NATIONAL BUREAU OF STANDARDS REPORT

5893

Report of a Survey of Visual Landing Aids

By

James E. Davis
John W. Simeroth

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

THE NATIONAL BUREAU OF STANDARDS

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NBS PROJECT | **NBS REPORT**

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NBS

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NATIONAL BUREAU OF STANDARDS

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Report of a Survey of Visual Landing Aids

ABSTRACT

This report presents the summary of a survey of visual landing aids conducted at seven Naval and Marine Corp Air Stations in California and recommendations resulting from this survey. The survey was made to determine the maintenance and operational problems in this area. A similar survey was made of the Atlantic Coast stations and reported in National Bureau of Standards Report 3260.

Many maintenance problems at the West Coast stations were found to be similar to those reported previously. Visual landing aids are not being utilized operationally to the fullest extent because of lack of pilot training. The more important requirements for better use and maintenance of visual landing aids are as follows: better standardization of lighting and marking systems at all fields; a comprehensive pilot training program in the use of all visual landing aids; more stringent requirements for contract installations; assignment of responsibility for maintenance to one man who has been given special training; and the provision to maintenance personnel of the needed equipment, particularly suitable vehicles and communications equipment, special tools, and technical and maintenance information.

1. INTRODUCTION

The importance of visual landing aids in conjunction with electronic and other instrumental aids for approach, landing, taxiing, and takeoff during low-visibility conditions is well established. High-intensity approach- and runway-lighting systems using a number of brightness-control regulators, lighting units whose adjustments and placement are critical, and other specialized related devices, are becoming increasingly complicated and difficult to maintain. Recognizing these facts and the possibilities of problems that arise in the field as a result of them, the Visual Landing Aids Branch, Bureau of Aeronautics, requested that the National Bureau of Standards make a survey under Project TED No. NBS AE-10011 to obtain suggestions and to recommend methods for improving installation, maintenance, and operational use of visual landing aids at both land and seaplane bases. The stations recommended by the Visual Landing Aids Branch for visiting are listed in Appendix A.

The expected results of the survey are recommendations which will increase the operational efficiency and reduce or eliminate recurring maintenance problems of visual landing aids. Reports of the men who are assigned to the maintenance of these aids are helpful in determining the need for modification of existing equipment, the need for specialized and common maintenance instruments, tools, and technical information, and in the design of new equipment. Comments recorded during conferences make possible the summarizing of pilot reaction to visual landing aids.

2. OBJECTIVES AND METHODS OF THE SURVEY

The objectives of the survey were to obtain data on the following subjects:

A. Methods of locating faults in airfield-lighting cables.
B. Difficulties encountered in the installation, operation, use, and maintenance of visual-landing-aids equipment.
C. Methods of testing and maintaining visual-landing-aids equipment.
D. Pilot reaction to all visual-landing-aids equipment.

The survey was accomplished by interviewing maintenance electricians, their supervisors, and by round table conferences with Public Works officers and engineers, pilots, and others interested in the problems of daily use and maintenance of visual landing aids. A survey questionnaire form was used to facilitate the interviewing of personnel and tabulation of the information, but many of the topics were covered by discussion rather than question-and-answer sessions. The Public Works and maintenance personnel were very cooperative in giving their time and in providing information and facilities.

Every effort was made to obtain unbiased replies to the questionnaires. Answers by maintenance personnel questioned separately on the same subject did not coincide completely with those given by their supervisors and the engineering personnel at the same station. This, however, is explainable by the fact that the maintenance personnel are in direct contact with the numerous small day-to-day problems, solving them without consulting their supervisors, while the supervisors and engineering personnel are concerned only with the visual landing aids problems in emergencies or when major changes or modifications are being made.

In the round-table conferences, questions pertaining to all visual landing aids were answered. Participants were encouraged to present their views, based on their own experience, on the adequacy of the various general categories of visual aids, as well as specific problems encountered within and outside of these general categories. In addition, other landing aids directly connected with the use of visual landing aids, and their integration, were considered.

Familiarization demonstrations of the operation and use of the Cable-Test Detecting Set AN/TSM-11 were made at each station. A copy of a preliminary draft of a Step-by-Step Maintenance Procedure was left at each of five stations, and the troubleshooting charts prepared to accompany this Procedure were left at two of the five stations.

Other technical and engineering information and assistance was given to personnel contacted at each of the seven stations.

3. DATA OBTAINED

A questionnaire form was used as a guide for determining the methods of locating faults in airfield lighting cable; difficulties encountered in installations, operations, and maintenance; and methods of testing and maintaining visual landing aids equipment. As noted in the report of a previous survey (NBS Report 3260) all stations do not maintain complete reports of airfield lighting installations, operations, and maintenance. Therefore the findings of this survey are generally presented in a narrative rather than tabular form.

The following data were obtained from interviews, conferences, and questionnaires, and from the stations' records. The results of conferences with pilots and operations personnel are given in Section 4.

3.1 General Station Data

3.1.1 Physical Data.

All stations visited in this survey were located within 25 miles of the coast, between the San Francisco Bay and the Mexican border. The elevations of the stations varied from 0 to 524 feet above sea level. Three of the landplane bases were on ground which was at least partly filled, and the other four were graded without major cuts. The soil of the landing area was sand, silt, and adobe fill at three stations; adobe hardpan over rock at two stations; and adobe and sand combination at the other two stations. Two stations had artificial drainage, three stations had natural or graded drainage, and two stations had graded drainage to catch basins. The topography of the nearby surrounding area was generally flat except at one station located on top of a mesa; however, most of the fields had one or more important approaches over hills that are a hazard for high-speed jet aircraft. The native vegetation was mostly grasses and bushes, but three stations had appreciable farming in the surrounding area. Two stations were located adjacent to cities, and one station was located adjacent to high-density residential and orchard area.

The seadromes were all at sea level and were located in bays with peninsulas to protect them. One landing area was dredged to a depth of 10 to 13 feet and the other two had natural depths, one with a minimum of 36 feet and the other from 10 to 32 feet. One seadrome had an anchorage with a minimum dredged depth of 12 feet, protected by breakwaters and rock jetties. The anchorages for the other seadromes were areas or ramps with the depth approximately equal to the minimum depth of the landing area. The average tidal change was from 3.5 to 4.2 feet with an extreme tidal change of from 8 to 12 feet. The currents were from tidal flow only, mostly weak and variable, with a maximum current of 4 knots. There was some shipping in the approach areas with small surface craft in the landing areas at two seadromes. One seadrome had some heavy shipping in the landing area. Debris on the sealanes was a problem at one seadrome.

3.1.2 Meteorological Data.

All stations in this survey had a humid mesothermal climate with an average temperature of 59 degrees. The minimum temperature recorded at any station was 19 degrees; the maximum recorded was 108 degrees. The average annual rainfall is about 10 inches, with a maximum annual precipitation of 28 inches and an annual minimum of 2.5 inches. The maximum recorded rainfall for a 24-hour period was 5.3 inches. Snowfall seldom amounted to more than a trace, with a maximum annual record of 1.5 inches. There was no icing on seadromes or frozen ground reported. Lightning was reported as a very rare occurrence. Wind averaged about 6 knots, generally from northwest but from south and east during the winter months. The maximum wind velocity reported was about 60 knots with gusts to 77 knots. The mean relative humidity was 74 percent. Most of the stations were located where fog, smog, smoke, haze, and low cloudiness were frequent. About 45 percent of the days were clear; 40 percent of the days were cloudy; and about 15 percent were partly cloudy. At each station ceilings were below 1000 feet approximately 1000 hours per year and below 200 feet approximately 200 hours per year. The low cloudiness was almost entirely of stratus-type clouds. Except at one station the annual average visibility was below 2 miles about 800 hours and below one-quarter mile about 200 hours per year. The other station (El Toro) reported visibility below 2 miles 6700 hours and below one-half mile 2000 hours per year. The fog was primarily of the advection type with occasional radiation-type fog. Smog and haze were reported as being particularly troublesome by generally restricting visibility at lower altitudes to less than 5 to 6 miles even with a clear sky.

3.1.3 Aircraft Operations Data.

The average operations per month for the six land stations (an average of 27 days of operations per months) were:

73,810	jet operations (approximately 60 percent)
16,285	night operations (approximately 10 percent)
130,300	total operations

Nearly all types of Naval aircraft operated from these stations.

The average number of operations per month for the three seadromes was 750, of which 5 to 10 percent were at night.

For the six land stations reporting, the total number of lights damaged by aircraft averaged 80 units per month, of which approximately one half were caused by jet or prop blast.

<u>No station reported any damage to aircraft from airfield lighting equipment at land stations.</u>

3.2 Lighting and Marking Installation Data

3.2.1 Approach Lighting.

Miramar, Moffett, and North Island stations were the only ones with approach lights. All of the systems were obsolete parallel-row systems using type D-1 lights. The system at Miramar was on approach 28 and the Ground Control Approach unit generally operated on runway 6R-24L. Hence the approach lights were not used on ground-controlled approaches. The system at Moffett consisted of 22 units. This approach-light system crossed Bayshore Freeway (US 101) at an angle. The Operations Officer reported there was some indication that vehicular traffic along this highway caused confusion when pilots were making approaches during low visibility conditions and at night. The system at North Island was installed on approach 29.

The need for approach lights or an improved approach-light system was indicated at most stations. Several stations would have serious problems to overcome in making an installation. At two stations the approach zone crossed highways, and one station had an overwater approach.

3.2.2 Runway Lighting and Marking.

Seven stations reported:

16	runways with a total length of 136,000 lineal feet of runway
603	type C-1 units
408	type AN-L-9 units
546	type M-1 units
153	type D-1 units
1710	total runway-light units

Two stations were still using yellow filters in the last 1500 feet of runways.

Two stations had obsolete type D-1 runway lights.

Threshold lighting at all stations was standard.

Approximately 125 miles (648,560 feet) of runway-lighting cable were installed.

Two stations were still using the old runway markings conforming to specification ANC-R-7 (26 Nov 1947) and one station had not completed all runways with the new standard markings conforming to S. E. drawings 118A and 119A, "Planning Standards for Naval Air Stations." Only one station was not using reflectorized paints for these markings. All markings had been applied within a year and the average date of application was four months previous to the survey. Most markings were in fair to good condition and were applied about once each year, but one station renewed the markings every six months, and another every two years.

North Island had a very large paved area with "scramble" runways marked by broken lines with compass headings, length of runway, and TAKE-OFF or LAND at the ends of these runways.

Two stations with the new standard runway markings were using the "old" length-of-runway markings at the threshold.

The runway distance markers were illuminated at two points along the runway at one station. Four other stations had installed nonilluminated runway distance markers; of these, one had removed the markers because they were being knocked down. There were no pilot requests that they be replaced.

3.2.3 Taxiway Lighting and Marking.

No taxiway lights were installed at one station. However, taxiway lighting was needed because only a very small percentage of the aircraft operating out of the station had landing or taxiing lights. Hence the retroreflectors installed along the taxiways were ineffective.

Six stations reported:

154,313	linear feet of lighted taxiways
70	individual circuits controlling these lights
2,480	type AN-L-9 units
272	type M-1 units
2,752	total taxiway-light units.

Approximately 118 miles (618,850 feet) of taxiway-lighting cable were installed.

Intensity control for the taxiway lights had been provided at one station by using obsolete runway brightness-control regulators. The taxiway lights on clear nights were usually operated on brightness step 3 (10% rated intensity). The brightness-control regulators were installed at the request of the pilots to provide a reduction of intensity of the taxiway lights.

All 45-watt lamps in the type M-1 taxiway lights had been replaced with 30-watt lamps at one station, and the number of pilot complaints had been reduced.

A long taxiway with a "dog-leg" offset in it caused considerable difficulty at one station since planes ran off the taxiway in this area. A 6-inch white painted stripe near each edge of the taxiway was added to define the limits of the pavement. The number of times planes taxied off the taxiway in this area was greatly reduced.

Several destination markers had been installed at one station. It was reported that this had reduced radio communication for taxiing instructions. Three other stations were installing a limited number of signs or arrows, but these markers were not in use long enough to indicate their value.

Six of the stations used taxiway markings conforming to the design of S. E. drawings 118A and 119A, "Planning Standards for Naval Air Stations," with minor variations only. One station had no markings on the taxiways. One station had TAXI painted on the surface of the taxiway at the entrance to the runway. Four stations used reflective paint for the taxiway markings.

3.2.4 Seadrome Lighting and Marking.

Two of the seadromes used type FMF-6B buoy channel-marker lights and one used type AN-L-10 pile-mounted lights with 1020-lumen lamps to mark the landing lanes at night. The width of the landing lanes was 1000 feet and the length varied from 8800 to 11,800 feet.

Three seadromes reported:

68	type FMF-6B units
104	type AN-L-10 units
172	total seadrome marker-light units
85,000	feet of underwater cable

The only beacons in use were the standard rotating beacon at the adjacent land-plane fields. One station had recently removed a pile-mounted flashing identification beacon located at the intersection of the landing lanes after it had been struck by planes on two occasions. The only taxi lights provided were the lights mounted on the breakwater wall to mark the opening in the breakwater and the entrance to the anchorage. Floodlights were used at the ramps.

Each of the buoy lights had a 24-inch diameter canvas day marker painted yellow and black. The pile-mounted sealane lights had a 6-foot square wooden pyramid painted yellow and white for day markers. Large areas on the breakwater at the entrances through the breakwater had been painted orange, but this had not prevented several accidents at this point.

3.2.5 Miscellaneous Airfield Lighting Equipment.

Six stations used time switches or local-control switches for controlling all obstruction and hazard beacon lights except those in the immediate area of the control tower which were controlled by a switch on the airfield-lighting control panel. The other station had provided a telephone circuit for control of all obstruction lights on the airfield. Two stations maintained hazard beacons and a third station had discontinued maintenance of hazard beacons.

Two stations maintained a set of type AN-S-2 portable field-lighting units for use in emergencies. One station used this type of light to mark the field carrier-landing-practice area. One station had modified a number of Embory battery-operated lights for use in emergencies. The lenses of these units had been replaced with lenses from AN-S-2 sets. The lights were placed as needed on the field.

One station had installed a closed-circuit television system for monitoring the approach zone and the touchdown area of one runway. "Wheels Watch" had been provided at all stations with flares for use as an emergency wave-off signalling device. Three stations had traffic-control signals in the approach-zone areas for controlling vehicular traffic. Four stations had type J5 lighting trucks for crash and mobile use. North Island had a special barricade lighting which consisted of four 60- or 100-watt 115-volt, ruby incandescent lamps connected in parallel. These were operated at 58 volts by a 200-watt, 6.6-ampere isolating transformer connected into the series runway-lighting circuit to mark obstructions on one taxiway when it was used for parking aircraft. One station had lights near the control tower indicating the runway in use.

Lighted tetrahedrons were used at all stations for landing-direction indicators.

3.3 Wiring and Cable Data

3.3.1 Underground-Power Wiring.

Most of the cable used for runway and taxiway lighting was 5000-volt, No. 8, solid, polychloroprene-jacketed, conforming to Specification MIL-C-5136. However, approximately 20 percent of the cable was of older types of 3000-volt, rubber-covered cable and 5000-volt, lead-covered, varnished-cambric or rubber-insulated cable. Generally the Specification MIL-C-5136 polychloroprene-jacketed cable was being used to replace the older types of cable as faults occurred. Some stations planned to replace the older types of cable in the immediate future, but two stations with a considerable amount of older cable had no program for its replacement.

Several stations felt that the contract specifications for insulation resistance requirements are not adequate. A minimum of 50,000 ohms per circuit was the stated value of insulation resistance for insulated interior wiring. Since no minimum value was stated in these specifications for underground wiring of airfield lighting circuits, this value was being used by the inspecting officers. Public Works personnel felt that the acceptance of an installation based on this value of insulation resistance is a principal cause of their cable faults. A requirement that lighting-maintenance personnel participate in the final acceptance testing of insulation resistance of a new installation would improve their attitude toward contracted installations.

