U.S. Department
of Transportation

Federal Aviation Administration

Advisory Circular

Subject: Maintenance of Airport Visual Aid Facilities

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Change:

1. PURPOSE. This advisory circular provides recommended guidelines for maintenance of airport visual aid facilities. Since the function of such facilities is to assist in the safe and efficient movement of aircraft during landing, takeoff, and taxiing maneuvers, it is essential that a high degree of operating reliability be maintained. To achieve this, it is necessary to establish and maintain an effective preventive maintenance program. This advisory circular provides suggestions on establishing such a program but, due to the varying complexities of airports and facilities provided, such a program must be tailored to suit each individual airport's particular needs. Since corrective and preventive maintenance procedures for specific equipment are adequately covered in manuals supplied with the equipment, this advisory circular addresses maintenance topics of a more general nature.

2. CANCELLATION. AC 150/5340-22, Maintenance Guide For Determining Degradation and Cleaning of Centerline and Touchdown Zone Lights, dated 4/20/71, is cancelled.

3. ILLUSTRATION SOURCE MATERIAL. Products shown in the illustrations in this advisory circular show typical examples of test equipment and do not constitute an endorsement of the products by the Federal Aviation Administration as many such products are commerically available. Permission to use these illustrations has been granted by the manufacturers of the products.

4. COMMENTS INVITED. Recommendations for improvement of this advisory circular are welcomed, and users are encouraged to submit suggestions by calling (202) 426-3824, or by writing to the:

Federal Aviation Administration
Office of Airport Standards
Attn: AAS-2OO
800 Independence Avenue, SW.
Washington, D.C. 20591

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CHAPTER 1. SAFETY

1. GENERAL. This chapter contains information that will aid airport owners/operators in establishing an effective safety program. Safety is the responsibility of each individual, regardless of position. Safety must be practiced daily in every maintenance activity that is performed. The safety program established at each airport should include preventive safety precautions used when servicing the equipment and first-aid procedures for use in the event of an injury.

2. COMMON CAUSES OF ACCIDENTS. Some common causes of accidents are listed below:

(a) Working on equipment without adequate coordination with equipment users.

(b) Working on equipment without sufffcient experience on that equipment.

(c) Failure to follow instructions in equipment manuals.

(d) Failure to follow safety precautions.

(e) Using unsafe equipment.

(f) Failure to use safety devices.

(g) Working at unsafe speeds.

(h) Poor housekeeping of work areas.

3. SAFETY PROCEDURES AND GUIDELINES. Most visual aids are exposed to weather and moisture and may develop electrical shock hazards through damage from lightning or insulation deterioration from exposure. Maintenance procedures should begin only after a visual inspection has been made for possible hazards. Due to the danger of lightning, lighting equipment should not be serviced during periods of local thunderstorm activity.

a. Two Basic Rules. A potential hazard exists whenever work is performed on or around energized electrical equipment. The following basic rules should be followed by all electricians:

(1) Rule Number 1. Work should never be performed on energized electrical conductors or equipment, except for measuring voltage or current.

(2) Rule Number 2. Always assume that power is on until the true condition is determined.

b. Safety Practices. The following safety practices should be followed by all personnel performing maintenance on visual aids:

(1) All commercial test equipment should be Underwriters Laboratory (UL) approved.

(2) Prior to beginning any maintenance work on airport lighting circuits, coordinate the work schedule with the tower, Flight Service Station (FSS), or UNICOM personnel. Make sure circuits will not be energized during maintenance; obtain authorization for local control if equipment is normally operated from a remote control point.

(3) Where maintenance work is to be accomplished on a high-voltage circuit, at least two electricians should be assigned with one having a thorough knowledge of the layout of all airport high-voltage circuits. The duties of an observer electrician include:

(i) Keeping other personnel not involved in the work clear of the equipment.

(ii) Being familiar with power disconnects and immediately disconnecting the power source in case of emergency.

(iii) Being qualified in first aid and prepared to render emergency care if necessary. The observer should bear in mind that prevention of an electrical accident is of primary importance even though first-aid treatment is available.

(iv) Observing the work being done to detect and warn against unsafe practices.

c. Personal Safety Precautions. The following common sense safety precautions should be standard procedure for every electrician:

(1) Know the location of main power disconnect devices.

(2) Know how to summon medical aid.

(3) Remove necessary fuses to deenergize the circuit using properly insulated fuse pullers. Consult circuit diagrams to identify all fuses involved. Remember that removal of a fuse does not remove the voltage from the "hot" fuse clip. Discharge all capacitors.

(4) Do not depend on interlocks to remove power nor on indicating lights to signal that power is off. Verify that voltage is off by using a voltmeter on the component after opening the power switch.

(5) Insulate feet by standing on a dry rubber mat. Remember, however, that contact with the grounded equipment cabinet could nullify this protection.

(6) Stay clear of terminals, leads, or comments which carry voltages of any magnitude. Also, avoid contact with comments which are grounded, including the frame.

(7) Shut down the equipment if it is necessary to reach into the equipment in locations where rapid and direct withdrawal of the hand is not possible. In any case, only one hand should be exposed, with the other hand kept away from contact with voltages or ground.

(8) Be certain that there is no power applied to a circuit when making a continuity or resistance check (the meter will be damaged.)

(9) Ground test equipment to the equipment under test unless otherwise specified in instruction manuals. Follow the test procedures in paragraph 25 for using uninsulated volt-ohm-millammeters (VOM) on live circuits.

(10) Place a warning sign, "DANGER - DO NOT USE OR OPERATE, " or a similar sign at the main switch or circuit breaker for the circuit on which you will be working (see paragraph 5).

(11) Do not wear jewelry, wristwatches, or rings while working with electrical equipment.

(12) Keep clothing, hands, and feet dry if at all possible.

(13) Use the correct tool (screwdriver, alignment tool, etc.) for doing the job.

(14) Never use toxic or flammable solvents for cleaning purposes.

(15) Where air pressure is required for cleaning, use a low-pressure (30 psi or less) air source. Eye protection (goggles or face mask) should be used when using compressed air for cleaning.

(16) Goggles and safety shoes should be worn when around high voltage.

(17) Do not take anything for granted when working with inexperienced help.

4. SAFETY BOARDS. A plywood board, for posting safety procedures, and a pegboard, for mounting safety equipment, should be located in the airport lighting vault, switchgear rooms, engine generator rooms, and other appropriate locations. Recommened safety procedures and safety items are as follows:

a. Accident and fire procedures.

b. Emergency telephone numbers, such as doctor, hospital, rescue squad, and fire department.

c. Resuscitation instructions.

d. Resuscitation equipment (Resuscitube or equivalent).

e. First-aid kit.

f. High-voltage disconnect (hot) stick.

g. Fifteen-foot (5 m) length of 4-inch diameter (1 cm) natural or synthetic fiber rope.

h. Rubber gloves.

i. Insulated fuse puller.

j. Nonmetallic flashlight.

k. Grounding stick.

l. Safety posters and bulletins.

m. Portable nonconductive warning signs with nonconductive hangers (see paragraph 5).

n. Fire extinguisher (see paragraph 13).

5. SAFETY WARNING SIGNS/DANGER TAGS. This paragraph discusses the use of warning signs on high voltage equipment.

a. "DANGER--HIGH VOLTAGE" Sign. "DANGER--HIGH VOLTAGE" signs (figure 1-1) should be permanently placed on all fixed electrical equipment where potentials of 500 volts or more terminal-to-ground are exposed. Signs should be placed in a conspicuous location, generally on the outside of the equipment.

b. "DANGER" Tag. "DANGER" tags (figure 1-2) should be used for personnel and equipment protection. The tags should be used when personnel are required to work on or near equipment that, if energized, would cause personal injury or damage to equipment. When deenergizing electrical equipment, "DANGER" tags should be put on all primary disconnecting devices and control components such as control switches. Each individual working on the deenergized equipment and other personnel authorized by the facility manager may attach tags; however, tags should be removed only by the person who has placed and signed the tags. In some circumstances, a "DANGER" tag may be removed by another authorized person after obtaining the verbal consent of the individual who has signed the tag. This exception would apply to conditions arising from shift changes, illnesses, vacations, etc. Tags that are placed on equipment which is exposed to the elements should be made ,of plastic or enclosed in transparent plastic envelopes. Equipment bearing a "DANGER" tag must never be operated at any time.

c. "DANGER" Tag Control. "DANGER" tags and locks should be controlled by the leading electrical or maintenance supervisor at each facility or other person authorized by the facility manager. The procedure is initiated with the supervisor issuing "DANGER" tags for each job. Each tag and corresponding stub has a unique serial number printed on both the tag and the stub. The recipient of the tags enters all information requested on the "DANGER" tags and stubs, including signature, and proceeds to personally fasten them to the deenergized equipment. Upon completion, the technician notifies the supervisor who personally insects all tag points to assure that the equipment is safety isolated for repairs or inspection. The supervisor's approval is then indicated by signing each tag and stub. After the work is completed and equipment put back in service, the "DANGER" tags should be removed and destroyed. The corresponding stubs should be retained for a period of time designated by the facility manager.

Figure 1-1. "DANGER HIGH VOLTAGE" sign

Figure 1-2. "DANGER" tag.

d. Locks and Padlocks. Built-in locks on switchgear and disconnecting switches should be used whenever the equipment is tagged, and the keys should be returned to the supervisor responsible for their control. Padlocks need not be used if it is decided that use and control of such locks would be difficult because of the type of switchgear and its location. However, padlocks should be used with "DANGER" tags when equipment or electrical lines remain out of service or electrical work has been discontinued until a later date. When outside contractors are involved, each contractor should attach and control tags and locks independently.

6. SAFETY TRAINING. A safety training course should be established and presented to all employees. Followup training should be presented on a periodic basis to ensure that employees are safety motivated.

7. SAFETY BOARD INSPECTION. The equipment located on the safety board should be inspected as indicated below:

a. Rubber gloves should be tested in accordance with ASTM Dl2O, Specification for Insulated Rubber Gloves. ASTM specifications may be obtained from the American Society for Testing and Materials, 1916 Race Street, Philadephia, Pennsylvania 19103.

b. Testing may be performed by qualified private testing labs, utility companies, and large military or Federal establishments.

c. Gloves should be proof-tested at the following intervals: in daily use--3O days; infrequently used--18O days. Gloves suspected of having defects should be proof-tested; gloves received from the manufacturer should be inspected and proof-tested.

d. Hotsticks shall be visually inspected for paint smears, carbon paths, dirt smears, etc. , ahd cleaned, if required, prior to use. Hotsticks which cannot be cleaned and/or have significant surface-coating ruptures should be resurfaced and tested.

NOTE: Certified rubber gloves and protective leather gauntlets should be worn whenever hotsticks are used.

8. SAFETY CHECKLIST. A safety inspection should be completed on a monthly basis to ensure that the safety boards contain all required items and that test equipment is in a safe operating condition. The completed checklist should be retained on file for at least 1 year.

9. ELECTRIC SHOCK. An electric shock is the passing of an electric current through a person. The amount of damage depends on the amount of voltage and current to which the person is subjected.

a. Voltages between 200 and 1000 volts at commercial powerline frequencies are particularly harmful since under these conditions heart muscle spasm and paralysis of the respiratory center occur in combination. However, lower voltages can also prove fatal, as evidenced by records of deaths caused by 32-volt farm lighting systems. The body response to current is as follows: 5-to-15 mA stimulates the muscles; 15-to-19 mA can paralyze the muscles and nerves through which it flows; 25 mA and above may produce permanent damage to nerve tissues and blood vessels; 70 mA and above may be fatal.

b. The injurious effects suffered during electric shock depend upon the path of the current through the body. The current path will take the most direct route through the body from the two points of contact. For this reason, any current path which involves the heart or the brain is particularly dangerous. Therefore, keeping one hand clear of the equipment will eliminate the possibility of a current path from arm-to-arm.

10. SOLDERING.

a. Soldering can be a safe process if the hazards are recognized and normal safety precautions are observed. The hazards include heat, fire, shock, fumes, and chemicals.

(1) Heat. Since soldering is a process which requires heat, the danger of burns is always present. Burns can be received from the primary source of heat (the torch or soldering iron), from explosions caused by open flames, and from handling soldered metals before they have cooled sufficiently. The number of burns can be reduced by adequate training of maintenance personnel.

(2) Fire. Closely associated with the danger of heat is the danger of fire. The torch frequently used for general-purpose soldering presents a definite fire hazard. Fires can result from the careless handling of flame-heating devices or from their use in the vicinity of flammable fumes or liquids.

(3) Fumes. Volatile fumes are an invisible hazard that may damage both personnel and property. During the soldering operation, the danger may be decreased by providing adequate ventilation. Combustible gases, such as acetylene, or fumes from gasoline or alcohol present an explosion hazard since they can be ignited by an open flame or by a spark. Other fumes may be dangerous to breathe; for example, fumes from heated fluxes and from degreasing liquids can cause lung and skin irritations.

(4) Shock. Since electrical soldering equipment is commonly used, the possibility of an electrical shock is often present. Electrical defects in soldering equipment and associated supply circuits may expose the technician to dangerous voltages. This hazard can be minimized by the use of equipment in good condition.

(5) Chemicals. Chemicals which may present a health hazard are used extensively in soldering fluxes and degreasing solutions. Noncorrosive fluxes present little problem, but the alkalies and acids used in corrosive fluxes may cause skin irritations and burns. Danger to the eyes also exists since many of the chemicals are in liquid solutions, and splashing or spattering may occur. The hazard presented by chemicals is slight if proper safety precautions are observed.

b. Many precautions are common to all types of soldering and should be observed to prevent injury or damage to property.

(1) Do not solder electronic equipment unless it is disconnected from the power supply. Death can result from contact with a high-voltage source.

(2) Ground all equipment to lessen the danger of electrical shock.

(3) Ground electrical soldering irons and guns when feasible and in accordance with the "National Electrical Code" handbook. Grounding will minimize the danger of electrical shock resulting from defective equipment. It will also reduce the danger of the soldering equipment producing a spark in explosive areas. Grounding will also protect semiconductor deviced by neutralizing any differences in potential between the soldering equipment and the semiconductors in transistorized equipment.

(4) Do not flip excess solder from the tip of a hot soldering iron. Bits of hot solder can cause serious skin and eye burns; they may also ignite combustible materials.

(5) Do not handle hot metals; allow the pieces to cool before handling.

(6) Select the proper working area for soldering. Choose a well-ventilated location away from all fire hazards.

(7) Mechanically secure large workpieces while they are being soldered. Severe injuries or burns may be received because of a filling workpiece.

(8) Wear the proper clothing and protective devices while soldering.

(9) Maintain a clean working area to prevent fires. Remove combustible materials from the floor and from the surrounding area.

(10) Keep firefighting devices and first-aid supplies near the soldering area. All equipment should be checked at regular intervals.

11. LIGHTNING.

a. When personnel are subjected to direct lightning strikes, the results are nearly always fatal. Although extraordinary escapes from direct strikes have been reported, the shock is so great that survival is rare. The major portion of lightning casualties arise from secondary effects, such as side flashes and induced charges.

NOTE: First-aid treatment, especially artificial respiration or cardiac-pulmonary resuscitation, if administered in time, may prevent death from any but direct charges.

b. The following rules for personal safety should be observed, if possible, during any thunderstorm:

(1) Remain indoors unless absolutely unavoidable. Stay within a dry area of the building, preferably away from all metal objects.

(2) If there is a choice of shelter, select the type of shelter in the following order:

(i) Large metal or metal-frame buildings.

(ii) Dwellings or other buildings which are protected against lightning.

(iii) Vehicles.

(iv) Large unprotected buildings.

(3) If remaining out-of-doors is unavoidable, keep away from the following:

(i) Small sheds and shelters in an exposed location; in particular, any which house power equipment.

(ii) Wire fences, antennas, supporting stuctures, or lines; whether telegraph, electric, or otherwise.

(iii) Hilltops and wide-open spaces.

(iv) Isolated trees.

12. TOXIC AGENTS. Toxic agents are poisonous substances that can cause injury by contact or ingestion. Substances termed "caustic" or "corrosive" cause the flesh to be eaten away on contact; the results of contact with these agents range from minor skin irritations to severe burns. There are materials that are toxic only if they are taken internally. Toxic agents also exist as a gaseous vapor and may be injurious immediately or over a long period of time. There are also a few substances used in electronic equipment that are basically nontoxic agents, but under certain conditions, can become highly toxic.

a. Carbon Tetrachloride. Never use carbon tetrachloride. contact with liquid carbon tetrachloride destroys the natural oils of the skin, producing a whitish appearance on skin surfhces that are exposed; continuous skin exposure may cause skin eruptions. Carbon tetrachloride fumes are highly toxic.

b. Trichloroethylene. This agent, used principally as a degreasing solvent, is a narcotic and anesthetic material. Organic injury rarely results from overexposure, but repeated overexposure can cause anemia and liver damage.

c. Battery Acids. The most common battery acid is sulphuric acid. Sulphuric acid is a corrosive toxic agent; repeated or prolonged inhalation of its fumes can cause inflammation of the upper respiratory tract, leading to chronic bronchitis. Loss of consciousness with severe damage to the lungs may result from inhalation of concentrated vapors when the sulphuric acid is hot. The acid in a highly concentrated form, prior to adding water for battery use, acts as a powerful caustic, destroying skin and other tissue. This destruction appears as severe burns, and such exposure may be accompanied by shock and collapse. The fumes from highly concentrated sulphuric acid cause coughing and irritation of the eyes; prolonged exposure may produce a chemical pneumonitis.

13. FIRE EXTINGUISHERS. Fire extinguishers of the proper type, and in good working condition, should be conveniently located near all high-voltage equipment. Table 1-1 lists the types of fire extinguishers that are normally available.

Table 1-1. Types of fire extinguishers.

Extinguisher	Uses
CO2	May be used on any fire, particularly on electrical fires.
Soda-acid	May be used only on ordinary fires, as liquid is a conductor of electricity. Not effective on burning compounds, oil, etc.
Foam	Very effective on burning compounds, oil, and similar materials. Not satisfactory for electrical fires, as compound is a conductor of electricity.

14. GROUNDING. Connections to grounding systems should never be removed, nor attempts made to replace connections, until all power is removed from equipment and a11 personnel warned of the ungrounded condition of the equipment. Appropriate warning signs should be displayed to warn personnel of the possible hazards.

15. FIRST AID. First aid is what to do before the doctor comes. It is never a substitute for medical help. The maintenance technician should take the lifesaving measures necessary in emergencies, but avoid doing harm. Many first-aid measures are quite simple and do not require "split-second speed" in their application. Haste without knowing what one is doing can be worse than doing nothing at all. At other times, immediate action is essential to save a life or prevent serious complications; this action can only be taken by someone who is on the scene when minutes are vital. Learn about first aid before emergencies happen. Be prepared to give help safely and beneficially when necessary. The American Red Cross should be contacted to provide refresher first-aid courses to maintenance personnel to keep them proficient.

