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Real Property Operation and Maintenance

MAINTENANCE OF AIRFIELD VISUAL AID FACILITIES

This pamphlet gives guidance to help electrical technicians perform maintenance on airfield visual aid systems. It applies to all Air Force civil engineering organizations having airfield lighting responsibilities, including United States Air Force Reserve units. It does not pertain to Air National Guard units. The Federal Aviation Administration (FAA) Advisory Circular AC 150/5340-26 is the source for most technical material in this pamphlet.

Send recommendations to improve this pamphlet to HQ AFESC/DEMM, Tyndall AFB FL 32403-6001.

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Chapter 1

Maintenance Management

1-1. Maintenance Philosophy. Visual aid systems are an important part of airfield operations. They assist in the safe and efficient movement of aircraft during landing, takeoff, and taxiing. If a system fails at a critical time, it could have an impact on lives and property. The reliability of these systems depends on dedicated managers, supervisors, and technicians working together to form a well-rounded maintenance program.

1-2. Program Development. When developing a maintenance program, consider the components below:

a. Management and Supervision. The success (or failure) of a maintenance program is usually attributed to the attitude and skills of leaders. Managers can demonstrate their commitment to recurring maintenance by visiting job-site and communicating with the workers. They should frequently observe worker technical abilities to ensure the completion of job assignments. Close supervision is essential.

b. Training. A highly motivated training program is probably the most important area of the maintenance shop. No system can function satisfactorily very long without trained workers to perform the maintenance. Managers should make sure their on-the-job training (OJT) programs are dynamic and effective. This pamphlet provides an excellent source for instruction. Managers should set aside time for classroom instruction led by senior shop personnel. They should also consider using local trade schools, the Sheppard Technical Training Center, video tapes, and other sources of training information. Time spent on training will pay big dividends by reducing the amount of time required to troubleshoot, repair, and maintain activities.

c. Publications. Publications also are an important ingredient to good maintenance. Publications should be on-hand for all installed airfield visual aids. Manufacturer service manuals, Air Force Technical Orders (AFTO), and FAA Advisory Circulars are available to cover all systems.

d. Maintenance Support. Technicians should have tools, test equipment, and instruments necessary to properly maintain the systems. Table of Allowance (TA) 486 lists the instruments and equipment authorized in the electrical shop.

e. Maintenance Records. Without documented maintenance data, it is difficult to accurately evaluate the reliability and maintainability of operating systems. Keep records on all systems to show inspections, observations, and maintenance actions. As-built drawings also are an essential part of good recordkeeping.

f. Maintenance Schedules. A Recurring Work Program (RWP) schedule is the foundation for successful maintenance of the equipment. A properly executed RWP promotes top system performance and minimizes unscheduled interruptions and breakdowns. Chapter 2 contains a RWP schedule for most airfield visual systems on Air Force bases. To further assist with the program, chapter 3 describes troubleshooting procedures for most series lighting circuits.

Chapter 2

Scheduled Maintenance

2-1. What This Chapter Covers. This chapter covers the scheduled maintenance program for the visual aid facilities and equipment. It contains a recommended recurring work program (RWP) schedule for most equipment with step-by-step instructions for performing the RWP. The RWP schedules (tables 2-1 through 2-13), can be changed to meet local conditions. The RWP tables contain the following letters to represent maintenance frequencies: D = daily; W = weekly; M = monthly; BM = bimonthly; SM = semimonthly; Q = quarterly; SA = semiannually; A = annually; U = unscheduled; BE = Biennially. Corrective maintenance procedures for specific equipment are in the manufacturer's operating and maintenance instructions and are not included in this pamphlet. Refer to AFRs 88-14 and 88-15 when substituting equipment or using alternative equipment is necessary.

2-2. Rotating Beacons: (See RWP table 2-1)

a. Quarterly Checks:

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

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

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

b. Semiannual Checks:

(1) Input Voltage. Check the input voltage and record the reading. It should be within 5 percent of the rated lamp voltage. Too high a voltage causes lamp burnouts; too low a voltage causes light output to be inadequate. Take the measurement at the beacon lamp terminals with all field equipment energized so that the voltage reading will reflect operating conditions. Beacon lamps are very sensitive to voltage changes. A drop of 10 percent will reduce the light output 31 percent, while a rise of 10 percent will shorten the lamp life 72 percent. 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, install a compensating device such as an autotransformer.

(2) Lamp Focus and Beam Elevation. Visually verify that beacon beam is narrow, well defined, and projects horizontally. If beam elevation disperses or projects other than horizontally, adjust focus and beam elevation.