3.3.1.1 Power-Cable Installations.

All stations reported that all or most of their underground wiring had been installed in nonmetallic duct. Five stations still had some cable buried directly, but most of this will be replaced soon. At one station part of the wiring for the approach lights was installed overhead on poles. The installation of cable dated from 1939 to the time of the survey. Over 20 percent of the cable had been installed more than 10 years. Approximately 70 percent of the cable had been installed less than 5 years.

3.3.1.2 Connectors and Transformers.

All stations reported that new installations of runway and taxiway lighting were being made with type MIL-C-7192A cable connectors. There had been only a few failures of these cable connectors at each station. Some of these failures were due to poor crimping of the copper pins to the conductor. At other stations, grounds developed at the connectors from undetermined causes. One station reported receipt of a group of connectors that did not fit properly, but these were replaced. One station reported that the contractor had cut the connectors off the isolating transformers and had made conventional splices to the cable. Five of the stations had splices in some of the older installations. Five stations had experienced one or two failures of type IL isolating transformers shortly after an installation was made and then had experienced little further trouble. Some stations reported that the older metal-can type IL transformers had caused some trouble from the rusting out of the cans and from moisture entering around the bushings.

3.3.1.3 Cable Failures.

An average of approximately four cable faults per station per year were reported. There were about three times as many faults in the taxiway-lighting cable as in the runway-lighting cable. The reported number of faults in underground cables is probably an underestimate. Usually the only faults reported were those which caused outages. The faults which were detected and repaired during preventive maintenance checks were not reported and most multiple faults, when repaired at the same time, were considered as a single fault. Approximately 90 percent of the cable faults were grounds and most of the rest were open faults. One station reported that one or two high-series-resistance overload faults had occurred. These faults apparently were caused by arcs across an open in the conductor which fused the sand into a mass of glass. This glass contained enough copper impurities from the conductor to allow a limited flow of current. A similar condition at Quonset Point was also reported in the previous survey report.

Installations of old types of cable continued to give trouble because of the deterioration and the effects of being continually subjected to the moisture that accumulates in the type AN-L-9 units. Water entering these units caused grounds in the fixtures, then entered the cables causing grounds later in the cable itself. The insulation of the 3000-volt, number 12, single-conductor cable deteriorated until the applied voltage caused numerous grounds.

Secondary or low-voltage power cables in airfield lighting were used mostly on short runs to obstruction lights, tetrahedron, Wheels Watch, etc., and were mostly in duct or conduit. Performance was satisfactory and the few faults that occurred presented no unusual maintenance problems.

Deterioration of the older type cable, water in cable, and faulty installation, in that order, were reported to be the chief causes of cable faults. Digging and trenching in cable areas, splices, and faulty original cable, corrosion of sockets in the AN-L-9 lights, and cable damaged in accidents were the less common causes of cable faults. One station reported about 30 faults per year in earlier cable installation caused by gophers gnawing the rubber insulation. No faults from this cause had occurred after the cable was installed in ducts. The ducts stopped the damage from gophers. Cable damage as a result of lighting strokes or freezing of the ground was not mentioned by any of the stations.

Repairs to cables were accomplished by installing new lengths of cables between lights and/or manholes.

The general use of connectors had greatly reduced the number of faults in connections. A large number of high-resistance-to-ground faults had occurred at connectors. These faults were removed as a regular part of preventive maintenance and were not reported as cable faults. These faults at connectors were attributed to improper installation. When the connectors were properly installed or cleaned up, their performance was satisfactory. With suitable insulation-resistance specifications for installation contracts (see Paragraph 3.3.1), the frequency of connector faults should be greatly reduced. Where splices were necessary, the type of splice used depended upon the past experience of the person in charge of maintenance and the type of cable being spliced. Lead-wiped splices were used on lead-covered cable. Splices of rubber- or neoprene-covered cable were generally made of plastic tape. Sticky tape may be used for filler. One station made "pigtail" type splices using dope, two layers of tape, dope, two layers of tape, etc., extending the tape and dope four inches along the cable from the splice. One station used a solder sleeve, straight-pencil rubber-tape filler and vinyl plastic tape on top, no finish, and very little tension of the tape. This station used connectors only for isolating transformers. One station was considering the use of "Scotch Cast" Kits. One station had used markers in the past to locate splices, but discontinues this, using connectors in newer installations.

3.3.2 Control Cable.

There were approximately 23,000 feet of multiconductor control cable installed at the seven stations. One station had 12,000 feet of 26-pair, paper-insulated, lead-covered telephone communication cable; four stations had a total of 8,000 feet of 12-conductor, number 14, neoprene-jacketed control cable; and two stations had a total of 3,000 feet of 16-conductor, number 14, rubber-covered control cable. For some short runs and special purposes, other types of cables were used for control cable. No unusual maintenance difficulties had been encountered.

A minimum of trouble was experienced with the control cable at these stations. At one station an accumulation of water in a junction box at the lower end of a vertical run of conduit to the control tower caused the wiring to ground and short out. Because the effect was intermittent, checks were made for several days before checks were made of control-cable resistance to locate the short (fault). Another station experienced difficulty with a splice in a manhole. One station had changed the control power from 120 volts ac to a d-c telephone-type control circuit with pilot relays. This change was made because of long lines which, when a-c voltage was used, apparently caused induced voltage to hold a previously selected relay or caused two relays to close simultaneously, resulting in burned relays and damaged regulators. It appears that the induced-voltage problem had been serious, since preventive maintenance procedures still required cleaning the relay contacts three times weekly, although no trouble was recalled since the change to direct current.

3.3.3 Underwater Cable.

The underwater cable installed at the two seadromes was the jute- and armor-jacketed, 5000-volt, single-conductor, number 6 submarine cable. This cable had been installed approximately five years by laying the cable on the bottom and securing it to the pilings at 5-foot intervals where the cable came up to the lights. No faults were reported in the 85,000 feet of cable installed, except for one or two breaks per year caused by dragging anchors of ships. Underwater cables and faults were located by pulling cables to the surface, and by grappling. Repairs were made by replacing whole section; no splices were used. Alameda reported that jute- and armor-jacketed cable, when freely suspended, was not satisfactory for underwater use. Submarine cable was satisfactory when laid on the bottom to the transformer, but faults occurred in the riser cables from the transformers to the lights of some earlier installations. Attaching buoys to submerged pilings by cable or by chains proved unsuccessful because the cable frayed or was damaged by the chains, or the chains and cable twisted and tangled at low tide and submerged the lights as the tide came in. The use of a fairly heavy flexible rubber column with the attaching cable and conductor enclosed was suggested.

3.4 Control Equipment Data

3.4.1 Tower Equipment.

Type II Airport Lighting Control Panels were used at all stations. Some were modified slightly to accommodate local needs. Three stations used type N-1 Airport Lighting Control Panels, and one station used the Nav-Aer-M-713 Airport Lighting Control Panel for controlling taxiway lights. One station had provided for simultaneous operation of two runways which are not parallel. Another station with intensity control on the taxiway lights had added a brightness-control switch to their N-1 control panel.

Several stations had experienced trouble with the brightness- and runway-selector switches. Some of these switches were the type with the stop and the switch jumped the stop. On others the switches were turned without pushing. This damaged the switches. The use of a cam-operated linkage for the interlock contacts instead of the push-to-turn type presently used was suggested.

Control panels designed for dual runways were wanted at three stations, so that both runways could be used simultaneously. Independent selection of runway lights and brightness for each of the dual runways was needed.

Larger knobs on the pull-push switches on the type N-1 taxiway control panels were wanted by one station.

One station did not have an alternate control panel in the airfield lighting vault. This made maintenance difficult and failed to provide an alternate control point in case of control-cable failure or loss of the control tower.

One station had a facsimile panel of the field in Operations, with lights to indicate which circuits were lighted. Runway-light intensity was adjusted to the setting requested by the pilot at all stations. Some stations seemed to encourage pilot requests. One or two stations felt that asking the pilot to state a preference on intensity invariably required a change in intensity, but that the change from the normal setting was not systematic. For clear nights, most stations normally set the intensity of medium- and high-intensity runway lights to brightness step 2. Two stations used step 1 for high-intensity lights on clear nights. Higher brightness settings were used for the semiflush lights during clear nights and for all lights during lower visibility conditions. One station reported that brightness step 5 on the high-intensity lights was normally used for good visibility, but that in rain or fog step 3 was used, to reduce the glare. The reason given for using the high brightness settings for good visibility was that it was desirable in order to help the pilot locate the runway before he broke out under a low overcast. At a station with a very limited number of nighttime operations where the lights can conveniently be changed at the pilot's request, this policy may not be as troublesome as it would appear. Since lamp replacement did not seem to be excessive, perhaps lights were on step 5 only when planes were making approaches during overcast conditions.

El Toro usually used brightness step 3 on the taxiway lights. They felt that at least three intensity settings were needed for taxiway lights. All stations that commented wanted intensity-control equipment on their taxiway-lighting systems. Most stations felt dividing the taxiway-lighting system into a larger number of sections, with better control on the sections which are to be lighted, would reduce confusion to pilots during taxiing.

3.4.2 Vault Equipment.

Some type NC-3 regulators were used at two stations. All stations had a number of type AN-R-17 regulators in use. Two or three stations were using moving-coil-type regulators for taxiway lights and obstruction lights. No induction-voltage regulators were used in the airfield lighting systems.

No serious problems were encountered with either the type NC-3 or the type AN-R-17 regulators at any of the seven stations. Three stations reported some relay failures in regulators and selector cabinets, but the cause was traced to defective wiring or control switches. One station reported that an open winding had developed in an older type regulator. The regulator was replaced. The maintenance personnel at most stations were aware of the problem of increased output current of the type NC-3 and type AN-R-17 regulators as lamps in the circuit with isolating transformers burned out. They make frequent checks for burned-out lamps so that a complete failure of lamps does not occur as a result of this characteristic. All of the lamps in a circuit burned out on one occasion at each of two stations. Four stations indicated some need for overcurrent protection and two of these stations use or suggest limiting by closely fusing the input to the regulator for the actual load.

Periodic checks of regulators were made at all stations on an established schedule. One station had installed IL transformers in each series circuit in the vault with indicator lamps mounted on the wall for quick visual checking of these circuits. Two stations had installed an ammeter in the output metering circuit of some regulators for maintenance checks. One station suggested that specifications for regulators should specify a standard position for input and output terminals in order to simplify installation in replacing a regulator.

Voltage and frequency regulation of the power source was adequate at all stations. Three stations had emergency generators for operation of the airfield-lighting system during station power failures. Other stations did not have satisfactory emergency power for airfield lighting, but stated that emergency power was needed. One of the stations with emergency power needed more dependable automatic switching and starting. One station suggested that two independent power feeder cables be provided to the airfield-lighting vault.

Specification AN-C-109-type runway-selector cabinets were used at all stations. At least two stations had runway-selector cabinets with type "RS" relays, part No. 6010 single-pole, single-throw, with simple break contacts. The number of stations that had single-pole, double-throw relays with simple make-or-break contacts (part No. 6021) instead of single-pole, double-throw relays with make-before-break contacts (part No. 6066) was not determined. In the older style relays, part Nos. 6010 and 6021, contact arcing had damaged relays. Only one failure in the new type relays, part No. 6066, was reported.

Standard 12-pole transfer relays were used at all stations. These require some cleaning and adjusting of contacts, but present no special maintenance problems.

Alameda station had an underground airfield-lighting vault. Leaks in the floor and seepage through the floor and ceiling created uncomfortable working conditions. Occasionally this vault flooded to a depth of two or three feet.

It was suggested that power for the vault lights, plugs, and control voltage should be taken from a transformer connected ahead of the incoming primary oil-fused cutouts. This would eliminate the necessity of operating numerous fuse cutouts, oil switches, etc., when checking control control circuits or doing other work in the vault. In addition, this would increase the safety of personnel in the vaults where open high-voltage bus bars are present. A few stations felt that, as an added safety factor and to expedite work on vault equipment, a remote-controlled oil switch (RCOC) should be placed in the high-voltage leads ahead of all regulators.

One station had installed a facsimile map of the airfield-lighting system on the wall of the vault, with pilot lights to indicate the circuits in use.

3.5 Maintenance Data

The maintenance at the stations included in this survey was found to be satisfactory to very good with one exception. The insulation resistance of all series circuits was very low, although the lights were kept operating satisfactorily.

3.5.1 Routine Maintenance.

At three stations Public Works personnel checked operation of visual landing aids twice daily, in addition to the daily checks made by Operations personnel. At three stations Public Works personnel made weekly checks, in addition to the daily checks made by Operations personnel. At the remaining station checks were made by Operations personnel only. The checks at all but this station were made by observing the lights while driving along the row of lights.

Generally glassware was checked, cleaned, and/or replaced during relamping.

Lighting units were aligned when lamps were replaced and/or when visual checks indicated a need for adjustment.

All stations replaced lamps as the need was indicated by visual daily or weekly checks. Miramar and El Toro used group lamp replacement on one runway each. North Island used group lamp replacement on obstruction lights. For group lamp replacement of runway lights, Miramar replaced annually or as lamps blackened, and El Toro replaced after 10 percent of the lamps burned out.

Routine maintenance records were kept at six stations. Methods of recording information varied with the station. Most stations used a ledger or record book, but some used maintenance forms or memorandum reports.

Methods of numbering or otherwise identifying light units and cables had been established at all stations. The identification of lights and cables was not kept current at most stations. Some stations were testing materials for marking lights and surfaces near areas of aircraft operations. Materials that will withstand the heat of jet blasts are needed.

Alameda used a hardwood mandrel and rubber mallet for straightening the cones of the type M-1 lights and a large hex wrench of the proper size to fit the couplings for use in removing broken couplings.

A need was indicated by lighting-maintenance personnel for a small portable 115-volt a-c generator and a pump suitable for removing water from the bases of semiflush lights.

3.5.2 Preventive Maintenance.

Preventive maintenance was performed at six stations on routine assignment. The other station relied on reports of outages and performed repairs and maintenance work only when trouble was reported. It was interesting to note that at some of the stations where a particular item had caused several failures, even though the cause of the failure had been eliminated, the frequency of the checks on this item was increased. The same item did not receive much attention at other stations. A breakdown of the preventive maintenance procedures is as follows:

Inspection and cleaning	5 stations annually, 1 at relamping
Load-circuit insulation resistance measurements	6 stations weekly to semiannually
Control-circuit insulation-resistance measurements	2 stations
Continuity measurements	2 stations
Check of open-circuit devices	3 stations
Load-current measurements	5 stations
Check of control switches and relays	7 stations
Check of induced or leakage voltage of control circuits	1 station
General check and servicing of all components	biannually, annually, or biennially
Preventive maintenance data recorded	6 stations
Faults and failures recorded	3 stations

The usefulness of recorded data was indicated as follows:

Helps to determine deterioration and to locate incipient faults before they cause trouble	4 stations
Helps locate outages after fault occurs	3 stations
Is used to help analyze cause of faults	3 stations

3.5.3 Troubleshooting.

All stations had available: insulation testers (meggers), clamp-on ammeters, accurate ammeters, accurate voltmeters, current and potential instrument transformers, hot-line clampsticks, and TSM-11 Cable Test - Detecting Sets. Six stations had multimeters. Two stations made socket adapters for use in making current measurements in the field. Some of these instruments were in the shops and were not readily available for airfield-lighting maintenance.

Two stations had "Wiggins" cable-fault locators and "Hi-pot" insulation-breakdown testers. One station had a "Vibroground" ground-resistance tester. These instruments were used little if any.

Some of the maintenance personnel would like some instructions in the use of certain test instruments. The test equipments most needed by airfield-lighting-maintenance personnel were suitable high-voltage limited-current insulation testers that will not damage cable, suitable and safe socket adapters, easy-to-use tools for aligning lights, a satisfactory means of locating open-circuit faults in cable, and a suitable shield with marking flags to protect maintenance personnel working near aircraft traffic from wind, jet, and prop blast.

