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NAVY DEPARTMENT

BUREAU OF ENGINEERING

Report

on

Installation of Naval Research Laboratory Lamination Detector at Philadelphia Navy Yard.

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WASHINGTON, D.C.

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Authorization: Navy Dept. ltr. SOSED-4-MR of 7 September 1938 and NRL ltrs. P16-4(9) of 9 September 1938 and 31 October 1938.

Dates of Work: 12 September through 25 November 1938.

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AUTHORIZATION FOR TEST

1. This test was authorized by the following references:

Reference: (a) Navy Dept. ltr. SOSED-4-MR of 7 September 1938.
(b) NRL ltr. P16-4(9) of 9 September 1938.
(c) NRL ltr. P16-4(9) of 31 October 1938.

OBJECT OF TEST

2. The object of this test was to install at the Philadelphia Navy Yard, and to use for a trial period, a lamination detector which had been developed by the Naval Research Laboratory for the Bureau of Construction and Repair. The term "lamination" is here used in its metallurgical sense to denote a layer of inclusions in rolled metal, a layer which if present is a plane of weakness in the material.

ABSTRACT

3. The period of the writer's duty at the Philadelphia Navy Yard extended from 12 September through 25 November 1938, a period of eleven weeks. The first three weeks of the time were required for the erection of a temporary building, for installation of equipment, including the mounting of rollers for a roller bed, and for preliminary tests. The remaining period of duty was spent in giving the equipment a thorough test to learn how suitable the installation was as a means for routine inspection of plates for laminations. The apparatus will not be described in detail here, being the subject of a later report.

4. The total number of items examined with the lamination detector was eighty-eight, and the total number of separate tests made was more than one hundred six. From the experience gained during the tests, conclusions can be drawn concerning how lamination detector indications will be affected by a change in any one of several possible variables. The effects which were particularly studied were in order of their importance, the effects of: (1) presence of a true lamination; (2) a certain phenomena which, due perhaps to bending strain, gave opposite indication when examined from opposite sides of a plate; (3) small changes in air gap of a pick-up unit, such as might be caused by rolling over dried puddles of paint, etc.; (4) differences in galvanizing over the surface of a plate; (5) presence of a pit in surface of metal; (6) presence of minute surface cracks running in a direction to obstruct eddy currents in the plate; (7) flexing of a plate during test because of lack of flatness of the plate, and (8) less important observations such as wetness of the plate surface, grinding of the plate for removal of "cold shuts," etc.

ABSTRACT OF CONCLUSIONS

(a) Out of the total of eighty-eight items tested at the Philadelphia Navy Yard only one gave unmistakable evidence of lamination. The probability is that none of the items which failed to give strong evidence of lamination really contained severe lamination.

(b) The one item, a "T" beam, which did give unmistakable evidence of lamination verified the fact that a true lamination will give a strong indication at the right location and of proper sign, when examined from either side of the metal surface.

(c) The equipment as now installed at the Philadelphia Navy Yard is sensitive to other defects and conditions in addition to true laminations.

ABSTRACT OF RECOMMENDATIONS

(a) The test work with the lamination detector at the Philadelphia Navy Yard should be continued.

(b) A length of laminated portion of the "T" beam at the Philadelphia Navy Yard should be shipped to the Naval Research Laboratory for further studies.

(c) Additional investigative work should be done at the Naval Research Laboratory, as outlined in paragraph 45.

(d) A new exciting coil, and additional pick-up units for use inverted under the plate should be authorized for manufacture by the Naval Research Laboratory.

DESCRIPTION OF MATERIAL UNDER TEST

5. The material which was tested at the Philadelphia Navy Yard consisted mostly of ordinary mild steel, pickled and painted hull plates. The length of hull plate tested ranged from 96 inches to 384 inches; the width from 25 inches to 96 inches, and the weight from 7 pounds to 20 pounds, per square foot.

6. Most of the plates tested were fairly flat, but some of the lighter weight plates were sufficiently wavy to bang against the rollers of the roller bed as the plates in turn were drawn through the lamination detector.

7. Besides the plates mentioned above, tests also were made on: (1) five plates which were merely pickled, having been rejected on account of surface imperfections revealed by the pickling; (2) two S.T.S. straps; (3) one large S.T.S. plate; (4) four galvanized plates, and (5) one "T" beam.

8. Of the total items tested seventeen were judged to be interesting enough to warrant examination of the items from both sides. Thus, while the total number of items tested was eighty-eight, the total number of inspections for lamination was one hundred five. In addition to the tests described above, one test was made with cardboard squares to determine the effect of change of air gap, upon pick-up voltages. Several tests also were made to determine variations of permeability, as revealed by in-phase component of pick-up voltage.

METHOD OF TEST

9. The equipment used for the tests is shown in Figures 1, 2, 3, 13, 14, 15 and 16. Figure 1 is a view of the building and roller bed foundation, both of which were especially constructed for the tests. Figure 2 is a close-up view showing a plate in position for test. Figure 3 is an interior view showing equipment shipped up from the Naval Research Laboratory. Figure 13 is a shop view of the exciting coil and assembly of pick-up units. Figure 14 is a close-up view of a single pick-up unit. Figure 15 is a view of the recorder. Figure 16 is a view of the illuminated screen of the cathode-ray oscillograph, with an indication of defect by pick-up unit number 6.

10. The test procedure divided itself into the following steps:

11. A plate, upon being selected for test, was picked up by the overhead crane.

12. The use of loading timbers alongside the roller bed made only one operation necessary during laying down or taking off plates. The plates upon being laid down were fastened to the winch cable by a clamp, as shown in Figure 2.

13. The plates were laid down so that the center line of the plate was directly under the center line of number 6 pick-up unit. Thus any location on a plate could be referred to its corresponding location on the record for that plate.

14. The necessity of rapid alignment of pick-up voltages made inconvenient the use of more pick-up units than were shown at one time on the viewing screen of the cathode-ray oscillograph. Thus the pick-up units were limited to ones in the center, namely, units 4, 5, 6, 7 and 8.

15. All tests made at Philadelphia were made with the same variac setting for obtaining voltage applied to the exciting coil. Hence, all tests were made with the same sensitivity. The reason for using only one sensitivity for all tests was to allow direct comparison of any record with any and every other record. The records were obtained from the recorder shown in Figure 15.

16. Best results were obtained by aligning the pick-up voltages anew for each new plate. The alignment was necessary because of differences in width, thickness, and composition from plate to plate. The pick-up voltages were aligned while the plate was run through a fair distance, forward and back. If the record obtained during the trial run for alignment was considered to be satisfactory, an entire record was taken as the permanent one for examination of the plate. All records were started and stopped a foot from end of the plate, to avoid distortion of indications due to nearness of end of the plate.

17. Each record upon being torn off was immediately stamped with a rubber stamp. The spaces printed by the stamp were filled in with all required information before the next record was taken. The information included number of the plate, date, observer, size, other plate identification, detector settings, and remarks, if any. The location of painted numbers on the plate also was shown, for identification of top and bottom and right and left for the plate.

18. If a particular record was judged to be of especial interest, the plate was turned over, and a record was taken for examination of this other side, as a check upon the first record.

DATA RECORDED DURING TEST

19. The data recorded during the test consisted almost entirely of automatic records, and was much too voluminous to be included in full in this report. A few of the more interesting records have been selected to serve as examples to prove certain points. The amount and variety of record included is that shown in Figures 4 to 10 inclusive. The photostat copies are full-scale and have been held to letter size, which limitation means that only a portion of each record as originally taken could be included. What points the records prove will be considered under discussion of results, later in this report.

20. Some explanation of how to read the records of Figures 4 to 10 inclusive needs to be made. Let us consider Figure 4. Notice that four of the lines of marking of the figure were retouched in the original record, in order that the photostat copy would show the record more distinctly. These four lines of marking which show up distinctly constitute the record for pick-up unit number 4 alone. The next similar four lines of marking is the record for pick-up unit number 5 alone, and so on across width of the record. The reason for having several lines of marking for each pick-up unit is in order to have an abundance of steps of indication for showing degrees of change in passing from a region of sound material to a region of defective material. The four lines of marking for a given pick-up differ among themselves in the voltage at which they start giving indication. The two outside lines (of the four) start marking first; one of the inside lines starts marking next, and the other inside line starts marking last. The number of steps of indication is further increased by the fact that each line of marking shows dots first, dashes next, and full line only for maximum indication. Thus in passing from the minimum indication of no mark in all four lines to the maximum indication of full mark in all four lines, the recorder will pass through nine steps of indication - if the change in voltage is gradual enough to allow the recording of all the steps of indication. An instance of maximum indication is shown by the region enclosed by heavy circle in Figures 4 and 5.

