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NOTES ON EXTERNAL AIRCRAFT LIGHTING DEVELOPMENTS

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By
Alan L. Morse

Aircraft Division
Technical Development

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CIVIL AERONAUTICS ADMINISTRATION
TECHNICAL DEVELOPMENT
AND EVALUATION CENTER
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INTRODUCTION

The problem of adequate lighting of aircraft to insure against air collisions involves the factor of the time available to avoid collision. However, the continuing increase in speeds and in the number of airplanes that are flying the airways requires continuing development to keep that factor at a safe level. The pilot must have time to locate the lighted airplane, estimate its speed and direction, decide what action to take and to maneuver out of its path. A 1-minute interval might be considered as a minimum safe value.

Closure speeds as high as 1,000 mph may soon be an every-night occurrence. Under such conditions, a 1-minute time interval would require that the aircraft's lights be positively visible at a distance of at least 15 miles.

CAA DEVELOPMENT AND EVALUATION PROGRAM

The aircraft external lighting development program initiated by the CAA Technical Development and Evaluation Center engineers produced the presently used flashing lights and is effecting further significant improvements. These include better flashing arrangements and new lighting units that are some 500 times brighter than those previously used. The CAA program has expanded considerably since its initiation, and is now a highly cooperative and well-coordinated activity in which the armed services, other government agencies and the industry are active participants. Although the CAA is undertaking a moderate amount of aircraft lighting development, its chief role is to act as a coordinating and evaluating group. Combined flight demonstrations and conferences are now yearly occurrences at the Technical Development and Evaluation Center at Indianapolis, Ind. The most recent of these was held on August 22 and 23, 1950. This was attended by representatives of the following:

(a) British Embassy
(b) Department of the Air Force
(c) Department of the Navy
(d) National Bureau of Standards
(e) Civil Aeronautics Board
(f) Daniel and Florence Guggenheim Aviation Safety Center
(g) Air Line Pilots Association
(h) Various aircraft manufacturers
(i) Various airlines

(j) Several aircraft lighting manufacturers
(k) Lamp manufacturers
(l) Regulatory groups of the CAA
(m) CAA Technical Development and Evaluation Center

Two DC-3 airplanes, a Boeing 247-D and a helicopter were flown in the demonstration. The helicopter was supplied by the Department of the Air Force and was equipped with a lighting unit mounted on top of the cabin ahead of the pylon. This consisted of two high-intensity sealed-beam lamps rotating in a horizontal plane inside a red glass dome. This light was developed at the Naval Air Test Center at Patuxent, Md., with the co-operation of Federal Enterprises, Inc., of Chicago, Ill.

One DC-3 was supplied by United Air Lines and mounted a United-Air-Lines-developed unit on top of the fin. This included a single sealed-beam lamp which rotated in a horizontal plane inside of a red plastic dome while it oscillated slowly in a vertical plane through about 70 degrees. The second DC-3 and the Boeing were supplied by the Technical Development and Evaluation Center. The Center's DC-3 had an experimental high-intensity light in the nose, which was developed by Luminator, Inc., of Chicago, Ill. This consisted of a fixed, sealed-beam light unit with two clear plastic, rotating discs ahead of it. Each disc was formed as a row of parallel prisms, and the speeds and directions of rotation of each disc could be adjusted to cause the resulting beam to follow a variety of patterns. A red plastic cover was mounted ahead of the discs. During the demonstration, the beam was caused to sweep from side to side.

In addition to its standard wing tip and fuselage lights, the Boeing airplane carried:

1. Five taillights in a vertical row with red, yellow, lunar white and clear cover glasses.
2. Six fuselage lights just aft of the cabin, with two on the center line and four at 45 degrees from the vertical.
3. Three sweep-beam high-intensity lights, with two in the leading edge of each wing tip and one in the tail of the fuselage.

These are shown in Figs. 1 to 4.