CHAPTER 2. MAINTENANCE MANAGEMENT

16. MAINTENANCE PHILOSOPHY. The purpose of a maintenance management system is to ensure the maximum availability of any given system at a minimum cost in man-hours or funds. "Availability" and "costs" are relative terms; they must be interpreted for each airport. For example, an 80-lamp runway edge lighting system is still considered operational if several lamps are out, while a visual approach slope indicator (VASI) may be inoperative with one box out. By the same reasoning, the cost of maintaining a spare regulator may be considered prohibitive, while stocking replacements for 10 percent of the runway edge lights may be considered normal practice. In addition, operational factors are a major consideration in determining what maintenance is required. Airports with heavy jet traffic may require more frequent maintenance servicing then those used only by light aircraft. Regardless of the actual maintenance routines decided upon, the following elements are essential to any controlled maintenance program:

a. Documenting the service checks that comprise the maintenance program.

b. Recording the performance of each maintenance action, scheduled or unscheduled.

17. MAINTENANCE SCHEDULE. Documenting the maintenance schedule by spelling out each item of routine maintenance is beneficial in several ways.

a. It allows planned allocation of man-hours to the maintenance function.

b. It helps to establish spare part stock levels.

c. It identifies the necessary maintenance routines to new employees, decreasing training time needed for system familiarization.

d. It identifies to management the scope of the maintenance task in terms of man-hours and materials requirements.

18. MAINTENANCE RECORDS. Maintenance records are an important part of an effective maintenance management system. They provide a service history of each piece of equipment, ensure regular maintenance without duplication oe effort, and give a data base for statistical analysis of lighting system performance. Without records, knowledge gained from regular inspections will not be retained, and preventive maintenance will be difficult. An effective records system should allow for the recording and retrieval of information with a minimum of effort. The records system should compile data that will document the effectiveness of the maintenance program. By checking the records, a manager should be able to determine whether a particular maintenance task is being done too frequently or not often enough. By such a trial-and-error process a maintenance program uniquely tailored to the facility can be developed.

19. PREVENTIVE MAINTENANCE PROGRAM. Reliable functioning of airport visual aids is essential to airport operation. Therefore, it is essential that a preventive maintenance program be established to ensure reliable service and proper equipment

operation. Airport lighting is designed to be dependable and may continue to operate for long periods of time even if maintenance is neglected. However, some portion of it will eventually fail. If failure occurs at a critical time, lives and property may be jeopardized. Visual aid maintenance should receive high priority to prevent equipment failure, false signals, and deterioration of the system.

a. Installation and Material. The first element in a preventive maintenance program is high quality, properly installed equipment. Preventive maintenance is difficult on equipment that has been installed haphazardly without consideration of maintenance requirements. When such conditions exist, they should be brought to the attention of the proper authority and corrected rather than trying to establish a preventive maintenance program to compensate for the condition.

b. Personnel. The second element in a preventive maintenance program is trained experienced personnel. Maintenance personnel should have a thorough knowledge of the equipment, should have experience with high voltage, and should be able to make careful inspections and necessary repairs. Special training may be desirable, but most well-qualified electricians can be trained on-the-job if suitable supervision and instructions are provided. Considerable experience with the equipment and its operation is desirable. These individuals should be present or on-call during the operating hours of the airport to correct any deficiencies that may develop. In short, airport visual aid maintenance personnel should be specialists in the field.

c. Tools and Test Equipment. The third element in a preventive maintenance program is the tools and test equipment required to perform the maintenance. This includes the proper tools, test equipment as described in chapter 3, adequate working space, adequate storage space, spare parts, and applicable technical manuals.

d. Preventive Maintenance Inspection Program. The fourth element in a preventive maintenance program is an effective preventive maintenance inspection schedule for each visual aid. The preventive maintenance inspection (PMI) schedule is the foundation for the successful maintenance of the equipment. If the PMI is performed properly it will ensure top system performance and will minimize unscheduled interruptions and breakdowns. A review of the inspection records, checks, tests, and repairs provides a constant awareness of the equipment condition and gives maintenance personnel advanced warning of impending trouble.

20. PREVENTIVE MAINTENANCE INSPECTION SCHEDULE. Scheduled inspections and tests are those accomplished on specific types of equipment on a periodic basis. The schedule may be based either on calendar or on hourly-use increments. The PMI schedules contained in chapter 4 are based upon recommendations from the manufacturers and users of the equipment. These PMIs are considered to be the typical requirements to keep the equipment in good condition. The frequency of a particular PMI should be adjusted after experience is gained under local operating conditions.

2l. RECORD RETENTION. There is no set period of time that maintenance records should be kept, but, in keeping within the goals mentioned above, a period of twice the longest period recorded would appear to be minimum (i.e., 2 years in the case of annual maintenance action). Records of daily inspection will, of course, lose their significance much sooner, probably within a month.

22. REFERENCE LIBRARY. A reference library should be established to maintain a master copy of all equipment technical manuals (ETM), advisory circulars, as-built drawings, and other useful technical data.

a. Equipment Technical Manuals. Equipment technical manuals and other manufacturer's literature form an important part of the reference library. Two copies of all ETMs and related manufacturer' s literature should be obtained. A master copy is retained in the reference library, and a xerox copy is provided for the shop. The master copy of the ETM should not be removed from the reference library as it can easily become misplaced or lost. In the event the shop copy is lost, another xerox copy of the ETM should be made from the reference library instead of releasing the master copy.

b. FAA Advisory Circulars. Important reference information on installation, design tolerances, and operation of visual aid equipment may be found in FAA advisory circulars. A copy of the advisory circulars covering the equipment at the facility should be included in the reference library.

c. Other Technical Data. Other reference information which is occasionally useful should also be added to the library. This might include local electrical codes, engineer's handbooks, test equipment manuals, and other general information publications.

d. As-Built Drawings. It is recommended that the master copy of all "as-built" drawings be maintained as part of the reference library. Modifications to any equipment should be incorporated into the drawings as soon as the modification is completed. A copy of the "as-built" lighting plan, showing the location of all cable runs, runways lights, etc., and including the wiring diagrams for the lighting, engine generator, and the visual aid system, should be given to the field technicians as a working copy.

23. SPARE PART PROVISIONING. This paragraph contains guidelines on how to establish a stock of spare parts to be used for quick repair of lighting equipment that fails unexpectedly. The purpose of a spare parts system is to have the necessary part on hand when a piece of equipment fails; this will minimize the time the system is out of operation. However, the greater the number of spare parts stored, the greater the inventory costs. The optimum spare part system balances the cost of system downtime (lost operations, tenant inconveninece, etc.) with the cost of purchasing and storing spare parts. A small airport with few operations may suffer little inconvenience with the loss of their lighting system and may, therefore, choose to stock few spare parts. A large airport may rely heavily on its lighting system for bad-weather operations and would, therefore, require a substantial quantity of spare parts. Then establishing a spare parts inventory, two

questions must be answered: (1) What parts should be stocked, and (2) How many of each part?

a. Choosing Spare Parts. To answer the two questions posed in the previous paragraph, several factors must be considered, including failure rate, part availability, and effect of the part failure.

(1) Failure Rate. The failure rate (or replacement rate) is the product of the expected life of an item and the number of that item in the system. For instance, if a bulb is expected to last 6 months, and we have 100 bulbs in the system, then an average of 100 bulbs will be replaced every 6 months, or approximately four per week. The failure rate pay be determined from the maintenance records, which should be compiled according to the instructions in paragraph 18.

(2) Part Availability. Part availability refers to the time it takes to secure a replacement part. This usually means procurement lead time. If a part can be readily procured from shelf stock of a local supplier, it might not be necessary to add the part to the spare part inventory; it could be purchased when needed. However, if there is a 6-week lead time required by the supplier, then six times the weekly failure rate (24 bulbs in the example above) should be stocked. There are methods of obtaining parts which may reduce the effect of a long lead time. These include substitution (the use of a functionally equivalent part from another manufacturer), cannibalization (replacing one of a pair of adjacent failed bulbs by "borrowing" a bulb from elsewhere in the system), and temporary fixes (such as the use of portable lights in place of the fixed light installation) while awaiting corrective maintenance.

(3) Effect of the Failure. The effect of the failure of a particular spare part depends on how important the part is to the equipment it is installed in, and how vital the equipment is to airport operation. The failure of a lamp in an edge light would not lead to any system downtime; the failure of a circuit board in a constant current regulator would cause the loss of the entire lighting circuit that it powers. The equipment manufacturer will give guidance on recommended spare parts. As experience is gained with a system, other parts may be added or deleted from the inventory. The impact of a part' s failure should be considered when building a spare parts inventory.

b. Part Identification. An important part of maintaining a spare parts inventory is accurately cataloging the parts on hand by manufacturer's part number. This is important to ensure that the correct part is used in a broken piece of equipment; many optical parts are visually similar but vary significantly in performance. The use of the manufacturer's part number is also vital when reordering; if a part is ordered by its generic name, the manufacturer may send a later version of the part which is incompatable with the existing system. It is extremely important to maintain manufacturer's data which reflects your equipment, describing the type, model, number, and serial details.

CHAPTER 3. ELECTRICAL TEST EQUIPMENT

24. GENERAL. This chapter describes several types of electrical test equipment used for maintenance of visual aid equipment. The test equipment is listed in order of relative usefulness. For maintenance purposes, it is recommended that every airport acquire at least a volt-ohm-milliammeter and an insulation tester. These two units are required for many maintenance routines and are useful for troubleshooting.

Operating instructions for the equipment listed are contained in the manufacturer's manual supplied with the equipment.

SECTION 1. VOLT-OHM-MILLIAMMETER

25. GENERAL. The volt-ohm-milliammeter (VOM), figure 3-1, is a highly versatile piece of test equipment that is capable of measuring AC/DC voltages, resistance, and low values of DC current. The VOM is particularly useful for checking control circuit voltage and checking the continuity of circuit components. These readings help isolate the problem when troubleshooting.

26. SAFETY. Safety must always be considered when using the VOM. Know the voltage levels and shock hazards related to all equipment to be tested. Be sure that the VOM has been tested and calibrated. Portable test instruments should be inspected and calibrated at least once a year. Check the condition of the VOM test leads before making any measurements. General safety recommendations for specific uses of a VOM are contained in the manufacturer' s manual supplied with the equipment.

a. High-Voltage Measurements. Never try to take direct voltage readings on power distribution circuits rated over 600 volts. Measurement of high voltage is accomplished by installing instrument transformers and meters.

b. Switch Settings. When making voltage measurements on power and control circuits, be sure that the meter selector and range switches are in the correct position for the circuit under test before applying test leads to the circuit conductors. To prevent damage to the meter movement, always use a range that ensures less than full-scale deflection of the pointer. A l/3-to-midscale deflection of the pointer assures the most accurate readings.

c. Case Insulation. Do not hold the VOM in the hand while taking the reading. Support the instrument on a flat surface. If holding the VOM is unavoidable, do not rely upon the insulation of the case.

SECTION 2. INSULATION RESISTANCE TESTER

27. GENERAL. The insulation resistance tester, or megohmmeter, figure 3-2, ts used for testing insulation resistance-to-ground of underground cables (paragraph 47); for testing insulation resistance between conductors; and for testing resistance-to-ground or between windings of transformers, motors, regulators, etc.

Figure 3-1. Typical vol-ohm-milliammeters

Figure 3-2. Insulation-resistance tester (typical)

28. SAFETY.

a. When preparing to make an insulation-resistance test, first make a complete safety check. This includes making certain that equipment to be tested is disconnected from all power sources. All safety switches should be opened, and other control equipment locked out so that the equipment cannot be accidently energized.

b. If neutral or ground conductors must be disconnected, make sure they are not carrying current and that, when disconnected, no other equipment will lack protection.

c. Observe the voltage rating of the tester and take suitable precautions.

d. Large equipment and cables usually have sufficient capacitance to store a dangerous amount of energy from the test current. After taking resistance readings and before handling the test leads, allow any energy stored in the equipment to discharge by leaving the tester connected for at least 30 seconds before touching the leads.

e. Do not use the tester in an explosive atmosphere. An explosion may result if slight sparking is encountered when attaching or removing test leads, or as a result of arcing through or over defective insulation.

SECTION 3. HIGH-RESISTANCE FAULT LOCATOR

29. GENERAL.

a. The high-resistance fault locator, figure 3-3, utilizes a modified wheat-stone bridge circuit in which the two sections of the faulted conductor (one on each side of the fault) comprise the two external arms of the bridge. The remaining two arms of the bridge are contained in the instrument. By use of a detector circuit of extremely high input resistance, it is possible to locate high- resistance faults. With this bridge arrangement, faults having resistances from 0 to 200 megohms can be located within an accuracy well within +0.5 percent. A typical error would be 6 inches (15 cm) in 500 feet (150 m) or +0.1 percent.

b. Due to the high sensitivity of this test set, a balance can often be obtained with a good conductor. (The fault location will be indicated as the center point of the conductor.) Such a balance would be due to normal cable leakage current and would result in a reading of approximately 50 percent in a cable of uniform insulation quality at a uniform temperature. For this reason, the existence of a fault should be established by insulation resistance measurements before attempting to determine actual location of the fault.

30. SAFETY. Before attempting to make any connections, make sure that all exposed cables are deenergized.

Figure 3-3. Typical high-resistance fault locator

SECTION 4. CLAMP-ON AMMETER

31. GENERAL. The clamp-on ammeter, figure 3-4, ts useful for measuring alternating current. Some models are provided with plug-in leads to permit the instrument to be used as a voltmeter or as an ohmmeter.

32. SAFETY. The clamp-on ammeter reduces operator exposure to high voltages. However, the operator must observe normal safety precautions to prevent coming in contact with exposed conductors when taking current readings.

SECTION 5. CABLE ROUTE TRACER

33. GENERAL. The cable route tracer, figure 3-5, is an electronic instrument designed for locating, tracing, and measuring the depth of an energized underground power cable. The instrument can also be used to locate underground transformers, T-splices, and ground faults on unshielded cable.

34. SAFETY. Since the cable route tracer is used to trace cables which are energized with voltages that are hazardous and potentially lethal, all persons making or assisting in tests must use all practical safety precautions to prevent contact with energized conductors, terminals, or other equipment.

SECTION 6. IMPULSE GENERATOR/PROOF TESTER

35. GENERAL.

a. The impulse generator/proof tester, figure 3-6, is a compact signal unit contained in a metal case. The test set is composed of an impulse generator and an internal DC power source. The impulse generator contains a capacitor bank that is periodically charged from the DC source and discharged into the cable to form the test voltage waveform.

b. In the "impulse" method of fault location, the impulse generator repeatedly applies a high-voltage waveform to the defective cable. This waveform travels along the cable until it reaches the fault. At the fault, the voltage causes significant current to pass through the return path. This current, or its results, can be located and the fault position along the cable length can be traced by an acoustic detector or a directional detector which are discussed in sections 7 and 8 of this chapter.

36. SAFETY.

a. The test set and the cable to which it is connected are a source of high-voltage electrical energy, and all persons performing or assisting in the tests must use all practical safety precautions to prevent contact with energized parts of the test equipment and associated circuits. Persons actually engaged in the test must stand clear (by at least 3 feet (1 m)) of all parts of the complete high-voltage circuit unless the test set is deenergized and all parts of the test

Figure 3-4. Typical clamp-on ammeters

Figure 3-5. Cable route tracer.

Figure 3-6. Typical impulse generator/proof tester.

circuit are grounded. Any person not directly associated with the work must be kept away from test activities by suitable barriers, barricades, or warnings.

b. High-voltage impulse waveforms and resultant current pulses create special safety problems. A large, rapidly changing current, even across small values of impedance, can generate dangerous voltage levels. The test set design provided two distinct ground systems--the apparatus case ground and the surge ground. The apparatus case ground, which must be connected to a good local ground, is designed to protect the operator by preventing a difference of potential between the apparatus case and the ground in the immediate vicinity. The surge ground is designed to return the impulse current back to the capacitor. This surge ground lead is a continuation of the output cable shield and should not be extended.

c. On termination of a test, even after power has been removed from the test set, energy can still be stored in the capacitor bank and cable. For this reason, a manual ground is included in this equipment. The voltmeter resistor will gradually reduce such stored energy to a safe, low level. Then the manual ground must be closed to place a direct short circuit across the capacitor bank and the cable under test. It is recommended that, before removal of the test set, a ground bond be placed across the cable under test and that this bond remain in place until access to the cable is again required.

d. If the test set is properly operated and all grounds correctly made, no rubber gloves are necessary. As a routine safety procedure, however, some users required the use of rubber gloves not only in making connections to the high-voltage terminals but also in manipulating the controls. This is an excellent safety practice.

SECTION 7. ACOUSTIC DETECTOR

37. GENERAL.

a. The acoustic detector, figure 3-7, is a unique instrumentation system designed to detect the intensity of pulsed sound waves in the earth. It is primarily used with impulse generators to locate faults in direct-buried electric cables by tracing the sound emitted from the fault when the impulse generator causes it to arc.

b. The set is designed for use in all weather and can easily be carried by the operator to any field location. A sturdy carrying case is provided for storing and transport.

c. In use, the operator places a pickup element on the ground and listens for the characteristic "pop" or "thump" in the earphones, then moves along the line toward the location of the loudest sound. The set has a calibrated sound intensity meter which is used to make a final precise location of the point of maximum sound, which is directly over the fault. The meter is also sometimes found to be more sensitive than the ear in detecting a very weak signal. The meter and a solid-state amplifier are contained in a lightweight compact housing which can be carried by a strap around the neck, leaving the hands free to operate the instrument.

Fiure 3-7. Typical acoustic detector.

d. An important feature of the detector is the impulse indicator. This is an entirely separate system which detects the current pulse as it is applied to the faulted cable and gives a visual signal to the operator. When the operator is at a distance from the impulse generator and cannot see or hear it operating, the indicator gives assurance that the impulse generator is operating. In addition, the indicator tells the operator exactly when to listen for the "thump" and watch the meter. This is most useful in areas of high background noise. The impulse indicator, complete with its magnetic antenna, is included in the main amplifier housing.

e. A simplified diagram showing how the acoustic detector is used to detect a fault is shown in figure 3-8.

SECTION 8. DIRECTIONAL DETECTOR

38. GENERAL.

a. The directional detector, figure 3-9, measures the direction and magnitude of short duration current pulses from capacitor-discharge generators. It is used for locating faults between conductors or between a conductor and shield in underground power cables.

Figure 3-8. Use of the acoustic detector.

b. With the selection of two magnetic pickups and one conductive pickup, it can be used to locate faults in shielded or unshielded cables, direct buried or in duct. The magnetic pickups give a general location of the fault; more accurate location of unshielded direct-buried cables is possible with the conductive or earth-gradient pickup.

c. The test set is also effective for tracing buried cable, giving a precise fix on both location and depth. In addition to impulse detecting, the test set, can be used for tracing buried cables energized at frequencies between 60 and 1000 Hz.

d. Finally, the test set includes a separate high-impedance voltmeter circuit for locating high-resistance earth faults in direct-buried cables energized at 60 Hz, using earth-gradient probes.

e. The test set is designed to give optimum response to the typical current impulse waveform produced in a cable by a capacitor discharge. The test set measures the strength and direction (polarity) of the magnetic field created by the impulse current. The test set not only indicates the presence or absence of an impulse current in the vicinity, but also its direction and magnitude. This information is valuable in fault locating.