21. Besides regular records, the data taken during the stay at the Philadelphia Navy Yard included: (1) a daily log for period of the first three weeks, as a work-and-progress report on construction of the lamination detector building, and (2) a visitors' register which was for the purpose of aiding in memorizing names and titles. Table 1 of this report summarizes results of examination of the 88 plates.

DISCUSSION OF PROBABLE ERRORS

22. Inspection of Figures 4 and 5 will show conclusively, as numerous similar records likewise have shown, that there are no sources of error in the automatic recorder. As long as the settings of the lamination detector are left unchanged, the recorder will give the same record for a given plate almost as faithfully as a mimeograph machine duplicates copies.

23. Saying that the recorder considered by itself is an entirely dependable instrument is not quite the same as saying that the lamination detector considered as a while is an equally reliable instrument. As a matter of fact, the evidence of Figures 4 to 10 inclusive as considered at length later in this report shows conclusively that the lamination detector in its present stage of development detects not only laminations but sometimes other conditions as well. In the latter case a re-examination from the other side of the plate enables the question to be decided. Fortunately, no inherent reason

has as yet appeared why with further development the lamination detector could not be made at least much more selective than it is at present, in regard to detection of laminations and laminations alone.

RESULTS OF TEST

24. From the results of the tests at the Philadelphia Navy Yard, nine results stand out as constituting the chief value gained from the work. Eight of the results apply to reliability of performance of the equipment, and the ninth applies to rate of testing.

25. The eight results which apply to reliability of performance are, in order of importance, the following:

26. Additional proof was gained that a serious degree of lamination can be detected by the equipment. The fact that few strong indications of lamination were found during the tests at Philadelphia may simply be evidence that extensive, severe laminations in mild steel hull plate are rare. The adjacent sound material in plates has the known effect of diminishing the strength of indication which otherwise would be given by a lamination of small extent, and hence for a lamination to give the strongest possible indication the lamination must not only be severe, but must cover a sizeable area. Thus, objects of narrow width, such as structural shapes, should give somewhat more unmistakable indication when lamination is present than will wide plates. The one lamination which with certainty was detected at Philadelphia was in the "T" beam shown in Figure 11. Portions of two records for examination of the beam are shown in Figures 9 and 10. Figure 12 is included to show portions from the other half of the original "I" beam from which the beam of Figure 11 was torch cut. Notice that in Figure 12 the lamination extended the whole length of one piece, and more than half the length of the other piece. Figure 12 shows that laminations in structural shapes not only may be severe, but may be quite extensive. If the original "I" beam had not been torch cut into two "T" beams, the existence of a dangerous degree of lamination in the beam could not have been known by ordinary inspection methods, prior to failure during construction or in service.

27. Indication of lamination for examination of one side of a plate must correlate positively with indication from the other side of the plate if either indication is to be significant as indicating presence of a lamination. Figures 6 and 7 show a case of decided negative correlation between lamination detector indications from top and bottom of a plate. The fact that examples of decided negative correlation not only do occur, but are fairly often observed is proof that the lamination detector is not yet entirely outside a laboratory stage of development. As mentioned earlier in this report, pick-up units mounted both above and below a plate would serve to eliminate

indications which signify a detection only of negative correlation effects. Incidentally, not all examples of negative correlation are at regularly spaced regions as in Figures 6 and 7. The more common form of such example is where the indication occurs singly, and at random, in the plate.

28. A test was made to determine how insensitive the pick-up units are to change of air gap between plate and iron core. The test was made by building up various thicknesses of spacer by one or more squares of cardboard. By use of such spacers the air gap under pick-up units was changed by increments up to a maximum of 0.143 inch. The changes of air gap had hardly any observable effect upon the indication given by the recorder of the lamination detector. The conclusion is that any changes of air gap to be expected in practice (such as due to dried puddles of paint) will have no observable effect upon lamination detector records. This fact had already been established at the Naval Research Laboratory.

29. Figures 4 and 5 are included as a representative record for examination of galvanized plate. For galvanized plate, the indications are consistently strong and quite irregular. The evidence is that either the galvanized coat itself or the process of galvanizing introduces some factor of marked effect upon lamination detector readings.

30. Figure 8 is included to show that the effect of a pit is opposite to effect of a lamination. The indication is one of rise in voltage (blank space on the record) instead of a fall in voltage (marked space on the record). The observation is what one should expect. The increase in voltage due to a pit is simply evidence that because of the discontinuity of surface condition, more magnetic flux is forced out into the air, to be detected by the pick-up coil. The detection of surface imperfections by the Magnaflux method depends upon this same principle of there being a concentration of magnetic flux wherever the normally smooth surface of a magnetized body is broken by a crack.

31. One plate was tested which gave a moderate amount of indication of lamination when the plate was examined from both sides. A punching was taken from the plate at an interesting location. Etching of the punching did not reveal a lamination proper, but only fine streaks of banding along center of the piece. The conclusion is that moderate indications of lamination must be passed over as insignificant when testing plates for severe lamination.

32. A plate was examined which showed regions of numerous, short, longitudinal, surface cracks. The cracks were presumably quite shallow, but were in a direction to obstruct eddy currents along top of the plate. Observations obtained for examination of the plate with the lamination detector did correlate well with the regions

of crack, but the strength of indication was not nearly enough to cause confusion with a true lamination.

33. Some plates were tested which were badly warped. The plates upon being pulled through the lamination detector flexed occasionally to bang against rollers of the roller bed. The interesting observation was made that the flexing of the plates scarcely affected indications of the lamination detector. The effect of flexing was observed by watching the viewing screen of the cathode-ray oscillograph.

34. The chief result from studies on rate of testing will now be considered, in the two paragraphs immediately following.

35. The studies on rate of testing showed that the equipment as now installed at Philadelphia has not near the capacity to examine all plates coming into the Navy Yard. No inherent reason was discovered why equipment could not in time be developed for examining all plates of the Yard, but before such quantity testing of plates could be accomplished the expense of installation would have to be quite considerably increased.

36. One of the present quite important limitations upon rate of testing is the time required for getting crane service. The time required for actual handling of a plate was only about ten minutes on the average (for the operation of laying down and lifting off), but sometimes the time required for waiting to get use of the crane was a serious handicap. The present rate of actual testing is somewhat slower than necessary, owing to slowness of the winch for pulling plates through. The time consumed at present for just pulling a long plate all the way through and back again runs up to around ten minutes. Approximately ten minutes was required for stamping and otherwise preparing a record, including study of record for writing of remarks. If the plate was to be examined from both sides, the testing time was doubled all around. All in all, a testing of six to eight plates a day was a good day's output of records, for experimental studies. Later, when the whole emphasis was to be upon quantity testing of plates, the time for actual testing (all operations other than crane service) might be reduced to around five minutes per plate, say - but only after installation of a much faster winch and after certain simplifications of test procedure. Perhaps the time for actual testing could, if important enough, be reduced even to as little as three minutes.

CONCLUSIONS

37. Out of the total of eighty-eight items tested at the Philadelphia Navy Yard only one gave unmistakable evidence of lamination. The probability is that none of the items which failed to give strong evidence of lamination really contained severe lamination.

38. The one item, a "T" beam, which did give unmistakable evidence of lamination verified the fact that a true lamination will give a strong indication at the right location and of proper sign, when examined from either side of the metal surface.

39. The equipment as now installed at the Philadelphia Navy Yard is sensitive to other defects and conditions in addition to true laminations.

RECOMMENDATIONS

40. The recommendations which follow from experience gained at Philadelphia are listed below. Each recommendation is followed by a brief explanation of reason or reasons for the recommendation.

41. The equipment, which is now installed at Philadelphia, should for the time being be kept there. It is recommended that the Bureau authorize the Philadelphia Yard to continue with the routine examination of the remainder of the original 200 items, using personnel of the Yard who have already been instructed in the method of using the instrument. It is also recommended that results of all those tests be compared with subsequent history of the plates as they go into fabrication, so far as this is possible.

