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Illumination for Battleship Aircraft  
Night Operations, Preliminary Tests.

REPORT NO. H-1339

DATE 14 January 1937

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SUBJECT

Illumination for Battleship Aircraft

Night Operations, Preliminary Tests.

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NRL Report No. H-1339

NAVY DEPARTMENT  
BUREAU OF ENGINEERING

Illumination for Battleship Aircraft  
Night Operations, Preliminary Tests.

NAVAL RESEARCH LABORATORY  
ANACOSTIA STATION  
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## ABSTRACT

Three systems of illumination of a ship's slick for night landing were given preliminary tests by pilots at the Naval Air Station, Anacostia, D.C., during December 1936. The three systems were, (1) polarized system, involving a polarized searchlight and polarized filters on the windshield of the plane, (2) swinging beam system, one or more ordinary searchlights were rotated to keep their streaks of light slightly ahead of the plane as it landed, (3) two beam system, two searchlights threw two streaks of light down the flying field with a dark streak between on which the plane was to land. In some of the tests the plane supplemented the illumination with its own wing landing lights, and in other tests it did not do so.

It was concluded, that the polarized system might be fairly satisfactory and that pilots would need training with it, that the swinging beam system was less satisfactory, and that the two beam system was unsatisfactory. Further tests of the polarized system and a system using a single ordinary searchlight were suggested.

Experiments on target illumination with polarized light and viewing with polarized filters showed that such a method did not give as good target visibility as was obtained with an ordinary searchlight and ordinary viewing.

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## INTRODUCTION

1. Authorization. This work was authorized by references (a), (b), and (c).

- Reference: (a) CO USS NEVADA let. BB36/A21-1/F11(116) of 13 January 1936 to BuEng, and five endorsements thereto.
- (b) BuEng let. C-BB/S66-(1-13-Ds) of 6 May 1936.
- (c) BuAero. let. Aer-E-34-AMS, A4/VV, N39/NA6 of 6 May 1936 to Naval Air Station, Anacostia, D. C.

Reference (a) requested the development of suitable illumination of a ship's slick for battleship aircraft night landing. References (b) and (c) authorized the investigation with appropriate cooperation of the Bureau of Aeronautics, Bureau of Engineering, and the Naval Research Laboratory.

2. Scope of the present report. Two methods were mentioned in reference (c), a method involving a polarized searchlight and polarized filters for pilots, and a method requiring two searchlights, or a split beam, so arranged that the incoming airplane will land in the unilluminated strip between the beams. Other methods were suggested in conferences. A number of the methods have been given preliminary experimental test. Further experiments are in view, but may be delayed by weather. Therefore, it appears of value to record in the present report a description of the tests and conclusions thus far reached. In Appendix A are given the pilot's comments on the experiments.

3. Requirements of the illuminating device. Reference (a), 3rd endorsement, stated, "Provide a device which may be used in connection with a ship's searchlight to illuminate own slick sufficiently for landing purposes." From this statement the requirements which the device should fulfill appear to be:

- (a) The device should illuminate the parent ship's own slick satisfactorily.
- (b) The device should be used in connection with the parent ship's own searchlight.

Pilots have mentioned the advisability of a third requirement:

- (c) The device should not require that landing be made on a course heading directly at the parent ship.

## CHAPTER 2

## SUMMARY OF TESTS AND CONCLUSIONS

4. Tests of illumination systems. The following three systems were tested at the Naval Air Station flying field on December 3 and 17, 1936:

- (a) Polarized system. A polarized searchlight threw a streak of light on the field. Polarized filters were mounted on the windshield of the plane. The filter eliminated to a considerable extent the direct glare of the searchlight but permitted the illuminated streak of field to be seen. In addition, wing landing lights were used. The pilot landed ~~near~~ the streak of light on a course nearly directly toward the light.
- (b) Swinging beam system. An ordinary, unpolarized searchlight directed its beam down the flying field. The plane approached on a course nearly toward the light and which passed the light at a distance of about 100 yards. As the plane drew near the beam was swung to keep always about 50 feet ahead of the plane. In addition, wing landing lights were used.
- (c) Two beam system. Two ordinary, unpolarized searchlights threw two parallel streaks of light down the flying field with a dark streak between them about 50 feet wide.

5. Conclusions. Preliminary conclusions were:

- (a) Polarized system. The system was fairly satisfactory, but not perfect. It might turn out to be sufficiently satisfactory. Wing landing lights should be used in connection with the system. Further tests should be made on land, on protected water, and finally at sea. In any case pilots will probably require instruction and practice on land prior to operations at sea. A procedure conducted along similar lines to that employed in preparation for night carrier landings was suggested.
- (b) Swinging beam system. The system was not entirely satisfactory. Although not greatly disturbed by glare, the pilot did not feel sufficiently in control of the situation to be as confident as he would like to be.

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- (c) Two beam system. Walking towards the searchlights in the dark streak between the beams convinced the pilot that the glare was too great to permit safe landing on a course more or less toward the searchlights.
- (d) Single fixed beam system. Tests appear desirable of a landing manoeuvre involving a single fixed beam and a plane landing on a course parallel to, close to, and outside of the beam.