The preferred methods of isolating faults were as follows:

Method	Choice 1st	2nd	3rd	4th
Symptoms	4	2		
Isolation and elimination	2	1	3	
Past experience	1	3	2	
Step-by-step procedure	0	0	0	
Substitution	0	0	0	

The preferred methods of locating grounds in series circuits were as follows:

Method	Choice 1st	2nd	3rd	4th
Visual inspection of lights	5			
Cut and try	2			1
Substitution			1	
Insulation-resistance measurements		2	1	
Past experience		1		
Intentional grounds		1	1	1

The preferred methods of locating opens in series circuits were as follows:

Method	Choice 1st	2nd	3rd
Intentional grounds and resistance measurements	2		
Sectionalizing	1	2	
Cut-and-try substitution	1		3
No experience	3		

The preferred methods of locating faults in controls, regulators, and input power were as follows:

Method	Choice 1st	Choice 2nd	Choice 3rd
Symptoms	5	1	
Isolation and elimination	1	2	
Past experience	1	3	
Visual inspection and measurement			1

The average number of failures or damaged runway- and taxiway-lighting units was approximately 150 per year per station. This number did not include cable faults. Damage from collision by aircraft and surface vehicles accounted for almost one-half of this total. More than one-fourth of the damaged units were damaged by propeller and jet blast. The damage to many of these units from both collision and blast was to the cones and not to the lights. Some of the units were damaged by heat from the jet aircraft. Water in the units, especially the semiflush units, and the resulting corrosion, were responsible for slightly less than one-fourth of the faults in lighting units. Although the faults from this cause were not as numerous as for collision and blast, the amount of time required for locating and repairing them was greater, proportionally. A few faults were attributed to faulty isolating transformers and other causes.

All stations but one made and recorded resistance measurements of cables after repairs were made. Three stations recorded the location of all repaired faults.

3.5.4 Maintenance Equipment.

3.5.4.1 Transportation Equipment.

Airfield-lighting-maintenance personnel encountered some problems in obtaining suitable transportation. No station had an assigned vehicle for airfield-lighting maintenance. Five stations had vehicles which might or might not be readily available for lighting assigned to the shops. The vehicles assigned ranged in size from a jeep to a 1 1/2-ton flatbed truck. All other vehicles for airfield-lighting maintenance were obtained from the motor pool daily as required.

Only three vehicles were painted in accordance with the requirements of TSO-N4 (Army-Naval-Civil Requirements for Marking of Vehicles Used on Landing Areas) for daytime operation on the field. None of the vehicles used for airfield-lighting maintenance was equipped with the obstruction lights specified for night operation on the airfield. All maintenance electricians indicated that is was desirable to have a properly painted and lighted vehicle assigned to them. Good visibility from the vehicle was desired. One station preferred an open "jeep." This type of vehicle provides better conditions for observing operating aircraft, and its maneuverability and rapid starting are needed in order to clear an area should an emergency occur. Vehicles assigned to airfield-lighting maintenance should have space to carry and store tools and equipment.

3.5.4.2 Communications Equipment.

Two-way radio communication equipment was not provided in the airfield-lighting-maintenance vehicles at any station. Four stations had either field phones or intercom-type communication equipment connected between the tower and vault. All stations indicated that two-way radio communication between the airfield-lighting-maintenance vehicle and the control tower, and land-line communications between the tower and airfield-lighting vault are urgently needed. Several of the stations believed that qualifying assigned airfield lighting maintenance electricians to use radio-communications equipment directly during maintenance work would be more satisfactory than having information relayed to them through an escort vehicle operator as is now done. The operators of the escort vehicle do not usually have a working knowledge of the electrical problems encountered in airfield-lighting maintenance and hence can not relay messages satisfactorily. One station suggested using a radio pack suitable for easy transfer between vehicles.

3.5.4.3 Emergency and Major Repairs.

All stations had established procedures for accomplishing emergency repairs and maintenance during nonworking hours. One station had a type AN-S-2 lighting set for an 8000-foot runway on hand for emergency use. Two other stations had a number of portable lights that could be used temporarily for emergency runway or taxiway lighting. Except for wire and cable, very little equipment was kept in readiness for emergency repairs.

Major repairs of equipment such as regulators and large transformers were obtained on the station at four stations and from the repair depot at three stations. Very few repairs outside of the station had been required. The requirements and procedures for obtaining repairs outside the station did not seem to be clearly understood.

3.5.4.4 Supplies.

All stations secured supplies through the Aviation Supply Office (A.S.O.). Only one station considered procurement and supply procedures satisfactory. At only one station were A.S.O. catalogs of airfield-lighting supplies available at the airfield-lighting-maintenance level. At four stations maintenance personnel considered that they were adequately familiar with procurement procedure. Average time for delivery of supplies ordered through A.S.O. was 2 1/2 months. Some of the comments on supply items were: different manufacturers' parts for similar stock items are not interchangeable; parts breakdown is inadequate; a separate catalog section of airfield-lighting equipment is needed because of noninterchangeability of these parts; an illustrated section of the catalog would help eliminate ordering errors; the follow-up on orders is not satisfactory; maintenance personnel need information concerning the expected date of delivery, delays, and action on mistakes; delivery of emergency supplies should be much faster; the procurement form is very poor; the catalog is not kept up-to-date; steel guards for semiflush lights can not be obtained. There were indications that errors and failures to obtain items resulted from a breakdown in the established channels for procurement between the maintenance personnel and the base procurement office.

3.5.4.5 Space for Maintenance Work.

Space in the airfield-lighting vault had been utilized for office, working, and immediate-use storage at five stations. The other two stations had space in the electrical shop for airfield-lighting equipment. No station had satisfactory space for airfield-lighting-maintenance personnel to store and work on drawings, keep records, and maintain and keep readily available needed technical information. Three stations would like to have additional space at the airfield-lighting vault for storage of immediate-use spare parts. Most stations had regulations limiting the quantities of supplies on hand to those normally needed for the next few weeks - 8 to 16 weeks. This period was often less than that required for procurement of supplies. The supplies maintained on the station were often insufficient to make immediate repairs or replacements, especially after an accident destroying several lights, unless the supplies maintained were based on the potential requirements instead of the average rate of use. Maintenance personnel preferred that the extra parts be stored at the airfield-lighting vault rather than at the base supply in order to make these parts available for emergency repairs at times other then regular working hours.

Five stations had adequate shop space; two did not.

3.5.5 Seadrome Lighting and Marking Maintenance.

Maintenance of the buoy channel-marker lights was performed by two independent groups. Military personnel installed and serviced the lights on the sealanes. Buoy tenders were used for most maintenance, but re-arming boats and tugs were sometimes used for turning the lights on and off. Most of the boats used in maintenance had no communication with the tower or aircraft except when the radio boat was standing by for sealane operations.

When repairs, including changing of batteries, were needed, the service group picked up the units and gave them to a group in Public Works. Public Works checked the units throughly and made the repairs as required.

The pile-mounted lights were maintained by the airfield lighting section of Public Works.

3.5.5.1 Batteries for Channel-Marker Lights.

One of the major problems in maintenance of the buoy sealane-marker lights was the replacement of batteries. Difficulty of replacement, short life, heavy weight, and the corrosion they caused were the main problems of maintenance. Because of the difficulty of replacing the batteries and of the required dependability of operation of the light, the battery life was considered too short. The cost of batteries was considered too high. One station replaced batteries every 15 days, or when the voltage dropped below 80 volts, whichever was earlier. The other station repaced batteries after observed or reported outages or after about every two months. To increase the life of the batteries North Island had substituted a 200-ohm resistor for the No.1-15 Amperite voltage regulator.

When water entered the battery compartment, the resulting corrosion often caused extensive damage to the unit. Alameda suggested sealing the lamp compartment from the battery compartment to keep water out of the batteries in case of breakage of the lamp enclosure. Because the switching was usually done with a boat hook, the lamp-enclosure assembly might be unknowingly cracked or broken. If the unit was left in service, the resulting corrosion might be severe.

3.5.5.2 Switching of Channel-Marker Lights.

Switching of the buoy lights, especially at night or in rough weather, is very difficult and is sometimes dangerous. There were reports of occasions when it had been necessary to lash a man to the bow of the boat in order to try to turn on these lights. When Maintenance knows that the lights will be needed, the lights are switched on before dark and turned off after the final operation. This method of switching reduces the life of the batteries, especially if more than one sealane must be kept ready for use. In addition, the use of boathooks to accomplish the switching often damages the lamp-enclosure assembly and the control-pedal assembly.

3.5.5.3 Alignment of Channel-Marker Lights.

Alameda reported considerable difficulty in properly locating and maintaining the line of buoy marker lights. They had tried to use a transit in a boat at one end of the line with some success, but the buoys drifted out of line rapidly. The buoys had been realigned about once each month. Concrete blocks were being used as anchors for the buoys. The weight of these anchors was not determined. This station suggested that the buoys should be attached to underwater pilings. North Island did not report aligning difficulties, perhaps because of the few units used and their high rate of replacement. North Island reported about 30 percent loss of light assemblies per month. Shipping was blamed, but wind and waves may have caused some of the losses. Only two buoy lights are known to have been hit by seaplanes in five or six years, but collisions by boats were much more frequent.

3.5.5.4 Cleaning of Channel-Marker Lights.

The outside of the glassware of the buoy marker lights is self-cleaning, but cleaning on the inside is required occasionally. Alameda cleaned the battery cases of barnacles and worms every three months. The barnacles have little effect on the life of the units, but caused injuries to personnel and created difficulties in servicing. Periodic sandblasting of the battery cases and metal parts to reduce the effects of salt-air corrosion had been tried, but was discontinued because the improvement did not seem to be worth the effort. No experience with icing and ice removal was reported.

3.5.5.5 Day Markers of Channel-Marker Lights.

The performance of the day markers for the buoys was not satisfactory. The life of the day markers was about four months. The markers are often difficult to see, especially from the surface. It was suggested that they should be painted with fluorescent paint.

3.5.5.6 Maintenance Problems of Pile-Mounted Lights.

The maintenance of the pile-mounted, shore-based-power sea-lane-lighting system had not been difficult. The underwater cable had been broken two or three times by the dragging anchors of ships. The salt air and water had corroded the junction boxes until after several years they needed replacement. The major problem in maintenance was cleaning the day markers of these lights. The pyramid day markers are rapidly soiled by seagulls and are difficult to clean. The maintenance of the lights and components developed no unusual problems.

3.6 Maintenance-Personnel Data

The maintenance personnel responsible for airfield lighting and the Public Works officers were questioned specifically on the most important needs in regard to maintenance personnel for improvement of airfield-lighting maintenance. They indicated that the things most necessary for improvement were:

1. Assignment of one man or more to airfield-lighting maintenance with direct responsibility. A special rating would help keep competent workmen in this position.

2. More and better training of maintenance personnel.

3.6.1 Assignment of Personnel.

One electrician was directly responsible for maintenance of the airfield lighting at each of five stations, with the amount of time assigned to this work varying from 25 percent to full time. The other two stations listed the leadingman or quarterman as responsible. Other duties of the airfield-lighting-maintenance electricians are generally street-lighting maintenance and other routine electrical work. In case of major failure or repair of airfield-lighting equipment, other personnel were utilized as required. One station assigned a large crew once a year for general repair and cleanup of the entire system. Major modifications and new installations were generally accomplished by contract. All stations which had tried assigning one man to the airfield-lighting maintenance agreed that this was the best method of accomplishing the maintenance. A special rating for the airfield-lighting-maintenance personnel was wanted. Only one station felt that such a rating might not be very desirable. This station used their maintenance man on airfield lighting only about 25 percent of his time. The following advantages of a special rating were given: a good incentive; seniority for reductions in force and work assignment; and the possibility of increased pay in line with extra responsibility.

3.6.2 Training of Maintenance Personnel.

The maintenance personnel working directly on airfield lighting are rated as electricians or linemen electricians. Training in airfield-lighting maintenance had been only on-the-job training and limited instructions from supervisors. At some stations the maintenance personnel attended periodic safety or supervisory meetings.

The maintenance men, more than their supervisors, felt that some additional training was needed. Only one station expressed a need for a training school, but the other stations indicated a need for instructions, other than on-the-job training, on theory of series circuits and special equipment, a briefing on new equipment, and a refresher on old airfield-lighting equipment and on maintenance procedures, and on requirements and limitations of equipment. Two practical means of providing the additional instructions were proposed: periodic instructions to groups of the men for a local area and periodic visits to each station by qualified personnel. The intervals suggested varied from about 3 to 12 months.

One maintenance electrician expressed the need for periodic conferences of airfield-lighting-maintenance personnel with the Operations Officer to obtain a better understanding of mutual problems and of emergency procedures.

3.7 Technical Information for Maintenance Personnel

3.7.1 Technical Data.

The technical information on hand and known to be avaiable for maintenance personnel was primarily that prepared on the station. Six stations had field-wiring drawings, installation plans, and maintenance records. Four stations had wiring drawings by systems. Field-wiring drawings and installation plans were the most used information, followed by the maintenance records and the system-wiring drawings. The drawings and plans were usually made at the time of installations, or after some major modification, and were not kept current. Other technical information on hand for maintenance in the order of availability and use was some equipment instruction manuals, some tehcnical orders, and the Design Manual. Less than half of the men in charge of airfield-lighting maintenance had available and were using the instruction manuals and technical orders. Most Public Works offices had considerably more information. The maintenance personnel were not aware of the available information or did not feel that it was available for their use. At the engineering level, only one or two stations reported reasonably satisfactory technical information available.

Most maintenance personnel reported that they did not know of much of the technical information available, and at only two stations did these men feel that they knew from whom or by what method additional information could be obtained. Generally they depended on the information received with the shipment of items, information left by the contractors, and, at some stations, the Design Manual, NavAer 19-1-517. The lack of knowledge of available technical information limited the maintenance men's ability to suggest what information was needed and how it could be improved. Four stations reported the need for a maintenance manual of some form. Three stations wanted technical orders, drawings, etc., kept current. Other items wanted were: pictorial supply catalogs, breakdown of component parts, operating theory of equipment, information on a standard control-tower console, and an improved and up-to-date Design Manual.

3.7.1.1 Maintenance Manual.

Most stations indicated that a brief maintenance manual covering all airfield lighting in a general way would be most useful. Other choices in the order preferred were: "some theory, but mostly maintenance and troubleshooting," "troubleshooting only," a "complete and detailed" manual, and "better technical orders and manuals." The type of troubleshooting instructions and type of manual needed was not agreed upon by the maintenance personnel. In both cases brevity was considered of prime importance. The indicated order of preference of troubleshooting instructions was: "brief step-by-step procedure," "brief troubleshooting charts," "brief symptoms," "detailed troubleshooting charts," and "detailed step-by-step procedure." One station specified "visiting personnel with practical knowledge" as their second choice. No station wanted a detailed trouble-shooting-by-symptoms procedure. Lack of familiarity with suitable maintenance manuals and troubleshooting instructions may have affected the choices. Preliminary copies of the troubleshooting information now issued as a maintenance manual (NBS Report 5243) were distributed to maintenance personnel at five stations. Time at the stations did not allow the men an opportunity to study the information enough for comment. One station suggested that the manual should be in two sections: one detailed, covering design and maintenance; and the other short, containing information directly useful for maintenance. Several of the maintenance personnel wanted information made available to indicate the reason for the placement and orientation of lighting units and for the use of certain types of equipment. Some information on the design requirements of equipment was also desired.

3.7.1.2 Study Time for Maintenance Personnel.

Three stations reported that some time was being allowed maintenance personnel for study of pertinent information. Two stations reported that more time would be allowed if material were available for study. Personnel of one station studied at home. The maintenance personnel indicated that after initial familiarization with the materials available, one or two hours per week would be adequate for studying and reviewing the information. Supervisors at three stations felt that job assignment and weekly meetings were adequate for educational purposes for maintenance personnel.