Figure 3-9. Typical directional detector.

e. The test set consists of an amplifier unit; sheath pickup coil; surface pickup coil; and earth gradient probe frame.

(1) Amplifier Unit. The amplifier unit contains the electronics, the battery, the output meter, and the controls.

(2) Sheath Pickup Coil. This unit is a "C-shaped" iron core and coil molded into a solid rubber assembly. It is designed for optimum pickup of the small, high-frequency magnetic field surrounding a cable and sheath and has the ability to accurately pick out the one of three conductors inside the sheath which is carrying the test impulse current.

(3) Surface Pickup Coil. This is a ferrite rod antenna enclosed in a protective tube. It is held in a T-bracket at the end of a telescoping aluminum rod with rubber handle grip. This pickup is designed specifically for detecting the magnitude and direction of impulse current magnetic fields. The T-joint is hinged and detented for positioning at 00, 450, and 900 to permit easy location of maximum and minimum signals and, thus, location of the cable.

(4) Earth Gradient Probe Frame. This is a rigid tubular frame supporting two stainless steel probes at a fixed separation of 20 inches (50 cm) which provides a means of detecting voltage differential along the surface of the earth. Each probe is wired through a connecting cord to a plug. The frame is insulated for operator safety.

39. SAFETY.

a. The impulse generator used with this directional detector and the cables to which it is connected may be a source of high-voltage electrical energy, and all safety precautions listed in section 6 on impulse generators should be followed. When the directional detector is used with the earth gradient probes, care must be exercised to avoid contact with any energized equipment or cables, whether on the surface or buried or whether energized by the impulse generator or the powerline.

b. A hazardous voltage may occur at any of the following locations:

(1) At or near connections to impulse generator, including earth or earthed conductors in the vicinity.

(2) At any other terminal of the cable or connected equipment.

(3) At or near the fault where earth voltage gradients may exist. The fault location is unknown, so caution must be exercised all along the buried cable run.

c. Any persons not directly associated with the work must be kept away from the danger area by suitable barriers, barricades, or warnings.

d. After the faulty section of cable has been isolated, the maintenance electrician should use a cable fault locator to pinpoint the actual location of the fault.

SECTION 9. PORTABLE OIL TESTER

40. GENERAL.

a. The portable oil tester, figure 3-10, is used to test the oil in large transformers.

b. The oil is the key to the length of life of a liquid-filled transformer. The oil provides the electrical insulation and conducts heat away from tke windings.

c. The oil should be sampled and tested as indicated in paragraph 51.

41. OPERATION.

a. To test the oil in a large transformer, samples are taken from both the top and bottom of the transformer and poured into the oil tester so that the oil covers two electrodes separated by a small gap. Oil from circuit breakers is tested in a similar manner.

b. Next, a high voltage is applied across the electrodes, gradually increasing up to 22 kilovolts (kV).

Figure 3-10. Typical portable oil tester.

c. If the oil can withstand a voltage of 22 kV, it is in good condition. Sparking across the electrodes indicates that the oil should be changed or filtered.

d. Do not use or add any type of oil that has not been approved by the manufacturer of the transformer. If the oil level changes appreciably from the normal range for the operating temperature, the cause should be identified and necessary repairs made.

e. As little as ten parts per million of water in the oil will reduce the dielectric strength below a satisfactory value. Breathing of a transformer through a defective seal may bring in enough moisture to cause a problem. Exposure to air or excessive temperatures may cause formation of sludge. If enough sludge and water accumulate in the oil, the entire oil supply may require filtering to gain acceptable dielectric strength. If too much water gets in the transformer, it may require drying out.

SECTION 10. GROUND-RESISTANCE TESTER

42. GENERAL.

a. The ground tester, figure 3-11, is used to measure the effectiveness of grounding systems. It does this by measuring the resistance between the grounding system and the earth ground. The grounding system in question may be used for beacon towers, lighting vaults, engine generators, and for other visual aids, or it may be a counterpoise system for underground cables.

b. The maximum acceptable ground resistance is 25 ohms. It is preferable that the resistance be 10 ohms or less.

c. In many locations, the water table is gradually falling. In these cases, the ground electrode systems that were effective when initially installed are no longer effective. This emphasizes the importance of a continuous program to periodically check the grounding system. It is not sufficient to check the grounding system only once at the time of installation.

Figure 3-11. Typical ground resistance tester.

43. SAFETY. A grounding system is a very important integral safety feature in airport lighting systems. In order to be effective, the grounding system must have a very low resistance-to-ground. The higher the inherent resistance of the grounding system, the greater the voltage that can build up on a "grounded" chassis or frame. When this built-up voltage discharges through a person, injury or death may result. For this reason, the effectiveness of the grounding system must be checked regularly.

CHAPTER 4. PREVENTlVE MAINTENANCE

44. GENERAL. This chapter discusses the preventive maintenance program for the visual aid facilities and equipment. It contains a preventive maintenance inspection schedule (PMI) for each major item of equipment with step-by-step instructions for performing the PMI. The PMIs establish a recommended routine which may be altered to suit local conditions. General trouble-shooting procedures for airport lighting systems are contained in chapter 5. Corrective maintenance procedures for specific equipment will be found in the manufacturer's operating and maintenance instructions and are not included in this advisory circular.

SECTION 1. ROTATING BEACONS

45. PREVENTIVE MAINTENANCE INSPECTION PROCEDURES. To perform the PMIs contained in table 4-1, proceed as follows:

a. Daily Checks.

(1) Check the operation of beacon. Verify beacon operation from dusk to dawn.

(2) Count the revolutions per minute (rpm) of beacon; should be either 6 or 12 rpm + 1 rpm, depending on equipment type.

(3) Check telltale indicator lamp to see if it is illuminated. If it is illuminated, it indicates that the beacon is operating on the reserve (spare) lamp. The burned-out lamp should be replaced immediately.

b. Bimonthly Checks.

(1) Lamp-changer. Check the operation of the lamp-changer. Deenergize the beacon circuit and remove the operating lamp from its receptacle. Energize the beacon circuit and observe that the beacon changes to the reserve lamp. Deenergize the beacon circuit and reinstall the lamp previously removed.

(2) Slip Rings. Check the condition of the slip rings and brushes. Clean the slip rings and brushes with a cloth moistened with trichloroethylene. If sparking or pitting has occurred, smooth rings according to manufacturer's instructions. Avoid sanding, if possible; sanding produces a raw copper surface which shortens brush life. If the slip rings are deeply pitted, replace or have them turned down. Replace worn out brushes.

(3) Clutch. Test the clutch torque by hooking a spring scale in one of the handles on the side of the housing.

(4) Lens Retainer. Check the clamps or screws that secure the beacon lens (or cover) in place to be sure they are tight, and the lens is properly seated.

(5) Telltale Light. Check the telltale light for a burned-out bulb. Clean glassware.

Table 4-1. Preventive maintenance inspection schedule for rotating beacons.

Maintenance requirement	
1. Check for beacon operation; count rpm.	Daily
2. Check telltale indicator lamp for reserve lamp status.	Daily
3. Check operation of the lamp-changer.	BiMonthly
4. Check slip rings and brushes.	BiMonthly
5. Test the clutch torque.	BiMonthly
6. Check lens retainers.	BiMonthly
7. Check telltale indicator lamp.	BiMonthly
8. Check operation of relays.	BiMonthly
9. Clean and polish glassware.	BiMonthly
10. Check and record input voltage.	SemiAnnually
11. Check lamp focus and beam elevation.	SemiAnnually
12. Lubricate main shaft, motor, ring gear, and padlocks.	SemiAnnually
13. Check operation of electrical switches and contacts.	SemiAnnually
14. Check lightning arresters and grounding system.	SemiAnnually
15. Check power meter.	SemiAnnually
16. Check level of base.	Annually
17. Clean and regrease gears.	Annually
18. Inspect wiring, lugs, and conduit.	Annually
19. Check weatherproofing and gaskets.	Annually

(6) Relays. Check the operation of the relay and clean relay contacts if they are pitted or show evidence of poor contact. Replace relay if points are badly pitted.

(7) Glassware. Clean and polish all glassware, both inside and outside, using a type of cleaner which does not scratch the lens.

c. Semiannual Checks.

(1) Input Voltage. Check the input voltage and record the reading. It should be within 5 percent of the rated lamp voltage. Too high a voltage causes lamp burnouts; too low a voltage causes light output to be inadequate. The measurement should be made at the beacon lamp terminals with all field equipment energized in order that the voltage reading will reflect operating conditions. Beacon lamps are very sensitive to voltage changes. A drop of 10 percent will reduce the light output 31 percent while a rise of 10 percent will shorten the lamp life 72 percent. Voltage regulation on airport power service is often quite poor, and frequently power supply conditions change so that the existing voltage is different from that measured at the time of installation. This is one of the most common causes of short-lived beacon lamps, and it is, therefore, important that the voltage ratings of the lamps used correspond closely to the actual prevailing supply voltage. If the voltage is out of tolerance, contact the power company to correct the situation, or install a compensating device such as an autotransformer.

(2) Lamp Focus and Beam Elevation. Verify that beacon beam is narrow, well defined, and projects horizontally. If beam elevation is dispersed and/or projects other than horizontally, focus and beam elevation should be adjusted.

(3) Lubrication.

(i) Vertical Main Shaft. Beacons supplied with a grease-gun fitting should be lubricated twice a year under ordinary operation. Use a high-quality, low-temperature silicone grease (ESSO #325 or equivalent).

(ii) Motor. If the motor is supplied with oil cups, lubricate with SAE 20 oil. If there are no oil cups, the bearings are sealed and do not need servicing.

(iii) Ring Gear. Apply a small amount of grease (ESSO #325 or equivalent) to the ring gear.

Caution: The use of an excessive amount of grease will result in its dropping down upon the slip rings and causing poor contact and arcing.

(iv) Padlocks. Any padlocks should be lubricated with dry graphite powder or equivalent.

(4) Switches. Check the operation of electrical switch blades and clips for good contact. Switches should have tension between the blades and hinges, but must also be free to move. Loose-fitting hinges or clips will cause overheating

and deterioration of the switch parts. Severe overheating can usually be detected by a bluish color of the switch part affected.

(5) Lightning Protection System. Check the lightning rod connections for tightness. Check and record the ground resistance. Compare the reading with previous ground resistance checks. Reading must be less than 25 ohms. If the reading exceeds 25 ohms, immediate action must be taken to correct the grounding problem.

(6) Watt-Hour Meter. No maintenance of the watt-hour meter is required as it is generally the property of the power company servicing the site. However, it should be observed for creeping under "no load" as this indicates a faulty meter or a ground in the circuit. If this condition is noted, check the wiring to busbar, and if no short-to-ground is noticed, request the power company to repair or replace the meter. Check the meter lead connection for tightness and keep out-side of meter clean.

d. Annual Checks.

(1) Base Level. Check the level of the beacon by placing a level on the leveling base. Remove all paint or other material to assure a true level. Loosen holddown bolts and insert or remove spacers as required for proper level. Check the level of the beacon in four directions. Be sure to tighten down the base.

(2) Gears. Remove the old grease from the gears by washing with kerosene. When installing new grease, observe the caution statement above.

(3) Wiring, Electrical Connections, Conduit, and Relays.

(i) Wiring. Inspect for abrasions, breaks, and loose connections. Repair or renew wiring when necessary. All repair patches should be covered with suitable insulating cement. Check the position of the wiring and, if necessary, reposition to maintain a neat appearance.

(ii) Terminal Lugs. Check terminal lugs for tight electrical connection. The flat portion of the lug should be clean and free of corrosion for good electrical contact. Minor deterioration of electrical wire insulation at the terminal lug may be repaired with tape. Use Scotch Brand No. 88 or equivalent. Insulating cement may be used to secure the tape.

(iii) Conduit. Inspect conduit for loose supports and connections. Replace broken brackets.

(4) Weatherproofing and Gaskets. Check the condition of the weather-proofing and gaskets. Gaskets should be replaced when cracked or deteriorated. Before installing new gaskets, clean the gasket channels and seats thoroughly. When it is necessary to secure the gasket with rubber cement, both the gasket and seat should be coated with appropriate cement and permitted to dry until tacky before the gasket is positioned.

SECTION 2. WIND CONE ASSEMBLIES

46. PREVENTIVE MAINTENANCE INSPECTION PROCEDURES. To perform the PMIs contained in table 4-2, proceed as follows:

a. Daily Checks.

(1) Visually check to see that the lights are burning properly each night. If the lamps burn dimly, the voltage is probably too low. If the lamps burn out too frequently, the voltage is probably too high. The voltage should be 120 volts +5% volts AC.

(2) If a photocell is used, cover it and verify that the lights turn on.

b. Monthly Checks.

(1) Check the cone assembly to see that it swings freely throughout the 3600 travel. If the wind is not sufficient, swing the cone down to the servicing position and manually check the freedom of movement. If the cone assembly does not move freely, the bearings are probably bad or need lubricating.

(2) Check the condition of the wind cone fabric. The fabric of the cone should be carefully examined at close range. The fabric should be completely replaced when it is badly worn, rotted, or soiled.

c. Bimonthly Checks.

(1) All of the lamps should be replaced after 80 percent of the rated life and prior to 90 percent of the rated lamp life.

(2) The globes should be cleaned when replacing the lamps.

(3) Check paint of segmented circle and repaint as necessary.

d. Semiannual Checks.

(1) Check the bearings to see if they need lubricating. An application of a light grease should be sufficient. In areas exposed to severe dust, clean the bearings with kerosene and repack with a light grease. In freezing weather, the grease becomes very viscous and action of the wind cone in light winds will often become sluggish. During such weather, it may be necessary to completely clean the bearings of grease and lubricate them with a light oil.

(2) Take an insulation reading of the underground feeder cable and record the results. Compare with the previous reading. When the readings fall below 25,000 ohms, the cables should be repaired or replaced.

Table 4-2. Preventive maintenance inspection schedule for wind cones.

Maintenance requirement	
1. Check lamp operation.	Daily
2. Check photocell operation.	Daily
3. Check for freedom of motion of windcone frame.	Monthly
4. Check condition of wind cone fabric.	Monthly
5. Check lamp age for scheduled replacement.	BiMonthly
6. Clean glassware.	BiMonthly
7. Check paint on segmented circle.	BiMonthly
8. Clean and grease bearings.	SemiAnnually
9. Read insulation resistance.	SemiAnnually
10. Check mounting bolts.	Annually
11. Check wiring at hinge.	Annually
12. Check grounding system resistance.	Annually
13. Check paint on wind cone structure.	Annually
14. Remove vegetation.	Unscheduled

e. Annual Checks.

(1) Check the assembly base securing bolts for tightness. Tighten, as required.
(2) Check the wiring at the hinged area. If frayed, repair or replace wiring.
(3) Check the ground system for loose connections.

(4) Test the resistance of the grounding system as described in paragraph 47.
(5) Check the condition of the paint on the wind cone structure. Touch up or repaint as required.

f. Unscheduled Maintenance. Remove growth in the vicinity of the segmented circle.

SECTION 3. AIRPORT LIGHTING VAULT

47. PREVENTIVE MAINTENANCE INSPECTION PROCEDURES. To perform the PMIs contained in table 4-3, proceed as follows:

a. Daily Check. Check the operations of all controls.

b. Bimonthly Checks.

(1) Cleanliness. Check the general cleanliness of the vault. Sweep out the vault regularly. Keep it free from dust, dirt, sand, spider webs, insect nests, etc.

(2) Moisture. Check for any collection of moisture. If there is a drain in the floor, make sure that it is operating properly. Mop up moisture from the floor.

(3) Screens. Check screens on all ventilators. Repair or replace, as necessary, to keep out wasps and other nest-building insects. Check operation of ventilation fans.

(4) Storage. Check vault for improper use as a storeroom. Avoid storing spare parts, rags, etc., near the high-voltage equipment. If the vault has an attached room, use this room for storing spare lamps, fuses, rags, spare parts, etc.

(5) Insulation-Resistance Test. Perform an insulation-resistance test on all field circuits. Record the readings, and compare them with the previous readings. For series circuits, the insulation resistance may be measured by simply removing the ends of the loop from the power supply. For parallel circuits, all

Table 4-3. Preventive maintenance inspection schedule for airport lighting vault.

Maintenance requirement	
1. Check control operation.	Daily
2. Check general cleanliness.	BiMonthly
3. Check insulation resistance.	BiMonthly
4. Check input voltage.	BiMonthly
5. Check ground resistance.	SemiAnnually
6. Inspect and clean buses.	SemiAnnually
7. Check relay operation.	SemiAnnually
8. Check oil fuse cutouts.	SemiAnnually
9. Check oil switches.	SemiAnnually
10. Operate power transfer switches.	SemiAnnually
11. Check control panel.	SemiAnnually
12. Check photoelectric switch.	SemiAnnually
13. Check astronomic time switch.	SemiAnnually
14. Check radio-control of lighting equipment.	SemiAnnually
15. Check lightning arresters.	SemiAnnually & Unscheduled
16. Inspect miscellaneous electrical hardware (fans).	SemiAnnually
17. Check oil dielectric.	Annually
18. Paint equipment as necessary.	Annually

connections must be removed before insulation resistance may be measured. There is no absolute ideal value for the loop circuit resistance since the resistance is higher in shorter circuits and lower in longer ones. The circuit resistance may also change with the amount of moisture in the soil. Operating the system before measuring insulation resistance may also affect the value since moisture will be driven out of the circuit by the heat of operation. For this reason, the insulation resistance should be measured at the same time of day to minimize these variations. The important information is the deterioration of the resistance value from month-to-month and year-to-year. The resistance value inevitably declines over the service life of a circuit; a 10-20 percent yearly decline is normal. A yearly decline of 50 percent (4 percent monthly) or greater indicates the existence of a problem (such as a high resistance ground) or serious deterioration of the circuit. The maintenance supervisor should consider troubleshooting the circuit (chapter 5) to locate the problem. A table of typical initial values for loop circuit resistance is provided in table 4-4.

Table 4-4. Table of initial resistance values versus circuit length.

Circuit length in feet	Suggested minimum resistance to ground in megohoms
10,000 or less	50
10,000-20,000	40
20,000 or more	30

(6) Input Voltage. Measure the input voltage to the vault. This measurement should be repeated every few hours throughout the day and night since the demand on the commercial power network varies throughout the day. The input voltage may consequently vary widely throughout the day. Record the input voltage of each phase for future reference. If it is out of tolerance, contact the power company and have them correct the problem.

c. Semiannual checks.

(1) Ground Resistance. Perform a ground-resistance measurement for each item of equipment using a ground resistance tester (paragraph 41) or a volt-ohm-milliammeter (paragraph 25). Record the readings and compare with previous readings to discover deterioration in the grounding system. The lower the resistance value, the better; a value of 5 to 10 ohms is desirable. If the resistance is greater than 25 ohms, immediate action must be taken to lower the resistance.

