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SUBJECT

Report on

Intensifying Screens for Gamma Ray Radiography

by

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NAVAL RESEARCH LABORATORY

BELLEVUE, D. C.

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NAVY DEPARTMENT

BUREAU OF ENGINEERING

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Intensifying Screens for Gamma Ray Radiography

NAVAL RESEARCH LABORATORY
ANACOSTIA STATION
WASHINGTON, D. C.

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ABSTRACT

Four different sets of calcium tungstage intensifying screens were exposed to gamma rays and from the resulting film densities, exposure charts were prepared. It was found that, when compared to the standard lead-foil intensifying screens, the calcium tungstate screens reduce the exposure time considerably. However, the intensity does not vary according to the inverse square law and the sensitivity or definition is not as good as can be obtained with the lead-foil screens.

AUTHORIZATION

1. The studies of calcium tungstate intensifying screens for Gamma Ray Radiography were authorized by the Bureau of Engineering letters CL41/S41(2-12-Ds) of 4 April 1936, and JJ46-11(5-6-Ds) of 29 May 1936.

STATEMENT OF PROBLEM

2. The problem consisted in comparing exposure times with calcium tungstate intensifying screens and usual lead-foil screens in order to produce equal film density when radiographing steel sections with radium. The Bureau of Engineering requested that this comparison be made for a range of thickness from 1/2 to 4 inches of steel.

KNOWN FACTS BEARING ON THE PROBLEM

3. A reduction in exposure time in gamma ray radiography can be obtained if materials which fluoresce in gamma rays are kept in intimate contact with the film during exposure. These materials can be made into effective intensifying screens for gamma rays, as has been done for X-ray radiography. The material used in X-ray radiography is calcium tungstate. Calcium tungstate screens are satisfactory in the gamma ray region.

4. Although calcium tungstate is the best known intensifier of the photographic action of X-rays, it is not necessarily the same with gamma rays. Because of this, the Naval Research Laboratory staff in 1929 and 1930 studied and tested more than a hundred other similar minerals in an attempt to find a more strongly fluorescent substance, but none of them was found equal to calcium tungstate.

5. A study was made at that time (1929 to 1930) of a commercial calcium tungstate screen (Patterson Screen) to determine the reduction in exposure time that could be obtained by the use of the intensifying screens. Tests showed that the reduction in exposure time with gamma rays from radium effected by these screens was from 1/7 to 1/5 the time required for the same film density when the customary practice of 2 lead-foil sheets is used. This was true only when a Patterson screen was placed on both sides of the film and in contact with it.

6. Intensifying screen manufacturers now claim that intensifying screens for X-ray radiography are much improved over those tested by the Laboratory staff in 1929 and 1930. From this statement in regard to X-rays it would seem, although not necessarily so, that a greater saving in exposure time could be effected by using the present manufactured intensifying screens for gamma ray radiography.

TEST METHODS

7. The General Electric Company submitted for testing two 5 x 7 inch cassettes containing two 5 x 7 inch General Electric intensifying screens designated as Ray-speed and two 5 x 7 inch Patterson screens designated as Hi-Speed.

8. The Patterson Screen Company submitted for testing three 5 x 7 inch screens without cassettes. Two screens were numbered 1419 and the other screen was numbered 1419A. It was recommended that the Laboratory try two combinations of these screens, one consisting of screens numbered 1419 to be placed both in front and in back of the film; the other combination being 1419 as the screen to be placed away from the radium and 1419A nearest to the radium. The former combination will be subsequently known as 1419 and the latter as 1419A to facilitate the reporting of the results.

9. Calcium tungstate screens consist of a backing of cardboard that is about 0.015 inches thick upon which the calcium tungstate preparation is laid and bonded to the cardboard. The calcium tungstate preparation will vary in thickness according to the manufacturer's ideas, but in general it will be from 0.012 to 0.030 inches thick. The finished screen will be quite stiff and have a glossy appearance on the calcium tungstate side. The general run of prices on calcium tungstate screens per pair is as follows:

5 x 7 inch	-	$4.00	without cassette
10 x 12 "	-	20.00	" "
10 x 12 "	-	35.00	with cassette

A large lead jug was used to hold the radium so that exposures to determine the time-density chart could be made. This cylindrical jug is about 8 inches deep and 8-1/2 inches in diameter with a hole in the center 1-1/2 inches in diameter by 6 inches deep. The radium was placed at the bottom of the hole and steel plates were placed over the hole. This allows at least 3-1/2 inches of lead around the radium for the protection of the operator and also results in a single exposure of 1-1/2 inches in diameter on a film directly above the radium. Steel plates 4 x 4 inches of varying thicknesses were built up so that exposure times could be obtained on increment thicknesses of 1/2 inch starting with a 1/2 inch steel plate.