3.7.2 Instructional Data.

TSM-11 Cable - Detecting Sets had been received at all stations. Four stations had tested their sets briefly. The TSM-11 was kept in the Public Works Office at two stations and was not readily available to the maintenance personnel. The set was discussed with maintenance personnel at all stations, and its use demonstrated. No station had been able to obtain the specified batteries for the amplifier-indicator unit of the TSM-11.

The use of a high-voltage, limited-current insulation tester was discussed with the maintenance personnel at six stations. Attempts to demonstrate the use of this instrument on the existing circuits were not satisfactory, because no circuit had sufficiently high insulation resistance to give a satisfactory result. All maintenance men appeared to have adequate ability to operate this tester. One leadingman was opposed to testing lighting circuits with voltage greater than that used in an ohmmeter. He opposed the use of a 500-volt insulation tester on the 5000-volt circuits! All other personnel felt that a high-voltage insulation tester such as the "Takk" would be useful.

3.8 Miscellaneous Lighting Installation Data

Troublesome glare from apron and hangar floodlights had been experienced at some stations, but most of these lights had been hooded or placed on circuits controlled from the tower. Sunlight reflected from the large hangars at Moffett Field caused trouble. These hangars were painted with aluminum paint, and during certain times of the day sunlight was reflected into the pilot's eyes.

At one station the electrician reported that the airfield-lighting (high-voltage) cables passed through manholes constructed in the high-speed fueling area. Aviation fuel spilled while aircraft were being fueled collected in these manholes. This is a particularly dangerous condition, as the accumulation of the aviation fuel in these manholes could cause an explosion or fire if a cable fault which caused arcing should occur in these manholes.. Explosion-proof manholes or rearrangement of conduits and electrical cables may be required in some areas.

Pilots at one station indicated the desirability of the installation of wind socks near the touchdown areas of the runways. It was recommended that the "WHEELS" signs be standardized, as there is some confusion among pilots from station to station. Maintenance personnel felt that they should be given easier access to the runways for maintenance. A less troublesome clearance procedure would result in better maintenance of the airfield-lighting system.

4. SUMMARY OF CONFERENCES

Conferences were held at six of the seven stations, to obtain the pilots' reactions to visual landing aids. Those present included representatives of Operations, Aerology, Traffic Control, Public Works, and from as many operational units as possible, usually including some Safety Officers. The conferences were general discussions of the various visual landing aids and were not directed by a questionnaire. The participants were most cooperative in the discussions, even to the point of self criticism on occasions. The discussions were recorded on tape. A conference was also held with members of ComAirPac headquarters but was not recorded.

4.1 Visual Landing Aids

The visual landing aids installed at the stations surveyed were performing as designed, but the performance of some of these aids did not satisfactorily meet the requirements for many of the existing conditions. The results of the survey of visual landing aids are summarized by systems below. Standardization of lighting and markings, item by item, or as an entire system, at all airports, would be the most important improvement for the effective use of visual landing aids. Better training of pilots in the use of the information provided by visual landing aids would be another major improvement. A large percentage of pilots, even of those with several years of flying experience, did not know the color coding of the lighting, the coding of beacons identifying civilian or military airfields, or the pattern of any standard runway markings. The carrier pilots, especially, were unaware of visual aids information, but other pilots also needed a review or orientation in the information provided by the long established aids, and needed to receive current information more promptly.

4.1.1 Approach Lighting.

The high frequency of moderately low visibility conditions in this area intensifies the need for high-intensity approach lights on at least one runway at all important airfields. A slopeline-type approach-light system was preferred by more pilots than was any other proposed system because of the altitude information, although many of the pilots liked a centerrow system. (None of the pilots had flown a high-intensity centerrow system.) No other type of high-intensity approach-light system was indicated as preferred, but almost all pilots agreed that adoption of any one good system and installation of this system at all major airfields was desired, rather than further delay awaiting an optimum system. Preferred intensities could not be determined because of lack of experience, but manual control of brightness should be satisfactory until experience indicates a need for automatic intensity control. In addition to the high-intensity approach lights, circling-approach and lead-in lighting for runways other than the instrument runways, and at fields which do not qualify for high-intensity lights, is needed because of the prevalent smog and haze conditions. The approach-beacon system may satisfy this need. This lighting should furnish continuous guidance at least from a point opposite the downwind end of the runway when the aircraft is on the downwind leg of the approach and throughout the remainder of the approach until the runway lights are able to provide the needed guidance. It should provide identification and information for aligning the aircraft with the runway before the runway lights can provide this information. Because of the lack of pilot experience, definite recommendations as to the length of lead-in and approach-light symptoms could not be obtained. For jet planes, 1500 feet seemed to be the minimum length of lead-in lighting, but about 300 feet appeared to be more desirable. Visual aids located at distances of a mile or more from the runway threshold were mentioned. The possibility of confusing lighted thoroughfares with runways needs to be eliminated. Suitable lead-in lighting may be very effective in reducing this confusion, but further investigation of the conflicts between airfield and thoroughfare lighting is desirable.

4.1.2 Runway Lighting and Marking.

The type C-1 lights are very effective for high-intensity lighting of runways. The main deficiencies of these lights are lack of intensity in the direction needed for circling guidance when the lights are operated at the lower brightness settings, and the height of the lights. Elevated lights are a problem in areas where snow removal is required and may present difficulty in the location of arrester gear. There were no reports of damage to aircraft resulting from collisions with type C-1 lights, although many such collisions had been investigated. There were no reports of damage to aircraft from collisions with types M-1 or AN-L-9 lights, but apparently collisions with these lights were less carefully investigated. For those runways not requiring high-intensity lights, the type M-1 lights were performing satisfactorily. The type AN-L-9 semiflush lights have too low an intensity to be satisfactory for runway lights. For those locations where flush or semiflush lights are necessary, a light of higher intensity is needed. Spacing closer than 200 feet, especially for low-intensity lights near the threshold, might be useful, but only a few pilots indicated such a need. The type C-1 lights are generally satisfactory as threshold lights, but a longer bar of lights and a higher intensity might be desirable for the wider runways. Most pilots indicated that red filters on the back, or runway side, of the threshold lights are desirable. No pilot disapproved of the suggested change. Intensity control was fairly satisfactory at most stations. Some stations tended to use too high intensities for some restricted atmospheric conditions, primarily because the controller did not have a suitable indication of the intensity of the lights. Some additional instructions on the differences in intensities of different types of lights are needed. The runway lights should be used more in moderately restricted atmospheric conditions in daytime and twilight. Automatic intensity control is not required at present.

Runway markings were in the process of being changed from the old standard ANC-R-7, 27 Nov 1947, markings to the new Navy standard markings, S. E. drawings Nos. 118A and 119A, "Planning Standards for Naval Air Stations." Markings were not a controversial subject with pilots. Many pilots were not consciously aware of the individual features of the markings of either standard. The length-of-runway marking in the old standard was the feature which received the most discussion. Nearly half of the pilots wanted these markings retained. One or two stations had retained this feature in the new markings. Other pilots either had no preference or disliked these markings, stating that they added to the confusion and were difficult to read on approach. The pilots who used the length-of-runway markings felt these markings reduced the radio communications required and might be an added safety factor in flame-out landings at a strange field and when a pilot is directed to land on a runway which is too short for his aircraft. Some pilots preferred the use of parallel 6-inch lines to mark the runway axis to a solid or broken centerline, but others liked the broken centerline. The edge markings were generally favored. Distance markings painted on the runway were not considered satisfactory, probably because these markings provide little or no information at a time when judging distance is most difficult, as at night, in restricted visibility, and when there is snow or water on the runways. The use of markings with the reflective "beads" was advantageous when the aircraft had landing or taxiing lights. Most runways are repainted every one or two years. Shorter intervals are required for stations having great amounts of field carrier landing practice (FCLP). Then the markings might be repainted as often as every six months. The traffic paint is usually in poor condition after two years of use. Tire marks were the primary cause of markings becoming unsatisfactory in shorter periods. Jet blast did not appreciably affect runway markings, although blast damaged painted markings in areas where the planes were stationary, such as warm-up areas or at the compass rose. An improved paint for markings, or a suitable cleaning method would be beneficial at many stations.

Lighted runway-distance markers indicating the distance along the runway were considered to be the most satisfactory way of providing distance information. The presently specified vertical markers with an international orange background and a white numeral to indicate the number of thousands of feet of runway remaining, and externally illuminated, received the pilots' approval. They felt that the illuminating lights should be hooded to prevent bothersome glare and that the construction of the markers must be of a type which would not damage an aircraft in case of collision.

Some pilots would like to have flush or semiflush lights installed in the runway at every 1000- or 2000-foot point, coded to indicated the length of runway remaining.

4.1.3 Taxiway Lighting and Marking.

Taxiway lighting received a large number of complaints from pilots. Any Naval Air Station which is used at night should have taxiway lights because many Navy aircraft do not have landing or taxiing lights. Thus delineators are of little use. Although the night operations at one station were very limited, there had been several accidents attributed primarily to lack of taxiway lights. The type M-1 lights are preferred to the type AN-L-9 lights for taxiways, but a semiflush-type light is necessary at many locations in taxiway circuits. The type AN-L-9 lights are usually satisfactory for these locations. Intensity control is seriously needed for taxiway lights. The taxiway lights without intensity control were considered too bright by most pilots. The intensity of the taxiway lights was so high that pilots frequently lined up during the approach on the taxiway lights rather than on the runway lights. Suitable hooding of the taxiway lights was suggested to reduce the confusion during the approach. An intensity control with at least three steps is desired. The point-source blue lights provide very poor depth perception. Spurious rows of lights are easily visualized. Proper intensity control may improve depth perception and thus reduce the tendency of the pilot to follow rows of these lights which do not mark taxiways. At most stations the spacing of the taxiway lights at turns and curves and on intersections was too wide. The maximum spacing should be much less than the width of the taxiway at curves, turns, and intersections. The spacing on straightaways was satisfactory.

An improved method of indicating runway turnoffs is needed. Information on the direction as well as the location of the turnoff should be provided. The use of linear light sources to mark turnoffs, turns, and intersections was favorably considered. The use of blue lights marking runway turnoffs was desired, but a semiflush yellow or amber light installed at the point where the centerline of the taxiway intersects the edge of the runway was suggested. This light was considered desirable because often the taxiways are flared into the runway for such a distance that the double blue lights at the edges of the taxiway do not adequately indicate the location of the taxiway.

Lighted destination markers were desired by the pilots. Their use would reduce the need for radio communications during taxiing. The internally lighted destination markers were considered best. Obvious short abbreviations were preferred to coded symbols. Lanes for taxiing on ramps and in parking areas should be lighted with semiflush lights. Lighting of only the edge of the ramp is not satisfactory. Some fields had taxiways with wide paved areas at intersections. These areas need flush or semiflush lights. The taxiway-lighting system should have enough circuits to provide the tower complete control over the selection of taxiways to be lighted. Traffic-control operators should light only those taxiways which are in use. The lighting of all of the taxiways in order to give the pilot a choice should be discouraged.

The taxiway markings appeared to be satisfactory. One improvement suggested was that the edge of the taxiway should be marked with a painted stripe. This is especially helpful on curves and turns.

4.1.4 Seadrome Lighting and Marking.

The present seadrome lighting was inadequate in restricted visibility conditions. The type FMF-6B battery-operated, buoy-mounted lights were considered the best lights in service. Lights mounted on piles projecting above the water were considered by pilots to present too great a hazard. Apparently the pilots considered the hazard greater during maneuvering on the surface than when landing or taking off. Higher intensities than those of the type FMF-6B lights are desired. To provide better guidance, a spacing between lights in the line of lights of less than 500 feet is needed, but the spacing is limited by that required for maneuvering the seaplanes. The greatest need in buoy-mounted lights was a better switching control, preferably by shore-based power or by radio signal. Another major deficiency was the drifting of the buoys. An improvement in the visibility of the day markers for the buoy-mounted lights was needed. Most sealanes were marked by a row of buoy-mounted lights on one side of the lane but two rows were used when the sealane was in a narrow channel. The accepted width of a sealane was 1000 feet, but with improved lighting and markings of the sealane some narrower width was considered feasible.

Approach lighting for seadromes had not been given much consideration since the sealane lighting was not satisfactory for low-visibility approaches. The taxi lanes needed lighting and marking. The lighting of the ramps and anchoring buoys needed improving.

4.1.5 Obstruction Lighting and Marking.

The standard obstruction lighting performed adequately, but better control of the switching was needed at some stations. The flashing hazard beacons were often not maintained properly. The flash rate might be in need of adjustment. The kerosene flare pots should be replaced with suitable battery-powered lights for marking temporary or construction hazards. There were no complaints on painted obstruction markings.

4.1.6 Beacons.

The airport and airway beacons did not have enough intensity at the higher angles of elevation to meet the needs of present high-altitude operations. The pilots needed training in the identification provided by the beacons and the use of the beacons to indicate IFR conditions.

4.1.7 Floodlights.

The ramps and parking areas at many stations needed improved floodlighting. This floodlighting should provide adequate illumination for the area but should not be distracting at other areas. Suitable control of illumination can be obtained by design and placement of the lights by hooding and by providing suitable control circuits.

4.1.8 Wheels Watch.

The Wheels Watch was considered by the pilots to be a worthwhile safety operation. The Very pistol flare fired ahead of the plane by remote control is the most effective warning device. There was a need for a better method by which the observer could determine the position of the landing gear at night without disturbing the pilot's vision. Two methods which should be investigated were suggested. One was the installation of a special light on the landing gear and the other was the use of fluorescent paint on the gear with an ultraviolet light controlled by the Wheels Watch. Either method could be designed to provide a positive indication that the landing gear was down.

4.1.9 Arrester-Gear Markings.

The location along the runway of the arrester gear should be clearly indicated. Suitable painted markings for daytime and lights for nighttime were needed. Perhaps a tailhook check should be included with the Wheels Watch.

4.1.10 Wind-Direction Indicator.

A local wind-direction indicator near the end of each runway would be helpful. A centrally located indicator is often not visible. The information provided by the tower or tetrahedron often is not representative of the wind at the point of interest to the pilot. The local wind-direction indicator should be visible at night.

4.2 Related Airfield Installations

Airfield installations which do not directly come under visual landing aids were discussed at the conferences. Some of these installations are related to visual aids by their location or use and are summarized below.

4.2.1 Erosion by Jet and Propeller Blast.

Jet and propeller blast had not appreciably damaged concrete pavement and had not been a serious problem on asphaltic-conrete runways and taxiways except where the aircraft stood, or in runup areas. Erosion from this blast of stabilized areas and at edges of pavements was a problem at many stations. Aircraft had been seriously damaged by landing short of the threshold and striking the pavement because the adjacent surface had been eroded away several inches below the level of the runway. One station had marked the stabilized shoulders to indicate that they were not suitable for high-density loads. A better filler than tar was needed for the cracks and expansion joints of concrete because the jet blast melted the tar and blew it onto the light fixtures.

4.2.2 High-Speed Turnoffs to Taxiways.

Many pilots would like to have taxiways constructed to allow fairly high-speed turnoffs from the main runways. These taxiways might branch off the runway at as much as a 45-degree angle, but a somewhat smaller angle would be preferred. Some persons were concerned that such taxiways would encourage speeding during taxiing.

5. RECOMMENDATIONS

5.1 Visual Landing Aids Systems

5.1.1 General.

1. Standardize the visual landing aid systems at all Naval Air Stations and to the practical limit at all military and civilian fields.

2. Initiate a program for pilot training in the use of visual landing aids. This program should extend from the beginning of flight training throughout the pilot's career.

3. Investigate the desirability for a phrase in the landing instructions to the pilot from the control-tower operator giving the length of the runway, in order to prevent landings on runways too short for the aircraft.

5.1.2 Approach Lighting.

1. Standardize and install high-intensity approach-light systems as rapidly as possible. Replace obsolete approach lights with high-intensity lights. Pilots considered standardization of approach lights the most important step in the improvement of visual landing aids.

2. Develop and install a circling-approach-light system where the installation of high-intensity approach lights is not justified but where atmospheric conditions create a need for some visual approach aids.