6. Tests of target illumination with polarized light. An experiment was performed, unconnected with the airplane landing problem, which consisted in illuminating targets and a plane in the air with the polarized searchlight and viewing through a polarized filter so as to eliminate the searchlight beam in the air. It was concluded that the polarized system did not give as good target visibility as an unpolarized searchlight of equal size, because of the reduction of light intensity occasioned by the polarizing filters.

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## CHAPTER 3

## POLARIZED SYSTEM

7. Apparatus. A 36-inch 12-kilowatt searchlight was equipped with a polarizing screen mounted about 6 inches in front of the front glass of the searchlight. Photographs of the searchlight and polarizing screen are shown in Plates 1, 2 and 3. A black cloth was wrapped around the open space between the screen and the searchlight to insure that no unpolarized light be emitted to one side; this was probably an unnecessary precaution. The complete screen weight is about 75 pounds. The added weight of the screen had no noticeable effect on the balance or operation of the searchlight.

8. The polarizing screen reduced the intensity of the searchlight beam to about 30 percent of its value without the screen. The screen was made of an aluminum frame with brass cross bars 6 inches apart in which were mounted polarizing plates 6 inches square and 1/4 inch thick. As seen in Plate 1 the four corner squares were filled in with opaque aluminum plates instead of polarizing plates; these caused an unimportant loss in intensity of the searchlight beam. The polarizing plates absorbed about 65 percent of the light and transmitted 35 percent. The loss of light due to absorption plus the loss due to the opaque parts of the screen frame amounted to a total reduction of about 70% in the searchlight beam. The polarizing plates became only slightly warm during several hours of continuous operation of the searchlight and showed no signs of deterioration. The axes of polarization of all the plates were arbitrarily set horizontal, i.e., so as to transmit the horizontal electric vector.

9. Two polarizing plates 6 inches square and 1/4 inch thick were mounted on either side of the windshield of the cockpit of an aluminum plane, Type SOC; the inner edges of the plates were about 8 inches apart. A view of the windshield is shown in Plate 4. The axes of polarization of the plates were at right angles to those of the searchlight and hence were vertical, i.e., the plates transmitted the vertical electric vector and refused transmission to the horizontal electric vector.

10. Description of the polarized system. The situation for which the polarized system was developed is sketched in Plate 5; the drawing is approximately to scale. The searchlight of the parent ship is assumed to be 50 feet above sea level and to direct a 3° beam to throw a long streak of illumination on the slick. Consider first the case with no polarized equipment. As the plane approaches on a course approximately toward the light the pilot sees ahead of him two illuminations, one the illuminated streak on the water and the other the bright disk of the searchlight. The first he wishes to see, and the second which is much brighter he does not wish to see for it dazzles him so much that

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he can not see the first. As he continues to approach and enters the beam the disk of the searchlight becomes enormously bright and because of its glare effectively prevents the pilot from seeing the illuminated streak on the water or anything else which he may wish to see.

11. Now consider the case with polarized equipment, i.e., the polarized searchlight and the polarizing plates on the windshield. The streak of light thrown on the water by the polarized searchlight is mainly unpolarized, for polarized light scattered from an irregular surface becomes largely unpolarized. Upon approaching on a course toward the light and looking through the polarizing plate on the windshield the pilot sees the illuminated streak pretty much as in the unpolarized case but does not see the bright disk of the searchlight at full intensity. In fact the intensity of the searchlight disk is reduced about 200 times and the disk appears as a red-purple spot of insufficient brilliancy to cause dazzle or glare even when the pilot enters the direct beam. Thus he can see what he wishes to see without glare interference. At the same time he can supplement the illuminated streak with the spot illumination from his own wing lights.

12. Landing tests with the polarized system at the Naval Air Station flying field, Anacostia. The polarized searchlight was mounted about 10 feet from the ground and threw a long narrow beam  $3^{\circ}$  wide along the flying field. The system functioned as described in paragraph 11, the pilot was not dazzled by the direct searchlight and could see the illuminated streak. Six landings were made, some with the addition of the plane's wing lights and some without. The pilot concluded that he gained confidence in the system with repeated landings, and that it was desirable to use the wing lights as an additional aid. However, he encountered a disturbing effect. When the plane entered the direct beam of the searchlight it became brightly illuminated. The light from this illumination was partially unpolarized and passed through the windshield plate. The pilot looking through the windshield plate saw fairly brilliantly illuminated areas, glints and reflections on various portions of the plane which caused an interfering glare. Therefore in the last part of the tests the pilot landed, and preferred to do so, on the unilluminated ground parallel to, and close along side of, the edge of the beam in such a way that no part of the plane entered the direct rays of the searchlight until the landing had been effected. He concluded that the correct approach should be made parallel to the beam but just a few feet outside of the beam until the plane had actually touched the ground. The course of the plane is indicated in Plate 5.