10. Throughout the study Eastman 5 x 7 inch X-ray films were used. Usually 4 exposures were made on each film.

11. About the time that the experimentation was in readiness to proceed, the 274 mg capsule of radium came into the Laboratory for repairs. While repairs were being made to the egg-shaped carrier and the lead safe, the radium was used in the intensifying screen studies.

12. Time-density curves were constructed for each plate thickness by exposing the film for different times and then reading the corresponding density on an Eastman Densitometer. An example of one of these Time-Density Curves is shown in Fig.1. About 350 exposures were made to determine these curves.

13. It was decided that a density of 1.0 H & D be adopted as the standard density. When all the time-density curves for the different steel thicknesses were completed, the points on the curves at a density of 1.0 were picked off to form the exposure curves as shown in Figs.2, 3 and 4.

14. After the tests with the 274 mgs of radium had been completed, it was decided to check one or two points with the 25 mgs of radium. The points did not check. All exposures were then repeated and new curves were constructed with the 25 mgs of radium. From these tests it was decided that for each amount of radium there would be a different exposure curve.

15. About this time the 500 mg capsule of radium came into the Laboratory for repairs, and while these were being made another set of time-density curves was obtained and an exposure time chart for the 500 mgs of radium was constructed.

16. In order that some idea of the sensitivity of the method with the different intensifying screens could be obtained, two sets of flat steel plates were prepared with holes of different depths and widths. One set of plates was 3 inches thick and the other 1 inch thick. Plate 6 shows the location and dimensions of these holes. When these steel plates were radiographed the drilled holes were in the face away from the film. Lead markers, to show the location of the holes, were taped to the plate. The bottoms of all holes were drilled flat.

DISCUSSION OF DATA OBTAINED

17. The exposure curves with the 500 mgs of radium did not check with either the 274 or the 25 mg curves and therefore bore out the theory that as the radium source or radium intensity was changed a new exposure curve was necessary. In plate 5 a comparison is made of the exposure curves obtained with 25, 274, and 500 mgs of radium for the Ray-Speed Screen, all calculated to a common base of exposures at 18 inches, 100 mgs of radium and H & D Density of 1.00. It will be noticed from the chart that as the amount of radium source increases the exposure times decrease. This condition holds true for all the other intensifying screens studied.

18. A number of checks were made on the lead-foil intensifying screens with the 25, 274, and 500 mgs of radium and all density measurements coincided and only the standard single curve was obtained. Thus the use of calcium tungstate screens offers a disadvantage in that an exposure curve must be constructed for each radium pellet as well as for each type of intensifying screens used.

19. An interesting point is brought out by Plates 2, 3, and 4, which is, that as the metal thickness increases, the relative exposure of the calcium tungstate screens falls off as compared to the lead screens. For example, comparing the 1419 screen to the lead screen at 1/2 inch steel thickness, the exposure with the 25 mg capsule is only 4.3% of the exposure necessary for the lead screens while at 3.5 inches the exposure time has increased so that it is 13.8% of the lead screens. Thus at great thicknesses of steel the time saved due to the use of calcium tungstate screens rather than lead screens would be unimportant.

20. During one phase of the work, films from a different batch were used and density measurements for identical exposure times would not check. This point was followed up further and it was found that variations in the film can make a difference of about 35 points H & D in density when the calcium tungstate intensifying screens are used, whereas with the lead screens a difference of about 10 points H & D will be obtained.

21. Studies on the test plates to determine sensitivity were made at distances of 18 inches or greater. The exposure time to obtain a density of 1.00 H & D at the jug was calculated to the increased distance of 18 inches. Thus the new exposure conditions would give exposure times for 18 inches at a density of 1.00. Some of the exposures, as in the case of the 3 inch plate, ran overnight. It was invariably found that instead of a density of 1.00 being obtained, a much greater density would be recorded. It was therefore decided that the calcium tungstate screens exhibit a building up of their fluoroscopic effect when long exposures are given, thereby increasing the actual amount of exposure, which of course results in an increase in the density of the film. This makes the use of calcium tungstage screens still more involved since an exposure chart is necessary for each source-to-film distance used as well as for different radium strengths.

22. The sensitivity tell-tale consisted of 6 holes drilled in the plate and distributed as shown in Plate 6. Three of these holes were made in the conventional manner of using a 3/16 inch diameter width. The other three holes were constructed so that the width of the hole was equal to its depth. This was done because it is believed that the present type of penetrameter or tell-tale is not sensitive enough, since it is fairly well known that a large spot of a certain density is much more perceptible to the eye than a small spot of the same density.

23. The sensitivity studies establish conclusively that film exposed between the lead foil screens had far greater sensitivity than those films exposed between the calcium tungstate screens. The following original films are included in the report (to be found only in the 1st copy to the Bureau of Engineering; copies of the negatives could not be made due to loss of sensitivity on reproduction) so that visual observation may be made of the degree of sensitivity attained.