5.1.3 Runway Lighting and Marking.

1. Replace type D-1 and type AN-L-9 runway lights with modern high- and medium-intensity lighting.

2. Train control-tower operators and pilots to use runway lights on a high brightness setting in daytime during many visual-flight-rules (VFR) conditions in which the visual range of the lights is significantly greater than that of the runway.

3. Install red filters on the back (downwind side) of the threshold lights to mark the end of the runway.

4. Install illuminated runway-distance markers to indicate the remaining distance to the end of the runway.

5. Develop and install improved lighting and markings to indicate runway turnoffs.

5.1.4 Taxiway Lighting and Marking.

1. Install intensity control on taxiway lighting.

2. Improve the lighting configuration at taxiway intersections and turns. (Closer spacing of present lights would help, but linear sources or other type lighting may be a greater improvement.)

3. Install parallel rows of lights to mark taxiways on ramps and in parking areas.

4. Install illuminated destination markers. Provide an adequate number of taxiway circuits and instruct control-tower operators in proper selection of lighted taxiway circuits.

5. Install taxiway edge markings.

5.1.5 Seadrome Lighting and Marking.

1. Develop and install sealane lights with higher intensity than that provided by type FMF-6B lights. These lights should have fixed directional orientation and should be anchored to prevent drifting out of line.

2. Develop better methods of switching sealane lights.

3. Develop a better battery for the type FMF-6B lights.

4. Develop larger, more conspicuous, and longer lasting day markers for buoy lights.

5. Develop and install lighting and markings for taxi lanes.

5.1.6 Miscellaneous Airfield Lighting.

1. Modify the airport beacon to provide higher intensities at the higher angles of elevation.

2. Develop a portable battery-powered light to replace flare pots for temporary marking of hazards or of construction on the airfield.

3. Develop a wind-direction indicator to indicate the wind direction in the touchdown areas of each runway.

5.1.7 Cables and Wiring.

1. Establish specifications for contract installations specifying satisfactory insulation resistance requirements for underground circuits.

2. Replace all obsolete type cables which do not meet established requirements for satisfactory insulation resistance.

3. Carefully locate electrical manholes in refueling areas to prevent accumulation of fuel in manholes.

5.1.8 Vault and Control Tower Equipment.

1. Standardize the position of input and output terminals of regulators and other major components in the vault to facilitate replacement by a unit of a different model or manufacturer.

2. Revise the vault circuitry so that power for the vault light, plugs, and control voltages is taken from a transformer connected ahead of the incoming primary oil-fused cutouts.

3. Install ammeters and voltmeters in the output circuits of all regulators.

4. Make a study of the desirability of and requirements for providing emergency power for visual landing aids.

5. Develop a runway selector and intensity-control system for stations with parallel runways.

5.2 Improvements in Maintenance

The maintenance of the visual landing aids at the stations visited on this survey was said to be satisfactory to very good. Suggestions on ways of improving maintenance were obtained. Those of particular importance are listed in the recommendations below.

5.2.1 Maintenance Personnel.

1. Assign the maintenance to one man as his direct responsibility and his primary task. (Additional personnel may be used as the work load requires.)

2. Establish a classification of airfield-lighting-maintenance technician.

3. Establish a training program for airfield-lighting technicians. (This program should include basic fundamentals of airfield-lighting maintenance for personnel without previous training, and periodic review and instructions on new procedures and equipment.)

4. Allot a definite amount of time for study of technical information by maintenance personnel.

5.2.2 Maintenance Equipment.

1. Assign a vehicle equipped with the required obstruction lighting and markings to the airfield-lighting-maintenance technician. The vehicle should be equipped with two-way radio communications to the tower.

2. Provide the maintenance technician with a suitable high-voltage limited-current insulation-resistance tester.

3. Provide special tools and equipment for maintenance of airfield lighting.

5.2.3 Maintenance and Troubleshooting Procedures.

1. Provide for participation by the airfield-lighting technician in the final acceptance testing of contract installations, especially the insulation-resistance testing.

2. Establish requirements for routine and preventive maintenance and for recording needed maintenance and troubleshooting data.

3. Develop a more satisfactory method of locating open faults in cables.

5.2.4 Supplies and Repairs.

1. Furnish maintenance personnel with an applicable Aviation Supply Office (ASO) catalog with a pictorial section of visual-landing-aids equipment. Include instructions on the channels for procurement.

2. Require that a technical order, instruction manual, or parts list shall be included with the shipment of each complete major item of equipment. These instructions should include the Navy stock number for each part that is not a standard hardware item and should indicate which items are to be procured from Navy stock, which are to be obtained from the manufacturer, and which require replacing the entire component.

3. Provide working, storage, and office space for the airfield-lighting technician, preferably at the airfield-lighting vault.

4. Improve the present method of determining whether major equipment should be returned to the depot for repair or repaired locally. Improve the procedure for determining when obsolete equipment should be scrapped instead of being repaired.

5.2.5 Technical Information for Maintenance.

1. Supply copies of the Air Force Manual AFM 88-14 and applicable Airfield Lighting and Marking Technical Instructions (ATL's and ATM's), or their equivalent to the airfield-lighting-maintenance technicians as soon as possible.

2. Establish a procedure for distributing technical information which will make certain that the needed information will go to the person performing the maintenance. A bibliography of available technical information should be distributed and revised periodically.

3. Provide the airfield-lighting-maintenance technician with all current drawings of airfield-lighting installations. Develop a procedure for keeping these drawings current.

4. Prepare a manual for maintenance and troubleshooting of airfield lighting.

APPENDIX A

Itinerary

Naval Air Station, Alameda, California	July 23-24, 1956
Naval Air Station, Moffett Field, California	July 25-26, 1956
Naval Air Station, Miramar, California	August 13-14, 1956
Naval Air Station, North Island, California	August 15-16, 1956
Naval Auxiliary Air Station, Brown Field, California	August 17, 1956
Marine Air Corps Station, El Toro, California	August 20-21, 1956
Naval Air Station, Point Mugu, California	August 22-23, 1956

APPENDIX B

Persons Interviewed

Naval Air Station, Alameda, California

Comdr. Heaman, PW Officer
Comdr. Riddick, Asst. Ops. Officer
Comdr. D. E. Johns, Aerology
Lt. Comdr. Croft, Ops.
W/O R. F. Nance, Chief BM, Seadrome Lighting
Mr. James M. Vance, PW Engineering
Mr. Tex Loomey, PW Maintenance Engineer
Mr. Douglas Heddell, PW Foreman
Mr. Henry Adams, PW Supervisor
Mr. Bill Richards, PW Quarterman
Mr. A. J. Squires, PW Airfield Lighting Electrician
Mr. L. F. Carries, PW Airfield Lighting Electrician
Mr. P. S. Ehrman, PW Maintenance
Mr. Arnold Seeprl, PW Electrician

Naval Air Station, Moffett Field, California

Capt. A. S. Hill, C.O.
Comdr. W. G. Wright III, Ex. O.
Comdr. J. A. Morrison, Asst. OPS Officer *
Comdr. M. L. Hall, VR-3
Lt. Comdr. R. G. Baker, Asst. ATC Officer, OPS *
Lt. Comdr. F. A. Nelson, Aerological Officer *
Lt. D. Hoskins, Asst. PWO *
Lt. W. S. Murphy, Pilot and FSO, VF(AW)3 *
Ens. M. L. Zuidema, Maintenance Officer
T. A. Wright, ACC, Chief Controller *
Mr. M. M. Viele, PW Director of Design *
Mr. P. Victors, PW Engineer *
Mr. R. R. Miller, PW Foreman *
Mr. A. R. Johnson, PW Maintenance Control *
Mr. G. M. Stillens, PW Leadingman *
Mr. R. A. Dorman, M.C.D. Inspector Electrical *
Mr. N. O. Hanson, M.C.D., P.E. Electrician *
Mr. P. F. Leverenz, PW Elect. Engineer *
Mr. E. Pace, PW Design
Mr. Clark Songer, PW Electrician

Persons Interviewed (continued)

Naval Air Station, Miramar, California

Lt. Comdr. J. B. Julian, Asst. PWO
Lt. Comdr. F. W. Brown, Flight Officer
Lt. Comdr. C. L. Duss, VA54 *
Lt. Comdr. John M. Suddreth, VFP61 *
Ens. J. P. Ussher, Line and Field Officer
Mr. R. J. Michel, PW Director of Design
Mr. E. Giorgi, PW Design *
Mr. G. L. Coburn, PW Quarterman *
Mr. W. F. McCullum, PW Electrician
Mr. G. W. Burton, PW Electrician
Mr. M. Fierro, PW Electrician
Mr. F. Norton, PW Electrician
Mr. C. R. Bradley, PW Leadingman

Naval Air Station, North Island, California

Capt. G. E. Fisher, PWO *2
Capt. J. Sinkankas, Air Safety Officer, ComAirPac *2
Comdr. B. S. Brooks, Base Planning Officer, ComAirPac *2
Comdr. B. G. Swonetz, PATRON Training Officer, ComAirPac *2
Lt. Comdr. J. W. Allen, Jr., Asst. PATRON Training Officer, ComAirPac *2
Lt. Comdr. D. G. Wilson, FAIR, San Diego, ComAirPac, DN90 *1, 2
Lt. W. R. Creel, OPS *1
Mr. G. B. Woodd, PW Director of Design
Mr. C. M. Neidelmen, Base Dev. Eng., ComAirPac *2
Mr. G. R. Dedman, PW Planning and Reports
Mr. R. N. Foster, PW Asst. Planning and Reports
Mr. W. D. Southworth, PW Engineering *1
Mr. P. M. Steelmen, PW Quarterman Elect. *1
Mr. R. G. White, PW Elect. Shop *1
Mr. A. R. Caraccio, PW Electrician
Mr. L. Castro, PW Electrician

Naval Auxiliary Air Station, Brown Field, California

Capt. J. Gazze, C.O.
Comdr. J. Southland, Ex. O.
Lt. Comdr. R. E. Edwards, OPS *
Lt. Comdr. R. E. Foltz, Asst. OPS *
Lt. Comdr. W. E. Rohde, VU-7 *
Lt. J. W. Bevin, VU-3 OPS *
Lt. (jg.) R. B. Reeves, PWO *

Persons Interviewed (continued)

Naval Auxiliary Air Station, Brown Field, California (continued)

Lt. (jg.) R. W. Marshall *
B. J. Spinks, AC1, OPS Tower *
Mr. H. J. Wheeler, PW Planner-Estimator
Mr. B. F. Schroeder, PW Quarterman
Mr. Austin L. Cartwright, PW Snapper, Elec. *

Marine Air Corps Station, El Toro, California

Major V. R. Martin, OPS O. *
Capt. John R. DuBois, Control Tower O. *
Capt. C. O. Reinhardt, PWO
Ens. R. J. Dietrich, PW Maintenance O.
M. Sgt. W. L. Simpson, VMF(AW)542 *
Mr. P. L. Vaughan, PW Director of Design
Mr. Robert H. Graham, PW Elect. Engineer *
Mr. M. E. Sorrell, PW Chief Quarterman *
Mr. L. A. Herman, PW Foreman
Mr. A. E. Johansen, PW *
Mr. H. Armor, PW Electrician
Mr. I. E. Nelson, Inspector, Installations
Mr. L. W. Selindh

Naval Air Station, Point Mugu, California

Comdr. E. S. Park, OPS VX4 *
Lt. Comdr. N. S. Kavanagh, OPS *
Lt. Comdr. D. M. Phillips, OPS *
Lt. P. L. Filson, Aerology *
Mr. V. T. Font, PW Elect. Eng. *
Mr. H. I. Davies, PW CE *
Mr. R. S. Longnecker, PW Quarterman *
Mr. J. L. Stead, PW Snapper Electrician

* Indicates attendance at conference for discussion of operational problems from pilot's view.

*1 or *2 Two conferences were held at North Island. Attendance at one or two conferences is indicated.

APPENDIX C

EXCERPTS OF COMMENTS RECORDED AT THE CONFERENCES

C.1 THE CONFERENCES

During the survey of visual landing aids at Naval and Marine Corps Air Stations in California, conferences on the operational requirements of these aids were held at six of the seven stations. These conferences were intended to obtain the pilots' reactions to visual landing aids. Representatives from the operational squadrons and units of the station were invited to attend. Frequently these representatives were the unit Safety Officers or Operations Officers. Others in attendance were representatives from the station's Operations Office, Control Tower, Aerology, Public Works Engineering, and Public Works Maintenance. In addition, a conference was held with members of ComAirPac headquarters. All conferences except that with the ComAirPac group were recorded by a magnetic tape recorder. A brief form with general headings of the subjects for discussion was used as a guide. Discussions were not limited to the outlined topic or to the visual aids at the station being surveyed.

C.1.1 Reporting Comments.

The tape recordings were reviewed and many of the informative and interesting remarks were transcribed. From the transcriptions of all conferences, important or pertinent comments were selected and compiled under the headings indicated below. For the more controversial subjects, remarks indicative of the different opinions are reported. Special introductory or explanatory statements or corrections of known errors in statements are set off by parenthesis. Each quoted comment is enclosed by quotation marks. Statements without quotations marks or parentheses are summaries or conclusions of the authors of this report.

C.2 STANDARDIZATION OF VISUAL LANDING AIDS

The pilots unanimously agreed that standardization was the greatest need in the field of visual landing aids. While the extent of standardization needed was not specified, the pilots considered that accepting something less than the optimum would be preferable to continued waiting for an agreement to be reached.

"In (regard to) lighting and distance markings at all fields, I think that it would help all pilots if you would come to a standard. (Applause) You get confused from one field to the other." "If you don't operate out of a field a few times, you don't know what the markings mean. (On) going into a strange field you have your landing completed before you can figure (out) what their markings mean." "If all pilots are flying the same thing, they will become more proficient on it." "I think that the Government should say one way or the other and (everyone) in the United States use (that)one. This bickering is ridiculous." "As long as you standardize, that's all that is required. As fast as you develop something, somebody is going to come up with a new idea - - but when you get a dozen different systems and (each) is different every place that you go, that's where you get into trouble."

C.3 APPROACH LIGHTING

C.3.1 General

Some visual aid ahead of the runway lights at all fields was indicated as a need by most pilots because of the smoke and haze in the areas around the stations which were surveyed. "Primarily here the pilots are interested in seeing the runway through haze and smog and getting lined up with it. Sometimes this is very hard, even in VFR conditions, when there is no overcast or anything else." "We need approach lights of any sort." "Approach lights are a real help for lining up in congested areas." "We need better lighting for circling approaches."

Standardization and as many installations as possible are regarded by pilots as the prime consideration in approach lighting. "They should standardize on most any one system." "I feel that as long as we standardize, that is all that is required. As long as you have a system that is satisfactory and does the job and everybody buys it, that is all that is required."

Some pilots reported that freeways and toll roads near airfields caused confusion and were a potential hazard, especially if these highways were near the airfield and approximately parallel to the direction of the runway. "The biggest trouble we run into is getting lined up with the runway, if you have one of those expressways or freeways or something like that. Sometimes they give off a greenish cast or bluish cast depending on what the haze is like. We've had people get lined up on those toll roads, or whatever they happen to be, particularly where there is a toll gate, thinking that this was the runway and threshold lights."

This confusion and glare from vehicles was a common complaint at Moffett Field although the highway is nearly perpendicular to the runway. "The traffic control system in effect in the San Francisco Bay area will seriously limit the usefulness of a good approach-light system here. At present all that is needed is something to help line up with the runway before you can see the runway lights, although we hope the traffic control system will be changed soon." This was the opinion of the pilots at Moffett Field.

C.3.2 Approach-Light Systems.

Only three stations had approach-light systems. All were obsolete parallel-row systems with the type D-1 lighting units. During the conferences only passing mention was made of these systems by the pilots. The following comments made by the pilots appear to be based on their knowledge of more recent developments in approach lighting.