(3) Lubrication:

(a) Vertical Main Shaft. Lubricate beacons supplied with a grease gun fitting twice a year under ordinary operation. Use a high quality, low temperature silicone grease.

(b) Motor. If the motor has oil cups, lubricate with SAE 20 oil, or oil suggested by manufacturer. If there are no oil cups, the bearings are sealed and do not need servicing.

(c) Ring Gear. Apply a small amount of low temperature silicone grease to the ring gear. *CAUTION: The use of an excessive amount of grease will result in its dropping down on the slip rings and causing poor contact and arcing.*

(4) Switches. Check the operation of electrical switch blades and clips for good contact. Switches should have tension between the blades and hinges, but should 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) 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.

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

c. 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 allow a true level. Loosen holddown bolts and insert or remove spacers as required for proper level.

Maintenance Requirement Checklist

	Q	SA	A	BE
1. Check telltale indicator lamp for reserve lamp status.	X			
2. Check operation of the lamp-changer.	X			
3. Check slip rings and brushes.		X		
4. Check lens retainers.	X			
5. Check operation of relays.		X		
6. Clean and polish glassware.	X			
7. Check and record input voltage.		X		
8. Check lamp focus and beam elevation.		X		
9. Lubricate main shaft, motor, ring gear, and padlocks.		X		
10. Check operation of electrical switches and contacts.		X		
11. Check level of base.			X	
12. Clean and regrease gears.			X	
13. Inspect wiring, lugs, and conduit.			X	
14. Check weatherproofing and gaskets.			X	
15. Check lightning protection system.				X

*LEGEND
A = Annually
BE = Biennally
Q = Quarterly
SA = Semiannually

Table 2-1. Recurring Work Program Schedule for Rotating Beacons.

Check the level of the beacon in four directions. Be sure to tighten down the base.

(2) Gears. Remove the old grease from the gears by washing with an approved cleaning solvent. When installing new grease, observe the caution statement in b (3)(c) above.

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

(a) Wiring. Inspect for abrasions, breaks, and loose connections. Repair or renew wiring when necessary. Cover all repair patches 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 position of the lug should be clean and free of corrosion for good electrical contact. Repair minor deterioration of electrical wire insulation at the terminal lug with electrical tape. Use insulating cement 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 weatherproofing and gaskets. Replace gaskets when cracked or deteriorated. Before installing new gaskets, clean the gasket channels and seals thoroughly. When it is necessary to secure the gasket with rubber cement, coat both the gasket and seat with appropriate cement and allow to dry until tacky, then position the gasket.

d. Biennial. Check the lightning rod connections for tightness every 2 years. Check and record ground resistance. Compare the reading with previous ground resistance checks. Make sure reading is less than 25 ohms. If the reading exceeds 25 ohms, immediately correct the grounding problem.

2-3. Wind Cone Assemblies: (See RWP table 2-2)

a. Monthly Checks. Check the condition of the wind cone fabric.

b. Bimonthly Checks:

(1) Clean the globes when replacing the lamps.

(2) 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.

c. Semiannual Checks. Check the bearings to see if they need lubricating. An application of a light grease should be sufficient. In areas exposed to severe dust, clean the bearings with an approved cleaning solvent 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.

d. Annual Checks:

(1) Check the assembly base securing bolts for tightness. Tighten, as required.

(2) Check the wiring at the hinge, if frayed, repair or replace wiring.

(3) Check the condition of the paint on the wind cone structure. Touch up or repaint as required.

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

Maintenance Requirement Checklist

	*	M	BM	SA	A	U
1. Check for freedom of motion of windcone frame.			X			
2. Check condition of wind cone fabric.		X				
3. Clean glassware.			X			
4. Check paint on segmented circle.					X	
5. Clean and grease bearings.				X		
6. Check mounting bolts.					X	
7. Check wiring at hinge.					X	
8. Check paint on wind cone structure.					X	
9. Remove vegetation.						X

*LEGEND

A = Annually

BM = Bimonthly

M = Monthly

SA = Semiannually

U = Unscheduled

Table 2-2. Recurring Work Program Schedule for Wind Cones.

2-4. Airfield Lighting Vault: (See RWP table 2-3)

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, and so forth.

(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 or other nest-building insects. Check operation of ventilation fans.

(4) Storage. Check vault for improper use as a storeroom. Avoid storing spare parts, rags or other objects near the high voltage equipment. If the vault has an attached room, use this room for storing parts and supplies.

c. Semiannual Checks:

(1) 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. Carefully check the ground bus throughout its entire length. If the bus or any ground connection to the bus is broken, repair immediately. Deenergize the system before cleaning or repairing the bus.