(2) Primary High-VoltaRe Buses and Ground Buses. Check the high-voltage bus installation with particular attention to the condition of the insulators, supports, and electrical connections. Keep the bus insulators wiped free of dust or any other deposits. Check the ground bus carefully throughout its entire length. If the bus or any ground connection to the bus is broken, make immediate repairs. Deenergize the system before cleaning or repairing the bus.

(3) Relays. Inspect the protective relay, runway-selector relays, and auxiliary relay panels when servicing the vault equipment. Check the operation of these devices, clean the contacts, adjust release springs, and check contact arms and dashpots. Replace all unserviceable parts.

(4) Oil Fuse Cutouts. Check operation and electrical connections of the oil fuse cutouts. Check the contacts and check the oil level. Add oil when necessary. If fuses with replaceable links have failed, replace them with fuse links especially manufactured for this purpose rather than string fuse wire. If the oil fuse cutouts have a manual operating lever, check the operation of the locking arrangement. Be sure the manual operating handle is locked in the "OFF" position before servicing vault equipment that is being supplied through the oil fuse cutout.

(5) Oil Switches. Check the operation of the oil switches. Be sure that the moveable handle on the oil switch, which has three positions, "MANUAL OFF," "MANUAL ON," and "AUTOMATIC", is in the "AUTOMATIC" position at all times. This allows the switch to be remotely controlled. Check the contacts and oil level and service when necessary.

(6) Power Transfer Switches. Check operation of power transfer switches. Check contacts for dirt or corrosion.

(7) Control Panel. In some cases, an auxiliary control panel is installed in the vault, or an outdoor-type control panel is installed on an outside wall of the vault. In such cases, carefully check the operation of all parts of the panel. Clean all contacts and make sure all electrical connections are in good condition. Clean the interior of the panel carefully.

(8) Photoelectric Time Switch. If a photoelectric time switch is installed, it should be maintained according to the manufacturer's instructions. The light levels should be checked with a photographic light meter to ensure that the control turns on and off at the proper ambient light levels (see appendix 1, table 8).

(9) Astronomic Time Switch. If this switch is installed, it should be serviced according to the manufucturer's instruction book. Inspect the operation, check clock, clean motor commutator and main switch contacts, and check all electrical connections. As this is a precision instrument, repairs should be made by the manufacturer or his authorized service representative.

(10) Radio-Control of Airport Lighting. Check the operation of radio-controlled airport lighting by keying a portable transmitter and observing the actuation of the switching mechanism. If a fault is detected, follow the manufacturer's recommendation for repair or replacement.

(11) Lightning Arresters. Check the lightning arresters for burning, scorching, or other signs of failure. Lightningarresters should be inspected for damage after each lightning storm in the area.

(12) Miscellaneous. Inspect all miscellaneous vault items, such as circuit breakers, terminal blocks, potheads, vault lights, switches, etc. Make sure they are clean and all connections are tight.

d. Annual Checks.

(1) Dielectric Checks. Perform dielectric tests on oil in oil-filled equipment such as circuit breakers, regulators, and transformers as described in paragraph 51.

(2) Paint. Check the condition of the paint on the equipment and vault. Repaint as necessary.

48. RECOMMENDED VAULT PROCEDURES.

a. Airport Plan. An airport plan should be permanently posted in the vault to aid in testing and troubleshooting the field circuit loops. This airport plan (preferably behind glass) shows the field layout, marked with the location of all lights, cable runs, cable splices, and visual aid equipment.

b. Schematic Diagram. Up-to-date diagrams of all power and control circuits should be displayed in the vault. Both a schematic diagram, which is a symbolic depiction of the logic of the circuit, and a wiring diagram, which is a detailed layout showing all wires and connections, should be displayed.

c. Vault Security. The vault should be kept locked, except during maintenance, to keep unauthorized personnel out. Contact with the high-voltage buses in an airport lighting vault is nearly always fatal. Only authorized personnel, experienced in the hazards of high voltage, should be allowed in the vault.

d. High-Voltage Warning Signs. High-voltage warning signs, as described in paragraph 5, should be prominently displayed at appropriate locations.

e. Safety Board. Safety boards, as described in paragraph 4, should be installed in the vault.

49. PREVENTIVE MAINTENANCE INSPECTION PROCEDURES. To perform the PMIs contained in table 4-5, proceed as follows:

a. Daily Checks.

(1) Perform a visual inspection of the system at twilight or night each day. This inspection should consist of a driving patrol to visually check for dimly burning bulbs, burned-out lamps, and for fixtures out of alignment. The locations of such fixtures should be recorded and corrections should be made as soon as possible. Replace dimly burning lamps and burned-out lamps when the system is dea activated.

(2) Replace broken lenses with proper type and color. Ensure lenses are properly oriented with respect to the runway according to marking on top of lenses. Split lenses or filters should be installed where required.

b. Weekly Checks.

(1) During the growing season, check for grass, dirt, and weeds around the lighting units. Vegetation should not block the pilot's view of the light. Growth can be controlled by using an effective weed killer, by use of diesel fuel, or by pouring a ring of concrete around each fixture.

(2) Check lenses for cleanliness and clean as required.

c. Monthly Checks.

(1) Check the orientation of all lenses. This check should be made by viewing the lights at night. Misaligned light units will appear dimmer or brighter than those that are properly aligned. The lenses may get out of adjustment when replacing lamps or when mowers and other vehicles strike the elevated lights.

(2) Straighten, level, and align all lighting units that have been knocked out of alignment.

(3) Check lamp sockets for cleanliness and good electrical connections. If moisture is present, replace the fixture gasket.

(4) Inspect and clean the weep holes in the frangible coupling of stake-mounted lights.

d. Semiannual Checks.

(1) Check the ground elevation around lighting fixtures. The frangible point should be approximately 1 inch (2.5 cm) above the ground elevation. Grade around fixture where necessary to maintain this fixture/grade relationship. Also, maintain the elevation of all lights the same height above the runway/taxiway

Table 4-5. Preventive maintenance inspection schedule for runway and taxiway edge lighting systems.

Maintenance requirement	
1. Inspect for outages; repair as necessary.	Daily
2. Check for vegetation growth.	Weekly
3. Check cleanliness of lenses.	Weekly
4. Check light alignment and orientation.	Monthly
5. Clean fixtures and sockets.	Monthly
6. Check light elevation.	SemiAnnually
7. Check for moisture in lights.	SemiAnnually
8. Check for rust, paint deterioration.	SemiAnnually
9. Inspect fixture for deterioration.	Annually
10. Check cable insulation.	Annually
11. Check gaskets.	Annually
12. Remove snow from around lights.	Unscheduled

pavement edge. The elevation should be checked more frequently during times of frequent freeze/thaw cycles. The height of the lights should not exceed 14 inches (35 cm) when located within 5 feet (1.5 m) of the runway or taxiway edge. In snow country, where the lights are located beyond 5 feet (1.5 m) from the runway or taxiway edge, the lights may be raised 2 inches (5 cm) for each foot beyond the 5 foot (1.5 m) point. At the 10 foot (3 m) position, the lights may have a maximum height of 30 inches (75 cm). The increase in height is permitted only if any overhanging part of an aircraft expected to use the runway or taxiway could clear the light by at least 6 inches (15 cm) when the plane's mpin landing gear is located on any part of the runway or taxiway.

(2) Check light bases and housings for evidence of moisture penetration. Check gaskets, seals, and clamps for deterioration and damage. Check the torque of light base cover bolts.

(3) Check fixtures, bases, and housing for corrosion, rust, and peeling paint.

f. Annual Checks.

(1) Check each light fixture carefully for cracking, corrosion, or shorts.

(2) Clean the contacts and assure that lamp fits firmly into receptacle.

(3) Check condition of all connections.

(4) Check runway cable insulation (paragraph 47). Check the insulation after severe thunderstorms.

(5) Check all gaskets on a leaky light unit and replace with new rubber gaskets.

g. Unscheduled Maintenance. Remove snow from around the lighting fixtures as soon as possible after a snowfall so the light fixtures are not obscured. If heavy snowfalls are predicted, red flags or sticks of sufficient length should be planted adjacent to the edge lights to mark their location. The flags will facilitate snow removal and will lessen the damage to fixtures by snow removal equipment.

50. MAINTENANCE PROCEDURES. The following paragraphs discuss general maintenance procedures for the runway and taxiway edge lighting system:

a. Lamp Replacement. With the lights operating, make a visual check to positively identify the lighting unit or units that are out.

CAUTION: Deenergize the circuit and lock out the circuit or regulator so that the circuit cannot be energized from the remote lighting panel or other means before starting work on the lights.

(1) Turn off lights and lock out circuits. Install safety warning signs (paragraph 5) at appropriate locations.

(2) With the replacement lamp at hand, open up the fixture and remove old lamp.

(i) Examine the old lamp to make certain that the lamp is at fault.

(ii) Compare the identification markings on the old and replacement lamps to be sure the replacement lamp is the correct type.

(iii) Inspect the lamp socket, the connections, and the wire insulation.

(iv) Check the light unit and base for evidence of leakage or condensation and remove any water present.

(v) Replace fused film disc cutout, if used.

(vi) Install new lamps.

(3) Check filters, when used, for cracking or misalignment and replace or adjust as required.

(4) Clean all reflectors, globes, filters, and covers as required. When hood or shield is used, check adjustment.

(5) When closing the light, make certain the gaskets are positioned for proper sealing. Tighten all screws, clamps, and fasteners.

(6) Check frangible couplings for cracks.

(7) Check the horizontal and vertical alignment of the lights for proper adjustment.

(8) When all outages have been corrected, energize the circuit and make a visual check of the repaired units for proper operation. Record the repairs.

b. Spare Unit Replacement. In some instances, it may be more convenient to fix defective edge lights by replacing the entire light with a spare unit. This fill minimize the runway downtime and allow troubleshooting and refurbishment of the defective light at a more convenient location. Spare unit replacement is very convenient for repairing lights struck by lightning or vehicles.

c. Film Disc Cutouts. Some of the older installations use fused film disc cutouts to bypass failed lamps. Some circuits that have more than one light on the secondary of each isolating transformer use them to bypass a burned-out lamp and keep the other lamps on the transformer operating. When replacing lamps in these lights, the film disc cutout must also be replaced. Use the disc cutout of proper type and size. The film disc is located within the light enclosure and is installed between spring-loaded terminals.

d. Inspection. When replacing the lamp, inspect the light thoroughly for other damage. Check for water in bases or lights, cracked and chipped glassware, defective or incorrectly positioned gaskets, loose connections, cracked or deteriorated insulation, and misalignment of lights or shields.

e. Cleaning. When changing lamps, clean the light fixture inside and outside, as required. Light surfaces must be kept clean to transmit light satisfactorily. In establishing a cleaning program, first consider the sources of the dirt problem. Many airfield lights are located at or near ground level and are subject to blowing dirt or dust, rain spattering, jet exhaust residue, bird droppings, corrosion, and heat and static attraction of dirt. In some cases, submersion or exposure to water may be a problem. Cleaning procedures will vary dependent upon the cause of the problem and its effect on the system. Cleaning problems may often be reduced by preventive measures.

(1) When bird droppings are a problem, installation of a thin, stiff vertical wire on top of the light may be helpful in preventing birds from perching.

(2) When spattering is a problem, paving or sodding of the area may help.

(3) When lights tend to fill with water, improved gaskets and better sealing procedures may be required.

f. Cleaning Schedule. The cleaning schedule will vary at each location dependent upon such factors as environment, geographical location, and the types of lighting units. Each light should be cleaned thoroughly at least once a year.

g. Cleaning Procedures. Glassware, reflectors, lenses, filters, lamps, and all optical surfaces should be washed. Washing may increase the light output by as much as 15 percent more than wiping with a dry cloth. A dry cloth also may seriously scratch reflective surfaces.

(1) Do not use strong alkaline or acid agents for cleaning.

(2) Do not use solutions that leave a film on the surface.

(3) Remove the unit when possible and clean in the shop.

(4) For reflectors or other optical surfaces that cannot be removed for cleaning, use alcohol or other cleaning agents that do not require rinsing or leave a residue.

(5) Where washing is not practical, glassware (but not reflectors) may be cleaned with fine steel wool and wiped with a dry clean cloth.

h. Moisture.

(1) Water and Condensation. Water is the most common cause of problems in airfield lighting fixtures. In bases, water may cause grounding of the lamp or circuit; in the optical assembly it may submerge optical components, cause corrosion and deterioration, form condensation on optical surfaces, and accelerate the accumulation of dirt on optical surfaces. Preventing water from entering bases is very difficult. The alternate heating and cooling of the lights can create a strong "breathing" effect, especially when the base is located in saturated ground. The water may also enter through conduits, along the conductor of the cable, through gaskets and seals, through damaged glassware, or through fine holes in the walls of the bases.

(2) Protection From and Removal of Water. The immediate problem of water in lights and bases is removal and prevention of reentry. In the light bases, the accumulated water can usually be drained or bailed out. Drain holes should be drilled, or cleaned out if already present. Gaskets, seals, and clamps that may admit water should be checked. Chipped, cracked, or broken glassware should be replaced. If water cannot be eliminated from light bases, ensure all electrical connections and insulation are watertight and above the waterline.

(i) Operation of lights on brightness step B4 or B5 should dry up any condensation, and maintaining a low brightness setting rather than turning the lights off should prevent more condensation from forming. Cost and energy conservation would be factors in determining the efficacy of this method.

(ii) A hand or power driven pump can be very useful for removing water in light bases. Water can also be removed by dipping and mopping.

(iii) Light bases can be modified for easy pumping by installing an air valve in the cover and soldering a tube to the cover that extends to near the bottom of the base. Applying compressed air to the air valve will force the water up the tube and out of the base.

(iv) Cable may need replacing if water travels along and enters around the conductor.

(v) Before installing the cover plate, blow out cover bolt holes to make certain that fastening bolts are not anchored in sand or debris that prevents cover from being torqued sufficiently on the gasket. Make sure the bolt holes have serviceable threads and that the gasket is in good condition and properly placed.

(vi) Use corrosion-resistant cover bolts, and keep the bolts well greased to facilitate their removal and lessen the possibility of moisture entry around their threads.

(vii) The base flange bolts should be drawn down in opposite pairs until all are tightened to the recommended torque. Avoid excessive torque.

i. Strikes and Blast Damage. Light units damaged by strikes from aircraft or vehicles, or by propeller or jet blasts, should be repaired or replaced immediately. The fact that these lights have been hit indicates a critical need for them. Areas where this damage recurs should be checked frequently. A careful check should be made following damage of this type because the attaching cable may also be damaged.

(1) Repair and Replacement. When possible, the entire damaged unit should be replaced. Simple repairs that can be accomplished usually consist of the following:

(i) Remove the broken frangible coupling from the base cover.

(ii) Connect the new light to the secondary connector.

(iii) Install a new light on a new frangible coupling.

(iv) Check for correct alignment; align as required.

j. Frangible Coupling Replacement. Frangible couplings are used primarily to reduce damage to aircraft in case of a strike. They provide an intentional weak point and aid in preventing damage to other components. An open-end wrench, pipe wrench, cold chisel, and punch and hammer are usually sufficient to remove and install frangible couplings. Some makes require replacement of the entire column when the frangible point breaks.

(1) Remove damaged coupling.

(2) Use antisieze compound on new coupling threads.

(3) Tighten by hand and use wrench to snug down.

k. Scheduled Painting. Scheduled painting is usually accomplished annually, but touchup is a constant requirement.

(1) Clean and remove rust, corrosion, dirt, and loose paint.

(2) Apply suitable primer coat.

(3) Apply finish.

(4) After repainting light fixtures, restore assigned identification by stenciling or painting number in a conspicuous location in large numerals.

51. PREVENTIVE MAINTENANCE INSPECTION PROCEDURES. The procedures for the PMIs are listed in table 4-6. Where measurement of current is called for, do not use the ammeter on the face of the regulator. This meter does not have the accuracy required for these measurements. Use a clamp-on ammeter, instrument transformer and ammeter, or similar setup.

a. Daily Checks. Check all control equipment for proper operation. Check remote control and/or radio control on each brightness step.

b. Monthly Checks.

(1) Check and record regulator input voltage and input current. If the voltage is not correct (must be within +5 percent of design voltage), notify power company to correct input voltage.

(2) Check the load on the regulator by multiplying the input voltage times the input current times the regulator power factor (P = E x I x pF). Assure that the load value does not exceed the given kW rating of the regulator.

(3) Check and record the output current into the circuit loop on each brightness 3 step. Compare results with the tolerances listed on page 51. Consult the manufacturer's instruction book for information on adjusting output current.

c. Annual Checks.

(1) Visually check regulator for burned relay contacts, frayed or burned insulation, and loose connections. If contacts are burned or pitted completely through the silver contact surface, they should be replaced. If the contacts touch only at points, or if they are slightly pitted or dirty, they should be cleaned. A fine file is the most desirable tool for surface cleaning. After cleaning, the contacts should be realigned before the regulator is put into operation.

(2) Make a dielectric strength test of the oil. Take at least a 1-pint sample of oil through the oil sampling valve at the base of tne regulator tank. The test may be conducted with the oil-tester described in paragraph 40. If no facilities are available for making dielectric tests, contact the nearest power company equipped to perform these tests. If the oil is dirty or the dielectric strength is low, it should be replaced or filtered and dried to restore its dielectric strength. Sludge deposits on the core and coil assembly and in the tank should be washed out with clean dry oil. Models with an internal primary switch will tend to collect more sludge due to arcing under oil. Fill with oil to the proper level.

Warning: Since high open-circuit voltages may be obtained by opening the primary of a series lighting circuit, only authorized personnel should be allowed to perform the short-circuit test, open-circuit test, and the load tests.

Table 4-6. Preventive maintenance inspection schedule for constant current regulators.

1.	Check control circuits on all brightness steps.	Daily
2.	Check input voltage and current.	Monthly
3.	Check the regulator load.	Monthly
4.	Check the output current on each brightness step.	Monthly
5.	Check relays, wiring, and insulation.	Annually
6.	Check dielectric strength of cooling oil (if used).	Annually
7.	Perform a short-circuit test.	Annually
8.	Perform an open-circuit test (only on regulators - with open-circuit protective devices).	Annually
9.	Clean rust spots and paint as necessary.	Unscheduled

A series circuit connected across a 50 kW, 20.0-ampere regulator may have an open-circuit voltage of 3,500 volts. However, the momentary surge before the open-circuit protection device actuates will be more than this.

(3) Short-Circuit Test. Make a short-circuit test as follows:

(i) Turn off power to regulator.

(ii) Short the output terminals using No. 10 AWG wire (or larger) across the terminals.

(iii) Turn on the regulator and advance intensity through each step.

(iv) Read the output current on each step. The output current should be within the tolerance shown below for the type of regulator specified.

TYPE	STANDARD	TOLERANCE
20 ampere, 5 step	20.0 A	19.50-20.50
	15.8 A	15.41-16.20
	12.4 A	12.09-12.71
	10.3 A	10.04-10.56
	8.5 A	8.29-8.71
6.6 ampere, 5 step	6.6 A	6.47-6.70
	5.2 A	5.07-5.33
	4.1 A	4.00-4.20
	3.4 A	3.22-3.49
	2.8 A	2.73-2.87
6.6 ampere, 3 step	6.6 A	6.40-6.80
	5.5 A	5.34-5.67
	4.8 A	4.66-4.97

(v) If the current output is not within limits, check the voltage input to the regulator. It should be within +5 percent of rated input voltage. Be sure the correct voltage tap is used (on dry-type transformers).

