3046

NATIONAL BUREAU OF STANDARDS REPORT

NBS PROJECT **NBS REPORT**

0201-20-2327 3046

January 19, 1954

Visual Landing Aids
Field Service Operation

Progress Report
For the Period
December 1, 1952 to November 30, 1953

Prepared By
C. A. Douglas
J. W. Simeroth
J. E. Davis
Photometry and Colorimetry Section
Optics and Metrology Division

To
Airborne Equipment Division
Bureau of Aeronautics
Department of the Navy
Washington 25, D. C.

NAer Order No. 01400
Project No. TED NBS AE-10011

NBS

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

TABLE OF CONTENTS

TABLE OF CONTENTS (cont.)

Visual Landing Aids
Field Service Operation

Progress Report
December 1, 1952 to November 30, 1953

ABSTRACT

This report reviews the progress in the establishment of the Visual Landing Aids Field Operation and in the testing program conducted by that Operation during the period December 1, 1952 to November 30, 1953.

1. INTRODUCTION AND CHRONOLOGICAL BACKGROUND

In the development and testing of visual landing aids and in the study of the effects of restrictions to visibility upon the performance of visual landing aids, there has been a recurring need for field facilities at which tests and experiments can be conducted under all visibility conditions. Accordingly, the Airborne Equipment Division, Bureau of Aeronautics, in their letter of 20 May 1952, Serial No. 71105, requested the National Bureau of Standards to study the feasibility of conducting such an operation. Following several conferences with members of the Visual Landing Aids Section, the National Bureau of Standards in their letter of June 6, 1952 submitted an estimated cost and personnel breakdown of the contemplated Field Service Operation. The establishment of the Field Service Operation was authorized by Bureau of Aeronautics Order NAer 01400 dated September 30, 1952. The project was approved by the National Bureau of Standards Program Review Board on November 26, 1952.

Immediately after the project was approved, attention was given to obtaining space and personnel for the Operation. After a study of possible locations, Arcata, California, was selected as the site for the Operation. On February 2, 1953 a lease with the Department of Airports, Humboldt County, California, for space at Arcata Airport was approved. Personnel actions were started as soon as the location of the Operation was reasonably firm and were completed in March 1953. The new personnel reported for duty in late March and early April 1953. The month of April was devoted to indoctrination and training of the personnel and to supplying and equipping the field laboratory. On May 2 all personnel except Mr. Davis left Washington for Arcata. During the latter part of April and early May, Mr. Davis made a survey of airfield lighting facilities at eleven Naval and Marine Air Stations.

On May 20 a truck load of instruments, equipment and supplies from the National Bureau of Standards and the Naval Air Test Center was shipped to Arcata.

On May 25 the Field Operation was activated.

2. FACTORS AFFECTING THE CHOICE OF LOCATION

The following conditions and facilities at the site of the Field Operation were considered essential.

2.1 Facilities Needed for Flight Testing

Although an extensive flight test program is not planned, the following features were considered essential in order that the necessary flight testing could be accomplished.

a. A small airport where traffic conditions into and over the field are sufficiently light to permit ready installation of test equipment on the field and to allow flight testing without undue delays or restrictions because of traffic.

b. Periods where the probability of low visibility is sufficiently great to warrant the assembly of test crews.

c. A radio range station.

d. An instrument runway at least 5000 feet long and 150 feet wide.

e. High intensity approach- and runway-lighting systems.

f. A system of electronic landing aids, preferably both ILS and GCA.

g. Refueling and minor repair facilities and hangar space.

2.2 Facilities Needed for Tests From the Ground

a. A location with a high frequency of fogs and restricted visibility.

b. A level visibility range from which lights and marks can be viewed, at least 5000 feet in length and preferably much longer. The range should not deviate from a plane surface by more than three or four feet. For distances less than 5000 feet, the observation distance should be continuously variable. For distances greater than this, continuously variable observation distances are not as necessary and a number of discrete observation stations may be used.

2.3 General Requirements

a. A location with living quarters for the personnel of the group sufficiently near the test site so that weather conditions at the site may be readily observed and so that tests may be called at any time of the day or night with a minimum of time spent in travel.

b. Equipment and personnel available to do by contract the installation and construction work which cannot be readily done by personnel of the group.

c. Ready access to the location by commercial transportation.

3. FACILITIES AVAILABLE AT ARCATA AIRPORT

3.1 General

Arcata Airport is located approximately 7 miles north of Arcata and 14 miles north of Eureka, California, between U. S. Highway 101 and the Pacific Ocean. It was the site of the former Landing Aids Experiment Station. It is now being operated as a commercial airport by the Department of Airports, County of Humboldt, under Revocable Permit NOy(R)-45432. Figure 1 is an aerial view of the airport. This airport was selected as the location of the Field Service Operation because of the unique combination of available facilities and weather conditions.

3.2 Laboratory and Shop Space
(See figure 2)

The lease with the Department of Airports provides for approximately 1000 square feet of office, laboratory, and shop space;

400 feet of warehouse space; garage space for two trucks; a variable amount of space on the airfield; heat, light, and electric power up to 3000 kilowatt hours per month. The charge for these facilities is $250.00 a month. Since the electric power rates are unusually high in the Arcata area, this charge is approximately equal to the cost of heat, light, and power.

The office and laboratory space consists of four rooms and a closet in the east wing on the first floor of the Operations Building. Sufficient conduit and cable runs are available here to permit ready connection of control lines to instruments and equipment in the field. The warehouse space is in one of the larger buildings, is totally enclosed, and is readily accessible by truck. It has sufficient shelf and bin space for storage of equipment and sufficient floor space so that shop work can be done on equipment too large for the laboratory shop.

3.3 Other Space and Facilities

In addition, the Airport has made available to the Operation photographic darkroom space in the former Administration Building and all unused cable and duct runs, transmissometer stands, distribution transformers and lighting equipment.

3.4 Living Quarters

Living quarters for personnel of the group are available at the Airport Apartments approximately a quarter mile from the office. These quarters are not government furnished but are rented directly from the county by the field personnel.

3.5 INSAC Station

A CAA Interstate Airways Communication Station with personnel on duty 24 hours a day is located in the control tower in the same building as the Bureau offices. The INSAC station makes hourly weather observations. Weather sequence reports and forecasts are received by teletype. The station acts in an advisory capacity in directing traffic on the field.

3.6 Instrument Runway

Runway 31 is used as the instrument runway. This runway is 150 feet wide and 6000 feet long. It was recently marked with a new system of runway markings. These markings are shown in figures 1 and 8.

3.7 Visual Landing Aids

The instrument runway is equipped with a slopeline approach-light system with transverse bars installed and maintained by the Civil Aeronautics Administration. There is a high intensity runway-light system using lights manufactured by the American Gas Accumulator Company to meet CAA Specification L-819, a semiflush runway lighting system, and a taxiway lighting system using the V-type gaseous-tube units developed by the Technical Development and Evaluation Center of the Civil Aeronautics Administration. The runway and taxiway lights are maintained by the Airport. The controls for all the lighting systems are located in the INSAC station and are operated by that station upon request.

3.8 Electronic Aids

3.8.1 ILS System

The airport has an ILS system installed and maintained by the CAA consisting of the following:

Localizer with voice, operating on 109.5 megacycles, located 421 feet beyond the northwest end of runway 31.

Glidepath with 3° slope, operating on 322.6 megacycles, located 380 feet to the right of the centerline of runway 31 and 1180 feet from the runway threshold.

Middle-marker beacon, operating on 75 megacycles, located 3500 feet from the threshold of runway 31.

Outer-marker beacon, operating on 75 megacycles, located 4.67 miles from the threshold of runway 31.

Middle compass-locator, operating on 233.0 kilocycles, located at the middle-marker site.

Outer compass-locator, operating on 257.0 kilocycles, located at the outer-marker site.

3.8.2 Radio Range Stations

There is a type MRL low-frequency range station, call letters ACV, operating at 209.0 kilocycles, located 3.5 miles at 204° true from the threshold of runway 31.

A VOR range, call letters FOT, operating at 114.1 megacycles, is located at Table Bluff, 22.0 miles from the airport at 201° true from the threshold of runway 31.

Both range stations have voice communication through the INSAC station.

3.8.4 Maintenance of Electronic Aids

The CAA has a maintenance group of three technicians based at the Airport who are responsible for the maintenance of these electronic aids.