42. It is recommended that the Naval Research Laboratory be authorized to construct the additional pick-up units for use underneath the plate, as mentioned in paragraph 27; likewise, to build an exciting coil to replace the present one, having an opening about 6 inches deeper than the latter. This new coil would accommodate the inverted pick-up units and also make possible the examination of shapes such as "I" beams and channels, the importance of which has already been alluded to.

43. The cause of negative correlation effects observed in lamination detector records should be investigated at the Naval Research Laboratory. Negative correlation effects as observed from records taken at Philadelphia are much too consistent and much too pronounced to be explainable as due solely to accident. Some as yet unknown condition of steel causes a lamination detector indication to be positive when the plate is examined from one side, but negative when the plate is examined at the exactly opposite location on the other side of the plate. What the condition is which can give lamination detector indications which correlate negatively is a property of metal which ought to warrant at least some investigation as a matter of interest in its own right. For instance, if the phenomena could be explained as due to residual bending strains, important applications of the discovery perhaps could be made.

44. The laminated "T" beam which was tested at Philadelphia should be cut to a convenient length and shipped to the Naval Research Laboratory for further studies. One of the purposes served would be that of investigating effect of width of lamination upon strength of lamination detector indication. No exact data are as yet available on how deep the lamination of the "T" beam extended into web of the beam, and hence little basis exists as yet for estimating how much stronger the indication of defect would have been if the lamination had been wider. The depth of lamination would be determined by cutting and etching the beam at appropriate locations. The cutting and etching would also serve to show whether or not certain regions which gave moderate indication of defect really were partially laminated. The other purpose served by having a length of laminated "T" beam at the Laboratory is that a specimen would have been provided for use in developing a lamination detector designed expressly for examining structural shapes.

APPENDIX

Below is given a complete list of items tested at the Philadelphia Navy Yard during the period covered by the present report.

Column (1) below gives the number of plate as marked on a record or records for that plate. In column (3) the letter "A" means that the indication for that plate was at one or more locations strong; the letter "B" means that the indication was only medium strong; while the letter "C" means that the indication was weak. In column (4) the number "2" means that the plate was examined on both sides, by turning the plate over after examining from one side.

Table 1

(1) Number of Plate	(2) Size of Plate	(3) Indication	(4) Sides	(5) Remarks
1	226 x 76 x 15#	C	-	-
2	264 x 60 x 15#	C	-	Surface cracks detected.
3	228 x 76 x 10#	A	-	Good duplicate records.
4	264 x 60 x 15#	C	-	-
5	264 x 96 x 10$\frac{2}{2}$#	B	-	Indication at end.
6	204 x 69 x 20#	B	-	Surface defects ground out.
7	264 x 96 x 10$\frac{2}{2}$	C	-	Plate badly warped.
8	240 x 84 x 9#	C	-	Plate badly warped.
9	192 x 72 x 20#	B	-	Indication at end.
10	175 x 54 x 15#	C	-	-
11	186 x 54 x 15#	C	-	Large areas of no marking.
12	175 x 54 x 15#	B	-	Better support of plate needed.
13	324 x 72 x 15#	C	-	Plate unusually long.
14	87 x 62 x -	C	-	"Cold shuts" not detected.

Table 1 (Continued)

(1) Number of Plate	(2) Size of Plate	(3) Indication	(4) Sides	(5) Remarks
15	324 x 60 x 15#	AA	2	Decided negative correlation.
16	192 x 72 x 20#	C	-	-
17	183 x 65 x 15#	C	-	Unusually sound plate.
18	186 x 54 x 15#	B	2	Positive correlation.
19	210 x 62 x 17-1/2#	C	-	Plate better supported.
20	170 x 53 x 15#	C	2	Zero correlation.
21	264 x 48 x 15#	C	-	-
22	264 x 90 x 9#	C	-	Unusually sound plate.
23	186 x 54 x 15#	B	-	Indication at end.
24	141 x 92 x 8-1/2#	B	-	-
25	186 x 54 x 15#	C	-	Unusually sound plate.
26	183 x 65 x 15#	B	2	Positive correlation.
27	186 x 54 x 15#	C	-	-
28	184 x 54 x 15#	C	-	-
29	254 x 70 x 20#	C	-	-
30	231 x 61 x 20#	B	2	Positive correlation.
31	300 x 72 x 15#	C	-	-
32	384 x 60 x 15#	C	-	Sound plate.
33	180 x 62 x 17-1/2#	C	-	-
34	212 x 62 x 17-1/2#	A	2	Evenly spaced negative correlation.
35	212 x 62 x 17-1/2#	C	-	-

Table 1 (Continued)

(1) Number of Plate	(2) Size of Plate	(3) Indication	(4) Sides	(5) Remarks
36	288 x 96 x 25#	C	-	S.T.S. plate; very sound.
37	300 x 54 x 7.65#	B	2	Correlation various.
38	300 x 48 x 17#	C	-	-
39	188 x 46 x 10#	C	-	-
40	300 x 48 x 17#	C	-	-
41	218 x 39 x 15#	BB	2	Similar to Plate 34.
42	360 x 66 x 7.65#	B	2	Plate rejected; "cold shuts."
43	324 x 72 x 10#	C	-	-
44	324 x 72 x 10#	C	-	Surface badly pitted.
45	300 x 72 x 15#	C	-	Pit gave blank space on record.
46	115 x 76 x 20#	C	-	-
47	300 x 96 x 10#	C	-	-
48	324 x 72 x 20#	C	-	Very sound plate.
49	324 x 72 x 10#	A	2	Negative correlation.
50	264 x 60 x 15#	C	2	Record blank towards end.
51	264 x 60 x 15#	B	2	Indefinite correlation.
52	153 x 58 x 17.85#	C	-	-
53	264 x 41 x 12#	A	2	Negative correlation.
54	324 x 72 x 20#	C	-	Unusually sound plate.
55	300 x 72 x 9#	C	-	-
56	324 x 72 x 10#	A	2	Plate extensively surface ground.

Table 1 (Continued)

(1) Number of Plate	(2) Size of Plate	(3) Indication	(4) Sides	(5) Remarks
78	348 x 81 x 15#	C	-	-
79	384 x 60 x 15#	C	-	-
80	264 x 72 x 20#	BB	2	Good positive correlation.
81	324 x 60 x 15#	B	-	-
82	300 x 60 x 15#	B	-	Light record towards end.
83	-	C	-	-
84	124 x 44 x 17$\frac{5}{}$#	B	-	-
85	108 x 50 x 15#	CC	-	-
86	97 x 87 x 7#	C	-	-
87	97 x 87 x 7#	C	-	-
88	96 x 86 x 20#	CC	-	Single indication.