The slopeline (composite) system, the ALPA center-row system, and the Air Force overrun system were the major approach-lighting configurations discussed. More pilots indicated a preference for the slopeline or composite approach lights than for any other system, but others were certain the center-row system was the better system. "The slopeline system is a secondhand GCA." "The center-row system affords good identification but there is a loss of attitude orientation." "The center-row system presents a mental problem." "Will the new system give any glide-slope information?" "I'll fight to my dying day for a single center row with the crossbars." "You can't miss at Los Angeles when you come in. They have the slopeline." "Those are the regular slopeline approach lights at Los Angeles. I like them; that is a good system." "I like a funnel-type of an approach-light system." "Cockpit cutoff of a center-row system will be less of a problem for most jets than for single-engine prop (fighter) aircraft."

Any approach-light system that extends only 1500 feet from the threshold will be seriously limited in effectiveness for jet aircraft. The opinion of several pilots was that landings in the approach zone short of the runway threshold caused by misinterpreting the approach lights can not be entirely eliminated by the configuration. "With any system a few pilots will land between them the same as a few pilots land wheels up with the horn blowing."

Red was considered the best color for approach lights, although not completely reliable, but some other color such as white would be acceptable if the benefits were increased sufficiently. In a system using rows of single red lights, such as the parallel-row system, "the obstruction lights outlining a series of buildings or poles would give a similar pattern" which could be a source of serious confusion.

Approval of an approach-beacon system similar to that being tested at the Field Laboratory at Arcata for use on approaches to runways not equipped with approach lights was expressed by many pilots. "An installation of this kind would be particularly useful because during an approach at altitudes of 1000 to 1500 feet over the field, the runway may be very easily seen, but when on base and final letdown, visibility in smog and haze is reduced and some aid is needed for alignment before the runway threshold is again visible." Regarding the use of red filters on the approach beacons, a Public Works Officer warned, "If a strange pilot came in and saw a flashing red, wouldn't that mean that he would have to take a wave-off?" The pilots expressed no opinion on this point.

The mirror landing system was generally praised as a great improvement over the Landing Signal Officer for carrier-deck landing. Some pilots reported some malfunctions in certain installations, but as one pilot said, "Not that it's perfect, but it is a real fine piece of gear right now. If you try to refine it more, the more likely you are to run into the basic features of the gear and that, in my opinion, isn't good. I hate to see them fool with it at all." "Trying to put everything into one piece of gear has advantages but if they get to fooling with the gear and get down to working on the basic pieces of the equipment, then it just isn't good any more."

C.3.3 Brightness Control.

No comments were made in regard to brightness settings of the approach lights. In the absence of comments, even when requested, it can be assumed that the tower operators are doing a satisfactory job of setting the brightness for the existing visibility conditions or that the intensity of the type D-1 lights with the red filters is so low for most directions of view that glare is not a problem.

C.3.4 Hazards.

Hazards of approach lights were not fully discussed because the pilots did not have enough experience with the high-intensity systems. Confusion of highways with runways and approach zones, and of rows of obstruction lights and red approach beacons with a wave-off signal are discussed above. The location of the landing mirror at one station conflicted with traffic.

C.4 RUNWAY LIGHTING AND MARKING

The comments on runway lights and markings include opinions on types of lighting systems, intensity control, painted runway markings, runway distance markers, turnoff indicators, and hazards of lighting and markings.

C.4.1 Lighting Systems.

Most pilots agreed that the type AN-L-9 semiflush runway lights are not adequate for use at these stations because of the prevalent haze and smog conditions. "The lights on (runway) 3-21 (type C-1) are fine; the ones on (runway) 9-27 (type AN-L-9) are not too bright. If you don't have pretty good visibility you have to be almost on top of them to see them." "We do need something a little brighter than we have now on (runway) 9-27 (type AN-L-9); the medium-intensity lights would be fine." "The high-intensity lights are better (than medium-intensity lights); there is no doubt about it. Here our main problem is restricted visibility a high percent of the time so the high-intensity lights are good. Of course the high-intensity lights have disadvantages too. Every military field that has snow operations, they just knock the heck out of the high-intensity lights." "During a normal circling approach the (type) C-1 lights can be seen very well, depending on the weather of course, but there is a tendency to lose them on a clear night on downwind and base legs when they (the type C-1 lights) are on brightness steps one or two."

Discontinuing the use of yellow filters on the runway lights on the final 1600 feet of runway was generally approved by the pilots except at one station where the end of the runway was difficult to observe. The use of illuminated runway distance markers will probably provide the information needed for these runways. "I thought that (elimination of the yellow lights) was a good idea. An increase in intensity as you get close to the end of the runway would help." "I think that they (yellow lights) did not serve any purpose. They tended to confuse people more than help them, particularly with present day aircraft." "We put in to have them (the yellow lights) reinstalled at the request of the tactical units here, not that we in Operations wanted them." "We had a particular problem on that runway (same station as previous comment). It is considerably lower in the middle and once you are down on it in these jet aircraft, you can't see the other end. They particularly wanted the amber (yellow) lights so they could tell where they were on it (the runway). Since (then) they have installed the lighted distance markers on the side of the runway."

Condensation inside the light units or dust on the lights may be a problem at some stations. "One of our local problems is dust settling on the lights (probably condensation). I have had pilots complain to the tower that the lights appear dimmer even though the lights were set brighter than the natural (normal) setting of the lights." "If you put the lights on high intensity, condensation should burn off in a short time. (It may take 15 to 30 minutes.)" "(Jet blast melts) the tar in the joints of the concrete section lines. They blow the tar all over (the lights) and this requires cleaning the light fixtures."

C.4.2 Brightness Control.

Most pilots seemed to be fairly well satisfied with the brightness settings of runway lights at night. The runway lights are not used as often as they should be during daytime and, if used, are likely to be set on a brightness step which is too low. No one indicated a real need for automatic intensity control for present installations. "We haven't had any squawks from the pilots due to intensity. Tower operators start off with a (brightness step) 2 setting on the high-intensity (lights) and on a clear night they bring it down to 1. When it is hazy or foggy they will turn it up or when any pilot requests it. It (the pilot's preference) varies all night." "I have been in the traffic pattern and asked for them (the runway lights) to be turned down and the next pilot will ask for them to be turned up. At nighttime it just gets to be pilot's choice." "You can set the lights to the (established) criteria and operate all night long without any comments. If you ask for comments nobody will like them the way they are, regardless of where you have them set. When we get a comment we change them, of course." "On a normal night (step) 2 or 3 would be very satisfactory. The only time you ever lose them is on a clear night when they are down to (step) 1. You do tend to lose them over at 180 (degrees) or downwind a ways. You can't help it." "At other fields I have frequently asked (the control tower) to turn the high-intensity lights down lower. They can get things too bright." "For FCLP (flight carrier landing practice) at night we have to call the tower to get the runway lights down to a very low level. If we could get them lower yet, it would be more ideal. They are too high (bright) at the lowest level they can get." "I have had to request that the lights be turned up numerous times. I have never yet been blinded by the lights. As a general rule I find that for a given visibility condition, they keep the lights too low. My remarks are on daylight conditions primarily. I get better depth perception from bright lights."

The momentary cutting off of power to the lights by the push-to-turn type switches was the subject of some comments. This did not appear to be a frequent problem. "We change them (the intensity of the lights) at the pilot's request. The switching is not the best because when you change intensity you have to push your switch down, which temporarily cuts off your lights. That could be improved considerably." "Momentarily the lights go out (as you change intensity settings) but the delay is short and I have never been bothered with it."

C.4.3 Painted Runway Markings.

Painted markings on the runway were not a controversial topic except for the length-of-runway symbols (see Paragraph C.5.2). Most naval aircraft do not have landing or taxiing lights; thus these markings are of limited use at night. The runway markings at some stations were still the old configuration, drawing ANC 1100, 26 Nov 47, but at most stations the markings were recently changed to the new configuration, drawing S. E. No. 119A, 16 May 55, with some minor variations. "No comments were received, one way or the other, after the markings were changed from the old (configuration) to the new configuration." "I like the present markings (old configuration). I like the distance markings on the ends (probably length-of-runway symbols) and the two stripes down the runway (longitudinal stripes). I like it a lot better than I do the dotted (broken) lines." "I like the new markings (new configurations) as they are. I have landed in low visibility conditions with landing lights and as you go over the end of the runway with all those marks you get a terrific glare. I would just as soon not have the reflective paint there." "I like it (the runway edge markings)." "The new all-weather runway painting (AGA-NS 2 standard configuration) is not dependent on the length of the runway--that is, in proportion to the runway. There is a big blank spot in the middle. I landed at Oxnard and thought I had come to the end of the runway when the paint stopped." "I have never noticed them (painted distance markings on the runway) (at night). I don't believe those would be satisfactory for carrier-type aircraft where you don't have floodlights (landing lights) on your aircraft. Unless you have landing lights on your aircraft you just don't see things like that on the runway at night. In the daytime it would be O.K." "It seems to me that any markings that are put along the sides (runway distance markers) would be more helpful, particularly at night."

Several special problems or suggestions on markings were mentioned. "One of the problems we have is that after about 1500 or 2000 landings the markings have to be painted again." "Our markings are holding up rather well (under jet blast)." "I think that every field should have a carrier deck marked out." "How about a flame-out circle? That was used for training purpose to practice flame-out landings. We are shifting to jets more and more every day and there will be more need for this marker." "Have you ever had anything at all on infrared or reflected (fluorescent) light, something like the fluorescent type (markings) with black light? You can wear dark glasses all day and, when they turn the lights on, your night vision is gone, just like that. Is there anything you can do about that? Something that won't ruin your night vision, but will outline the runway?"

C.4.4 Runway Distance Markers.

Markers indicating the distance along the runway were desired by a majority of the pilots. Unless otherwise indicated, the runway distance markers referred to are the vertical signs placed outside the edge of the runway at 1000-foot intervals with a numeral indicating the remaining distance in thousands of feet to the end of the runway. "Something that was put in at Atlantic City that I found extremely helpful was the side markings along the sides of the runway indicating how much runway there was left to go." "They like the ones (runway distance markers) we have here and use them." "I like to know where I am all the time if I can. I use them all the way down the runway. That way I can save the brakes and tires." "Another confusion is when you don't notice the first couple (of markers) because you are busy aligning the aircraft and the first one you see is, say (at) 5000 feet. The first thought is, you don't know whether you are 5000 feet down or have 5000 feet left, until you get used to it. It is strictly a matter of becoming familiar with what the standards are." "Any good clear combination (of numeral and background) will be all right except black and white."

These markers should be illuminated for use at night. "We can't see them at night. Even in the daytime when we get a few of them knocked down, we begin to get complaints. They are used in daytime." "We have the 2600-foot and 1500-foot (markers) on both sides of the runway illuminated. It's (the marker is illuminated by) a special lamp developed by the Air Force for that purpose (not specifically). It is the 200-watt, PAR 56 (lamp). We had to build a special shielding for it. They are right in series with the rest of the (runway-light) circuit. When they are running (using) reduced intensity on the runway lights, we have reduced brightness on our signs. I think they are adequate because there haven't been any complaints about them." "I think you will have to make those signs terribly large for a pilot landing at night to notice the number. I don't know what value they would be at all." "You don't want to get them (the runway distance markers) up too high because at night you are watching the runway lights and so long as you don't have to look above them much they will be O.K. If the signs sit low enough, then you can see the sign. You can go that high (18 inches off the ground) without any trouble."

Some possible hazards in the installation of runway distance markers were pointed out. "Those distance markers that we have in now may be actually a slight hazard. They are held upright by two steel rods driven into the ground. What we need is something that will bend or get knocked over and not break." "Several of these markers have been destroyed by aircraft collisions and no reported damage to aircraft has resulted." "I use them and they do get knocked down." "Unshaded white light (for illuminating markers) is a hazard."

Some changes or other methods of distance marking were suggested. "How about black light (to illuminate runway distance markers); have they tried that?" "How about a black light with fluorescent paint? You can get very bright colors." "If you had two lights and the next thousand feet (you had) three lights and keep building up every thousand or two thousand feet (by) coming in toward the centerline without coming all the way, would that be visible? What would be the problem of designing and placing lights of that nature every 2000 feet along the runway?" "Something obvious like a light in the middle of the runway, for example at the halfway point (is better). The stripe or strip lighting across the runway is one of the more popular things for marking off runway distance at night. Maybe reflective markings?" "All runways should be marked with a distance marker. If he (the pilot) is passing over the top of it, say it is marked on the runway, he unconsciously knows just what it is and it registers on him at that point." "Painting (distance markers) on the runway I do not agree with. Off to the side of the runway, I think I would like that."

C.4.5 Runway Turnoff Indicators.

The opinion of most pilots was that runway turnoff identification, especially at night, needs improvement. "Turnoff indicator lights are needed." "If you have the high-intensity lights up on (step) 3, 4, or 5, regardless of the weather conditions, you have difficulty locating the taxiway lights for your turnoffs." Those lights (double blue, type M-1 lights at taxiway entrances but no other taxiway lights) are about as far from the taxiway edge as the taxiway is wide. Somewhere in the middle third is a taxiway and that is no good." "It would be desirable to see the lights marking the runway turnoffs 2000 feet away." "You have to know whether you are going to turn 30°, or 90°, or whether it goes back 150°." "I don't think that (runway turnoff lights) are too much of a problem because you light the taxiway that you want the guy to turn onto." "When the pilot gets to the end of his rollout we turn the lights down and flash on the taxiway (lights) we want him to take. We have no problem there at all. Before we could do that (flash the taxiway lights), it was quite a problem."

Some other possible methods of marking turnoffs were suggested. "Those arrows (illuminated taxiway destination markers) are really a big help." "Something like lucite (plastic linear lights) which can be curved are needed as lights for turnoffs and turns." "What would be wrong with putting a partly submersed (flush or semiflush), say yellow, light where the yellow stripe intersects the runway edge?"

C.4.6 Hazards in Runway Lighting and Markings.

There were no reports of damage to aircraft from striking runway lights although many lights had been hit. "Three or four light units per week, average, are damaged by planes. (Damage to aircraft from light units) none reported. The break-off nipples are fine and do a good job." "We do get quite a lot of the lights damaged by both aircraft and vehicles. I would say that damage to aircraft is practically none. The new lights (type C-1) just get knocked down. It would seem that there is more damage (to aircraft) from our auxiliary power units and things like that than from the runway and taxiway lights." "I sat on several accident boards (investigating accidents) which took out runway lights. The lights are a good gauge of where things begin to happen. We never had anything that you could attribute to the lights, no damage whatsoever." "There is very minor damage to aircraft from crashing into lights. Even on the drones you don't notice any marks on the aircraft except for a little yellow paint on the surface."

The glare from improperly shielded lights for illuminating the runway distance markers and steel rods or pipes for supporting the distance markers can be a hazard.

One station often used intersecting runways alternately. This increased the possibility of a collision. "We operate both runways practically at the same time quite a bit. Both runways are in use alternately. We'll have planes landing on (runway) 29 and at the same time our takeoffs are departing on (runway) 18." "(Regarding possible collision) Well, they are spaced. Primarily when we have instruments (are on instrument flight rules) this (runway 29) is our GCA runway for landing and all our departures go off of (runway) 18 because we have a 195 (degree) climbout. GCA can pick them up and track them out on departure. We hold up departures to bring the landings in on (runway) 29. We're practically using dual runways that cross." "It really doesn't bother anybody." "It works out pretty good. We can get traffic in and out."

The hazards produced by confusion of taxiway lights with runway lights, causing pilots to land on taxiways or between the taxiway and runway is discussed in Paragraph C.6.1.

C.5 THRESHOLD LIGHTING AND MARKING

C.5.1 System.

All stations had standard threshold-lighting configurations. All pilots are familiar with and use the green threshold lights for the purpose for which they were designed. There were no adverse comments on the use of red-green (red for takeoff and green for landing) threshold lights and in most instances it was indicated that this would be preferred over the green-green. As summed up by one pilot, "Green and red is O.K. as you are in an entirely different situation." Some pilots wanted stronger threshold lights for more positive identification. "I want a solid row (of green lights) across there (threshold) where I can see them." Others state, "Those lights in the middle aren't any good to me. Where the runways are very wide and the lights are way out to the side you feel as though you are sinking into a well."

