NOTICE OF CANCELLATION

INCH-POUND

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DEPARTMENT OF DEFENSE
HANDBOOK

MAINTENANCE OF VISUAL AIR NAVIGATION FACILITIES

MIL-HDBK-1023/4 dated 30 November 1998 is hereby canceled. For future design criteria refer to MIL-STD-3007, "STANDARD PRACTICE FOR UNIFIED FACILITIES CRITERIA AND UNIFIED FACILITIES GUIDE SPECIFICATIONS".

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INCH-POUND

MIL-HDBK-1023/4
30 NOVEMBER 1998

DEPARTMENT OF DEFENSE
HANDBOOK

MAINTENANCE OF VISUAL AIR NAVIGATION FACILITIES

AMSC N/A

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FOREWORD

This handbook is approved for use by all departments and agencies of the Department of Defense (DOD).

Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: Commander, Naval Facilities Engineering Command (NAVFAC), Criteria Office, 1510 Gilbert Street, Norfolk, VA 23511-2699, telephone commercial (757) 322-4200, by using the Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document, or by letter. The Air Force point of contact is HQ AFCESA/CESE, 139 Barnes Drive, Suite 1, Tyndall AFB, FL 32403-5319, telephone commercial (850) 283-6352. The Army point of contact is USACE, CPW, 7701 Telegraph Road, Ft. Belvoir, VA 22060-5580, telephone commercial (703) 806-5163.

This handbook was prepared by NAVFAC Criteria Office, Norfolk, VA. The contents were taken from Federal Aviation Administration (FAA) documents and inputs from various departments of the U.S. Navy, U.S. Army, and the U.S. Air Force. A special thanks to Crouse-Hinds Airport Lighting, Windsor, CT, Mr. Phil Rakowski, who supplied many of the troubleshooting procedure write-ups and figures.

Do not use this handbook as a reference in a procurement document for facilities construction. It is to be used in the purchase and preparation of facilities planning and engineering studies and design documents used for the procurement of facilities construction (scope, basis of design, technical requirements, plans, specifications, cost estimates, request for proposals, and invitation for bids). Do not reference it in military or federal specifications or other procurement documents.

ABSTRACT

This handbook provides recommended guidelines for maintenance of airport, heliport, and helipad lighted navigational 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 handbook provides suggestions for establishing such a program but, due to the varying complexities of airfields and facilities provided, such a program must be tailored to suit each individual airfield's particular needs. Since corrective and preventive maintenance procedures for specific equipment are adequately covered in manuals supplied with the equipment, this handbook addresses maintenance topics of a more general nature.

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Section 1: INTRODUCTION

1.1 General. This handbook provides the recommended minimum guidance, to be used in conjunction with information available in instruction books, advisory circulars, and other handbooks, for the maintenance of lighted navigational aids. Additional information is available in FAA Advisory Circular AC 150/5340-26, Maintenance of Airport Visual Aid Facilities, and FAA Order 6850.5, Maintenance of Lighted Navigational Aids.

1.2 Scope. This handbook provides system maintenance information and establishes a maintenance program for lighted navigational aids. The information provided covers the following systems, subsystems, or components:

a) Airport and heliport beacons

b) Wind cone assemblies

c) Airfield lighting vaults

d) Constant current regulators

e) Isolation transformers

f) Runway and taxiway light systems

(1) Elevated fixtures

(2) In pavement fixtures

g) Runway centerline and touchdown lighting systems

h) Precision approach path indicator (PAPI) and chase helicopter approach path indicator (CHAPI) systems

i) Obstruction lights

j) Runway end identifier lights (REIL)

k) Medium intensity approach light system with flashers (MALSR)

l) Approach light system with sequence flashers (ALSF-1/ALSF-2)

m) Standby engine generator plants

1.3 Other Systems. There are a number of DOD lighted navigational aids that have their own maintenance and troubleshooting procedure manuals, which are not included in this handbook, such as: Mirror Optical Visual Landing Aid System (MOVLAS) USN, Fresnel Lens Optical Landing System (FLOLS) USN, and Emergency Airfield Lighting System (EALS)

USAF. Tables 1, 2, 3, and 4 list documents where additional guidance may be found for the maintenance of lighted navigational aids.

a) A complete listing of FAA advisory circulars, including those referenced in Table 2 as well as other airport planning documents, can be found on the world wide web (www) home page menu located at: http://www.faa.gov, and choose “airports” from the menu. For other FAA publications, write to the Department of Transportation, Distribution Unit, Washington, DC 20590.

b) For Navy publications, including those referenced in Table 3, write to: Commanding Officer, Naval Air Technical Services Facility, 700 Robbins Ave., Philadelphia, PA 19111-5097.

c) Air Force documents, including those referenced in Tables 3 and 4, are located in the Air Force Electronic Publishing Library, which is located at: http://afpubs.hq.af.mil/elec-products/pubs-pages/.

d) For Army documents, including those referenced in Table 3, write to: Commander, USACE Publications Depot, ATTN: CEIM-IM-PD, 2803 52nd Avenue, Hyattsville, MD 20781-1102.

e) Additional DOD publication resources are located at: http://www.defenselink.mil/pubs/.

Table 1
List of Standards and Specifications

DOCUMENT NO.	TITLE
FAA-E-910G	Structural Steel
FAA-E-982G	PAR 56 Lamp Holder
FAA-E-1315A	Light Base and Transformer Housing
FAA-E-2159B	Runway End Identifier Lighting System (REIL)
FAA-E-2325D	Medium Intensity Approach Light System with Alignment Indicator Lights
FAA-E-2491-B	Approach Light, Semi-flush, Steady Burning
FAA-E-2628B	Sequenced Flashing Lighting System Elevated and Semi-flush with Dimming and Monitoring
FAA-E-2689A	Dual Mode High Intensity Approach Lighting System (ALSF-2/SSALR)
FAA-E-2702	Low Impact Resistant Structures
FAA-E-2756	Four Box PAPI
FAA Drawing C-6046A	Frangible Coupling Type 1 and Type 1A, Details
FAA Drawing C-6076	ALSF-2 Approach Lighting System 6’-0” to 128’-0” Low Impact Resistant (LIR) Structures
FAA Drawing D-6155	ALSF-2, 6’ to 128’ and MALS, 40’ to 128’ LIR Structures

Table 2
List of FAA ACs

DOCUMENT NO.	TITLE AND DESCRIPTION
AC 70/7460-1	Obstruction Marking and Lighting. Describes the FAA standards for marking and lighting structures to promote safety.
AC 150/5200-18	Airport Safety Self-Inspection. Provides information to airport operations on self-inspection programs
AC 150/5210-5	Painting, Marking, and Lighting of Vehicles Used on an Airport. Provides guidance, specifications and standards in the interest of airport personnel safety and operational efficiency, for painting, marking and lighting of vehicles.
AC 150/5300-13	Airport Design. Contains the FAA standards for airport design.
AC 150/5340-18	Standards for Airport Sign Systems. Contains standards for siting and installation of runway and taxiway signs.
AC 150/5340-26	Maintenance of Airport Visual Aid Facilities. Provides recommended guidelines for maintenance of airport visual aid facilities.
AC 150/5345-3	Specification for L-821 Panels for Remote Control of Airport Lighting. Contains the specification requirements for panels used for remote control of airport lighting systems.
AC 150/5345-5	Circuit Selector Switch. This advisory circular contains a specification for a circuit selector switch for use in airport lighting circuits.
AC 150/5345-7	Specification for L-824 Underground Electrical Cable for Airport Lighting Circuits. Describes the specification requirements for L-824 electrical cables.
AC 150/5345-10	Specification for L-828 Constant Current Regulators Regulator Monitors. Contains a specification for constant current regulators, used on airport lighting circuits, and for a monitor that reports on the status of the regulator.
AC 150/5345-12	Specification for Airport and Heliport Beacon. Contains equipment specifications for light beacons which are used to locate and identify civil airports, seaplane bases, and heliports.
AC 150/5345-13	Specification for L-841 Auxiliary Relay Cabinet Assembly for Pilot Control of Airport Lighting Circuits. Contains the specification requirements for a relay cabinet used to control airfield lighting circuits. The L-841 consists of an enclosure containing a DC power supply, control circuit protection and 20 pilot relays.
AC 150/5345-26	Specification for L-823 Plug and Receptacle, Cable Connectors. Describes the subject specification requirements.
AC 150/5345-27	Specification for Wind Cone Assemblies. This advisory circular contains a specification for wind cone assemblies to be used to provide wind information to pilots of aircraft.

Table 2
List of FAA ACs (Continued)

DOCUMENT NO.	TITLE and DESCRIPTION
AC 150/5345-28	Precision Approach Path Indicator (PAPI) Systems. Describes the specification requirements for Visual Approach Slope Indicator (VASI) and Simple Abbreviated Visual Approach Slope Indicator (SAVASI) equipment and accessories.
AC 150/5345-42	Specification for Airport Light Bases, Transformer Houses, Junction Boxes, and Accessories. - Specification for containers designed to serve as airport light bases, transformer housings, junction boxes, and related accessories.
AC 150/5345-43	Specification for Obstruction Lighting Equipment. Contains FAA specification for obstruction lighting equipment.
AC 150/5345-44	Specification for Taxiway and Runway Signs. Contains a specification for light on unlighted signs to be used on taxiways and runways.
AC 150/5345-45	Lightweight Approach Light Structure. Presents the specification for lightweight structures for supporting lights as used in visual navigational aid systems.
AC 150/5345-46	Specification for Runway and Taxiway Light Fixtures. Contains specifications for light fixtures to be used on airport runways and taxiways
AC 150/5345-47	Isolation Transformers for Airport Lighting Systems. Contains the specification requirements for series-to-series isolation transformers used in airport lighting systems.
AC 150/5345-49	Airport Lighting Systems Specification L-854, Radio Control Equipment. Contains the specification for radio control equipment to be used for controlling airport lighting facilities.
AC 150/5345-50	Specification for Portable Runway Lights. Creates a standard and specification for a battery operated light unit to be used to outline a runway area temporarily.
AC 150/5345-51	Specification for Discharge-Type Flasher Equipment. Contains the specification for discharge-type flashing light equipment to be used for Runway End Identification Lights (REIL) and for an Omnidirectional Approach Lighting System (ODALS).

Table 3
List of Department of Defense (DOD) References

DOCUMENT NO.	TITLE
NAEC-91-8082	Navy Precision Approach Path Indicator (PAPI) Certification Requirements
NAEC-91-8071	Certification Test Procedure for Visual Approach Slope Indicator (VASI) System
MIL-HDBK-1023/1	Airfield Lighting
NAVFAC P-272	Definitive Designs for Naval Shore Facilities
NAVAIR 51-40AAA-4	Tech Manual, Installation, Service, Operation and Maintenance Instructions with Illustrated Parts Breakdown PAPI Type L-880, Style A, Class 2
NAVAIR 51-50AAA-2	Tech Manual, General Requirements for Shorebased Airfield Marking and Lighting
ARMY, TM5-811-5	Army Aviation Lighting
ARMY, TM5-682	Electrical Engineering, Electrical Facilities Safety (1983)
USACE, EM 385-1-1	Safety and Health Requirements
ARMY, STD DET 40-60-05	Army Aviation Lighting Fixtures
AFI 11-218	Aircraft Operations and Movement on the Ground (formerly AFR 60-11)
AFJMAN 11-225	Flight Inspection (FAAH 8200.1)
AFJMAN 11-226	US Standard for Terminal Instrument Procedures (TERPS) AFM 55-9 (formerly FAAH 8260.3)
AFI 13-213	Airfield Management (formerly AFR 55-48)
AFI 24-301	Vehicle Operations (formerly AFR 77-310)
AFMAN 24-306	Manual for Wheeled Vehicle Driver (formerly AFR 77-2)
AFI 31-204 Motor	Vehicle Traffic Supervision (formerly AFR 125-14)
AFPAM 32-1006	Service Contract Guide for Civil Engineers
AFJMAN 32-1013v1	Airfield and Heliport Planning and Design Criteria
AFMAN 32-1013v2	Planning Criteria and Waivers for Airfield Support Facilities
AFI 32-1021	Planning and Programming of Facility Construction Projects
AFI 32-1023	Design and Construction Standards and Execution of Facility Construction Projects
AFI 32-1024	Standard Facility Requirements (formerly AFR 86-2)
AFI 32-1026	Planning and Design of Airfield (formerly AFR 86-5/86-14)
AFI 32-1032	Planning and Programming Real Property Maintenance Projects Using Appropriated Funds (APF)
AFI 32-1041	Airfield Pavement Evaluation Program (formerly AFR 93-13)
AFI 32-1042	Standards for Marking Airfields (formerly AFR 88-16)
AFI 32-1043	Managing Aircraft Arresting Systems (formerly AFR 55-42)
AFI 32-1044	Visual Air Navigation Systems (formerly AFR 88-14)
AFI 32-1045	Snow and Ice Control (formerly AFR 91-15)
AFI 32-1054	Corrosion Control
AFI 32-1062	Electrical Power Plants and Generators

Table 3 (Continued)
List of Department of Defense (DOD) References

DOCUMENT NO.	TITLE
AFI 32-1063	Electric Power Systems
AFI 32-1064	Electrical Safe Practices
AFI 32-1065	Grounding Systems
AFMAN 32-1187	Design Standards for Visual Air Navigation Facilities (formerly AFR 88-14)
AFH 32-1084	Standard Facility Requirements Handbook
AFPAM 32-1097	Sign Standards Pamphlet
AFI 32-4001	Disaster Preparedness Planning and Operations
AFI 32-4002	Hazardous Material Emergency Planning and Response Program
AFMAN 32-4004	Emergency Response Operations
AFMAN 32-4005	Personnel Protection and Attack Actions
AFI 32-4007	Camouflage, Concealment, and Deception
AFVA 32-4010	USAF Standardized Alarm Signals
AFVA 32-4011	USAF Standardized Alarm Signals
AFMAN 32-4013	Hazardous Material Emergency Planning and Response Guide
AFH 32-4016v2	Civil Engineer Readiness Flight Response and Recovery Handbook
AFI 32-7086	Hazardous Materials Management

Table 4
Additional Reference Documents

DOCUMENT NO.	TITLE
FAA Publications:	
FAA-H 7930.2	Notices to Airmen
FAA-H 8200.1	Flight Inspection (AFJMAN 11-225)
FAA-H 8260.3	Terminal Instrument Procedures (TERPS) (AFJMAN 11-226)
FAA-O 6850.5	Maintenance of Lighted Navigational Aids
Federal Air Regulations (FAR):	
FAR Part 1	Definitions and Abbreviations
FAR Part 73	Special Use Airspace
FAR Part 139	Certification and Operations: Land Airports Serving Certain Air Carriers
Technical Orders:	
TO 36-1-3	Painting, Marking, and Lighting Requirements for USAF Vehicles
Forms:	
AF Form 332	Base Civil Engineers Work Request
AF Form 457	USAF Hazard Report
AF Form 483	Certificate of Competency
AF Form 3546	AFFSA IFC Comment Card
AF Form 3616	Daily Record of Facility Operation
FAA Form 5280-7	Airfield Visual Aid Safety Placard (NSN 0052-00-918-1000)

Section 2: SAFETY

2.1 General. This chapter contains information that will aid facility personnel 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. Local operational procedures, and OSHA requirements should also be followed. The safety program established at each facility should include preventive safety precautions, and first-aid procedures for use in the event of an injury.

2.2 Causes of Accidents. Some common causes of accidents are:

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

b) Working on equipment without sufficient experience on that equipment.

c) Failure to following 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.

2.3 Safety Procedures and Guidelines. Most lighted navigational 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, lighted navigational aids should not be serviced during periods of local thunderstorm activity. Develop and implement a set of action plans to follow in the event of an accident occurring. A known set of predetermined responses should be in place to ensure that positive responsive actions take place within moments of accident notification. For example: on airfield frequencies, using the phrase “man down… man down, we need assistance” over the radio to the tower personnel would result in the tower placing a 911 call for medical assistance and dispatching the fire department to the caller’s location. Precious seconds are saved getting medical assistance to those in need when action plans are in place. Action plans should be rehearsed and reviewed regularly.

2.3.1 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 personnel:

a) Work should never be performed on energized electrical conductors or equipment, except for measuring voltage or current.

b) Always assume that power is on until the true condition is determined.

2.3.2 Safety Practices. The following safety practices should be followed by all personnel performing maintenance on lighted navigational aids:

a) Workers should be trained and familiar with electrical safety.

b) Safety rules should be strictly observed.

c) Commercial test equipment should be Underwriters Laboratory (UL) approved.

d) Prior to beginning any maintenance work on airport lighting circuits, coordinate the work schedule with the tower, facility manager or public works personnel. Make sure circuits will not be energized during maintenance, and obtain authorization for local control if equipment is normally operated from a remote control point.

e) 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 the other electrician include:

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

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

(3) 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.

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

2.3.3 Personal Safety Precautions. The following commonsense safety precautions should be standard procedure for every electrician:

a) Know the location of main power disconnect devices.

b) Know how to summon medical aid.

c) Remove necessary fuses to de-energize 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.

d) Do not depend on interlocks to remove power or 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.

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

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

g) De-energize the equipment when 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.

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

i) Ground test equipment to the equipment under test unless otherwise specified in instruction manuals. Following the test procedures in par. 4.2 for using volt-ohm-milliammeters (VOM) on live circuits.

j) Place a warning sign, such as “DANGER - DO NOT USE OR OPERATE”, at the main switch or circuit breaker, and provide a lockout for the circuit on which you will be working.

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

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

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

n) Never use toxic or flammable solvents for cleaning purposes.

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

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

2.4 Safety Boards. A plywood board or similar device, 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. Recommended safety procedures should be followed as designated by the local authority or command. Some safety items to be followed are:

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 1/2-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.

n) Fire extinguisher (refer to par. 2.12).

2.5 Safety Warning Signs/Danger Tags. This paragraph discusses the use of warning signs on high-voltage equipment, and lists some recommendations.

2.5.1 "DANGER—HIGH-VOLTAGE" Sign. These signs (see Figure 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.

Figure 1
"DANGER HIGH-VOLTAGE" Sign

2.5.2 <u>"DANGER" Tag</u>. The tags (see Figure 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.

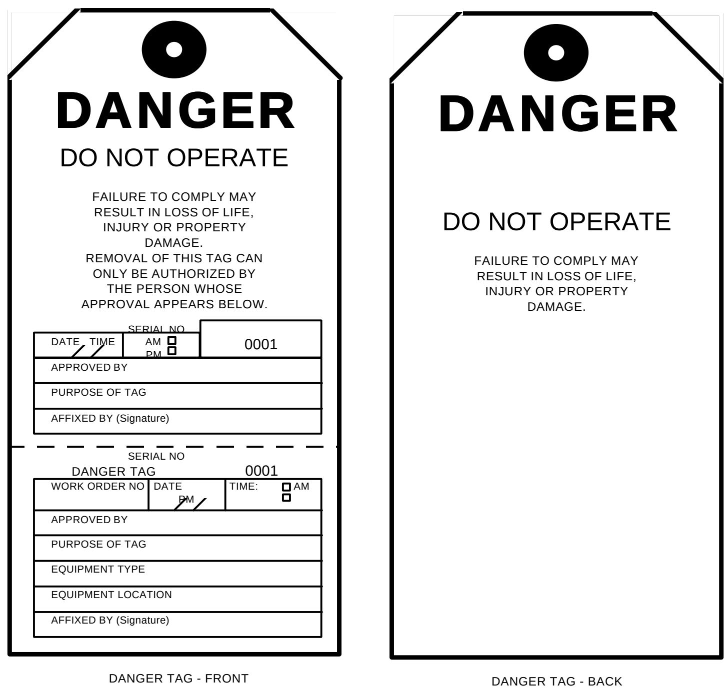


Figure 2
"DANGER" Tag

2.5.3 <u>"DANGER" Tag Control</u>. "DANGER" tags and locks should be controlled by the leading electrical or maintenance supervisor at each facility or other personnel 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 de-energized equipment. On completion, the electrician notifies the supervisor who personally inspects all tag points to assure that the equipment is safely 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.

2.5.4 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.

2.6 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 D120, Insulated Rubber Gloves. ASTM specifications may be obtained from the American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

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

c) Gloves should be proof-tested at the following intervals: in daily use—30 days; or infrequent use—180 days. Gloves suspected of having defects should be proof-tested; gloves received from the manufacturer should be inspected and proof-tested.

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

CAUTION:

Certified rubber gloves and protective leather gauntlets should be worn whenever hot-sticks are used.

2.7 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 one year.

2.8 Electric Shock. An electric shock is the passing of an electric current through a person. The amount of damage depends on the level of voltage and the amount of current to which the person is subjected.

a) Voltages between 200 and 1000 volts at commercial power line 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; and, 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.

2.9 Soldering Safety

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.

(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-heated devices or their use near 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. Fumes are dangerous to breathe; fumes from heated fluxes and degreasing liquids can cause lung and skin irritations.

(4) Shock. Since electrical soldering equipment is commonly used, the possibility of an electrical shock is 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. Non-corrosive fluxes present little problem, but the alkalis 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 electrical equipment unless it is disconnected from the power supply. Death can result from contact with the high-voltage source being worked on.

(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 devices by neutralizing any differences in potential between the soldering equipment and the semiconductors in transistor 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 falling 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 fire-fighting devices and first-aid supplies near the soldering area. All equipment should be checked at regular intervals.

2.10 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, may prevent death from any but direct charges.

b) The following rules for personnel safety should be observed 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 a suitable shelter such as: large metal or metal-frame buildings, buildings which are protected against lightning, or vehicles.

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

small sheds and shelters in an exposed location; which house power equipment, wire fences, antennas, supporting structures, or telephone, and electric lines.

2.11 Toxic Agents and Solvents. Toxic agents and solvents 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 (CCL_4). Never use carbon tetrachloride. Contact with carbon tetrachloride destroys the natural oils of the skin, producing a whitish appearance on skin surfaces that are exposed; continuous skin exposure may cause skin eruptions. Carbon tetrachloride fumes are highly toxic.

b) Trichloroethylene (C_2HCL_3). 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 sulfuric acid (H_2SO_4). Sulfuric 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 sulfuric 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 sulfuric acid cause coughing and irritation of the eyes; prolonged exposure may produce a chemical pneumonitis.

2.12 Fire Extinguishers. Fire extinguishers of the proper type, and in good working condition, should be conveniently located near all high-voltage equipment. Table 5 lists the types of fire extinguishers that are normally available.

Table 5
Types of Fire Extinguishers

Extinguisher	Uses
CO_2	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.

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

2.14 First Aid. First aid is essential before professional help arrives. It is never a substitute for medical help. The electricians 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.

2.15 Safety Training. A safety training course should be established and presented to all employees. Follow-up training should be presented on a periodic basis to ensure that employees are safety motivated. Check with the local safety office or medical facility to arrange for proper training.

Section 3: MAINTENANCE MANAGEMENT

3.1 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 of funds. “Availability” and “costs” are relative terms; they must be interpreted for each facility. The maintenance of Visual and Air Navigational Lighting Systems is an integral part of aviation maintenance performed at DOD shore installations. Maintenance of the navigational lighting systems is a mission essential part of air operations. Maintenance operations must be scheduled and coordinated with the fleet or MAJCOM air operational exercises and training missions. The maintenance operations include maintenance planning, preventive maintenance inspection, visual inspection, repair, installation, and calibration, and unscheduled maintenance procedures. Maintenance procedures including the work order and documentation required may vary between activities. The purpose of this document is to provide the minimum maintenance procedures required for safe and efficient movement of aircraft during takeoff, landing, and taxiing operations.

In addition, operational factors are a major consideration in determining what maintenance is required. Facilities with heavy traffic may require more frequent maintenance servicing than those used only by light traffic.

Regardless of the actual maintenance routines decided upon, the following elements are essential to any controlled maintenance program. The maintenance procedures in this handbook are considered minimum guidelines. Check with the local authority for additional guidance and related DOD manuals and instructions to ensure there is not a conflict with these procedures.

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

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

3.2 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.

3.3 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 of 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.

3.4 Preventive Maintenance Program. Reliable functioning of airport lighted navigational 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. Lighting systems are designed to be dependable and may continue to operate for long periods of time even if maintenance is neglected. If failure occurs at a critical time, lives and property may be jeopardized. Lighted navigational aid maintenance should receive high priority to prevent equipment failure, false signals, and deterioration of the system.

3.4.1 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.

3.4.2 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. Visual air navigation facilities maintenance personnel should be specialists in the field.

3.4.3 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 Section 4, adequate working space, adequate storage space, spare parts, and applicable technical manuals.

3.4.4 Inspection Program. The fourth element in a preventive maintenance program is an effective Preventive Maintenance Inspection (PMI) schedule for each lighted navigational aid. The PMI schedule is the foundation for the successful maintenance of the equipment. If the PMI schedule 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.

3.5 Preventive Maintenance Inspection (PMI) 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 are based on 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 justified after experience is gained under local operating conditions.

3.6 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 be minimum (e.g., 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).

3.7 Reference Library. A reference library should be established to maintain a master copy of all equipment technical manuals, advisory circulars, as-built drawings, and other useful technical data. An office of primary responsibility should be established to maintain records.

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

3.7.2 FAA Advisory Circulars (ACs). Important reference information on installation, design tolerances, and operation of lighted navigational aid equipment may be found in FAA ACs. A copy of the ACs covering the equipment at the facility should be included in the reference library. A partial list is shown in Table 1.

3.7.3 Other Technical Data. Other less frequently used reference information should also be added to the library. This might include local electrical codes, engineer's handbooks, test equipment manuals, and other general information publications. For a listing of DOD reference material, see Table 3.

3.7.4 As-built Drawings. It is recommended that the master copy of 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, runway lights, etc., and including the wiring diagrams for the lighting, engine generator, and the lighted navigational aid, should be given to the field technicians as a working copy.

3.8 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; minimizing 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 inconvenience, etc.) with the cost of purchasing and storing spare parts. A small facility 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 facility may rely heavily on its lighting system for bad weather operations and would, therefore, require a substantial quantity of various spare parts. When establishing a spare parts inventory, two questions must be answered: (1) Which parts should be stocked, and (2) How many of each part?.

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

a) 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 4 per week. The failure rate may be determined from the maintenance records, which should be compiled according to the instructions in par. 3.3.

b) Part Availability. Part availability refers to the time it takes to secure a replacement part (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.

c) 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. For example, the failure of a lamp in an edge light would not lead to any system downtime, but 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.

3.8.2 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, since 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 incompatible with the existing system. It is extremely important to maintain manufacturer's data which reflects the facility equipment; describing the type, model, number, and serial details.