(vi) Turn off regulator.

(vii) Disconnect the short and reconnect output cables.

(viii) Compare the short circuit values with those obtained from the monthly output current readings. If the values differ by more than the tolerance above, there is a problem with the field loop or regulator.

(4) Open Circuit Test. This test should be performed only on those regulators with open circuit protective devices.

(i) Turn off power to regulator.

(ii) Disconnect cables from output terminals.

(iii) Turn on power to regulator.

(iv) Advance the brightness selector switch to any step.

(v) The open-circuit protective device should automatically operate within 2 seconds to turn off the regulator.

(vi) Turn off the selector switch. The open-circuit protective device should reset. Turn the selector switch to any step. The regulator should turn on, then off again within 2 seconds.

(vii) If the test is satisfactory, turn off regulator power and reconnect the output cables.

d. Unscheduled Check. Clean rust spots on the equipment and repaint as necessary.

SECTION 6. CENTERLINE AND TOUCHDOWN ZONE LIGATING SYSTEMS

52. PREVENTIVE MAINTENANCE INSPECTION PROCEDURES. Because semiflush lights are installed in the aircraft traffic area and are run over by aircraft, they are high-maintenance items that require frequent attention to maintain specified performance. Additionally, their location below ground level make them prone to water infiltration; this also requires frequent attention. These problems should be remembered when performing the PMIs contained in table 4-7 and described below.

a. Daily Check. A driving patrol should be made daily at twilight. The inspector should look for burned-out or dimly burning lamps and record their location.

b. Weekly Check. A field electrician should inspect and service any lights reported as defective in the daily inspections. The preferred method of servicing is to replace the semiflush light unit with a spare and take the defective unit back to the shop for repair. The lighting circuit must be deactivated (fuses pulled) before any maintenance is attempted on the lights. The following defects may be the cause of the malfunction.

(1) No Light.

(i) Burned-out Lamp. The lamp may be replaced as described in the manufacturer ' s instruction book. The fused disc cutout should also be replaced where used.

Table 4-7. Preventive maintenance inspection schedule for centerline and touchdown zone lighting systems.

1.	Check for burned-out or dimly burning lights	Daily
2.	Repair or replace defective lights.	Weekly
3.	Clean lights with dirty lenses.	Monthly
4.	Check the intensity of selected lights.	Monthly
5.	Check the torque of mounting bolts.	BiMonthly
6.	Clean and service light; check electrical connections.	SemiAnnually
7.	Check for water in the light base.	SemiAnnually
8.	Replace lamps after 80 percent of service life.	Unscheduled
9.	Remove snow from around fixtures.	Unscheduled
10.	Check wires in saw kerfs.	Unscheduled

(ii) Electrical Failure. If the replacement light also fails to operate, or a string of lights fail, the problem is probably in the series circuit. Troubleshooting procedures are contained in chapter 5.

(2) Dim Light.

(i) Dirty Light. The exposed optical surface of the semiflush light gets dirty from exposure to aircraft traffic and weather. The lights should be cleaned periodically as described in paragraph 53.

(ii) Light Aiming. Shallow-base semiflush light fixtures sometimes are twisted out of alignment by aircraft landing or turning. Visually check any dimly burning lights to see if they are merely misaligned. The alignment procedure is discussed in paragraph 53.

(iii) Water in the Fixture. Examine the lens for standing water or condensation behind the lens. If water is present, the fixture should be removed and serviced as described in paragraph 53.

c. Monthly Checks. Until a regular maintenance schedule is established, the checks below should be performed at least once a month; it may be advisable to do them every 2 weeks at busy facilities. After some experience has been gained, the interval may be adjusted to operational needs.

(1) Cleaning. Due to their position at ground level, semiflush lights require frequent cleaning to maintain their specified performance. The frequency with which the lights must be cleaned depends on the light's location, weather conditions, and number of airport operations. The lights should be cleaned when the brightness of the fixture is less than 70 percent of the initial brightness when operated at full intensity. A fixture degraded below this is ineffective for high background brightness, low visibility conditions.

(2) Intensity Checks. To complement the cleaning process, a check should be made of the light output of several fixtures located on different parts of the field, particularly near the ends and in the touchdown zone. The light out-put may be measured with a photographic 10 spotmeter as explained in paragraph 53. The procedure may be conducted to provide the following information:

(i) Before cleaning, to establish whether cleaning is necessary, or

(ii) After cleaning, to check the effectiveness of the cleaning and determine the degradation of the internal optical assembly. Lights that are below minimum levels should be scheduled for removal and servicing.

d. Bimonthly Checks.

(1) Bolt Torque. The torque of the bolts attaching the light to its base should be checked. The impact of aircraft wheels can loosen mounting bolts and cause misalignment or fixture damage; this is particularly troublesome in the touchdown zone.

e. Semiannual Checks.

(1) Remove light, and clean and service as described in paragraph 53. If an intensity check reveals that the light has sufficient brightness, then it need not be disassembled; however, the light should be removed from its base so that the base and cable connections may be examined.

(2) Check the base for the presence of water. Any water found should be removed and the base should be sealed to prevent its reentry. This check should be conducted more frequently in winter months since freezing may cause damage to the fixture by shearing the fixture holddown bolts or rupturing the base.

(3) To maintain maximum system performance and minimize unscheduled outages, group replacement of lamps for semiflush fixtures should be considered. The fixtures should be relamped when the time on the high-intensity step equals 80-100 percent of the nominal lamp life.

f. Unscheduled Maintenance.

(1) Snow should be removed from around the lighting fixtures as soon as possible after a snowfall to prevent obscuring the light fixtures. Extra care should be exercised to prevent striking the lighting fixtures with snowplow blades. After snow removal operations, inspect all lighting fixtures and replace any damaged light assemblies. Whenever snowplows must traverse over in-pavement light fixtures, they should be traveling at less than 5 miles per hour or have the blades lifted clear of the fixture. Rubber and plastic snowplow blades that are especially suited to plowing wet or slushy snow are available; rotary brooms are also recommended. If snow removal is a frequent winter job, high-strength steel light fixtures may be specified to better withstand the impact of snow plowing.

(2) Check wireways in saw kerfs. If wires are floating out, reinstall using wedges for anchoring wires. Space wedges 2 feet (60 cm) on center. Seal wireways using P-606 sealer.

53. MAINTENANCE PROCEDURES. Servicing semiflush lighting should be scheduled to cause the minimum disruption to normal airport operations. For this reason, it is recommended that a number of spare fixtures be kept for installation in place of defective fixtures. The number of spare fixtures should be about 10 percent of the total number of semiflush lights in use. By replacing the defective light with a spare unit, minimum time is spent on the runway; the defective light may be repaired in the shop. The procedures below give a generalized approach to repair; for more specific information about a particular light, consult the manufacturer's instruction book.

a. Light Removal. The light fixture must be removed for relamping or base inspection. When removing the fixture for base inspection, be careful not to damage the connections to the isolation transformers. In cold weather, ice or snow may obstruct the bolt heads and make fixture removal difficult. Some facilities have constructed a wooden box, slightly larger than the fixture and a few inches tall. The box has an electric heating element inside, and an open bottom. When it is necessary to remove a frozen fixture, the box is placed over it, and the heating element is connected to a power source (usually a generator on the back of a truck.) When the box heats the fixture enough to melt the ice, removal may be easily accomplished.

b. Cleaning. Several different techniques are available for cleaning the exterior glassware of inset lights. Some require special equipment and are suited to large scale and frequent use with the light installed, while other techniques are more suited to bench cleaning of a light. The maintenance supervisor should select the method best adapted to the facility. Remember that not all techniques may be used with all lights; the manufacturer' s recommendations contained in the instruction book are the final authority.

(1) Manual. Commercially available cleaning detergents and pads can be used for removal of deposits from the lighting fixture lens unless prohibited by the manufacturer. Abrasive materials such as sandpaper or emery cloth should not be used as they will scratch the glass. Solvents are available that will clean the lens, but the solvent must be left on for a period of time to dissolve the deposit. The solvent used must be compatible with the lens sealing material. While manual techniques are well suited for bench cleaning of lights, they are very time- consuming for cleaning lights when installed in pavement.

(2) Ground Shells. Unless not recommended by the light fixture manufacturer, the cleaning can be done by using 20/30 grade, clean, ground walnut or pecan shells and clean, dry compressed air or nitrogen (nozzle pressure 85 psi). Figure 4-1 shows a typical example of how to clean the lighting fixture with shells.

(i) An average time of 10 seconds is required for cleaning the external surface of the lens.

(ii) The average usage of ground walnut shells is 0.6 pound (0.25 kg) per fixture.

Figure 4-1. Cleaning centerline and douchdown zone lights.

(iii) The cleaning system shown is not available as an assembled unit; however, a commercially available air compressor with controls and gauges, a sandblaster unit, and abrasive resistant hoses may be used.

(iv) After removal of the deposit from the lens, the fixture's light channel should be cleaned of shells with a blast of air, and the remaining dust wiped off with a clean cloth.

(3). Abrasive Brush. An abrasive brush may be used to clean rubber deposits by mounting it on a rotary hand tool powered by air pressure or electricity. The average cleaning time is 30 seconds per lens. Care must be taken not to remove the lens-sealing material in the cleaning process; this can be avoided with the use of a shield.

c. Light Aiming. The semiflush lights are aimed as part of the installation procedure. For lights installed on the tops of transformer housings, the aiming is fixed and nonadjustable. For lights installed on glue-in bases, the aiming may come out of alignment due to twisting of the light bases. The runway centerline lights should be aligned to within 20 of a line parallel to the runway centerline. When reinstalling the base, use an adhesive compatable with the type of pavement. P-606 sealer has compounds that are compatible with both concrete and asphalt pavements; be sure to choose the correct mixture. The aiming of semiflush lights may readily be checked by turning the lights on during foggy weather. The fog makes the light beam visible and it is easy to tell if a light is properly oriented. For touchdown zone lights, the light beam is offset 40 toward the runway centerline. The aiming of touchdown zone lights may be judged by viewing the barettes on either side of the runway while standing on the centerline. When viewing the barettes on either side of the runway from some distance, any light appearing dimmer or brighter than the lights next to it may be improperly aimed and should be checked.

d. Light Cleaning and Sealing. Semiflush lights gradually get dirty internally, and the internal optical surfaces should be cleaned when the light is disassembled for relamping or maintenance. Sandblasting may be used to clean rubber deposits off the casting after all removable parts have been taken off. Use a cleaning solution that does not leave a residue after drying. When relamping a light, be careful to handle the lamp by the leads only; fingerprints on the glass assembly will shorten lamp life. Lamps in brackets should be mounted according to manufacturer' s recommendations; using the wrong lamp or mounting it improperly can drastically reduce the light output of the fixture. When reassembling the light, carefully examine all gaskets and O-rings for cracks, tears, or malformation that will prevent them from resealing properly. Examine the optical prism to make sure that the sealer around the edges is in good shape. If the optical prism is cracked or badly pitted, it should be replaced.

e. Reinstallation. When mounting a semiflush unit on its base, care must be used to be sure that a watertight seal is obtained. The fixture connections to the series circuit should be sealed with two layers of plastic tape or with heat-shrink-able sleeving. The connection may also be varnished with a heat-resistant varnish to further improve the sealing of the connection and protect the tape from heat. Be sure that the gasket and its mating surface are free of sand or grit; this is a

Figure 4-2. Typical spotmeter

common fault in servicing that allows moisture to enter. Graphite compound or gasket cement may be used on the gasket surfaces to ensure a watertight seal. Securely tighten all fixtures to the manufacturer's specified torque. The bolts and threads should be cleaned, and the threads may be coated with a securing compound such as Locktite 242, or equivalent.

f. Water Removal. The procedure for removing water from the base of semiflush lights and preventing reentry is similar to that described in paragraph 50 for runway edge lights. If the fixture itself leaks, renew all gaskets and sealants.

g. Photometric Measurements. Photometric measurements of semiflush lights are the most direct way of determining if they are emitting the specified amount of light. The procedure presented below, using a photographic 10 spotmeter (figure 4-1), may be used when the light is installed or in the shop. Photometric measurements of installed semiflush lights help determine if the window area should be cleaned, or if the light is in need of maintenance. The photometric procedure presented below relies on the comparison of relative values of light. While it is useful for determining the relative performance of the light, care should be used when comparing dissimilar lights, as the standard values established may not apply.

(1) Energize a new light at maximum intensity (6.6 amperes). Take a reading with the spotmeter at a distance where the window area of the light unit just fills the 10 measuring spot of the meter. The observer should move the meter vertically and horizontally far enough to ensure that the maximum reading is observed (center of the light beam). This maximum value, usually in exposure value (EV) units, should be recorded and used as the standard value to which field measurements are compared.

(2) Next take photometric readings of the lights to be sampled, using the technique described in (1). The lights should be set on the maximum intensity step. If the EV reading of the spotmeter is more than 2/3 EV lower than the reference value determined in (1), the light is in need of servicing. In the event a scale other than EV is used, the light should be serviced when it emits less than 70 percent of the light it emitted when new.

(3) Since there are variations in the manufacture and installation of semiflush lights, some lights may remain below the standard value as measured in (1) above even after cleaning and servicing. If the difference in light output is significant, then it may be necessary to establish individual standards for lights with sub-par readings.

SECTION 7. VISUAL APPROACH SLOPE INDICATOR SYSTEM

54. PREVENTIVE MAINTENANCE INSPECTION PROCEDURES. To perform the PMIs contained in table 4-8, proceed as follows:

a. Daily Checks. Check that all lamps are burning and areof equal brightness. Adequate spare lamps should be available to permit a complete replacement of all lamps in the system. Spare bypass (grasshopper) fuses, if used, should also be stocked. Lamps should be replaced immediately if they burn out or

Table 4-8. Preventive maintenance inspection schedule for visual approach slope indicator (VASI) system.

Maintenance requirement	
1. Check lamps for operation.	Daily
2. Check operation of controls.	Monthly
3. Check for damage by service vehicles or aircraft.	Monthly
4. Clean lamps and filters.	Monthly
5. Check mechanical parts for damage.	Monthly
6. Check lightning arrester.	Monthly
7. Check for water damage or insect infestation.	Monthly
8. Check for presence of rodents.	Monthly
9. Record output current and input voltage of adapter (if used).	Monthly
10. Check alignment and aiming of light boxes.	Monthly
11. Check leveling and operation of tilt switch.	Monthly
12. Check integrity of obstacle-free approach plane.	Quarterly
13. Check insulation resistance of underground cables.	SemiAnnually
14. Check resistance of grounding system.	SemiAnnually

become darkened. If the Visual Approach Slope Indicator (VASI) uses bypass fuses, never replace a lamp until the associated fuse is checked.

b. Monthly Checks.

(1) Check operation of controls. Check photocell brightness control and runway light circuit interlock (if used), radio control (if used), and/or remote control switch.

(2) Check for damage by mowers, snowplows, etc.

(3) Clean lamps and filters.

(4) Visually check mechanical parts for cleanliness, burned wires or connections, cracked insulators, lamps or filters, etc.

(5) Check if lightning arresters and/or surge suppressors are scorched or show other signs of being burned out and replace as necessary. Also, check after electrical storms.

(6) Check for damage or debris from water, mice, wasps, bird nests, spider webs, etc., in lamp boxes and adapter units and clean or repair as needed.

(7) Check for burrows or other signs of rodent activity in vicinity of cables; take steps to discoura@e their presence to minimize likelihood of cable damage.

(8) If an adapter unit is used, read and record the output current and the input voltage to the adapter unit

(9) Check the horizontal and lateral alignment of the light boxes, and check the aiming (vertical angle) with the VASI aiming bar (see paragraph 55 for procedures). Record the angle setting and the date in a maintenance log. It is particularly important to check aiming frequently whenever the soil freezes or thaws or has a change in moisture content (especially clay soils).

(10) Check levelling and operation of tilt switch (used in VASI-2 and some VASI-4 installations).

c. Quarterly Checks. Check the obstacle-free approach plane for clearance from tree growth, new towers, pole lines, or other obstacles. The obstacle free plane starts at the first VASI light bar, and extends over the approach area at an angle 10 lower than that of the first VASI bar. The obstacle free plane is 4 miles long and extends 100 on either side of the runway centerline.

d. Semiannual Checks.

(1) Check insulation resistance of underground cables (paragraph 47) and record the results.

(2) Check resistance of the grounding system (paragraph 47) and record the results.

55. MAINTENANCE PROCEDURES.

a. Adjustment of the Vertical Aiming. This is normally done with an aiming bar, calibration bar, and small (machinist's) level. Handle these precision instruments carefully. Make sure the aiming bar is the one supplied with the VASI light units. The followingsteps should be followed each time the VASI is checked.

(1) Place the calibration bar on a rigid surface that is approximately level, such as a concrete floor or a table or counter that is sitting on a concrete floor. Most wooden floors will deflect enough under one person's weight to make it impossible to accurately level the calibration bar.

(2) Place the small level on the calibration bar and level it with the adjustable feet, both in the linear and transverse directions.

(3) Turn the small level 1800 to check for centering of the bubble. If it does not check when reversed, adjust the small level so that the bubble will remain centered when the small level is reversed.

(4) Place the aiming bar on the calibration bar and check that its spirit level remains centered in the 00, 30, and 60 positions and settings. Adjust spirit level if necessary to center the bubble. If the bubble cannot be centered at each of the three angles, the aiming bar should be replaced.

(5) Place the instruments in the carrying case for transporting out to the VASI Soxes.

(6) Place the small level on the bottom center of the aperture (light slot) at the front of the box and level the box transversely with the two front adjusting (mounting) screws.

(7) Set the proper angle on the aiming bar (usually 2 1/20 for light bar No. 1, closest to runway end, and 30 for light bar No. 2) and insert through the aperture so the end of the aiming bar rests on the transition bar.

(8) With aiming bar in line with left-hand lamp, adjust left rear adjusting screw. Move the aiming bar to the right side of box and adjust right rear screw. Repeat for left and right side until bubble is centered at each position.

(9) Recheck transverse levelling, and recheck longitudinal levelling with the aiming bar in center of light box.

(10) Stand in front of the VASI box (approximately 50 feet away) and check that the light changes color simultaneously along with the whole width of the unit. If not, either the levelling was not done properly, the box is warped, or the transition bar is not in its proper place.

(11) Check the tilt switch on all VASI-2 systems and VASI-4 systems (where provided) by placing the small level on the marked top surface of the tilt switch and adjusting the tilt switch if necessary. If the tilt switch shuts off the power when it is level, the tilt switch should be replaced. The main switch may have to be turned off, and back on, to reset tilt switch circuit.

b. Check of Adapter Unit Current Output.

(1) With system on, adjust day current to 6.4 to 6.6 amperes.

(2) Cover photocell with a heavy glove or other dark material, wait for time delay to deenergize, and read current. If the VASI has a night adjustment, set current to 4 .8 to 5.0 amperes.