Lighting arrangements 1 and 2 were suggested during the previous year's conference, so that the same group could evaluate the effectiveness of various colors, taillight spacings, fuselage light locations and flashing speeds. Special switching arrangements and a variable speed flasher were used to demonstrate those factors.

The sweep-beam lights are the outgrowth of a Technical Development and Evaluation Center development in which the design requirements were determined through the modification and testing of a fire-engine light. The

Standard-Thomson Corp. undertook the design of an aircraft light in accordance with those design requirements and supplied three such lights to the Technical Development and Evaluation Center.

Considerable predemonstration testing was done to determine the characteristics of this unit. It is 5 5/8 inches in diameter, 4 inches long, weighs 2 1/4 pounds, and uses 78 watts of electrical power. It includes a 4 1/4-inch diameter sealed-beam lamp, which is caused to oscillate from side to side through an angle of 60 degrees and which makes 40 round trips per minute. Special lamps were supplied by both the General Electric Co. and the Westinghouse Electric Corp. They have a maximum beam intensity of 50,000 candle power. However, where colored plastic covers are used the intensity of the resulting beam is reduced to 10,000 candle power.

As installed in the Boeing, red and green plastic covers were used on the wing tip installations, and a clear plastic cover was used on the fuselage tail installation. The forward beams covered a horizontal angle from straight ahead to 60 degrees outboard on each side. The tail unit swept through a total angle of 60 degrees. The vertical spread of the high-intensity portion of the beams was 10 degrees. They were visible at 20 to 30 miles distance, and appeared as a steady light punctuated by very intense flashes at the rate of 80 per minute. It was a clear night with 15 miles visibility reported by the weather bureau at the airport.

At the conference that followed the demonstration, expressions of opinion were obtained as follows:

1. The adoption of greatly improved external lighting for aircraft cannot be delayed any longer, even though developments in this field are continuing.
2. Any improvement of the presently used system of flashing lights that can be effected practically should be adopted immediately.
3. The immediate use of a practical and reliable high-intensity light is considered desirable. Either the rotating or sweeping type will provide the long-distance visibility required by existing speeds. The operation of such lights on airline aircraft will provide an experience basis for standardization of such installations.
4. The use of red and white taillights should be continued. The yellow light did not provide a distinct color.
5. The taillights should be separated as much as possible, since wide spacing gave a "jump effect" that added to the over-all conspicuousness. However, separation distance should be standardized.
6. The lights should be flashed at a rate of from 60 to 80 times per minute, with alternate flashing of the taillights; each one flashing at a rate of from 30 to 40 times per minute.
7. The presently used fuselage light arrangement should be continued.

8. The rotating helicopter light is very effective, but further development should be undertaken to improve it.

9. The development of a rotating high-intensity light for airplanes should be undertaken.

10. High-intensity lights should either be located outboard of the propeller discs or as far back on the fuselage as possible. The fuselage nose location was considered undesirable.

11. All airplanes, including personal type aircraft, should have flashing lights.

12. The intensity of any rearward shining light should not be such as to "blind" the pilot of a following airplane, especially when taxiing out for a take-off.

13. Any attempt to use a high-intensity light to cover too much "territory" results in serious loss in effectiveness.

14. The sweeping-beam lights on the Boeing are effective within the areas covered by the beams. However, more area should be covered.

15. No consensus as to the optimum type of high-intensity light was obtained during the conference. It was felt that the development of such lights should continue, and that new types should be shown in next year's demonstration.

The question as to how the wing tip, fuselage and taillights should be flashed with respect to one another was not resolved at the conference. In order to obtain a consensus in this matter, the Air Line Pilots Association arranged for a representative group of pilots to witness further demonstrations. The Center's Boeing airplane was flown to Chicago, and on the evening of September 13, 1950, various flashing arrangements were shown. As a result of this demonstration, it was agreed that the present flasher systems could be easily modified to provide for flashing the wing tip and fuselage lights at the rate of 80 per minute, together with alternate flashing of the red and white taillights with each flashing at the rate of 40 per minute. This will provide 80 flashes per minute from the two taillights; first red, and then white. Plans have been made for United Air Lines to modify their entire fleet to provide such a flashing arrangement.