Section 4: ELECTRICAL TEST EQUIPMENT

4.1 General. This section describes several types of electrical test equipment used for maintenance of lighted navigational aid equipment. The test equipment is listed in order of relative usefulness. For maintenance purposes, it is recommended that every facility 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. Periodic condition checks should be performed on all test equipment to ensure safe operation.

4.2 Volt-Ohm-Milliammeter

4.2.1 General. The volt-ohm-milliammeter (VOM), Figure 3 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.

4.2.2 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.

4.2.2.1 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.

4.2.2.2 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 being tested 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 1/3-to-midscale deflection of the pointer ensures the most accurate reading.

4.2.2.3 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 on the insulation of the case.

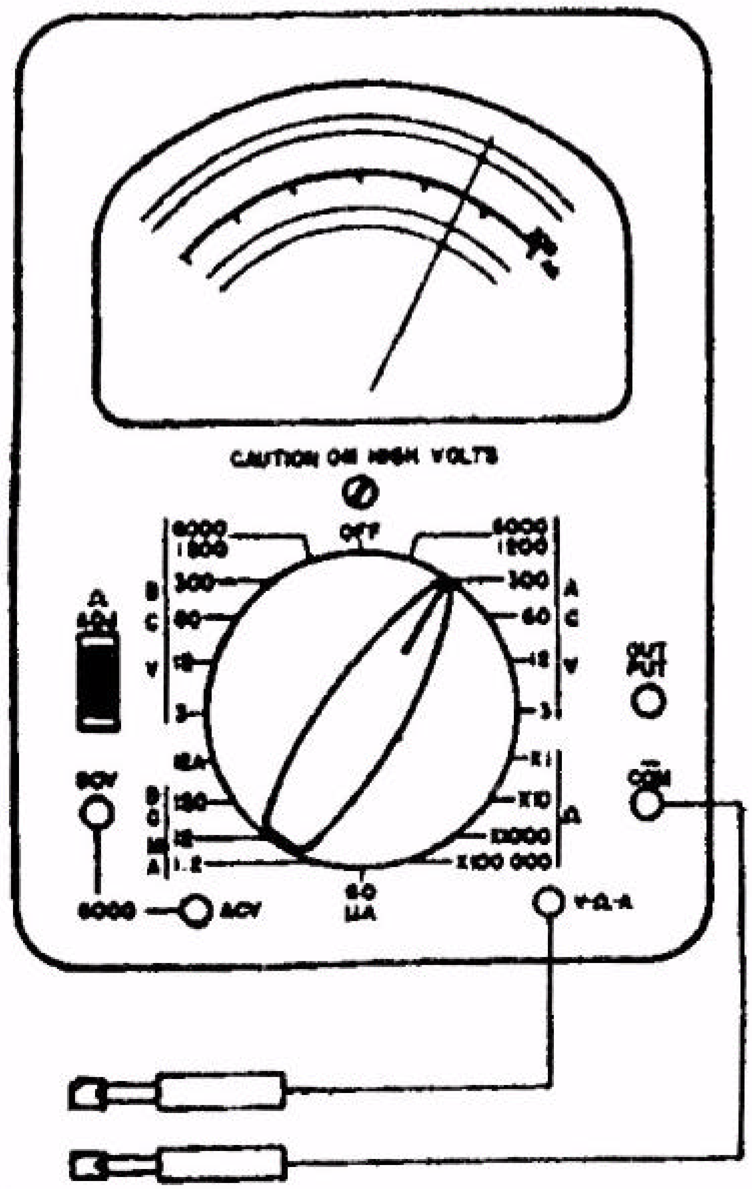


Figure 3
Typical Volt-Ohm-Milliammeters

4.3 Insulation Resistance Tester

4.3.1 General. The insulation resistance tester, or megohmmeter, Figure 4 is used for testing insulation resistance-to-ground of underground cables (refer to par. 4.3); for testing insulation resistance between conductors; and for testing resistance-to-ground or between windings of transformers, motors, regulators, etc.

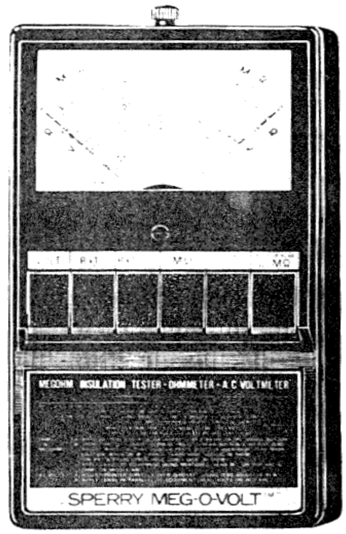


Figure 4
Insulation Resistance Tester (Typical).

4.3.2 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 accidentally 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, 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.

4.4 High-Resistance Fault Locator

4.4.1 General

a) The high-resistance fault locator, Figure 5 utilizes a modified wheatstone 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 using 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.

4.4.2 Safety. Before attempting to make any connections, make sure that all exposed cables are de-energized.

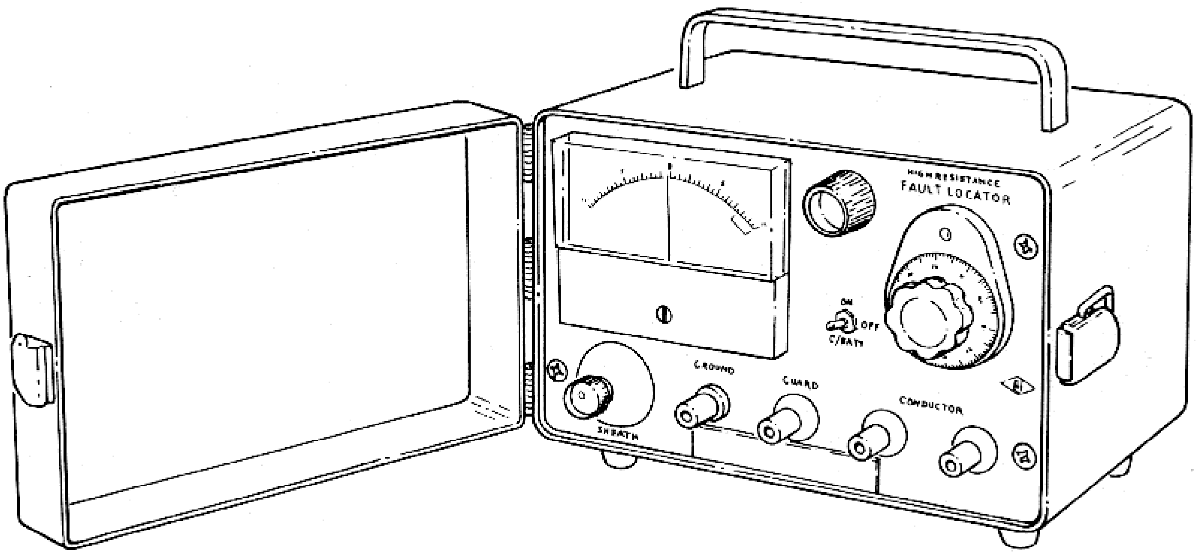


Figure 5
Typical High-Resistance Fault Locator

4.5 Clamp-on Ammeter

4.5.1 General. The true RMS (root mean squared) ammeters (true RMS) shown in Figure 6measure alternating current. Some models are provided with plug-in leads to permit the instrument to be used as a voltmeter or as an ohmmeter. When checking current, use a current clamp probe, as shown in Figure 6 The ammeter is the airfield electrician's most important tool, and should be a true RMS ammeter. Other ammeters (averaging and peak indicating) are inadequate for airport lighting use. Averaging and peak indicating ammeters will not measure the non-sinusoidal waveforms correctly and will indicate current levels below actual current levels. Only true RMS ammeters are capable of reading non-sinusoidal waveforms that are present on constant current regulator outputs and airfield load circuits. The typical true RMS ammeter used by airfield electricians consists of a true RMS multi-meter connected to a current clamp accessory. The current clamp accessory allows current measurement without interrupting or directly coming in contact with the circuit being measured. Electricians should avoid "Hall Effect" current clamp accessories.

4.5.2 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.

Figure 6
Typical Ammeters and Current Clamp Probe

4.6 Cable Route Tracer

4.6.1 General. The cable route tracer, Figure 7 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.

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

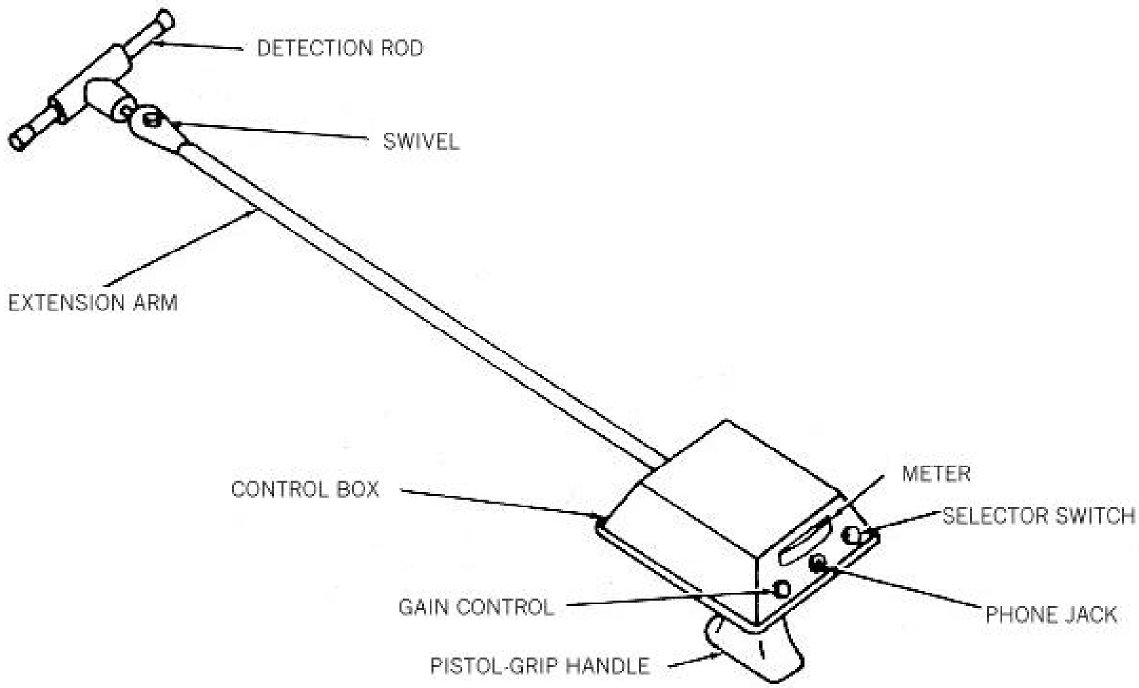


Figure 7
Cable Route Tracer

4.7 Impulse Generator/Proof Tester

4.7.1 General

a) The impulse generator/proof tester, Figure 8, 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 pars. 4.8 and 4.9.

4.7.2 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 de-energized and all parts of the test 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 provides 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 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 sites require 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.

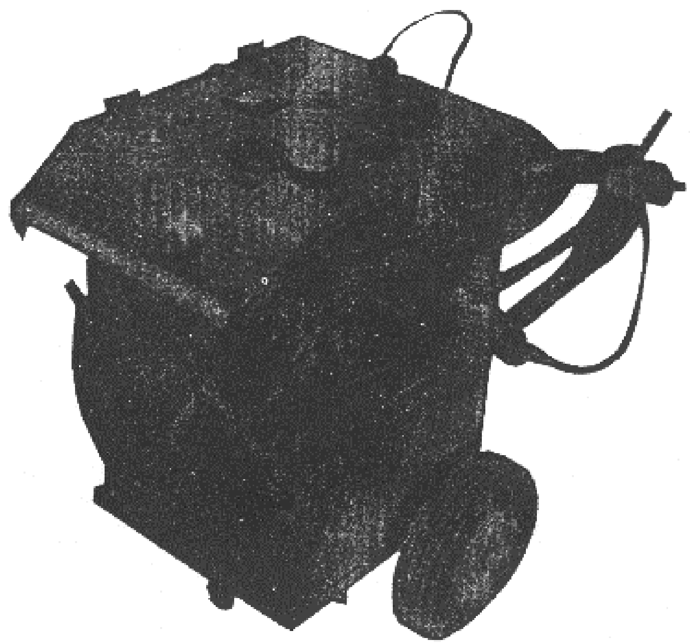


Figure 8
Typical Impulse Generator/Proof Tester

4.8 Acoustic Detector

4.8.1 General

a) The acoustic detector, Figure 9, 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.

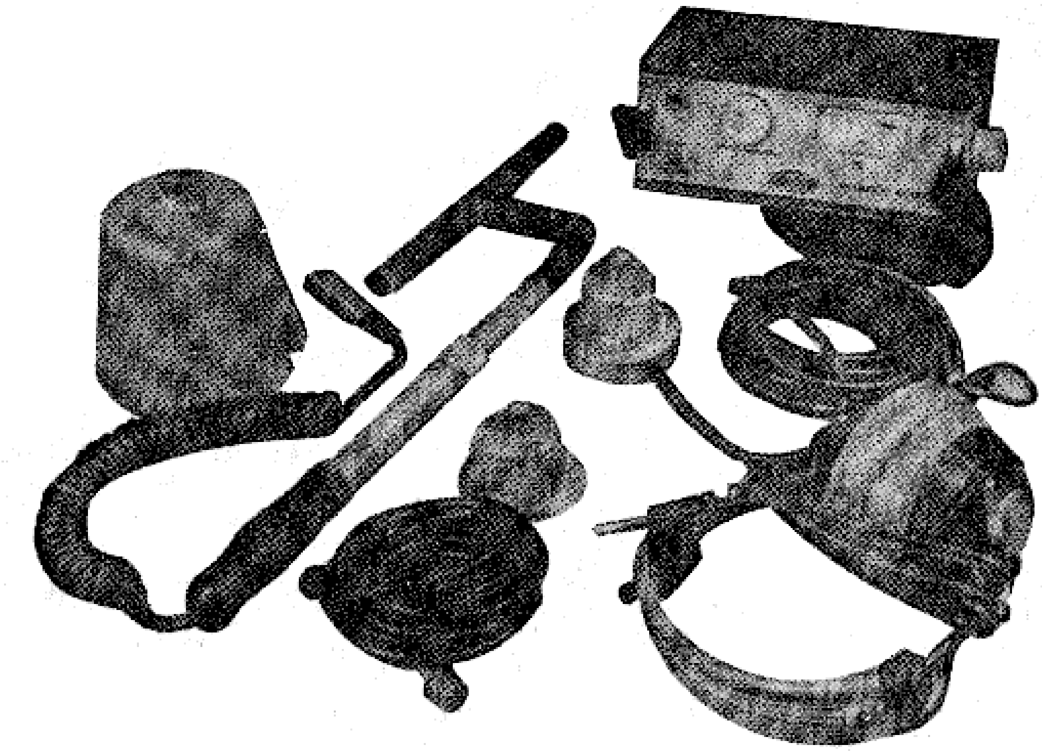


Figure 9
Typical Acoustic Detector

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 often 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.

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 ensures 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 10.

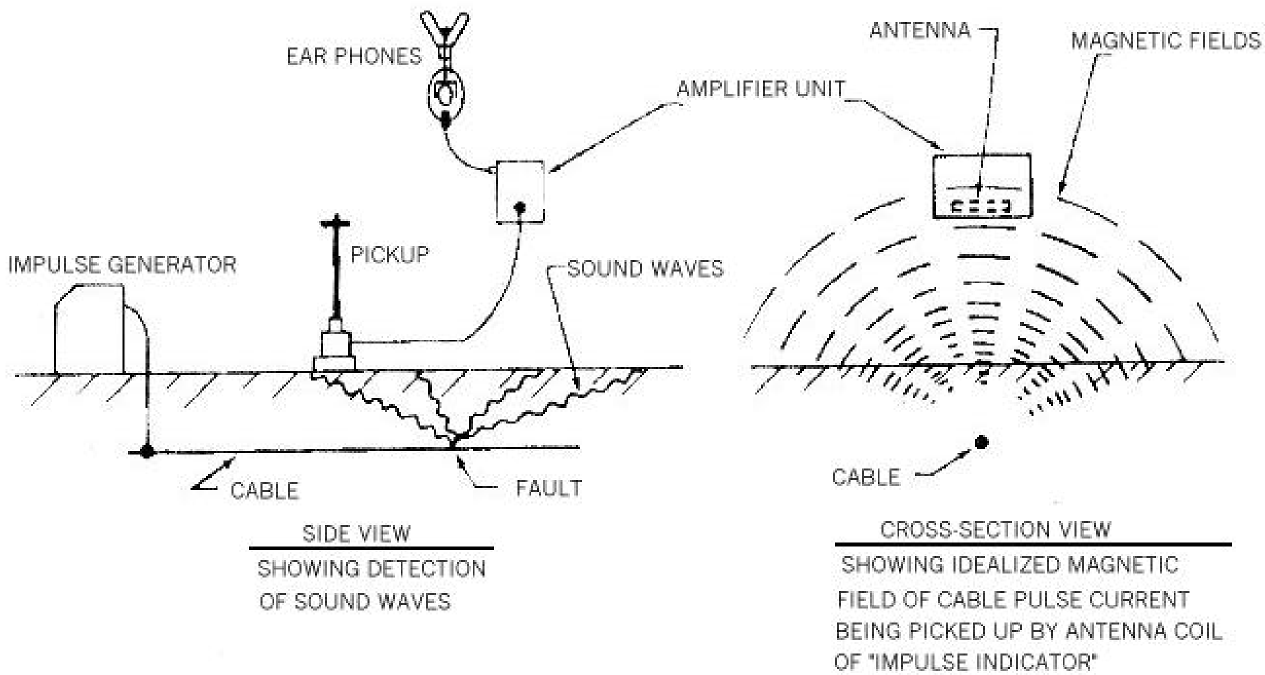


Figure 10
Use of the Acoustic Detector

4.9 Directional Detector

4.9.1 General

a) The directional detector, Figure 11measures 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.

b) With the selection of two magnetic pickups and one conductive pickup, it can be used to locate faults in shielded or unshielded cables, either 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 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.

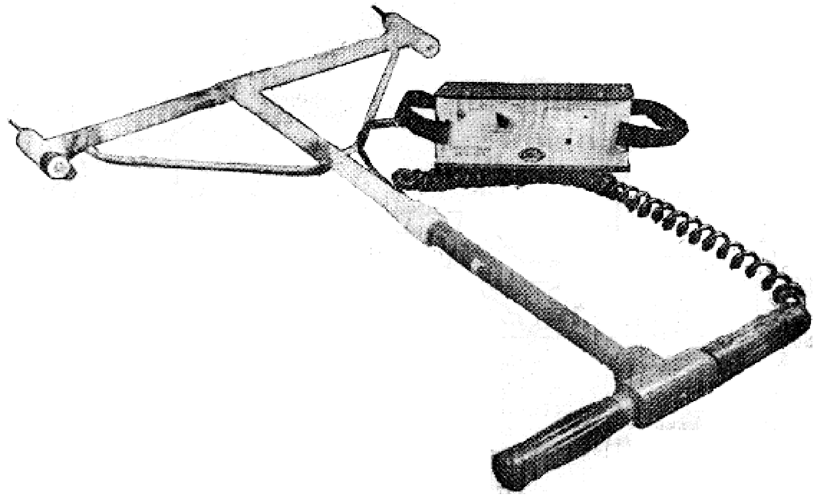


Figure 11
Typical Directional Detector

f) 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 0 degrees, 45 degrees, and 90 degrees 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.

4.9.2 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 par. 4.7 regarding 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 power line.

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

(1) At or near connections to the 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.

4.10 Portable Oil Tester

4.10.1 General

a) The portable oil tester, Figure 12, 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 the windings.

c) The oil should be sampled and tested as indicated in the section on regulators.

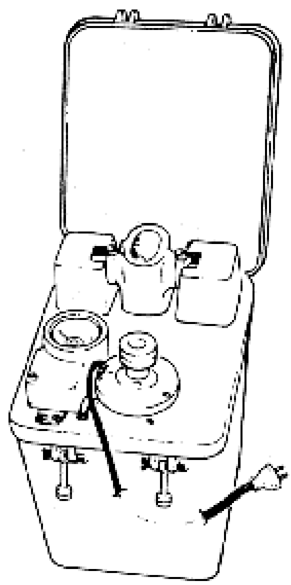


Figure 12
Typical Portable Oil Tester

4.10.2 Operation

a) To test the oil in a large transformer, separate samples are taken from both the top and bottom of the transformer and poured into the oil tester separately 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).

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 10 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.

4.11 Ground Resistance Tester

4.11.1 General

a) The ground resistance tester, Figure 13, is used to measure the effectiveness of grounding systems. It does this by measuring the resistance between the grounding system and the earth ground. Follow manufacturer's instructions closely to obtain an accurate ground resistance reading, thus avoiding a false, lower than actual resistance-to-ground measurement that can result from incorrect use. The grounding system in question may be used for beacon towers, lighting vaults, engine generators, and for other lighted navigational 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 at the time of installation.

4.11.2 Safety. A grounding system is a very important integral safety feature in airport lighting systems. 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.

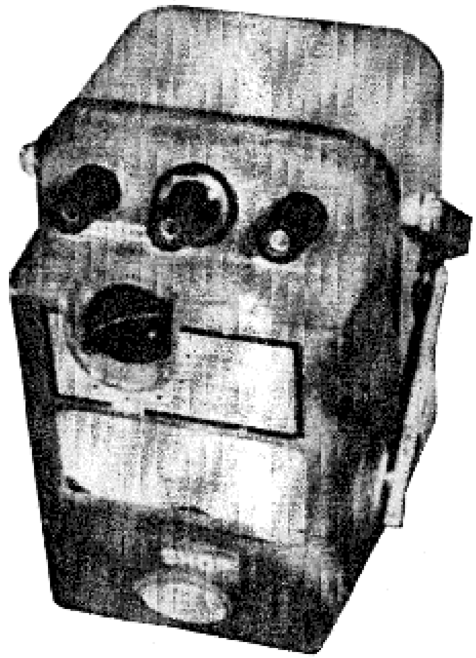


Figure 13
Typical Ground Resistance Tester

Section 5: PREVENTIVE MAINTENANCE

5.1 General. This chapter discusses the preventive maintenance program for the lighted navigational aid facilities and equipment. It contains a preventive maintenance inspection schedule (PMI) for 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 troubleshooting procedure for facility lighting systems are contained in Section 6. Corrective maintenance procedures for specific equipment will be found in the manufacturer's operating and maintenance instructions.

5.2 Rotating Beacons Airfield, Helipads, and Heliports

5.2.1 Preventive Maintenance Inspection (PMI) Procedures. To perform the PMIs contained in Table 6 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. Check for proper color and flash sequence. For military airports the sequence is double peak white, single peak green. For helicopter facilities the sequence is double peak white, single peak green and single peak yellow. For medical facilities the sequence is double peak white, single peak green and single peak red.

(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. De-energize 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. De-energize 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; 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. The clutch should slip between 8 to 10 pounds.

(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.

(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 non-abrasive cleaner that will 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. Voltage levels higher than a lamp's nominal rating will prematurely reduce the lamp's life proportionally to the increased voltage, and conversely, voltage levels lower than a lamp's nominal rating will reduce the lamp's light output proportionally to the reduced voltage. The measurement should be made at the beacon lamp terminals, with all field equipment energized, so 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

(a) 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).

(b) 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.

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

CAUTION:

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

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

(4) Switches. Check the operation of electrical switchblades 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, and check the condition of the down conductor for corrosion or damage. Check and record the ground resistance. Compare the reading with the 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 busbar, and if no short-to-ground is noticed, contact the power company to repair or replace the meter. Check the meter lead connection for tightness and keep the outside of the 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. Clean the old grease from the gears. When installing new grease, observe the caution statement above.

(3) Wiring, electrical connections, conduit, and relays

(a) 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.

(b) 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.

(c) 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.

Table 6
Preventive Maintenance Inspection Schedule for Rotating Beacons

Maintenance Requirement	DAILY	WKLY	MTHLY	BIMHY	QTRLY	SMANY	ANNLY
1. Check for beacon operation and proper color sequence.	X						
2. Count rpm of beacon.	X						
3. Check telltale indicator lamp for reserve lamp status.	X						
4. Check operation of the lamp-changer.				X			
5. Check slip rings and brushes.				X			
6. Test the clutch torque.				X			
7. Check lens retainers.				X			
8. Check telltale indicator lamp.				X			
9. Check operation of relays.				X			
10. Clean and polish glassware.				X			
11. Check and record input voltage.						X	
12. Check lamp focus and beam elevation.						X	
13. Lubricate main shaft, motor, ring gear, and padlocks.						X	
14. Check operation of electrical switches and contacts.						X	
15. Check lightning arresters and grounding system.						X	
16. Check power meter.						X	
17. Check level of base.							X
18. Clean and re-grease gears.							X
19. Inspect wiring, lugs, and conduit.							X
20. Check weatherproofing and gaskets							X

5.3 Wind Cone Assemblies

5.3.1 Preventive Maintenance Inspection Procedures. To perform the PMIs contained in Table 7 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 percent volts AC, or as defined in the manufacturer's specifications.

(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 360 degree 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. Use low temperature grease (ESSO #325) on wind cone bearings.

(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, soiled, or faded in color.

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 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 250,000 ohms, the cables should be repaired or replaced.

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.

(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 and check condition of the footings and foundations for deterioration, and repair as required.

Table 7
Preventive Maintenance Inspection Schedule for Wind Cones

Maintenance Requirement	DAILY	WKLY	MTHLY	BIMHY	SMANY	ANNLY	UNSCH
1. Check lamp operation.	X						
2. Check photocell operation.	X						
3. Check for freedom of motion of wind cone frame.			X				
4. Check condition of wind cone fabric.			X				
5. Check lamp age for scheduled replacement.				X			
6. Clean glassware.				X			
7. Check paint on segmented circle.				X			
8. Clean and grease bearings.					X		
9. Read insulation resistance.					X		
10. Check mounting bolts.						X	
11. Check wiring at hinge.						X	
12. Check grounding system resistance.						X	
13. Check paint on wind cone structure.						X	
14. Remove vegetation and check condition at foundation.							X

5.4 Airport Lighting Vault

5.4.1 Preventive Maintenance Inspection Procedures. To perform the PMIs contained in Table 8, 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 connections must be removed before insulation resistance may be measured. The maintenance supervisor should consider troubleshooting the circuit resistance, using the guidelines provided in Table 9 High voltage insulation resistance test on each series and multiple underground circuit to determine complete freedom from grounds. Whenever possible, these tests should be performed when the ground is thoroughly wet. Circuits which pass insulation resistance tests during dry weather may fail after a heavy rain. A 10 to 20 percent annual decrease in insulation resistance value (in mega-ohms) is normal. An annual decline of over 50 percent, or 4 percent decrease, from one reading to the next indicates the existence of a problem that should be troubleshot. Consistent testing and good record keeping is the essential. The test procedure is as follows for each circuit:

(a) Disconnect both leads from the regulator output terminals. Support both leads so there are air gaps of several inches between bare conductors and ground. Make sure the cable sheath is clean and dry for a distance of at least 1 foot (300mm) from the end of the cable. Also make sure exposed insulation at the end of the cable is clean and dry.