3.9 Construction and Service Facilities Offered by Arcata Airport

In performing the tests and development work falling within the scope of the Field Service Operation, there are occasional construction and installation jobs requiring construction and other heavy equipment and the services of tradesmen. Because of the infrequent occurrence of this type of work, it is neither practical nor economical to equip and staff the Field Operation so that the work can be performed directly. Arrangements have been made to have work of this type requiring the use of skilled tradesmen and special equipment performed by the Humboldt County Department of Aviation at the rates listed in table 1. Charges are made to the nearest one-half hour. Since the personnel and the equipment are based at the Arcata Airport, the charges for moving to the location of the work are minimized.

3.10 Weather Conditions

The Arcata Airport is one of the foggiest airports in the continental United States. Data from the Landing Aids Experiment Station(1) show the following. There are approximately 700 hours a year during which the visibility is below 1 mile and 1400 hours a year during which the visibility is between 1 and 3 miles. The fog season extends from June through November with the highest incidence during the months of September and October. The periods of fog by day and by night are approximately equal. Most of the daylight fogs occur in the early morning or the late evening.

4. INSTRUMENTATION

4.1 Transmissometers

Transmissometers in the approach zone and touchdown zone had been installed for operational use under the jurisdiction of the Civil Aeronautics Administration. Arrangements were made to transfer jurisdiction of these instruments to the Field Operation. In addition, one transmissometer from the Naval Air Test Center and one transmissometer and a number of spare components from the NBS laboratory in Washington were shipped to the field location. These instruments are now installed, as indicated on figure 2. These instruments provide adquate measurements of atmospheric transmission throughout the area in which visibility observations are made. Use was made of permanent and portable transmissometer stands already at the airport in making these installations. Details of some of these installations are shown in figure 3. The indicators were installed in the laboratory space in the Operations Building. Two additional automatic sensitivity controls were constructed so that the sensitivity range of all indicators can be controlled automatically. Signal lines between the field units were obtained by using existing cable runs where possible and installing lines where necessary.

4.2 Visibility Test Site

A visibility test site was established approximately 500 feet from the northern end of the north-south taxiway (figure 4). A 2400-volt feeder and a 5-kva distribution transformer were installed to supply power to the site. An eight-foot-square visibility target and two 25-candle threshold lamps for use as test controls were mounted at a height sufficient for observing over the length of the taxiway (figure 5). Calibrated comparison lamps were installed for use in determining the apparent intensities of flashing sources and for other intensity matches. Platforms were added to the stand to facilitate the installation of test equipment. An instrument shelter was installed at the base of the stand to house the control equipment.

4.3 Miscellaneous Instrumentation

4.3.1 Brightness Meters

Three portable visual brightness meters, a Macbeth, a Luckiesh-Taylor, and an SEI, are used for photometric brightness measurements in the runway and approach areas. Existing towers in the approach zone are used to bring the observer up to runway level.

4.3.2 Weather Instruments

The Field Operation has no weather instruments assigned to it. Routine observations are made by the INSAC station and extra copies of these observations are prepared for the Field Operation. Installation of recording anemometers, wind direction indicators, and thermometers at the visibility test site and at other locations along the visibility range is desirable but has not yet been accomplished.

4.3.3 Communication Equipment

Two-way radio communication is provided between the visibility test site, the laboratory, and the two vehicles assigned to the group on an assigned frequency of 164.025 megacycles. A microphone and speaker from the laboratory station are installed in the INSAC station so that direct communication may be obtained with that office.

A tape recorder was obtained on loan from the Airport. It is used to monitor the radio and other communication facilities during tests.

5. WORK IN PROGRESS

5.1 Introduction

Because of the uncertainties in the funding and of the duration of this project which existed during the first part of fiscal 1954, the test program has been modified from that originally planned. The following program was chosen as best adapted to the circumstances.

The results given below are preliminary results only. Final results cannot be given until after tests have been made under a wide range of conditions.

5.2 Field Survey of Visual Landing Aids Systems

In response to the request of the Bureau of Aeronautics, a survey of the visual landing aids systems of eleven Naval and Marine Corps Air Stations on the East Coast was made to obtain detailed data on systems as outlined in Bureau of Aeronautics letter Aer-AE-101, #47164, dated 7 April 1953.. Preparation of a detailed report has been delayed because of the work load at Arcata during the fog season. However, oral reports of the results of the survey were made to personnel of the Visual Landing Aids Section immediately after completion of the survey.

The findings are summarized as follows:

a. Installation and performance of earth-burial cables, cable connectors and splices.

Most stations visited were either in the process of installing new cables and runway and taxi lighting systems or had just completed the installation of new systems. Therefore, it was not possible to determine trends or common faults in the new type 5000-volt direct-burial cables. No cases of connector failures directly attributable to the connectors were encountered. In isolated cases there has been trouble with conventional splices. Most failures in the 5000-volt cable were attributed to lightning or to faulty installation. M.A.C.S. Cherry Point reported several cases where the lead sheath of the old runway system had been attacked by chemical action of the soil.

b. Methods of locating or repairing faults in cables.

The most common method of locating faults was by isolation. This method is satisfactory between lights along runways and taxiways but is difficult and expensive in long feeder lines. Two stations, NAS Patuxent River and NAS Oceana, used the Model OBB Cable Detecting Equipment with good results, reporting that faults were located to within a few inches in cable runs over 5000 feet long. Some experience and training is required before satisfactory use can be made of the equipment. All stations had available, for use by airfield lighting personnel, ohmmeters, ammeters (usually clamp-on type), voltmeters, and "meggers" (500- or 1000-volt).

c. Difficulties encountered in the installation, maintenance, and operation of equipment other than cables.

Reports of installation difficulties were not readily available as most installations are made by outside contractors.

The operating difficulty reported most frequently was the failure of the type M-1 lights under jet or propellor blast. These units are being blown off their mounting clips. In one instance where the cones were bolted to the clips, a cone collapsed under jet blast.

Nearly all Operations Officers reported that on clear, dark nights the type M-1 taxiway lights were too bright.

Frequently difficulty in the obtaining of standard items was reported. Much of this difficulty appears to be in finding the stock numbers for these items. It was apparent that available current information was not reaching the maintenance personnel level. A set of current "standard" drawings was left at each station to help alleviate this difficulty.

Several control tower operators were not satisfied with the control panels now in use. They reported a need for a positive method of indicating when a section of the runway lights was inoperative and for a method of changing the taxiway light pattern without stopping all traffic on the field and then turning off all taxiway lights so that the change in pattern can be made.

One station felt that the new "U"-shaped vault should have an emergency exit in the rear.

Difficulty was reported with 15-kilowatt regulators on new installations when the regulators are operating near full load. The current regulation is affected by presence in the circuit of isolating transformers with open secondaries so that the current increases with the number of open-secondary transformers. The result is that when about 20% of the lamps have burned out, the current at the 100% setting is so great that the remainder of the lamps will burn out.

d. Methods of installing, testing, and maintaining equipment.

Generally there has been no established method for testing and maintaining equipment. Except where one person is assigned the responsibility of maintaining the airfield lighting system, testing and maintenance is generally confined to work after a fault has occurred. At those stations where preventive maintenance checks are made, most potential faults are located before the fault occurs.

At NAS Oceana, ammeters have been installed in the output circuit of each regulator. The current through each circuit is checked daily with the output at the 100% setting. A current above 6.6 amperes in a circuit indicates that some lamps in that circuit have failed and that field checks are necessary.

When the taxiway lighting system has many loops, an open in the circuit of one loop will extinguish all taxiway lights until the open loop has been found by a process of elimination and removed from the circuit. To overcome this difficulty, NAS Quonset Point has connected a "Thyrite" cutout across each loop so that, when the loop opens, the "Thyrite" across the loop completes the circuit.

5.3 Tests of Cable Fault Locating Equipment

As requested by Bureau of Aeronautics letter of 24 March 1953, file reference Aer-AE-101, #40158, a study was made of the feasibility of using the Model OBB Cable Detecting Equipment for locating faults in airfield lighting cables.

As reported in paragraph 5.2, this equipment is now being used with good results at NAS Patuxent River and NAS Oceana. The equipment from NAS Patuxent River was taken to all fields visited during the survey of visual landing aids and demonstrated to the maintenance personnel. All who tried the equipment felt that it would be very useful and not unduly difficult to operate. The equipment was also used extensively with good results at Arcata after the NBS Operation was established to locate and trouble-shoot the existing cable runs on the field. Laboratory tests were made of the sensitivity, frequency response, and noise level of the equipment from NAS Patuxent River. On the basis of the field experience and laboratory tests, modifications to Specification MIL-C-16163 (Ships) covering this equipment were forwarded to the Bureau of Aeronautics in NBS letters of May 13 and July 2, 1953.