(2) Oil Switches. Before operating oil switch, make sure oil has been dielectric tested within the past 2 years. Check the operation of the oil switches. Be sure that the movable 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.

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

(4) 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. Carefully clean the interior of the panel.

(5) Photoelectric Control. If a photoelectric time switch is installed, maintain it according to the manufacturer's instructions. Check the light levels with a photographic light meter to ensure that the control turns on and off at the proper ambient light levels.

(6) Astronomic Time Switch. If this switch is installed, service it according to the manufacturer's instruction book. Inspect the operation, check the clock, clean all motor commutator and main switch contacts, and check all electrical connections. Since this is a precision instrument, the manufacturer or other authorized service organization should make repairs.

(7) Radio-Control of Airfield Lighting. Check the operation of radio-controlled airfield lighting by keying a portable transmitter and observing the actuation of the switching mechanism. If you detect a fault, follow the manufacturer's recommendation for repair or replacement.

(8) Lightning Arresters. Check the lightning arresters for burning, scorching, or other signs of failure. Inspect lightning arresters for damage after each lightning storm in the area.

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

Maintenance Requirement Checklist	*	D	BM	SA	A
1. Check control operation.		X			
2. Check general cleanliness.			X		
3. Check insulation resistance.					X
4. Inspect and clean buses.				X	
5. Check relay operation.				X	
6. Check oil switches.				X	
7. Operate power transfer switches.				X	
8. Check control panel.				X	
9. Check photoelectric switch.				X	
10. Check astronomic time switch.				X	
11. Check radio-control of lighting equipment.				X	
12. Check lightning arresters.				X	
13. Inspect miscellaneous electrical hardware (fans).				X	
14. Paint equipment as necessary.					X
15. Test insulation resistance.					X

*LEGEND

A = Annually

BM = Bimonthly

D = Daily

SA = Semiannually

Table 2-3. Recurring Work Program Schedule for Airfield Lighting Vault.

d. Annual Checks:

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

(2) Insulation-Resistance Test. Perform an insulation-resistance test on all field circuits with a megohmmeter. Record the readings, and compare them with the previous readings. For series circuits, measure the insulation resistance by simply removing the ends of the loop from the power supply. For parallel circuits, remove all connections before measuring insulation resistance. There is no absolute ideal value for the loop-circuit resistance since the resistance is higher in shorter circuits and lower in longer ones. The circuit resistance also may change with the amount of moisture in the soil. Operating the system before measuring insulation resistance also may affect the value since moisture will be driven out of the circuit by the heat of operation. For this reason, measure the insulation resistance at the same time of day to minimize these variations. The important information is the deterioration of the resistance value from year-to-year. The resistance value inevitably declines over the service life of a circuit; a 10 to 20 percent yearly decline is normal. A yearly decline of 50 percent (4 percent monthly) or greater indicates the existence of a problem (such as a high resistance ground) or serious deterioration of the circuit. The maintenance supervisor should troubleshoot the circuit (chapter 3) to locate the problem. Table 2-4 outlines typical initial values for loop circuit resistance.

e. DC Hi-Potential Test. This test, which measures leakage current, provides more information than the test in d(2) above, which requires the use of a megohmmeter. If the cable fails the megohmmeter test, "hipot" it to ascertain it's true status.

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

(2) Test complete approach systems, touchdown zone and centerline light systems, and high intensity runway edge lights at 5000 volts. Test medium intensity runway and taxiway lights at 3000 volts.

(3) Connect both conductors and apply the test voltage for a period of 5 minutes between conductors and ground.

(4) During the last minute of the test, measure the insulation leakage current in microamperes. The measured value should not exceed 2 microamperes for each isolation transformer and 3 microamperes for each 1000 feet of cable.

(5) If the leakage currents exceed the above values, section off the current and repeat the above test for each section. Locate defective components and repair or replace them until the entire circuit passes the test.

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

Table 2-4. Initial Resistance Values versus Circuit Length (Series Circuit).

2-5. Recommended Vault Procedures:

a. Airfield Lighting Plan. Permanently and conspicuously post an airfield lighting plan in the vault, under transparent cover, to aid in testing and troubleshooting the field circuit loops. Make sure it shows the field layout, marked with the location of all lights, cable runs, cable splices, and visual aid equipment.

b. Schematic Diagram. Display an up-to-date diagram of all power and control circuits in the vault. Display 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.

c. Vault Security. Keep the vault locked, except during maintenance. Contact with the high voltage buses in an airfield lighting vault is usually fatal. So, allow only authorized personnel experienced in the hazards of high voltage in the vault. At least two qualified technicians should enter the vault together.

d. High-Voltage Warning Signs. Prominently display high voltage warning signs at appropriate locations as standard practice.

