Report No. NA-69-7
(RD-69-8)

FINAL REPORT

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TEST AND EVALUATE RUNWAY ALIGNMENT INDICATOR LIGHT (RAIL) FOR APPROACH GUIDANCE

MARCH 1969

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
National Aviation Facilities Experimental Center
Atlantic City, New Jersey 08405

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for

SYSTEMS RESEARCH AND DEVELOPMENT SERVICE

March 1969

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DEPARTMENT OF TRANSPORTATION
Federal Aviation Administration
National Aviation Facilities Experimental Center
Atlantic City, New Jersey 08405

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The National Aviation Facilities Experimental Center maintains laboratories, facilities, skills and services to support FAA research, development and implementation programs through analysis, experimentation and evaluation of aviation concepts, procedures, systems and equipment.

ABSTRACT

An evaluation has been completed at the National Aviation Facilities Experimental Center (NAFEC), Atlantic City, New Jersey, comparing the Runway Alignment Indicator Lights (RAIL) with the Medium Intensity Approach Light System (MALS) for effectiveness in providing identification and guidance as visual approach aids. The two aids were flown alternately in each available weather condition to permit comparison. The results obtained from pilot questionnaires and radar data during day and night IFR/VFR operations with weather minimums down to 3/4-mile visibility indicated the following: While the RAIL provided earlier identification and displacement information than did the MALS, the glare from the RAIL was so distracting during VFR night operations that pilots considered the RAIL unacceptable. On the other hand, the MALS was acceptable during day and night IFR/VFR operations and was rated the better approach aid during VFR night operations.

It was recommended that RAIL not be approved for operational use.

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INTRODUCTION

Purpose

The purpose of this project was to compare the effectiveness of the Runway Alignment Indicator Light (RAIL) and the Medium Intensity Approach Light System (MALS) as visual approach aids for conducting non-precision type instrument approaches with a wide range of aircraft during day and night operations down to 3/4-mile visibility.

Background

In March 1967, Flight Standards Service requested the Systems Research and Development Service (SRDS) to evaluate the RAIL on a comparative basis with the MALS to determine (1) the effective range of the system, (2) effectiveness in providing alignment guidance and (3) effectiveness in providing identification of the approach to the runway during day and night 1-mile visibility conditions. In addition, an investigation was to be made of the RAIL glare problem which existed when strobes were installed within 1,000 feet of the approach end of the runways. Glare reduction experiments were planned using glare shields and intensity control attempting to minimize glare to an acceptable operational level.

A comparative evaluation between the MALS and RAIL had not been conducted by the FAA and this program was intended to establish the adequacy of RAIL using MALS as a reference. Prior flight testing has determined that MALS did provide adequate visual guidance, but experience on RAIL with controlled test conditions was lacking. Since RAIL had the lower cost hardware, it would be an advantage to adopt it, if it provided minimum adequate visual guidance.

DISCUSSION

General

The MALS and RAIL approach light aids tested in this effort were compared and evaluated regarding guidance and identification capabilities during IFR/VFR, day and night operations. In addition, glare reduction experiments were conducted on the RAIL in an attempt to develop a method for solving an excessive glare problem which exists on strobes installed within 1,000 feet of the runway threshold.

Equipment Description

The RAIL (Figure 1) installed on the approach end of Runway 4, NAFEC, consisted of six condenser-discharge lights, Type FT-34/HP (Figure 2). Each had an effective intensity of 17,000 candelas at the peak with a conical beam of 20° at 15,000 candelas. During the glare reduction tests the Type FAA-1250 (Figure 3) was used in the same pattern as in Figure 1. The Type FAA-1250 had an effective intensity of 9,000 candelas at the peak with a conical beam of 25° at 5,000 candelas.[1] The lights were stake mounted on frangible couplings, 24 inches above the surface, the axis initially elevated 2°, aligned along the runway extended centerline and spaced 250 feet apart for a distance of 1,500 feet from the runway threshold. The installation in the approach zone of Runway 4 (Figure 4) followed the terrain slope which falls off approximately 1.5 percent for the first 1,200 feet from threshold. A 1 percent positive grade occurs for the next 400 feet and then changes back to a negative 1.5 percent slope to 3,000 feet from the threshold. Power for the RAIL came from a 240 V, single phase line while 120 V, single phase was used for control. System energizing was either manual or automatic by the use of a 24-hour timer. The 240 V power was stepped up to several thousand volts in the condenser-discharge power supply, rectified to direct current and stored in a large capacitor connected across each condenser-discharge light. A motor-driven timer supplied the 120 V control voltage to the condenser-discharge circuit twich a second to flash the condenser-discharge lights (strobes). The strobes were flashed in sequence towards the runway threshold.

[1]National Bureau of Standards Test Report 21P-49/62.