(b) Test each circuit immediately after installation according to “First Test for New Circuits,” as listed in Table 10 Test any circuit installed for 60 days or more, even if it has not been operated, according to “Succeeding Tests and Old Circuits.”

(c) The maximum acceptable leakage current, in microamperes, should not exceed the values in subpar. (f) below.

(d) When additions are made to old circuits, test only the new sections according to “First Test on New Circuits.” Test the complete circuit at the reduced voltages to ensure reliable operation.

(e) Connect both conductors, and apply the test voltage shown for 5 minutes between conductors and ground. The above tests must be performed with a suitable high voltage tester which has a steady, filtered output voltage. The high voltage tester must have an accurate voltmeter and microammeter for reading the voltage applied to the circuit and the insulation leakage current. All high voltage tests on airfield lighting circuits must be carefully supervised by qualified personnel to ensure that excessive voltages are not applied to circuits.

(f) During the last minute of the above tests, the insulation leakage current in microamperes for each complete circuit must not exceed the following value calculated for each circuit:

1. Allow 2 microamperes for each 30/45, 100, 200, 300 and 500W series transformer.

2. Allow 3 microamperes for each 1000 feet of cable. This value includes allowances for the normal number of connectors and splices.

3. Add the above values to determine the total allowable microampere leakage for each complete circuit.

(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 of each phase should be

recorded for future reference. If it is out of tolerance, contact the power company to correct the problem.

c) Semiannual checks

(1) Ground Resistance. Perform a ground-resistance measurement for each item of equipment using a ground resistance tester (refer to par. 4.11). 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-Voltage 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. De-energize 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 A, Table A-7).

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

Table 8
Preventive Maintenance Inspection Schedule for Airport Lighting Vault

Maintenance requirement	DAILY	WKLY	MTHLY	BIMHY	SMANY	ANNLY	UNSCH
1. Check control operation.	X						
2. Check general cleanliness.				X			
3. Check for moisture.				X			
4. Check screens on ventilators.				X			
5. Check vault.				X			
6. Check insulation resistance.			X				
7. Check input voltage.				X			
8. Check ground resistance.					X		
9. Inspect and clean buses.					X		
10. Check relay operation.					X		
11. Check oil fuse cutouts.					X		
12. Check oil switches.					X		
13. Operate power transfer switches.					X		
14. Check control panel.					X		
15. Check photoelectric switch.					X		
16. Check astronomic time switch.					X		
17. Check radio-control of lighting equipment.					X		
18. Check lightning arresters.					X		X
19. Inspect miscellaneous electrical hardware (fans).					X		
20. Check oil dielectric.						X	
21. Paint equipment as necessary.						X	

Table 9
Table of Initial Resistance Values Versus Circuit Length

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

Table 10
Table of Insulation-Resistance Test Values for Field Circuits

	First Test on New Circuit	Succeeding Tests and Old Circuits
Complete Approach System (5000V leads, 500 and 300W transformers)	9000V	5000V
Touchdown Zone and Centerline Light Circuits (5000V leads, 200W transformers)	9000V	5000V
High Intensity Runway Edge Light Circuits (5000V leads, 500 and 200W transformers)	9000V	5000V
Medium Intensity Runway and Taxiway Circuits (5000V leads and 30/45W transformers)	6000V	3000V
600 Volt Circuits	1800V	600V

(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. Lightning arresters 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 par. 5.6.1.

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

5.4.2 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 lighted navigational 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 par. 2.5, should be prominently displayed at appropriate locations.

e) Safety Board. Safety boards, as described in par. 2.4, should be installed in the vault.

5.5 Runway and Taxiway Edge Lighting Systems

5.5.1 Preventive Maintenance Inspection Procedures. To perform the PMIs contained in Table 11, proceed as follows:

a) Daily checks

(1) Perform a visual inspection of the system at twilight or night each day. This inspection consists of a driving patrol to visually check for dimly burning bulbs, burned-out lamps, and 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 deactivated.

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

b) 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 hole in the frangible coupling of stake-mounted lights.

c) 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 the fixture where necessary to maintain this fixture/grade relationship. Also, maintain the elevation of all lights the same height above the runway/taxiway 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 regions, 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 main 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.

d) Annual checks

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

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

(3) Check condition of all connections.

(4) Check runway cable insulation (refer to par. 4.7). Check the insulation after severe thunderstorms.

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

e) 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.

5.5.2 Maintenance Procedures. The following paragraphs discuss general maintenance procedures for the runway and taxiway units that are not functioning, and also discuss troubleshooting of series circuits.

a) Lamp Replacement. With the lights operating, make a visual check to positively identify the lighting unit or units that are not functioning.

CAUTION:

De-energize 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. Remove S-1 switch cutouts if present.

(1) Turn off the lights and lock out circuits. Install safety warning signs (refer to par. 2.5) at appropriate locations.

Table 11
Preventive Maintenance Inspection Schedule for
Runway and Taxiway Edge Lighting Systems

Maintenance Requirement	DAILY	WKLY	MTHLY	BIMHY	SMANY	ANNLY	UNSCH
1. Inspect for outages; repair as necessary.	X						
2. Check cleanliness of lenses.	X						
3. Check light alignment and orientation.			X				
4. Re-align lights as needed.			X				
5. Clean fixtures and sockets.			X				
6. Inspect and clean frangible coupling weep hole.			X				
7. Check light elevation.					X		
8. Check for moisture in lights.					X		
9. Check for rust, paint deterioration.					X		
10. Inspect fixture for deterioration.						X	
11. Check lamp fitting and clean contacts.						X	
12. Check conditions of all connections.						X	
13. Check cable insulation.						X	
14. Check gaskets.						X	
15. Remove snow from around lights.							X

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

(a) Examine the old lamp to confirm the source of failure.

(b) Compare the identification markings on the old and replacement lamps to verify that the replacement lamp is the correct type.

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

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

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

(f) Install new lamps, ensuring that the lamp face is clean and free of oils, fingerprints, etc. Use a clean, dry, soft cloth and never touch the lamp with unprotected fingers.

(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, confirm that 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 will 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 side 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 depending on 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 depending on such factors as environment, geographical location, and the types of lighting units. Each light hould 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.

(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 or 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.

(a) Operation of lights on brightness step B4 or B5 should dry up any condensation. Also, 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.

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

(c) 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.

(d) Cable may need to be replaced if water travels along and enters around the conductor.

(e) 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 the 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.

(f) 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.

(g) 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 usually consist of the following:

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

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

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

(d) 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 styles require replacement of the entire column when the frangible point breaks.

(1) Remove damaged coupling.

(2) Use Locktite Antisieze Thread Compound #767 on new coupling threads.

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

k) Scheduled Painting. Scheduled painting is usually accomplished annually, but touch-up 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.

5.6 Constant Current Regulators. Constant current regulators come in two basic types, air cooled and liquid filled. The two basic types of regulators can be further classified as either magnetic or electronic. Magnetic types typically utilize either a resonant circuit or a saturated reactor principal. In a resonant network circuit the current output is proportional to the input voltage and is independent of the impedance of the load. It is recommended that manufacturer literature on the operations, theory of operation, and recommended maintenance procedures for the particular regulator being used be obtained.

5.6.1 Preventive Maintenance Inspection Procedures. The procedures for the PMIs are listed in Table 12. Where measurement of current is called for, use a clamp-on ammeter, instrument transformer and ammeter, or similar setup. Do not use the ammeter on the face of the regulator. This meter does not have the accuracy required for these measurements.

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 the power company to correct the input voltage.

(2) Ensure 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 step. Compare results with the tolerances listed in the following paragraphs defining required annual checks. 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 do not touch at all 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 the regulator tank. The test may be conducted with the oil-tester described in par. 4.10. 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 - ELECTRICAL HAZARD:

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

A series circuit connected across a 50 kW, 20.0-ampere regulator may have a full load voltage of 2,500 volts. However, the momentary surge before the open-circuit protection device actuates will approach 5,000 volts.

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

(a) Turn off power to regulator.

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

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

(d) 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 AMPERES
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

(e) 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).

(f) Turn off regulator.

(g) Disconnect the short and reconnect output cables.

(h) 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.

Caution: Close all control cabinet doors and access panels on regulator prior to open circuit testing. Note: Flash over may occur at primary contactor during open circuit testing.

Caution: Do not repeat open circuit test repetitively on constant current regulators. Open circuit test only once to determine pass or fail of open circuit protection. Note: Open circuits are very stressful on constant current regulators.

(a) Turn off power to regulator.

(b) Disconnect cables from output terminals.

(c) Turn on power to regulator.

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

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

(f) 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.

(g) 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.

Table 12
Preventive Maintenance Inspection Schedule for
Constant Current Regulators

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

5.7 Centerline and Touchdown Zone Lighting Systems

5.7.1 Preventive Maintenance Inspection Procedures. Because in pavement 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 filtration; this also requires frequent attention. These problems should be remembered when performing the PMIs contained in Table 13 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 service method is to replace the in pavement 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

(a) 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.

(b) 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 Section 6.

(2) Dim light

(a) Dirty Light. The exposed optical surface of the in pavement light gets dirty from exposure to aircraft traffic and weather. The lights should be cleaned periodically as described in par. 5.5.2.

(b) Light Aiming. Shallow-base in pavement 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 par. 5.7.2.

(c) 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 par. 5.7.2.

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, in pavement 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 and 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 of the field and in the touchdown zone. The light output may be measured with a photographic 1 degree spotmeter as explained in par. 5.7.2.g). The procedure may be conducted to provide the following information:

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

(b) 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 the light, and clean and service as described in par. 5.5.2. 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 hold-down bolts or rupturing the base. Having a dry light base is the exception rather than the rule. Water in light bases is very common, resulting from the miles of conduit that leak and slowly fill the system with water. To avoid water freezing in bases, place 2 inches thick by 8 inches diameter ETHA-foam (also known as closed cell foam) disks in the bases to displace the water. This prevents ice damage to the base, fixture and transformer by allowing any remaining water to crush the ETHA-foam disks.

(3) To maintain maximum system performance and minimize unscheduled outages, group replacement of lamps for in pavement 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.

Table 13
Preventive Maintenance Inspection Schedule for
Centerline and Touchdown Zone Lighting Systems

Maintenance requirement	DAILY	WKLY	MTHLY	BIMHY	SMANY	ANNLY	UNSCH
1. Check for burned-out or dimly burning lights.	X						
2. Repair or replace defective lights.		X					
3. Clean lights with dirty lenses.			X				
4. Check the intensity of selected lights.			X				
5. Check the torque of mounting bolts.				X			
6. Clean and service light; check electrical connections.					X		
7. Check for water in the light base.					X		
8. Replace lamps after 80 percent of service life.					X		X
9. Remove snow from around fixtures.							X
10. Check wires in saw kerfs.							X

5.7.2 Maintenance Procedures. Servicing in pavement 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 in pavement 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 techniques require special equipment and are suited to large scale and frequent access 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 because 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 manual 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 14 shows a typical example of how to clean the lighting fixture with shells.

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

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

(c) 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.

(d) 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.

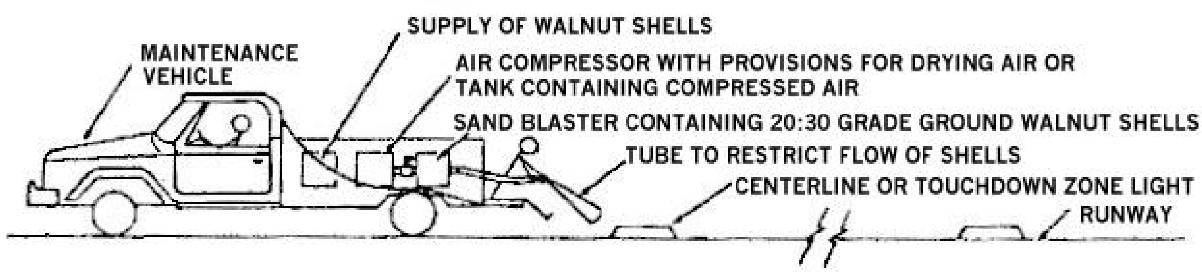


Figure 14
Cleaning Centerline and Touchdown Zone Lights

(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 second 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 in pavement 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 2° of a line parallel to the runway centerline. When reinstalling the base, use an adhesive compatible 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 in pavement 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 in such conditions. For touchdown zone lights, the light beam is offset 4 degrees toward the runway centerline. The aiming of touchdown zone lights may be judged by viewing the barrettes on either side of the runway while standing on the centerline. When viewing the barrettes 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. In pavement 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, replace all gaskets and O-rings exposed during the relamping process. 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 an in pavement 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-shrinkable sleeving. Heat-resistant varnish may also be used to improve the sealing of the connection and protect the tape from heat. Be sure the gasket and its mating surface are free of sand or grit; this is a 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 in pavement lights and preventing reentry is similar to that described in par. 5.5.2.h(2) for runway edge lights. If the fixture itself leaks, renew all gaskets and sealants.

g) Photometric Measurements. Photometric measurement of in pavement lights is the most direct way of determining if they are emitting the specified amount of light. The procedure presented below, using a photographic 1 degree spotmeter, may be used when the light is installed or in the shop. Photometric measurements of installed in pavement 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 1° 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 subpar. (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 subpar. (1), the light is in need of servicing. If 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 in pavement lights, some lights may remain below the standard value, as measured in step (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.

5.8 Precision Approach Path Indicator System (PAPI/CHAPI)

5.8.1 Preventive Maintenance Inspection Procedures. A typical layout of the PAPI system is shown in Figure 15. To perform the PMIs contained in Table 14, proceed as follows; for tolerances see Appendix A, Table A-5.

a) Daily Checks. Confirm all lamps are burning and are of equal brightness. Adequate spare lamps should be available to permit a complete replacement of all lamps in the system. Spare bypass fuses, if used, should also be stocked. Lamps should be replaced immediately if they burn out or become darkened. If the PAPI 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 the lightning arresters and/or surge suppressers are scorched or show other signs of being burned out, and replace as necessary. Also, check after electrical storms.

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

(7) Check for burrows or other signs of rodent activity in vicinity of cables; take steps to discourage 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 PAPI aiming instrument. 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 leveling and operating of tilt switch - if applicable.

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 is 4 miles long and extends 10 degrees on either side of the runway centerline.

d) Semiannual checks

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

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

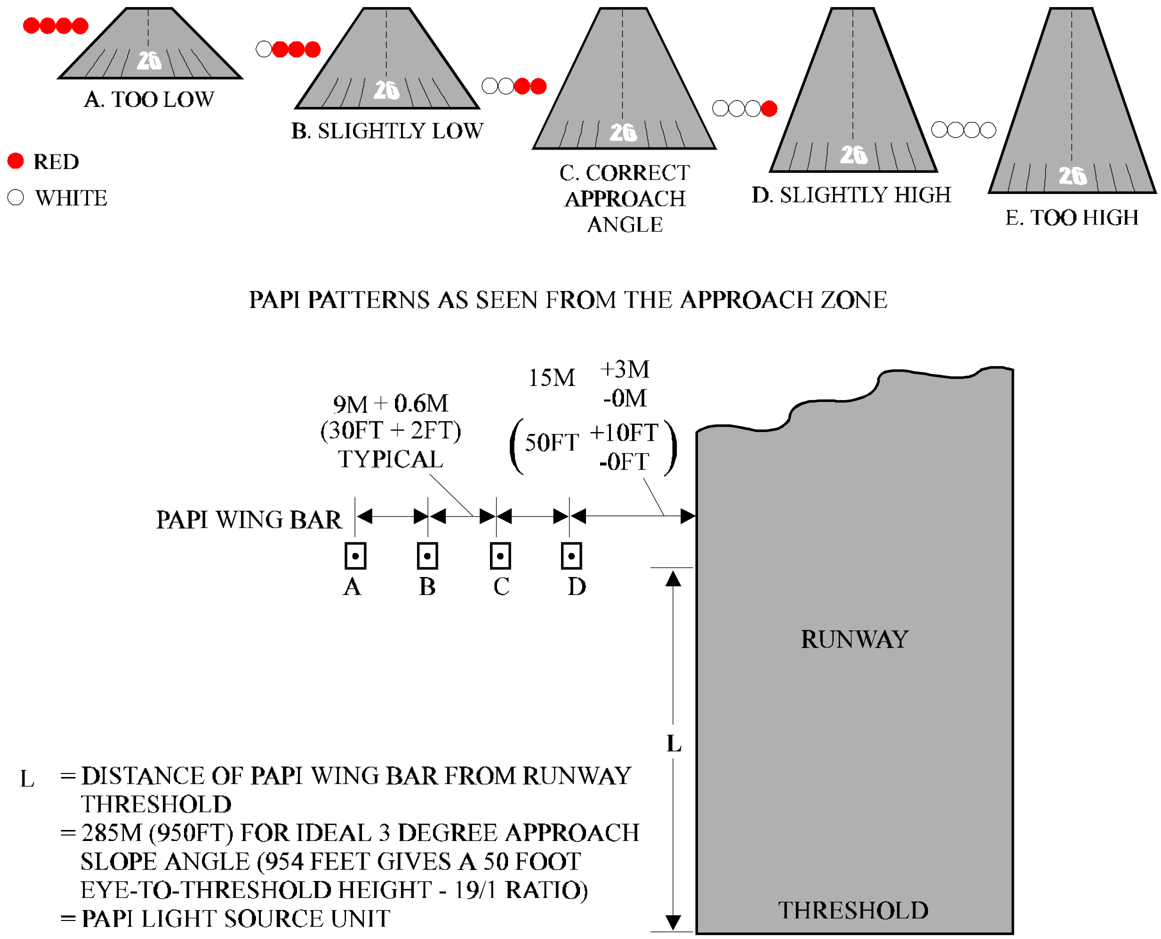


Figure 15
PAPI Configuration

Table 14
Preventive Maintenance Inspection Schedule for
Precision Approach Path Indicator (PAPI) System

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

5.8.2 Maintenance Procedures

a) Adjustment of the Vertical Aiming. This is normally done with a clinometer or small (machinist's) level. Handle these precision instruments carefully. Make sure the aiming device is the one supplied with the PAPI light units.

(1) Check the manufacturer manual (supplied with the units) for the procedures used to check each PAPI unit for proper aiming angle. Follow the procedures recommended for using the manufacturer's leveling device.

(2) Stand in front of the PAPI units (approximately 50 feet away) and check that the light changes color simultaneously along the whole width of each unit. If not, horizontal leveling was not done properly, the red filters are out of position, or the box is warped.

(3) Check the tilt switch on all units (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 toggled off and on to reset tilt switch circuit. For tolerances, refer to the manufacturer's installation manual.

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 de-energize, and read current. If the system has a night adjustment, set current to 4.8 to 5.0 amperes.

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

5.8.3 Visual Approach Slope Indicator (VASI). Some facilities have VASI systems which are currently being replaced with PAPI systems. The procedures in Table 14 are applicable, for the most part, for VASI as well. Check the manufacturer's maintenance manual for unique procedures applicable for the system installed, as most are old and replacement parts are not always available.

5.9 Airfield Beacons and Obstruction Lights

5.9.1 Preventive Maintenance Inspection Procedures. To perform the PMIs contained in Table 15, 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 (refer to par. 4.7).

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 fuse holder should be tight with clean, uncorroded contacts. Check the wiring for loose connections and the insulation for breaks or fraying. Check switches for loose, burned, or misaligned contacts.

(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 levels.

(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, thoroughly clean the gasket channel to make the gasket seat 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:

(a) 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.

(b) Using a brush 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.

(c) Check the load contactor for pitted, burned, or misaligned contacts. Ensure that the armature moves freely and that the spring tension is sufficient to pull the armature away from the coil when de-energized.

e) Unscheduled Maintenance. Change the lamp when the burning time has attained 80 percent and 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.

Table 15
Preventive Maintenance Inspection Schedule for
Hazard Beacons and Obstruction Lights

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

5.10 Runway End Identification Lights (REIL)

5.10.1 Preventive Maintenance Inspection Procedures. A typical layout of the REIL System is shown in Figure 16. To perform the PMIs contained in Table 16, 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 electrical contacts and connections to ensure tightness.

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

(a) A plywood triangle cut to angles of 15 degrees, 80 degrees,. and 85 degrees.

(b) A 4 inch-line level.

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

(a) To check the 15 degree toe-out, hold the triangle horizontally against the face with the 15 degree angle pointed toward the other light unit. By aligning the outside edge of the triangle to point at the opposite light unit, 15 degree toe-out is achieved.

(b) To attain the 10 degree vertical aiming, the 80 degree angle is placed against the flat portion of the REIL face with the 15 degree point-down. When the line level shows the upper edge of the triangle level, the REIL is 10 degrees up from the horizontal (see Figure 17).

(5) Check baffles, if used on REIL. Where baffles are installed, the light units should be aimed at an angle of 3 degrees vertical and 10 degrees toed out. The louvers should be sloped down 10 degrees toward the runway and down 5 degrees toward the approaching aircraft. The louvers should be painted black to lower the reflected light.

d) Annual checks

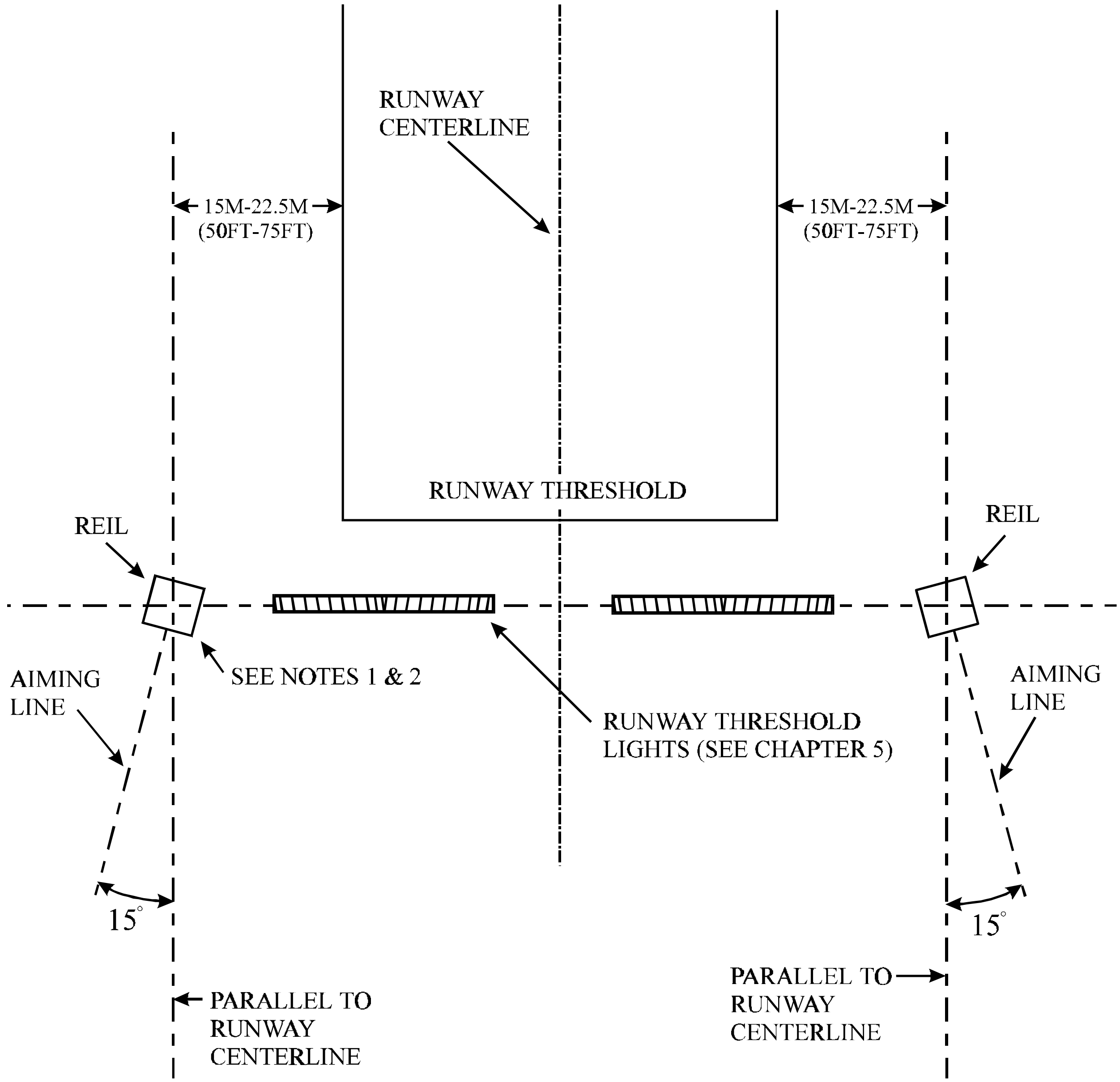
(1) Make a careful inspection of all power distribution equipment and protective devices at terminal pole and lights.

(2) Check insulation resistance of power cables (refer to par. 4.7).

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

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

(5) Repaint as required.



NOTES:

1. LONGITUDINAL LOCATION OF REIL FIXTURES MAY BE VARIED FROM IN LINE WITH THRESHOLD TO 15M (50FT) DOWNWIND OF THRESHOLD. BOTH FIXTURES WILL BE AT THE SAME DISTANCE.