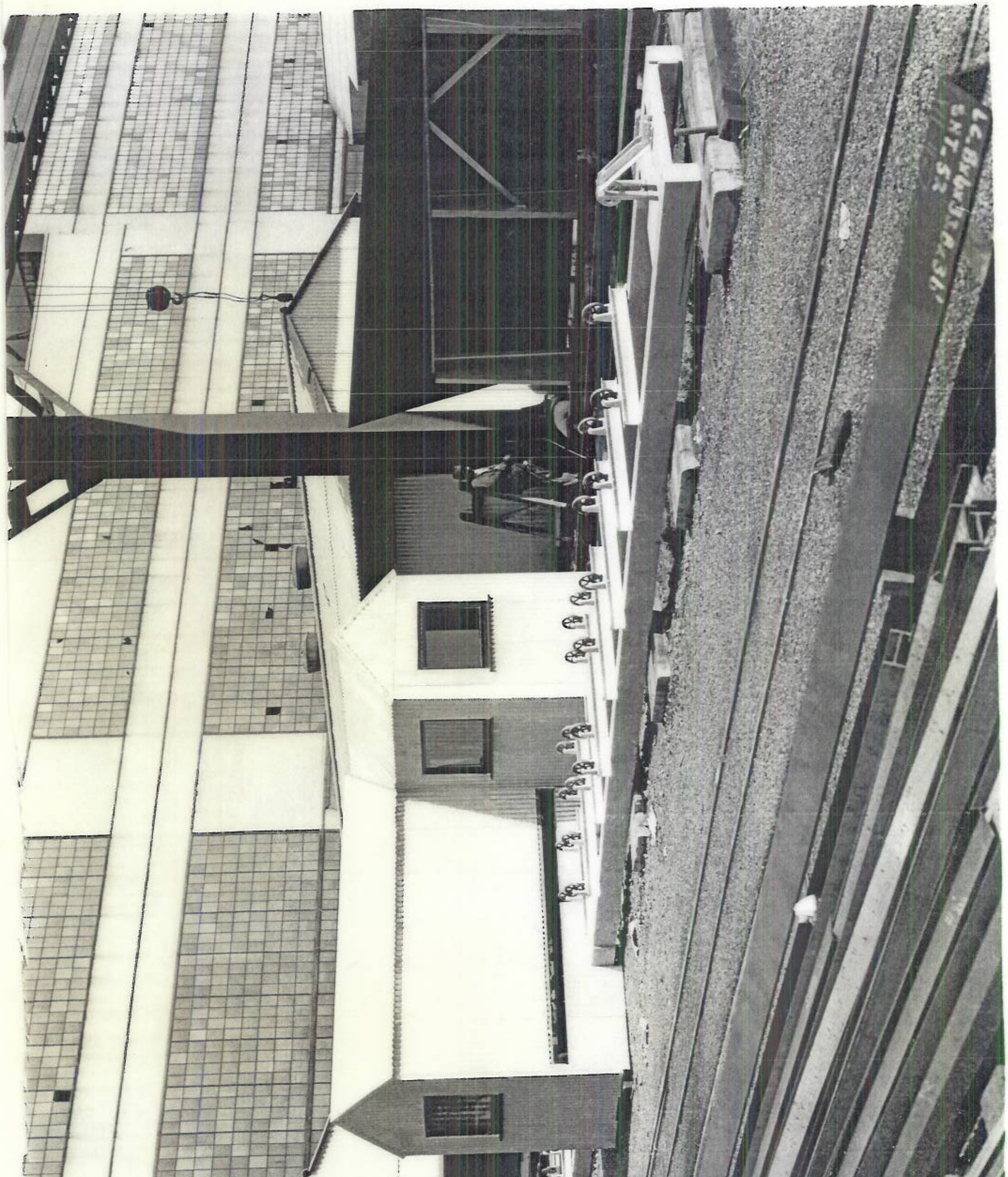


Figure 1

Figure 2

Figure 3

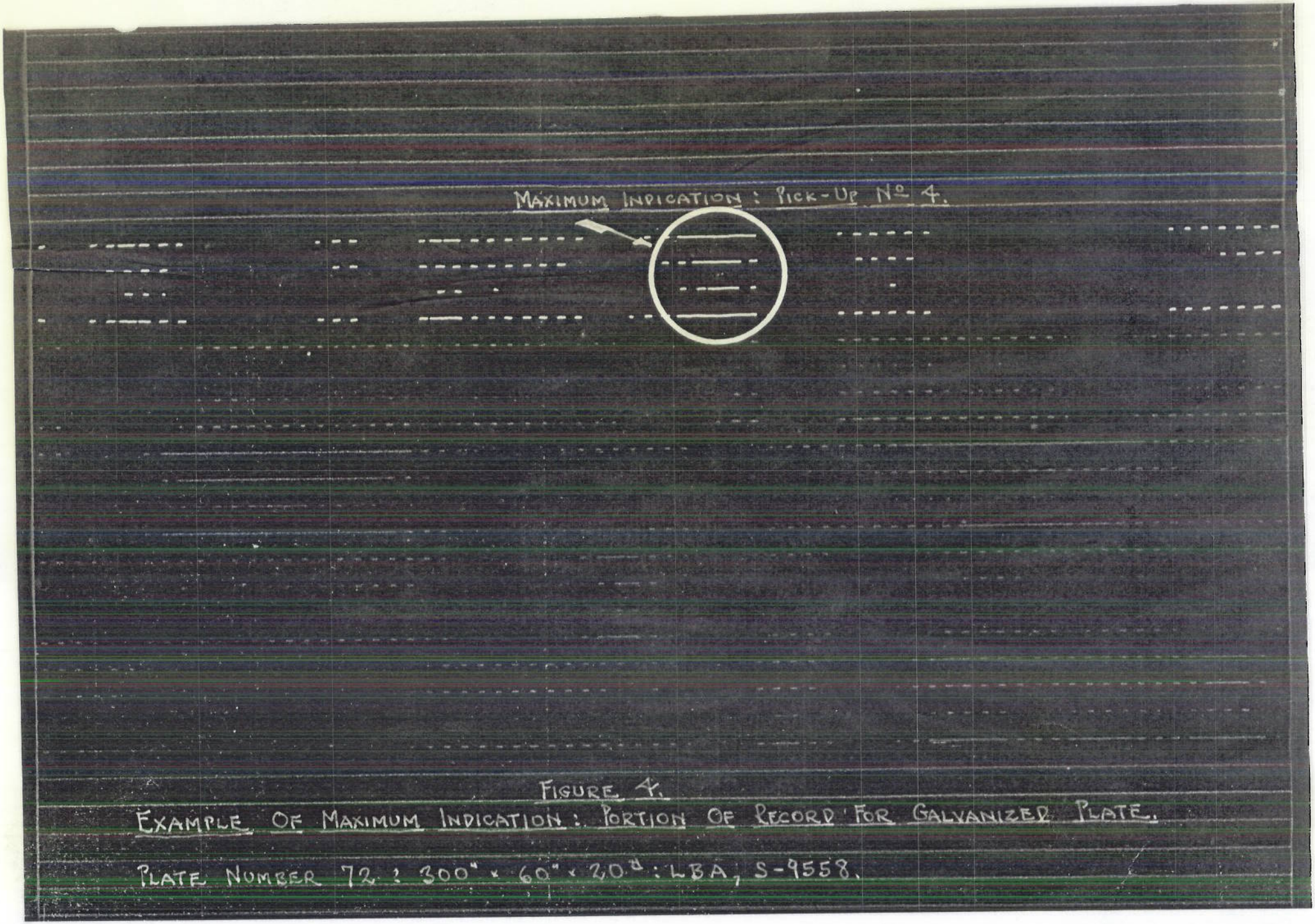


FIGURE 4.

EXAMPLE OF MAXIMUM INDICATION : PORTION OF RECORD FOR GALVANIZED PLATE.

PLATE NUMBER 72 : 300" x 60" x 20" : LBA, S-9558.

