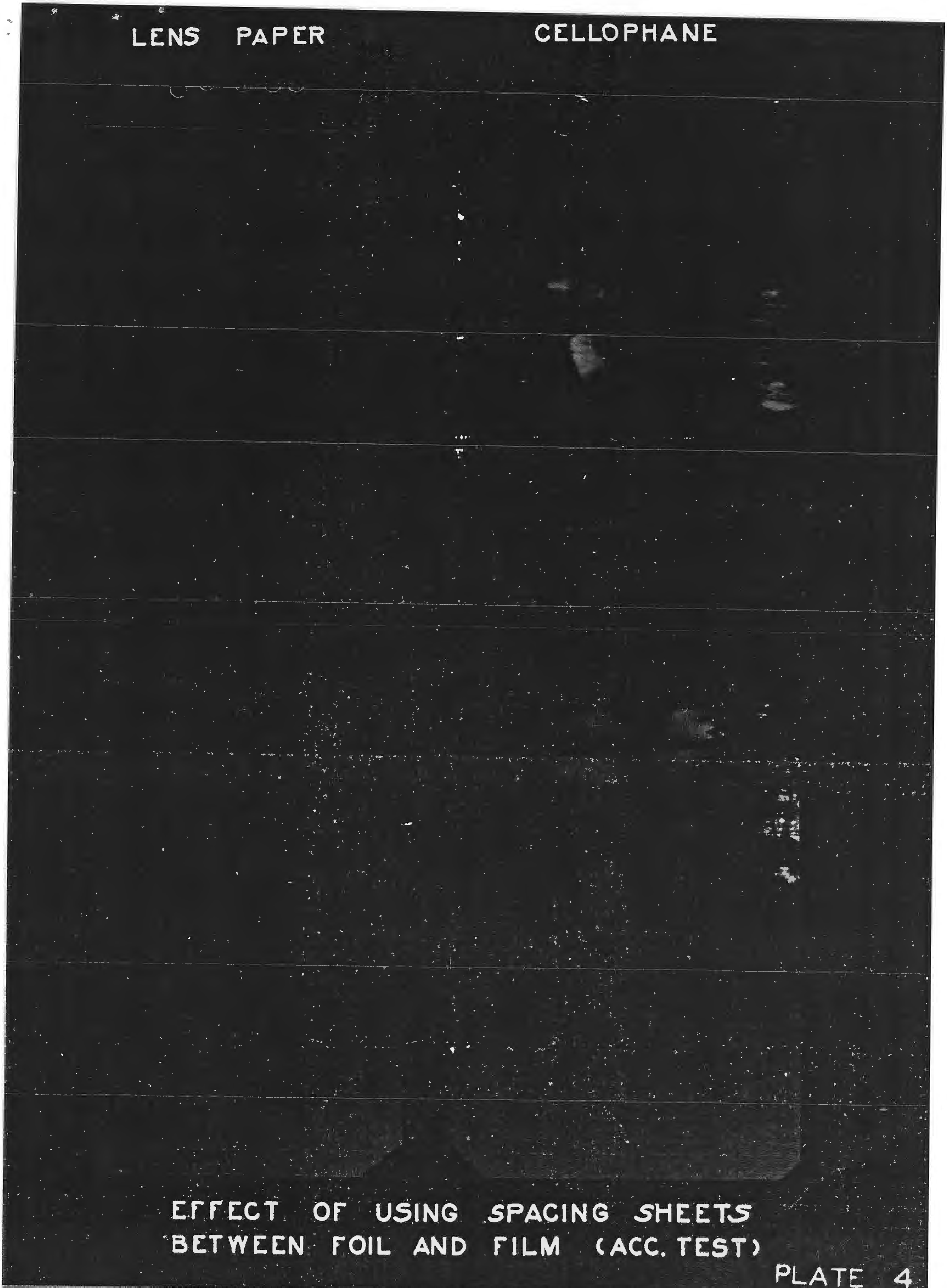
EFFECT OF TEST FOILS IN ROOM TEMP. STORAGE