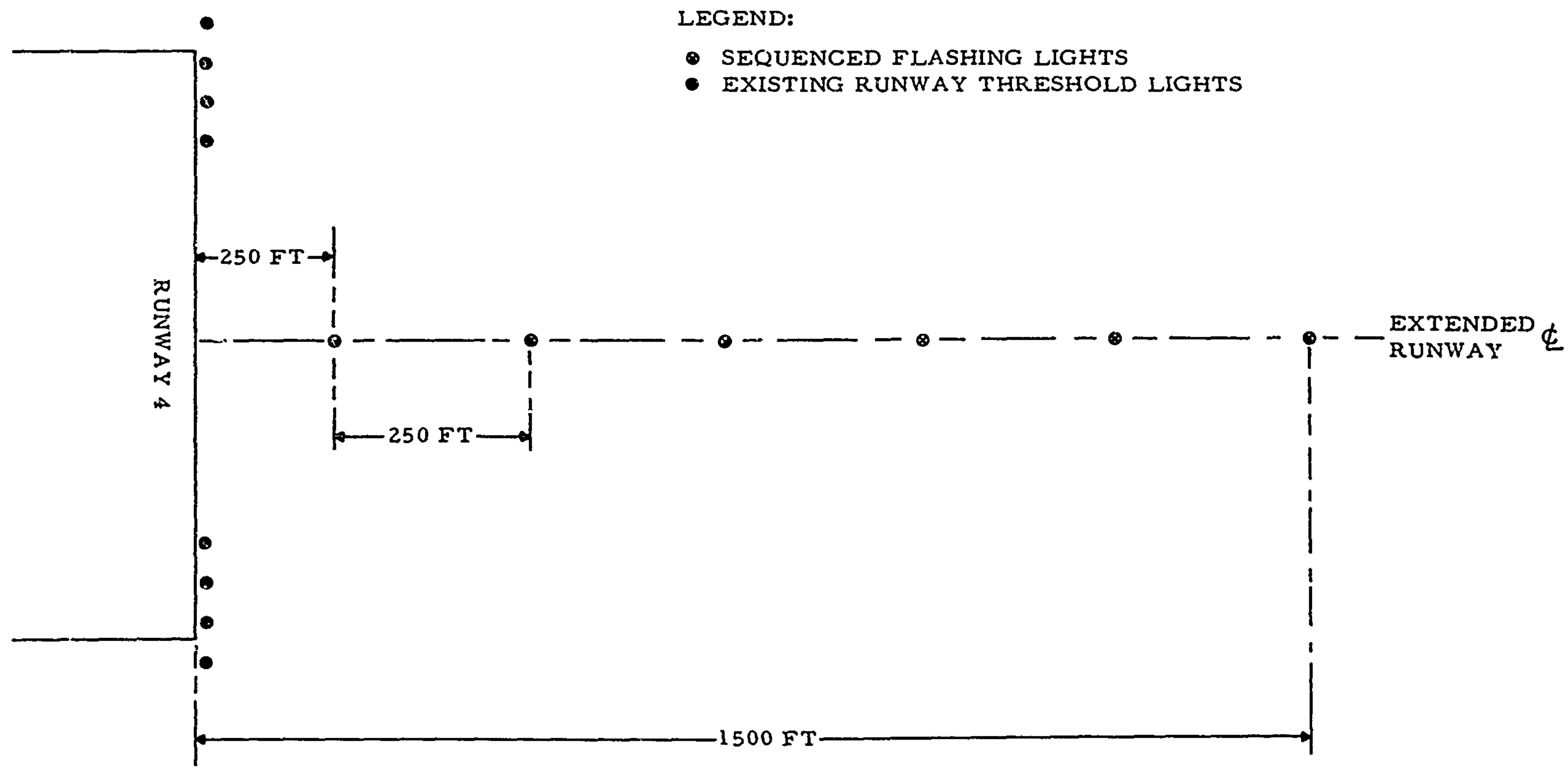

FIG. 1 THE RUNWAY ALIGNMENT INDICATOR LIGHT (RAIL) FOR RUNWAY 4, NAFEC

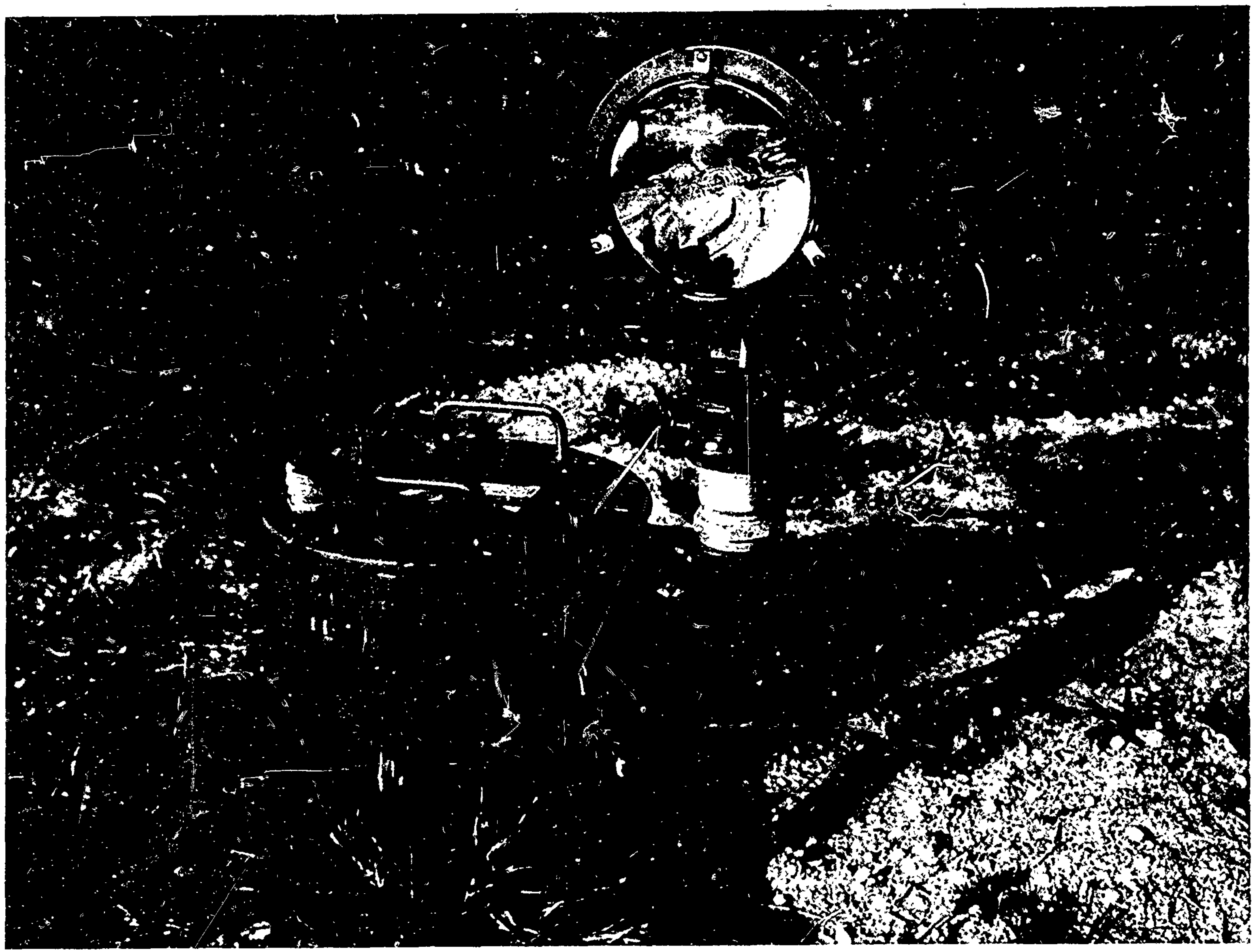

FIG. 2 TYPE FT-34/HP CONDENSER-DISCHARGE STROBE LIGHT PART OF THE RAIL

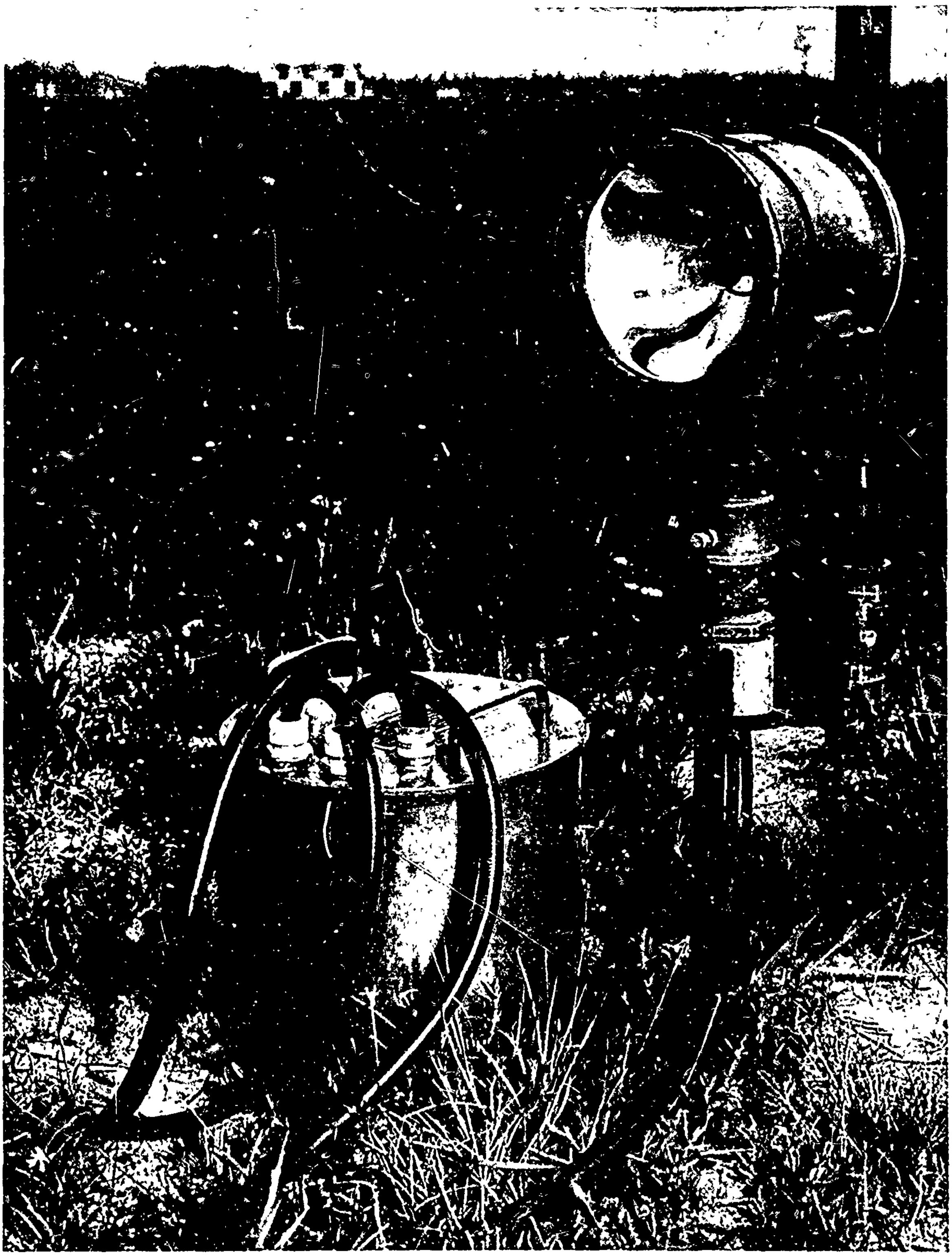

FIG. 3 TYPE FAA-1250 CONDENSER-DISCHARGE STROBE LIGHT

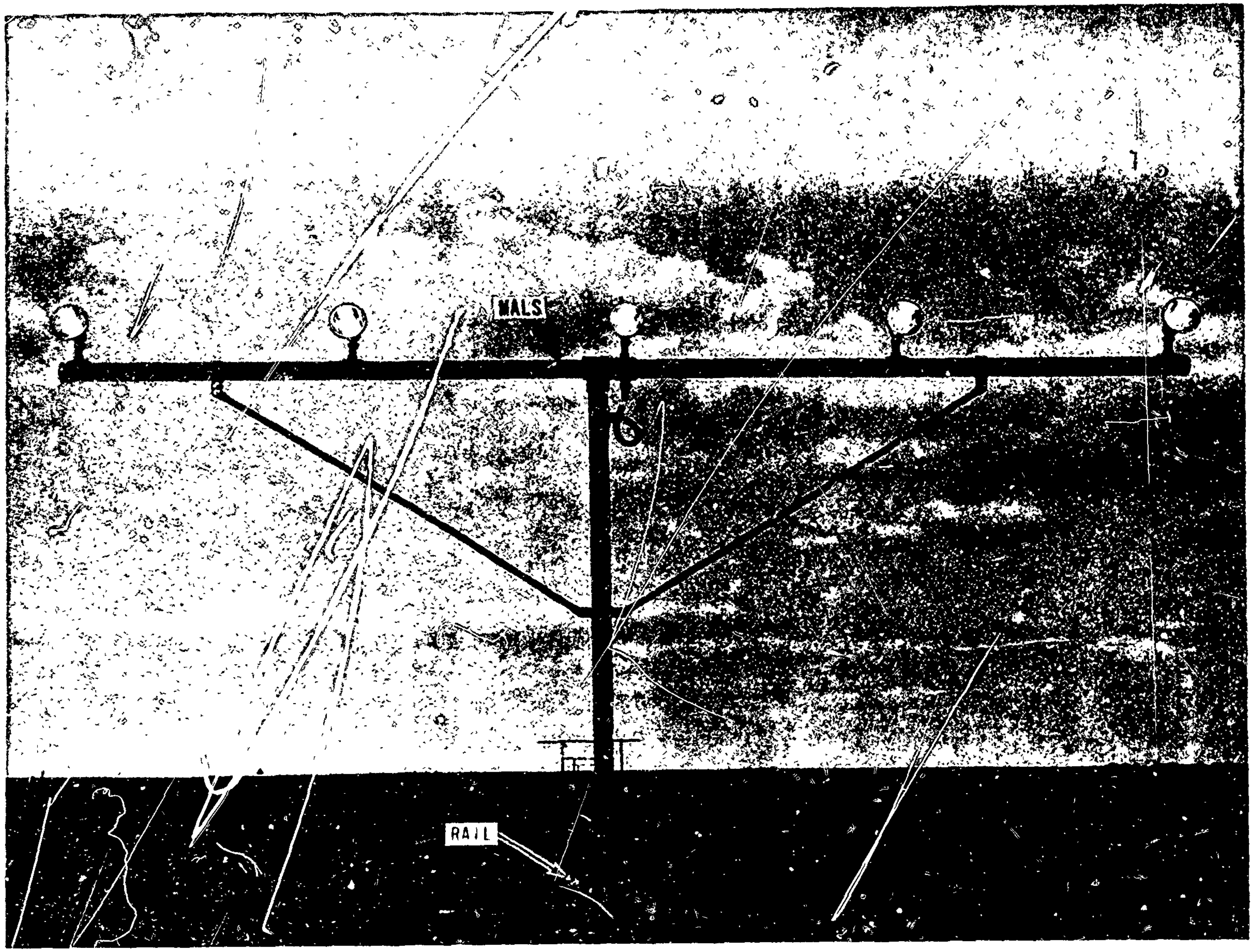

FIG. 4 THE MALS AND THE RAIL
IN THE RUNWAY 4 APPROACH ZONE

The MALS system on Runway 4, NAFEC, consisted of seven barrettes of steady-burning incandescent lamps containing five lamps per barrett (Figure 4 and Figure 5). The barrettes were spaced 200 feet apart along the extended runway centerline for a distance of 1,400 feet and were in a horizontal plane from the runway threshold. The lamps were Type PAR-38, 150-watt spotlights with an effective intensity of 5,000 candelas within a conical beam spread of 20°. Two additional barrettes, installed at 1,000 feet from the runway threshold on each side of the centerline barrette formed a 1,000-foot decision bar. Condenser-discharge lights having the same characteristics as those used in the RAIL were used in the outer two stations while the condenser-discharge light at the 1,000-foot station was shared by RAIL and MALS. Again, 240 V and 120 V were used for power and control of the three sequenced-flashing strobes while 120 V powered the PAR-38 spotlights. The strobe lights were triggered by the same motor-driven timer unit used for the RAIL. Two brightness settings for the PAR-38 lamps (100 percent and approximately 4 percent) were used during the tests. One hundred percent intensity was used for day and IFR operations, and 4 percent intensity was used for VFR night flights.