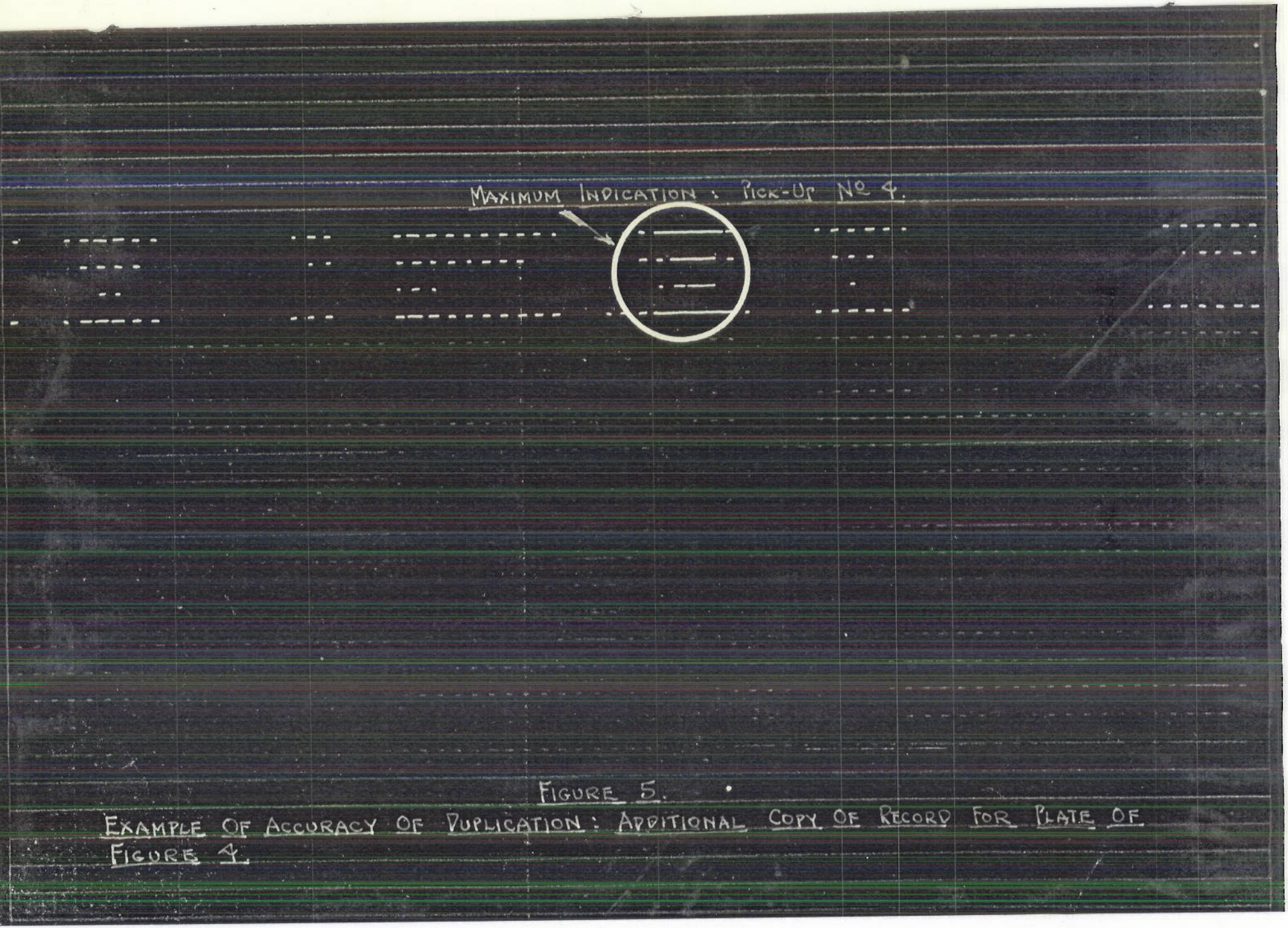


FIGURE 5.

EXAMPLE OF ACCURACY OF DUPLICATION : ADDITIONAL COPY OF RECORD FOR PLATE OF FIGURE 4.

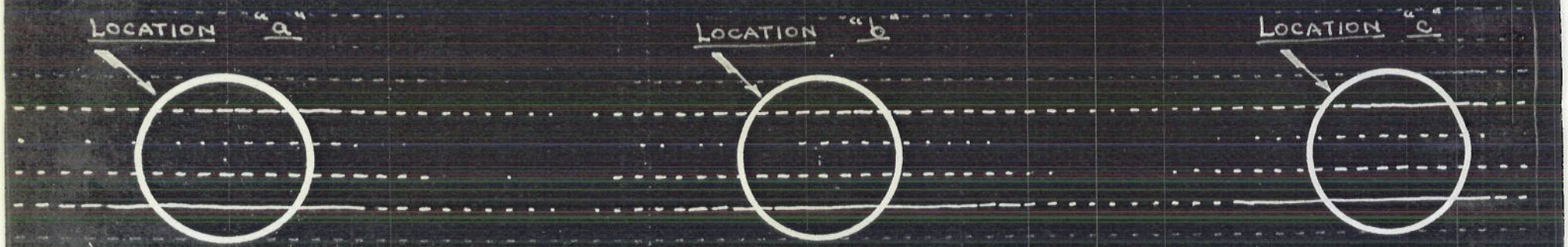


FIGURE 6.

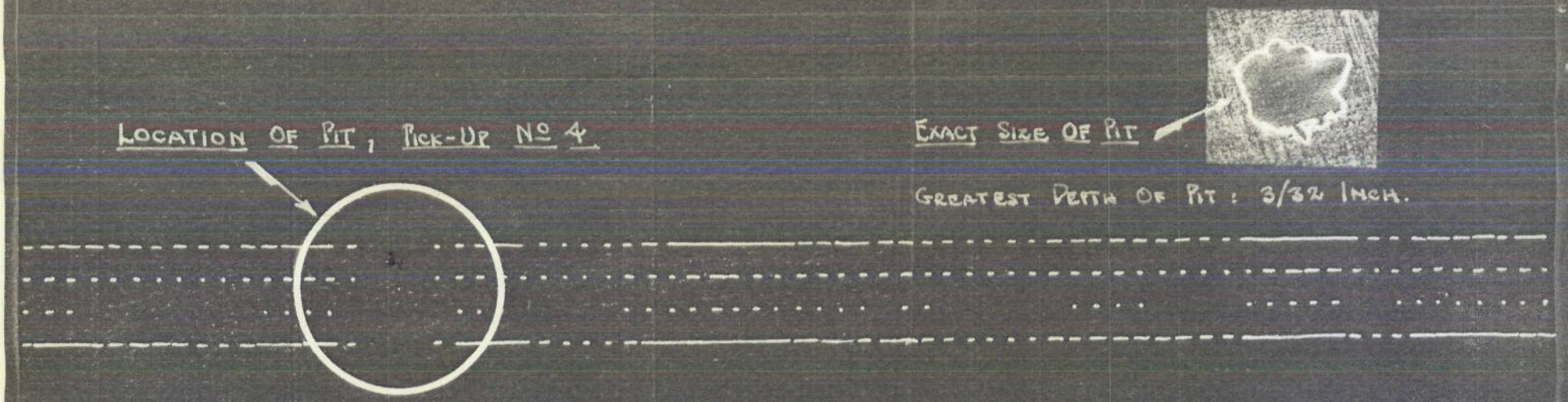
EXAMPLE OF EVENLY SPACED, MODERATELY STRONG INDICATIONS: PICK-UP No. 5, TWO OUTSIDE LINES FULL AT LOCATIONS "a", "b", AND "c".

PLATE NUMBER 34: 212" × 62" × 17½ #: L-1105-BCC-10.

NOTE : THE ORDER OF LOCATIONS IS REVERSED DUE TO PLATE HAVING BEEN TURNED END FOR END WHEN THE PLATE WAS TURNED OVER.

FIGURE 7.

EXAMPLE OF NEGATIVE CORRELATION BETWEEN TOP AND BOTTOM INDICATIONS : ABSENCE OF MARKING AT LOCATIONS "a", "b", AND "c" OPPOSITE "a", "b", AND "c" OF FIGURE 6.



NOTE: THE INDICATION FOR PICK-UP NO 4 HAS BEEN "TURNED UP", THE BETTER TO SHOW ABSENCE OF MARKING AT LOCATION OF THE PIT. THE PIT IS ON TOP SURFACE OF THE PLATE, DIRECTLY IN LINE WITH PICK-UP NO 4.

FIGURE 8

EXAMPLE OF EFFECT OF DEEP PIT : INDICATION IS OPPOSITE TO EFFECT OF LAMINATION.

PLATE NUMBER 45 : 300" x 72" x 15/8" : LBA.