5.4 Tests of Approach Beacons

5.4.1 Historical Background

It has been shown that under low sun or twilight conditions the distance at which a runway can be seen may be much less than the reported visibility.(2) At the same time the brightness of the background is so high that the runway or approach lights cannot be seen unless the pilot is within the main beam of these lights. In addition, during periods of darkness when there are moderate restrictions to visibility, the intensity settings of the approach- and runway-light systems must be low so that the main beams of the lights will not be glaring. This reduction in the intensity setting of the system will reduce the light outside the main beam to an intensity too low to be useful in circling or off-axis approaches. Thus, although the visibility is above the minimum at which circling approaches are permitted, the pilot may not find the runway or the lighting system in time to make the correction required and will miss the approach. These considerations indicated a need for marking the axis of the runway in such a way that it can be located and identified from distances at least as great as the reported visibility from the time a pilot comes abreast of the system on the downwind leg of the approach until he lines up with the runway. To accomplish this we proposed in 1947 the installation of two or three approach beacons along the extended centerline of the runway at distances of 1000 to 5000 feet from the threshold. The beacons were to have a horizontal coverage of at least 180° and a flash repetition rate sufficiently rapid to provide adequate guidance. Following this, using design data supplied by the National Bureau of Standards, the Naval Air Test Center constructed and flight tested experimental approach beacons. Their tests indicated that the concept was a useful one.(3) The approach beacons were then sent to the Landing Aids Experiment Station for further development. However, the station was closed before this work was completed.

5.4.2 Field Tests

The following are now being investigated:

a. Optimum Flash Duration and Frequency.

It has been shown that the maximum visual range of a light of constant flux is obtained when the beam spread of the light in the plane of rotation is a minimum.(4) On the other hand, under these conditions the flash duration is generally so short in comparison to the interval between flashes that the guidance furnished by the beacon is decreased. The problem then is to determine the best compromise between flash duration, flash frequency, apparent intensity, and power consumption. A secondary problem is the determination of the number of approach beacons and the distances from the runway threshold that they should be located to provide adequate guidance and freedom from glare.

b. Effects of Glare.

The distance at which the approach beacon becomes glaring is a function of the vertical angle at which the unit is viewed, the visibility, and the sky brightness. Knowledge of the minimum distance at which the light can be viewed without undue glare is required for determining the minimum distance from the runway threshold at which a unit may be installed, and in determining whether intensity control is required.

c. Comparative Visual Range.

The visual range of the approach beacon compared with that of black objects and 25-candle threshold lamps, and with comparison lamps of known intensity, is required in order to determine the effectiveness of the beacon.

5.4.3 Field Installation

A test approach beacon was constructed by using the base of a beacon and installing on it a turntable with provision for 12 lamps (figure 6). Lamp holders were obtained for fixtures of the multi-row system which had been left at Arcata when the Landing Aids Experiment Station was closed. These holders provide a means of adjusting the elevation of the lamps. Power is fed to the turntable through the slip rings of the beacon base at 120 volts and reduced to the voltage of the lamps being used by the transformers mounted on the turntable. A continuously variable autotransformer in the input to the beacon is used to control the voltage. A system of relays mounted on the turntable provides for rapid selection of 1, 2, 3, 4, 6, or 12 operating lamps, thus providing flash frequencies of 12, 24, 36, 48, 72, and 144 flashes per minute. The duration and peak intensity of the flashes is changed by changing the types of lamps used or their orientation in the lamp holders.

The beacon was mounted on the tower at the visibility test site (figures 4 and 5) and viewed from the taxiway. The visual range of the beacon, the intensity of a fixed light necessary to match the apparent intensity of the beacon, the visibility (the visual range of the 6-foot target by day or of a 25-candle lamp by night), the transmissometer readings, the amount of glare, and the quality of guidance were observed.

5.4.4 Results

Results to date indicate that a flash duration of approximately 0.5 second and a flash frequency of approximately 72 per minute provide the optimum balance between guidance and visual range. These conditions may be obtained by using six 400-watt, 115-volt, PAR-56 approach-light lamps on a 12-rpm beacon base. Under these conditions, the visual range of the approach beacon by day is approximately 1.3 times the visual range of a black object against the sky. Since the visibility of even a well-marked runway is at best only about half the reported visibility,[(2)] the use of the approach beacons will produce an appreciable increase in the visual guidance given the pilots. At night the visibility of the beacon is 2 to 3 times the reported visibility (visual range of a 25-candle light). The minimum distance from the runway threshold at which a unit can be located without undue glare is about 1000 feet.

5.4.5 Future Work

Plans are now being made for the installation of approach beacons on the extended centerline of the runway at distances of 1000 and 2000 feet from the threshold so that their performance under service conditions can be evaluated. The frequency of weather conditions suitable for these tests is high during the winter season at Arcata.

5.5 Measurements of Photometric Brightness and Illumination

5.5.1 Night Brightnesses in the Approach and Runway Areas

In computations involving the visual range of runway and approach lights at night the effect of these lights upon the brightness of their background is generally ignored. As the number of lights in the systems and the power of the units has increased, the effect of the systems on their background has increased. Surprisingly, there are no data available relating the background brightness to the fog density and the other parameters affecting it. Measurements of the sky and runway (or ground) brightnesses are being made in a wide range of visibility conditions. The points from which these measurements are being made are shown on figure 2. The results to date indicate that the background brightness of the runway area ranges from 0.1 foot-lambert in clear weather to 0.25 foot-lamberts when the visibility is below one-eighth mile and the brightness setting is step 4. The corresponding brightnesses of the approach area are 1.0 and 5.0 foot-lamberts, respectively, when the system is operating on the 100% setting.

5.5.2 Sky and Object Brightness Under Natural Conditions

It has been shown that the ratio of ground to sky brightness has an important effect on the visibility of the runway markings or of the runway.[2] Measurements of this ratio are being made in a wide range of visibility conditions to determine the magnitude of this effect. It is hoped that these measurements can be used to prepare a table of factors applicable to various types of weather. Then, by applying these measurements to routine visibility observations, a more accurate measure of the visual guidance or contact height may be obtained. Measurements to date indicate that even in dense fogs the zenith sky brightness is two to three times the horizon-sky brightness. The result of this is that horizontal surfaces are seen somewhat farther than they would be if the sky brightness were uniform.

5.6 Comparative Visual Ranges

5.6.1 Visual Range of Flashing Lights

The use of gaseous discharge lights with flash durations in the milli- or micro-second range has been proposed frequently. At times an exaggerated measure of their effectiveness is obtained by using the maximum instantaneous intensity of the light in computations instead of the apparent intensity computed according to Blondel and Rey's law.(4) In order to eliminate any uncertainties regarding the effect of field conditions, the visual range of a "Strobeacon" flash-tube light assembly manufactured by Sylvania Electric Products, Inc. is being compared directly with the visual range of a black object by day and a 25-candle lamp by night and with the approach beacon described in paragraph 5.4. The intensity of a fixed light which will give a visual range equal to that of the flashing light is being determined. Tests are being conducted in a wide range of visibilities.

Results to date indicate that the flashing light has a visual range approximately equal to that of a fixed light with an intensity of about 30,000 candles. The visual range of the "Strobeacon" is approximately equal to that of the approach beacon described in section 5.4, but because of the short duration of the flashes, it supplies less guidance.

Similar tests will be made with a Westinghouse flashing approach-light unit when one is obtained.

5.6.2 Visual Range of Slopeline Fixture

The visual range of a unit consisting of a number of closely spaced lights such as a slopeline fixture is generally greater than the visual range of a single lamp of the type used in the unit but is not as great as a light having an intensity equal to the sum of the intensities of the lamps in the unit. The cumulative effect will vary with the angular separation of the individual lights, and hence with the number of lamps in the unit and the distance the unit can be seen; with the background brightness; and possibly with the scattering coefficient of the fog. These effects are being investigated under field conditions by finding the intensity of a single light which will give the same visual range as the slopeline unit. The slopeline unit and the comparison light are mounted on the stand at the visibility site (figure 5). These lights are observed from the taxiway at distances up to the visual range of the slopeline unit. At each observation station the intensity of the comparison light is adjusted to match the slopeline unit. Observations have been made to date in visibilities ranging from 400 to 6200 feet.