13. Discussion of the polarized system. Sufficient experiments have not yet been performed to decide how serious the glare effect of the illuminated plane may turn out to be, or whether the manoeuvre of landing just outside of the edge

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of the beam is a satisfactory way of avoiding the difficulty. The plane glare can be reduced considerably by using a dull black painted plane instead of the shiny aluminum plane of the tests, although this may be objectionable in time of war for other reasons, such as camouflage.

14. Another difficulty, well recognized, with the polarized system should be mentioned. It is inherent in the nature of polarized light and can not be eliminated. However, the tests indicated that the difficulty may not be serious. The glare improvement occasioned by the polarizing filter was at its best only when the axis of the filter was in the plane fixed by the axis of polarization of the searchlight and the line of the searchlight beam. When the filter was tilted away from this plane more than 10 degrees the direct searchlight became bright and its glare disturbing. It was estimated that the filter axis had to be within about  $\pm 5$  degrees of the correct plane in order that its glare-reducing effect be sufficient. For example, if the filter were mounted on the windshield of a plane flying directly toward the polarized searchlight, with axis of polarization horizontal, its glare-eliminating action would not be affected by nosing up and down of the plane or by weaving to and fro of the plane, but would be lessened by rolling of the plane. Actually, during the tests the plane never rolled sufficiently for the pilot to notice the effect of rolling.

15. In this connection we may comment on the suggestion that the pilot be equipped with polarized goggles instead of using polarized plates on the windshield. To obtain the best result with polarized goggles the pilot should maintain his head in the vertical plane passing through the searchlight beam. Thus he could bend his head in a forward and backward direction, and could turn his head to starboard or port, without losing the glare reduction effect of the goggles, but could not tilt his head from side to side too much. Further, since the goggles transmit only about 35 percent of unpolarized light, they would reduce the pilot's vision by that amount, which might be disadvantageous for conditions at night. It seems better not to handicap the pilot with such an optical drag but to leave him free vision as far as clear glass goggles permit, and to put the polarizing plates over a portion of the wind shield to be used or not as he pleases. The pilot was averse to the notion of using polarized goggles.

16. Polarized plates. The polarized plates are made by cementing a film of polarizing material between glass plates. The plates used in the present tests were obtained from the Polaroid Corporation, 168 Dartmouth Street, Boston, Mass., at a cost of \$65 for each plate 6 inches square. The price seemed high. The commercial development of the plates is new

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and its future progress as to price and quality of product is uncertain. Although the keeping qualities of the plates over a long period of time is not known it seems certain that the plates will deteriorate in a few years time. An order has been placed with another firm, Polarized Products Company, White Stone, Long Island, N.Y., who are undertaking to make 6 inch square plates for \$10 each of a somewhat poorer optical quality than those of the Polaroid Corporation.

17. Further suggested tests of the polarized system. Further desirable experiments with the polarized system would appear to be as follows, the details of each test being dependent on the outcome of the tests which precede it:

- (a) Tests on land with the polarizing plates of the Polaroid Corporation and of the Polarized Products Company, the first being those already tested.
- (b) Tests on protected water.
- (c) Tests at sea.

18. We illuminate the foregoing suggested tests by quoting from Appendix A, "It is recommended that tests be conducted with the polarized beam for landings on water before any conclusions are definitely drawn. It is believed that landings on the surface of the water can not be made with the same ease as on land. It is recommended that all pilots get at least two hours and a minimum of ten landings employing the polarized beam on land before attempting similar landings at sea."

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CHAPTER 4

SWINGING BEAM SYSTEM

19. Tests of the swinging beam system. Two ordinary 36 inch searchlights about 10 feet from the ground and 50 feet apart directed two beams about 50 feet apart down the flying field. The plane approached on a course nearly toward the lights and which passed the lights at a distance of about 100 yards. As the plane drew near the beams were swung so that the nearer beam was always about 50 feet ahead of the plane. In addition wing landing lights were used. Three landings were made. The pilot concluded that he was not greatly disturbed by the glare of the direct searchlights. He felt, however, that the manoeuvre was a little uncertain and that he might not have sufficient control of the situation to be able to adapt himself to unanticipated circumstances. He felt vaguely uncomfortable about the moving paths of light in front of him, for he could not see beyond them. He preferred the fixed path of light laid down for him in the polarized system.

20. The pilot believed that the two moving narrow paths of light delivered by the two searchlights gave a better illumination of the landing area than a single path of light from a single searchlight would have given. However, the single rotating beam was not tried.

21. No further tests of the swinging beam system, or modifications thereof, are suggested.

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CHAPTER 5

SINGLE FIXED BEAM SYSTEM

22. Single fixed beam system. The foregoing tests led to the opinion that a single fixed streak from an ordinary searchlight thrown on the landing surface was very desirable from the pilot's point of view because of its fixity and its brilliancy. It seemed probable that by approaching on a course close to, parallel to, and out of the streak, as indicated in Plate 5, the pilot could avoid glare and yet find sufficient surface illumination for satisfactory landing in spite of the fact that the actual spot where the plane touched was not directly illuminated.