2. UNIDIRECTIONAL FIXTURE IS ILLUSTRATED, FOR OMNIDIRECTIONAL FIXTURE IGNORE HORIZONTAL AIMING.

Figure 16
REIL Layout

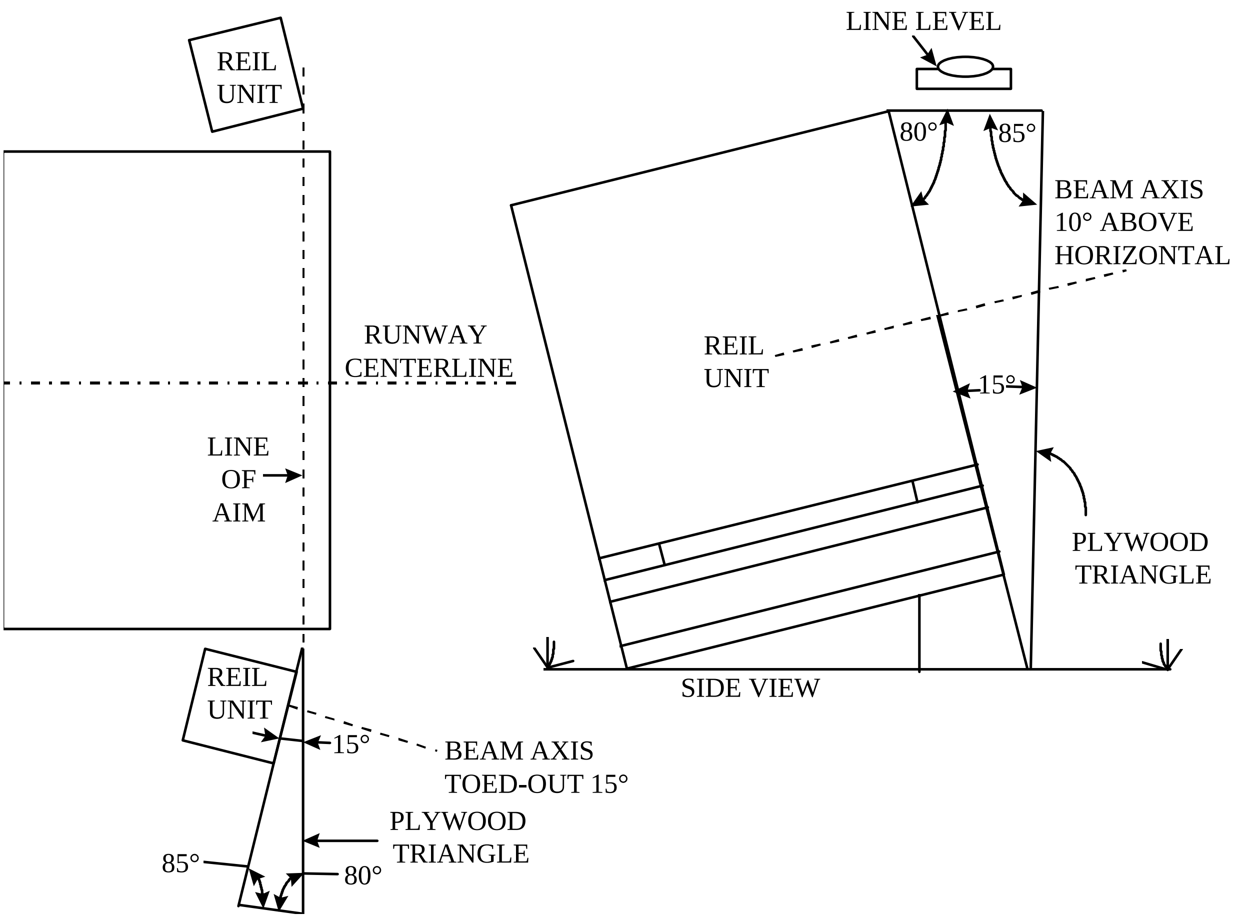


Figure 17
REIL Aiming

Table 16
Preventive Maintenance Inspection Schedule for Runway End Identifier Lights (REIL)

Maintenance Requirement	DAILY	WKLY	MTHLY	BIMHY	SMANY	ANNLY	UNSCH
1. Check operation of lamps.	X						
2. Check the operation of controls.				X			
3. Check cleanliness of optical system.				X			
4. Check for mechanical damage or misaligned parts.				X			
5. Check operation of interlocks.				X			
6. Check for vegetation around lights.				X			
7. Check cabinets for cleanliness and moisture.					X		
8. Check electrical connections.					X		
9. Check alignment and elevation of unidirectional REIL; Check elevation only of omnidirectional units.					X		
10. Realign unidirectional REILs, as required.					X		
11. Check baffles on REIL (if used).					X		
12. Check power distribution equipment.						X	
13 Check insulation resistance of cable.						X	
14. Check resistance of grounding systems.						X	
15. Service timer motor and contacts (if used).						X	
16. Check need for painting.						X	

5.11 Medium Intensity Approach Lighting Systems (MALSR)

5.11.1 Preventive Maintenance Inspection Procedures. A typical layout of the MALSR System is shown in Figure 18. To perform PMIs contained in Table 17, 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 cycle 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 Appendix A, Table A-2.

(3) Check the exterior optical surface of all 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 all lights to ensure adequate visibility. Diesel fuel or other approved chemicals can be used to help control the growth of vegetation around the lights.

c) Semiannual checks

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

(2) Check structures carefully for hidden corrosion. Special attention should be paid to wood-to-wood, wood-to-steel, wood-to-earth, and steel-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 1/2 degree below the glide slope extending 250 feet (75 m) from 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 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 footcandles and turn off at 58 footcandles. 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 before sunset to 1/2 hour after sunrise. Also, check the orientation of the photoelectric cell. The cell should be oriented by aiming at the north sky at or slightly above the northern horizon. 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 (refer to par. 4.7). Record reading on the insulation resistance form. Compare the current reading with previous readings to determine if cables are deteriorating.

(3) Check fuse holders, 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 contacts. Discoloration of contacts or some roughness due to normal arcing 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, 150-watt lamps after 1800 hours of operation on maximum brightness, recorded on an elapsed time meter.

Table 17
Preventive Maintenance Inspection Schedule for
Medium Intensity Approach Lighting Systems (MALSR)

Maintenance Requirement	DAILY	WKLY	MTHLY	BIMHY	SMANY	ANNLY	UNSCH
1 Check for burned-out lamps.	X						
2. Check system operation.		X					
3. Replace burned-out lamps.		X					
4. Check in pavement lights for cleanliness.		X					
5. Record input and output voltages of control cabinet.			X				
6. Clear any vegetation obstructing the lights.			X				
7. Check angle of elevation of lights.					X		
8. Check structures for integrity.					X		
9. Check approach area for new obstructions.					X		
10. Check photoelectric controls (if used).					X		
11. Check electrical distribution equipment.						X	
12. Check insulation resistance of cable.						X	
13. Check fuse holders, breakers, and contacts.						X	

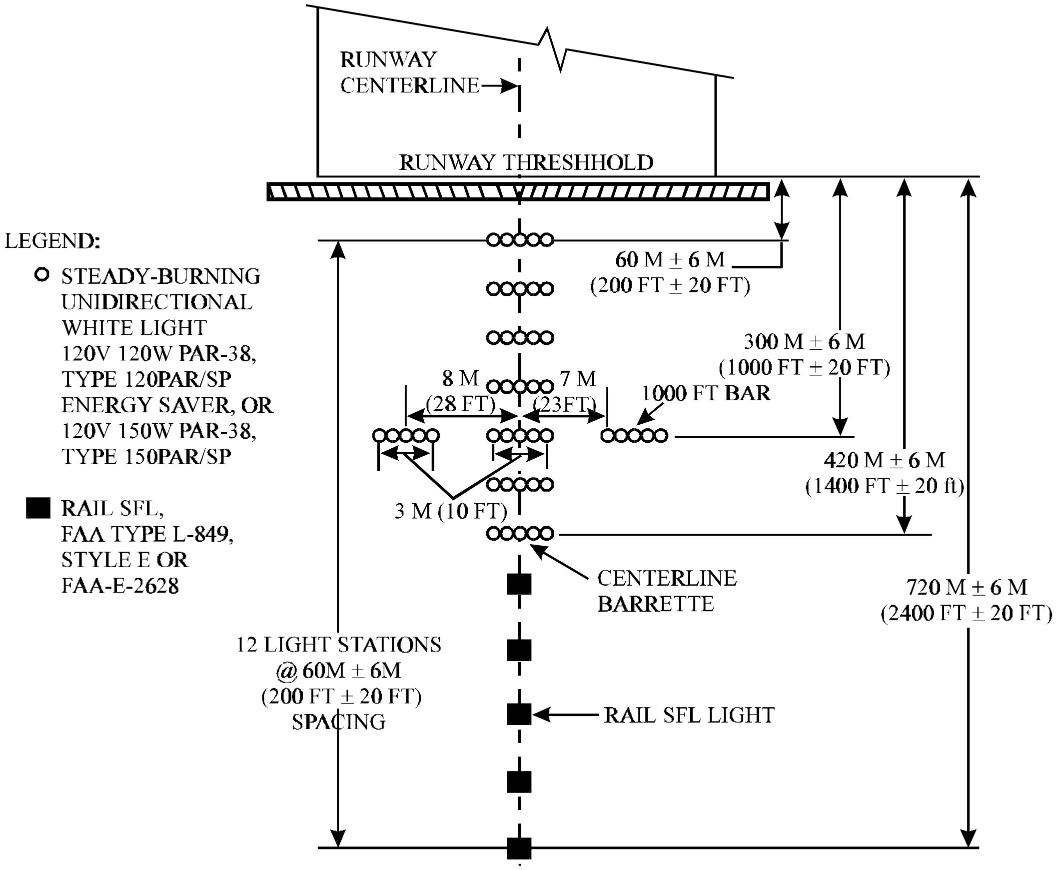


Figure 18
MALSR Configuration

5.12 Standby Engine Generator Plants

5.12.1 Preventive Maintenance Inspection Procedures. To perform the PMIs contained in Table 18, proceed as follows:

a) Weekly checks

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

(a) Battery water level.

(b) Immersion heater operating.

(c) Engine oil level.

(d) Governor oil level.

(e) Engine generator coolant level.

(f) Fuel level in main storage tank.

(g) Battery trickle-charge current.

(h) Clean fuel traps and filters.

(i) 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. After all generator engine tests, allow approximately 15 minutes of engine cool down time prior to engine turn off.

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

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

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

(c) Check for normal operation of controls.

(d) Take the following readings after the engine generator has operated for 1 minute under load:

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

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

(f) 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.

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

(3) Clean the engine generator set, its accessories, and 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.

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

(a) Check flexible duct from engine generator radiator.

(b) Check connecting hoses and fittings.

(c) Lubricate pulleys and pumps.

(d) Check condition of filter elements.

(e) Examine engine oil for contamination.

(f) Check fuel tanks for contamination.

(g) Check all control cable and power cable terminations for tightness.

(h) Check condition of all wiring insulation.

(i) Clean and adjust control panel devices.

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

(k) Check fan belt condition.

(l) Record battery voltage.

(m) Check specific gravity of batter electrolyte.

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

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

(p) 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 checks:

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

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

(c) Check generator for abnormal heating.

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

(4) Stop engine generator after 3 hours under full load. After all generator engine tests, disconnect all loads and allow approximately 15 minutes of engine cool down time prior to engine turn off. Note and record any unusual conditions and describe any repairs needed.

c) Annual checks

(1) 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:

(a) Change air filter.

(b) Inspect transfer switch.

1. Switch movement.

2. Condition of contacts.

3. Delays.

(c) Determine revolutions per minute for overspeed lockout.

(d) Check operation of low-oil safety.

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

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

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

(h) Measure manifold vacuum.

(i) Measure fuel pump pressure.

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

(k) Drain and replace oil in crankcase.

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

(m) Inspect condition of generator bearings and bearing lubrication.

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

(o) 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 non-detergent 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 suitable for standby engine generators on 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 should be extended 8 hours. Drain the crankcase while the engine is still hot and refill with multi-viscosity detergent oil.

d) Biannual checks

(1) Perform 2-year servicing as follows:

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

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

(c) 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 of operation, should be considered for overhaul.

Table 18

Preventive Maintenance Inspection Schedule for
Standby Engine Generator Plants

Maintenance Requirement	WEEKLY	MTHLY	QTRLY	SMANY	ANNLY	BIANN	UNSCH
1. Do pre-start checks.	X						
2. Perform 1-hour load test.	X						
3. Clean engine/generator and surrounding area.	X						
4. Perform 3-hour load test.			X				
5. Perform annual check.					X		
6. Change oil.					X		
7. Perform 2-year servicing.						X	

5.12.2 <u>Maintenance Procedures</u>. The maintenance of engine generators requires a skilled mechanic. It is recommended that the person assigned to 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 one or more years of 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.

5.13 <u>High Intensity Approach Lighting Systems (ALSF-1/ALSF-2)</u>. A typical layout of the ALSF-1 and ALSF-2 systems are shown in Figures 18 and 19. To perform the PMIs contained in Table 19, 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 cycle 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) Clean vegetation or obstructions from the front of all lights to ensure adequate visibility. Use approved chemicals to help control the growth of vegetation around the lights.

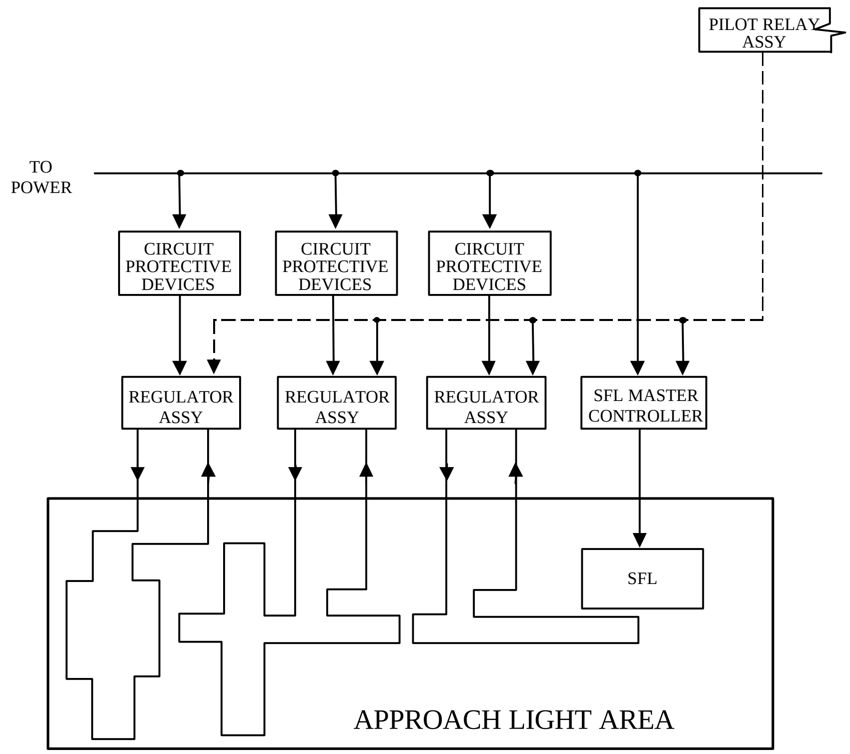


Figure 19
ALSF-1 Block Diagram

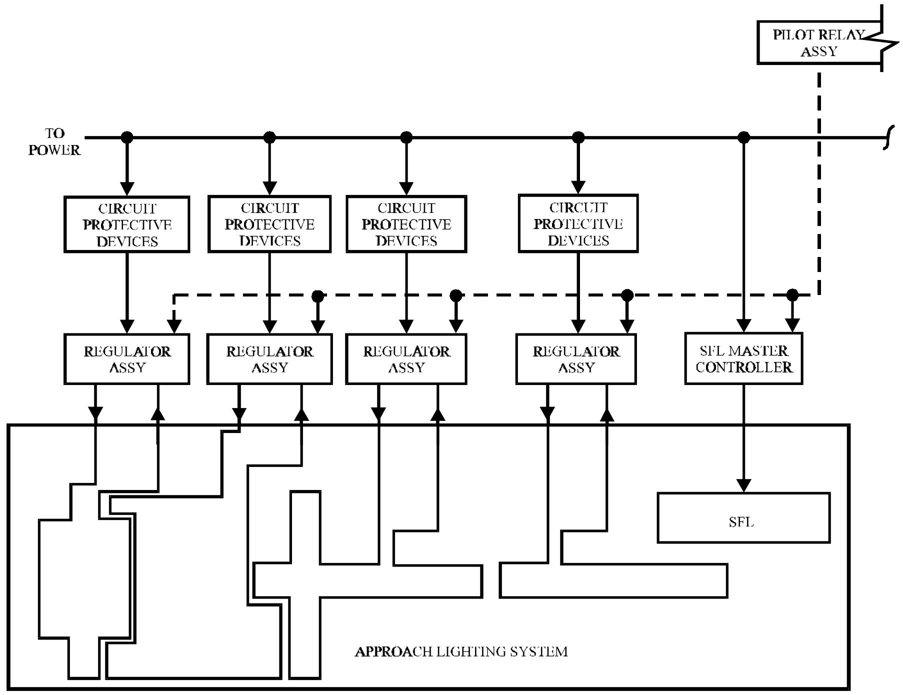


Figure 20
ALSF-2 Block Diagram

d) Semiannual checks

(1) Check light fixtures for alignment. The elevation angle settings of the lamps differ at each light bar station. Permanently display these angles at each station to facilitate maintenance.

(2) Check structures carefully for hidden corrosion. Pay special attention to wood-to-wood, wood-to-steel, wood-to-earth, and steel-to-earth contacts.

(3) If used, check and adjust the photoelectric controls. Verify that the photoelectric control is adjusted to turn the lights on at a north-sky light intensity level of 35 footcandles and to turn off at 58 footcandles. 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 photoelectric cell. Orient the cell by aiming at or slightly above the northern horizon. If adjustments are necessary, refer to the applicable manufacturer’s instruction book for detailed adjustment procedures.

(4) Every 6 months, sparingly lubricate the timer cam shaft ball bearings and gear train of the sequenced flasher position timer. Use a good grade of bearing grease and avoid excessive amounts. Operate timer for several minutes after lubrication, then remove any loose or excessive grease with a lint-free cloth.

e) Annual checks

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

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

(3) Check fuse holders, breakers, and contacts. Carefully inspect contacts in the control cabinet. If the contacts are badly worn, replace them. Do not file or burnish contacts. Discoloration of contacts or some roughness due to normal arcing is not harmful. Wipe the contacts to remove the dust. Replace blown fuses with the correct size and type. Do not assume that the old fuse is the correct size and type.

Table 19
Preventive Maintenance Inspection Schedule for
High-Intensity Approach Systems (ALSF-1/ALSF-2)

Maintenance Requirement Checklist	DAILY	WKLY	MTHLY	SMANY	ANNLY
1. Check for burned-out lamps.	X				
2. Check system operation.		X			
3. Replace burned-out lamps.		X			
4. Check in pavement lights for cleanliness.		X			
5. Record input and output voltages of control cabinet.			X		
6. Clean any vegetation obstructing the lights.			X		
7. Check structures for integrity.				X	
8. Check photoelectric controls (if used).				X	
9. Check electrical distribution equipment.					X
10. Check insulation resistance of cable.					X
11. Check fuse holders, breakers, and contacts.					X
12. Lubricate sequenced flasher position timer.				X	

5.14 Illuminated Signs

5.14.1 Preventive Maintenance Inspection Procedures. To perform PMI's on runway and taxiway signs contained in Table 20, proceed as follows:

a) Daily Checks. Check that signs are illuminated. This should be accomplished during hours of darkness, or low ambient light, because it is difficult to establish levels of illumination in sunlight. Any mandatory signs must have lamps replaced immediately so that a safety hazard is not caused. When replacing burned out lamps in a sign it is advisable to replace all lamps at the same time.

b) Bimonthly checks

(1) Check cleanliness of sign faces, and clean with a non-abrasive glass cleaner if necessary.

(2) Check for any mechanical damage or misaligned parts, such as cracked faces or bent frangible couplings.

(3) Check operation of interlocks when the signs are connected to other lighting systems.

(4) Check for vegetation around signs which would obstruct the view of the sign, check condition of footings and foundations, and repair if necessary.

c) Semiannual checks

(1) Remove power from the sign and check internally for cleanliness and moisture.

(2) Check electrical connections.

(3) Check drain holes and clean as necessary.

(4) Restore power to sign and check for proper lamp current.

(5) Check for loose sign mounts at the frangible supports, and check that the can mounting flange is secure.

d) Annual checks

(1) Check insulation resistance of power cables.

(2) Check resistance of the grounding system.

(3) Check for the need of paint.

5.15 Control Systems

5.15.1 Energizing and Brightness Control. The control systems for airfields and heliports will consist of properly rated regulators having a constant current output to the lights, and a control system to energize, de-energize and control the brightness (intensity) of the lighting systems. Operational safety requires that the air traffic controllers be able to energize, de-energize, change brightness, and switch the various aviation lighting circuits instantly as required by the dictates of the operation of the moment. It is essential that the controls in the tower be maintained at all times.

Table 20
Preventive Maintenance Inspection Schedule for
Illuminated Signs

Maintenance requirement	DAILY	WKLY	MTHLY	BIMHY	SMANY	ANNLY	UNSCH
1. Check operation of lamps.	X						
2. Check cleanliness of sign faces.				X			
3. Check for mechanical damage or misaligned parts.				X			
4. Check operation of interlocks.				X			
5. Check for vegetation around lights.				X			
6. Check internally for cleanliness and moisture.					X		
7. Check electrical connections.					X		
8. Check and clean drain holes.					X		
9. Check lamp current.					X		
10. Check frangible coupling mounts.					X		
11. Check insulation resistance of cable.						X	
12. Check resistance of grounding system.						X	
13. Check need for painting.						X	

5.15.2 Lighting System Control Points. At airfields and heliports there normally will be two points of control for the lighting system. The primary point of control will be in the operations room of the control tower. The alternate (secondary) point of control will be located in the equipment vault unless specifically directed or approved location elsewhere.

5.15.3 Maintenance Responsibility. The responsibility for maintaining lighting control panels varies at DOD facilities such as the Directorate of Public Works (DPW), Ground Electronics Group, or Base Civil Engineering (BCE), either using in-house personnel or by contract.

Section 6: TROUBLESHOOTING PROCEDURES FOR SERIES LIGHTING CIRCUITS

6.1 General. This section contains general troubleshooting procedures for isolating a fault in all types of airport series lighting circuits. The troubleshooting procedures contained in the following paragraphs provide detailed step-by-step procedures for isolating a fault. The procedures are based on the assumption that the only available information about the trouble is a report specifying which circuit is not operating satisfactorily. The tests start with 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. There are some lighting systems that use shielded conductors, the following general procedures can be used for both shielded and non-shielded systems. However, some shielded systems are unique, and local maintenance procedures should be established.

6.2 Safety Warning. Troubleshooting tests in this chapter often involve voltages that are dangerous. Safety precautions must be exercised for the protection of personnel and equipment. Personnel performing the testing and troubleshooting procedures must be experienced in high-voltage techniques or must be adequately supervised. Maintenance personnel should be thoroughly trained in emergency procedures for treatment of electrical shock.

6.3 Initial Fault Isolation

6.3.1 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 the current is set to the values defined in par. 5.6.1. 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, then the regulator, incoming primary voltage, input voltage circuit breakers and relays are functioning properly. The protective and brightness controls from the control panel are also satisfactory, therefore, the fault is probably in the series circuit.

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

(3) If the current is appreciably higher or lower than specified for all brightness settings, then the wrong input voltage is being used (where applicable), 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, then the remote-energizing controls, the protective relays, or the regulator are defective. The airfield load circuit may also have an open in the series circuit.

(5) If the current is zero at all times for all brightness settings, then the fault is in the incoming primary voltage, the energizing controls, the regulator, or the protective relays. The airfield load circuit may also have an open in the series circuit.

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

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

(a) Burned-out lamps.

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

(c) Faulty isolating transformers.

(d) If the maximum brightness current if still too high when lamps are back in operation, perform par. 6.4 checks first; then check for adapter units newly connected into the circuit. If these adapter units cannot be moved to another circuit, reset the incoming voltage tap so that the load current is correct. On regulators with output current adjustment controls, carefully follow manufacturer’s instructions and adjust output current to proper levels. Use extreme care to assure that accurate true RMS ammeters are used to measure output current levels.

(8) If the short-circuit current is normal, but the load current is too low, then 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, then 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, de-energize the regulator and proceed as follows:

(a) 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. If the faulty lights at each end of the faulty section are found without these faults, the remainder of the units in this section need not be checked. Make the required repairs as each fault is located.

1. Burned-out lamps.

2. Wrong type of lamps.

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

4. Shorts or grounds in the isolating transformer or in the wiring of the unit.

(b) 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 precise location of the position of the ground(s) is required, refer to par. 6.4.2.

(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, de-energize 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).

6.4 Locating Grounds in the Field Circuit

6.4.1 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 resolve any other problems. Grounds are usually easier to locate, and often occur in conjunction with opens, overloads, or shorts.

a) Symptoms. Dim and/or dark section or sections of lights on load circuit or low megger readings on load circuit.

b) Troubleshooting. If there is a dim and/or dark section of lights, two grounds will be found at the transition points between normal lights and the dim and/or dark lights. The affected circuit should be driven at night to identify the lights that define the edges of the dim section. The fault may not always be located at the last dim light, as it may be at the location of last bright light, or in the cable between the two lights.

(1) As repairs are made, the dim section may clear up or shift position (frequently the case with lighting damage). Remember to always repair both sides of a dim section. If the dim section shifts, multiple grounds exist, and more grounds will be found at the edges of the new dim section.

(2) When troubleshooting a single ground (no dim lights), use the “Intentional Ground” method, “Ground Return” method, or “Sectional” method to locate the grounded point in the cable. See the instructions and illustrations in the “Airfield Troubleshooting Methods” section for further details.

(3) There are many devices and methods to assist you in locating grounds in load circuits. The methods in this booklet are what the writer believes to be the easiest to use, which do not require additional expensive equipment.

c) Causes. Grounds in airfield cables have many causes such as:

(1) Lightning (probably the largest single source). Lightning entering a load circuit will exit in many locations, sometimes miles away.

(2) Animals such as gophers and groundhogs cause much damage to airfield cable.

(3) High resistance connections overheat and burn off insulation.

(4) Improper installation of cables may cause insulation to be damaged resulting in premature cable failure.

d) The following figures will help in understanding grounds and shorts in series circuits, and in the power of "taking a look" at the circuit.