5.6.3 Comparative Visual Ranges of Objects and Lights

In the design of systems of visual guidance for use during hours of daylight, a knowledge of the comparative visual ranges of objects and lights is necessary. The use of arbitrary values of threshold constants is not satisfactory in computing the effectiveness of lights as compared to objects because of the large effect of these values on the intensities determined by computation. The problem is therefore being studied under field conditions by observing the visual range of the visibility mark and of lights of known intensity located at the visibility test site.

5.6.4 Visual Ranges Obtained Using Recognition and Detection Thresholds

A study is being made of the comparative visual ranges of objects or lights when recognition and detection are used as the criteria for seeing. This data will be used in the preparation of transmissometer calibration curves and in the study of the relation between laboratory values of threshold and those obtained under service conditions.

5.7 Atmospheric Transmissometry

5.7.1 Influence of Field of View of Transmissometer Receiver Upon Errors in Transmission Measurements

In all measurements of atmospheric transmission made with a telephotometer such as the transmissometer, there are errors introduced because the transmitted light includes some scattered light which, though radiated by the source, would not reach the receiver in clear weather.(5) To reduce these errors the field of view of the transmissometer is kept as small as practicable. In the early transmissometer installations, baffles were placed between the projector and receiver to reduce this effect. Later the use of baffles was discontinued because of the inconvenience and expense involved in their installation and because no significant differences in indicated visibility were observed. A study of the problem by Middleton(6) indicates that the problem should have more consideration. Since any errors will be a function of the particle size distribution of the fog, a series of measurements in fogs of many types is required. From these measurements it will be possible to determine whether the cost of installing baffles is warranted.

Two transmissometers are installed on parallel 500-foot baselines 20 feet apart. One transmissometer is installed in the usual manner (without baffles). The other instrument is provided with five baffles (figure 7) so spaced that the beam from the projector and the field of the receiver are restricted to a cylinder 10 inches in diameter. The chart drives of the recorders of the two indicators are coupled together mechanically so that simultaneous measurements of transmission can be obtained from the two instruments. The effects of random variations of transmission with time and location are made insignificant by making a continuous record of the transmission readings of the two instruments and computing the average of the ratios of these measurements over periods of time during which the transmission does not vary significantly.

5.7.2 Selective Transmission of Fogs

The present transmissometers use photoelectric cells which are not spectrally corrected. This is done for a number of reasons and is justified when the spectral transmission of the fog is essentially uniform. The rapid variations of the transmission of fogs with time make a study of their spectral transmission difficult. The significance of the effects of selective transmission on indicated visibility will be studied with the two parallel transmissometers after completion of the tests of the effects of scattered light. The two receivers will have photoelectric cells with different spectral responses and the measurements obtained will be compared.

5.7.3 100%-Setting Calibrator

An experimental calibrator for determining the 100% setting of the transmissometer was constructed at the Bureau and sent to Arcata for field tests. These tests indicated that some minor revisions in design were needed to increase the range of adjustments and improve the stability of the system. A prototype unit in which these modifications have been included has been constructed and is ready for service testing.

5.8 Study of Factors Affecting the Determination of Visual Guidance

Data correlating atmospheric transmittance, sky brightness, etc. with the visual guidance obtained by the pilot of an aircraft landing under low visibility conditions, are needed. To obtain data of this type, arrangements were made for the pilots of Southwest Airways to report the guidance received on ILS approaches. The forms used and the instructions for using them are included in Appendix 1. The data received will be correlated with the readings of the transmissometers in the approach and touchdown areas, measurements of brightness, approach- and runway-light intensity, etc.

5.9 Runway Markings

The instrument runway of Arcata Airport has been marked recently with a system of runway markings designed by Mr. W. H. Levings, the Airport Manager. Figure 8 is a photograph of the runway marked with this system. Pilot opinions regarding this system and the effectiveness of runway markings in general are being obtained, using the questionnaire given in Appendix 2.

This questionnaire is based upon a questionnaire suggested by Mr. Levings and has been modified to obtain basic design information as well as pilot opinion regarding this particular system.

6. SUMMARY

This report has described the facilities of the Field Service Operation at Arcata Airport and has discussed the tests in progress and the background of these tests. Since no two fogs are alike, observation or measurements must be made in a number of fogs covering a wide range of fog densities in order to obtain meaningful results. These measurements are now being made. When sufficient data are obtained on a particular test, a report covering that phase of the work will be issued.

References

1. Annual Reports of the Meteorology Department of the Landing Aids Experiment Station for 1947, 1948, and 1949.

2. C. A. Douglas, "Factors Affecting the Relation Between Reported Visibility and Visibility From Aircraft," NBS Report #2715, August 12, 1953.

3. Naval Air Test Center Interim Report A1-1/SE203,ET333-1089, 14 November 1950.

4. I. Langmuir and W. F. Westendorp, "A Study of Light Signals in Aviation and Navigation," Physics 1, 273-317 (1931).

5. C. A. Douglas and L. L. Young, "Development of a Transmissometer for Determining Visual Range," CAA Technical Development Report #47, February 1945.

6. W. E. K. Middleton, "The Effect of the Angular Aperture of a Telephotometer on the Telephotometry of Collimated and Noncollimated Beams," Journal of the Optical Society of America, 39, 576-581 (1949).

Table 1

Hourly Rates for Services Performed by
Humboldt County Department of Aviation

Classification	Hourly Rate
Carpenter	$ 2.25
Plumber	2.25
Electrician	2.25
Welder	2.25
Mechanic	2.25
Equipment Operator	2.50
Driver	2.00
Painter	2.25
Pick-up Truck	3.50
Flat Bed Truck	4.00
Heavy Cargo Truck (w/Hydraulic Hoist)	6.00
Winch Truck	4.00
Welding Machine	3.75
Grader	8.00
Road Roller	12.00
Ditch Machine	12.00
Crawler Crane	12.00
Bulldozer	7.50
Shovel-Overhead Tractor	7.50
Fork Lift	5.00
Cargo Trailer	4.00

Note: All of the above rates include necessary operator and/or driver.

Table 2

Tests in Fog
(Visibility Below Two Miles)

Test Period		Type of Test*						
Date 1953	Time	A**	B	C	D	E	F	G
7-3	0430-0615	x						
13	2015-2200	x						
14	0440-0545	x						
22	0450-0630	x						
8-6	1615-1715	x						
9	0845-1030	x						
10	2200-2315	x						
11	0845-1045	x						
12	0930-1050	x						
17	1915-2100	x						
18	1515-1710	x						
23	1030-1145	x						
24	1020-1215	x						
27	0845-1015	x						
9-1	0830-1000	x	x	x				
2	0745-1145	x	x	x				
3	0445-0545	x						
	0830-0915	x						
	2000-2345	x	x	x				
-4	0000-0100		x					
	0800-0850	x						
-8	1600-1645	x						
-9	0500-0730	x	x	x				
	0830-1245	x	x	x				
-11	2315-0145		x					
-15	0530-0730		x					
	0800-1130	x		x				
-18	0500-0700		x	x				
	0800-0945	x	x	x				
-23	1430-1515	x						
	2330-0045		x					

* See end of Table for explanation of symbols.
** Additional brightness measurements were made in fog in connection with the other tests. Brightness measurements in visibilities exceeding two miles have been made on a more extensive schedule than indicated above.

Table 2 (cont.)

Tests in Fog
(Visibility Below Two Miles)

Test Period		Type of Test*						
Date 1953	Time	A**	B	C	D	E	F	G
9-24	1915-2030	x						
27	1340-1415	x						
28	0815-0845	x						
10-5	1700-1830		x	x	x			
	1945-2245		x	x				
6	0830-1000		x	x	x			
	1700-1730	x						
	1945-2230	x	x	x				
7	0645-0945	x	x		x			
8	1015-1945			x		x		
27	0715-0930		x	x		x		
	1600-1645	x						
	1900-2130		x	x		x		
28	0800-0930	x			x			
31	0700-0930		x	x	x	x		
11-2	0615-0945		x	x		x	x	
3	0730-1015		x	x	x	x		
	1500-1730			x	x	x	x	
	2330-0245		x	x		x		x
4	0830-0915					x		
6	0815-0830	x						
23	0830-1200		x		x	x		
	1530-1630				x			
24	0815-1145	x	x		x	x	x	
	1300-1330	x						
	1915-2315		x			x		
27	0810-0830	x						

Explanation of Symbols

A. Measurements of ground and sky brightnesses in the runway and approach areas.

B. Determination of the optimum flash duration and frequency and the optimum location of approach beacons.

Explanation of Symbols (cont.)