Tests

Laboratory Tests: Photometric tests were not required of the RAIL FT-34/HP strobes and the MALS PAR-38 spotlights as their photometric characteristics were known. However, photometric tests were made of a Type FAA-1250 strobe light[2] (Figure 6) to determine (1) similarity of photometric characteristics with the Type FT-34/HP strobe, and (2) whether satisfactory strobe operation could be obtained with intensity control. Tests indicated that intensity control of the FAA-1250 strobe was feasible. Stable operation was obtained at two pulses per second with effective intensity variations from 7,000 candelas to 2,900 candelas by changing the input supply voltage from 240 V to 170 V. There was, however, no attempt to determine the long-term stability.

[2]The Sylvania numbers for this light are--condenser-discharge light Type 1250 and power unit Type CD-100F.

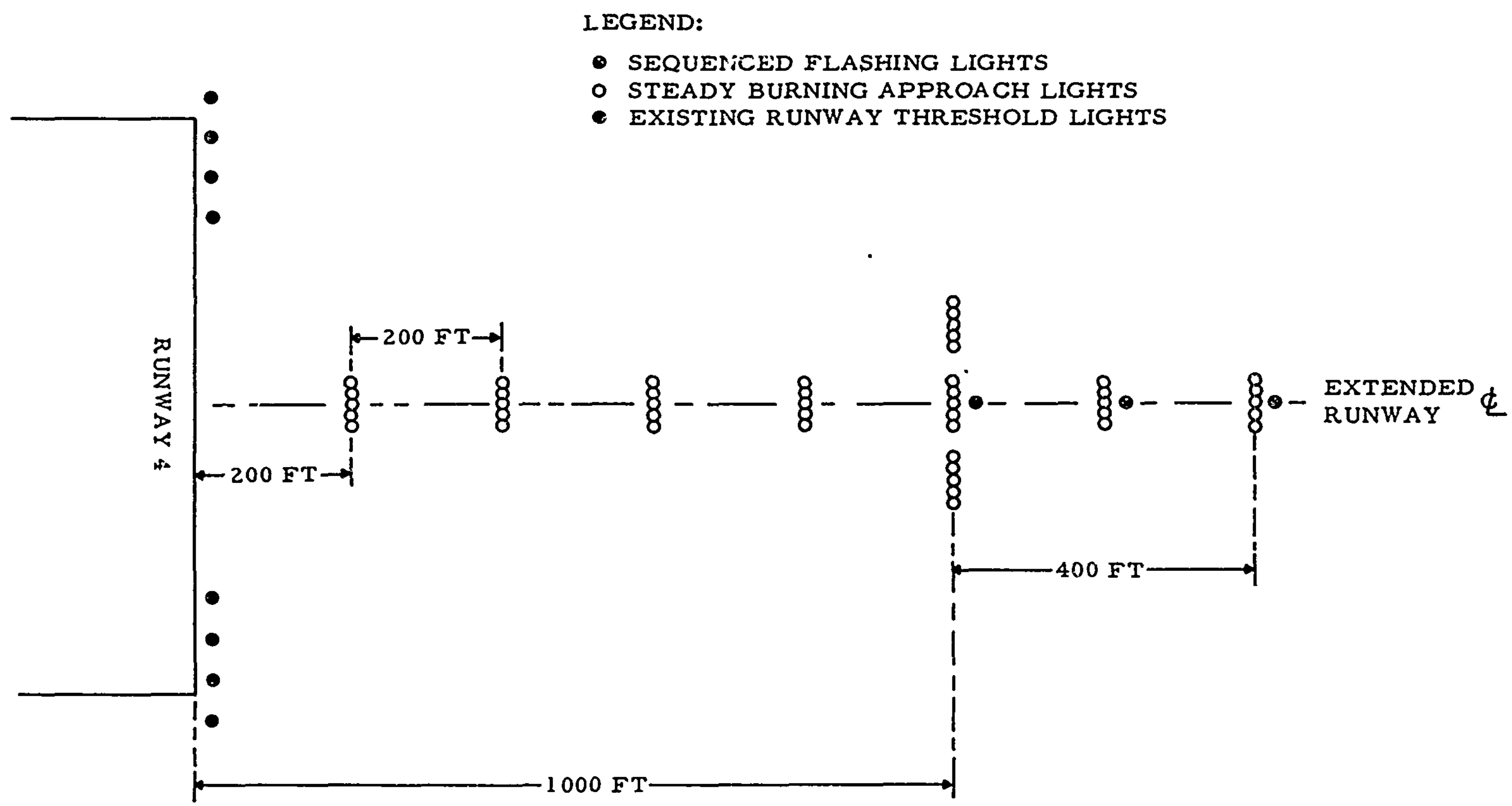

FIG. 5 THE MEDIUM INTENSITY APPROACH LIGHT SYSTEM (MALS) ON RUNWAY 4, NAFEC

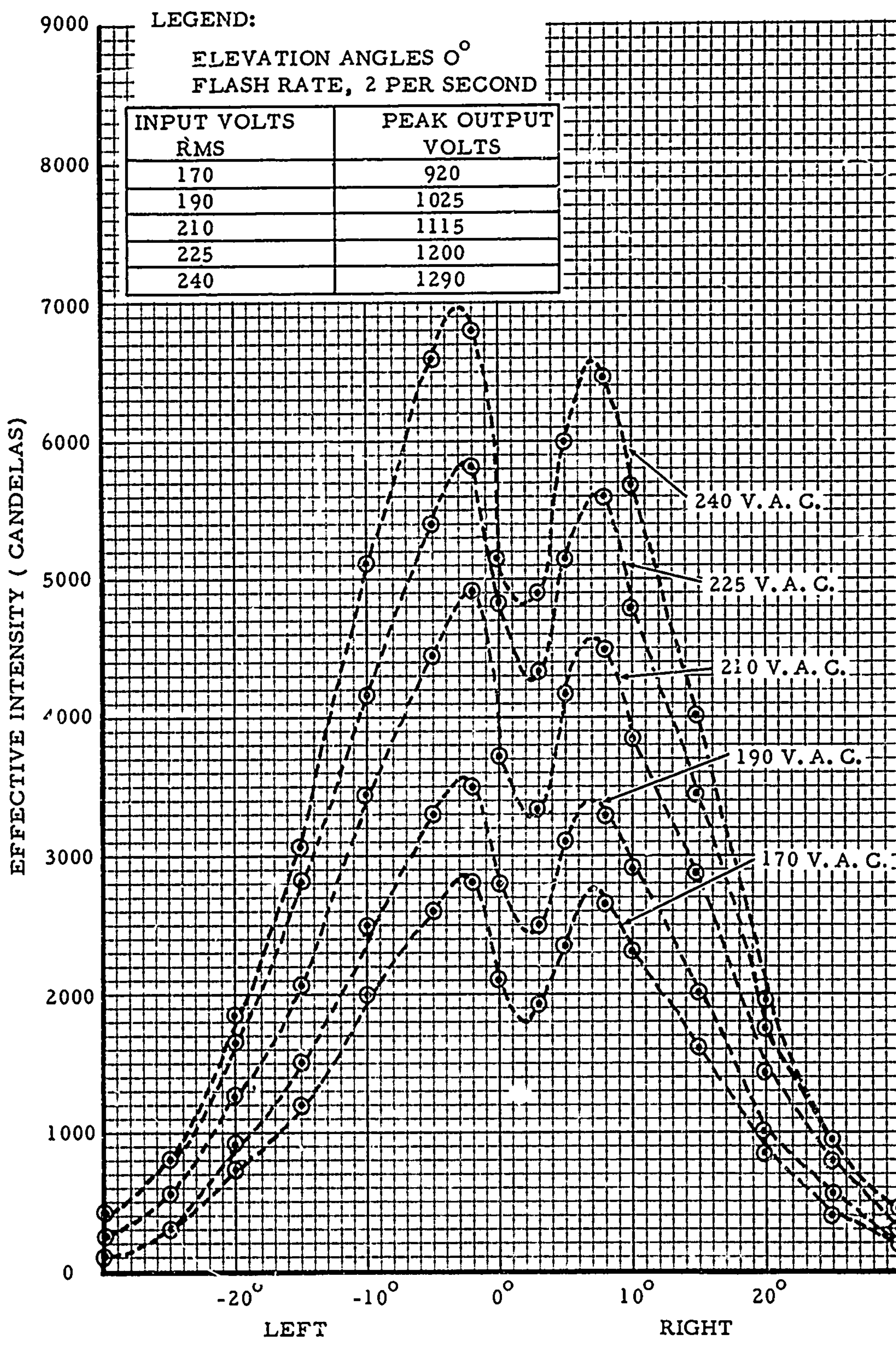

FIG. 6 INTENSITY DISTRIBUTION COMPOSITE
OF TYPE FAA-1250 CONDENSER-DISCHARGE STROBE LIGHT

The FT-34/HP strobe was unsuitable for intensity control operation as low input voltages caused unstable strobe operation, while having little effect on intensity. Glare shields for light-cutoff angles of between 20° and 22° (Figure 7) were fabricated and mounted on the Type FT-34/HP strobes.

It was planned to flight test the hooded lights to determine if glare could be reduced to an acceptable level for VFR night flights and still obtain satisfactory day operation. In addition, flights would also be made with the FAA-1250 strobes with and without intensity control. The lower intensity output of 2,900 candelas would be used for VFR night and the high intensity output of 7,000 candelas for the other conditions.

Flight Tests:

General - Glare reduction tests were made with glare shields and variable intensity control to determine if either method were feasible in reducing glare to an acceptable level for VFR night operations while still providing adequate approach guidance.

Operational tests were conducted to compare the RAIL with the MALS as visual approach aids. Factors considered were:

1. The effective range/early identification of the aids.

2. Displacement left or right of the runway centerline.

3. Guidance to the approach runway.

Glare Reduction Tests - On January 25, 1968, four VFR night approaches were made on the RAIL with glare shields mounted on the FT-34/HP strobes. Post-flight questionnaires (Figure 8A) by four subject pilots indicated that glare was very distracting and was not reduced to an acceptable level. As a result of these flights, it was decided to continue glare reduction testing with the lower intensity FAA-1250 strobes.

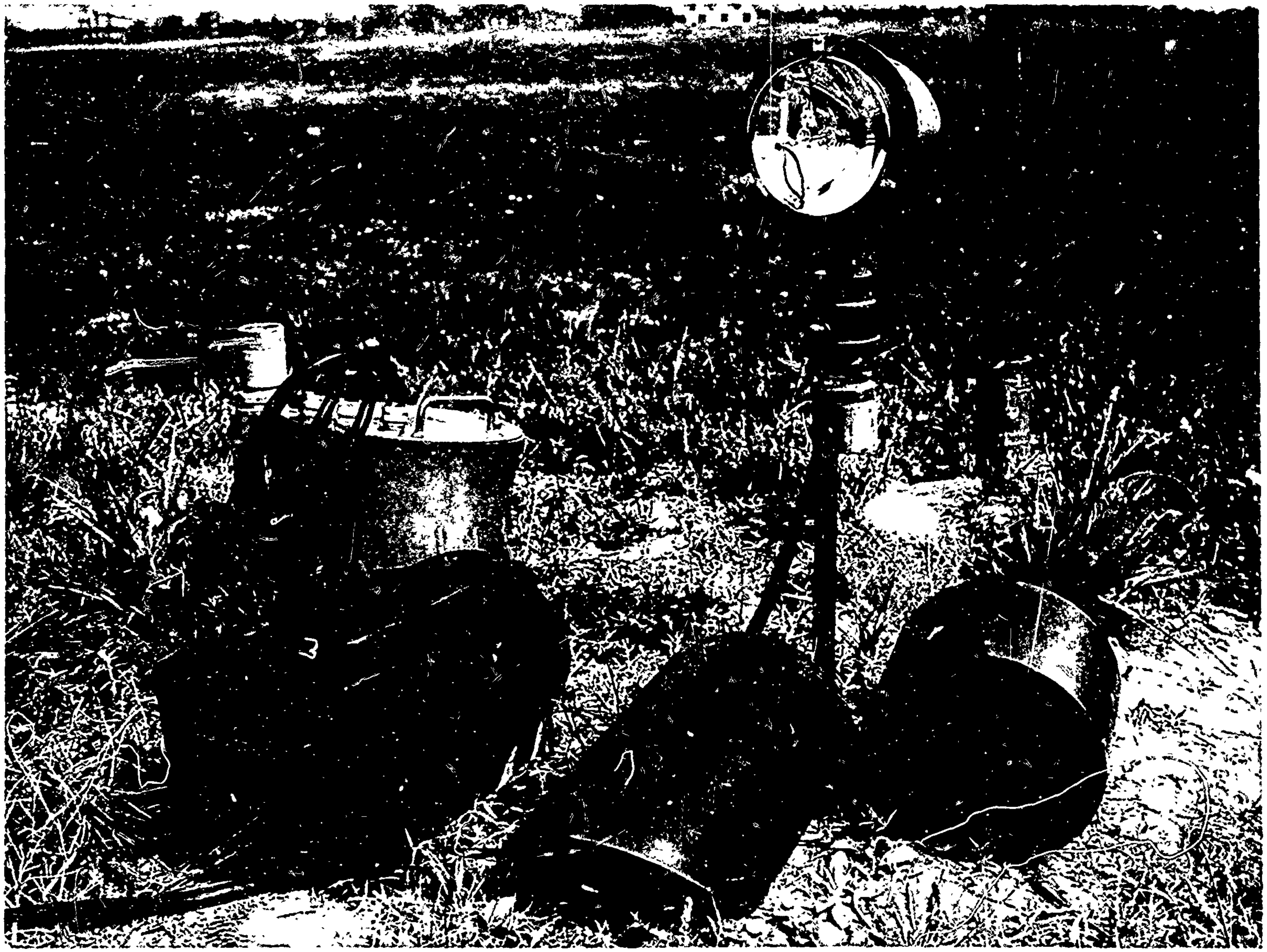

FIG. 7 GLARE SHIELDS USED ON TYPE FT-34/HP CONDENSER-DISCHARGE STROBE LIGHTS

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QUESTIONNAIRE

PILOT_______________ AIRCRAFT______________ DATE______________

WEATHER_____________ DAY______ NIGHT______ TIME______________

1. Is the RAIL adequate for the weather conditions flown in this period?
   YES______ NO______

2. Did the strobes present any glare problems? YES______ NO________

3. Rate the guidance elements below for the RAIL.

   a. Early identification — Adequate______ Inadequate_______

   b. Directional guidance — Adequate______ Inadequate_______

   c. Roll guidance — Adequate______ Inadequate_______

   d. Height guidance — Adequate______ Inadequate_______

   e. Boldness (intensity) of the system — Adequate______ Inadequate_______

Please provide any comments of a general nature in the space below.