Plate 7 -	1 inch	plate	with	lead screens.
8 -	1 inch	"	"	1419 screens.
9 -	1 inch	"	"	Ray-Speed Screens.
10 -	1 inch	"	"	Hi-Speed "
11 -	3 inch	"	"	lead screens.
12 -	3 inch	"	"	1419 screens.
13 -	3 inch	"	"	Hi-Speed Screens.

In general, the conditions as set forth in Table 1 were observed.

24. The calcium tungstate screens produce a cloudy effect that tends to cover up the tell-tale, and the longer the exposure the more pronounced the cloudy condition becomes, so that the tell-tale is completely fogged out for all practical purposes. The films presented in the

report are the best obtained from a series of exposures. If the exact positions of the tell-tale on the film were not known it would be extremely difficult to determine a defect that was much less than 5% of the plate thickness when calcium tungstate screens are used.

25. Another important point worth recording is that even with the lead screens it is very difficult to locate those points of the tell-tale that have a diameter smaller than 3/16 of an inch even though they are as much as 4% of the total plate thickness. This point should be carefully borne in mind when the porosity in welded plates is being studied by means of gamma ray radiography.

26. Careful consideration must be given to the practical application of calcium tungstate screens. These screens can not be bent to conform to surfaces of castings, as they will be broken or become permanently bent. Their application is limited practically to flat surfaces. They also must receive careful handling so that they may not be defaced.

CONCLUSIONS

27. The intensifying effect of calcium tungstate screens varies with the intensity of the radiation used. (Lead screens follow the inverse square law; calcium tungstate screens apparently do not.)

28. With calcium tungstate screens the exposure does not vary directly with the amount of radium used. The greater the amount of radium available the shorter is the exposure time per milligram. With lead screens the exposure varies directly with the amount of radium used.

29. Calcium tungstate intensifying screens show considerable variations among themselves. Each screen studied had different characteristics.

30. In order that calcium tungstate screens may be used effectively and correctly as to proper film density, exposure charts would have to be prepared for each screen separately at distances commonly employed and with a definite amount of radium.

31. Calcium tungstate screens retain their fluoroscopic effect when long exposures are given, thereby acting to increase the length of exposure and the film density.

32. The sensitivity recorded by using the calcium tungstate screens was inferior to that of the lead-foil screens. Also the longer the exposure the poorer the definition due to the fogging or clouding over of the defects by the fluoroscopic effect retained by the screens.

33. Variations on the film can make a difference of about 35 points H & D in density with the use of calcium tungstate screens under the same exposure conditions, whereas with lead screens a difference of about 10 points is obtained.

RECOMMENDATIONS

34. In view of the numerous difficulties in obtaining correct exposure charts and of attaining suitable sensitivity and definition of defect, as well as other constitutional deficiencies, it is recommended that the particular screens considered in this investigation be not adopted for Naval use.

Table 1

Sensitivity Obtained by the Use of Intensifying Screens

Screen	Sensitivity (% defect that can be seen) 1 inch Plate	3 inch Plate
Lead		
Defect position	1, 3, 5, 6	1, 2, 4, 5, 6
Defect % of thickness	4, 3, 2, 4	4, 2, 3, 3, 4
Film characteristics	Fine grain, clear	Fine grain, clear
1419*		
Defect position	1, 3 faint	1, 4, 6
Defect % of thickness	4, 3	4, 3, 4
Film characteristics	Large grain-Cloudy	Medium grain-Cloudy
Ray Speed		
Defect position	1, 3, 5	1, 4, 5, 6
Defect % of thickness	4, 3, 2 faint	4, 3, 3, 4
Film characteristics	Large grain, Cloudy	Medium grain-Cloudy
Hi-Speed		
Defect position	1, 3 faint	1, 4, 6
Defect % of thickness	4, 3	4, 3, 4
Film characteristics	Large grain, Cloudy	Large grain-Cloudy

*1419A is identical to 1419.