C. Determination of the effective intensity of Strobeacons.

D. Determination of the intensity required to produce a visual range equal to object visibility.

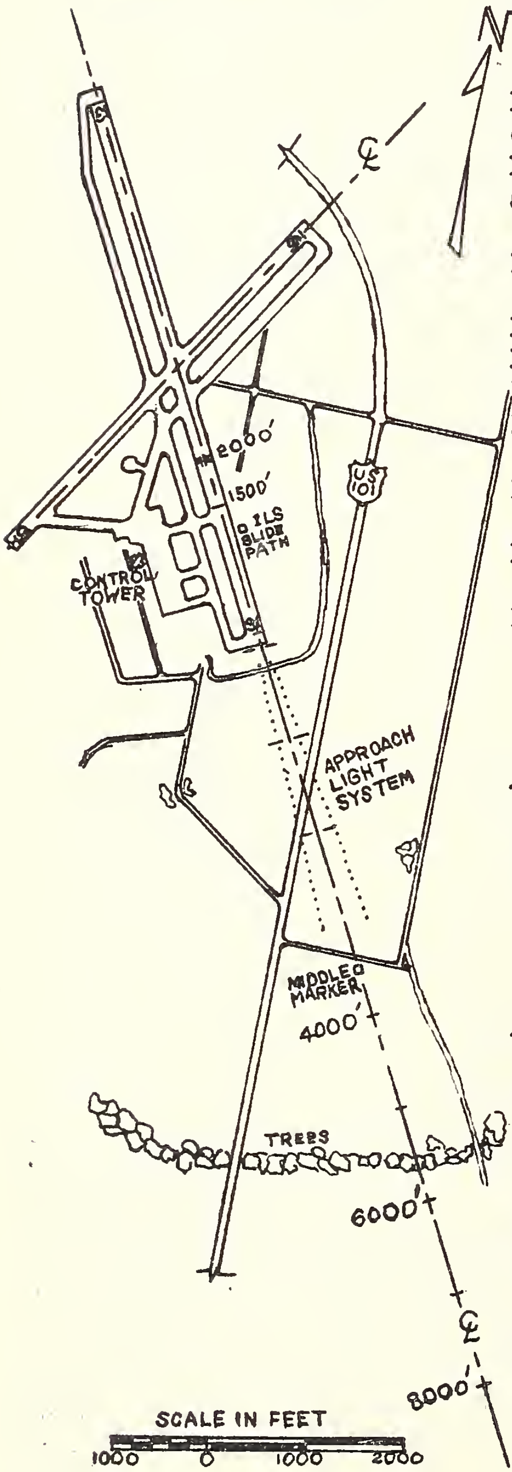
E. Determination of the apparent intensity of six- and ten-light slopeline lighting units.

F. Comparison of the visual ranges obtained when detection and recognition are used as criteria.

G. Study of the errors introduced in transmission measurements by scattered light.

REPORT OF ILS APPROACH

Arcata, California



Date______ Time_____ Flt.______
Pilot__________ Copilot_________

	Pilot	Copilot
Handled controls on instruments	☐	☐
Handled controls after contact	☐	☐

Indicate on chart by proper symbol:
Pilot ① Copilot ◇1

Point approach lights sighted	①	◇1
Point contact flight started	②	◇2
Point runway lights sighted	③	◇3
Point of touchdown	④	◇4

Number approach lights first sighted
Pilot_______ Copilot_______

Number approach lights carried
Pilot_______ Copilot_______

Number runway lights carried
Pilot_______ Copilot_______

Intensity of lights

	High	OK	Low
Approach Lights	☐	☐	☐
Runway Lights	☐	☐	☐

Guidance

	Adequate	Inadequate
Approach lights	☐	☐
Ground plane	☐	☐
Threshold lights	☐	☐
Runway lights	☐	☐
Runway markings	☐	☐

Remarks:

APPENDIX 1 (cont.)

REPORT OF WEATHER DURING ILS APPROACH

Date __________ Time ___________ Flt. _________ Pilot ________

Ceiling _________________ Top of Fog _____________ feet

Visibility ______________ Weather _____________________

Wind: Direction _________ Speed ________________ m.p.h.

Transmissometer Reading

T-A ________________ Range _______________________

T-D ________________ Range _______________________

Background Brightness

Bright ☐ Average ☐ Dull ☐ Twilight ☐ Night ☐

Approach Light Intensity __________________%

Runway Light Intensity ____________________%

Remarks:

APPENDIX 1 (cont.)
Explanatory Notes
for
"Report of ILS Approach"

This report form is intended to furnish data which will assist the National Bureau of Standards in studies of the effects of atmospheric transmission upon the performance of visual landing aids. A copy of the form should be completed for every ILS approach into Arcata Airport. It may be used for approaches other than ILS when desired. The form should be completed immediately after a landing or as soon thereafter as possible. Completed forms should be sent weekly, or more often if they accumulate rapidly, to National Bureau of Standards, Box 193, Arcata, California, or may be left at the Eureka-Arcata terminal to be picked up there by our personnel.

In order to conserve the reporter's time, the form was designed to provide the minimum of information needed. Any elaboration of this information or of related information by noting comments or observations on the back of the form will be appreciated.

Time: Use the 24-hour clock on Pacific Standard Time.

Chart: The chart on the left of the form is of the approach zone and runway 31 of the Arcata Airport, and is to be used for locating significant points.

Handled Controls: Check the proper blocks to identify the person handling the controls during the first part of the ILS approach and after contact flight is started. This is necessary as there may be differences in the distance at which the lights are seen as a result of the different duties of the two pilots.

Points Indicated on Chart: The position of the plane at significant points should be located on the chart by proper symbol and number. The pilot as designated at the top of the form - not necessarily the person handling the controls - designates his observations by circumscribing the numbers locating the points with a circle ○ . The co-pilot, as listed at the top of the form, designates his points with a diamond Δ. Show the approximate position of the aircraft to the left or right of the center line as well as the distance from the runway threshold. As shown on the form, 1 is the position at which the approach lights were first sighted; 2 is the point contact flight was started; 3 is the point the runway or threshold lights were first sighted; and 4 is the point of touchdown. If either pilot or co-pilot should fail to make an observation or if the position of the aircraft can not be determined approximately, then that observation should be omitted from the chart and an explanation given in the remarks.

APPENDIX 1 (cont.)

Number of Lights: Indicate the approximate numbers of approach lights seen at the time the lights are first sighted, the average number visible during contact flight, and the average number of runway lights visible after the threshold is crossed. If there is a marked difference between the number visible in the left and right rows list the number visible for each row. When most of the system is visible, all, or the fraction of the system, may be indicated rather than the approximate number of lights.

Intensity of Lights: Indicate in the proper box the opinion of the pilot handling the controls during visual flight as to the intensity setting of the approach and of the runway lights with respect to the desired intensity. Do not indicate the actual position setting as this will be obtained from the control tower.

Guidance: Indicate in the proper box the opinion of the pilot handling the controls during visual flight as to the adequacy of the guidance supplied by the lighting systems, by the ground plane, and by the "runway" markings. The ratings given apply to the particular approach and not to the over-all performance of the system. In rating the lighting systems consider the purpose for which they were designed. Since the lighting systems are intended to supply information at distances greater than objects can be seen, they should be considered as supplying inadequate guidance when the ground plane or runway markings supply the information at greater distances. Thus, if the markings on the end of the runway are seen before the threshold lights, the threshold lights should be considered inadequate. Similarly, the runway lights should be considered inadequate when the runway markings are visible from greater distances. A brief note under remarks explaining why a given item is considered inadequate will be helpful.

Remarks: Include in this section any significant information not covered by the form and any explanations required to clarify any of the observations. All missed approaches caused by inadequate visual guidance should be explained in detail.

Appendix 2

Questionnaire on Runway Marking Configuration at Arcata Airport

I. Identification Information.
(Answer only those questions in this section which are necessary to describe your flight and previous experience. The other questions will be completed by airport personnel.)

1. Pilot ________________ Rating ____________________

2. Date _________________ Time ______________________

3. Type of aircraft ____________ Operated by ______________

4. Have you made any previous approaches on this runway marking system?

   Circling _________ Straight in _________ None __________

5. The airports listed below have different types of runway markings. Check those at which you have made approaches or landings.

   _________ Oakland (broken center line)

   _________ La Guardia (CAA Standard M. TSO-N10a)

   _________ Los Angeles (TSO-N10)

   ____

   ____

   ____

II. Appraisal Information.

6. What was seen first: airport buildings _____, runway_____, runway lights_____, centerline ____, threshold markings _____, edge markings _____, distance markings _____.