(3) Remove covering from photocell. The lights should switch @ack to day brightness after a short time delay (15 seconds to 1 minute),

SECTION 8. HAZARD BEACONS AND OBSTRUCTION LIGHTS.

56. PREVENTIVE MAINTENANCE INSPECTION PROCEDURES. To perform the PMIs contained in table 4-9, proceed as follows:

a. Daily Checks. Verify that all hazard beacons and obstruction lights are burning each night. Replace burned-out lamps.

b. Monthly Checks.

(1) For flashing hazard beacons, count the number of flashes of the hazard beacon over a full 2-minute period. The flashing rate may range from 20 to 40 per minute; the beacon "OFF" time should be about half the "ON" time.

(2) Check the operation of the photocell or other automatic control devices.

c. Semiannual Check. Test the insulation resistance of feeder cables and ground resistance of the grounding system (paragraph 47).

d. Annual Checks.

(1) Check the condition of the wire, insulation,splices, switches, connections and fuses. Check the fuse size (should not be more than 120 percent of rated load). The fuseholder should be tight with clean, uncorroded contacts. Check the wiring for loose connections and the insulation for breaks or fraying. Checkswitches for loose, burned, or misaligned contacts.

Table 4-9. Preventive maintenance inspection schedule for hazard beacons and obstruction lights.

Maintenance requirement	
1. Check operation of lamps.	Daily
2. Check flash rate of hazard beacons.	Monthly
3. Check operation of photocell.	Monthly
4. Check insulation resistance and ground resistance.	SemiAnnually
5. Check wire and connections.	Annually
6. Check voltage at lamp socket.	Annually
7. Check weatherproofing of the fixture.	Annually
8. Check lightning protection system.	Annually
9. Check power meter.	Annually
10. Service lowering device and other supporting hardware.	Annually
11. Check changeover relay in dual fixture.	Annually
12. Clean and recondition beacon.	Annually
13. Install new lamp after 80 percent of rated life.	Unscheduled

(2) Check the lamp voltage at the lamp socket and record the voltage. Compare the voltage with the previous reading. If the voltage reading is more than 10 percent different from the nominal value, determine the cause and correct the problem. If a booster transformer is used, check the input and output voltage level@.

(3) Check gaskets and seals for leaks. Adequate weatherproofing is necessary for the protection of lights. All gaskets should be renewed when cracked or deteriorated. Before installing a new gasket, throughly clean the gasket channel to make the gasket seats properly. When it is necessary to secure the gasket with rubber cement, both gasket and seal should be coated with cement and permitted to dry until tacky before the gasket is placed in position.

(4) Visually check the lightning-protection system. Check all connections for tightness and continuity. Check lightning arresters for cracked or broken porcelain and for missing mounting brackets. Repair as required.

(5) Check the power company meter. The meter should be checked for creeping under no-load conditions. If it is creeping with the light off, carefully check for grounds. If none are found, notify the power company to correct the problem. Check the leads for tightness and keep the meter surface clean.

(6) When the obstruction lights are mounted on disconnect hangers and are equipped with lowering devices, wire guides, and pulleys, all fittings, supports, and cables should be cleaned and lubricated. The contact surfaces of the electrical disconnect should be cleaned.

(7) The duplex obstruction lights should be serviced as described above. In addition, if a changeover relay is used, it should be cleaned, and the relay housing gasket should be kept in good condition. All missing cover screws should be replaced to prevent water, moisture, and dust from entering the relay enclosure. Only one light in the double obstruction light is energized when a transfer relay is used. Upon failure of the first lamp, the relay should transfer power to the second or standby lamp. The relay is mounted in the fixture base. A pilot lamp is normally provided across the standby lamp to provide a remote indication that one lamp has burned out. Check the operation of this remote lamp.

(8) The beacon should be cleaned and reconditioned yearly or when a lamp is replaced. Follow the procedures below:

(i) Clean and polish the globes and lenses using a glass cleaner or ammonia and water. Wipe the globes dry before reassembling. Remove dust and dirt from grooves. A stenciling brush or a small paint brush is especially useful for this purpose. Remove all paint spots and streaks from along the edge of glass.

(ii) Using a brusn or cloth, clean the dirt and dust from fixture and open all drain holes. Check the condition of sockets. Look for burned or galled screw bases, loose connections, and frayed or broken insulation.

(iii) Check the load contactor for pitted, barned, or misaliKned contacts. Ensure that the armature moves freely and that the spring tension is sufficient to pull the armature away from the coil when deenergized.

e. Unscheduled Maintenance. Change the lamp when the burning time has attained 80 percent but not more than 95 percent of its rated life. Make certain that the correct lamp is installed. Allow the new lamp to burn for a few minutes to make certain that the lamp is not defective.

SECTION 9. RUNWAY END IDENTIFICATION LIGHTS (REIL) AND OMNIDIRECTIONAL APPROACH LIGHT SYSTEM (ODALS).

57. PREVENTIVE MAINTENANCE INSPECTION PROCEDURES. To perform the PMIs contained in table 4-10, proceed as follows:

a. Daily Checks. Check that lamps are operating and are flashing in proper sequence.

b. Bimonthly Checks.

(1) Check the controls for proper operation. Observe operation on each intensity step.

(2) Check cleanliness of optical surfaces, both interior and exterior.

(3) Check for damage or misaligned lights.

(4) Check interlock device on door of each cabinet. Verify that shutdown occurs when each door is opened.

(5) Check for vegetation or other obstruction around lights.

c. Semiannual Checks.

(1) Check the interior of control panel and flasher cabinets for cleanliness and moisture.

(2) Check all electrical contacts and connections to ensure tightness.

(3) Check and adjust alignment and level of light wnits. For omnidirectional units, only the level is checked. For unidirectional REILs, check alignment and elevation using the following tools:

(i) A plywood triangle cut to angles of 150, 800, and 850.

(ii) A 4"-line level.

Figure 4-3. REIL aiming.

Table 4-10. Preventive maintenance inspection schedule for runway end identifier lights (REIL) and omnidirectional approach light systems (ODALS).

Maintenance requirement	
1. Check operation of lamps.	Daily
2. Check the operation of controls.	BiMonthly
3. Check cleanliness of optical system.	BiMonthly
4. Check for mechanical damage or misaligned parts.	BiMonthly
5. Check operation of interlocks.	BiMonthly
6. Check for vegetation around lights.	BiMonthly
7. Check cabinets for cleanliness and moisture.	SemiAnnually
8. Check electrical connections.	SemiAnnually
9. Check alignment and elevation of unidirectional REIL	SemiAnnually
10. Check level of optical heads for ODALS.	SemiAnnually
11. Check oaffles on REIL (if used).	SemiAnnually
12. Check power distribution equipment.	Annually
13. Check insulation resistance of cable.	Annually
14. Check resistance of grounding system.	Annually
15. Service timer motor and contacts (if used).	Annually
16. Check need for painting.	Annually

(4) The procedure to align the unidirectional REIL is as follows:

(i) To check for l5o-toe-out, hold the triangle horizontally with the 150 angle pointed toward the other light unit. By aligning the outside edge of the triangle to point at the opposite light unit, l5o-toe-out is achieved.

(ii) To attain the 100 vertical aiming, the 800 angle is placed against the flat portion of the REIL face with the l5o-point down. When the line level shows the upper edKe of the triangle level, the REIL is 100 up from the horizontal.

(5) Check level of ODALS optical heads.

(6) Check baffles, if used on REIL. Where baffles are installed, the light units should be aimed at an anAle of 30 vertical and toed out 100. The louvers should be sloped down 100 toward the runway and 50 down toward the approaching aircraft. The louvers should be painted black to lower the reflected light.

d. Annual Checks.

(1) Make a careful inspection of all power distribution equipment and protective devices at terminal pole and lights.

(2) Check insulation resistance of power cables (paragraph 47).

(3) Check the ground resistance at terminal pole and each light fixture (paragraph 47).

(4) Service timer motor and contacts (if used).

(5) Repaint as required.

SECTION 10. MEDIUM INTENSITY APPROACH LIGHTING SYSTEMS (MALS, MALSF, MALSR).

58. PREVENTIVE MAINTENANCE INSPECTION PROCEDURES. To perform the PMIs contained in table 4-1 1, proceed as follows:

a. Daily Check. Check and record burned-out lamps.

b. Weekly Checks.

(1) Request tower personnel to turn on the system and go through each brightness step from the remote control panel. If the system is equipped with air-to-ground radio control, check each brightness step for proper operation. During the sequence, the maintenance technician should be in a position to observe the system operation.

(2) Replace burned-out lamps as necessary to meet the criteria in table 2 of appendix 1.

Table 4-11. Preventive maintenance inspection schedule for medium intensity approach lighting systems (MALS, MALSR, MALSF)

Maintenance requirement	
1. Check for burned-out lamps.	Daily
2. Check system operation.	Weekly
3. Replace burned-out lamps.	Weekly
4. Check semiflush lights for cleanliness.	Weekly
5. Record input and output voltages of control cabinet.	Monthly
6. Clear any vegetation obstructing the lights.	Monthly
7. Check angle of elevation of lights.	SemiAnnually
8. Check structures for integrity.	SemiAnnually
9. Check approach area for new obstructions.	SemiAnnually
10. Check photoelectric controls (if used).	SemiAnnually
11. Check electrical distribution equipment.	Annually
12. Check insulation resistance of cable.	Annually
13. Check fuseholders, breakers, and contacts.	Annually
14. Replace all PAR 38 lamps after 1800 hours on maximum intensity.	Unscheduled

(3) Check the exterior optical surface of any semiflush lights. Clean as required.

b. Monthly Checks.

(1) Record the input and output voltages of the control cabinet and compare with previous readings to ascertain the rate of deterioration of the system.

(2) Clear vegetation or obstructions from the front of semiflush and/or ground-mounted lights to ensure adequate visibility. Diesel fuel or otker approved chemicals can be used to help control the Krowth of vegetation around the lights.

c. Semiannual Checks.

(1) Check all light fixtures for alignment. The elevation angle settings of the lamps differ at each light bar station. These angle@ should be permanently displayed at each station to facilitate maintenance.

(2) Check all structures carefully for hidden corrosion or rot. Special attention should be paid to wood-to-wood, wood-to-steel, wood-to-earth, and @teel- to-earth contacts.

(3) Check the approach area for new structures or for growth of vegetation which may "'violate the approach clearance criteria. A clear line-of-sight is required from any point on a plane 1/20 below the glide slope extending 250 feet (75 m) each side of centerline for a distance up to 1 ,600 feet (500 m) in advance of the outermost lights in the system. If objects exist which block a view of the lights and cannot be removed, refer the problem to appropriate airport authorities.

(4) If used, check and adjust the photoelectric controls. Use a photometer to verify the photoelectric control is adjusted to turn the lights on at a north-sky light intensity level of 35 foot-candles and turn off at 58 foot-candles. If the unit is properly adjusted, the system will operate on the high brightness position on a relatively clear day from approximately 1/2 hour after sunset to 1/2 hour before sunrise. Also, check the orientation of the photo- electric cell. The cell should be oriented by aiming at the north sky at an angle of 250 from the vertical pointing toward the ground. If adjustments are required, refer to the applicable manufacturer's instruction book for detailed adjustment procedures.

d. Annual Checks.

(1) Check pole-top-mounted or termination switches.

(2) Check all main power and control cable insulation resistance (paragraph 47). Record reading on the insulation resistance form. Compare current reading with previous readings to determine if cables are deteriorating.

(3) Check fuseholders, breakers, and contacts. Contacts in the control cabinet should be carefully inspected. If the contacts are badly worn, they should be replaced. Do not file or burnish conta;ts. Discoloration of co@tacts or some roughness due to normal arcin8 is not harmful. The contacts should be wiped to remove the dust. Blown fuses should be replaced with the correct size and type. Do not assume that the old fuse is the correct size and type.

f. Unscheduled Maintenance. Consideration should be given to group changing of all PAR 38, l5O-watt lamps after 1800 hours of operation on maximum brightness, recorded on an elapsed time meter.

SECTION 11. MARKING OF PAVED AREAS ON AIRPORTS

59. MAINTENANCE OF MARKING. All markings on paved areas should be inspected at least semiannually and repainted when they become faded or discolored by soil. Local climate considerations will dictate when to inspect, but, in general, a spring and fall inspection will suffice to detect deterioration due to the winter and summer weather extremes. Touch up pavement markings using a high-quality traffic-marking paint (drying time 30 minutes at 7OoF (250C) or equivalent.

SECTION 12. STANDBY ENGINE GENERATOR PLANTS

60. PREVENTIVE MAINTENANCE INSPECTION PROCEDURES. To perform the PMIs contained in table 4-12, proceed as follows:

a. Weekly Checks.

(1) Before starting the engine, check the following:

(i) Battery water level.

(ii) Immersion heater operating.

(iii) Engine oil level.

(iv) Governor oil level.

(v) Engine generator coolant level.

(vi) Fuel level in main storage tank.

(vii) Battery trickle-charge current

(viii) Clean fuel traps and filters.

(ix) Check engine timing.

NOTE: If necessary to add oil, water, or fuel, record amount. Do not operate diesel engines without load as it results in fouling the cylinders and injectors.

(2) Load-test the engine generator for 1 hour, Turn the airport lights and visual aids on before beginning the test.

(i) Start the generator by one of the two methods below. The method of starting the generator should be alternated on successive load tests.

(A) Start the generator by using the remote control in the tower. If there is no remote control, use the controls in the vault.

(B) Start the engine by simulating a power failure. This may be done by switching off incoming commercial power. This procedure should be used only after ooordination with the tower, flight service station, or other authority in charge of air traffic control.

(ii) Record the time for engine generator to start and transfer switch to operate.

(iii) Check for normal operation of controls.

(iv) Take readings of the following after engine generator has operated for 15 minutes under load:

Output voltage Phase: 1______ 2_____ 3_____
Output current Phase: 1______ 2_____ 3_____
Output frequency ______
Engine oil pressure ________
Coolant temperature ________

(v) Check room ventilation louvers for freedom of operation and manual and automatic operation of fan.

(vi) For starting method (A), stop the engine/generator. The transfer switch should operate and transfer the load to commercial power. Check time for load transfer after pressing the engine/generator stop button.

(vii) For starting method (B), turn the commercial power back on, and measure the delay from the resumption of commercial power until transfer of load to commercial power. Then measure the delay from load transfer until shutoff of the engine.

(3) Clean the engine generator set, its accessories, control compartments, and do necessary housekeeping of the immediate area.

b. Quarterly Checks. Perform 3-hour load test as follows:

(1) Perform checks and record readings same as those noted on weekly checks.

Table 4-12. Preventive maintenance inspection schedule for standby engine generator plants.

Maintenance requirement	
1. Do pre-start checks.	Weekly
2. Perform 1-hour load test.	Weekly
3. Clean engine/generator and surrounding area.	Weekly
4. Perform 3-hour load test.	Quarterly
5. Perform annual check.	Annually
6. Change oil.	Annually
7. Perform 2-year servicing.	BiAnnually
8. Overhaul engine.	Unscheduled

(2) In addition to the weekly checks, perform the following before starting the engine:

(i) Check flexible duct from engine generator radiator.

(ii) Check conneoting hoses and fittings.

(iii) Lubricate pulleys and pumps.

(iv) Check condition of filter elements.

(v) Examine engine oil for contamination.

(vi) Check fuel tanks for contamination.

vii) Check all control cable and power cable terminations for tightness.

(viii) Check condition of all wiring insulation.

(ix) Clean and adjust control panel devices.

(x) Drain and replace oil in governor and morse clutch.

(xi) Fan belt condition.

(xii) Record battery voltage.

(xiii) Check specific gravity of battery electrolyte.

(xiv) Check complete sequence of operation of control and safety devices.

(xv) Record pick-up volts for the line voltage sensing relays by using a Variac and iron vane voltmeter.

(xvi) Record dropout volts for the line voltage sensing relays.

(3) Start engine generator under full load same as for the weekly tests. Operate for 3 hours. During the last 30 minutes, perform the following check@:

(i) Check color of engine exhaust for complete combustion.

(ii) Check for exhaust, fuel, lubricant, or coolant leaks.

(iii) Check generator for abnormal heating.

(iv) Pop compressed air safety valves, if any.

(4) Stop engine generator after 3 hours under full load. Note and record any unusual conditions and describe any repairs needed.

c. Annual Checks

(1) Perform check and record readings same as those noted in weekly and quarterly checks.

(2) In addition to the quarterly checks, perform the following before starting the engine:

(i) Change air filter.

(ii) Inspect transfer switch.

(A) Switch movement.

(B) Condition of contacts.

(C) Delays.

(iii) Determine revolutions per minute for overspeed lockout.

(iv) Check operation of low-oil safety.

(v) Determine time to lockout overcrank safety (for starter).

(vi) Check accuracy of high coolant temperature shutdown device.

(vii) Inspect, clean, and gap spark plugs (gasoline engine).

(viii) Measure manifold vacuum.

(ix) Measure fuel pump pressure.

(x) Drain and clean immersion heater housing and check necessary accuracy of heater operation.

(xi) Drain and replace oil in crankcase.

(xii) Inspect and clean positive crankcase ventilation filter, valve, and connecting lines.

(xiii) Inspect condition of @enerator bearings and bearing lubrication.

(xiv) Measure frequency-sensing relay pickup and dropout frequency.

(xv) Check compressed air tank, if any.

(3) Perform 3-hour load tests and record readings as for weekly and quarterly tests. Record any unusual conditions, repairs, part numbers, etc.

(4) Perform a compression test.

(5) Change oil in the engine after a maximum of 150 hours of operation or at least once a year unless otherwise specified by the manufacturer. Diesel engines generally place more demands on the oil in the lubricating system than do gasoline engines. The American Petroleum Institute (API) Service Classification of Oils for diesel engines are: diesel general (DG); diesel moderate (DM); and diesel severe (DS). Diesel oils may be used in gasoline engines, but not vice versa. (Do not use detergent oil in an engine which was previously operated with nondetergent oil.) DG classification may be used where the engine is operated in a clean location under moderate loads using good grade of fuel where no extremes in temperature are encountered and where wear and control of engine deposits are not a problem. (This grade generally would be suited for standby engine generators for airport lighting systems in the Southern Region.) Oils used in diesels should at least meet the DG service classification. Fill the crankcase of new or rebuilt engines with oil as recommended by the manufacturer. Operate the unit at variable reduced loads (not to exceed 75 percent of full load) for approximately 40 hours. Continue operation of the unit on normal load for approximately 40 hours; however, if chrome piston rings are installed, this time shall be extended 8 hours. Drain the crank-case while the engine is still hot and refill with multiviscosity detergent oil.

d. Biannual Checks.

(1) Perform 2-year servicing as follows:

(i) Drain and flush engine-cooling system after operating the engine under load for 1 hour.

(ii) Remove covers and inspect generator bearings for wear and condition of lubrication.

(iii) Check condensers and diodes in line voltage sensing and transfer circuits.

e. Unscheduled Checks. Engines normally perform under a variety of climatic and operational conditions. Therefore, a thorough analysis of the engine by a qualified technician will be the determining factor in scheduling and defining the depth of overhaul for a particular plant. All standby engines after 10 years or 2,000 hours should be considered for overhaul.