C.5.2 Painted Threshold Markings.

The length-of-runway symbols were the threshold markings that received the most discussion. Of the pilots indicating a preference, more pilots hoped to keep the length-of-runway symbols than felt that elimination of these markings was an improvement. "I use the length-of-runway at the threshold, keeping in mind the type of aircraft I am flying." "I have been directed to land on a certain runway and then call the tower to find out the length of the runway. Then if it is too short I'll take a wave-off." "When you have an engine failure you immediately start scanning for runways and for the longest one. When you are down to 10,000 or 15,000 feet you can pick out the runway length by looking at those marks. If there is a cross mark that indicates 5000 feet, you can make your decision."

"Pilots of carrier-type planes are not worried as much about them (threshold markings) as other pilots." "There is too much marking in the threshold; just a number (heading) and simple centerline and side markings. All of the other markings are sometimes confusing." "That's right, the important things you can't find because of all of the other marks." "Something is needed to indicate the threshold as different from the overrun area." Some pilots stated that illuminating the threshold markings with "dust-pan" lighting is useful, but others do not want this area illuminated.

C.5.3 Hazards in Threshold Lighting and Marking.

Comments in Paragraph C.4.6 apply also to threshold lights.

Improper alignment of threshold lights may be a hazard. "Because of pilot complaints that the threshold lights were too bright, we turned the lights 90 degrees on the base so the pilot landing and taking off was looking at the side of them. Then a pilot ran off the end and said he couldn't see the lights at the end so we have turned them back around correctly now."

C.6 TAXIWAY LIGHTING AND MARKING

Changes in taxiway lighting and markings, in the opinion of the pilots, seemed less urgent than changes in some of the other visual landing aids, but when the changes were discussed in detail, the pilots were in better agreement on complaints, deficiencies, and suggested improvements of taxiway lighting than on most other types of visual landing aids. When first queried about the use of blue taxiway lights most pilots replied, "I have learned to use and like them." "Our lights here are better than at most stations." It was interesting to note that almost without exception the pilots who had stated that they had not had any difficulty with the blue taxiway lights, during the course of the conference remarked on the difficulty of using them. The majority of the difficulties appeared to be due to the loss of depth perception, which is apparently caused by point-source blue lights. Other common problems encountered were glare from these lights and the identification of intersections and curves.

C.6.1 Taxiway Lighting - General.

The opinion of many pilots was that the blue lights used in taxiway lighting furnish very poor distance information at night and are hard to line up properly. "Depth perception on a blue light at night is very poor." "The lights on the opposite side of that turn look just as close as the ones on this side until you are right on top of them." "You can't judge distance with blue lights. In following another plane it is pretty easy to overrun it unless you see its tail lights." "At El Toro I have been more confused than anywhere else in my life. Even with the landing lights on I couldn't find my way around. Not only the taxiway blue lights but they also have traffic lane blue lights, so it appears as one maze of conglomeration." (This may have been before El Toro put intensity control on the taxiway lights.) "Quonset Point has the most horrible taxiing system I have ever seen anywhere." On commenting that the local pilots were not complaining of a taxiway-lighting system being critized, "You know your own field, but going into a strange field it is a much different matter." "They have an end of a runway where they have a taxiway, another that 'Y's into it, and the master taxiway at another angle. All you see down there is a blue forest." "You can get most any kind of pattern that you look for out there."

Taxiway lights were a source of confusion during approaches and may be responsible for some landings off the runway. "You can see those things (taxiway lights) way before you can see the runway lights (when downwind or off to the side of the runway)." "You are always looking for the field at night and all of a sudden you see those and you think there is the runway without really paying attention whether it is the runway or not, and being far away you can't tell the color." "We have had people line up on the taxiway here at night--transients coming in here (line up) on the high-speed taxiway. They felt there should be some sort of shield over the taxiway lights." "(Taxiway lights) should have black tops so they can't be seen from above." "Paint the top half of the taxiway light black or have a hood made to form a reflector, to reflect the light onto the taxiway." "At Atlantic City there were landings, particularly field-carrier landings, between the taxiway and runway."

Several pilots indicated that improvement in taxiway lighting was lagging behind that in runway lighting. "I feel that improvement of the runway lights is something we have and the taxiway lights are something we have to have." "The biggest thing we get squawks about is the taxiway lights. They get lost out here." "My experiences have been mostly with multi-engine aircraft where they have taxiing lights attached to the nose wheel or landing lights and you can see where you are going. The bulk of our operation here is carrier-type aircraft that do not have any forward visibility (lighting) so consequently our taxiway-lighting system should be better than normal for multi-engine (aircraft)."

C.6.2 Taxiway-Lighting Systems and Configurations.

The most needed improvements in taxiway-lighting systems, according to the pilots, are better lighting and identification at intersections, curves, turns, and runway turnoffs; lighted taxi lanes on aprons, not just a row of lights marking the edge of the apron; brightness control; and better control of the taxiway circuits.

"I think that where you have a straight taxiway the lights are sufficient now, but are not if you have a long curve or turn." "On a turn you get confused; these lights start running together. Now at this curve, those lights run right across it. You say, 'Just which way does it go?' Now if the lights were closer spaced (that would help)." "You wouldn't know whether to go between those two, or these two, or where to go. On those 90 degree turns, have enough lights to get a fellow straightened out and then you can space them wider." "On the taxiway turns there are just not enough blue lights and you have to stop and figure out exactly where you are or you can miss the turns. There should be a greater number of lights on the outside of the turns." "On a curve the lights should be (spaced) less than the width of the taxiway at all times, so you can't confuse the two lights on one side as one to one side and one on the other and head out between them." "I don't believe that intersections of the taxiways, taxiways and runways, or the corners, are marked as plainly as they should be."

"Has anything been proposed on putting a single, different colored (light) at the intersection marks? In other words where you come down the runway and have a taxiway turnoff or where two taxiways joint at right angles or pretty close to a right angle, put a yellow light in the center to indicate that this is an intersection." "Have you people evaluated the lucite curved line of lights for turns?" Most of the comments on the taxiway lighting of runway turnoffs are included in Paragraph C.4.5.

Taxiing on the paved apron or ramp at night was a difficult problem at many stations because lighted lanes were not provided. The edge of the apron was often lighted by the blue taxiway lights, but most stations did not have lighted lanes in this area. Floodlighting was not available or did not satisfactorily cover many of these areas. "On the ramps you lose directions very easily because you may have only one row of taxi lights along one side." "The parking area with flood and apron lighting is confusingto transients. Definitely both rows of taxi lights are needed in ramp areas."

Flexibility in control of taxiway lighting was considered very desirable by Operations Officers and pilots. "I don't think you can get too many controls for the taxiway lighting as far as circuits are concerned. Then you can turn the lights off, flash them, etc., to get the pilots around the field. Comes in real handy for a stranger at the field." "When the pilot gets to the end of his rollout, we turn the (runway) lights down and flash the taxiway we want him to take and we have no problem at all. Before we could do that (flash the taxiway lights) it was quite a problem. It's no problem taxiing people now." "Probably the tower operators don't know which switch is which. If you have all the taxiway lights on all over the field regardless of what runway you are using, it can get confusing." "Break taxiway circuits into small units and light necessary units only, to avoid confusion."

The type M-1 lights were preferred to the type AN-L-9 lights for taxiway lights by most pilots. "I think these (M-1 lights) are wonderful lights compared to the flush type that used to be installed. You can see them fine so long as you don't have other lights to divert your attention. If there are lighted hangars or searchlights around, taxi lights are pretty rough to follow." "The taxiway lights should be wired better so all of the lights are at the same intensity." "Some of the (taxiway) lights look dim to me and some are bright."

Some comments were received on the usefulness of the reflector delineators to mark the edge of taxiways that do not have taxiway lights. "I had lights on the airplane and they (the reflector delineators) are all right if the plane has lights." At a field without taxiway lights but using the reflector delineators for nighttime marking of the taxiways, the following comments were recorded. "I have never noticed any help from them." "I would say the yellow stripe is more useful. You just turn your lights down there and follow it."

Taxiways that crossed runways created a lighting problem. "You are crossing an open expanse, the width of runway 28, without a marker of any kind, blue light, and it is very difficult."

C.6.3 Brightness Control of Taxiway Lights.

That taxiway lights are too bright was a general complaint. One station had been using intensity control on taxiway lights for some time and the comments were especially interesting. "A lot of people complain about the taxiway lights being too bright. You can't turn them up or down." "On taxiway lighting it seems most places get them too bright. At one field in Maine they had the brightest taxiway lights I have ever seen. I had to circle the field before I could separate the taxiway lights from the runway lights. They were just too bright." "We have had a few squawks on the brightness of the system. We don't get very many squawks here." "It is very simple. If they are too bright we can put a brightness control on them." "I think if you turned them down you would get more squawks than we ever do now." "Well, the taxiways (lights) are much too bright. The taxiways (lights) to the east are so bright that some of the pilots would rather taxi in the dark than put up with the lights as bright as they are. There should be some improved intensity control so you can turn them up or down according to the visibility." "We changed out the 45-watt lamps for 30-watt (lamps) and the pilots are very happy with those." "A blue light can be pretty bright sometimes. I don't think that you need as much of a range as for runway lights, but you should have some kind of a bright and dim switch." "A blue light on a clear night when you get near it, it hits you right in the eye." "We did have trouble with tactical units saying the taxiway lights were too bright. We requested dimmers for our regulators which they do not have." "Yes, we had (comments) that the taxiway lights were too bright), but I haven't heard any comments since we have had the lower intensity. I like them all right." "When you looked at things from the air (before intensity control) all you saw was a bunch of blue lights and you didn't even see the runway. All you would see was a big glob of blue." "We are using

45-watt (lamps) all over. As long as we have our brightness (control) we feel that it is better to use the high wattage. When the (pilots) do need the bright lights, we can give them to them." "I believe a three step (intensity control) would be much better (than two)." "We have five steps (on intensity control) and normally use step 3."

C.6.4 Painted Taxiway Markings.

The standard taxiway markings were generally satisfactory to most pilots for use in daytime. Edge marking, especially in critical taxiing areas, was the principal improvement suggested for taxiway markings. "We made one modification to the standard (taxiway markings) and that was to stripe the edge of our taxiway the same as (similar to) the runway setup. The main reason for it is the big turn in it (one taxiway). Planes run off it because the pilot doesn't see the turn (a multiple dog-leg)." "Pilot comments I have heard on it is that it is excellent. As a matter of fact, even for an airplane without taxi lights, just the wing lights alone are sufficient to give guidance around that area. They really like them (edge markings). The only suggestion I have is that they should be broadened to at least 8 or 10 inches (now it is 6 inches)."

Pilots at other stations were familiar with and approved the edge markings. "I like them." "That (edge markings of taxiways) has been suggested, but I don't know just how successful that would be (at night) because you don't have lights on the planes." "Pilots get lost on the inboard taxiway to the tower (a large paved area) due to poor markings. Paint the inboard taxiway with reflective type of paint on boundaries and centerline." "I would say the yellow stripe is more useful (than delineators). You just turn your lights down there and follow it."

C.6.5 Destination Markers and Signs.

The pilot's experience with destination markers and signs had been limited, but all those who had had the opportunity to use them approved the markers. In most cases the pilots referred to the internally illuminated signs and their usefulness at night. "We have the shadow-box signs around the fueling area. We haven't really tested those yet." "We have several painted (only) signs elsewhere and like them. They have reduced the number of radio communications." "At Washington National Airport they have a blue (amber) arrow on each taxiway for each turnoff. So everywhere there is a blue arrow you know you can turn off inside, just short of that." "So long as they (destination markers) are very low so you can't see them from above, if they are only seen when taxiing, they should be very helpful. I would hate for them to be where you can see (them) more than you have to; they bother." "The first time I went there (Baltimore) it was at night and I had no trouble at all." "You couldn't miss them (taxiway turnoff markers at Baltimore)." "I certainly do (feel that destination markers are worthwhile)." "The Air Force (has markers) like the 'OPS'. They are very good, particularly at a large field. It helps to get strangers to where they want to go." "At large fields with split activities, they (destination markers) would cut down radio transmissions considerably." "Anything that will reduce that (chatter on the air) is a big help." "I don't think we (Point Mugu) have enough traffic to warrant the necessary expenditure here now." "I agree that the field with its present setup wouldn't warrant it, but if we were to get extensions to our present runways and acquire parallel taxiways, that is something different." "I would like vertical signs (at intersections and runway turnoffs) stating it is a taxiway and pointing the direction."

C.6.6 High-Speed-Turnoff Taxiways.

Taxiways suitable for high-speed turnoffs from the runway were discussed at most conferences and generally received the approval of the pilots. "That's the only way in rapid traffic that I see." "(It would help a lot) if they were such that after you are down a ways and everything is under control and you could turn off at a slight angle." "My experience is that if you have rapid traffic you want everybody going to the end; slower planes keep their power on and get down there rapidly and you don't have to worry about it." "Are any high-speed taxiway turnoffs in the mill? Say about 45 degrees? It would really help. I know (a plane) landed the other day kind of heavy and there was a Banshee trying to turn off the runway at the taxiway. (This plane) had to turn and go right on by him. If there had been a 45-degree turnoff, the Banshee could have kept his speed and turned clear of the runway." "A high-speed turnoff is fine in the daytime. It would be a good way of clearing the runways." "I hope it doesn't encourage speeding on the taxiways." "I think that (high-speed turnoffs) would be helpful."

C.7 SEADROME LIGHTING AND MARKING

Pilot comments on seadrome lighting and markings were limited because the pilots participating in the conferences were not currently flying seaplanes. Most comments obtained were from the COMAIRPAC staff or from Operations Officers. Sealane lighting received most of the comments.

C.7.1 Sealane Lighting.

The fluorescent, buoy-mounted, channel-marker lights, type FMF-6, were preferred by the pilots. Major improvements in sealane lighting were desired. Hazards to aircraft during surface maneuvering should be kept to a minimum. "Just about the best seadrome lighting seems to be the battery-operated units (type FMF-6). The color is very good." "The (pilots) don't like them (pile-mounted lights). Nothing sticking above the water out there. They are afraid of dragging a wing float into them or something." "Primarily that (the seadrome with pile-mounted lights) is used for touch-and-go landings. We very seldom have planes land and taxi off the sealane. I think that if we had planes using that primarily (for operations) and taxiing off, we would have more difficulty with it." "Sangley Point has an excellent seadrome." "The fluorescent, battery lights are the best we have at present but we need higher intensity than the buoy-battery lights provide." "The pilots do not like pilings, and I am afraid that submerged pilings will still be a hazard. You can't remove the mental hazard." "We used lighting on only one side, we didn't use dual rows. Of course, where you have a channel you would have to use two rows." Width of landing lanes was discussed but not recorded. Lanes 1000 feet wide were considered adequate, but any appreciable narrowing of the lanes was considered objectionable by most of the pilots.

Maintenance and switching of sealane lights were problems which concerned pilots and Operations. "The only difficulty we experienced was the matter of going out and turning the units (type FMF-6) on and off." "If (we had) some sort of linkage for turning the (type FMF-6) lights on and off, they would be much better (than at present)." "Why couldn't they make a small transistor receiver and turn the battery-operated (type FMF-6) lights on by flipping a switch in the tower?" "We have to monkey around with them (type FMF-6) to get them on and off. Takes an hour or two, I guess. When you first turn them on, your battery power will last, say, for an hour pretty good, then, after that, you have three or four lights out (out of nine total), and you have to go out and replace batteries or maybe just turn them on again." "When you can't get to them on account of the weather (to turn them off), the batteries just run down." "We do, too (turn the type FMF-6 lights on before dark if they are going to be needed during the night)." Some other operational problems with the type FMF-6 lights were discussed. "For buoy lights, of course, the biggest trouble is alignment (drifting out of line)." "The buoy lights should be stabilized to prevent them from drifting out of alignment (out of line)." "I personally would like to have a permanent position for the lights, say a pile in the water cut off down at the ground where the light could be attached. That way, if you do get a light taken out, you can run out and attach another to it." "Our biggest trouble is the ships taking them (the buoy lights) out." "At Argentia they would use as emergency lights the small water-activated lights and throw them over the side of the crash boat for a one-landing use. They were very effective, strictly for emergency use." On the maintenance of pile-mounted lights, the following comments were recorded. "We have very little trouble with the pile-mounted lights. I guess until recently there hadn't been a routine check on them."