7. At what distance from the threshold were the runway markings first sighted: _____ mi.: altitude _______ ft.

Appendix 2 (cont.)

8. At what distance from the threshold did the runway marking configurations furnish adequate visual guidance: _____ mi.; altitude _______ ft.

9. Evaluate the information furnished by the configuration by checking the proper boxes.

	Excellent	Adequate	Marginal	Unsatisfactory
System (as a whole)				
Centerline				
Threshold				
Edge Marking				
Distance Marking				

10. Number in order of usefulness on this approach:

_____ center line _____ edge markers

_____ threshold _____ distance markers

11. Number the airports at which you have made landings in the order of personal preference of the runway marking configuration.

_____ Arcata _____ _____________

_____ LaGuardia _____ _____________

_____ Los Angeles _____ _____________

_____ Oakland _____ _____________

12. Number in order of preference for centerline marking.

_____ solid stripe _____ diamonds

_____ broken stripe _____ none

Appendix 2 (cont.)

III. Supplementary Information.

13. Check any of the following comments you consider applicable. Cross out inapplicable words.

Centerline.

_____ Diamonds are clearly defined.
_____ Diamonds become indistinct when aircraft is below glide path.
_____ Length of each diamond should be (increased)(decreased)(unchanged).
_____ Diamonds (are)(are not) a desirable form of centerline marking.
_____ Other (explain).

Threshold Markings.

_____ Threshold markings are satisfactory without change.
_____ Information regarding runway length (is)(is not) desirable in threshold markings.
_____ More space between bars is required.
_____ (Diminish) (Increase) the (length) (width) of the bars.
_____ (Increase) (Decrease) number of bars.
_____ Other (explain).

Edge Markings.

_____ Edge markings are (desirable)(not useful).
_____ The edge markings (do)(do not) supplement the guidance supplied by the center line.
_____ The width of the edge markings should be (increased)(decreased) (unchanged)
_____ A broken line (is)(is not) preferable to a solid line.
_____ Other. (explain).

Distance Markers.

_____ Distance markers (are)(are not) useful.
_____ The shape of the distance markers (is)(is not) readily distinguishable.
_____ The distance markers (give)(do not give) an easily interpreted indication of the distance down the runway.
_____ More distance markers (are)(are not) desirable.
_____ Other. (explain).

14. Remarks:

Appendix 2 (cont.)

IV. Project Information.

15. Is it your personal opinion that this runway marking configuration is of sufficient value to warrant its use at other airports?
Yes _____ No _____

16. If, in your opinion, the entire configuration should not be adopted, what features of this configuration would you like to see included? Diamond center line _____, threshold markings _____, edge markings_____, distance markers _____.

17. Would you prefer to have the same type and size of markings on the three types of runways (all weather, basic instrument, and VFR)?
Yes _____ No _____

If this is not economically feasible, which would you prefer:

_____ Scaling down the size of all the markings.
_____ Eliminating some of the markings. Which? Diamond, center-line, edge markers, threshold markers, distance markers.
_____ Using other, simpler configurations for basic instrument and VFR runways.
_____ Other (explain).

18. In your opinion, should the design of the runway marking configuration consider its utility in VFR as well as IFR conditions?
Yes _____ No _____

19. Remarks:

Approach Weather Information
To Be Completed By Arcata Airport

1. Ceiling _______________ Ft.
2. Visibility: Visual _____ Mi.
TA __________ Mi.
TD __________ Mi.
3. Wind: _______________

4. Fog __________
5. Rain __________
6. Haze __________
7. Snow __________
8. Other __________

9. Brightness Measurement _______ Foot-lamberts

FIG. 1 AERIAL VIEW OF ARCATA AIRPORT


VISIBILITY
TEST SITE

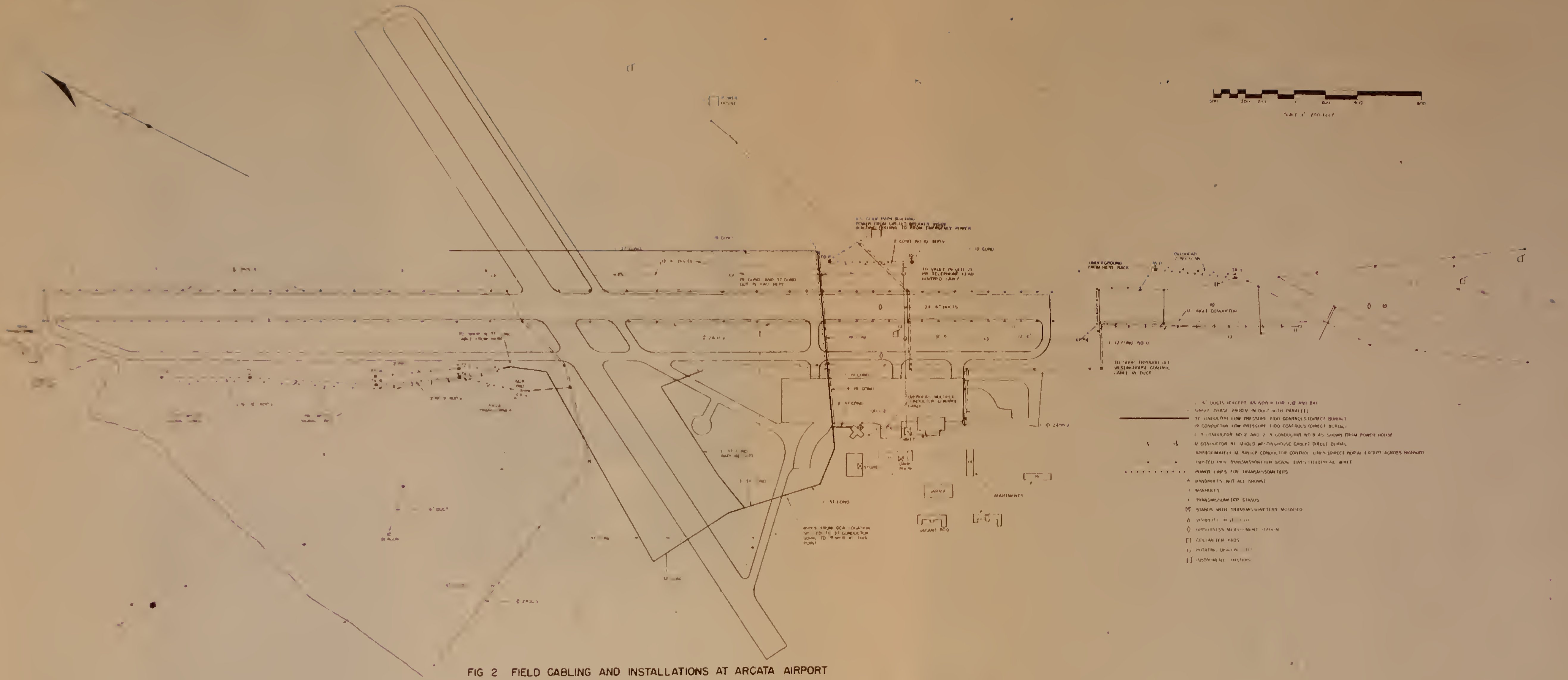
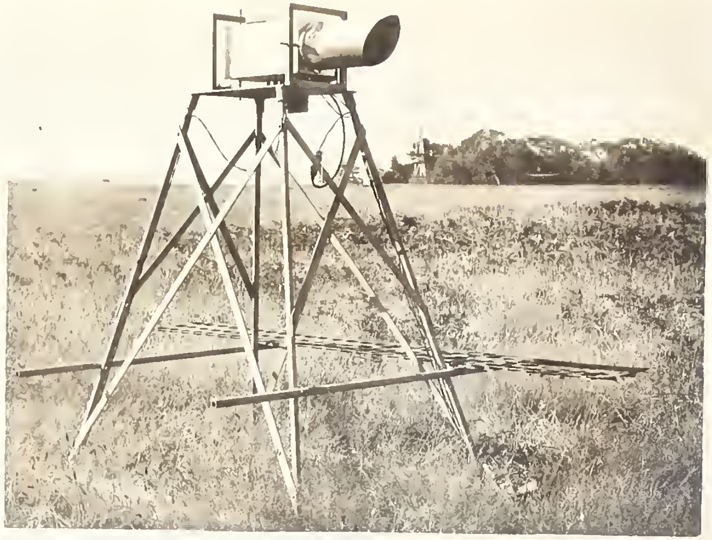