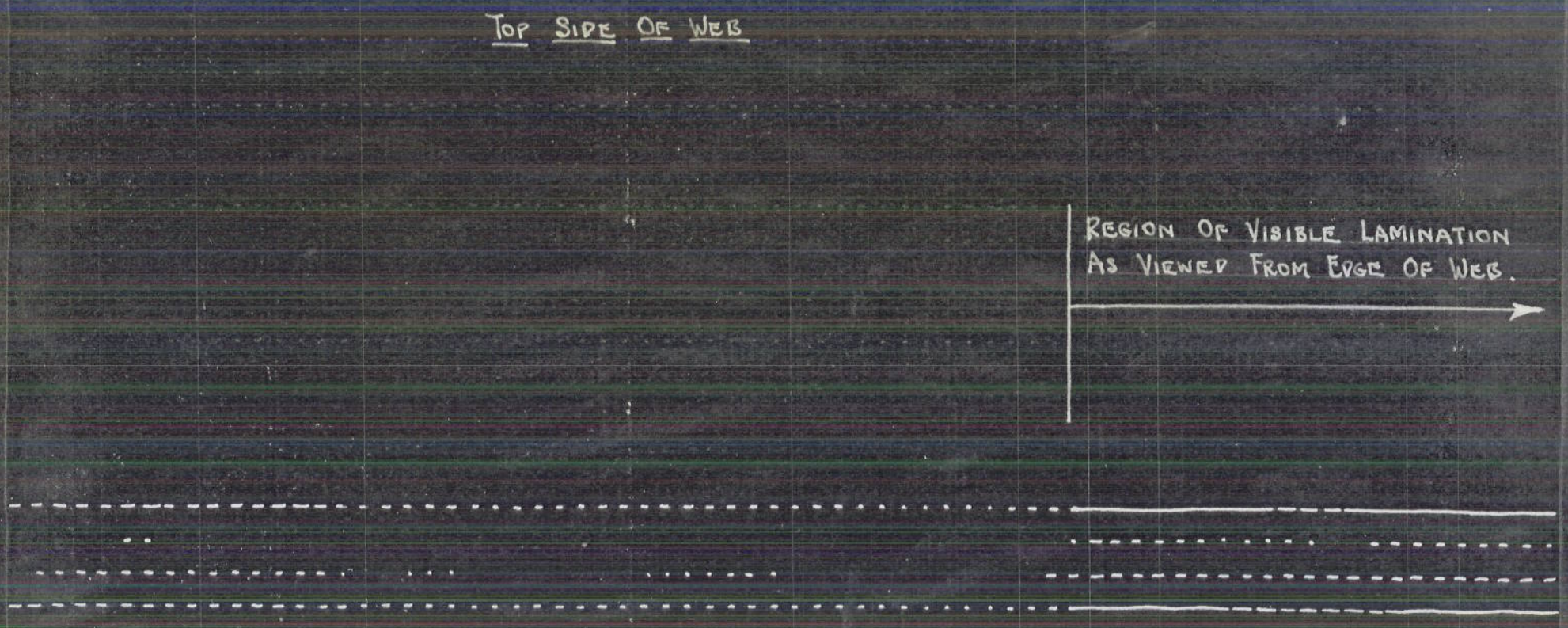


FIGURE 9.

EXAMPLE OF DETECTION OF TRUE LAMINATION : RECORD FOR INSPECTION OF WEB OF THE "T" BEAM OF FIGURE 11.

ITEM NUMBER 66 : 48' 0" x 6" BY 4" : 9.5 # : 3S 6986 : "I" BEAM CUT INTO TWO "T" BEAMS.

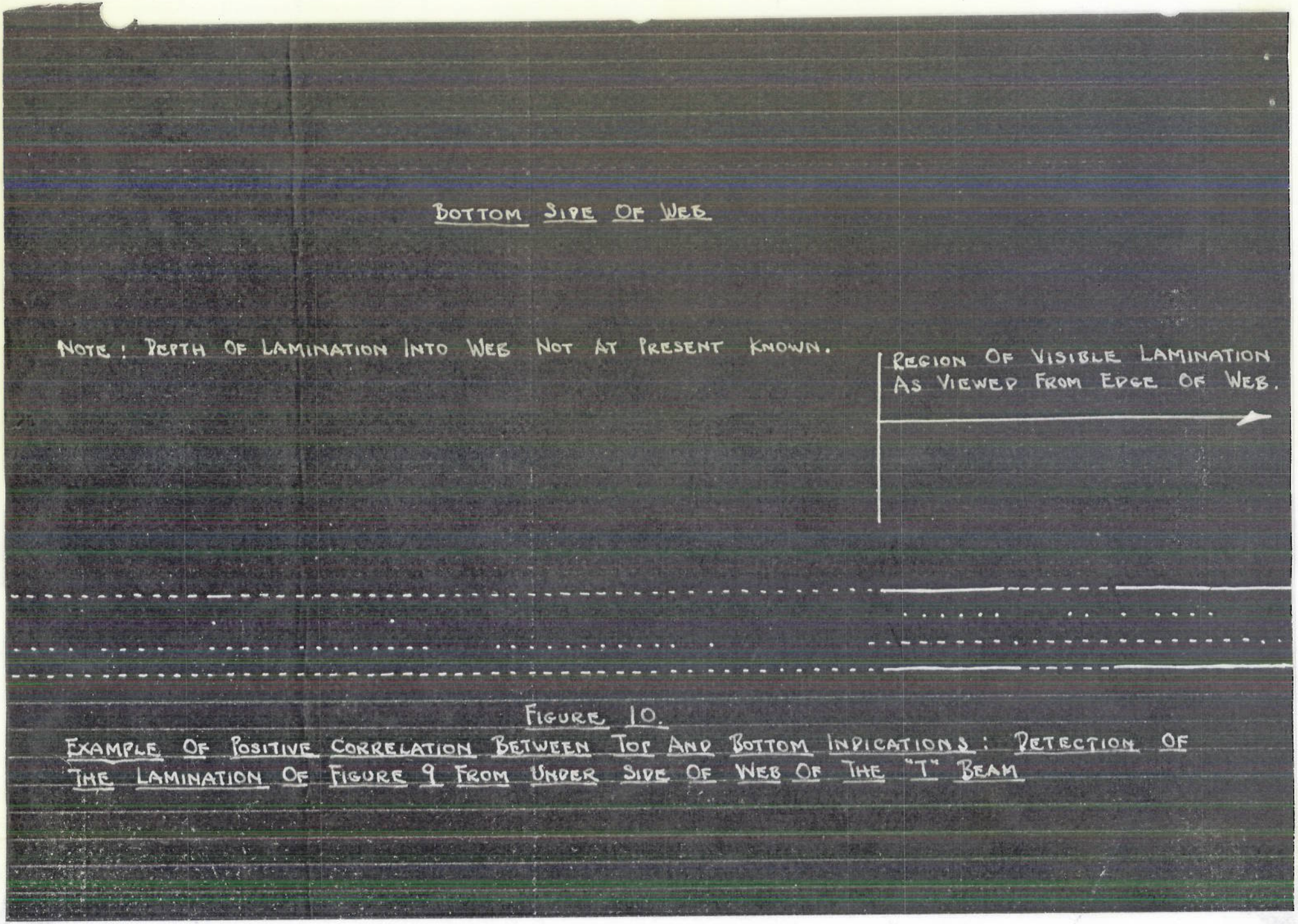


FIGURE 10.

EXAMPLE OF POSITIVE CORRELATION BETWEEN TOP AND BOTTOM INDICATIONS : DETECTION OF THE LAMINATION OF FIGURE 9 FROM UNDER SIDE OF WEB OF THE "I" BEAM