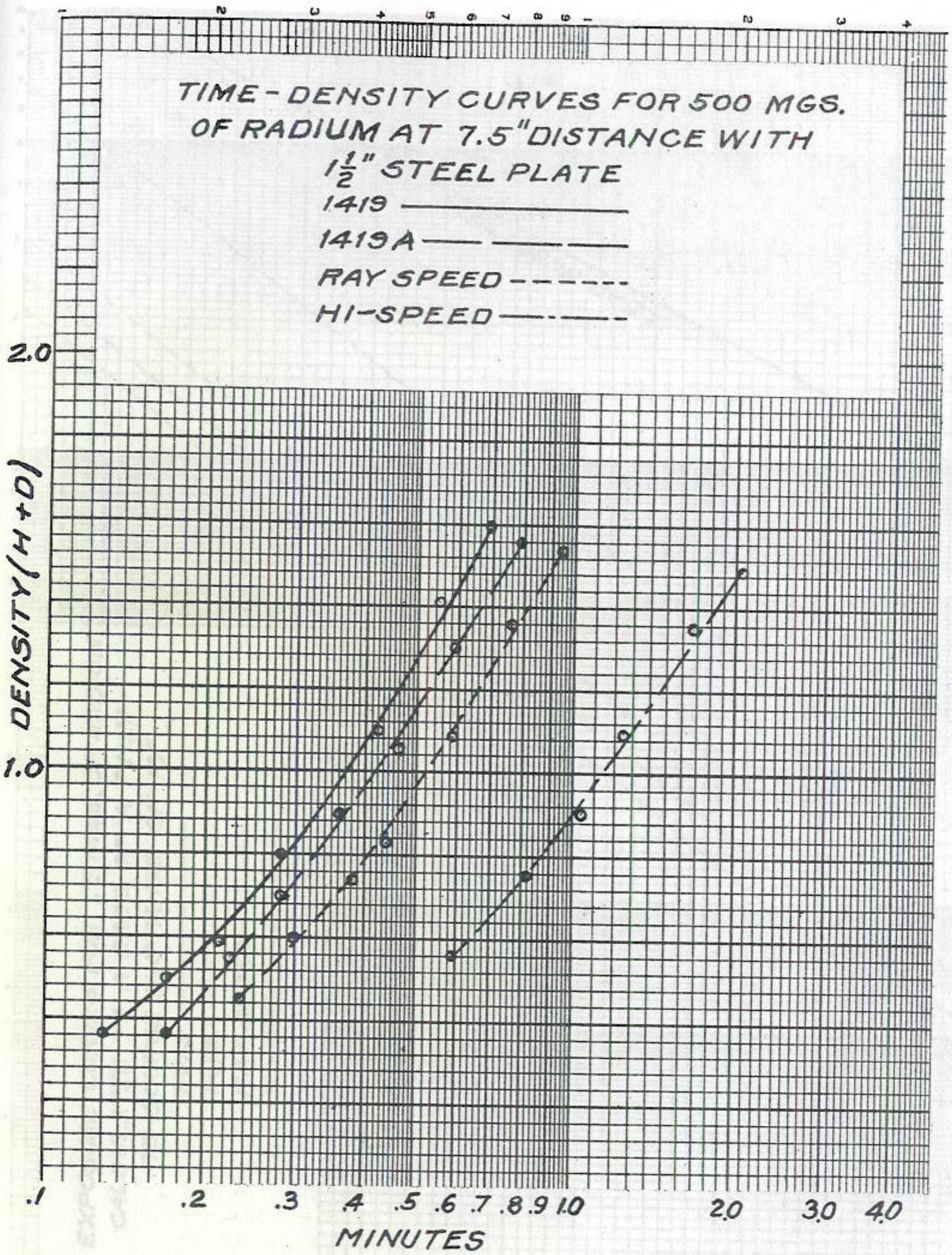

TIME - DENSITY CURVES FOR 500 MGS.
OF RADIUM AT 7.5" DISTANCE WITH
1½" STEEL PLATE
1419
1419A
RAY SPEED
HI-SPEED
2.0
1.0
DENSITY (H + D)
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
2.0
3.0
4.0
MINUTES