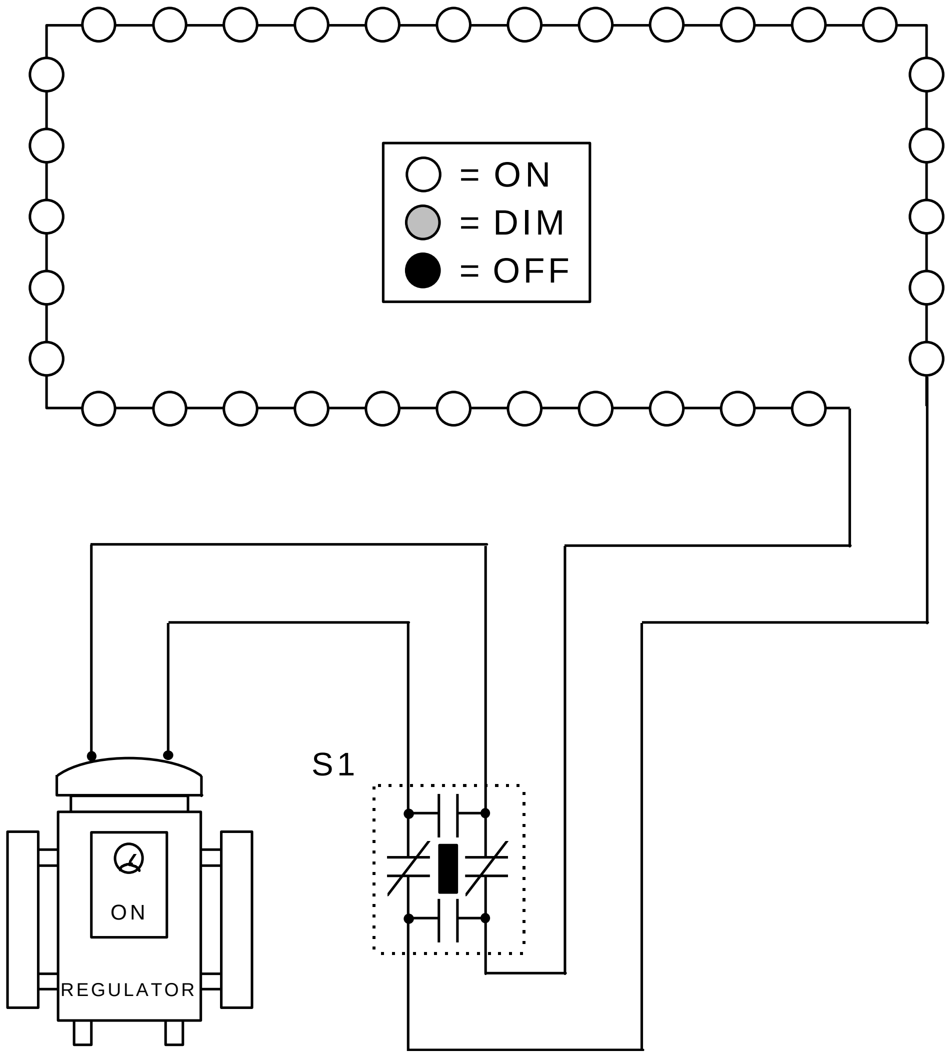


Figure 21
Typical Load Circuit With S1 Cutout - No Faults

(1) Figure 21 illustrates a regulator with the output on, a S1 cutout with the handle installed and the load with no faults present.

(2) Figure 22 illustrates the same equipment and load with a single ground on the circuit. As illustrated, the lights are not affected by the single ground.

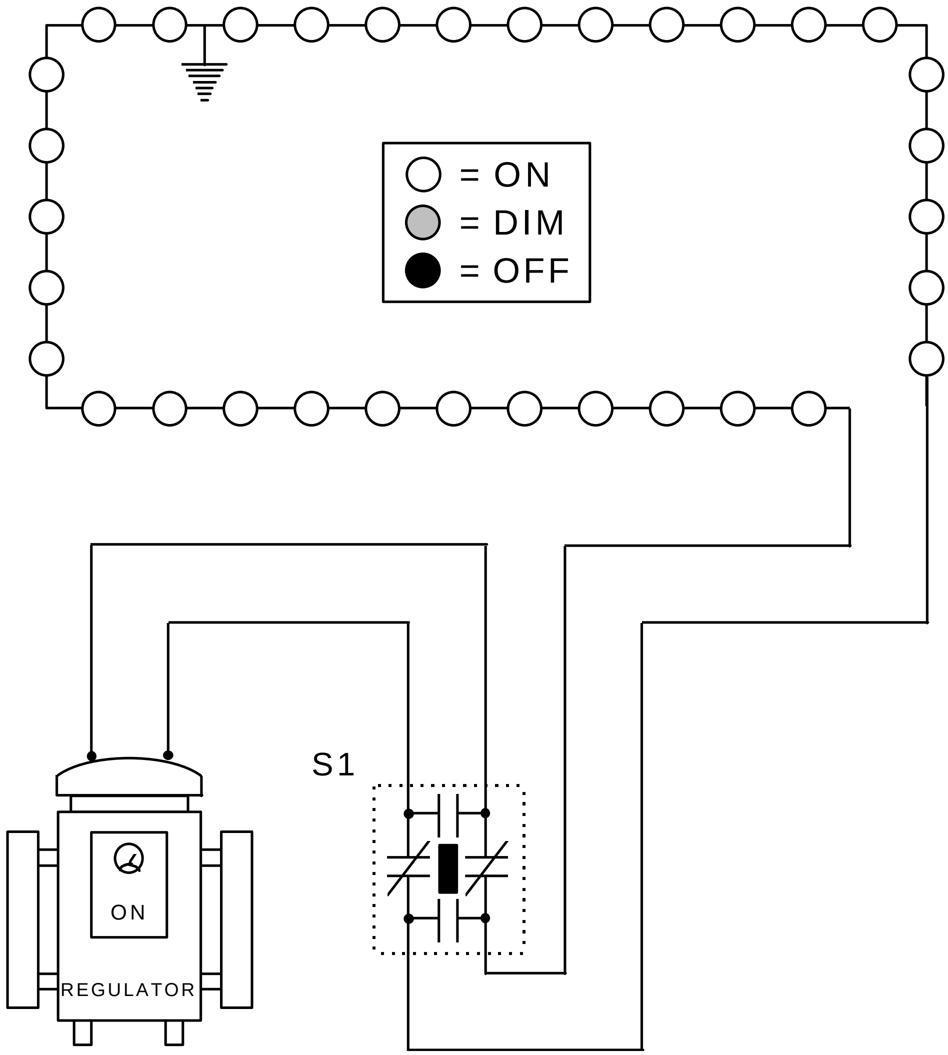


Figure 22
Typical Load Circuit With S1 Cutout - Single Ground on Load

(3) Figure 23 illustrates the same equipment and load with two grounds on the load. Note the intensity of the lights between the grounds has dimmed. This is a very common condition the reader should be aware of. Driving the circuit will locate the bright to dim transition in the fixtures, locating the grounds. The amount the lights dim will vary with the resistance of the grounds. Low resistance grounds may conduct enough current to darken the lamps entirely, while a high resistance ground may only dim the lamps enough to be detected with an ammeter.

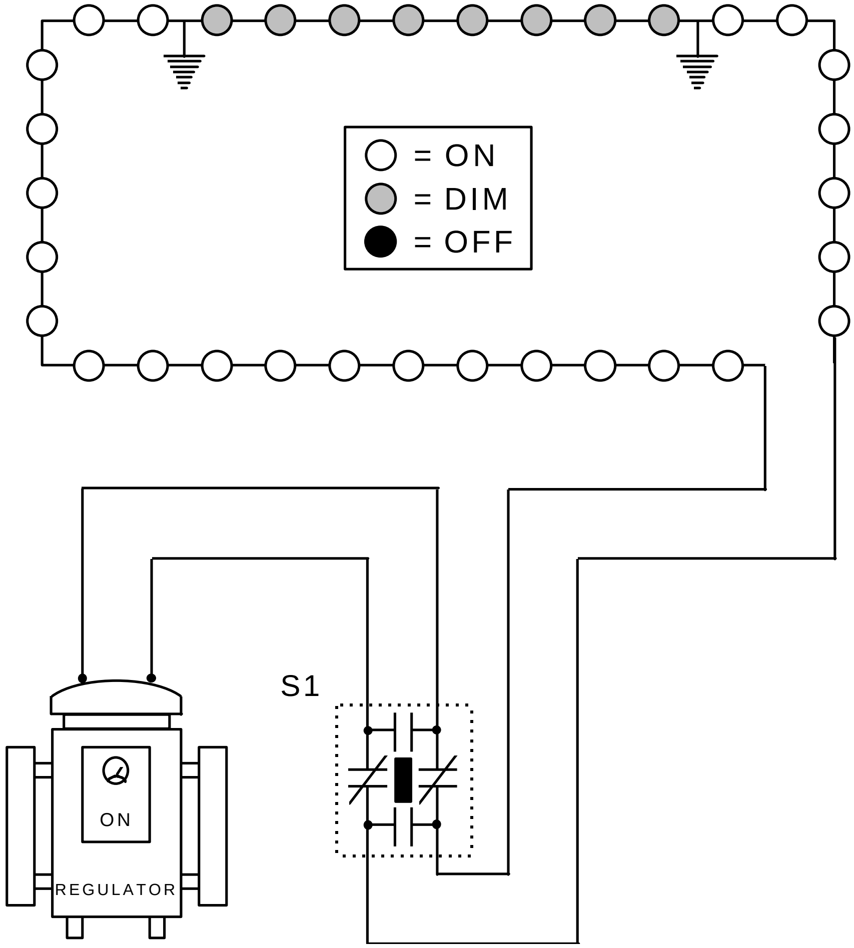


Figure 23
Typical Load Circuit With S1 Cutout - Two Grounds on Load

e) Intentional Ground Method. The intentional ground method of airfield load troubleshooting is very useful in detecting and locating low and medium resistance grounds. When used to locate grounds, this method presents little or no hazard to regulators, isolation transformers, connector kits and cable.

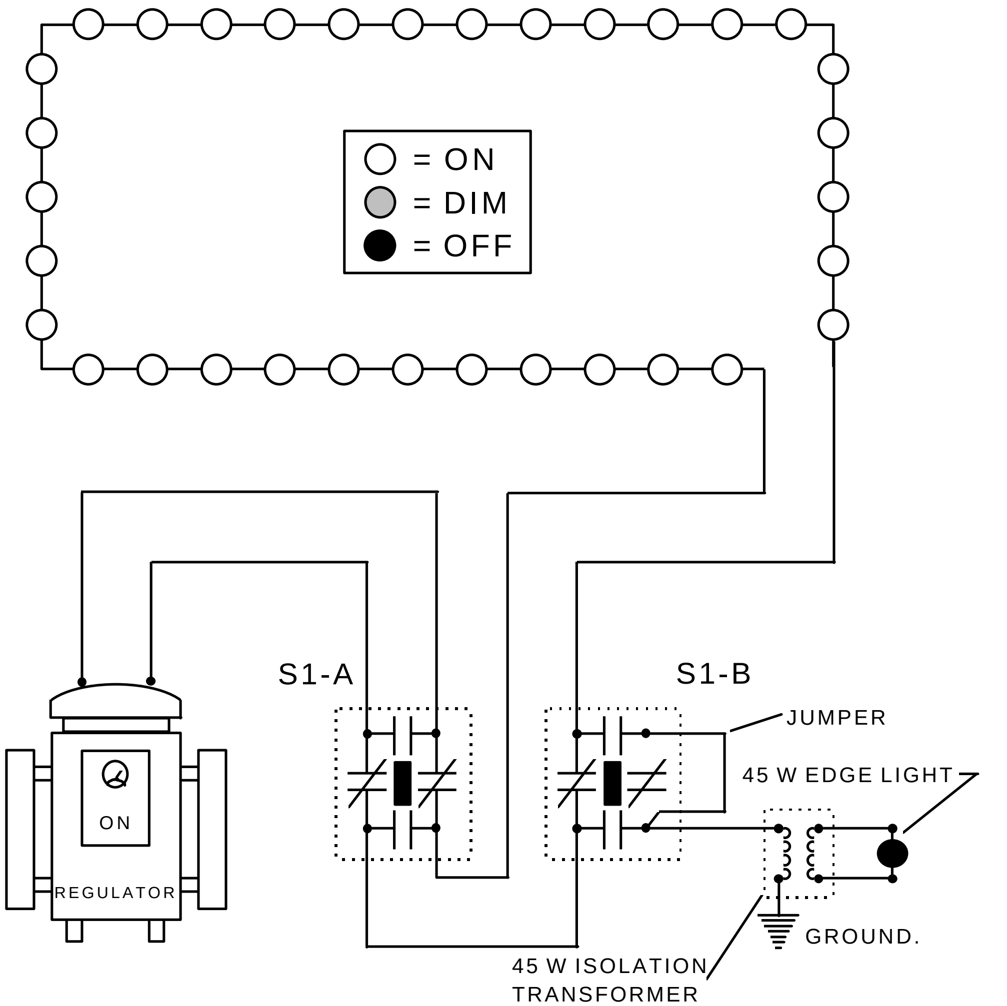
(1) Grounds are common to most series circuit failures. Shorts, opens and high resistance sections of cable frequently start as high resistance grounds. If ignored long enough they become actual ground faults or worse. With this fact in mind it is easy to understand the importance of detecting, locating, and repairing grounds as they occur.

(2) The “Intentional Ground Method” connects a grounded #8 AWG cable to one side of the regulator output, providing an alternate parallel path for current to flow to the series circuit via the earth and the ground fault on the circuit. The regulator should be operated at its highest current level, producing the highest level of current on the circuit. Also, larger regulators with higher kilowatt ratings (higher output voltage) will be more successful in this type of troubleshooting. However, do not mix 20 ampere loads with 6.6 ampere loads.

(3) When the intentional ground is conducting current, the lights on the paralleled portion of the circuit dim due to the reduced amount of current flow, making it easy to find the location on the load where the current is entering the load via the ground fault. Observing the

light intensities or comparing current measurements at various load locations will isolate the fault location.

(1) Figure 24 illustrates a typical airfield circuit using an S1 cutout (S1-A) and an S1 arranged as an "Intentional Ground Switch" (S1-B). The intentional ground is not being applied to the load. To do so we would have to remove the handle on the intentional ground switch. Notice in the figure that the ground current indicating light is off.

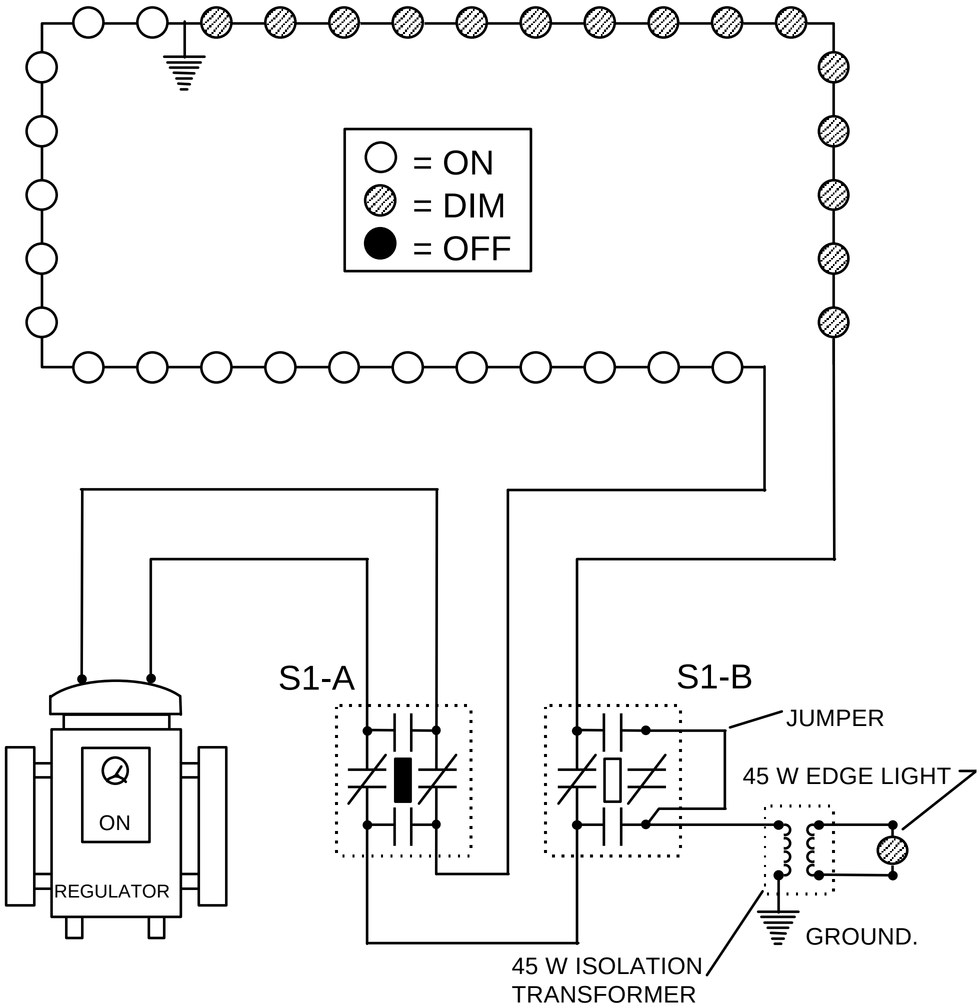


S1-A: TYPICAL INSTALLATION ON LOAD CIRCUIT
S1-B: INTENTIONAL GROUND SWITCH WITH GROUND CURRENT INDICATING LIGHT
SCHEMATIC ILLUSTRATES S1 HANDLES INSTALLED.
CAUTION: OPERATE S1 HANDLES WITH LOAD DE-ENGERGIZED

Figure 24
Regulator Connected to Typical S1 Cutout and Intentional Ground Switch With Ground Current Indicating Circuit

(2) Figure 25 illustrates what happens to the lights when the handle of the intentional ground switch is removed. The ground point on the load is providing an alternate path for the circuit current, causing the lights between the intentional ground and the ground fault

to dim, making the task of locating the ground fault much easier. Simply driving the circuit and looking for the bright to dim transition in the lights will isolate the area of the ground.

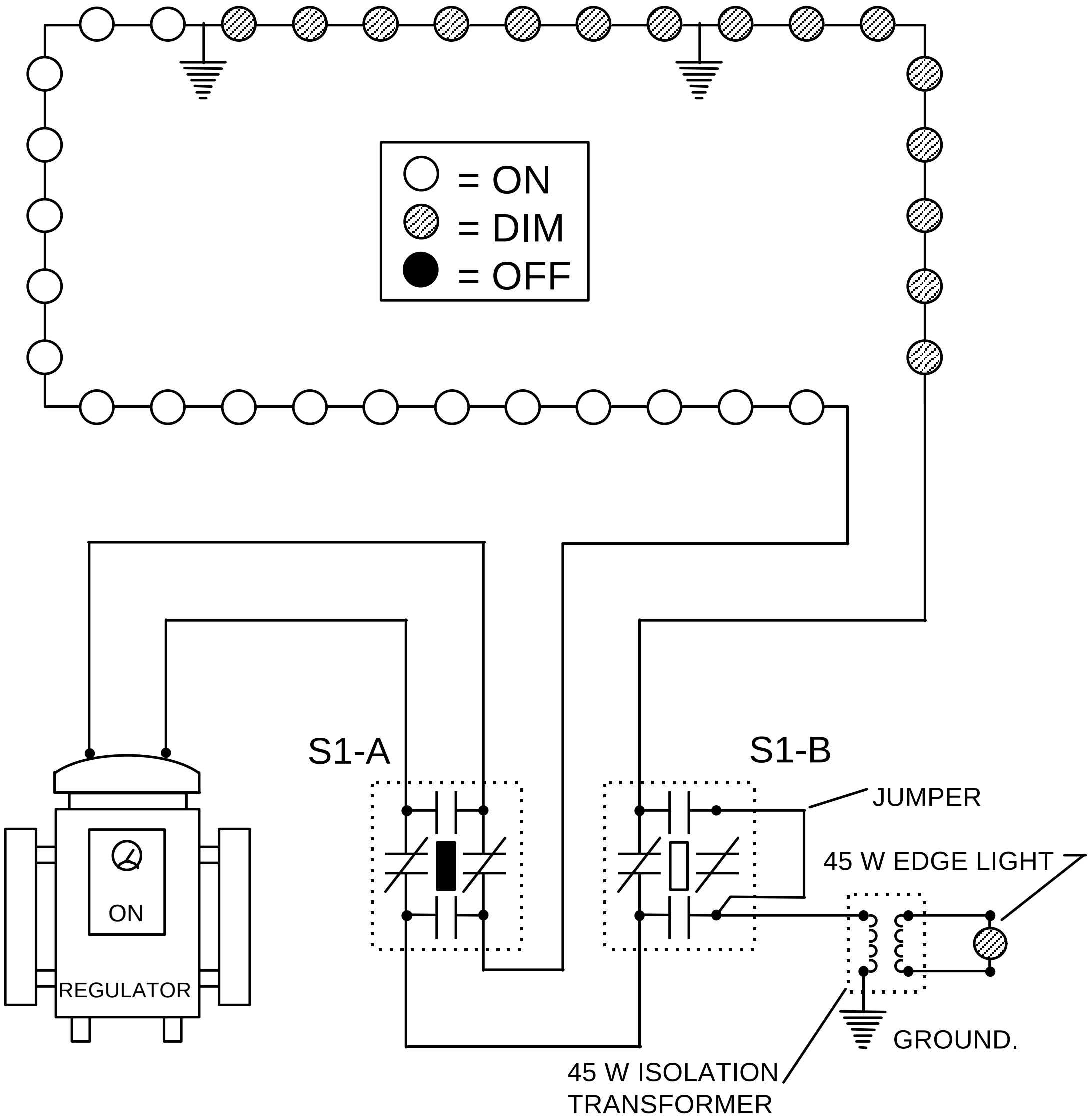


S1-A: TYPICAL INSTALLATION ON LOAD CIRCUIT - HANDLE INSTALLED.
S1-B: GROUND RETURN SWITCH WITH GROUND CURRENT INDICATING LIGHT - HANDLE REMOVED.
CAUTION: OPERATE S1 HANDLES WITH LOAD DE-ENERGIZED.

Figure 25
Single Ground on Load Circuit - Intentional Ground Method

(3) Notice that the indicating light connected to the intentional ground is also dim. The ground current indicating circuit provides the operator of the regulator with a visual indication of current flow through the intentional ground, as well as a pass/fail test for the presence of a significant ground on the load, a significant ground being a ground fault of low enough resistance to conduct enough current to light the indicating lamp.

(4) Figure 26 illustrates the results of multiple grounds on the load circuit with an intentional ground connected to the load.



S1-A: TYPICAL INSTALLATION ON LOAD CIRCUIT - HANDLE INSTALLED.
S1-B: INTENTIONAL GROUND SWITCH WITH GROUND CURRENT INDICATING LIGHT - HANDLE REMOVED
CAUTION: OPERATE S1 HANDLES WITH LOAD DE-ENERGIZED

Figure 26
Two Grounds on Load Circuit Intentional Ground Method

(5) As Figure 26 shows, the ground fault to the right might not be easy to find as the fault on the left, but fixing the ground fault on the left side of the load will shift the light intensity transition over to the fault on the right and finding its location will be easy.

f) Ground Return Method. The ground return method is similar to the intentional ground method with one big exception. The ground return method is very good for detecting and locating grounds faults and opens of all resistance levels. However, the ground return method is a much more aggressive route to take in troubleshooting load circuits. The risk to regulator, isolation transformers, connector kits and cable is higher than with the intentional ground method. There are times when using the ground return method is warranted, but indiscriminate use of this method should be discouraged.

(1) The “Ground Return Method” connects a #8 AWG cable to one side of the regulator output, as does the intentional ground method. However, the exception is that the “Ground Return Method” disconnects the grounded side of the regulator output from the load, allowing only one path, through the ground, for the current on the grounded side of the regulator to flow. Due to the open nature of the load at start up, this arrangement causes the regulator to produce higher voltages on the output. Until the current strikes over to the fault, the regulator is in an open circuit condition. The regulator may likely trip out in an open circuit condition if the fault resistance is too high.

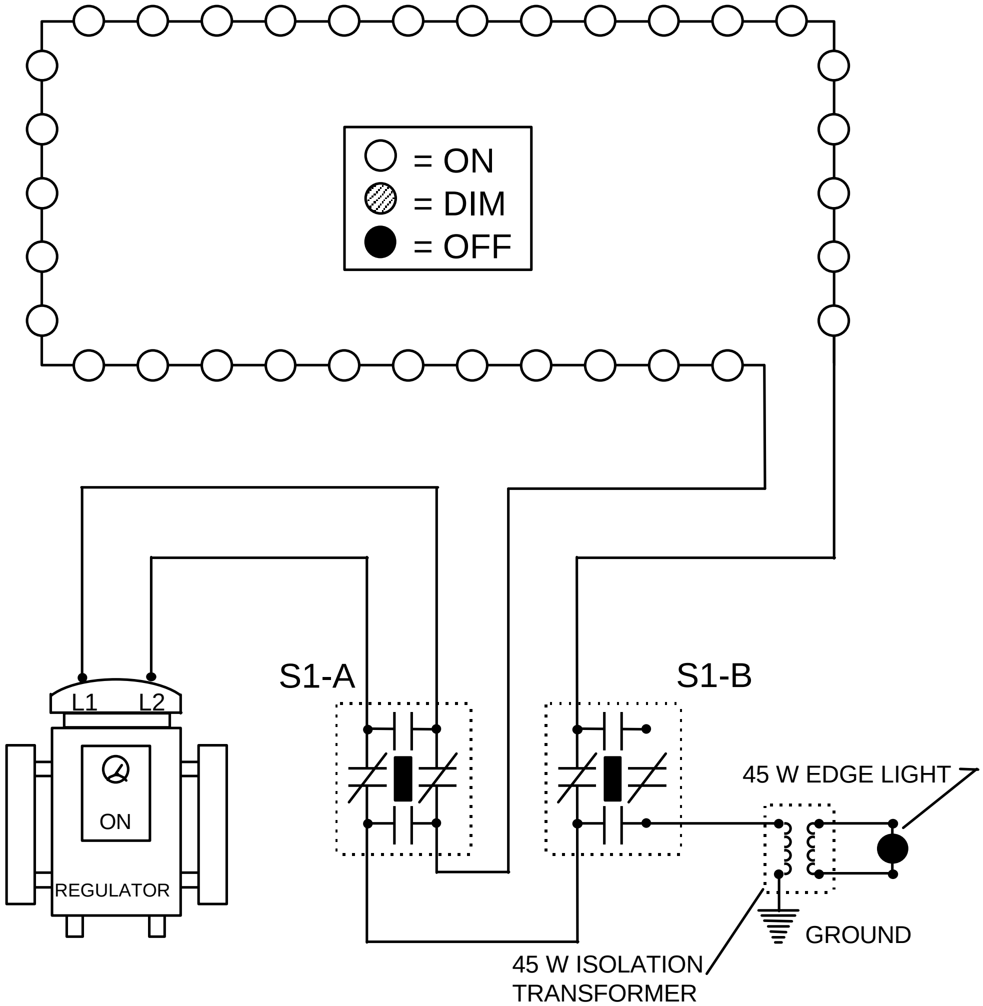
(2) Do not persist in cycling the regulator through open circuit trip outs.

(3) The “Ground Return Method” is not recommended for regulators with 2400 volt or 4160 volt inputs due to the stress open circuits place on the internal primary switch.