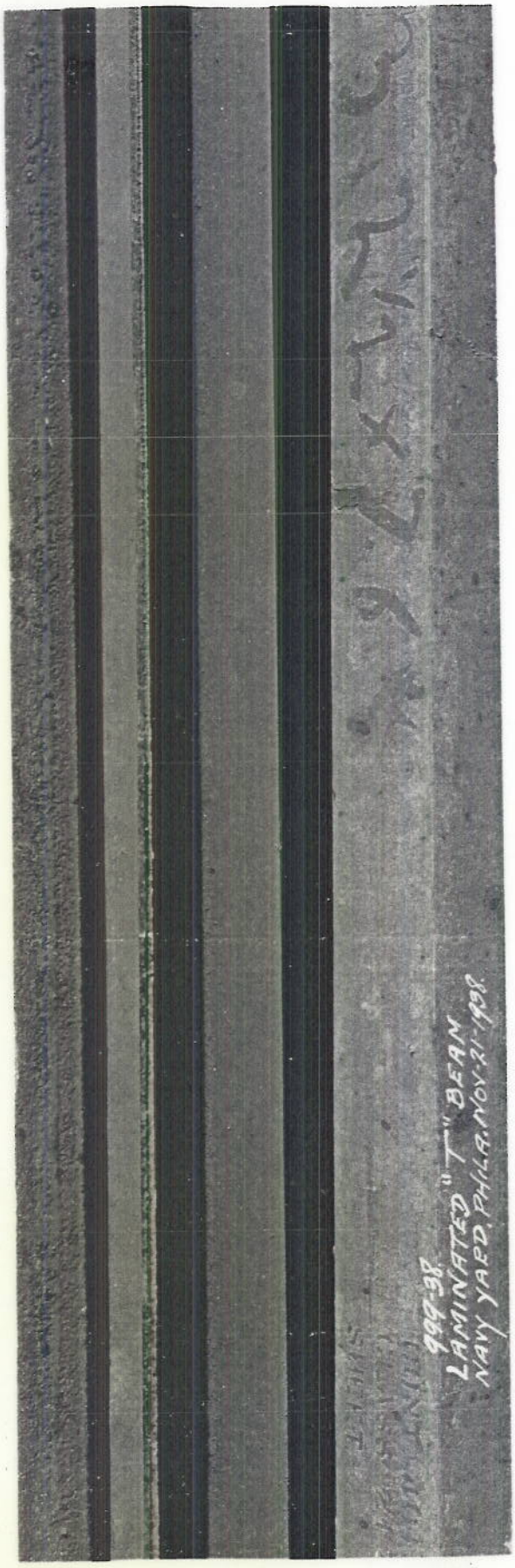


Figure 11

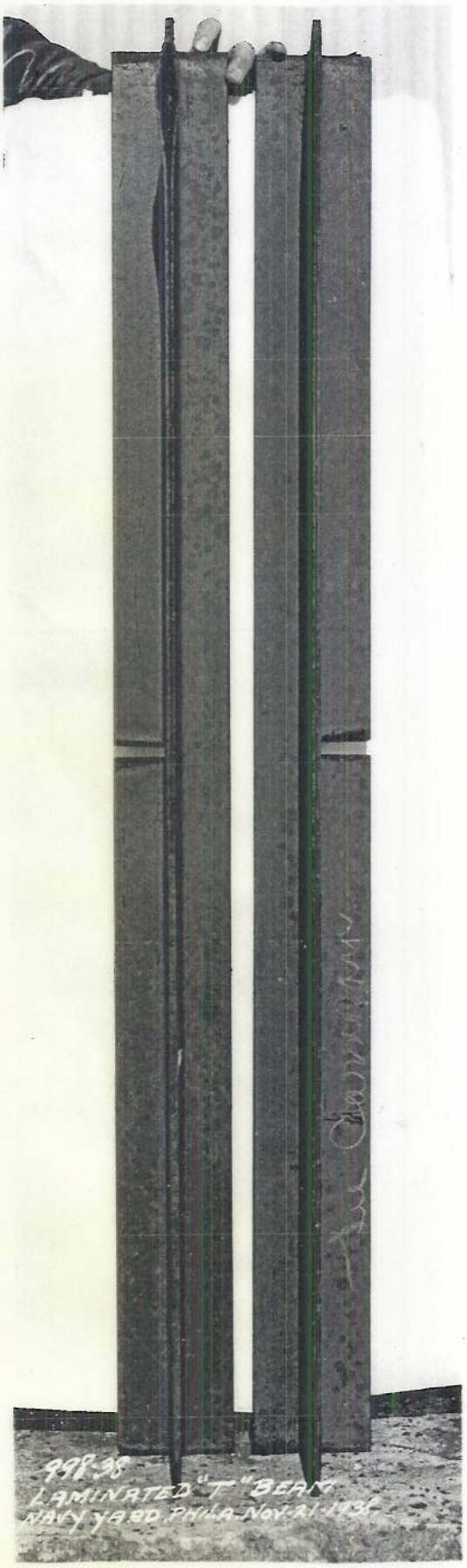


Figure 12

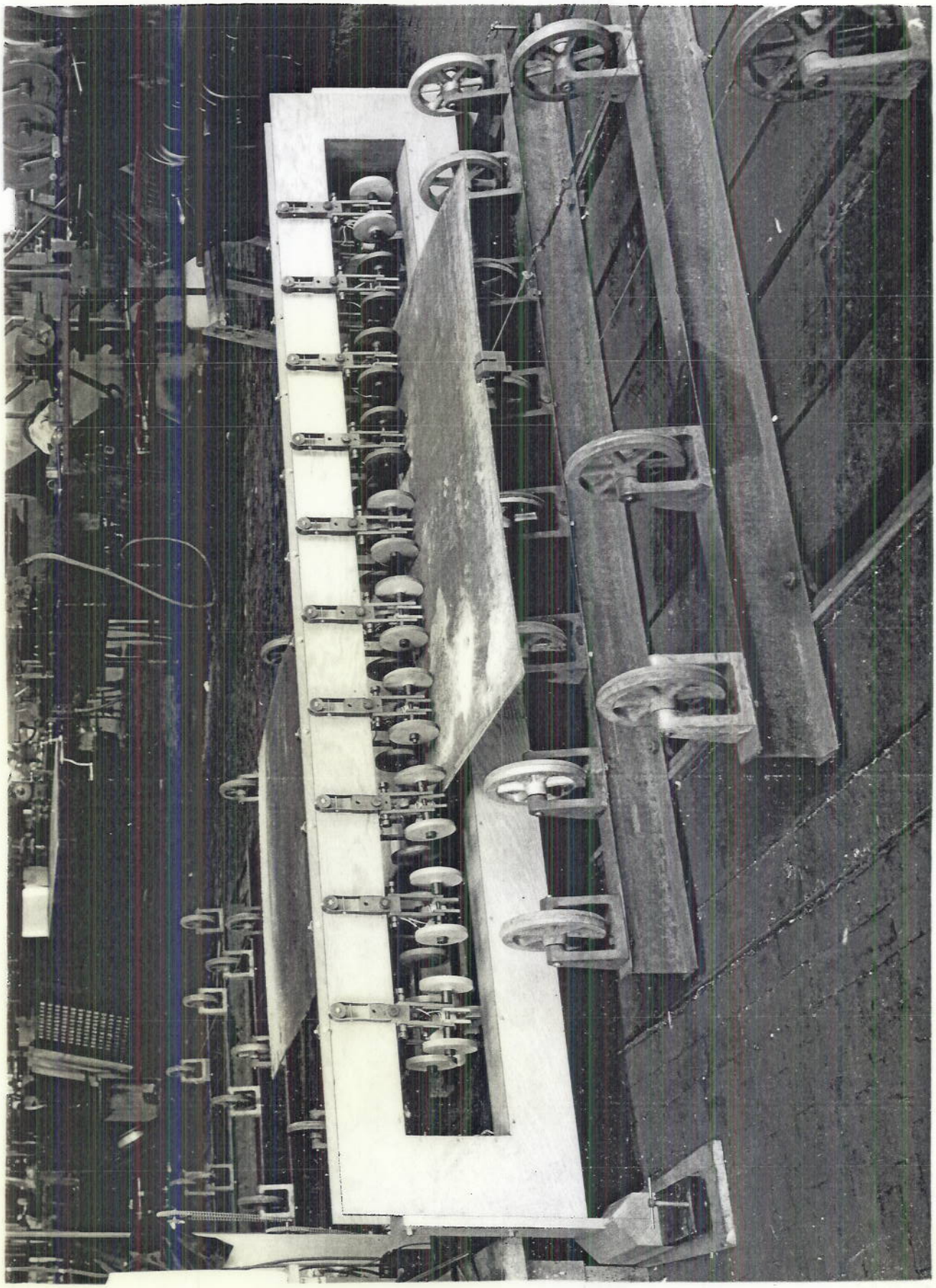


Figure 13

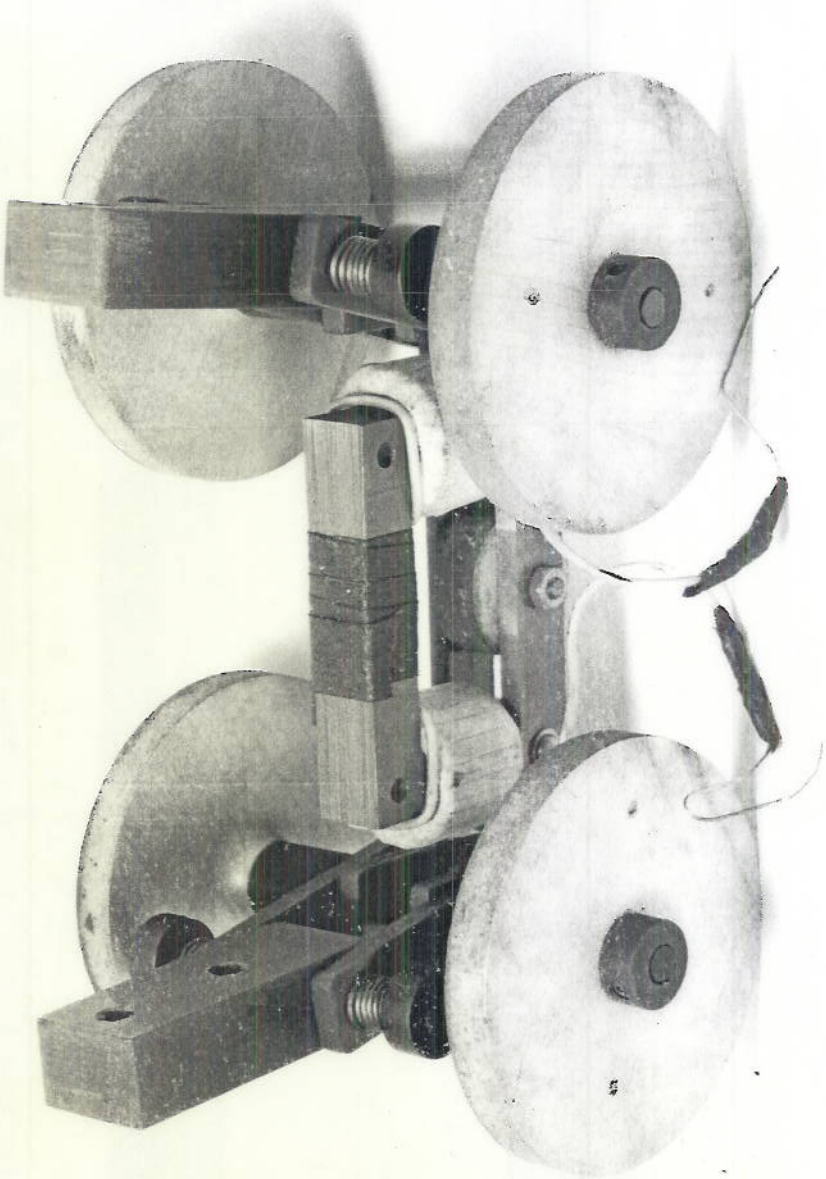


Figure 14

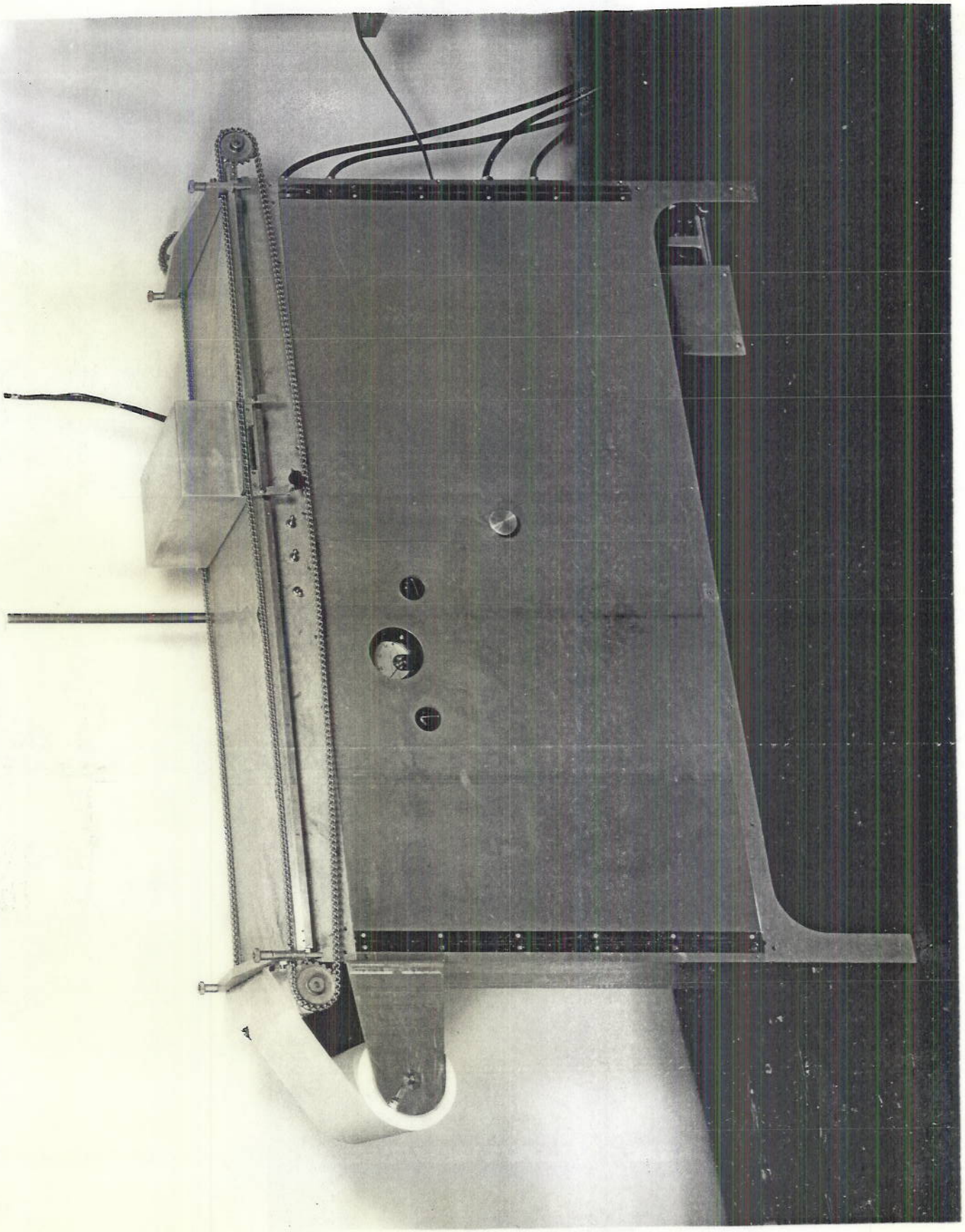