DISCUSSION

In considering future development of high-intensity lighting, it is believed important to give careful study to the question of "how many lamps?" This, of course, depends upon the lamp characteristics and the areas to be covered.

If positive brightness as seen by a pilot at 15 miles is considered necessary, the threshold visibility distance should be of the order of 25 miles. From this, it can be stated that the lamp that was used in the various high-intensity units shown during the demonstration has optimum characteristics. When used with a red plastic cover and in clear weather, it can be seen from 20 to 30 miles away, and practically no halation is visible. It is small enough for practical purposes (4 1/4 inches in diameter) and requires only 75 watts for its operation. However, the high-intensity portion of its beam is limited to approximately 6 by 10 degrees.

The use of such a light for aircraft requires that it either oscillate or rotate to provide increased coverage. This, however, is believed to be particularly advantageous, since it appears to the pilot of the oncoming airplane as a series of very intense flashes which attract his attention and cause him to look in its direction even though he may happen to be looking elsewhere at the time.

However, there is the important matter of presenting a lighting arrangement to the pilot that will make it possible for him to estimate the speed and direction of the lighted airplane immediately. This requires continuous flashing at an adequate number of flashes per minute. During the conference, it was determined that the flashing frequency should be from 60 to 80 flashes per minute.

The matter of flash duration is most important, since very short flashes seriously reduce the effective intensity of a light as seen by the human eye. This duration is governed by the speed with which the beam sweeps past the pilot's eyes. It will be seen that as the beam of a single lamp is caused to move through increasingly greater angles, and if the frequency of flashes is maintained at the proper level, the angular speed of the beam will be increased. This progressively reduces the flash duration and the resulting effective intensity.

Attempts to increase the amount of coverage per lamp by spreading the beam are disappointing also, since this again causes a serious drop in beam intensity, unless more light energy is provided by the filament. This would require either larger lamps, higher wattage, or hotter filaments. Hotter filaments will result in shorter life. The present lamps have approximately 300 hours of life.

From a review of the demonstrated effectiveness of the various high-intensity lights exhibited, and the many opinions expressed during the conference, it is recommended that the amount of coverage to be obtained from one light be defined by 10 degrees in one direction and 90 degrees in the other. This limitation of "territory" to be covered per lamp can be expressed in terms of the area of the surface of a sphere having a radius of unity (steradians). The minimum recommended value is 0.274 steradian. Applying the previous limitation to the design of a rotating light which would cover 360 by 10 degrees would require that four lamps in a cluster be used. It would rotate at about 17 1/2 rpm, and the flashes would appear at about 70 per minute.

Extending the previously mentioned design standard to provide total coverage, the number of lamps required to cover the entire spherical area around an airplane would be $4\pi/0.274 = 46$. This is obviously impractical, and suggests that more study be given as to the critical areas to be covered and the intensities required in the various areas. For example, if overtaking closure speeds of 300 mph are considered likely, a 1-minute time factor would require positive light visibility at five miles, which would require much less intensity than would be required in the forward zones.

It is believed that considerable improvement in external aircraft lighting has been obtained in the last three or four years, and that we have developed some general principles and broad design requirements that will expedite continued development.