(4) Revert to other means of fault isolation if the regulator trips off or has a 2400 volt or 4160 volt input. The “Ground Return Method” may also transform high resistance grounds in cable, connectors, and transformers into low resistance grounds or smoking holes in the ground. The reader is advised that this method is aggressive, and hard on equipment.

(5) This troubleshooting method should be reserved for cases where the “Intentional Ground Method” has been tried and is not producing the desired results. High resistance to ground type opens and high resistance ground faults would be typical applications for the “Ground Return Method.”

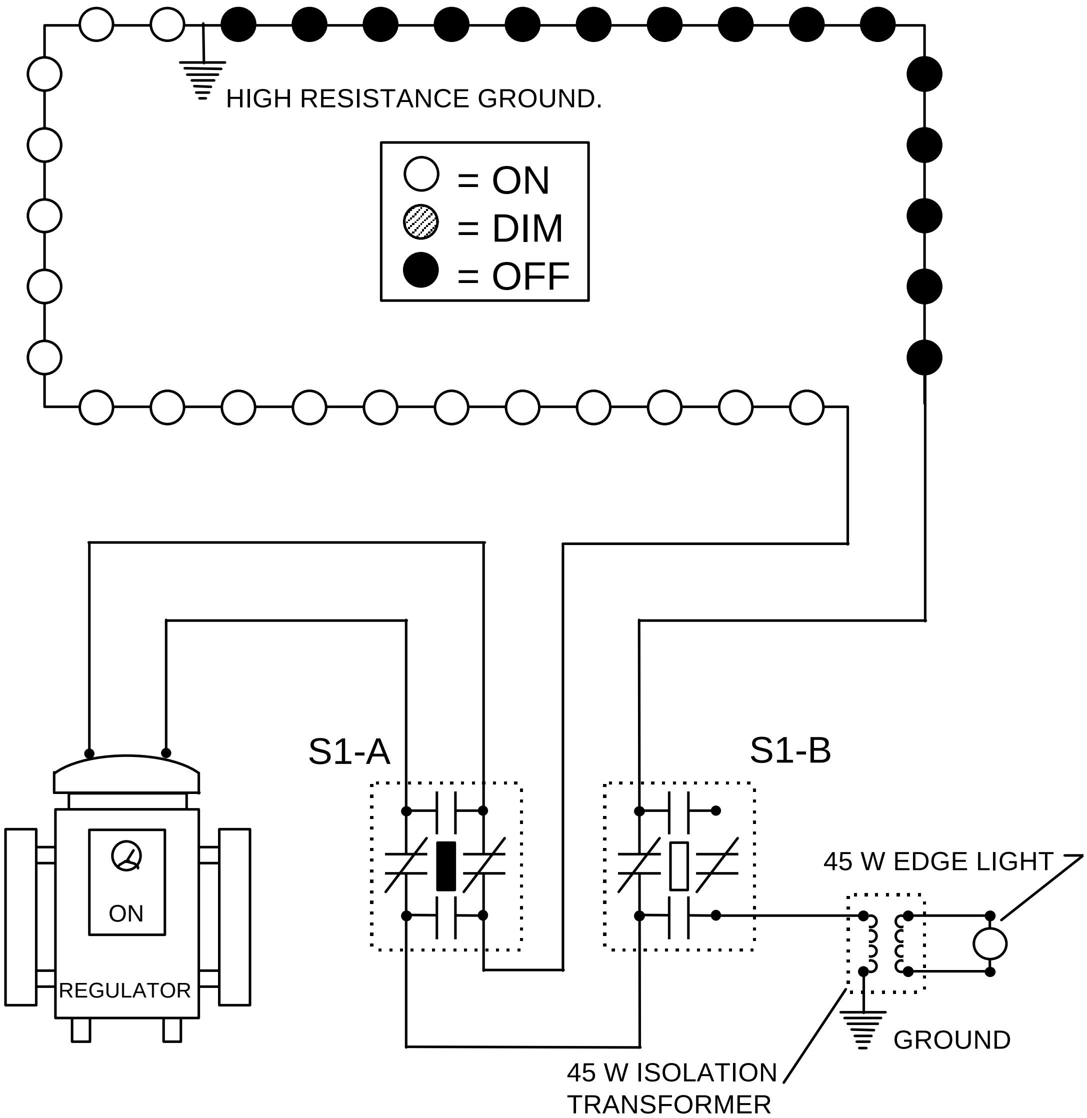
(a) Figure 27 illustrates a regulator and load with a typical S1 cutout (S1-A) and an S1 arranged as a “Ground Return Switch.” Notice that if the ground return switch handle is removed, the L2 line will be grounded, and direct continuity with the load will be broken.



S1-A: TYPICAL INSTALLATION ON LOAD CIRCUIT.
S1-B: GROUND RETURN SWITCH WITH GROUND CURRENT INDICATING LIGHT.
SCHEMATIC ILLUSTRATES S1 HANDLES INSTALLED.
CAUTION: NOT RECOMMENDED FOR REGULATORS WITH 2400V OR 4160V INPUTS.
CAUTION: OPERATE S1 HANDLES WITH LOAD DE-ENERGIZED.

Figure 27
Regulator Connected to Typical S1 Cutout and Ground Return Switch With Ground Current Indicating Circuit

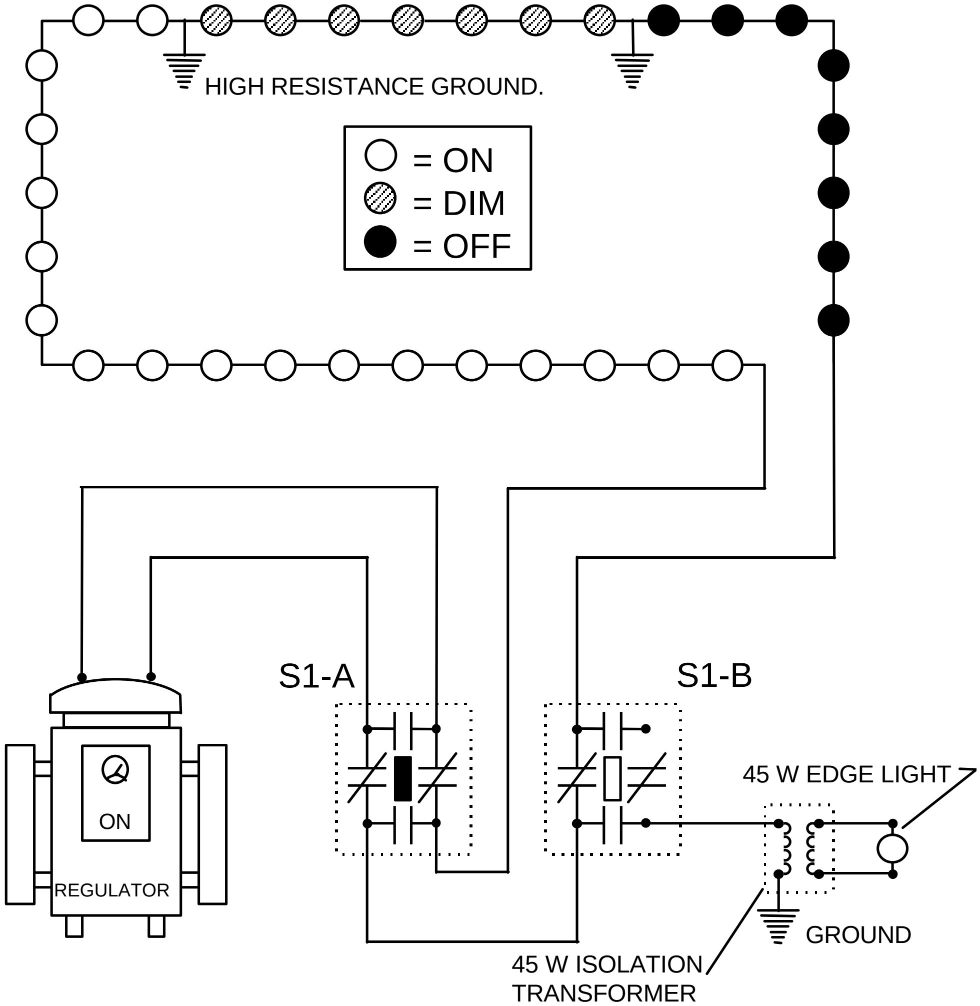
(b) Figure 28 illustrates troubleshooting a single high resistance ground on the load circuit. The illustration employs the “Ground Return Switch” and ground current indicating circuit. Notice that the indicating light is on. The ground is located quickly by driving the circuit and looking for the on/off light transition.



S1-A: TYPICAL INSTALLATION ON LOAD CIRCUIT - HANDLE INSTALLED.
S1-B: GROUND RETURN SWITCH WITH GROUND CURRENT INDICATING LIGHT - HANDLE REMOVED.
NOT RECOMMENDED FOR REGULATORS WITH 2400V AND 4160V INPUTS.
CAUTION: OPERATE S1 HANDLES WITH LOAD DE-ENERGIZED.

Figure 28
Single Ground on Load Circuit - Ground Return Method

(c) Figure 29 illustrates troubleshooting two separate grounds on the load circuit. The illustration employs the “Ground Return Switch” and ground current indicating circuit. Notice that the indicating light is on.



S1-A: TYPICAL INSTALLATION ON LOAD CIRCUIT - HANDLE INSTALLED.
S1-B: GROUND RETURN SWITCH WITH GROUND CURRENT INDICATING LIGHT - HANDLE REMOVED.
NOT RECOMMENDED FOR REGULATORS WITH 2400V OR 4160V INPUTS.
CAUTION: OPERATE S1 HANDLES WITH LOAD DE-ENERGIZED

Figure 29
Two Grounds on Load Circuit - Ground Return Method

(d) Notice that we have three light conditions: on (full intensity), dim, and off. The two grounds can be located quickly by driving the circuit and looking for the on/dim and dim/off light transition.

g) Sectional Isolation Method. The sectional isolation method is the most common approach to isolating grounded and open circuit type faults in a series circuit. This approach requires more time and labor than the previous methods but will locate those faults when all other methods have failed.

(1) The "Sectional Isolation Method" is a process of elimination to locate grounds and opens in series circuits. Both procedures for troubleshooting grounds and opens utilize a Megger insulation tester lengths of load circuits.

(2) The sectional isolation method for pursuing grounds divides the load circuit into subsections that are tested separately. Megger insulation testing of subsections identifies those subsections that are grounded or have low resistance to ground for further subdividing and testing.

(3) When isolating grounds in the circuit, the load circuit is broken at several locations, an equal distance apart along the load circuit. Each section is then tested independently to ground with a megger. Bad sections with low resistance readings are identified and broken again into several suspect sections. Megger testing then resumes on the suspect sections, further identifying the location of the ground or grounds. This process of elimination continues until the remaining section is small enough to investigate directly.

(a) Figure 30 illustrates a grounded load circuit that has been manually opened in three locations, creating four separate sections of load circuit. The four sections of load circuit are subjected to four megger tests at two locations in the vault and field. Megger tests 1, 2, and 3 all passed. However, test 4 indicates a grounded section. These first four tests have narrowed the ground location to 25 percent of the load cable.

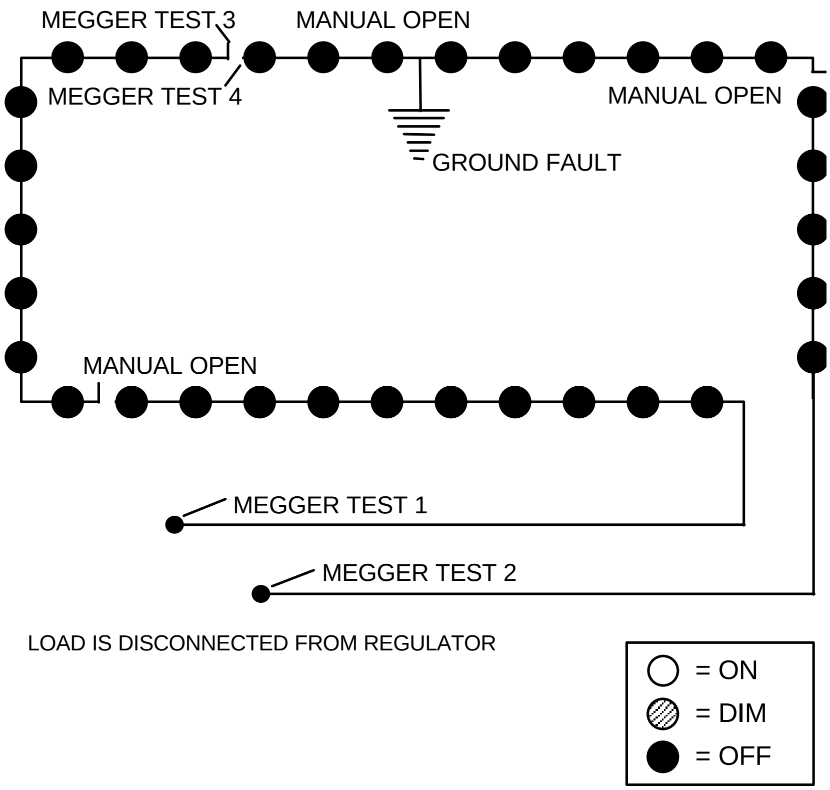


Figure 30
Sectional Isolation Method - Megger Tests Locate Grounded Section of Load

(b) Notice: The load has been disconnected from the regulator preventing possible damage to the regulator and false readings through lightning protection devices.

(c) Figure 31 illustrates the further testing of the grounded load section discovered in Figure 30. The grounded load section is divided up into four subsections by manually opening the grounded load section in three more locations, creating four subsections from the grounded load section.

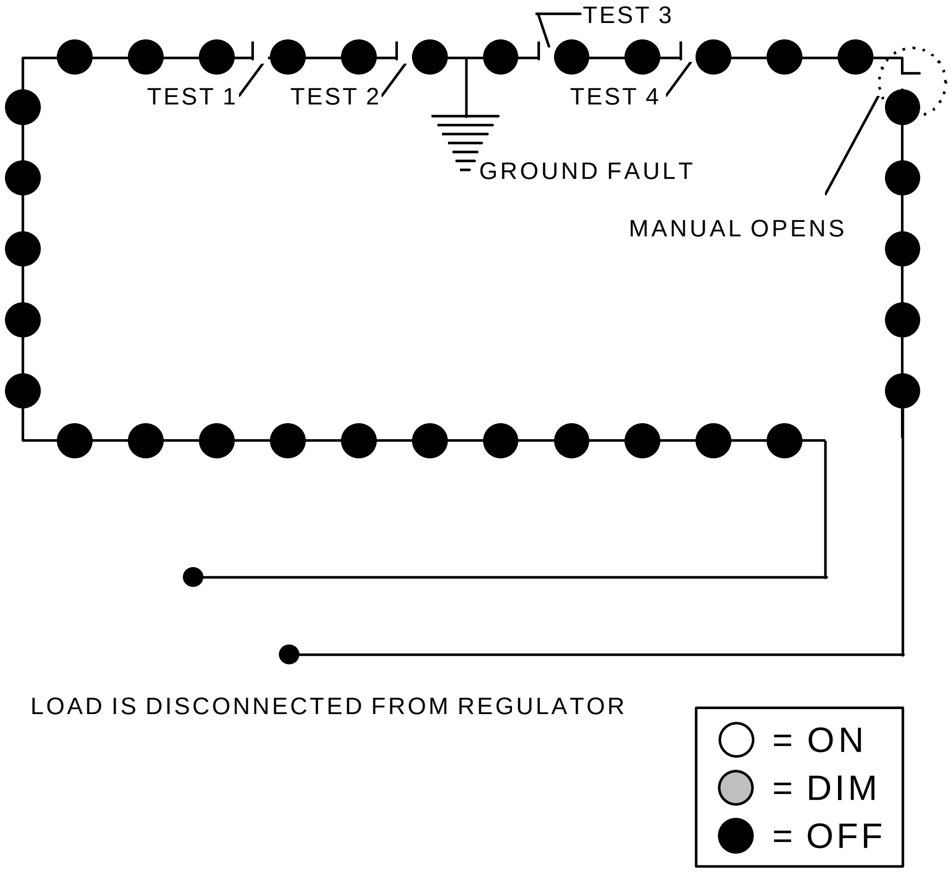


Figure 31
Sectional Isolation Method - Megger Tests Locate Grounded Section of Load

(d) During the megger tests 1 through 4 each subsection is megger tested to ground. Tests 1, 2, and 4 passed without indicating ground. However, test 3 failed indicating that the ground is within the two-fixture length of cable and transformer installations tested in test 3.

(e) Direct investigation of the failed circuit should reveal the ground. If no apparent faults can be located, the remaining portion of the grounded circuit could be subdivided again.

6.5 Locating Ungrounded Shorts in Field Circuits

6.5.1 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 using a clamp-on ammeter or performing the following circuit analysis test.

a) Symptoms. Short within load: Regulator operates normally, but entire sections of the load are out, or all of the load is out. Megger tests of load circuit may or may not reveal grounds on circuit.

Short cross connecting loads: Operating one regulator in vault causes another regulator to trip out or malfunction in some way. Ammeter on regulator in the "off" position indicates current. Lights on a circuit that should be off are on "dim" when another regulator is operating.

b) Troubleshooting. Short within load: If grounds are present on load circuit, troubleshoot as if it were a ground. If grounds are not present and some lights are on, investigate transition points in load between lights that are working normally and lights that are not.

(1) If no lights are coming on and the regulator is working normally on the suspected load, the short is in the home run between the load and the regulator.

(2) Short cross connecting loads: Drive the circuit and look for lights that are out or dim. Investigate those points where the lights change intensity.

(3) Megger between various load circuits looking for continuity, regulator 1 load to regulator 2 load, etc. With all other regulators off, turn on the regulator with the suspected short. If the current is detected on an "off" regulator load or continuity is measured between loads, measure all other regulator outputs for current with clamp-on ammeter. Then, loads can be cross connected in an effort to find the cross connection.

c) Causes. Shorts in airfield loads are usually caused by heat from a grounded cable or bad connection burning away or melting insulation on an adjacent cable, shorting the two together.

(1) Figure 32 illustrates what happens when the load becomes shorted to itself. Note the lights are dim after the short in the load, and may be off altogether if the remaining portion of the load, after the short is long. The short may or may not be grounded and have the same effect, if no other grounds exist on the circuit. Again, driving the circuit and "taking a look" will locate the problem.

d) Circuit Integration Method. The circuit integration method is very useful in locating load circuit to load circuit shorts. This load-to-load short condition is usually discovered by one of the following: load-to-load resistance tests, visual abnormalities in the load, reports of voltage present on "off" regulators or load circuits, investigations into unusual regulator behavior.

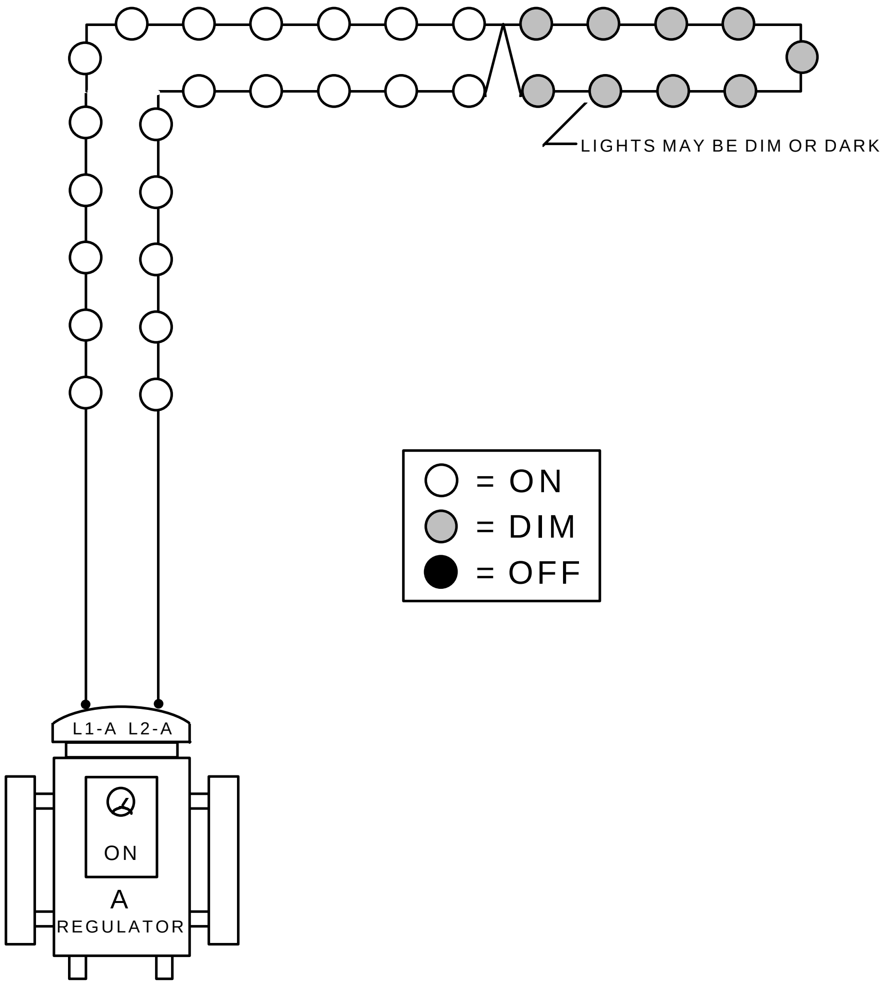
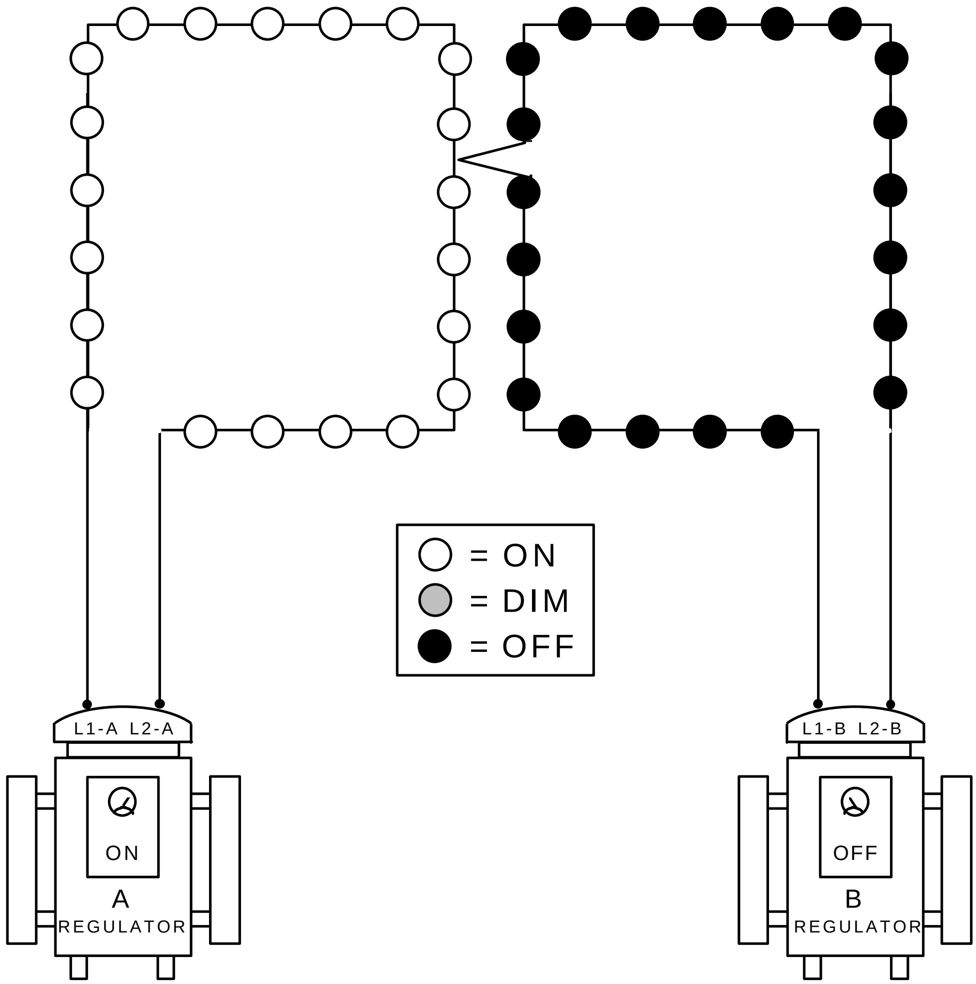


Figure 32
Single Short on Load

Whenever this load-to-load short condition is detected or suspected, action should begin immediately. First, warn all personnel who could possibly come into contact with the circuits which have the hazardous condition. Then, repairs should begin as soon as possible to prevent damage to regulators and other circuit components.

The “Circuit Integration Method” involves splitting the load of two shorted loads and running portions of those two loads on one regulator, with the purpose of locating shorts from one load circuit to another.
Prior to troubleshooting with the circuit integration method, the two loads involved should be meggered between the two loads to verify that the loads are in fact shorted together. Otherwise, the regulator used in the test will trip out in an open circuit condition, a condition to be avoided if possible.

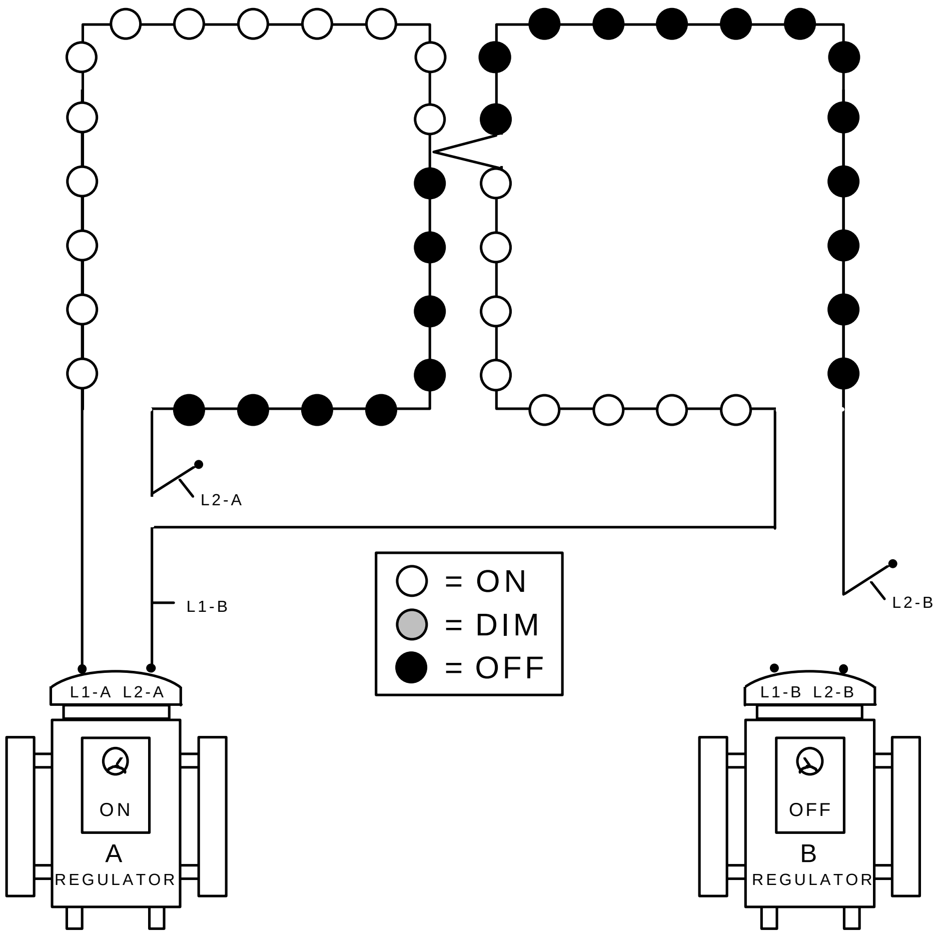
(1) Figure 33 illustrates a single load-to-load short. This condition is hazardous to personnel working on both regulator A or B when the other regulator is operating. Note that the condition with a single load-to-load short has no effect on the lights. The lights and regulators might start behaving abnormally if grounds exist on the two circuits.