2-6. Runway and Taxiway Edge Lighting Systems (RTELS): (See RWP table 2-5)

a. Weekly Checks:

(1) Perform a visual inspection of the systems. This inspection should consist of a driving patrol to visually check for dimly burning bulbs, for burned-out lamps, and for fixtures out of alignment. Make corrections as soon as possible. Replace dimly burning lamps and burned-out lamps when the system is deactivated. If this is not possible and the system is energized, use rubber gloves and protectors, make sure the lamp is intact. Daily checks may be necessary at bases where the control tower does not report outages.

(2) Replace broken lenses with proper type and color. Make sure lenses are properly oriented with respect to the runway according to marking on top of lenses. Install split lenses or filters where required. Clean lenses as required.

(3) During the growing season, check for grass, dirt, and weeds around the lighting units. Make sure that vegetation does not block the pilot's view of the light. Contact the pest management shop for herbicide treatment.

b. Monthly Checks:

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

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

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

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

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 fixture where necessary to maintain this fixture and grade relationship. Also, maintain the elevation of all lights the same height above the runway or taxiway pavement edge. Check the elevation more frequently during times of frequent freeze and thaw cycles. The height of the lights should not exceed 14 inches (35 cm) when located within 5 feet of the runway or taxiway edge. In snow country, where the lights are beyond 5 feet (1.5 m) from the runway or taxiway edge, raise the lights 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 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) Carefully check each light fixture for cracking, corrosion, or shorts.

(2) Clean the contacts and make sure the lamp fits firmly into receptacle.

(3) Check condition of all connections.

(4) Check runway cable installation. (See paragraph 2-4d(2).)

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

Maintenance Requirement Checklist

*	W	M	SA	A	U
1. Inspect for outages; repair as necessary.	X				
2. Check for vegetation growth.	X				
3. Check cleanliness of lenses.	X				
4. Check light alignment and orientation.		X			
5. Clean fixtures and sockets.		X			
6. Check light elevation.			X		
7. Check for moisture in lights.			X		
8. Check for rust, paint deterioration.			X		
9. Inspect fixture for deterioration.				X	
10. Check cable insulation.				X	
11. Check gaskets.				X	
12. Remove snow from around lights.					X
13. Check aircraft arresting barrier marker light housings and distance markers for corrosion and serviceability.			X		

*LEGEND

A = Annually

M = Monthly

SA = Semiannually

U = Unscheduled

Table 2-5. Recurring Work Program Schedule for Runway and Taxiway Edge Lighting Systems.

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, place red flags or sticks of sufficient length adjacent to the edge lights to mark their location. The flags alert operators of snow removal equipment to use caution.

2-7. RTELS Maintenance Procedures. Following are general maintenance procedures for the runway and taxiway edge lighting system:

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

CAUTION: Deenergize the circuit and lock out the circuit or regulator so that the circuit cannot be energized from the remote lighting panel or other means before starting work on the lights. (See paragraph 2-6a(1) for energized replacement.)

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

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

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

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

(c) Inspect the lamp socket, the connections, and the 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. If possible, obtain prefocused, replacement lamp from the original lamp manufacturer, since lamps from other sources may change the lamp photometrics. When replacing quartz lamps, use clean gloves as fingerprints may shorten lamp life.

(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 using hoods or shields, check adjustment.

(5) When closing the light, be sure to position the gaskets 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) After correcting all outages, energize the circuit and make a visual check of the repaired units for proper operation.

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 of each isolating transformer use them to bypass a burned-out lamp and to keep the other lamps on the transformer operating. When replacing lamps in these lights, also replace the film disc cutout. Use the disc output of proper type and size. Place the film disc within the light enclosures and between the 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 shipped 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 out, as required. Keep light surfaces clean to transmit light satisfactorily. When establishing a cleaning program, first consider the sources of the dirt problem. Many airfield lights are at or near ground level and are subject to blowing dirt or dust, spattering rain, 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. Preventive measures may often reduce cleaning problems.

(1) When bird droppings are a problem, install a thin, stiff vertical wire on top of the light to help prevent birds from perching.

(2) When spattering is a problem, pave the affected area.