23. The system was not purposely tested although approximately the manoeuvre was carried out in some of the early landings before opinion had crystalized.

24. Suggested tests. We quote from Appendix A, "It is recommended that tests be conducted with an unpolarized beam and simple unpolarized ray filters on the windshield of the plane prior to the purchase of large quantities of polarized filters, as the blinding effect of looking toward the light with the naked eye is not so pronounced until the pilot reaches the leveling off altitude, at which point the filter may be sufficient protection."

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CHAPTER 6

MISCELLANEOUS SUGGESTIONS

25. In the course of the investigation various systems were suggested. Some of these, with comments, are given in the following paragraphs. It seems probable that some or all of these systems have been considered already by Fleet personnel.

26. Two beam system. The system was mentioned in reference (c). It required two searchlights to direct two parallel beams of light down the flying field with a dark streak of light between them about 50 feet wide. The plane was to approach on a course toward the lights and to land on the unilluminated dark streak. In this way it was hoped that the pilot might avoid the direct glare of the searchlights and yet have enough illumination on the field for landing. The system was tested by the pilot walking on the field in the dark streak. He concluded that the glare was too great to permit safe landing. He believed that once in the unilluminated area and heading towards the lights he would feel trapped, for he could not get out without entering areas of blinding glare.

27. Use of another ship. In this system the slick of the parent ship is lighted by the searchlights of another ship. The suggestion appears practicable; it requires a proper cooperative manœuvre of the two ships.

28. Use of flares. Use either landing flares dropped from plane, or float lights or parachute flares fired from parent ship, or both. The system might be difficult to operate in a positive and successful manner; it would require accurately timed coordination. It might however be used to supplement another system of illumination.

29. Use of airport floodlight. Put regular airport floodlights, or the equivalent, on, say, the stern of the parent ship. This would require a separate lighting installation. The pilot would experience considerable glare in landing towards the lights.

30. Use of cylindrical lens. Put a cylindrical lens on the standard searchlight of the parent ship, thus spreading its narrow beam into a fan shaped sheet. The pilot would unquestionably experience considerable glare as he landed in the illuminated area on a course more or less toward the light. The system is simpler than the polarized system in that it does not require a special filter on the plane. However, 36-inch cylindrical lenses are not available and would have to be designed and constructed.

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CHAPTER 7

ILLUMINATION OF A TARGET WITH THE POLARIZED SEARCHLIGHT

31. Target illumination with polarized light. Army personnel, present at the foregoing tests, suggested and cooperated in tests of target illumination with the polarized searchlight. It was observed that the beam of light from the polarized searchlight passing through the atmosphere was strongly polarized; it could be reduced to invisibility by looking through a polarizing plate oriented correctly. Now, an observer near a searchlight looking at a target illuminated by the searchlight has to look through, or nearly along, the beam of the searchlight, and often finds that his ability to see the target is hampered by the slight luminosity of the beam. Therefore, since the light scattered back by the target itself is unpolarized, it was suggested that the visibility of the target might be increased by illuminating the target with the polarized searchlight and viewing through a polarized plate oriented so as to eliminate the beam.

32. Experimental results. The experiment was carried out using targets on the ground and a black painted plane in the air illuminated successively by an ordinary 36 inch searchlight and by the polarized 36 inch searchlight. The night was cloudy but below the clouds the air was moderately clear with slight haze. It was found that the polarized system did not give as good seeing as the ordinary searchlight. True, eliminating the searchlight beam improved the visibility of the target, but this was more than offset by the reduced intensity of the polarized searchlight caused by the  $2/3$  absorption of the polarizing screen, and the reduced effectiveness of the observer's vision caused by the  $2/3$  absorption of the polarizing plate through which he was looking.

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APPENDIX A

COMMENT OF PILOT ON NIGHT LANDING EXPERIMENTS

A standard SOC-1 landplane was used for the experiments. Due to the limitations of the landing field the searchlight beam could not be trained down wind and most of the landings were made with a wind of approximately six to eight knots on the port bow of the plane. The excellent landing qualities of this plane for this type work were readily apparent. The pilot did not notice any tendency of the plane to ground loop due to the cross-wind component and the slot action provided easy landings from slightly uncertain altitudes. Due to the cross-wind only half flaps were used.

The pilot's first reaction to the beam was that it was too narrow and did not afford a sufficient area of illumination for safe landings. However, after several trial runs down the shadow area parallel to the beam it became apparent that the narrow beam was an asset instead of a detriment in approaches where the plane is headed almost directly toward the searchlight. The narrow beam furnishes brilliant illumination of the landing surface directly in its path and by virtue of its concentration permits the pilot to fly very close to its edge without having the fringe rays cause blinding reflections from bright parts of the plane. The steady polarized beam was preferred to the swinging beam because the steady beam allows the pilot to set a landing course straight into the wind and also furnishes a fixed reference point on the landing surface. The necessity for the landing course to clear the stern of the ship is obvious. The steady beam provides a longer area of illumination down the landing axis of the slick. Another reason in favor of the steady beam is that it eliminates one source of personal error, i.e., inability of searchlight personnel to keep the swinging beam a constant distance ahead of the landing plane. If the plane inadvertently enters the direct rays of the light the blinding reflections from the bright surfaces of the plane will greatly impair the pilot's vision and consequent landing efficiency.