61. MAINTENANCE PROCEDURES. The maintenance of engine generators requires a skilled mechanic. It is recommended that the person assigned these duties be a graduate of a technical school on types of engine generators similar to the one to be maintained. In addition, the person should have had 1 or more years experience as an automotive, truck, or diesel engine mechanic and technician. If a qualified mechanic is not available on the airport maintenance staff, it is recommended that a contract be made with a qualified local repair shop for periodic maintenance.

CHAPTER 5. TROUBLESHOOTING PROCEDURES FOR SERIES LIGHTING CIRCUITS

62. GENERAL. This chapter contains general troubleshooting procedures for isolating a fault in all types of airport series lighting circuits. The troubleshooting procedures contained in sections 1 through 9 provide detailed step-by-step procedures for isolating a fault. The procedures are based upon the assumption that the only available information about the trouble i@ a report of which circuit is not operating satisfactorily. The tests are started from a check in the vault. It is presumed that the problem is more involved than a burned-out lamp, although these procedures will result in isolating a burned-out lamp if that is the problem. Tn sections 1-5, eield problems are covered; in sections 6-9, vault problems are covered.

63. SAFETY.

a. Troubleshooting tests cantained in this chapter often involve voltages that are dangerous. Safety precautions must be exercised for the protection of personnel and equipment.

b. Personnel performing the testing and troubleshooting procedures must be experienced in high-voltage techniques or must be adequately supervised. All maintenance personnel should be thoroughly trained in emergency procedures for treatment of electrical shock.

SECTION 1. INITIAL FAULT ISOLATION

64. INITIAL FAULT ISOLATION PROCEDURE.

a. Select the circuit to be tested and set the brightness switch to 100 percent intensity.

b. Energize the regulator and measure the load current. Be sure current i3 set to the values given in paragraph 51. If the load current is normal, proceed to step d. If the load current is out of tolerance, adjust the current according to the procedure in the instruction manual.

c. If the load current cannot be brought into tolerance, short-circuit the output of the regulator for the circuit being tested. Energize the regulator and measure the short-circuit current for each brightness setting.

(1) If the current is satisfactory for each brightness setting, the regulator, the incoming primary voltage, and the input voltage circuit breakers and relays are functioning properly. The protective and brightness controls from the control panel are also satisfactory. The fault is probably in the series circuit.

(2) If the current is satiseactory for one or more brightness setting, but is too high, too low, or zero for other settings, the input voltage and protective controls are satisfactory. The regulator brightness controls are probably at fault.

(3) If the current is appreciably higher or lower than specified for all brightness settings, the wrong input voltage has is used, the input voltage has changed, or the regulator is not operating properly.

(4) If the current reads momentarily and then becomes zero for all brightness settings, the remote-energizing controls, the protective relays, or the regulator are defective.

(5) If the current is zero at all times for all brightness settings, the fault is in the incoming primary voltage, the energizing controls, the regulator, or the protective relays.

(6) If the short circuit current is out of tolerance and is approximately the same as the load current, the fault is in the input voltage, in the control circuits, or in the regulator.

(7) If the short circuit current is normal but the load current is too high, the load is affecting the regulator output; probably too much reactance is in the circuit. Check for the following routine maintenance faults at any lights which are not operating and replace or repair as required:

(i) Burned-out lamps.

(ii) Opens in the secondary circuit of isolating transformers.

(iii) Faulty isolating transformers.

(iv) If the maximum brightness current is still too high when all lamps are back in operation, then perform section 2 checks first, then check for adapter units newly connected into the circuit. If there adapter units cannot be moved to another circuit, reset the incoming voltage tap so that the load current is correct.

(8) If the short-circuit current is normal, but the load current is too low, the regulator is probably overloaded due to a series fault or a new load added to the circuit, or the voltage protective device is malfunctioning.

(9) If the short-circuit current is normal but the load current is zero, there is an open fault in the field circuit, or the regulator is greatly overloaded, or the runway selector cabinet wiring is faulty.

d. If the load current is normal with the circuit energized, visually check the operation of the lights in this circuit.

(1) If some, or all, of the lights are dim or out, deenergize the regulator and proceed as follows:

(i) Beginning with the first unlighted or dim unit from each end of the faulty section of the circuit, progressively check each faulty light along the circuit for each of the following routine maintenance faults. Ie the eaulty lights at each end of the faulty section are eound without these faults, the remainder of the units in this section need not be checked. Make the required repairs as each fault is located.

(A) Burned-out lamps.

(B) Wrong type of lamps.

(C) Blown or omitted film cutouts (where used).

(D) Shorts or grounds in the isolating transformer or in the wiring of the unit.

(ii) If some of the lights are still dim or out, there are grounds or shorts in the circuit between the lights of satisfactory intensity and the adjacent lights of unsatisfactory intensity. Repair by replacing this section of cable. If replacing this section of cable is not practical and more exactly locating the position of the ground(s) is required, refer to section 2.

(2) If all of the lights are still dim or out, carefully check the relay and wiring in the runway selector cabinet to make certain that only the proper circuit is being selected and is not being shorted out in the selector cabinet. Also, check series plug cutouts, if used.

e. To determine if a fault is an open or an overload, deenergize the field circuit and disconnect it from the output terminals of the runway selector cabinet or constant current regulator. With an ohmmeter on a low-resistance range, measure the continuity of the field circuit. If the circuit does not have continuity or it has a resistance of several thousand ohms, the field circuit has an open fault. If the circuit has continuity, the regulator may be overloaded (due to a ground or additional lighting load.)

SECTION 2. LOCATING GROUNDS IN THE FIELD CIRCUIT

65. TROUBLESHOOTING UNDERGROUND CIRCUITS. When troubleshooting a field circuit, the easiest procedure is to find and eliminate any grounds in the circuit, and then proceed to rectify any other problems. Grounds are usually easier to locate, and often occur in conjunction with opens, overloads, or shorts.

a. The most common troubles experienced with underground cable are grounds, short circuits, or open circuits. The symptoms produced by these faults are dimming of a string of lights, burning out of equipment, or total failure of the circuit to operate.

b. Common causes of cable trouble are failure of splices, deterioration of insulation, mechanical injury to the cable (due to man, rodents, or insects), chemical action of the soil, and damage caused by lightning.

c. Low insulation resistance values may be obtained for a circuit even though there is no specific fault in the cable (paragraph 47b). Often this is the result of leakage through the insulation of isolating transformers and/or cable connectors. In order to assure that the ground fault is exclusively a cable problem, any suspected sections should be freed of all connections and tested independently.

d. The type of fault in underground cable may often be inferred from the symptoms and nature of the failure. If the log of insulation resistance readings (paragraph 47) shows a gradual decline, then it is likely that the cable insulation or a splice has failed somewhere. If the circuit catastrophically fails while excavation is going on nearby, it is likely there was mechanical damage. If a string of lights is dim, it is likely that there are two faults in the circuit. Such deductive reasoning may save steps in finding the problem.

66. PROCEDURE FOR LOCATING GROUNDS. When grounds or shorts are indicated and the location is not readily apparent from the appearance of the lights, disconnect the field circuit from the runway selector cabinet or constant current regulator and measure the insulation resistance of each feeder. To measure insulation resistance use an insulation-resistance tester (paragraph 27). As each fault is cleared, repeat this insulation-resistance measurement for the circuit to determine if other grounds exist. If a combination of faults exists, clear the grounds first because these faults are usually easier to locate and often occur in conjunction with opens, overloads, or shorts. Clear any high-resistance grounds and then locate any remaining opens, overloads, or ungrounded shorts.

a. After the proper connections have been made between the tester and the circuit, operate the tester for approximately 1 minute. At the end of this time, the insulation-resistance value should be recorded. If the tester reads zero there are one or more grounds which must be located before any other faults may be found.

b. In locating the ground, the first step is to completely isolate the circuit to be tested from other series circuits. By sectionalizing the field circuit and taking insulation-resistance readings on each section, the ground can often be found rather quickly by the simple process of elimination. The field circuit can be first divided in one-half, then in one-fourth, then one-eighth, and so on, until the section of cable with the ground fault is located.

c. If the resistance of each feeder-to-ground is fairly high (between 1000 ohms and 10 megohms) but is not adequate for a good circuit, there are one or more high-resistance grounds. To locate high-resistance grounds, use an impulse generator/proof tester, insulation resistance tester, or high resistance fault tester.

d. If the resistance of each feeder-to-ground is very high or infinite (above 10 megohms) and the intensity of all of the lights is satisfactory, the regulator and this specific field circuit have been proven satisfactory. If some or all of the lights are out, there is an ungrounded short.

e. If the resistance of one feeder-to-around is low or unsatisfactory and the resistance of the other feeder is much higher, the faults are a combination of grounds, opens, or poor circuit conductivity.

f. To locate a ground by using an intentional ground and energizing the circuit with the load connected to the regulator, ground one of the feeders in the vault. Energize this circuit with the regulator and make a visual check of the operation of each of the lights in this circuit.

(1) If some of the lights are out or dim, there is a ground fault between the last light operating satisfactorily and the adjacent light that is operating unsatisfactorily.

(2) If all of the lights are out or dim, the ground fault is in the feeder without the intentional grounds.

(3) If all of the appear to operate satisfactorily, move the intentional ground to the other feeder; energize the circuit and make a visual check of the operation of the lights as described above.

(4) If the lights appear to operate satisfactorily when each feeder is tested with the intentional ground, the fault may have resistance too high for a change in intensity to be recognized.

SECTION 3. LOCATING UNGROUNDED SHORTS IN FIELD CIRCUITS

67. ISOLATING UNGROUNDED SHORTS. When ungrounded shorts are indicated, an initial analysis should be made by energizing the circuit and visually determining which lights are operating. Then, the fault may be further isolated by losing a clamp-on ammeter or performing a circuit analysis test as described below.

a. The initial analysis of ungrounded shorts is made by inspecting the operation of the lights with the circuit energized.

(1) If some of the lights are operating satisfactorily but others are out, the short is between the lighted and the adjacent unlighted units. Repair by replacing the faulty cable or connectors between the lights.

(2) If all of the lights are out, the short is between the feeders.

b. To locate ungrounded shorts losing a clamp-on ammeter, select a test point. The lights may give a hint where the problem area is; if not, select a test point at the start of one feeder and progress systematically through the field circuit. Connect the ammeter around the conductor of the circuit. Energize the circuit with the regulator and read the current in the circuit at the test point.

Warning: Do not come in contact with the cable or meter while the circuit is energized. If the meter must be handled or attached to the circuit while the circuit is energized, use a hot-line clamp-stick.

(1) If the current in the circuit at the test point is approximately normal, the short is beyond the test point.

(2) If the current in the circuit at the test point is very low or zero, the short is between the test point and the regulator.

(3) Continue moving the test point forward until the fault is located.

c. To locate ungrounded shorts by open-circuit tests, select a test point as described above. Open the circuit. Keep the open clear of the ground and personnel clear of the circuit. Energize the circuit with the regulator and check to see if the protective relays turn off the regulator. This test may be used only with regulators that have built-in open circuit protection circuitry.

Note: If the regulator turns itself off, do not energize the circuit again until the open at the test point has been reconnected and a new test point has been selected.

(1) If the protective relays turn off the regulator, the test point is between the ungrounded short and the regulator.

(2) If the protective relays do not turn off the regulator, the ungrounded short is between the test point and the regulator.

(3) Reconnect the circuit at the test point and continue moving the test point toward the short until it is located.

(4) Repair both sections of cable which contain the short.

SECTION 4. LOCATING OPENS IN FIELD CIRCUITS

68. ISOLATING OPEN CIRCUITS. Before checking for open circuits, Se sure that any grounds are removed as described in section 2. An insulation resistance test provides the quickest check. If the insulation resistance of both feeders is satisfactory, the ungrounded open fault can be found using the intentional ground and open circuit test, the installation resistance tester, or the cable test set.

a. To locate ungrounded opens by using the intentional ground and open-circuit test, intentionally ground one of the feeders of the circuit in the vault and then, by energizing the circuit with the regulator, determine if the circuit will break down to ground at the open fault. Check the operation of the regulator as it is energized to see if the open-circuit protective relays (if included) turn the regulator off.

(1) If the protective relays do not turn off the regulator, the circuit has become grounded beyond the open from the intentionally grounded feeder.

(2) If the protective relays turn off the regulator, the circuit beyond the open from the intentionally grounded feeder does not break down to ground.

(3) Move the intentional ground to the other feeder and repeat the above steps.

(4) Sectionalize the circuit, using intentional grounds by grounding one feeder in the vault, and at a selected test point, also ground the conductor of the

circuit without breaking continuity. Energize the circuit and check the operation of the regulator to see if the protective relays turn it off.

(5) If the protective relays do not turn off the regulator, the open fault is between the intentional grounds.

(6) If the protective relays turn off the regulator, both intentional grounds are on the same side of the circuit from the open fault.

(7) Continue moving the test point and intentional ground in the field toward the open fault and checking the regulator operation until the fault is located.

b. To locate ungrounded opens by resistance measurements, disconnect the feeders from the runway selector cabinet and intentionally ground one feeder of the circuit in the vault. Then at a selected test point, maintaining continuity of the circuit, measure the resistance between the conductor and ground.

Note: The ground at the selected test point must provide adequate continuity to the system ground. If desired, the circuit may be grounded at the selected test point and the measurements made in the vault.

(1) If the resistance is very high or infinite, the open fault is between the test point and the grounded feeder.

(2) If the resistance to ground is low or zero, the test point is between the open fault and the grounded feeder.

(3) Continue moving the test point toward the open until the fault is located.

c. To locate ungrounded opens with the cable test set, study the instructions given in the operations handbook for locating open faults. The signal generator should be operated with the "OUTPUT IMPEDANCE" switch in the "HI" position, and the amplifier gain will have to be much higher than that required for the same response from a grounded cable. The characteristics of the signal at the fault may also be much different from the indications at a ground fault.

d. If the open vault cannot be located with the cable test set, perform the intentional ground and open-circuit test or perform the resistance-measurement test.

e. A voltmeter may also be used to locate ground vaults or open circuits using probes. This technique is not suitable for lights mounted in paved areas. The procedure is described below.

(1) Determine type of faults, i.e., whether open circuit or grounded. If grounded, lights will burn dimly between grounded points; or there will be a section of lights out. If open circuit, a high-resistance reading will be obtained

between ends of the field loop cables at the regulator, and the open-circuit protector of the regulator will be tripped (if so equipped).

(2) If cables are determined to be grounded, the regulator can be turned "ON." If cables have an open circuit, disconnect the cables from the regulator and connect two 3OO-watt incandescent lamps in parallel with each other and in series with the lighting circuit. Connect to l2O-volt AC source (or use two 3OO-watt lamps in series with each other and in series with the lighting circuit and use 2O8-volt or 24O-volt supply). This will limit the current to 0.8 amperes (120 V) or 0.4 amperes (240 V).

(3) Use a sensitive VOM with an input impedance not less than 20,000 ohms/volt AC. Connect the meter terminals for AC volt measurement to a l/2-inch-diameter solid-aluminum rod 4-feet long with 25 feet of No. 12 or No. 14 wire.

(4) Set meter on high AC scale and work down to low scale. Starting at home, run circuit over the underground cables; probe every 3 feet along the conductor while an assistant probes approximately 20 feet behind you along the series lighting circuit with the other probe. The probe should be pressed into the ground a couple of inches. Never change scales without the probes being planted in the earth. The meter may read as high as 300 volts AC or as low as 0.001 volt AC. Dim sections of lights will read between 3 to 50 volts AC, when directly over the fault. (The highest reading obtained will be directly over the fault.) Lights that are completely out will have a higher voltage reading.

g. Example Problems. The following are several examples of finding locations of open circuits in series lighting circuits:

(1) One Open in the Circuit.

(i) The following conditions exist:

(A) There is only one open in the circuit.

(B) The circuit is free from grounds, including the location of the open.

(C) The earth (ground) resistance is relatively low.

(ii) Use the following procedure to locate the open:

(A) Disconnect the series-loop wires from the regulator-output terminals or runway circuit selector. Call these wires Ll and L2. (See figure 5-1 .)

(B) Ground Ll and the midpoint of the series loop at Gm without breaking continuity.

(C) Check with a megohmmeter for continuity across Ll and L2.

(D) If there is continuity, the open is between Ll and Gm.

(E) If there is no continuity, the open is between L2 and Gm.

Figure 5-1. Test example No. 1.

(F) To double check the above finding, remove ground from Ll and ground L2 and repeat the procedure.

(G) Where the open is between Ll and Gm, ground Ll and move ground Gm toward Ll along the circuit to locations (light stations), Gl, G2, G3, etc. Ground one location at a time. (See figure 5-2.)

(H) The open is between the last ground location (G2) which will give continuity across Ll and L2 and the first ground location (G3) which will cause no continuity Ll and L2.

Figure 5-2. Multiple grounding, example No. 1

(I) In case the continuity is obtained with circuit grounded at the last light on Ll side of the loop (closest to the Ll, i.e., where the home run begins), then the open is on the Ll side of the home run.

(J) To verify this, move ground from Ll to L2; leave ground at the last light (as in previous step).

(K) When check for continuity is made across Ll and L2, there should be no continuity.

(L) Where the open is between L2 and Gm, use steps (G) through (K) but in place of Ll, use L2.

(2) Several opens in the circuit.

(i) The following conditions exist:

(A) There is more than one open in the loop circuit, and they may be anywhere in the loop.

(B) The circuit is free from all grounds, including at open fault locations.

(C) The earth (ground) resistance is relatively low.

(ii) Use the following procedure to locate the opens:

(A) Disconnect the series loopwires from the regulator or circuit-selector switch output terminals. Call these wires Ll and L2. (See figure 5-3.)

(B) Ground Ll and midpoint of the loop at Gm while maintaining continuity.

(C) Check with a megohmeter for continuity across Ll and L2.

(D) If there is continuity, there are no opens between L2 and Gm and therefore all the opens are between Ll and Gm.

(E) If there is no continuity, there are opens between L2 and Gm. This does not mean that there are no opens between Ll and Gm.

Figure 5-3. Example No. 2.

(F) To find out whether there are any opens between Ll and Gm, remove ground from Ll and ground L2, leave Gm in, and repeat steps (C), (D), and (E).

(G) Where the opens are only between Ll and Gm, ground Ll and move ground Gm toward Ll along the circuit to locations (light stations) Gl, G2, G3, etc. Ground one location at a time. (See figure 5-4.)

(H) The first open is between the last ground location which will give continuity across Ll and L2 and the first ground location which will cause no continuity across Ll and L2.

(I) Repair the open and continue moving the ground toward Ll until all opens are located and repaired.

Figure 5-4. Open circuits in one leg, example No. 2.

(J) When the opens are only between L2 and Gm, repeat steps (G) through (I) but in place of L1, use L2.

(K) Where there are opens between Ll and Gm as well as between L2 and Gm (in both halves of the loop), ground L2; leave Gm in. (See figure 5-5.)