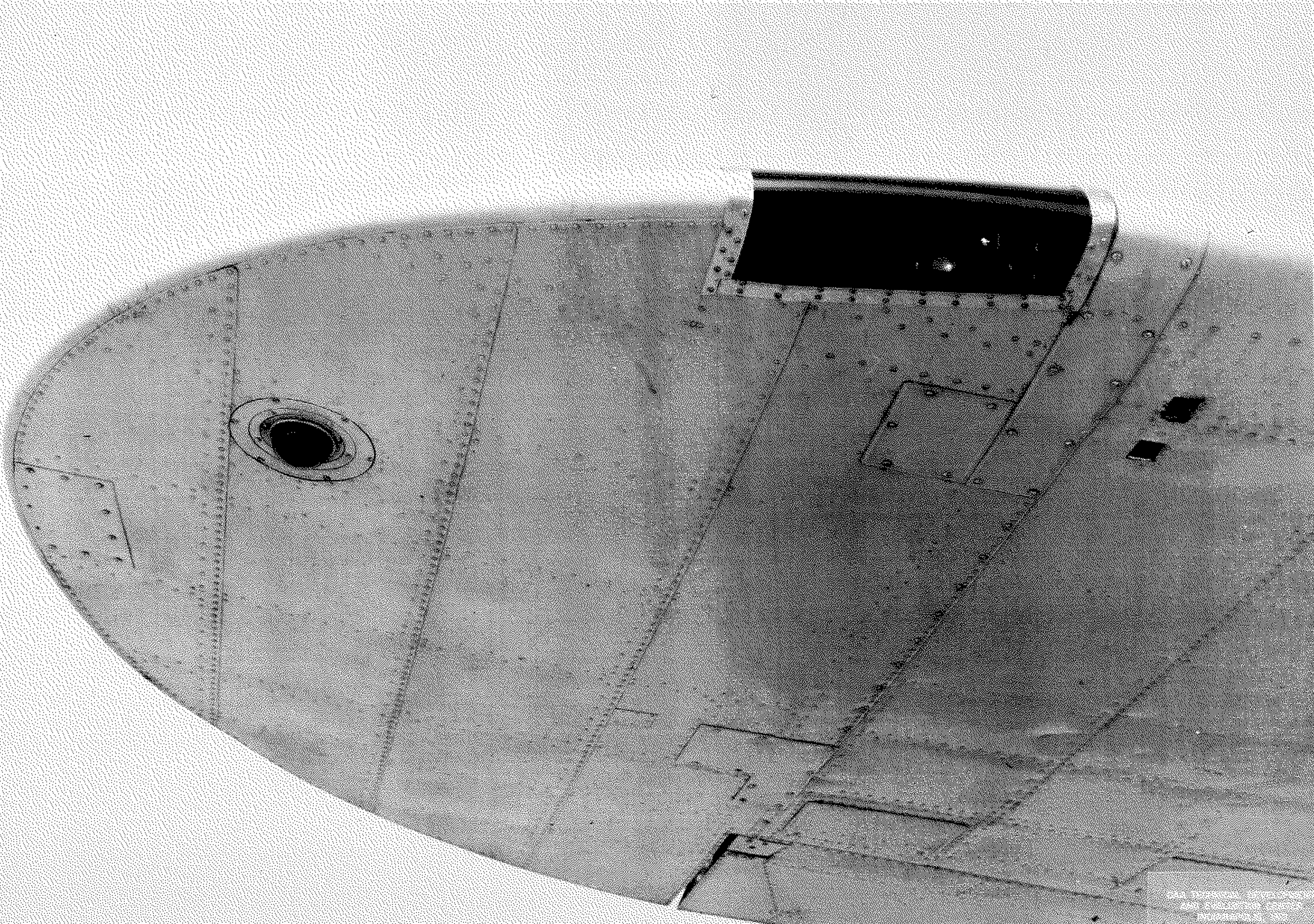

FIG. 1 HIGH INTENSITY SWEEP-BEAM LIGHT