It is recommended that tests be conducted with the polarized beam for landings on the water before any conclusions are definitely drawn. It is believed that landings on the surface of the water cannot be made with the same ease as on land. It is recommended that all pilots get at least two hours and a minimum of ten landings employing the polarized beam on land before attempting similar landings at sea.

It is recommended that tests be conducted with an unpolarized beam and simple unpolarized ray filters on the windshield of the plane prior to the purchase of large

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quantities of polarized filters, as the blinding effect of looking toward the light with the naked eye is not pronounced until the pilot reaches the leveling off altitude, at which point the filter may be sufficient protection.

The wing landing light is a definite and decided aid to night landings on land with the polarized beam method. The efficiency of the wing landing light on landings on the water with the polarized beam method has not been determined.

It is definitely recommended that shipboard based seaplanes be equipped with landing lights in both the right and left wings as half of the recoveries at sea will be made to port and half to starboard, thus placing the searchlight beam at one time on the pilot's left and at the other on his right.

It is believed that the polarized beam with filters furnishes a feasible method for operating seaplanes in the open sea in time of peace. In time of war the employment of searchlights for recovery of seaplanes of capital ships would have a decidedly restricted usage.

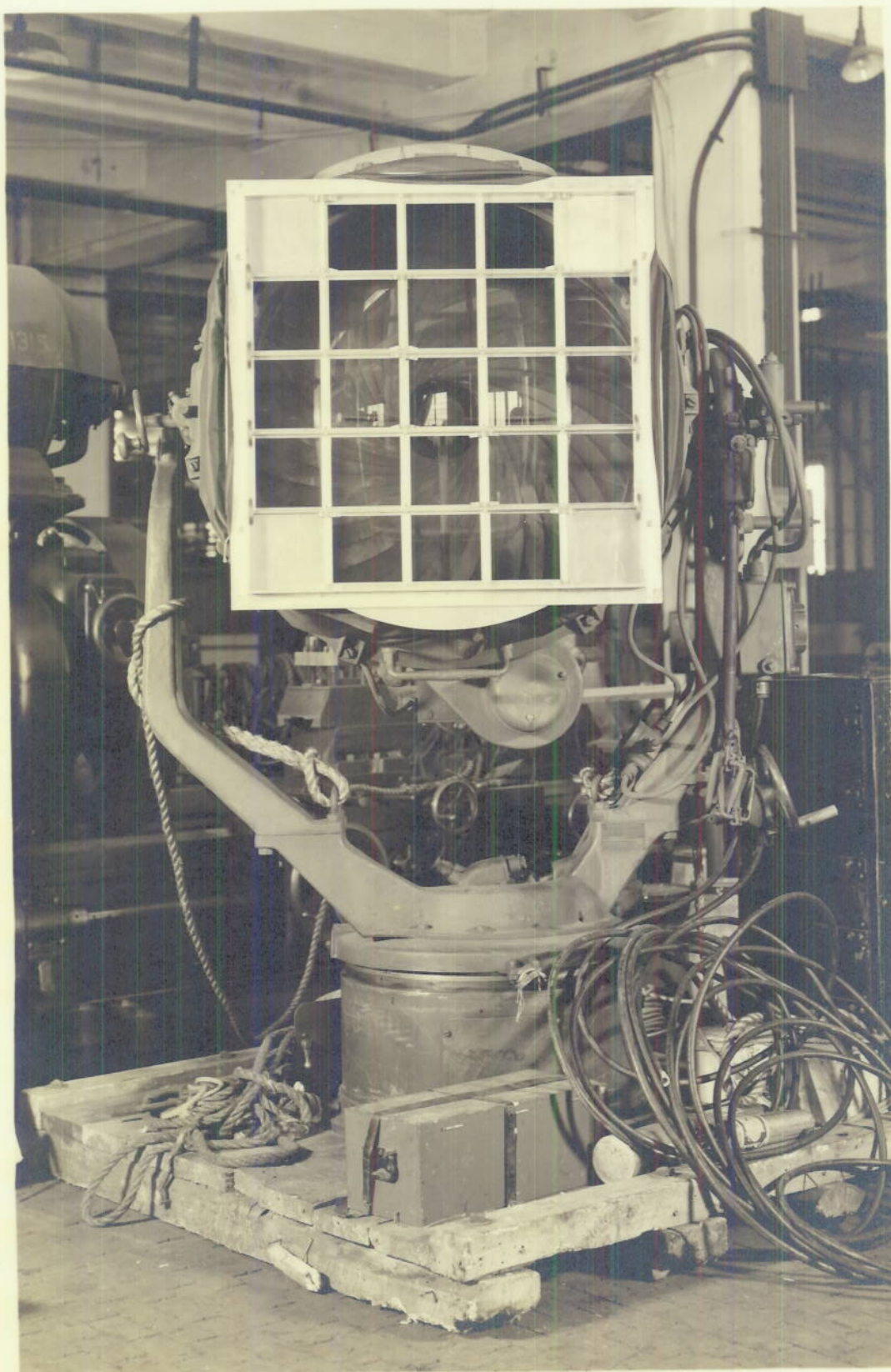
J. G. CROMMELIN  
Lieutenant, U. S. Navy.