FIG 2 FIELD CABLING AND INSTALLATIONS AT ARCATA AIRPORT


RECEIVER


PROJECTOR

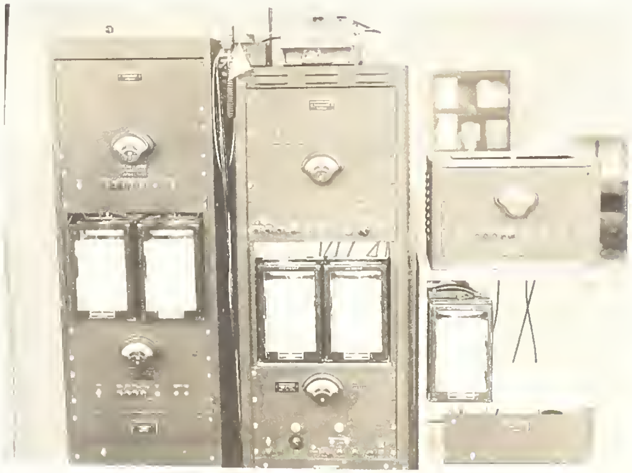

INDICATORS

FIG. 3 EXAMPLES OF TRANSMISSOMETER INSTALLATIONS

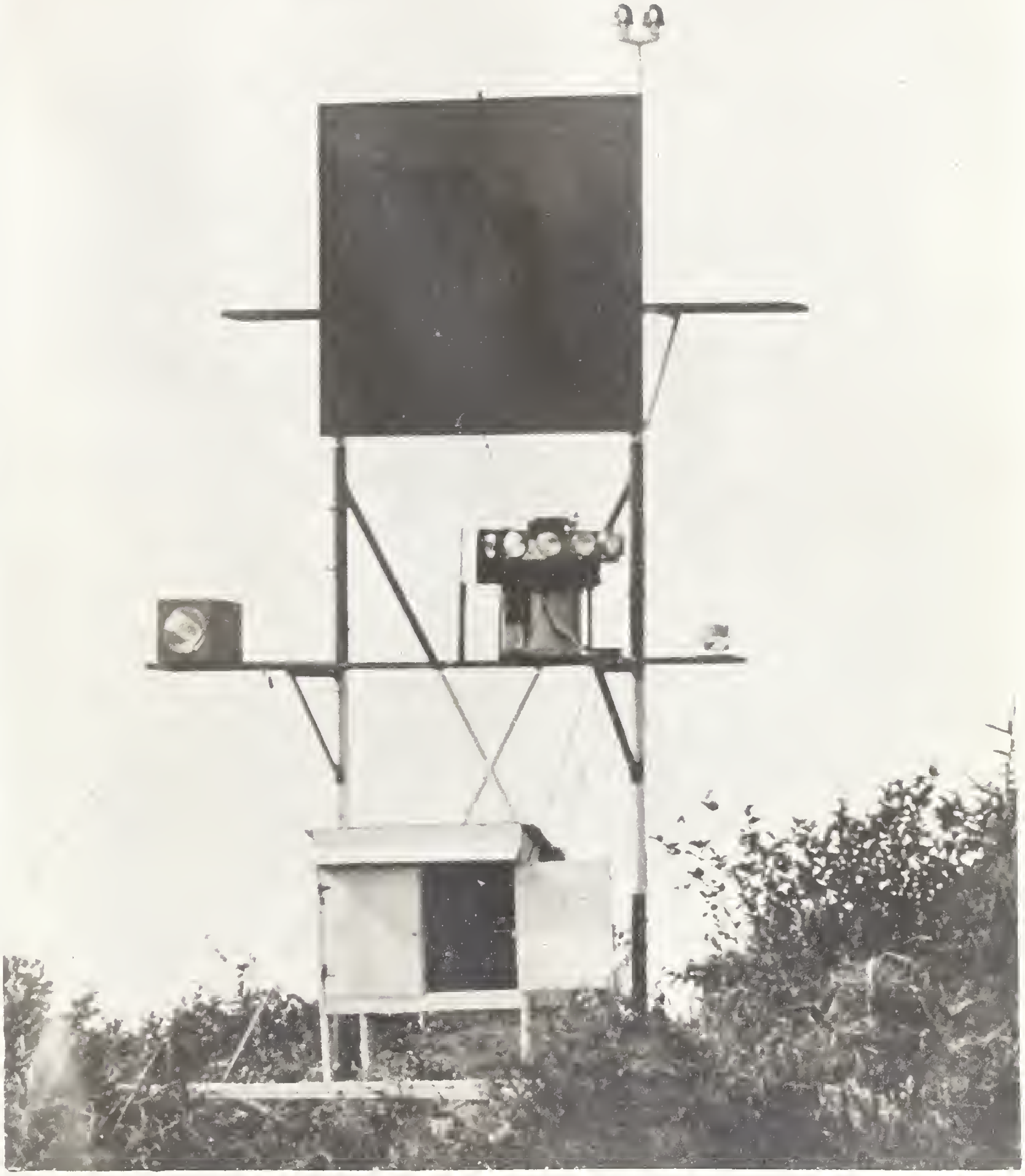


FIG. 4 VISIBILITY TEST SITE

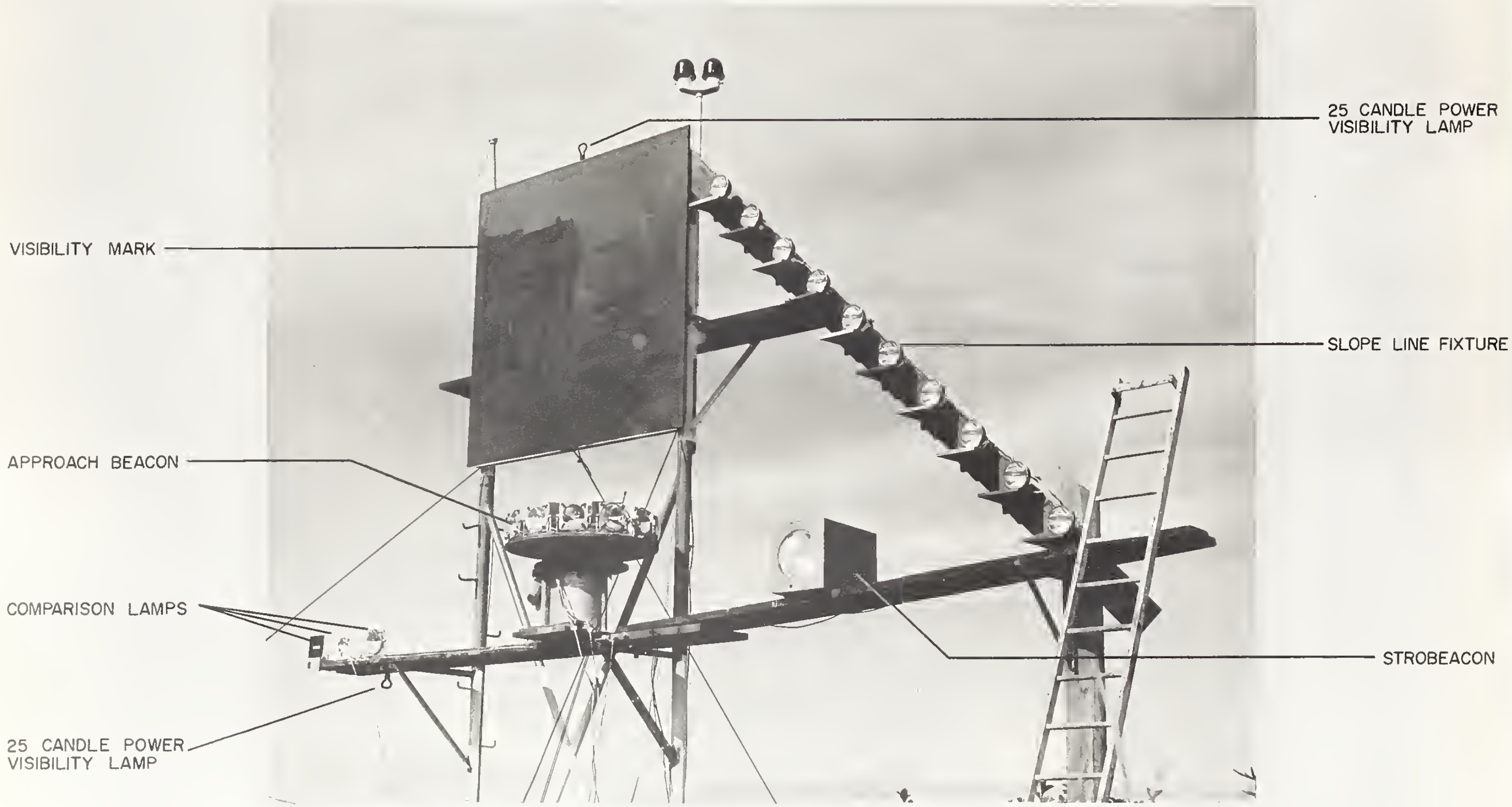