FIG. 8A PILOT POST-FLIGHT QUESTIONNAIRE

On April 23, 1968, seven night approaches were made in a Gulfstream with visibilities varying between one-half mile and one mile using the FAA-1250 strobes. The purpose of these flights was to observe the effectiveness of these units in providing adequate approach guidance during reduced visibility conditions. Post-flight questionnaires completed by two subject pilots indicated the following:

1. The RAIL provided adequate guidance and did not present any glare problems for the weather conditions flown.

2. All specified guidance elements, i.e., early identification, directional guidance, roll guidance,[3] height guidance, and boldness were adequate.

On May 1, 1968 and May 2, 1968, eight VFR night approaches were made to observe the glare aspects of the FAA-1250 strobes during clear night operations.

Post-flight questionnaires by five subject pilots indicated the following:

1. The strobes presented a distracting glare problem.

2. Four pilots rated the RAIL adequate for the weather conditions flown, while the fifth rated the system inadequate.

3. All rated the RAIL adequate in providing early identification, directional guidance and boldness.

The following comments were made by the subject pilots:

1. The system was too bright in close. The glare was actually painful within about one mile or so. The three strobes closest to the threshold and possibly one more should be eliminated.

2. The system was too bright; it blots out approach and edge lights on approach.

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[3]The value of strobe lighting for roll or height guidance can be questioned. It is possible that pilots derive these elements of guidance from other visual cues which they are not aware of. Simulation tests have shown that when there are no other visual cues available, pilots have extreme difficulty in obtaining roll or height guidance from strobe lighting such as the RAIL.

On May 21, 1968, four VFR night approaches were made in a Gulfstream, G-159, on the MALS and RAIL aids using Type FAA-1250 strobes with intensity control.

Run No. 1 - RAIL at high-intensity setting, 7,000 candelas (effective).

Run No. 2 - RAIL at low-intensity settings, 2,900 candelas (effective).

Run No. 3 - The MALS, Step 3.

Run No. 4 - RAIL at intensity setting of 2,900 candelas (effective).

Post-flight questionnaires completed by two subject pilots indicated the following:

1. RAIL was distracting and was rated unacceptable during VFR night operations (on both intensity settings).

2. MALS was rated adequate and was the better approach aid during VFR night operations.

The following comments were made by the subject pilots:

1. RAIL intensity was too high, MALS flash intensity was too high.

2. RAIL was still too bright close in, probably okay under IFR. Liked MALS.

Operational Tests - All data were gathered in IFR/VFR day and night flights with visibilities down to approximately three-fourths mile. The VOR approach procedure was used with Precision Approach Radar (PAR) monitoring and issuing flight advisories when needed. The PAR glide-path angle on Runway 4 was 2.95^{o} and the glide-path intercept point was located 750 feet from threshold. Aero Commander AC-680, Convair T-29, and Gulfstream G-159 type aircraft were used.

During an approach, airborne motion picture photography and video recording were used to film the segment ahead of the aircraft. On the ground, PAR scope photography/ASR-4 Radar provided a fix on the aircraft when lights of the approach system being tested were first observed by the crew. The PAR provided aircraft detection ranges within 3 miles while the ASR-4 provided target identification greater than 3 miles.

The pilot making the approach announced, "Mark I," when the strobe lights became visible and "Mark II," when the steady-burning lights became visible. These sightings were transmitted by radio to the PAR console/ASR-4 console. Photographs were made of the PAR scope and ranges recorded at the ASR-4 as quickly as possible to provide a fix of the aircraft. Touch-and-go landings were normally flown whenever wind and runway conditions were suitable. Post-flight questionnaires, (Figure 8B) were completed at the conclusion of the flight period to rate the effectiveness of the systems in providing identification, displacement, and guidance.

A total of 51 day and night approaches were flown; 17 in variable weather conditions with the reported visibility close to three-fourths mile and the remainder made during VFR conditions.

On January 4, 1968, five day approaches were flown in a Gulfstream. Before takeoff, visibility was reported near three-fourths mile. The reported visibility for Run 1 was 5/8 mile, for Runs 2, 3, and 4, it was 1 mile and for Run 5, it was slightly greater than 1 mile.

Data for the flights were obtained from analysis of PAR scope photographs and pilot questionnaires. Radar acquisition of the test aircraft during sightings of the approach light systems for the first four runs are shown in Figure 9. Run 5 was not included as the PAR camera was misaligned.

Post flight questionnaires completed by the three subject pilots indicated the following:

1. Both aids were rated adequate for the weather conditions flown.

2. RAIL was selected as the superior aid for this period.

3. RAIL was rated as providing the best identification, displacement information, roll guidance, and height guidance.

PROJECT NO. 430-209-08X
QUESTIONNAIRE

PILOT________________AIRCRAFT____________DATE______________

WEATHER____________DAY______NIGHT______TIME______________

1. Which system provided the best identification? RAIL___MALS___

2. Which system provided the best alignment guidance* with the runway centerline? RAIL____MALS____

3. Which system provided the best roll guidance? RAIL____MALS___

4. Which system provided the best height guidance? RAIL___MALS___

5. Considering all elements of guidance requirements, was the RAIL adequate for the weather conditions flown in this period?
   YES____NO____

   Was the MALS adequate for the weather conditions flown in this period?
   YES____NO____

6. Which system would you prefer as an approach aid in the weather conditions flown in this period? RAIL____MALS____

7. Were any problems encountered with either system? YES____NO____
   If so, please describe.

8. Additional Comments:

*Alignment guidance in this context means displacement left and right of the runway centerline.