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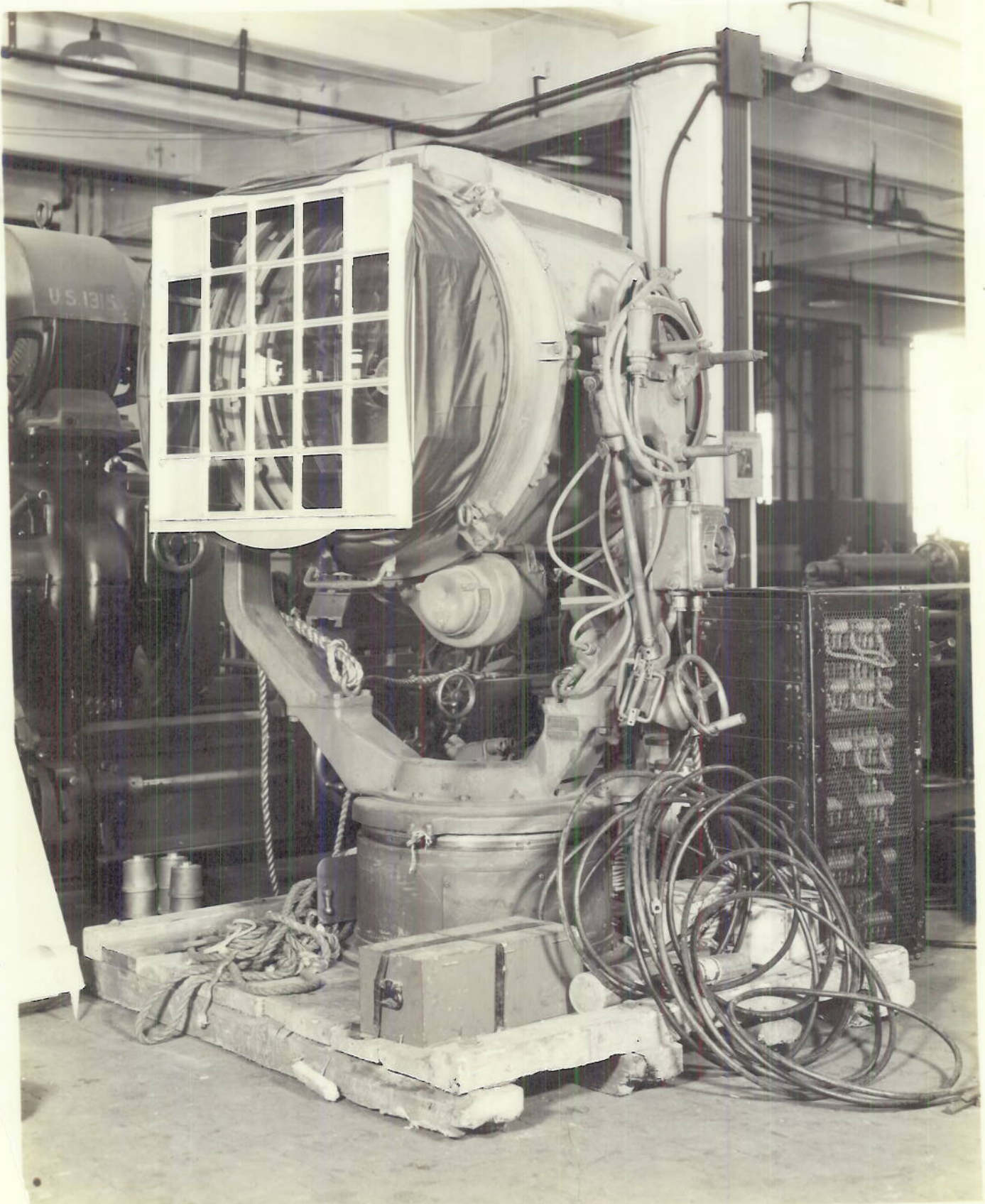
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POLARIZED