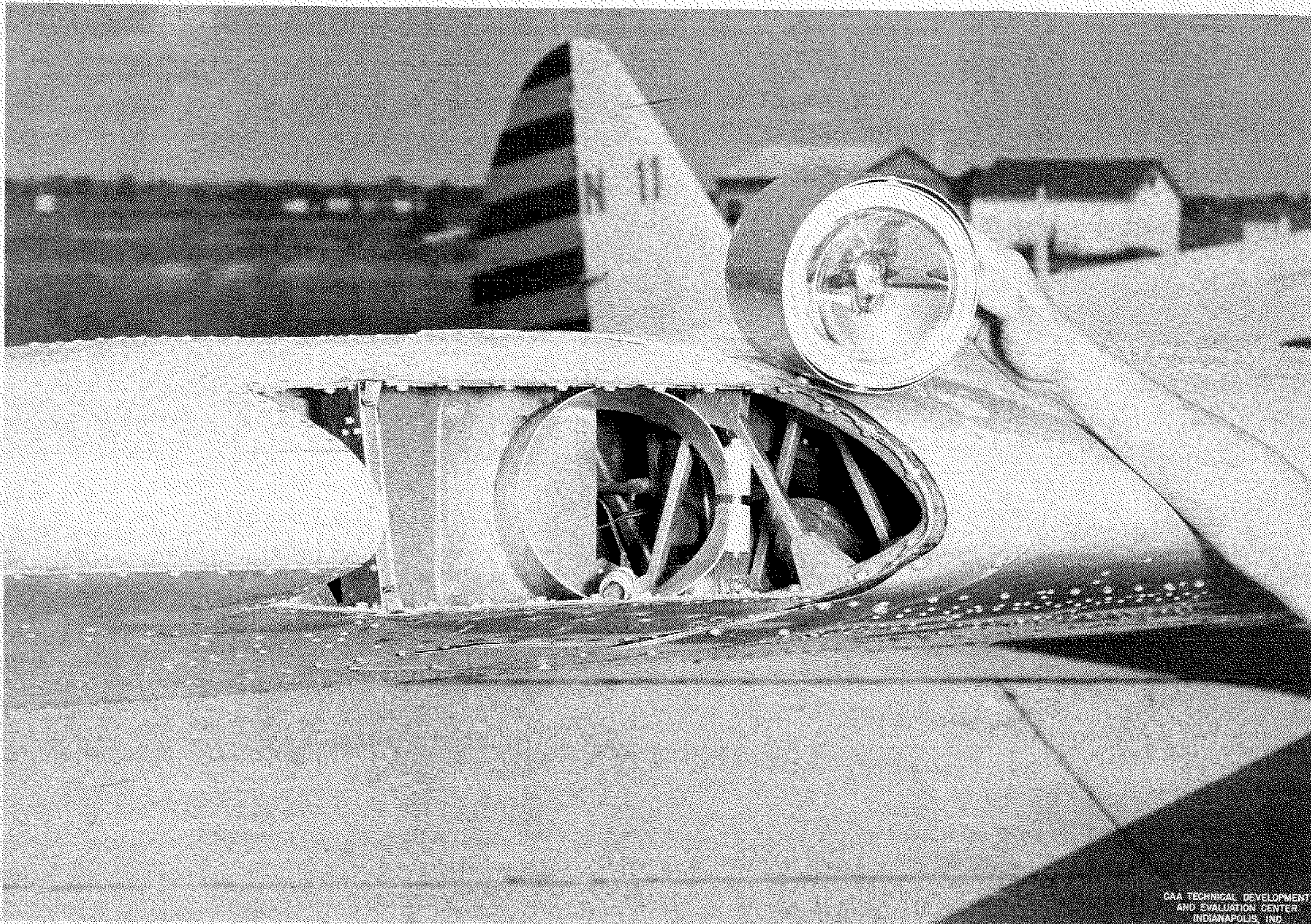

FIG. 2 SWEEP-BEAM LIGHT UNIT

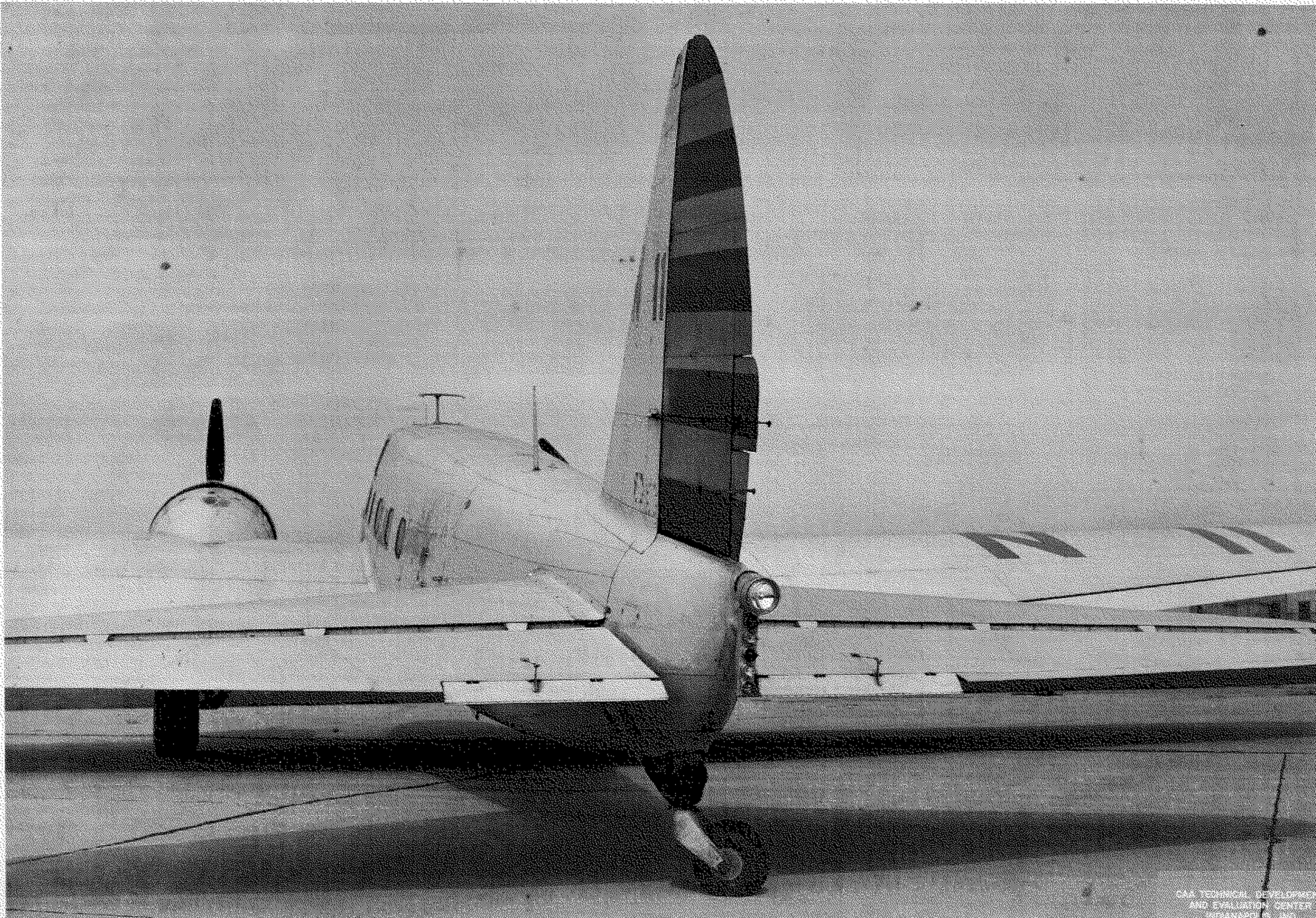

FIG. 3 EXPERIMENTAL FLASHING TAILLIGHT ARRAY

FIG. 4 EXPERIMENTAL FLASHING FUSELAGE LIGHT ARRAY