FIG. 5 DETAILS OF VISIBILITY TEST SITE

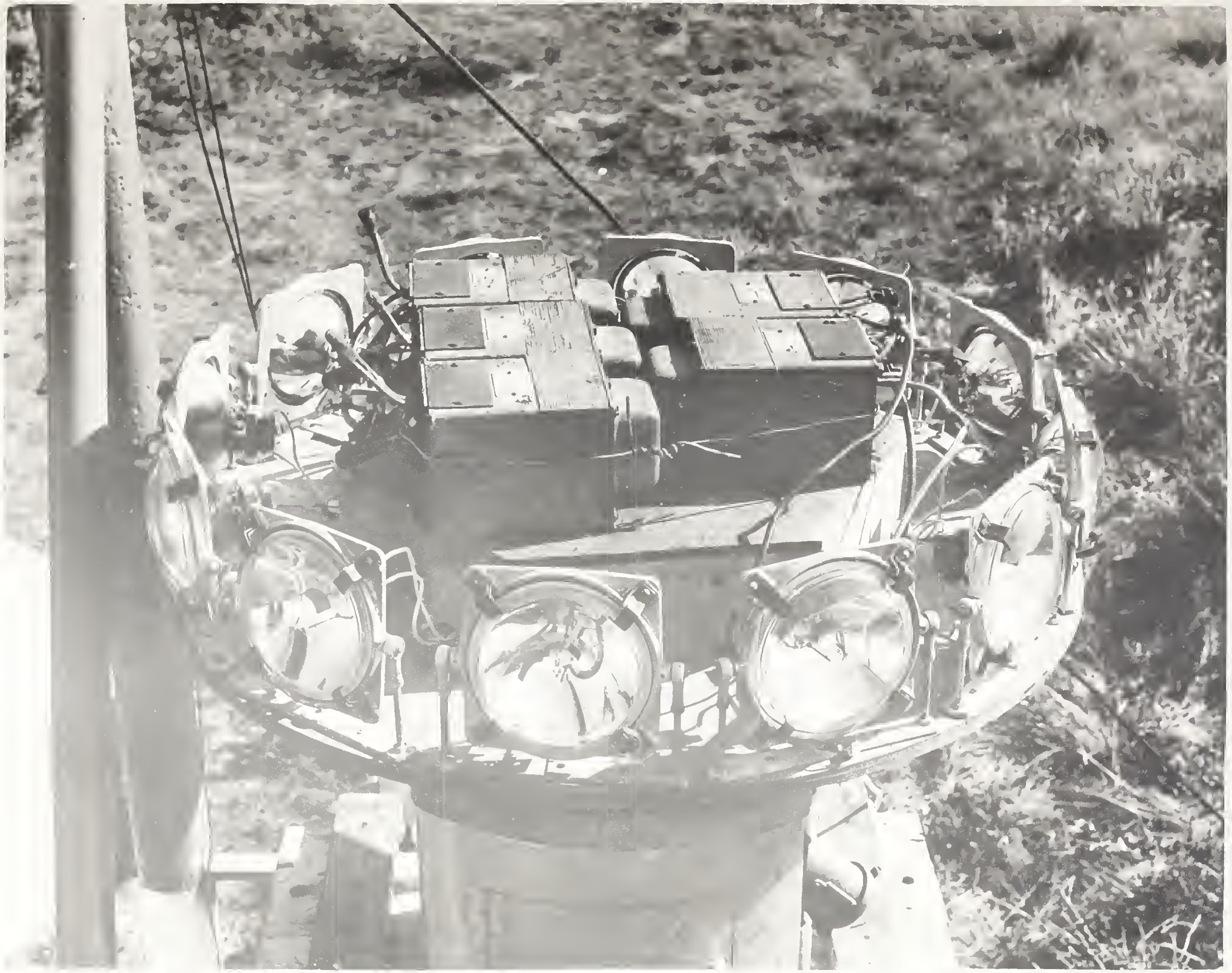


FIG. 6 DETAILS OF EXPERIMENTAL APPROACH BEACON

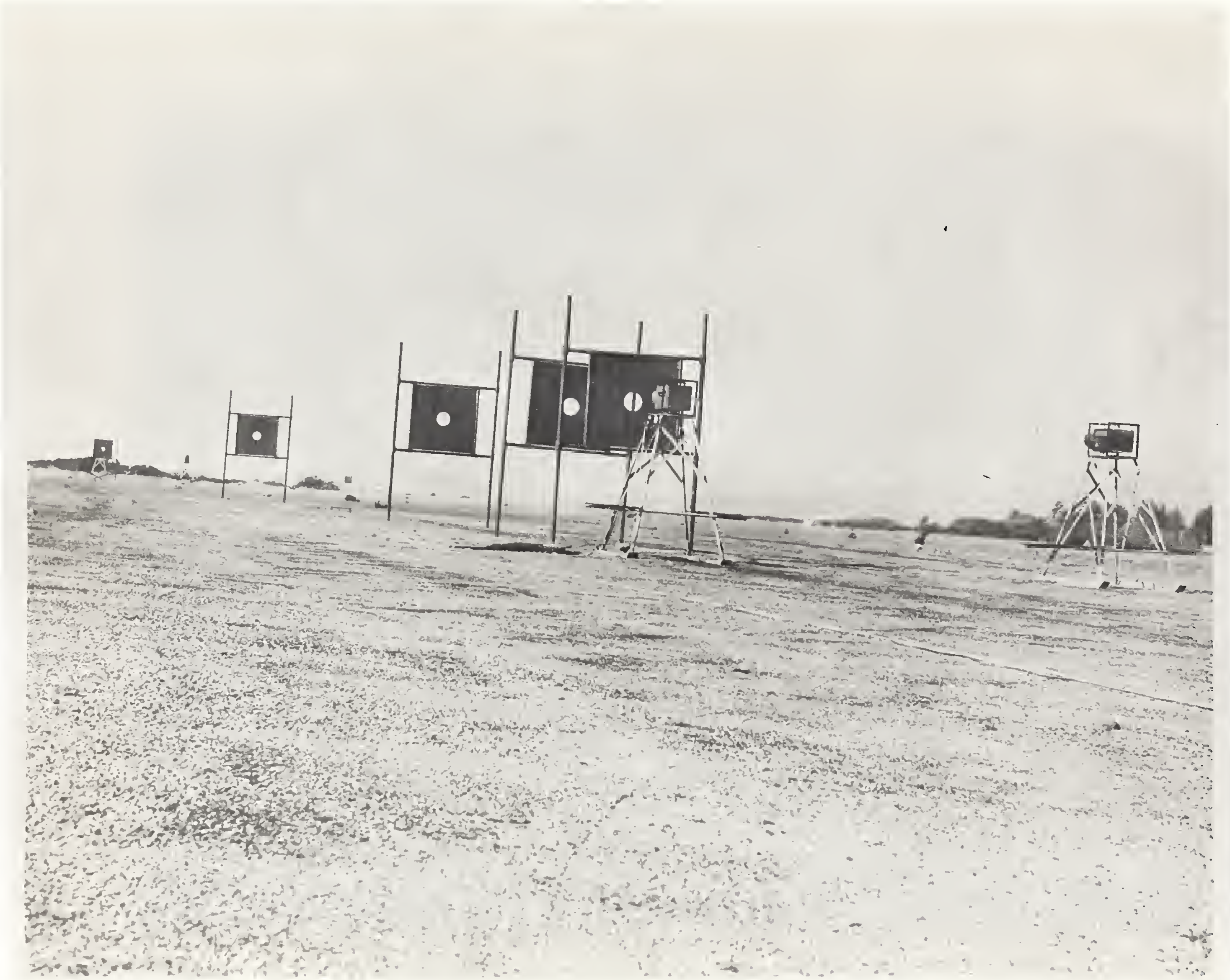


FIG. 7 TRANSMISSOMETER INSTALLATION FOR SCATTERED LIGHT TEST

FIG. 8 RUNWAY MARKING SYSTEM AT ARCATA AIRPORT