PLATE 2



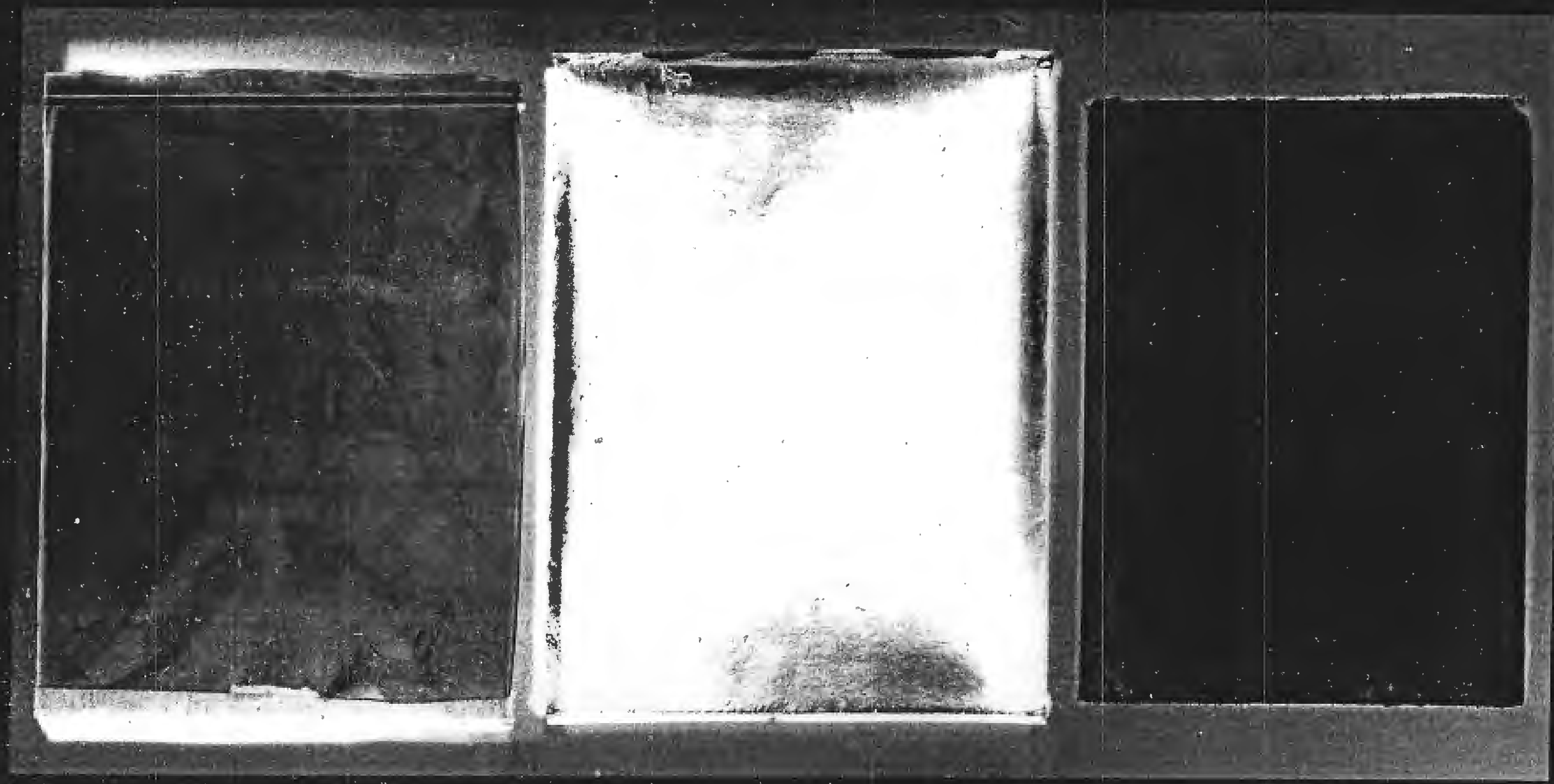
EFFECT OF TEST FOIL IN ACCELERATED
5 DAY TEST