(L) Ground a point (Gl) near Ll (preferably the first light on that side of the loop) and continue moving this ground (Gl) to locations G2, G3, etc., away from Ll. Check the continuity at each position.

(M) The first open is between the last ground location which gives continuity across Ll and L2 and the first ground location which gives no continuity across L1 and L2.

(N) Repair the open and continue moving the ground toward Gm until all opens between Ll and Gm are repaired.

Figure 5-5. Open circuits in both legs, example No. 2.

(0) To find opens between L2 and Gm, use steps (K) and (N), but in place of Ll, use L2.

SECTION 5. OVERLOADS IN SERIES CIRCUITS

69. ISOLATING OVERLOADS IN SERIES CIRCUITS. A circuit is overloaded when there are areas of poor conductivity (high resistance) in the circuit loop, or when extra lights have been added to the circuit and the total load is increased beyond the capacity of the regulator. An overload is indicated when the regulator provides reduced current to the field circuit on all steps, yet the regulator current is normal when the outputs are short circuited. If an overload is indicated and the possibility of grounds on the circuit has not already been investigated, check for grounds by following the procedure in paragraph 66.

a. If the insulating resistance of the circuit is not satisfactory, some combination of grounds and an overload exist, such as high-resistance grounds on each side of an open or a high-series resistance and ground fault. Use the cable test set, insulation resistance measurements, or the intentional ground procedure to isolate the fault.

b. If the insulation resistance of the circuit is satisfactory, the circuit is clear of grounds. To locate the overload, sectionalize and take load current measurements, or compare the actual load to normal circuit loads.

c. Sectionalizing Procedure. To locate overloads (particularly those caused by high-series resistance faults or by open faults which have become partially grounded) by sectionalizing, turn off the regulator; remove a section of the load from the circuit by shorting it out with a jumper or length of cable. Energize the remainder of the circuit and remeasure the output load current.

(1) If the load current is still low, or the protective relays continue to turn off the regulator, the fault is in the section of the circuit still being energized by the regulator.

(2) If the load current is now normal, the fault or overload is in the section of the circuit which is short-circuited.

(3) Continue sectionalizing by moving the jumper toward the fault or overload until the fault is located.

d. Comparison Procedure. To locate overloads by comparing the actual load on the regulator to the nominal load of the circuit, determine the actual load by accurately measuring the output voltage of the regulator and the load current at brightness step B5. Compute the actual load as the product of the output voltage and current. Compute the nominal load of the circuit including losse@ and any recent additions to the circuit. Compare the actual load to the normal load of the circuit and to the nameplate of the regulator.

Note: If the protective relays turn off the regulator or the load current is more than 10 percent below rated value, do not use this method to obtain the actual load.

(1) If the nominal load and the actual load are approximately the same but they exceed the rating of the regulator, redistribute the load to another regulator or replace the regulator with a regulator of adequate capacity.

(2) If the actual load exceeds the nominal load and the rating of the regulator, the circuit has a high-resistance fault.

(3) Sectionalize by connecting a suitable jumper or length of cable between convenient test points of the circuit. Compute and compare the actual load and the normal load for the section of the circuit still being energized by the regulator.

(i) If the actual load current and the normal load for this section of the circuit are approximately the same, the fault is in the section of the circuit that is not shorted out and not being energized.

(ii) If the actual load exceeds the normal load for this section oe the circuit, the fault is in the section of the circuit still being energized by the regulator.

(4) Continue sectionalizing by moving the jumper toward the fault and computing and comparing the actual load and the normal load of the section of the circuit still being energized by the regulator until the fault is located.

SECTION 6. INPUT POWER CIRCUITS

70. INPUT POWER CIRCUIT FAULT ISOLATION. This section contains step-by-step procedures for locating faults in the input power circuit. Be certain that no one is working on or near a deenergized circuit before attempting to energize it.

a. In checking the input voltage, first check the operation of lights or other equipment in the vault that are connected to the same phase of power. If the lights or other equipment on this circuit do not operate, the input power circuits are not energized.

b. If the lights and other equipment on this circuit are operating, set the switches, relays, and contractors in the required position for energizing the regulator.

(1) Check for hum and vibration of the input transformer of the regulator as the remote-control oil switch, the input switch, or the main contractor is momentarily placed in the manual "ON" position and then returned to "OFF" or "AUTO" position.

(2) If the energizing controls cannot be set for energizing the regulator, the energizing controls have failed.

(3) If hum or vibration occurs, the input voltage is available; there may be a fault in the remote-energizing control circuit, in the regulator, or the incoming voltage may be too low.

c. If no hum or vibration occurs, check the input circuit for blown fuses, tripped circuit breakers, opened cutouts, and switches in the "OFF" position.

(1) If the switches or circuit breakers are in the "OFF" position or a cutout is open, make certain that no one is or will be working on the circuits. Then close the switch, circuit breakers, or cutouts.

(2) If fuses are blown or a circuit breaker is tripped, replace the fuse or reset the circuit breaker only once to determine if it now holds as the regulator is energized again.

(i) If the fuse or circuit breaker holds, the trouble is over, but keep this in mind should the device open again.

(ii) If the fuse blows or the circuit breaker trips again, check for any possible overloads which could cause this protective device to fail; e.g., grounds or shorts on the input circuit, inadequate capacity of the fuse or circuit breaker to handle the total possible load, other loads beside the regulator which could overload this component in normal or faulty operation, or two or more brightness relays closed or energized at the same time creating a short on the transformer in the regulator. Only after other possible causes of this overload have been eliminated, assume that the fault is in the regulator.

(3) If the switches are in the proper position and the overcurrent protective devices still provide continuity, deenergize the circuit and check for opens, especially at connections, terminals, terminal bushings, switches, circuit breakers, fuse cutouts, and input switch contacts. Also check the taps on the regulator input for proper seating and the input winding of the input transformer of the regulator for continuity.

(i) If an open circuit is found, make the repairs.

(ii) If the tap-selector switch (if used) is not seated properly, reset the switch to the "CURRENT" position.

(iii) If the input switch contact is burned off or fails to close, then the input switch has been overloaded or worn.

(iv) If the input winding of the input transformer of the regulator is open, the regulator has failed internally.

(v) If there are no opens in the input circuit, measure the input voltage at the input terminals of the regulator as follows. Disconnect the input circuit from the primary supply system and connect a suitable potential transformer and/or voltmeter (using adequate leads) to the input terminals of the regulator. Reconnect the input voltage to the regulator, energize the normal load, and determine the input voltage to the regulator.

Warning: Use extreme care in measuring high voltages. Do not come in contact with the potential transformer, the voltmeter, or the leads, while the circuit is energized.

(A) If the input voltage is present but does not agree with the taps or tap-selector switch setting, reset the taps or tap-selector switch to agree with the input voltage when the regulator is energizing its normal load. Note that regulators larger than 70 kW will automatically compensate for an input voltage deviation of + 10 percent. If the input voltage is outside this tolerance, contact the local power company and have it corrected. If this is not practical, autotransformers may be used to adjust the input voltage.

(B) If the input voltage is present but it is not within the range of the tap or tap-selector switch (when used), connect the regulator to a suitable source of power by using the required distribution transformers or use a regulator with an input rating suitable for this input voltage.

(C) If the input voltage is present and agrees with the setting of the taps or tap-selector switch, the regulator is not operating satisfactorily, and the fault is in the brightness controls, in the regulator, or in the load circuit.

(4) If the input voltage is zero, continue moving the potential transformer and/or the voltmeter toward the source of power and repeating the voltage measurements until the fault is located. Note that the circuit must be deenergized every time the meter is moved.

(i) When the point of failure of the input voltage is located, make the repairs.

(ii) If the incoming power lines are dead and cannot be restored by facility personnel, notify the power company or other local authority.

(5) Inspect the operation of the brightness relays in the regulator.

(i) Be sure only one relay is closed as the regulator is energized. If no relays or two relays are engaged, check the remote and local brightness selection controls for the fault.

(ii) Check the wiring in the brightness control circuitry for loose wires, shorting, or other damage.

(iii) Check the condition of the points on the brightness relays, and recondition or replace as necessary.

(iv) If the regulator does not change brightness steps properly when remotely controlled, the problem may be inductance between remote control lines.

(6) If the remote-energizing controls operate satisfactorily, check the continuity of the regulator secondary with an ohmmeter. Be sure the input power is disabled, either by opening a switch or removing the lines, then remove the output cables and measure the resistance across the output terminals.

APPENDIX 1. STANDARDS AND TOLERANCES

1. PURPOSE. This appendix contains standards and tolerances for visual aid equipment and systems as contained in the following tables;

Table	Equipment or system
1	Beacons
2	Medium intensity approach lighting systems (MALS, MALSF, and MALSR)
3	Omnidirectional approach lighting systems (ODALS)
4	Lead-in lights
5	Runway end identifier lights (REIL)
6	Visual approach slope indicators (VASI)
7	Runway and taxiway lighting systems
8	Photoelectric devices
9	Standby engine generators

Table 1. Beacons

Parameter	Standard	Tolerance/limit	
		Initial	Operating
1. Rotation Speed			
a. 10-inch	6 rpm 12 rpm	Same as standard Same as standard	+/-1 rpm +/-1 rpm
b. 36-inch	6 rpm	Same as standard	+/-1 rpm
2. Input Voltage	Same as lamp voltage rating	+/- 3%	+/- 5%
3. Vertical aiming	Locally established between 2-10 degrees	+/-1/2 degree from established angle	Same as initial

Table 2. Medium Intensity Approach Lighting Systems (MALS, MALSF, MALSR)

Parameter	Standard	Tolerance/limit	
		Initial	Operating
1. Light units operational			
a. Steady burning	All	All	15% lamps out (random) -2 lamps out in 5-light bar - 1 light bar out
b. Flashing	All	All	1 Unit out
2. Flashing rate	120 fpm	+/-2 fpm	+/-2 fpm
3. Input voltage	120 V or 240 V	+/-3%	+/-5%
4. Light unit alignment			
a. Vertical	Locally established	+/-1 degree	+/-2 degrees
b. Horizontal	Parallel to runway centerline	+/-1 degree	+/-2 degrees
5. Obstructions due to vegetation, etc.	No obstruction	Same as standard	Same as standard

Table 3. Omni-directional approach lighting systems (ODALS)

Parameter	Standard	Tolerance/limit	
		Initial	Operating
1. Light units operational	All	All	1 unit out
2. Input voltage	120 V or 240 V	+/-3%	+/-5%
3. Flashing rate	60 fpm	+/-2 fpm	+/-2 fpm
4. Light unit level	Level	+/-1 degree	+/-2 degrees
5. Obstructions due to vegetation, etc.	No obstruction	Same as standard	Same as standard

Table 4. Lead-in-lights

Parameter	Standard	Tolerance/limit Initial	Tolerance/limit Operating
1. Light units operational	All	All	1 unit out in 3-light cluster
2. Flashing rate	Locally established	+/-2 fpm	+/-2 fpm
3. Input voltage	120 V or 240 V	+/-3%	+/-5%
4. Light unit alignment			
a. Vertical	Locally established	+/-1 degree	+/-2 degrees
b. Horizontal	Locally estab.	+/-1 degree	+/-2 degrees
5. Obstructions due to vegetation, etc.	No obstruction	Same as standard	Same as standard

Table 5. Runway end identifier lights (REIL)

Parameter	Standard	Tolerance/limit	
		Initial	Operating
1. Light unit operational	All	All	All
2. Flashing rate			
a. Unidirectional type	120 fpm	+/-2 fpm	+/-2 fpm
b. Ominidirectional type	60 fpm	+/-2 fpm	+/-2 fpm
3. Input voltage	120 V or	+/-3%	+/-5%
4. Alignment (Unidirectional)			
a. Vertical			
(1) With baffles	3 degrees	+/-1 degree	-1 degree +2 degree
(2) Without baffles	10 degrees	+/-1 degree	+/-2 degrees
b. Horizontal			
(1) With baffles	10 degrees	+/-1 degree	+/-2 degrees
(2) Without baffles	15 degrees (Away from runway centerline)	+/-1 degree	+/-2 degrees
6. Light leveling (omni-directional)	Level	+/-1 degree	+/-2 degrees
7. Obstructions due to vegetation, etc.	No obstruction	Same as standard	Same as standard

Table 6. Visual approach slope indicators (VASI)

Parameter	Standard	Tolerance/limit	
		Initial	Operating
1. Lamps burning a. VASI b. SAVASI	 All All	 All All	Not more than one lamp out per box
2. Vertical aiming(VASI and SAVASI)			
a. Downwind bar (bar no. 1)	1/2 degree below established glide path angle (1)	+/-2 minutes	+/-6 minutes
b. Upwind bar (bar no. 2)	Established glide path angle	+/-2 minutes	+/-6 minutes
3. Vertical aiming (3-bar VASI)			
a. Downwind bar (bar no. 1)	2.75 degrees	+/-2 minutes	+/-6 minutes
b. Middle bar (bar no. 2)	3.0 degrees	+/-2 minutes	+/-6 minutes
c. Upwind bar	3.25 degrees	+/-2 minutes	+/-6 minutes
4. Horizontal alignment	Parallel to runway centerline	+/-1/2 degree	+/-1/2 degree
5. Tilt switch	1/4 to 1/2 degree below and 1/2 to 1 degree above established light bar angle	Same as standard	Same as standard
6. Lamp current (current-regulated)	Rated current of lamps	Same as regulator currents listed in par. 51 for type of regulator used	
7. Lamp voltage (voltage-regulated)	Rated voltage of lamps	+/-3%	+/-5%
8. Obstruction due to veget-ation, etc.		Same as standard	Same as standard

Table 7. Runway and taxiway lighting systems

Parameter	Standard	Tolerance/limit	
		Initial	Operating
1. Runway lights			
a. Threshold lights	All on	All on	75% on for VFR and non-precision IFR runways (2)
b. End lights	All on	All on	75% on
c. Edge lights	All on	All on	85% on except for CAT 2 & 3 runways which require 95% on
d. Centerline lights	All on	All on	95% on
e. Touchdown zone lights	All on	All on	90% on
2. Taxiway lights	All on	All on	
a. Edge lights	All on	All on	85% on
b. Centerline lights	All on	All on	90% on

(1) In order to provide continuity of guidance, the allowable percentage of unserviceable lights should not be in such a way as to alter the basic pattern of the lighting system. Additionally, an unserviceable lights should not be adjacent to another unserviceable light except in a barrette or a crossbar where two adjacent unserviceable lights may be permitted. With respect to barrettes, crossbars and runway edge lights, lights are considered to be adjacent if located consecutively and:

laterally - in the same barette or crossbar; or

longitudinally - in the same row of the edge lights or barrettes.

(2) Threshold lights for precision runways are part of the approach lighting system and are not included in this table.

Table 7. Runway and taxiway lighting systems (continued)

Parameter	Standard	Tolerance/limit	
		Initial	Operating
3. Lamp current (series circuit)	Amperes	Amperes	Amperes
a. 3 step, 6.6A	6.6 5.5 4.8	6.40-6.70 5.33-5.67 4.66-4.94	Same as initial
b. 5 step, 6.6A	6.6 5.2 4.1 3.4 2.8	6.40-6.70 5.04-5.36 3.98-4.22 3.30-3.50 2.72-2.88	Same as initial
c. 5 step, 20A	20.0 15.8 12.4 10.3 8.5	19.40-20.30 15.33-16.27 12.03-12.77 9.99-10.61 8.24-8.76	Same as initial
4. Lamp voltage (parallel circuits)	Lamp voltage rating	+/-3%	+/-5%

Table 8. Photoelectric devices

Parameter	Standard	Tolerance/limit	
		Initial	Operating
1. Photocell operation (VASI)			
a. Turn-on to high setting	55 ft-cd	+/- 5 ft-cd	Same as initial
b. Turn-on to low setting	30 ft-cd	+5 ft-cd	Same as initial
2. Photocell operation (wind tee, beacon, runway lights)			
a. Turn-on	below 55 ft-cd	+/-5 ft-cd	Same as initial
b. Turn-off	above 30 ft-cd	+/-5 ft-cd	Same as initial
3. Vertical orientation	25 degrees from vertical	+/-5 degrees	Same as initial
4. Horizontal orientation	True north	+/-5 degrees	Same as initial

Table 9. Standby engine generators

Parameter	Standard	Tolerance/limit	
		Initial	Operating
1. Starting time(1)	15 seconds or less	same as standard	same as standard
2. Potential relays commercial power			
a. 120 V system			
Dropout	108V	+/-3 V	Same as initial
Pickup	114V	+/-3 V	Same as initial
b. 208 V system			
Dropout	191 V	+/-3 V	Same as initial
Pickup	191 V	+/-3 V	Same as initial
c. 240 V system			
Dropout	200 V	+/-3 V	Same as initial
Pickup	210 V	+/-3 V	Same as initial
d. 480 V system			
Dropout	455 V	-0,+5 V	Same as initial
Pickup	465 V	-0,+5 V	Same as initial
3. Potential relay engine power			
a. Pickup voltage			
120 V	112 V	+/-3 V	Same as initial
208 V	197 V	+/-3 V	Same as initial
240 V	210 V	+/-3 V	Same as initial
480 V	465 V	-0,+5 V	Same as initial
b. Dropout voltage	N/A	N/A	N/A
4. Pickup frequency	60 Hz	57-60 Hz	Same as initial

(1) For CAT-II operations, the engine generator is normally started and used for prime power. In the event of geneator failure during this time, it is required that the CAT-II lighting load be switched back to commercial power within 1.1 seconds.

Table 9. Standydby engine generators (continued)

Parameter	Standard	Tolerance/limit	
		Initial	Operating
5. Time delay setting (2)	15 minutes	15-20 minutes	Same as initial
6. Voltage regulator	Set to match commercial power	+/-3 V	Same as initial
7. Frequency sensing device	Contacts to open below 57 Hz	Same as standard	Same as standard
8. Transfer relay (3)	1-3 seconds	Same as standard	Same as standard
9. Frequency	60 Hz	+/-5 Hz	Same as initial
10. Output voltage (4)			
a. 120 V system	114-126 V	Same as standard	Same as standard
b. 280 V system	197-218 V	Same as standard	Same as standard
c. 240 V system	228-252 V	Same as standard	Same as standard
d. 480 V system	456-504 V	Same as standard	Same as standard

(2) Maximum before transfer to commercial power - not valid where manual transferto commercial power is made.

(3) At facilities where the commercial power source has a record of momentary transients resulting in voltage drops, unnecessary engine starts and power transfer may be eliminated by increasing the tolerances, of the PR relays or undervoltage devices dropout and pickup voltage settings shown in this table. The tolerances may be extended to, but no exceed, the acceptable frequency and voltage characteristics of the facility equipment. Any voltage regulators installed to stablize the commercial voltage to the facility will be considered facility equipment. The TR relay or device time delay may be extended beyond 3 seconds to where, under normal starting conditions, the power from the engine generator will be available to the facility within 15 seconds after commercial power failure. The locally established tolerances shall be posted on the inside of the engine generator control panel door near the PR and TR relays.

(4) Adjust output voltage to match service entrance voltage or facility requirements.

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