THIS CONDITION CAN BE DETECTED BY MEGGER TESTING RESISTANCE BETWEEN LOAD “A” AND LOAD “B”.
HAZARD EXISTS TO PERSONAL WORKING ON EITHER LOAD “A” OR ‘B” WHEN THE THE OTHER LOAD IS ENERGIZED.

Figure 33
Single Load-to-Load Short

(2) Figure 34 illustrates how two loads are "integrated" into one load circuit for the purpose of locating the load-to-load short location. The two regulator loads have been split at the short location. Now, driving the load will locate the on/off transition of the lights and locate the short.



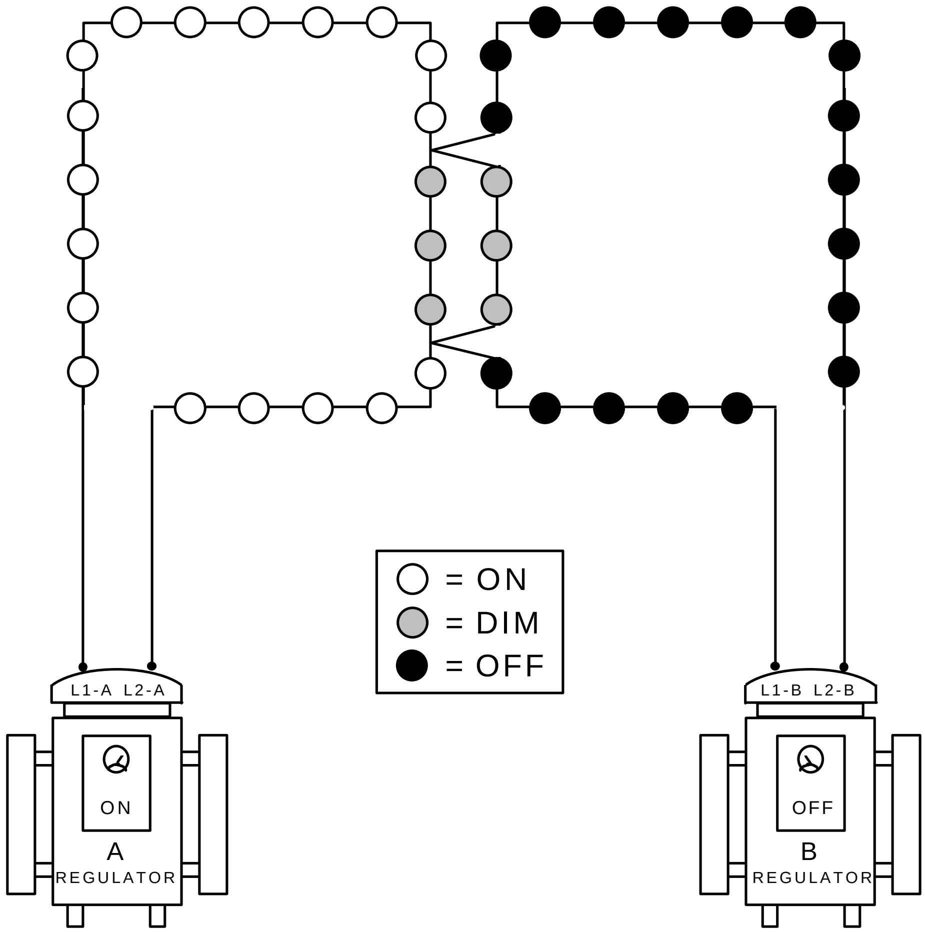
HIGH VOLTAGES EXIST ON CABLES L2-A AND L2-B. TAPE EXPOSED CONDUCTORS PRIOR TO ENERGIZING.

Figure 34
Single Load-to-Load Short Circuit Integration Method

Caution: The disconnected cables (L2-A and L2-B in the illustration) have high voltages on them during this test. Provisions should be made to protect personnel from coming in contact with these disconnected cables.

Caution: Never integrate a 20.0 ampere regulator onto a 6.6 ampere load. The 20.0 ampere regulator will surely blow out all of the 6.6 ampere lamps. If a 20.0 ampere load and a 6.6 ampere load become shorted together, troubleshoot the circuit with the 6.6 ampere regulator. It will still be possible to locate the short looking for the on/off transitions.

(3) Figure 35 illustrates two load-to-load shorts. Notice that the lights in this condition are affected, causing the area between the two shorts to dim on both loads.



THIS CONDITION CAN BE DETECTED BY MEGGER TESTING RESISTANCE BETWEEN LOAD "A" AND LOAD "B."
HAZARD EXISTS TO PERSONNEL WORKING ON EITHER LOAD "A" OR "B" WHEN THE OTHER LOAD IS ENERGIZED.

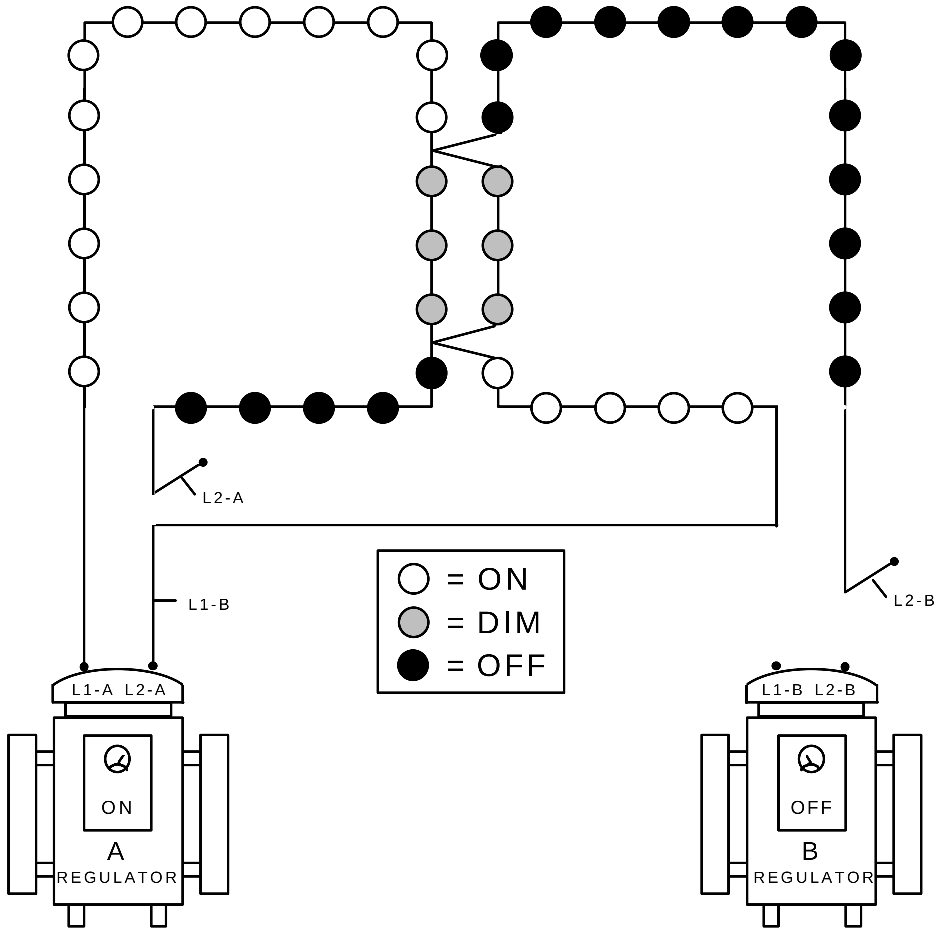
Figure 35
Two Load-to-Load Shorts

If the illuminated lights on the B load were to go unnoticed, the presence of this condition could easily be confused with symptoms of two grounds on a single circuit. The give-away is the portion of the B load lights that are on.

Driving the circuit would locate the bright/dim transitions and the location of the shorts.

Had the load between the shorts of load A been much larger (more lights) than the load in between the shorts of load B, the smaller load would have been brighter. In the illustration, the loads between the shorts are equal and the current is divided equally between the two loads.

(4) Figure 36 illustrates the results of "Circuit Integration" on the two load-to-load shorts. The actual shorts would be located in the area of the dim/off and dim/on light transition in the loads.



HIGH VOLTAGES EXIST ON CABLES L2-A AND L2-B.
TAPE EXPOSED CONDUCTORS PRIOR TO ENERGIZING.

Figure 36
Two Load-to-Load Shorts - Circuit Integration Method

Caution: Never integrate a 20.0 ampere regulator onto a 6.6 ampere load. The 20.0 ampere regulator will surely blow out all the 6.6 ampere lamps. If a 20.0 ampere load and a 6.6 ampere load become shorted together, troubleshoot the circuit with the 6.6 ampere regulator. It will still be possible to locate the short looking for the on/off transition.

In the case of Figure 36 with two load-to-load shorts, let's say regulator B is a 20.0 ampere regulator and A is a 6.6 ampere regulator. The first thing that might need to be done is to replace some lamps on load A if the 20.0 ampere circuit has been run. Then the test should be run as illustrated. Identify the on/off or on/dim transition and locate one of the shorts, on that one side, i.e., where the 6.6 ampere and 20.0 ampere circuits first merge. Next, disconnect the two load cables (L1-A and L1-B) presently connected to the 6.6 ampere regulator. Then connect the other two load cables (L2-A and L2-B) to the 6.6 ampere regulator and test. Now, the on/off or on/dim transition will be on the other side of the shorts and each short will be located.

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.

6.6 Locating Opens in Field Circuits

6.6.1 Isolating Open Circuits. Before checking for open circuits, be sure that any grounds are removed as described in par. 6.4. 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 insulation resistance tester, or the cable test set.

a) Symptoms. Regulator trips off line when turned on either remotely or locally. Regulator operates normally into shorted load. Megger tests across load circuit confirm that an open load condition exists.

b) Troubleshooting. Check across the load with a Megger or ohmmeter. Verify that the load has an open or high resistance across it. Label each output coming from the regulator (L1 and L2) and Megger to ground. If one or both have a low resistance to ground, either the “Intentional Ground” or “Ground Return” method can be used. If a measurement of resistance to ground does not yield a reading, an “ungrounded open” exists and either the “Manual Ground” or “Sectional” method will have to be used. See the instructions and illustrations on the various methods in the “Airfield Troubleshooting Methods” section.

c) Causes. Opens are caused by the same reasons grounds occur, with the following exceptions:

(1) Ice tends to pull circuits apart as it freezes in manholes, base cans, and conduit, most often at connector kits which do not have heatshrink kits over connectors. However, in some cases ice has been known to completely sever the conductor.

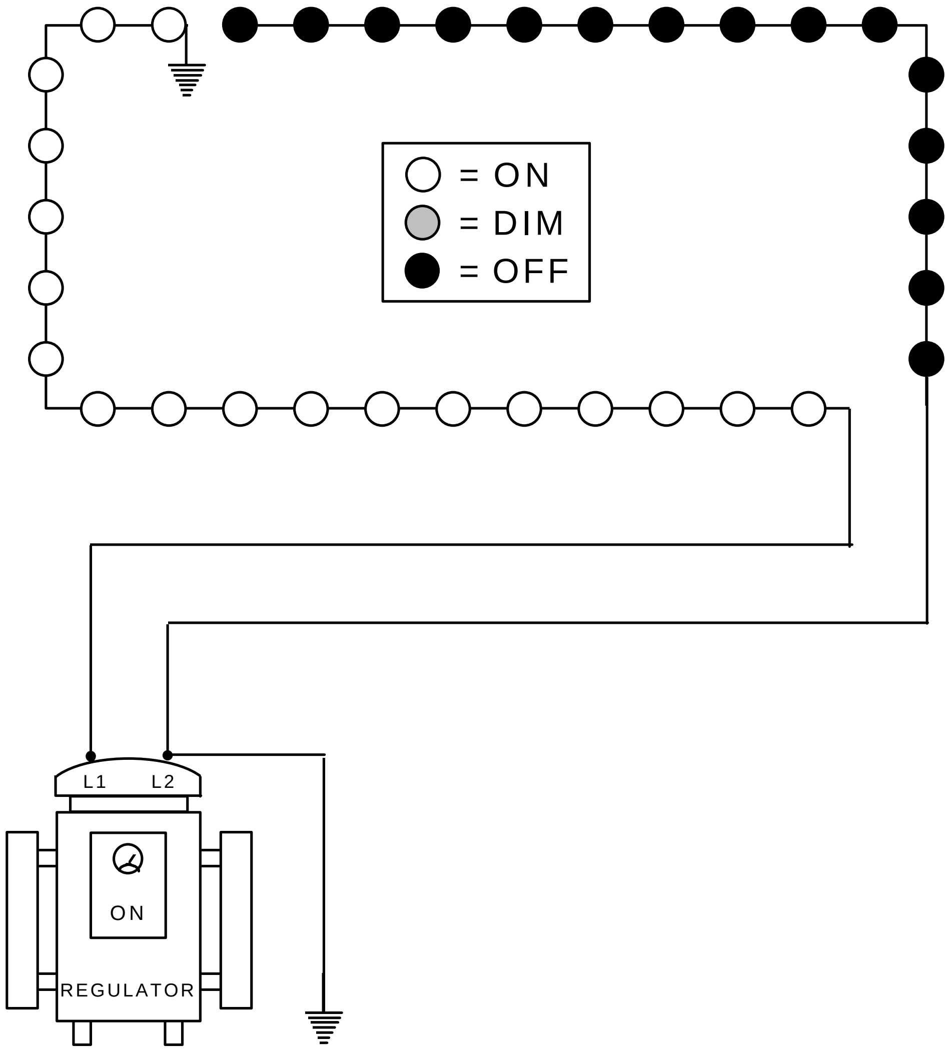
(2) Personnel working on a circuit made errors in reconnecting the load.

(3) Isolation transformer failures frequently cause opens.

(4) Ground settling after construction breaks connections in direct buried circuits.

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

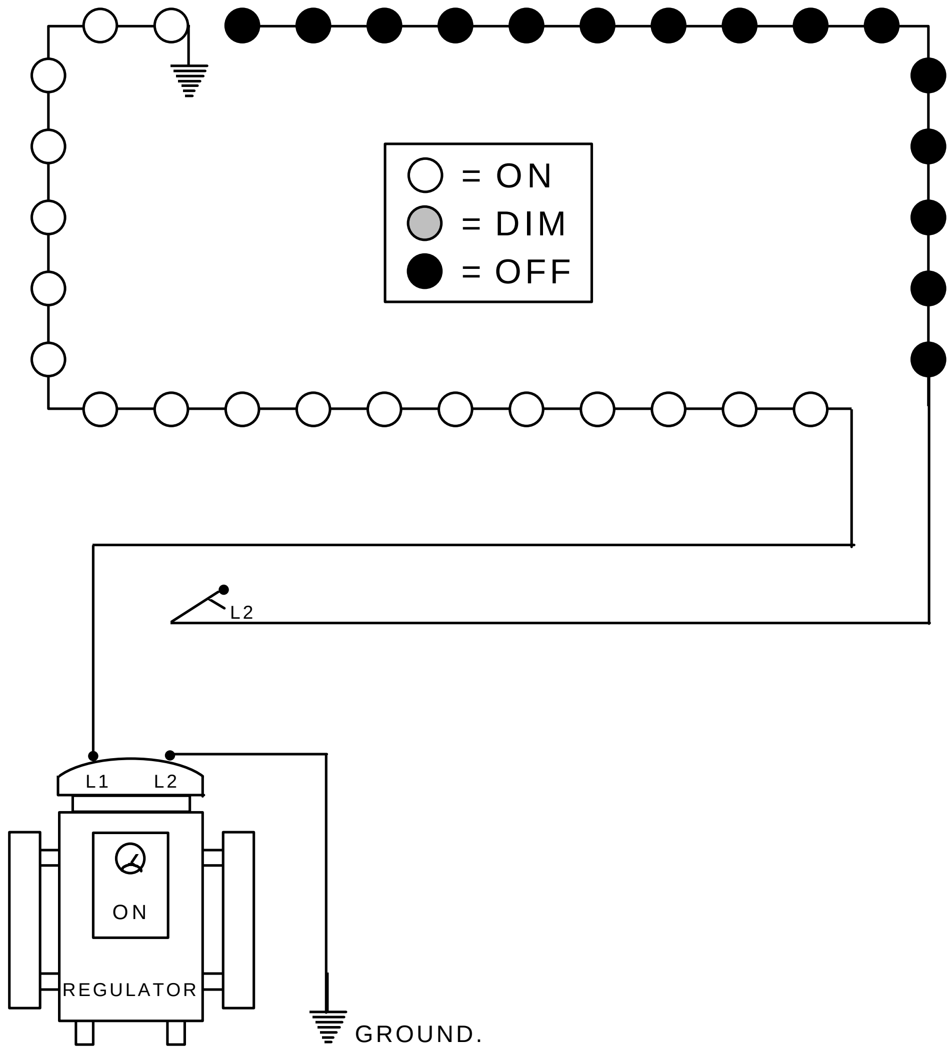
(1) Figure 37 illustrates troubleshooting a grounded open on the load circuit using the “Intentional Ground Method.” Prior to test, each load cable has been meggered. The intentional ground is connected to the cable with the highest resistance to ground. The regulator may likely trip out in an open circuit condition if the ground resistance at the open is too high. Revert to other methods of load troubleshooting. In the example, the resistance to ground of open circuit is low enough to allow for current flow. The open can be found quickly by driving the load and finding the on/off light transition.



MEGGER LOAD CABLES L1 AND L2 PRIOR TO CONNECTING GROUND.
CONNECT INTENTIONAL GROUND TO LOAD LINE WITH HIGHEST RESISTANCE TO GROUND.
ONE LOAD LINE SHOULD HAVE LOW RESISTANCE TO GROUND FOR THIS METHOD TO WORK.

Figure 37
Grounded Open on Load Circuit - Intentional Ground Method

(2) Figure 38 illustrates troubleshooting a grounded open using the "Ground Return Method." Prior to this test each load cable should be meggered to ground. The cable with the highest resistance to ground should be disconnected. The ground return ground should be connected to the regulator in its place. In determining which cable to disconnect, this same procedure should be followed when using the "Ground Return Switch."



MEGGER LOAD CABLES L1 AND L2 PRIOR TO CONNECTING GROUND.
CONNECT GROUND TO REGULATOR OUTPUT IN PLACE OF CABLE WITH HIGHEST RESISTANCE TO GROUND.
ONE LOAD CABLE SHOULD HAVE AT LEAST MED TO HIGH RESISTANCE TO GROUND.
HIGH VOLTAGES EXISTS ON CABLE L2. TAPE EXPOSED CONDUCTOR PRIOR TO ENERGIZING.

Figure 38
Grounded Open on Load Circuit Ground Return Method

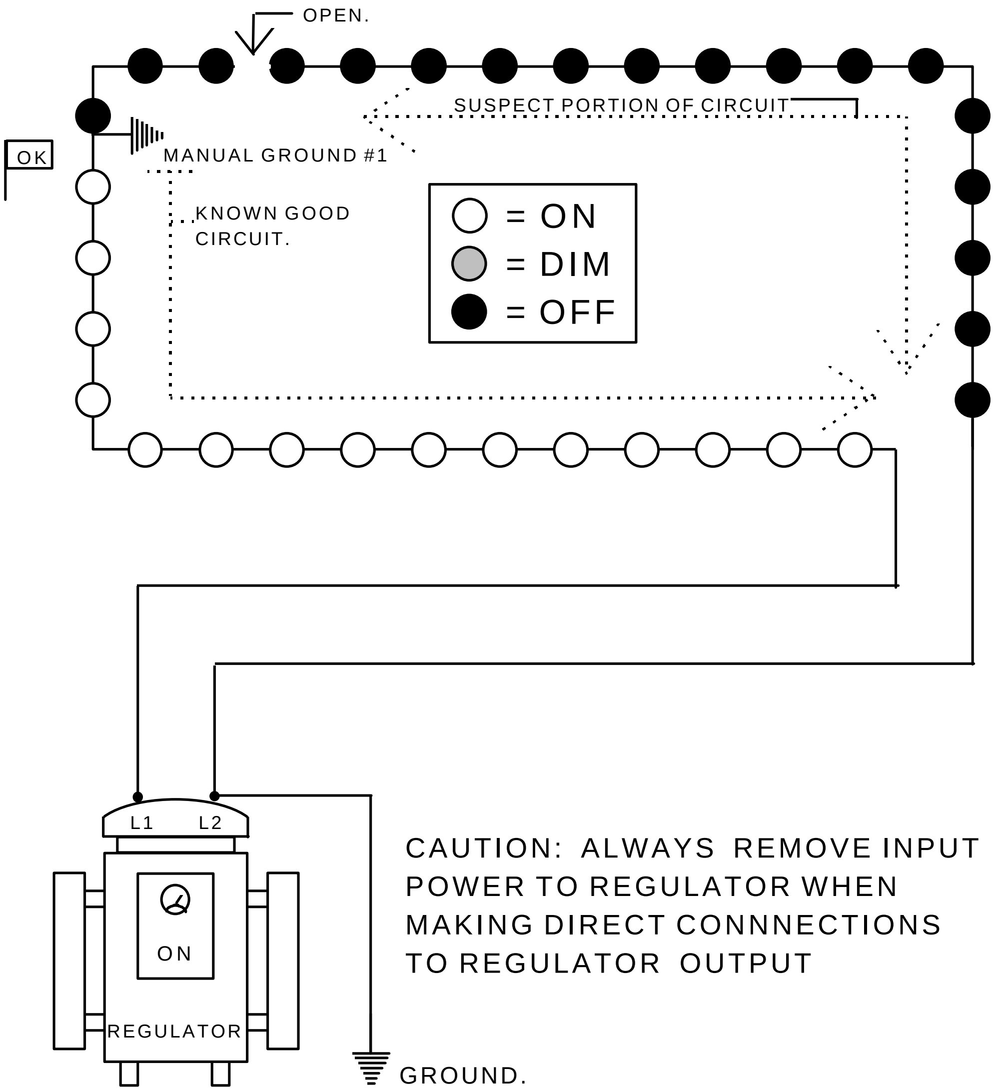
The ground fault is located quickly by driving the circuit and looking for the on/off transition.

Use care to insulate the disconnected load cable prior to testing. High voltages may be present during testing.

e) Manual Ground Method. The manual ground method is useful for isolating ungrounded opens in the load that can't be found be other means. The "Manual Ground Method" involves the manual introduction of a low resistance ground in the load on the airfield, as well as grounding of one side of the regulator as in the "Intentional Ground Method," providing an alternate path for current to flow in sections of the circuit in an attempt to identify sections of the load that are continuous and functioning. This reduces the number of possible sections of the load that could contain the open.

The manual ground itself is usually a male and female connector kit connected to a rod and/or heavy alligator clamp. The manual ground is usually first connected in series to the existing load at the circuit midpoint, then connected to the base can ground via the clamp. If a good ground is not available, drive in the ground rod. Stay clear of the manual ground during testing. High voltages exist.

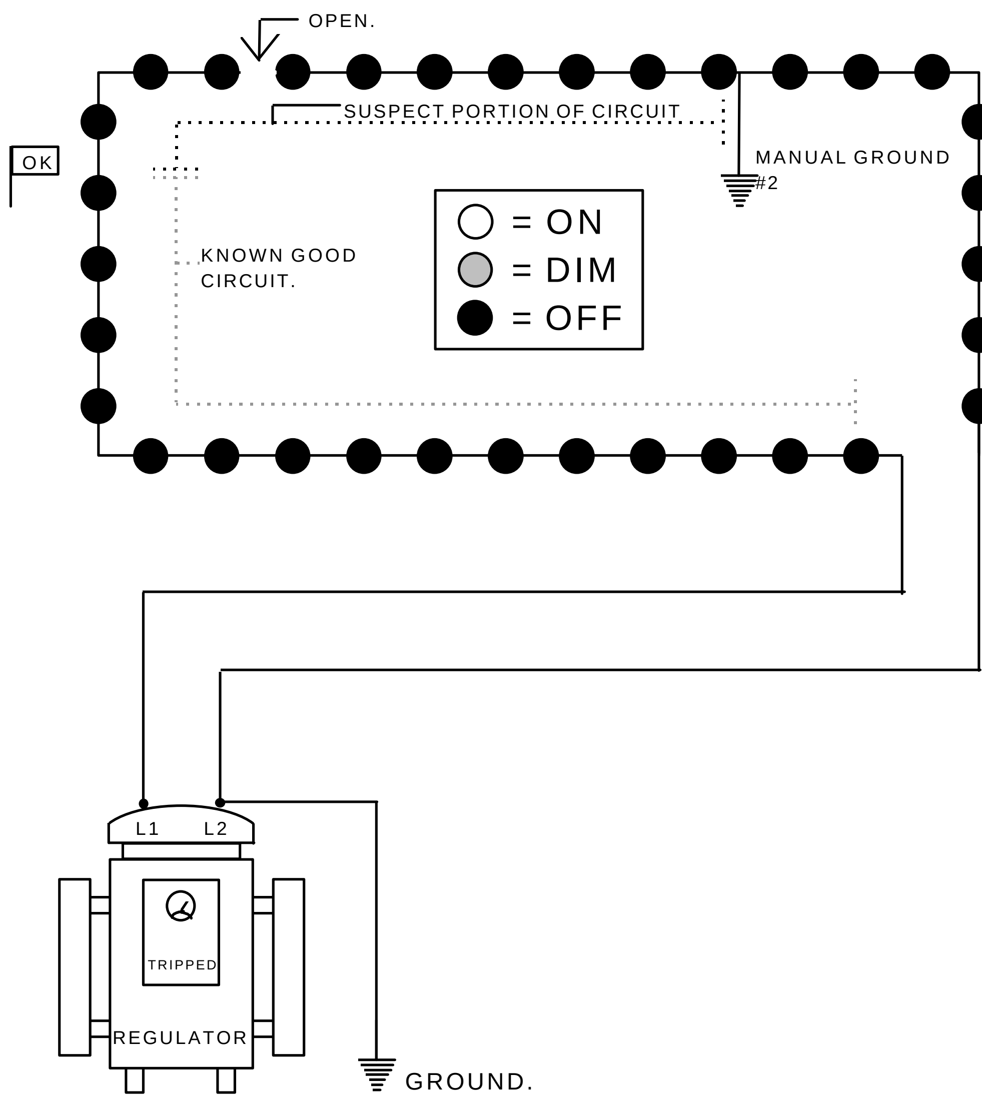
(1) Figure 39 illustrates the first test in troubleshooting an ungrounded open on the load. The first manual ground has been inserted at the circuit midpoint. Energizing the regulator reveals that a portion of the load is operating. A marker is placed in the ground adjacent to the first manual ground. We know that the circuit between the marker and the regulator is good. The entire circuit that did not come up is suspected of containing the open.