C.7.2 Other Seadrome Visual Aids.

While sealane lighting was the most important aid to seaplane pilots, some improvements in other visual aids for seadromes were indicated. Although approach lighting for seadromes was mentioned as desirable, no specific recommendations or requirements were brought out. Some lighting to identify the center of the multilane seadrome was needed. An amber rotating beacon on a piling about 15 feet above the water had been installed to mark the sealanes' intersection at one station, at the request of the operating units, but this was removed after the second collision with this piling. Green and amber buoy lights are now marking the intersection, but these do not give satisfactory identification. "The daytime markers on the buoy lights (type FMF-6) are not adequately visible." "Guidance after landing is badly needed. How about setting up a standard, such as neon lamps, for (seadrome) taxilanes?" "Ramps and (mooring) buoys need illumination."

C.8 ADDITIONAL COMMENTS ON AIRPORT LIGHTING AND MARKING.

Comments were obtained on deficiencies and suggested improvements of obstruction lights, hazard lighting, beacons, floodlighting, wheels watch, and other miscellaneous lighting and marking, in addition to those obtained on the major lighting and marking components.

C.8.1 Obstruction and Hazard Lighting.

Regular obstruction lighting at the air stations did not receive any pertinent comment from pilots, but the Operations Officers and Public Works Officers did have some comments on control and maintenance of these lights. "I believe all obstruction lights should be wired into the control console so they can be controlled from the tower. All of our outlying lights have to be turned on at the location. You can turn on only three or four from the tower." "We have several obstruction lights at places which are difficult and dangerous to go to to service. We need hazard pay or something to get the men to do it."

Hazard beacons and obstruction lighting away from the station received more comments. "We have those flashing hazard beacons on the hills and they are too slow (flash rate). Sometimes you get out there, you get vertigo. You think they are moving and you are standing still. The flashes are so far apart that you can't locate them. You see one flash, next time it flashes it is somewhere else. You don't know whether that is the same one or not." "We could set them (flash rate of the hazard beacons) up a little bit. We'll set them according to the book." "Servicing them (the hazard beacons in the hills) in rainy weather is very difficult. We need a neon type (hazard beacon) for longer lamp life." "Hazard beacons are supplied by (the) base, but P.G. & E. (public utility) maintains them. The beacons are no longer flashing and burn continuously because (it is believed) the motors are burned out." The obstruction lighting on a high hill off the end of a runway at one station consisted of a high-intensity, narrow-beam, white light directed from the top of the hill toward the threshold of the runway, and the red obstruction lights. "There is one thing I don't like around here (the lights on the hill). It looks just like an airplane coming right at you. (On one approach) I turned to the right because it looked like an airplane. (After landing and taxiing back) I looked up and it looked just like an airplane that was setting up there and was going to cross the field, but the thing never moved. It just gave me a weird sensation." "I have seen it on the mountain top, and it looked like a plane coming at me." "They have the red light and they leave the white light on. If they didn't leave the white light on, it would be O.K."

Temporary obstruction lighting for construction on the airfields was discussed. "One of the hazards around here is having flare pots to mark our constructional obstructions. The Bureau (of Aeronautics) should come up with some sort of standard blinker light to use so we don't have to mark our runways (hazards) with lighted flare pots. Lights something like the Highway Department uses." "I checked on those (highway blinker lights) and they said that the candlepower output was not high enough, especially in low visibility." "It (the flare pot) does two things. If it turns over, even if it doesn't burn the kerosene, the kerosene gets all over the asphalt and makes holes in it, and a jet can roll them right into a hangar or fueling area. It takes a lot of labor to place and fuel those (flare pots) every day."

C.8.2 Airfield Beacons.

The airport beacons did not provide satisfactory intensity at higher altitudes. "Something else on those things (beacons), they send out a beam of light that is about two feet wide over the horizon a hundred miles away. You have to be too low to see them." On an improved beacon being developed for better intensities at higher elevation, these comments were recorded. "One that will go up vertically? It (the present beacon) hasn't even reached 10,000 feet yet." The pilots questioned the use of the beacons to indicate IFR conditions. "I have never seen the usefulness of a rotating beacon for indicating IFR conditions." "I use it, especially at a strange field." "There are pilots who don't know what the green-white beacon is for." "I know now but I didn't know when I came in (to this conference)."

C.8.3 Floodlights.

Floodlighting for ramps, parking areas, and hangar areas presented some problems. "We have a few spots around on the taxiways where the pilots say hangar lights or floodlights do interfere with them." "Our parking for night operations needs floodlighting." "We damaged one plane severely about a year ago when it ran up on one of those exposed pipes (fire plugs)." "I think the control (of floodlighting) should be with the tower and they will know what the operations are." "That (floodlighting) is a problem. We are requested to turn off the floodlights on the hangars when we have operations on the field at night." "Bayshore Highway bothers a lot. There has been quite a bit of work done on that; street lights have been hooded, etc."

C.8.4 Wheels Watch.

The problems of wheels watch and signalling to prevent wheels-up landings were given some attention by pilots. "I feel that a flashing sign would be best." "You can put a voice on the air using a very low-powered transmitter a certain distance from the runway that would say 'Check your wheels.' or something like that." "How technically feasible would it be to use black light, that wouldn't bother the pilot, at the end of the runway aimed up into the air and the wheels watch could have filtered glasses with which he could see the gear?" "How about a reflective paint that the observer could see with the black light?" "Maybe some sort of light on the gear that the observer could see (at night to tell if the gear was down)?" The pilots seemed to agree on the best signal for attracting attention. "We have the Very pistol that is set off by remote control and I don't think that anybody has ever missed them yet." "A Very pistol is the very thing because it is a moving signal. You may not know right away what it is, but it wakes you up all of a sudden."

C.8.5 Arrester-Gear Lighting and Marking.

The location of the arrester gear needs better identification for both daytime and nighttime. "Are there any recommendations for lighting and markings along the runways where you hit the arrester gear?" "Some sort of markings are needed to show the location of the arrester gear." "Most Navy fields have an arrester gear made out of anchor chain and you can't put that on the runway with the high-intensity lights. We should have high-intensity (lights) now on runway 7 but it would be kind of foolish to install them because we have to have arrester gear somewhere." "(If the arrester gear chain were laid inside the lights) ours would be almost on the runway. That wouldn't constitute much of an obstruction unless, of course, you hit it with the wheel." "Have you considered a HOOK DOWN sign?" "Special markings to identify the barricade are needed."

C.8.6 Wind-Direction Indicators.

A wind sock or other suitable wind-direction indicator located near each end of the runway was desired by many pilots. "We could use another wind tee here as the one we have here is on the downwind end of runway 14 and I would like to know exactly which way the wind is so I can stay on the upwind side of the plane I am flying wing on. I think just a small wind Tee or wind sock would be adequate. Just anything on the ends of the runways both for landings and take-offs." "How about a wind sock at the end of the runway, a small wind sock right at that position? That's something our pilots have talked about. It gives the current wind condition; whereas, with a free wind Tee halfway down the runway, you can't see it when you take off or just at touchdown." "It can be to the side far enough to be O. K. (with respect to an obstruction) and up high enough to see."

C.8.7 Miscellaneous Comments on Lighting and Marking.

"The parking areas need improved markings." "Reliability of temporary lighting for advanced bases is a minimum safety factor."

"We have put in pylon lights to mark an area from which a number of complaints of excessive noise had been received. The pilots have been instructed not to fly over this area, but probably these lights make a good identification point for the approach." "I don't know what kind of (color and) light people react to best, but they (Human Engineering Branch) might have some ideas on these colors. They might like fuchsia or violet or something. Maybe you ought to talk to them." "At night when I come back I can't find the airfield until I am almost on it; the things that are best for locating this field at night are the white lights on the east side of hangar 3."

C.9 BLAST EROSION

Jet and prop blast erosion damaged paved and adjacent areas causing potential hazards to aircraft and visual landing aids. The concrete areas were not seriously affected by the jet blast but some asphalt areas, especially in run-up areas, at the compass rose, and at hold areas on taxiways have been damaged. Thin asphalt-covered areas and unpaved shoulders and ends of runways were often seriously eroded. "No (jet blast damage) to concrete, but it just rolls up the asphalt, particularly the shoulders and the tar in the joints of the concrete section lines." "Blast erosion at the end of the runways is a problem. The ground blows away from the concrete, making a sharp rise of several inches. Then if a plane lands a few feet short, it may cause quite a bit of damage."

C.10 PILOT EDUCATION IN VISUAL LANDING AIDS

All of the pilots were very helpful with their comments and observations. In some instances they were helpful to the point of self-criticism. The following comments in most cases are concerned with better training of pilots in the use of visual landing aids, or show the lack of information which should be common knowledge to pilots.

C.10.1 Need for Pilot Education.

Much of the information which visual landing aids are intended to provide was not adequately known to all pilots. "The need for pilot education on visual landing aids is practically universal." "There is a definite need for training on visual aids." "Pilots don't get into the technical information on lighting." "They (pilots) don't have access to the lighting manual and, if they did, they wouldn't have time to read it." "Even the basic simple things need reviewing and there are new pilots." "Information going back so far as to explain the split-white-beam beacons indicating a military airfield would not be out of order at all."

Many pilots were not fully aware of information provided by installations that had been standard for several years. "Not many of the pilots know what the blinker code on the airway beacon means." "There are pilots who don't know what the green-white beacon means." "I know it now, but I didn't know it when I came in (to this meeting)." "That's like the light (the airport beacon) they have on when we have morning fog (to indicate instrument flight conditions)." "I never looked for the (length-of-) runway (threshold) markings and never knew how to read them until I got here." "I thought everyone knew that (the meaning of the length-of-runway threshold markings)." "You'll have to train the pilots (to ask for and use the runway and approach lights in daylight conditions)." "After 15 years of flying I have learned that some of the taxiway lights are an even blue all the way around and others are bright in some directions (only). I didn't know that." "Can you vary the (flash) rate (of the hazard flashing beacons)?"

Recently adopted standards, special civilian or Air Force standards, or installations for testing or evaluating may be confusing the pilots. "Sometimes it takes quite awhile (for information on new items to get around to all pilots)." "In general, the only way I know (to learn of new installations) is to figure it out yourself or ask someone, but generally they won't or can't tell you." "If I am real inquisitive I'll ask them at Operations, 'What have you got that out for?'" "I saw that method of marking on an Air Force field and asked about them and they didn't know themselves." "The runway markings at the 1500-foot point have been changed and the word hasn't been passed around. The 1500-foot stripe is no longer down there; it is now at 500 feet." "I don't know what the standards (runway markings) are but --." "What I am interested in is that they have a system (runway markings specifically)." "Have they developed a substitute system for (length-of-runway threshold) markings or just discontinued them?" "Will there be any distinguishing of instrument runways (on the new Navy standard markings)?" "We put in to have them (the yellow lights in the final 1500-foot zone of the runway) reinstalled at the request of the tactical units. (We checked) and found that they had been discontinued." "At first I didn't know what those signs were along the runway, but after a while you can figure out what they are for." "If you ask these pilots that are flying out of here every day if we have runway (distance markers) markings, I'll bet that 75 percent would say 'No.'" "They are changing the taxiway lights. I don't know what they (the new lights) are, but at most of the new air stations they are being put in." "At Atlantic City they are changing from what was the taxiway lights to a new type. I don't know if they are something new because I am not familiar with the terms of the lights." "Navy fields have an arrester gear made out of anchor chain and you don't (can't) put that on the runway with high-intensity (elevated) lights."

C.10.2 Dissemination of Information.

Finding suitable means of disseminating information about visual landing aids, and instructing in the best use of these aids is a problem. The pilots made several worthwhile suggestions. "I say more Navy pilots read NavAir News (Naval Aviation News) than any other given publication. If you are going to put it (visual landing aids information) any place, put it in there; because, for a Navy pilot, if he doesn't read anything else, he reads NavAir News." "There are lots of posters around on practically everything, but something that is really compact could be put out for flight clearance rooms. You are going to have pilots coming in there." "At the present time there is no common method for passing visual landing aids information to pilots." "We have a safety meeting once a month at North Island (not at Brown Field where the pilots are stationed) and anything (new) like that (runway distance markers) is brought up at those meetings. It should get around within a month. Of course, that doesn't mean that each representative passes that information on to each and every member of the Squadron when he gets back. I think that the jet pilots are pretty well informed on that (runway distance markers)." "In this particular installation (no operating squadrons) about the only way to get information around is to put it on a route sheet. After it gets to each department it has to be individually passed out."

U. S. DEPARTMENT OF COMMERCE
Sinclair Weeks, *Secretary*

NATIONAL BUREAU OF STANDARDS
A. V. Astin, *Director*

THE NATIONAL BUREAU OF STANDARDS

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Electricity and Electronics. Resistance and Reactance. Electron Devices. Electrical Instruments. Magnetic Measurements. Dielectrics. Engineering Electronics. Electronic Instrumentation. Electrochemistry.
Optics and Metrology. Photometry and Colorimetry. Optical Instruments. Photographic Technology. Length. Engineering Metrology.
Heat. Temperature Physics. Thermodynamics. Cryogenic Physics. Rheology. Engine Fuels. Free Radicals Research.
Atomic and Radiation Physics. Spectroscopy. Radiometry. Mass Spectrometry. Solid State Physics. Electron Physics. Atomic Physics. Neutron Physics. Nuclear Physics. Radioactivity. X-rays. Betatron. Nucleonic Instrumentation. Radiological Equipment.
Chemistry. Organic Coatings. Surface Chemistry. Organic Chemistry. Analytical Chemistry. Inorganic Chemistry. Electrodeposition. Molecular Structure and Properties of Gases. Physical Chemistry. Thermochemistry. Spectrochemistry. Pure Substances.
Mechanics. Sound. Mechanical Instruments. Fluid Mechanics. Engineering Mechanics. Mass and Scale. Capacity, Density, and Fluid Meters. Combustion Controls.
Organic and Fibrous Materials. Rubber. Textiles. Paper. Leather. Testing and Specifications. Polymer Structure. Plastics. Dental Research.
Metallurgy. Thermal Metallurgy. Chemical Metallurgy. Mechanical Metallurgy. Corrosion. Metal Physics.
Mineral Products. Engineering Ceramics. Glass. Refractories. Enameled Metals. Concreting Materials. Constitution and Microstructure.
Building Technology. Structural Engineering. Fire Protection. Air Conditioning, Heating, and Refrigeration. Floor, Roof, and Wall Coverings. Codes and Safety Standards. Heat Transfer.
Applied Mathematics. Numerical Analysis. Computation. Statistical Engineering. Mathematical Physics.
Data Processing Systems. SEAC Engineering Group. Components and Techniques. Digital Circuitry. Digital Systems. Analog Systems. Application Engineering.

- Office of Basic Instrumentation.
- Office of Weights and Measures.

BOULDER, COLORADO

Cryogenic Engineering. Cryogenic Equipment. Cryogenic Processes. Properties of Materials. Gas Liquefaction.
Radio Propagation Physics. Upper Atmosphere Research. Ionospheric Research. Regular Propagation Services. Sun-Earth Relationships. VHF Research.
Radio Propagation Engineering. Data Reduction Instrumentation. Modulation Systems. Navigation Systems. Radio Noise. Tropospheric Measurements. Tropospheric Analysis. Radio Systems Application Engineering. Radio Meteorology.
Radio Standards. High Frequency Electrical Standards. Radio Broadcast Service. High Frequency Impedance Standards. Calibration Center. Microwave Physics. Microwave Circuit Standards.

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