SEARCHLIGHT  
FRONT VIEW  
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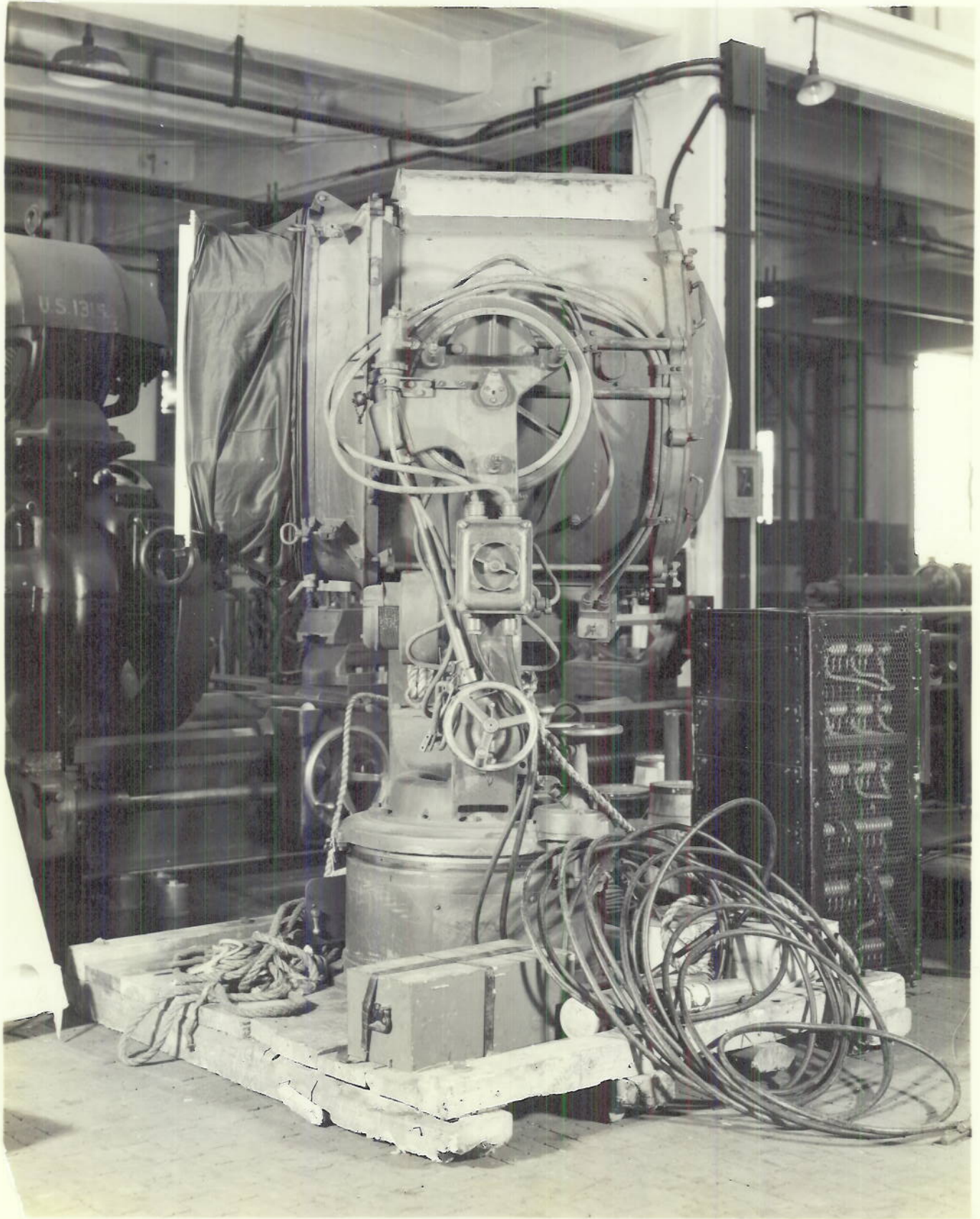