PLATE 1

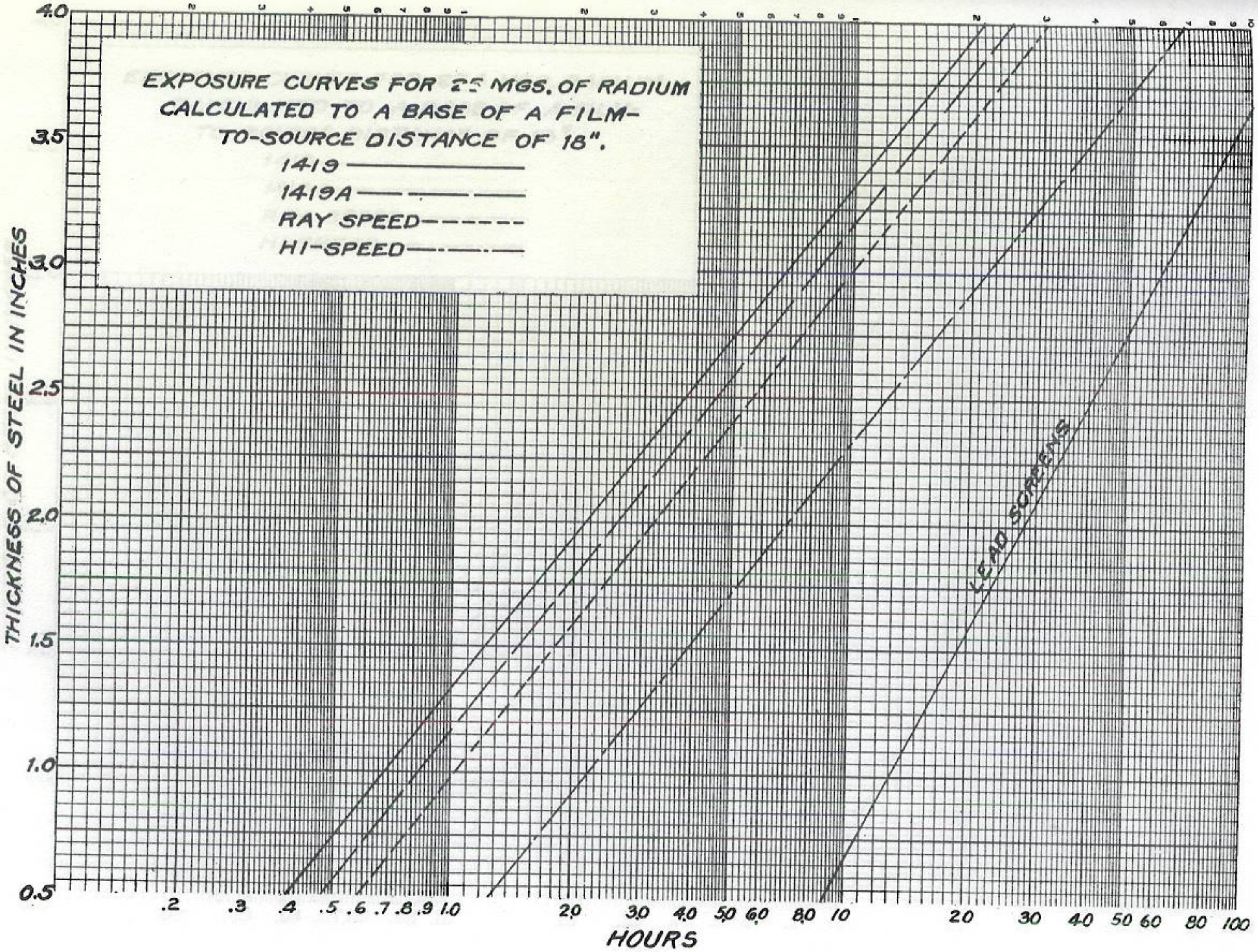

EXPOSURE CURVES FOR 25 MGS. OF RADIUM
CALCULATED TO A BASE OF A FILM-
TO-SOURCE DISTANCE OF 18".
1419
1419A
RAY SPEED
HI-SPEED
LEAD SCREENS
THICKNESS OF STEEL IN INCHES
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
.2 .3 .4 .5 .6 .7 .8 .9 1.0 2.0 3.0 4.0 5.0 6.0 8.0 10 20 30 40 50 60 80 100
HOURS