MEGGER READINGS INDICATE OPEN ACROSS LOAD AND HIGH OR NO RESISTANCE TO GROUND.
CONNECT GROUND TO L2. INSTALL MANUAL GROUND ON LOAD MIDFIELD.

Figure 39
Ungrounded Open on Load Circuit Manual - Ground Method First Test

(2) Figure 40 is an illustration of our second test using the manual ground method. The manual ground from the first manual ground location has been moved to the midpoint of the suspect section, illustrated at the manual ground #2 location.

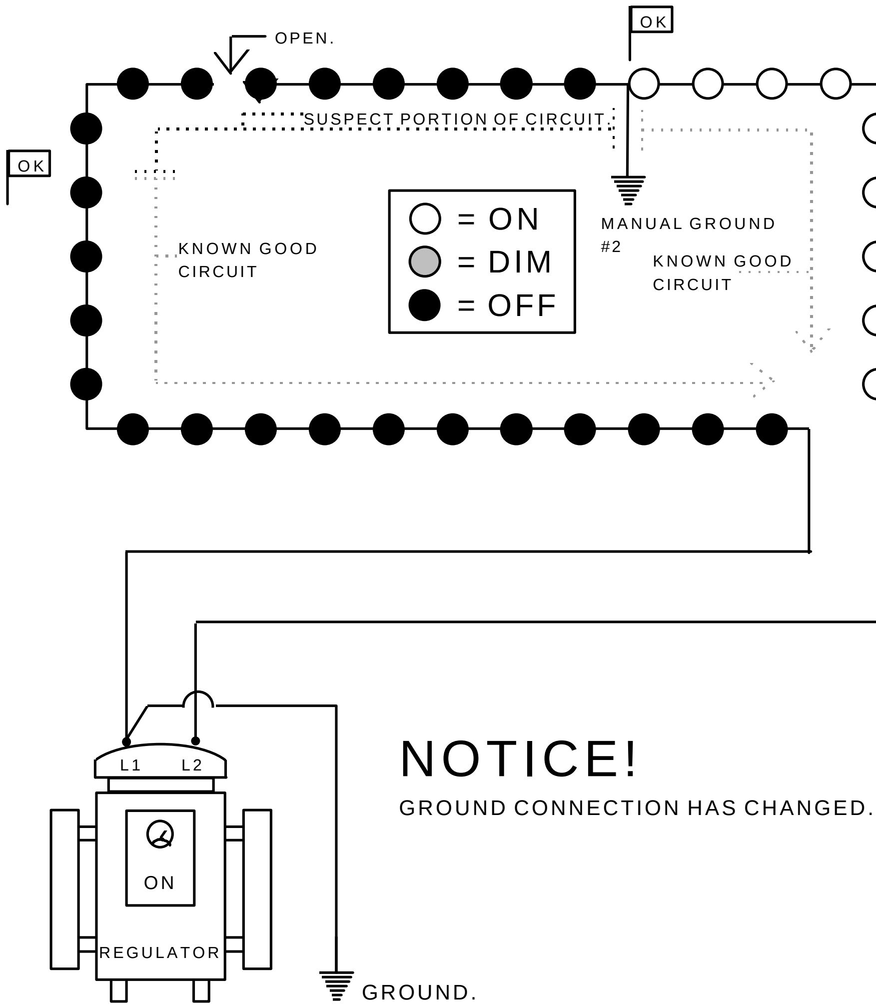


INSTALL SECOND MANUAL GROUND ON MIDPOINT OF REMAINING LOAD.

Figure 40
Ungrounded Open on Load Circuit - Manual Ground Method Second Test

Turning on the regulator, the regulator tripped off in an open circuit condition, which reveals that we passed over the open circuit as we proceeded into the suspect portion of the load from our first manual ground location. Logic dictates that the open is probably between the present second manual ground location and our first manual location. However, we would like some proof (see Figure 41).

(3) See Figure 41. In the second test using the manual ground method the regulator tripped out indicating an open circuit on the load.

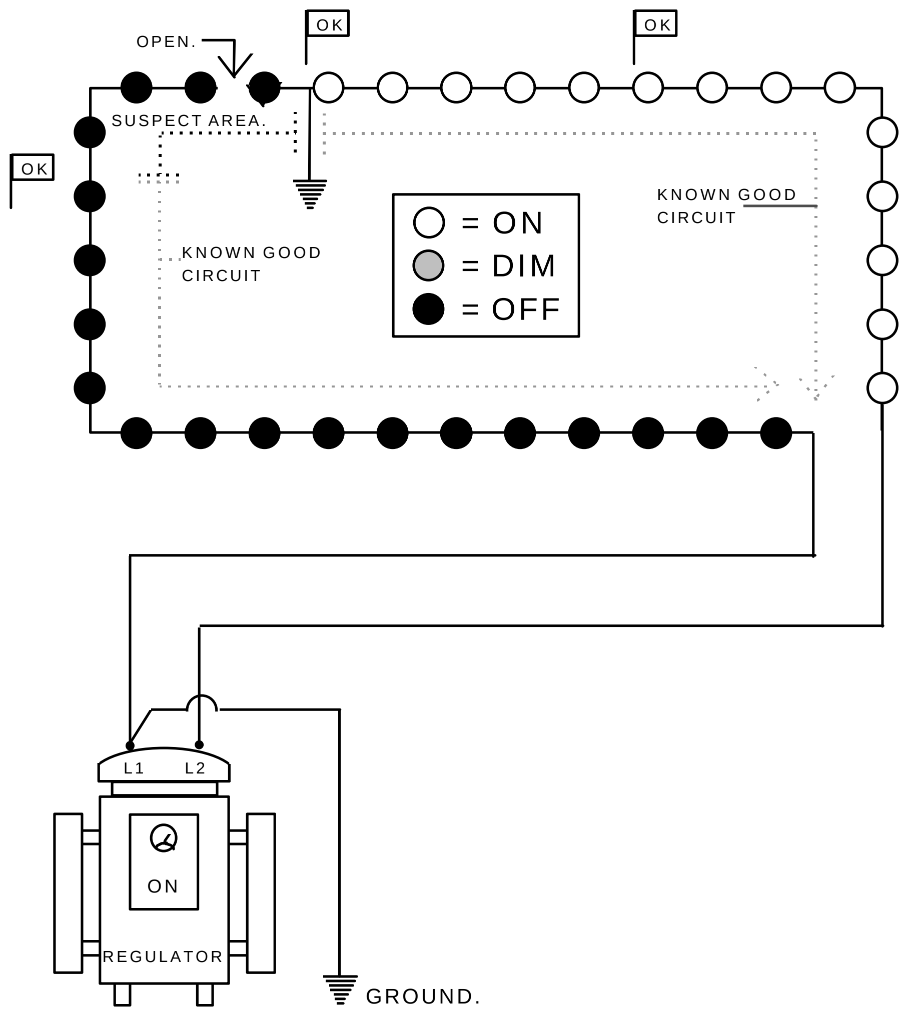


IN SECOND TEST REGULATOR TRIPPED OFF DUE TO OPEN CIRCUIT. TO PROVE THAT THE OPEN IS BETWEEN THE FIRST AND SECOND MANUAL GROUND, WITH REGULATOR INPUT OFF, SWAP GROUND ON REGULATOR TO L1.

Figure 41
Ungrounded Open on Load Circuit Manual - Ground Method Third Test

We have assumed that the open is between the first and present manual ground location. To prove it, swap the intentional ground on the regulator output to the other output cable (the other half of the load). Leave the second manual ground where it is. Energize the regulator and notice that a portion of the load is operating. The operating portion of the load is continuous, and now known to be good. Place a marker adjacent to the second manual ground. Now we cut this problem in half again (see Figure 41).

(4) See Figure 42. In the third test we narrowed the suspect area of the circuit down to about nine lights, leaving the intentional ground on the regulator where it is (since it is conducting to the load). We move to manual ground #3 at the remaining suspect area midpoint. Turning on the regulator we have five more lights operating and have narrowed our suspect area for the open to four fixtures. If we were to pursue this further, we would cut the suspect area in half again and again until we found the open.



DIVIDE SUSPECT AREA OF LOAD IN HALF WITH MANUAL GROUND #3.
IN FOUR TESTS OPEN HAS BEEN ISOLATED TO A FOUR FIXTURE AREA.

Figure 42
Ungrounded Open on Load Circuit Manual - Ground Test Fourth Test

f) The sectional isolation method for locating opens in series circuits is very similar to the intentional ground method discussed earlier in this text. As in the intentional ground method, a manual ground is inserted into the load circuit, and earth ground provides a return path for our tests. However, a megger is used to locate the open in the load rather than a regulator as in the intentional ground method.

(1) After an open is reported on a load circuit, we can verify the open by reading the resistance across the load as illustrated in Figure 43. As you can see, the load is open and the megger reads a very high resistance, confirming the open on the load.

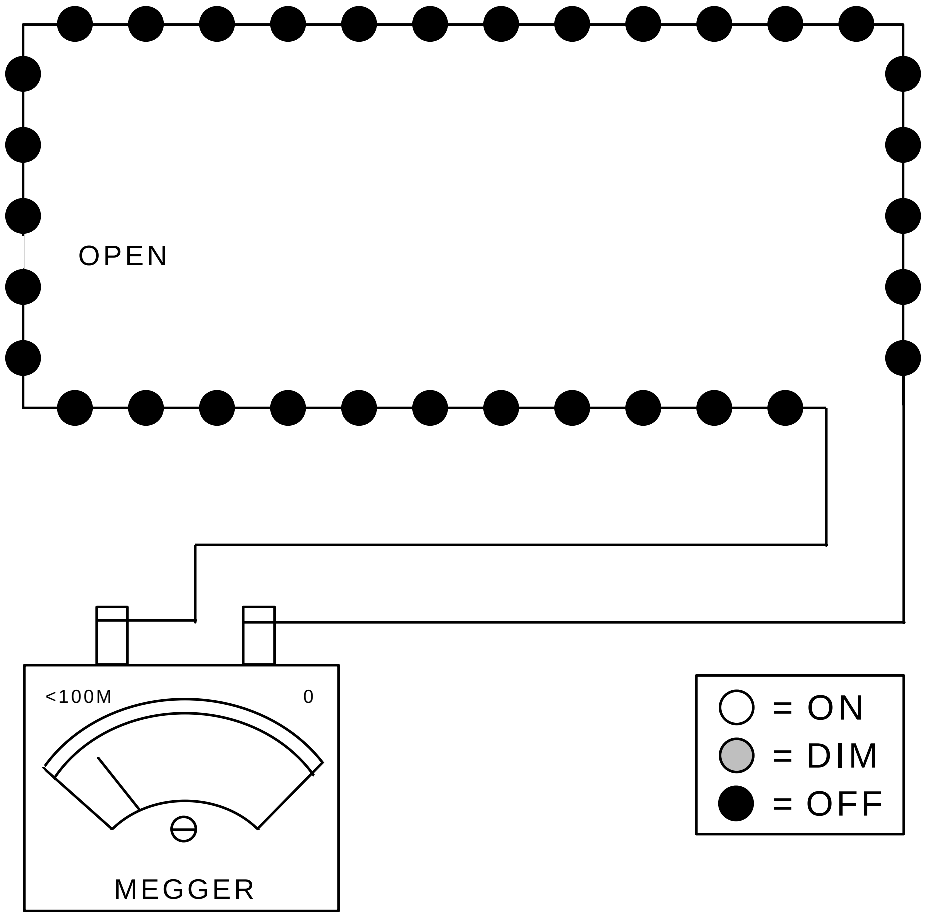


Figure 43
Sectional Isolation Method - Megger Confirms Open on Load Circuit

As discussed earlier in this text, when an open is detected, the load should be first checked for grounds. If grounds are detected, those grounds should be located and repaired. Quite often the open circuit fault is grounded and locating the open is simplified when the open is grounded on at least one side of the open fault. The following illustrations and text are based on locating ungrounded opens in the load circuit.

(2) Figure 44 illustrates the megger connection to the load and ground for testing load wire L2. Notice that a manually inserted ground has been connected to the load at the circuit midpoint.

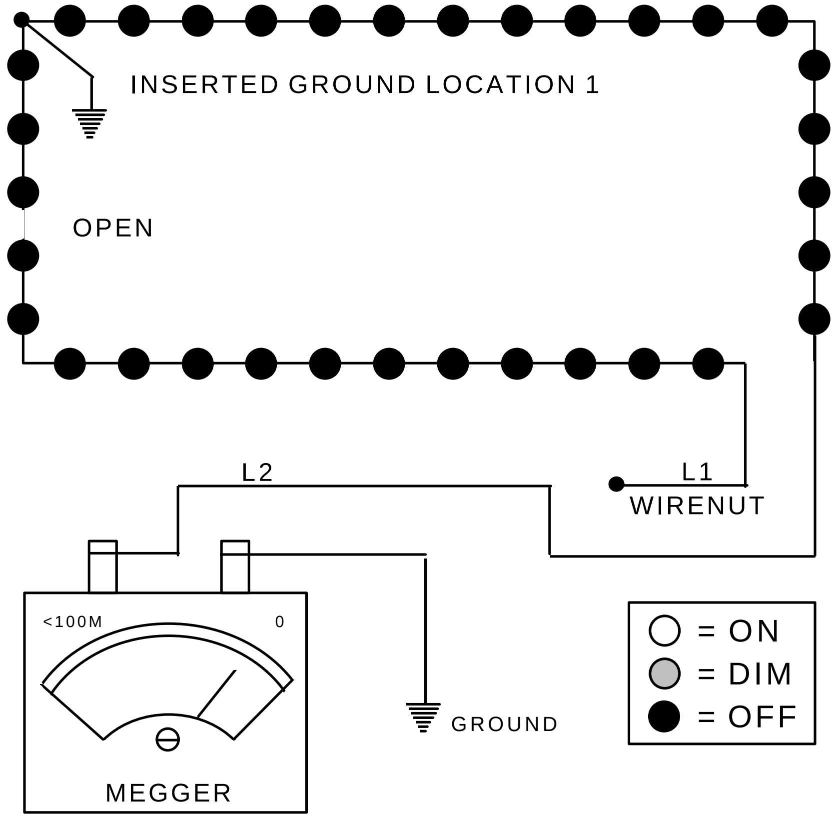


Figure 44
Sectional Isolation Method - Megger Confirms Continuity Between L2 and Inserted Ground

(a) Testing the circuit, as illustrated, proves that the load cable L2 is intact between the vault and the inserted ground at the field midpoint. We have learned that the open fault lies between the inserted ground and the vault along long cable L1.

(b) Now that we have established that the open fault is along L1 between the vault and the inserted ground, we can begin to track down the fault location further. We have disconnected L2 and swapped the megger to the L1 cable. Testing the circuit confirms that the open fault is indeed between the vault and the inserted ground.

(c) The inserted ground is moved to location 2, dividing the L1 cable between the vault and location 1 in half. Testing the circuit confirms that the cable between vault and location 2 is good. The open fault location has now been reduced to the cable between ground location 1 and location 2.

(d) We continue to divide the suspect section of the load circuit in half by moving the inserted ground to location 3. Testing the circuit confirms that the cable between the vault and location 3 is good. The open fault location has been reduced to the cable between ground location 1 and 3.

(e) We continue to divide the suspect section of the load circuit in half by moving the inserted ground to location 4. Testing the circuit reveals that the circuit indicates an open between the vault and location 4. However, we know from our previous test that the circuit is good up to location 3. The open fault is located between location 3 and 4. See Figure 45.

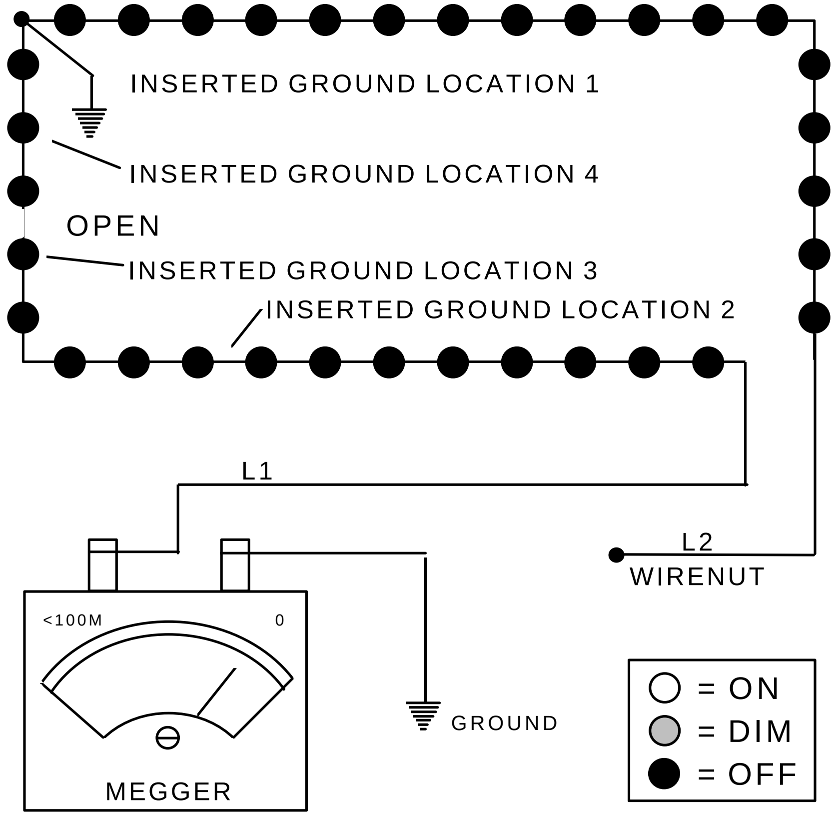


Figure 45
Sectional Isolation Method - Megger Confirms Open Between L1 and Inserted Ground

6.7 Overloads in Series Circuits

6.7.1 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 or only higher 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 par. 6.4.2.

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) Symptom. Lights on suspected circuit don’t reach full intensity. Current on output of regulator is out of specification for high intensity. Usually the problem exists in higher brightness levels only, but overloads may affect all brightness steps if severe enough.

c) Troubleshooting. With the suspect regulator connected to shorted load, check that output current levels are within tolerance. Use an RMS ammeter to measure the regulator output current in each brightness level. Check the regulator nameplate for current level specifications.

(1) If the regulator output levels are acceptable in a shorted load, and low when connected to the circuit, then an overload exists in the series circuit.

(2) Check with maintenance personnel and contractors to determine if anyone has been working on the overloaded circuit or on the airfield circuits in general. If so, drive the circuit. Check for the addition of new load circuits. Also, check load intersections for cross-connected loads.

(3) If no work has been done on the suspect circuit, megger the load and repair grounds, if present.

(4) Check for and replace bad lamps on the effected circuit. Also, look for dim or dead sections of the circuit that might indicate grounds or grounded opens.

(5) If a new circuit section has been installed and is connected to the proper circuit, let the supervisor know that the additional load has overloaded the circuit and that a bigger regulator is needed.

d) Cause. The most typical reason for an overload is the addition of new load(s) to an existing circuit. With the addition of new load(s), the total load is now exceeding the rated load of the regulator. Other common causes for overloaded regulators are:

(1) Cross connecting in another series circuit by accident.

(2) Large percentage of circuit lamps out, generally more than 30% of the regulator wattage rating.

(3) Multiple grounds or grounded opens on suspect circuit.

(4) Several loose connector kits, bad crimps or bad splices.

6.8 Input Power Circuits

6.8.1 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 de-energized 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 contactors 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 contactor 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.

(a) If the fuse or circuit breaker holds, the trouble is over, but notate the incident in case the device ever opens again.

(b) 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 bushing, 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.

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

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

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

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

(e) 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.

1. 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 correspond with the input voltage when the regulator is energizing its normal load. Note that regulators larger than 7 1/2 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.

2. 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.

3. If the input voltage is present and corresponds with the setting of the taps or tap-selector switch, then 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 de-energized every time the meter is moved.

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

(b) 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.

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

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

(c) 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 A

STANDARDS AND TOLERANCES

A.1 PURPOSE. This appendix contains standards and tolerances for lighted navigational aid equipment and systems as contained in the following tables:

Table	Equipment or system
A-1	Beacons
A-2	Medium Intensity Approach Light System with Flashers (MALSR)
A-3	Approach Light System with Sequence Flashers (ALSF-1/ALSF-2)
A-4	Runway End Identifier Lights (REIL)
A-5	Precision Approach Path Indicator (PAPI)/ Chase Helicopter Approach Path Indicator (CHAPI) Systems
A-6	Runway and taxiway lighting systems
A-7	Photoelectric devices
A-8	Standby engine generators

Table A-1
Beacons

Parameter	Standard	Tolerance / limit: Initial	Tolerance / limit: 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 percent	± 5 percent
3. Vertical aiming	Locally established between 2-10 degrees	± ½ degree from established angle	Same as initial

Table A-2
Medium Intensity Approach Lighting Systems With Flashers (MALSR)

Parameter	Standard	Tolerance / limit: Initial	Tolerance / limit: 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 A-3
High Intensity Approach Lighting Systems With Flashers (ALSF-1/ALSF-2)

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 A-4
Runway End Identifier Lights (REIL)

Parameter	Standard	Tolerance / limit Initial	Tolerance / limit Operating
1. Light units operational	All	All	All
2. Flashing rate			
a. Unidirectional type	120 fpm	± 2 fpm	± 2 fpm
b. Omnidirectional type	60 fpm	± 2 fpm	± 2 fpm
3. Input voltage	120 V or 240 V	± 3%	± 5%
4. Alignment (unidirectional)			
a. Vertical			
(1) With baffles	3 degrees	± 1 degree	-1 degree +2 degrees
(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
5. Light leveling (omnidirectional)	Level	± 1 degree	± 2 degrees
6. Obstructions due to vegetation, etc.	No obstruction	Same as standard	Same as standard

Table A-5
Precision Approach Path Indicator (PAPI)/
Chase Helicopter Approach Path Indicator (CHAPI) Systems

Parameter	Standard	Tolerance / limit: Initial	Tolerance / limit: Operating
1. Lamps burning			
a. PAPI	All	All	Not more than one lamp out per box
b. CHAPI	All	All	
2. Vertical aiming [1/]			
a. Unit D (close to runway)	3° 30’	± 2 minutes	± 6 minutes
b. Unit C (2nd from runway)	3° 10’	± 2 minutes	± 6 minutes
c. Unit B	2° 50’	± 2 minutes	± 6 minutes
d. Unit A (farthest from runway)	2° 30’	± 2 minutes	± 6 minutes
3. Horizontal alignment	Parallel to runway centerline	± ½ degree	± ½ degree
4. Tilt switch	-¼ below to +½ degree above established light bar	Same as standard	Same as standard
5. Lamp current (current-regulated)	Rated current of lamps	Same as regulator currents for type of regulator used	
6. Lamp voltage (voltage-regulated)	Rated voltage of lamps	± 3%	± 5%
7. Obstructions due to vegetation, etc.	No obstruction	Same as standard	Same as standard

[1/] Unless a different standard is established locally, angles shown are for a 3 degree glide path.

Table A-6
Runway and Taxiway Lighting Systems

Parameter	Standard	Tolerance / limit: Initial	Tolerance / limit: Operating [1/]
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 and 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			
a. Edge lights	All on	All on	85% on
b. Centerline lights	All on	All on	90% on
3. Lamp current (series circuit)	Amperes	Amperes	Amperes
a. 3 step, 6.6 A	6.6 5.5 4.8	6.40-6.70 5.33-5.67 4.66-4.94	Same as initial
b. 5 step, 6.6 A	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, 20 A	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 A-6 (Continued)
Runway and Taxiway Lighting Systems

[1/] To provide continuity of guidance, the allowable percentage of unserviceable lights should not be in a pattern that would alter the basic pattern of the lighting system. Additionally, an unserviceable light 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 barrette 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 A-7
Photoelectric devices

Parameter	Standard	Tolerance / limit	
		Initial	Operating
1. Photocell operation (PAPI)			
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 (windsock, 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 A-8
Standby Engine Generators

Parameter	Standard	Tolerance / limit: Initial	Tolerance / limit: Operating [1/]
1. Starting time [1/]	15 seconds or less	Same as standard	Same as standard
2. Potential relays commercial power			
a. 120 V system			
Dropout	108 V	± 3 V	Same as initial
Pickup	114 V	± 3 V	Same as initial
b. 208 V system			
Dropout	191 V	± 3 V	Same as initial
Pickup	197 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. If a generator failure occurs during this time, the CAT-II lighting load must be switched back to commercial power within 1.1 seconds.

GLOSSARY

AC. Advisory circular.

CHAPI. Chase helicopter approach path indicator.

DOD. Department of Defense.

EALS. Emergency airfield lighting system.

EV. Exposure value.

FAA. Federal Aviation Administration.

FLOLS. Fresnel lens optical landing system.

MALSR. Medium intensity approach lighting systems.

MOVLAS. Mirror optical visual landing aid system.

NAVFAC. Commander, Naval Facilities Engineering Command.

ODALS. Omnidirectional approah lighting system.

PAPI. Precision approach path indicator.

PMI. Preventive maintenance inspection.

REIL. Runway end identification lights.

SAVASI. Simple abbreviated visual approach slope indicator.

VASI. Visual approach slope indicator.

VOM. Volt-ohm-milliammeters.

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