FIG. 8B PILOT POST-FLIGHT QUESTIONNAIRE

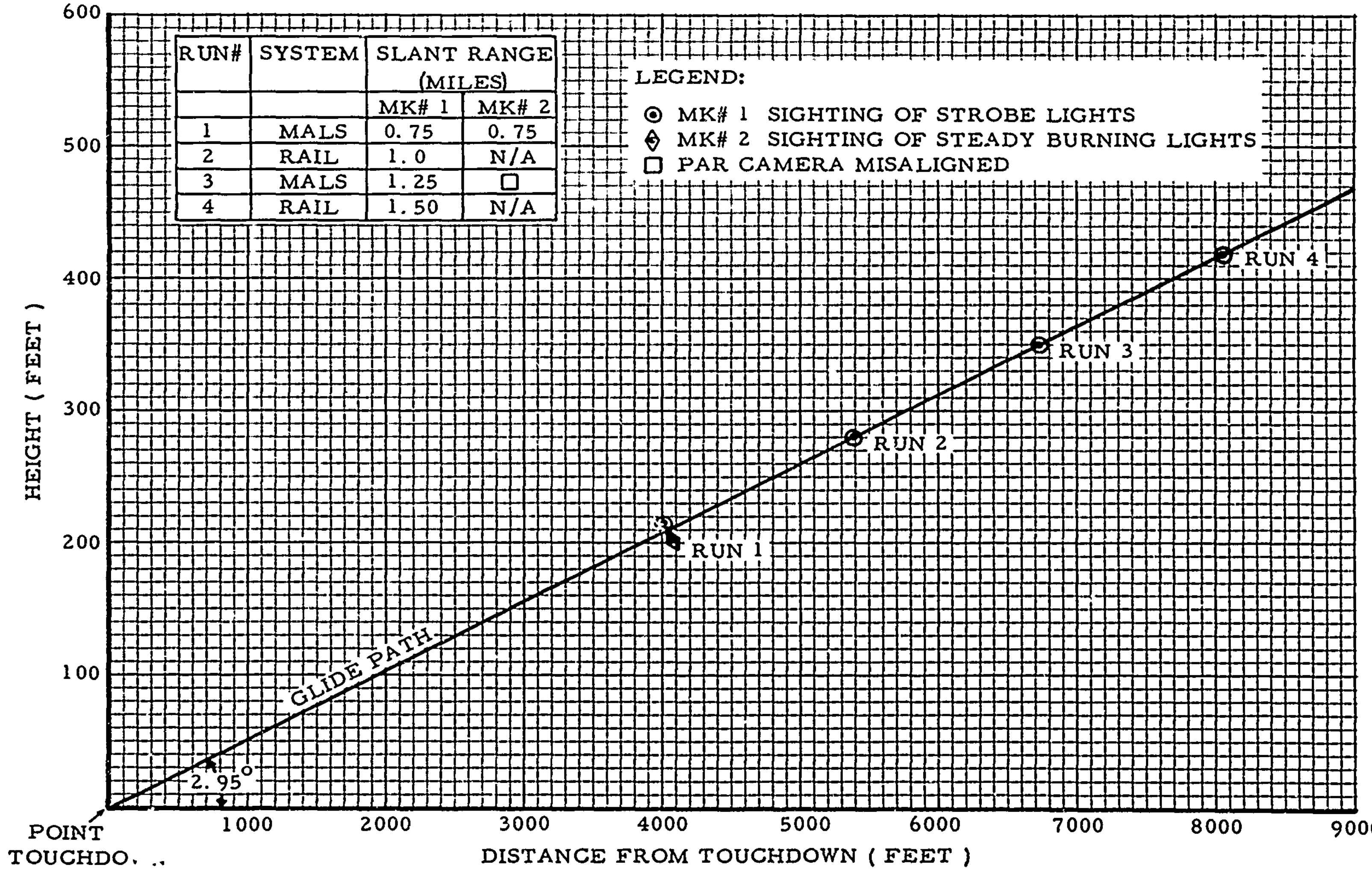

FIG. 9 VISUAL APPROACH CONTACTS ON JANUARY 4, 1968

The following comments were made by the subject pilots:

1. Either system was adequate, but RAIL was much better in low visibility; MALS was better at night under good visibility conditions.

On February 1, 1968, five night approaches were made in a T-29 with the visibility averaging three-fourths mile. PAR data were obtained for Runs 4 and 5 only (Figure 10). Run 2 was a missed approach and no marks were called for Runs 1 and 3.

Post-flight questionnaires were completed by two subject pilots. Both aids were rated adequate for the weather conditions flown. One pilot rated the MALS the better approach aid while the other pilot did not express preference for either aid. The RAIL was selected as providing better initial identification and displacement information. The MALS was rated superior in providing roll guidance. In providing better height guidance one subject selected the MALS.

The following comments were made by the subject pilots:

1. I did not feel I had any height information. Strobes alone do not have enough roll guidance.

2. A combination of both systems would be my preference.

On May 13, 1968, four VFR day flights were flown. Post-flight questionnaires completed by four pilot subjects indicated the following: Both aids provided adequate guidance; RAIL was rated the better approach aid by three out of four pilots; RAIL was superior in identification and alignment guidance (displacement). One pilot rated the MALS superior in height and roll guidance. Two pilots rated both aids equal in height and roll guidance and one pilot was noncommital.

The following comments were made by the subject pilots:

1. Neither system aided in roll guidance or height guidance. Primarily they helped locate where the end of the active runway was, but after the runway was in sight, they were of little, if any, value.