PLATE 2

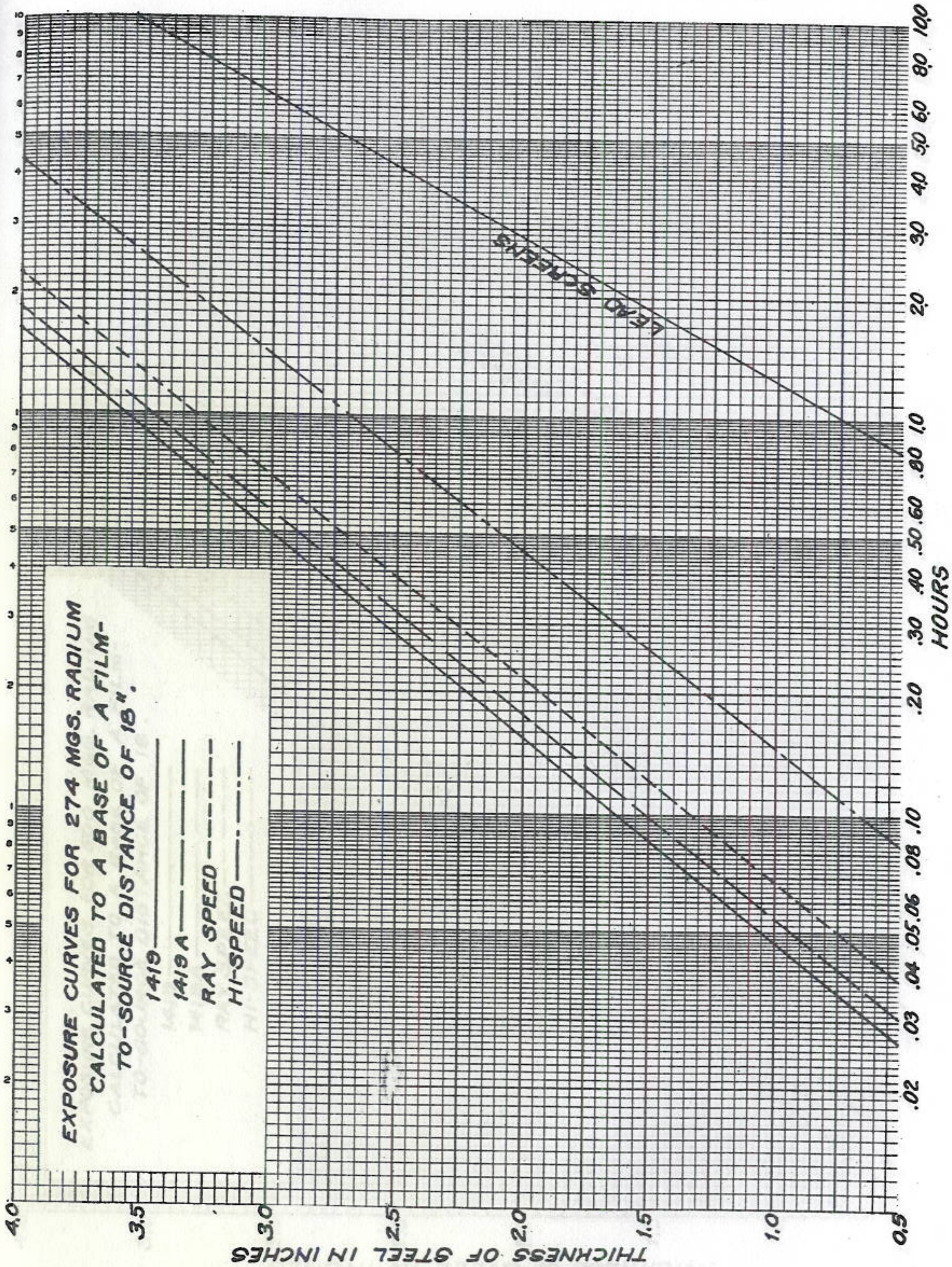

EXPOSURE CURVES FOR 274 MGS. RADIUM
CALCULATED TO A BASE OF A FILM-
TO-SOURCE DISTANCE OF 18".
1419
1419 A
RAY SPEED
HI-SPEED
LEAD SCREENS
HOURS
.02 .03 .04 .05 .06 .08 .10 .20 .30 .40 .50 .60 .80 1.0 2.0 3.0 4.0 5.0 6.0 8.0 10.0
THICKNESS OF STEEL IN INCHES
4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5