PLATE 3



EFFECT OF USING SPACING SHEETS BETWEEN FOIL AND FILM (ACC. TEST)

PLATE 4



SEALED EXPOSURE HOLDERS AND BLOTTER TYPE DRIER

PLATE

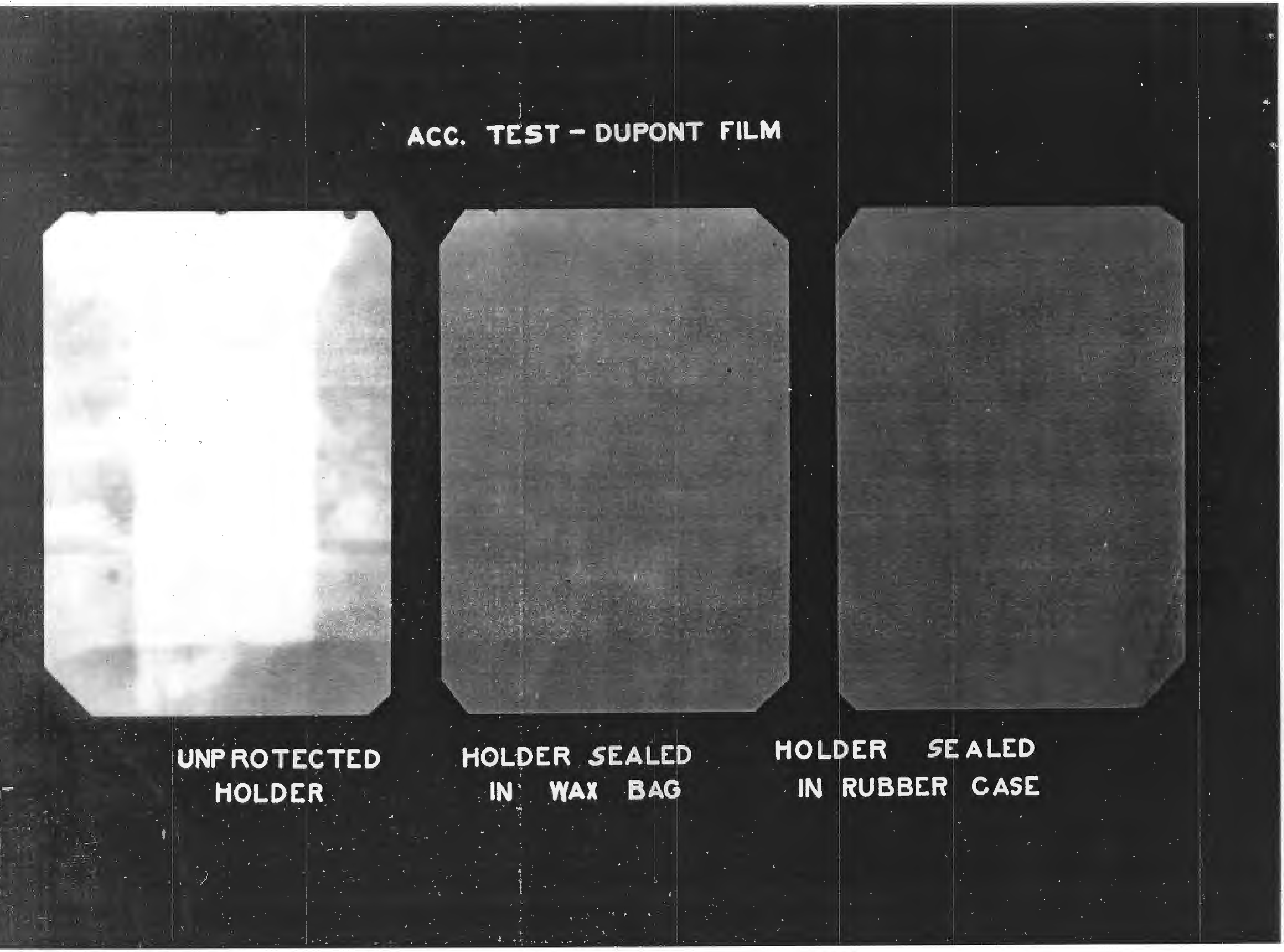
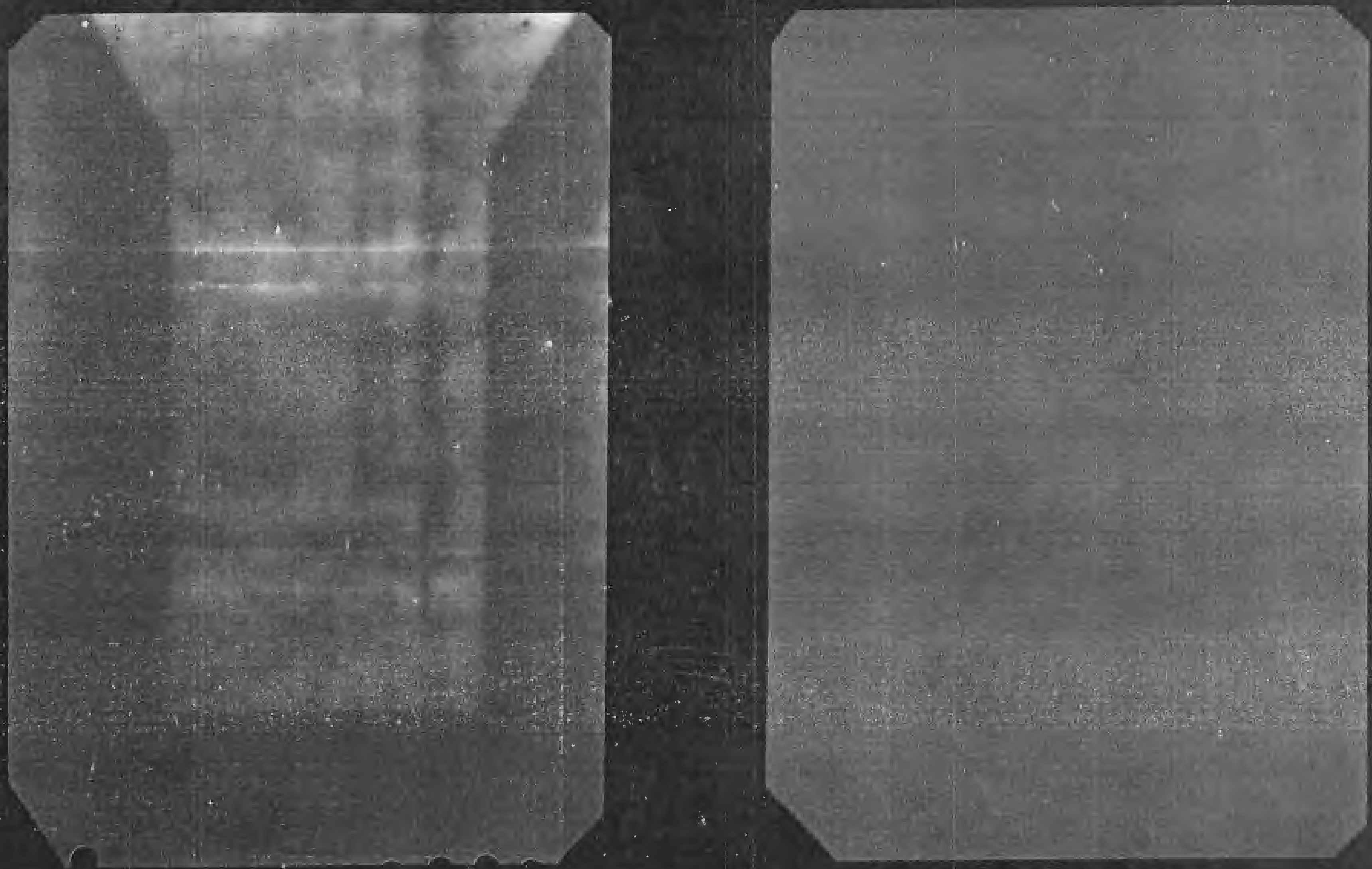