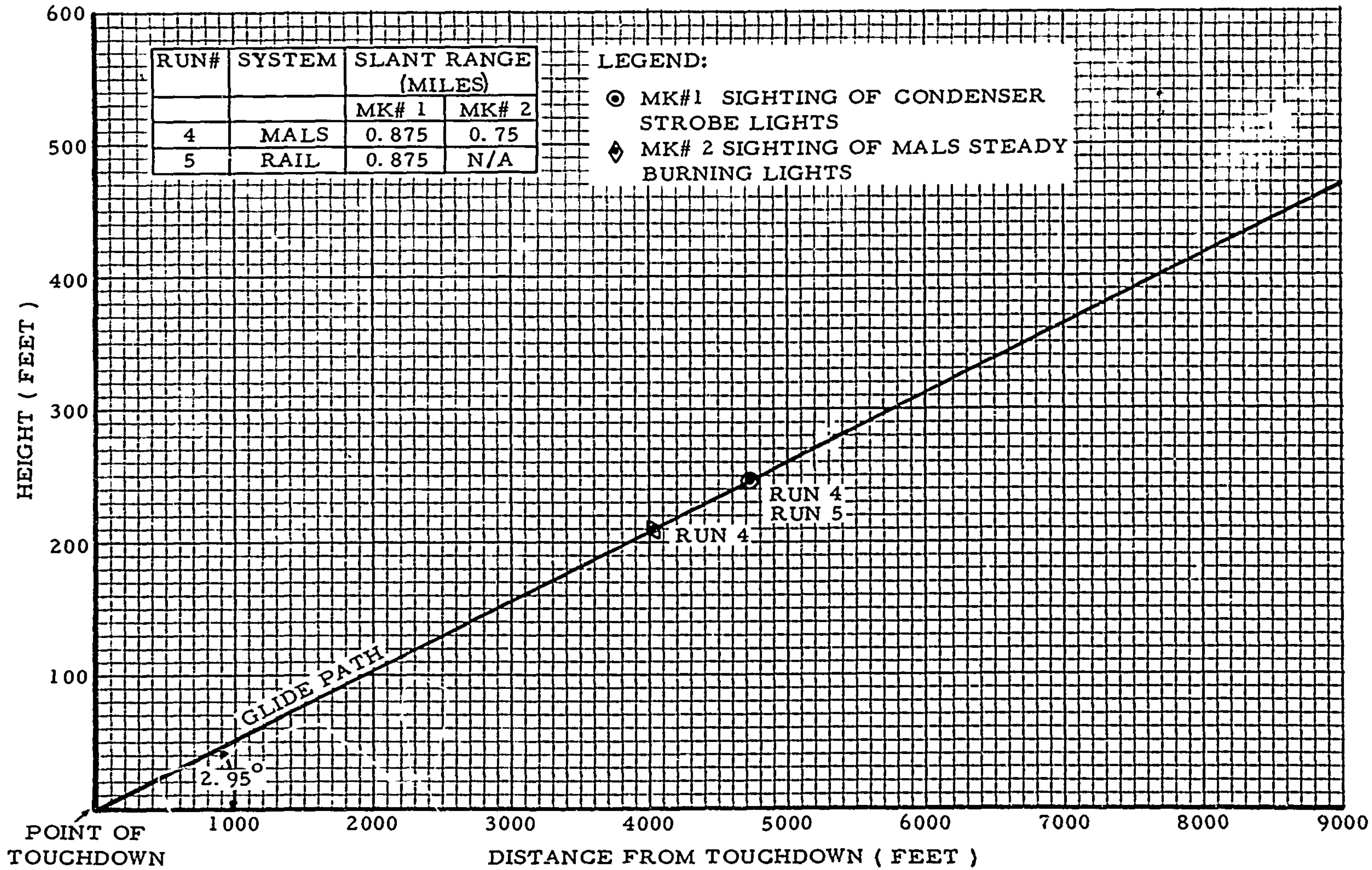

FIG. 10 VISUAL APPROACH CONTACTS ON FEBRUARY 1, 1968

2. Condenser lights were much too bright and distracted the crew on approach. The strobes were actually detrimental to guidance normally provided by natural terrain.

3. MALS was difficult to find on base leg. Aircraft was turning on final before the MALS would be reliably in view. The runway outline was visible and identified minutes before either aid.

4. I feel that the flash rate on the RAIL was too fast--It seemed to blend into one light--the number one light (1,500-foot position) should be colored.

On May 8, 1968, 12 VFR day flights were flown by five pilot subjects. Type FAA-1250 strobes were used in the morning flights and Type FT-34/HP strobes in the afternoon flights. Visual approach contacts, Tables I and II, show the following average detection ranges:

RAIL (FAA-1250) 8.5 miles; RAIL (FT-34/HP) 9.7 miles; MALS 9.1 miles.

Post-flight questionnaires completed by the subject pilots indicated the following: RAIL provided the better identification; RAIL provided the better displacement information; all three visual aids provided adequate visual guidance; and RAIL was rated the better approach aid in VFR weather conditions.

The following comments were made by the subject pilots:

1. MALS strobes were hard to catch visually.

2. Roll and height guidance initially were acquired by natural airport horizon.

3. The weather was such that no lights were required for any guidance.

4. Difficult to evaluate in CAVU weather since runway was visible before lights.

On May 13, 1968, two VFR night approaches were made in a Gulfstream by four pilot subjects.

TABLE I

ASR-4 VISUAL APPROACH CONTACTS (FT-34/HP STROBES)

RUN #	SYSTEM	SLANT RANGE (MILES) *MK#1	o MK#2	NOTES
1	RAIL (FT-34/HP)	9.0	N/A	* SIGHTING OF CONDENSER STROBE LIGHTS o SIGHTING OF MALS STEADY BURNING LIGHTS
2	MALS (STEP 5)	9.4	4.25	
3	RAIL	10.3	N/A	
4	MALS	8.6	5.9	
5	RAIL	9.9	N/A	
6	MALS	9.8	7.8	

TABLE II

ASR-4 VISUAL APPROACH CONTACTS (FAA-1250 STROBES)

RUN #	SYSTEM	SLANT RANGE (MILES) *MK#1	oMK#2	NOTES
1	RAIL FAA-1250	8.0	N/A	*,o SEE NOTES IN TABLE I
2	MALS (STEP 5)	10.0	7.0	
3	RAIL	8.5	N/A	
4	MALS	7.5	6.0	
5	RAIL	9.5	N/A	
6	MALS	9.5	7.0	

Post-flight questionnaires were completed by the pilots. The MALS was rated adequate and the better approach aid for the weather conditions flown. Three pilot subjects indicated that RAIL furnished adequate guidance and one pilot rated it inadequate. Two pilots expressed preference for the RAIL as providing better identification and two pilots selected the MALS as superior in identification. Three pilot subjects rated the MALS superior in identification. Three pilot subjects rated the MALS superior in displacement information and the fourth pilot was noncommital.

The following comments were made by the subject pilots:

1. RAIL was much too bright at close range. Once identification of the runway was made the system became distracting and hazardous. Landing lights had to be put on to see the runway.

2. Condensers were too bright. Brightness of the strobes were deterimental to safety of flight. Had to use landing lights to see runway.

3. Strobe lights were too bright close in.

On May 21, 1968, four VFR night approaches were made in a Gulfstream in clear visibility conditions.

Post-flight questionnaires were completed by two subject pilots. Both rated the MALS adequate for the weather condition flown and the better approach aid. The RAIL was rated inadequate and was judged too bright close in. The MALS was rated superior in all guidance elements and identification. In providing better displacement information, one pilot favored the RAIL while the other preferred the MALS.

The following comments were made by the subject pilots:

1. RAIL was still too bright close in.

2. RAIL intensity was too high.

SUMMARY OF TEST RESULTS

Glare Reduction Test Results

1. Shielding of the FT-34/HP strobes did not reduce glare to an acceptable level for VFR night operations.

2. Intensity control of Type FAA-1250 condenser-discharge lights failed to minimize glare to an acceptable level.

3. The less expensive FAA-1250 strobes were adequate for displacement and initial identification during day and night IFR/VFR operations and could be used as a replacement for the Type FT-34/HP and the Type CD-2 condenser-discharge strobes.

Flight Test Results

1. RAIL provided earlier identification and displacement information in all weather conditions except VFR night operations.

2. RAIL was very distracting and considered unacceptable during VFR night operations.

3. RAIL was rated the better approach aid for VFR/IFR day operations.

4. RAIL provided adequate approach guidance for IFR night operations.

5. MALS provided adequate approach guidance for VFR/IFR day operations.

6. MALS was rated the better approach aid for VFR/IFR night operations.

7. MALS provided better height guidance and roll guidance during VFR day and night operations.

CONCLUSIONS

Based on the results of testing and evaluating the RAIL for approach guidance it is concluded that:

1. RAIL in its present configuration and intensity output is very distracting during VFR night operations.

2. Glare reduction experiments with intensity control reduces RAIL intensities but failed to minimize glare to an acceptable level for VFR night operations.

3. MALS provides adequate day guidance, is preferred for VFR night operations, and is considered the better aid.

RECOMMENDATIONS

It is recommended that, in view of the very distracting characteristics of the RAIL during VFR night operations, it not be approved for operational use.

ACKNOWLEDGMENTS

The author acknowledges the contributions made to the project by NAFEC personnel in the Flight Operations Branch, the Photographic Section, the Engineering Support Section, the Standards and Calibration Laboratory, the Electric Shop, and his associates in the Airport Section. To project pilot, William Tranter, Jr., appreciation is particularly expressed for his assistance in the flight test program.