PLATE 3

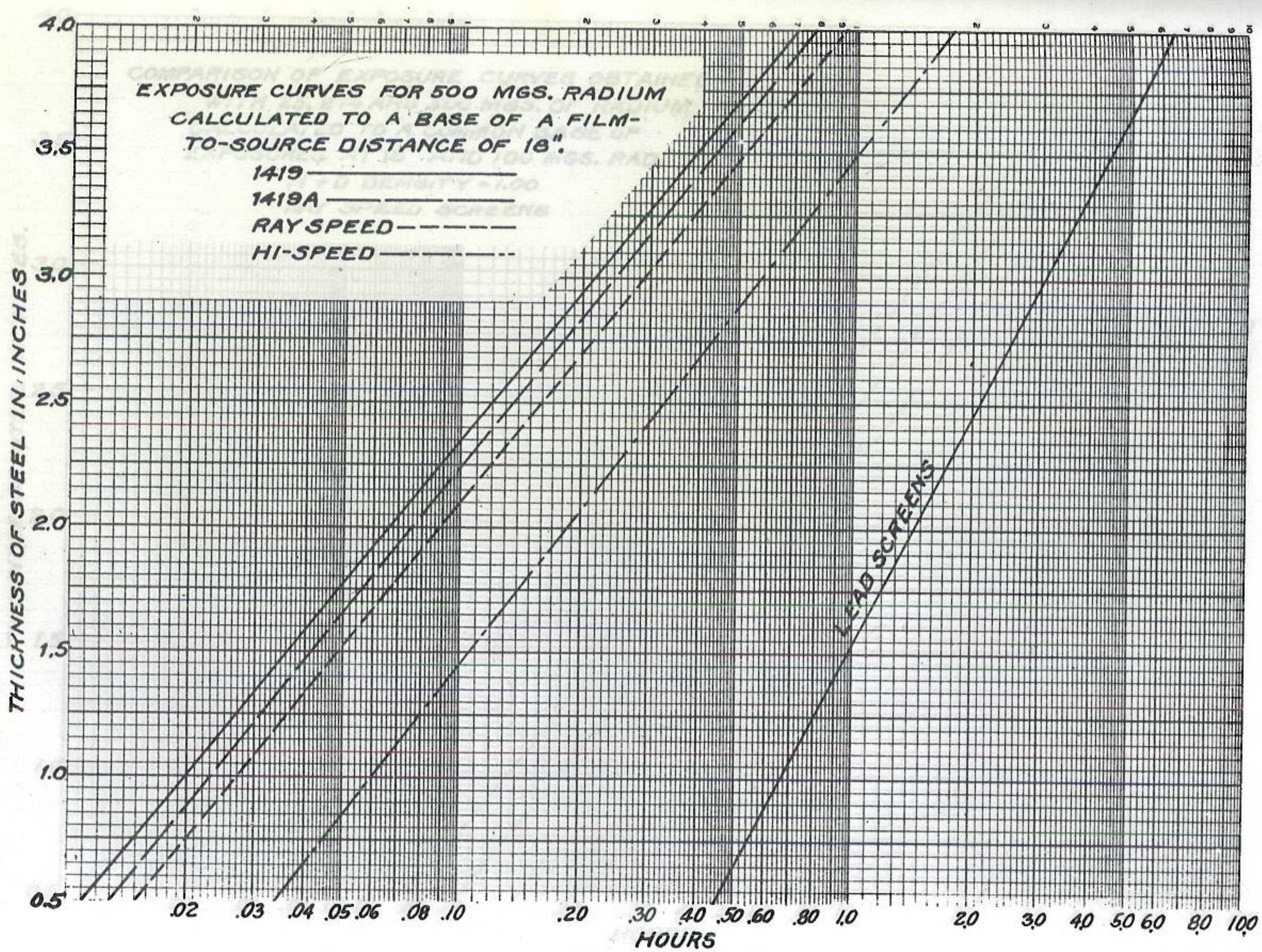

EXPOSURE CURVES FOR 500 MGS. RADIUM
CALCULATED TO A BASE OF A FILM-
TO-SOURCE DISTANCE OF 18".
1419
1419A
RAY SPEED
HI-SPEED
LEAD SCREENS
THICKNESS OF STEEL IN INCHES
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
.02
.03
.04
.05
.06
.08
.10
.20
.30
.40
.50
.60
.80
1.0
2.0
3.0
4.0
5.0
6.0
8.0
10.0
HOURS

PLATE 4

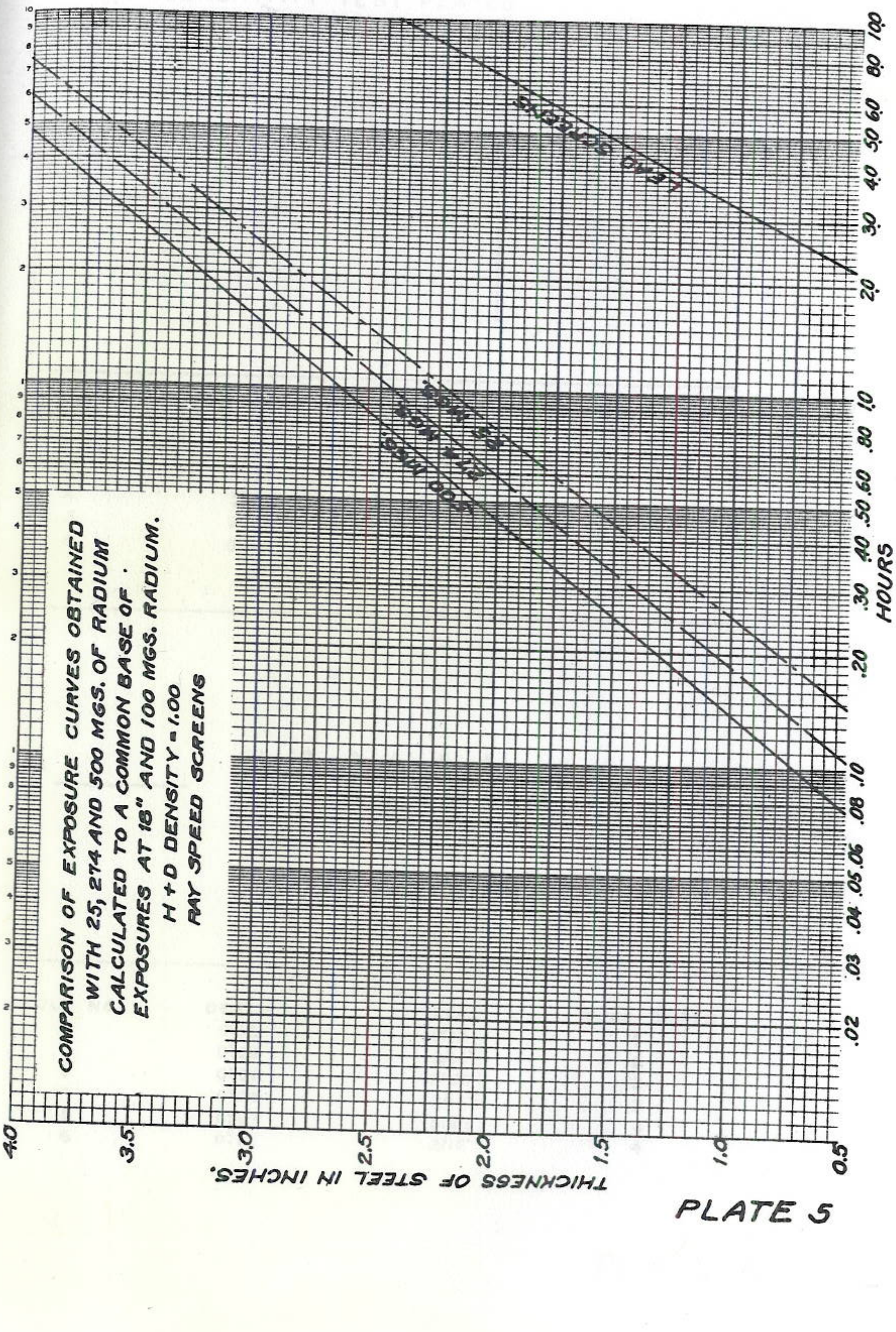
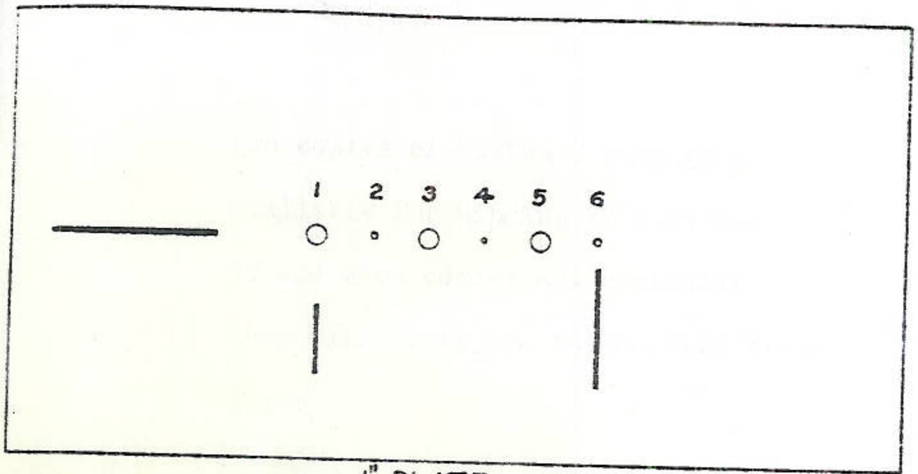