ACC. TEST - DUPONT FILM
UNPROTECTED HOLDER
HOLDER SEALED IN WAX BAG
HOLDER SEALED IN RUBBER CASE

PLATE 6



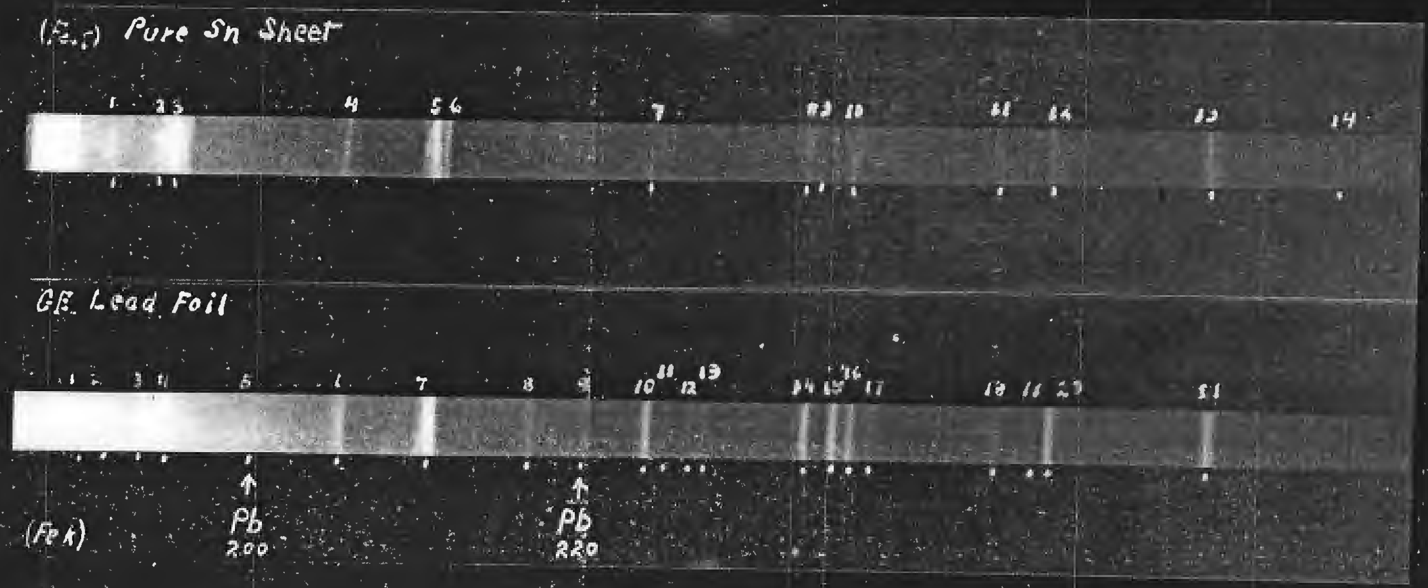
UNPROTECTED HOLDER

HOLDER SEALED IN WAY BAG WITH DRIER CARD

PLATE 7

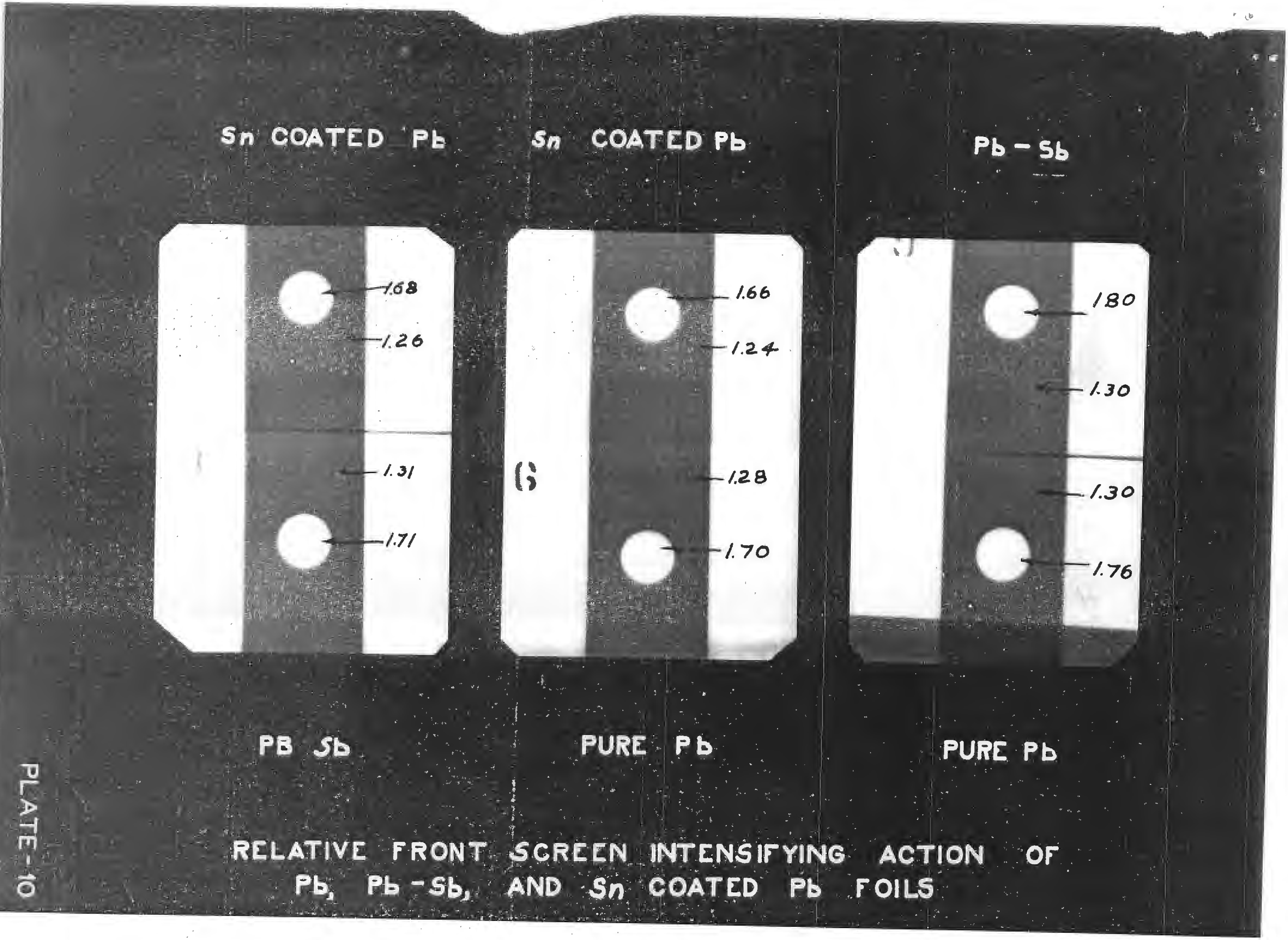
FILMS LEAD MARKED IN RADIOGRAPHIC HOLDERS

PLATE 8



DIFFRACTION PATTERNS SHOWING PRESENCE OF LEAD IN SURFACE OF TIN COATED RADIOGRAPHIC FOIL

PLATE 9



RELATIVE FRONT SCREEN INTENSIFYING ACTION OF Pb, Pb-Sb, AND Sn COATED Pb FOILS

PLATE-10