POLARIZED SEARCHLIGHT  
THREE QUARTERS VIEW

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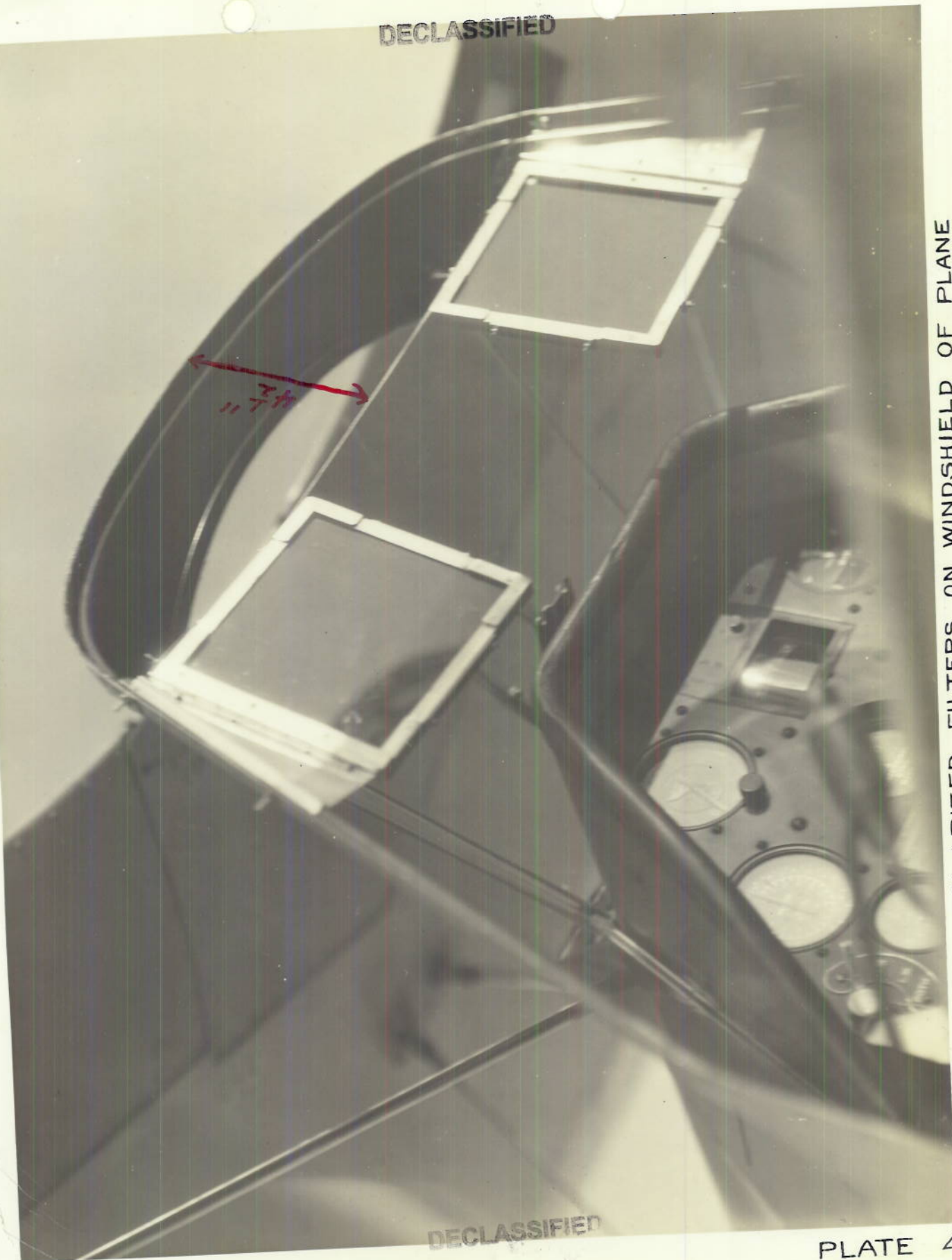
PLATE 2

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POLARIZED SEARCHLIGHT  
SIDE VIEW  
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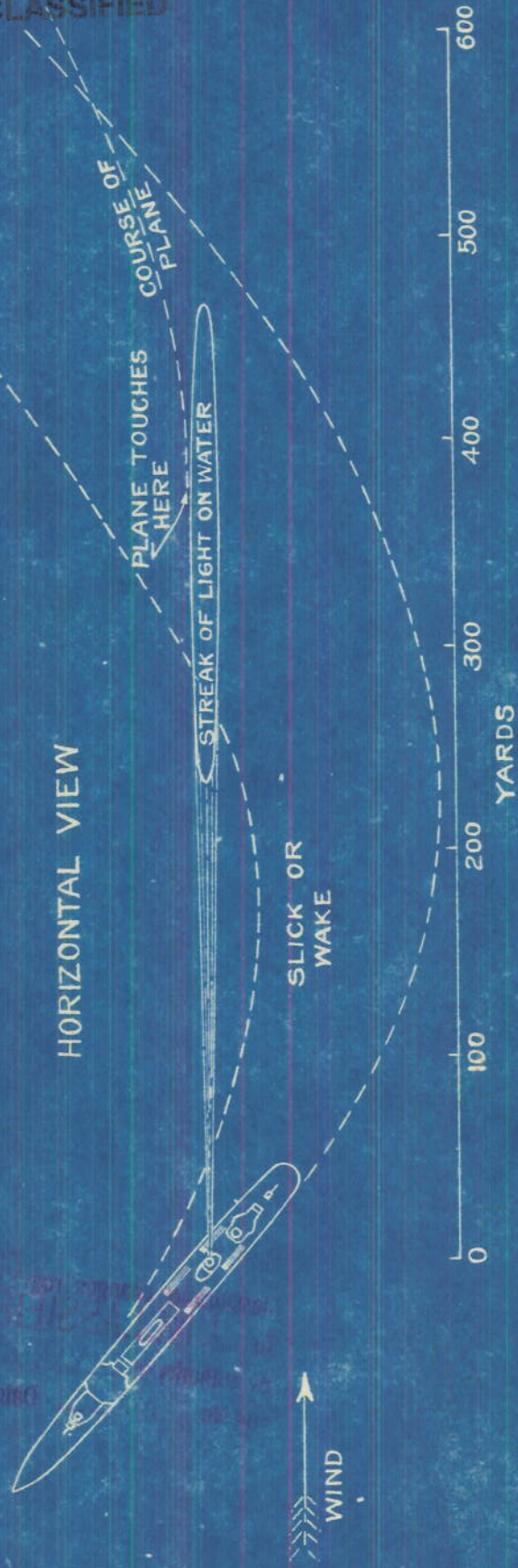
POLARIZED FILTERS ON WINDSHIELD OF PLANE

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VERTICAL VIEW



HORIZONTAL VIEW



NIGHT LANDING SITUATION