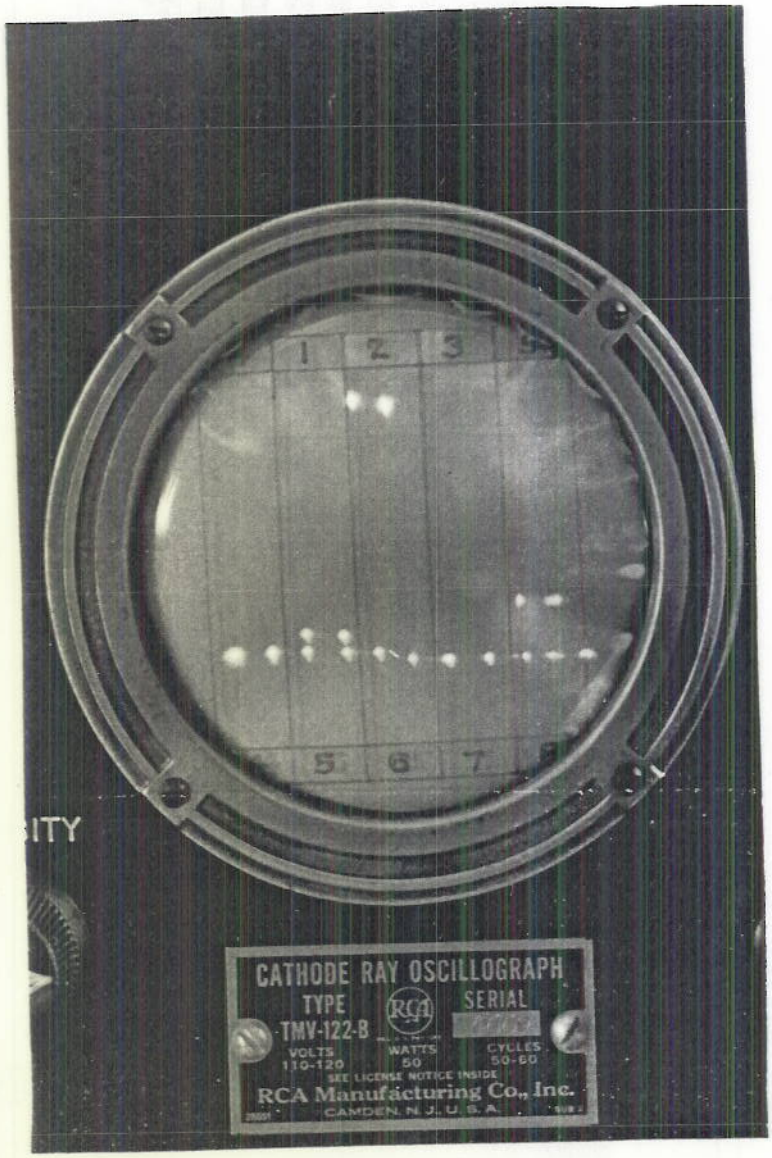


Figure 15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5 6 7
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CYCLES
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Figure 16