COMPARISON OF EXPOSURE CURVES OBTAINED
WITH 25, 274 AND 500 MGS. OF RADIUM
CALCULATED TO A COMMON BASE OF
EXPOSURES AT 18" AND 100 MGS. RADIUM.
H + D DENSITY = 1.00
RAY SPEED SCREENS
25 MGS.
274 MGS.
500 MGS.
LEAD SCREENS
HOURS
.02 .03 .04 .05 .06 .08 .10 .20 .30 .40 .50 .60 .80 1.0 2.0 3.0 4.0 5.0 6.0 8.0 10.0
THICKNESS OF STEEL IN INCHES.
4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5

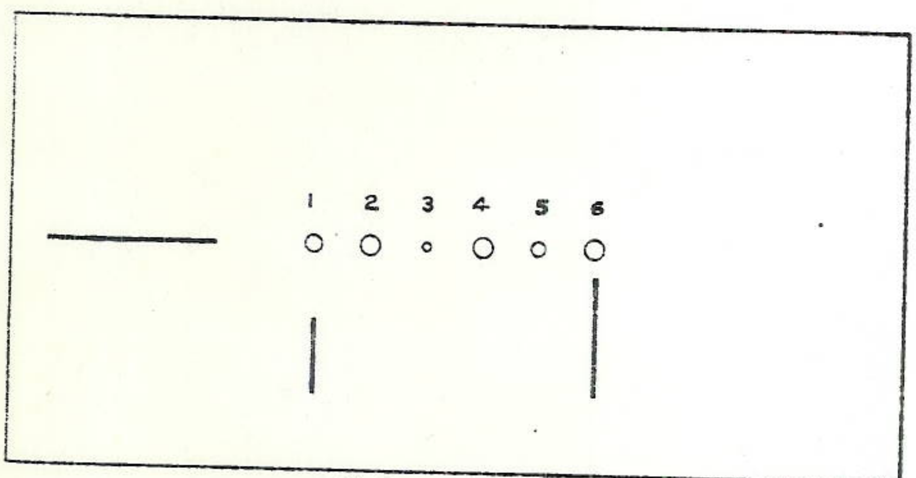
PLATE 5

SENSITIVITY TEST PLATES



1" PLATE

HOLE NO.	DEPTH	DIA.	% OF DEPTH
1	0".04	3/16"	4
2	0".03	0".03	3
3	0".03	3/16"	3
4	0".02	0".02	2
5	0".02	3/16"	2
6	0".04	0".04	4



3" PLATE

HOLE NO.	DEPTH	DIA.	% OF DEPTH
1	0".12	0".12	4
2	0".06	3/16"	2
3	0".06	0".06	2
4	0".09	3/16"	3
5	0".09	0".09	3
6	0".12	3/16"	4

PLATE 6

(No copies of Plates 7 thru 13 are available for binding at this time. If and when copies are available they will be tipped in on these blank pages)