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

f. Cleaning Schedule. The cleaning schedule will vary at each location depending on such factors as environment, geographical location, and the type of lighting units. At least once a year, clean each light thoroughly

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

(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, clean glassware (but not reflectors) 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 in saturated ground. The water also may enter through conduits, cable, gaskets and seals, damaged glassware, or 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. Drill or clean out drain holes if already present. Check gaskets, seals, and clamps that may admit water. Replace chipped, cracked, or broken glassware. If water cannot be eliminated from light bases, make sure all electrical connections and insulation are watertight and above the waterline.

(a) When operating lights on brightness follow step B4 or B5 on control panel to dry up any condensation. If moisture problems continue, maintain a low brightness setting rather than turning the lights off. This should prevent more condensation from forming. Cost and energy conservation are factors in determining the efficiency of this method.

(b) To remove water in light bases, use a hand- or power-driven pump. Dip or mop the water.

(c) Modify light bases 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 forces the water up the tube and out of the base.

(d) Replace the cable 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 to prevent 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 allow easier removal and to lessen the possibility of moisture entry around threads.

(g) Draw the base flange bolts down in opposite pairs until all are tightened to the recommended torque. Avoid excessive torque.

i. Strikes and Blast Damage. Immediately repair or replace light units damaged by strikes from aircraft or vehicles, or by propeller or jet blasts. The fact that these lights have been hit indicates a critical need for them. Frequently check areas where this damage recurs. This is important because the attaching cable may also be damaged. When practical, replace the entire damaged unit. Simple repairs that can be accomplished usually consist of the following:

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

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

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

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

j. Frangible Coupling Replacement. Frangible couplings are primarily used 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 models require replacement of the entire column when the frangible point breaks.

(1) Remove damaged coupling.

(2) Use antisieze compound on new coupling threads.

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

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

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

(2) Apply suitable primer coat.

(3) Apply finish.

2-8. Constant Current Regulators. (See RWP table 2-6) Where measurement of current is called for, do not use the ammeter on the face of the regulator. This meter does not have the accuracy required for these measurements. Use a clamp-on ammeter, instrument transformer and ammeter, or similar setup.

a. Daily Checks. Check all control equipment for proper operation. Check remote control 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 (within ±5 percent of design voltage), notify the electrical superintendent.

(2) Check the load on the regulator by multiplying the input voltage times the input current times the regulator power factor (P = E x I x .95 pF). Make sure 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 c(3)(d) below. 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 completely burned or pitted through the silver contact surface, replace them. If the contacts touch only at points, or if they are slightly pitted or dirty, clean them. Use only tools designed to clean contacts. After cleaning, align the contacts 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. If the oil is dirty or the dielectric strength is low, replace or filter it and allow to dry to restore its dielectric strength. Wash out sludge deposits on the core and coil assembly and in the tank and clean with dry oil. Models with an internal primary switch will tend to collect more sludge due to arcing under oil. Fill with oil to the proper level. *WARNING: Since high open-circuit voltages may be obtained by opening the primary of a series lighting circuit, allow only qualified and authorized personnel to perform the short-circuit test, open-circuit test, or the load tests.* A series circuit connected across a 50 kW, 20.0-ampere regulator may have an open-circuit voltage of 3,500 volts. However, the momentary surge before the open-circuit protection device actuates will be more than this.

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

(a) Turn off power to regulator. Remove plug cutouts if present.

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

(c) Turn on the regulator, install plug cutouts 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
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 to use the correct voltage tap (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. Perform this test only on those regulators with open circuit protective devices.

(a) Turn off power to regulator.

(b) Disconnect cables from output terminals.

(c) Turn on power to regulator.

Maintenance Requirement Checklist

	* D	M	A	U
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 relay, 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

*LEGEND

A = Annually

D = Daily

M = Monthly

U = Unscheduled

Table 2-6. Recurring Work Program Schedule for Constant Current Regulators.

(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.

2-9. Centerline and Touchdown Zone Lighting System (CTZLS). (See RWP table 2-7) Because semiflush lights are installed in the aircraft traffic area and are run over by aircraft, they are high-maintenance items that require frequent attention to maintain specified performance. Also their location below ground level make them prone to water infiltration; this also requires frequent attention. Remember these problems when performing RWPs and determining bench stock levels.

a. Weekly Check. Field electrician inspect and service any lights reported as defective by the control tower during their daily inspections. The preferred method of servicing is to replace the semiflush light unit with a spare and take the defective unit back to the shop for repair. Shop repair prevents possible contamination and loss of parts in the field. Deactivate the lighting circuit (fuses pulled) before attempting any maintenance on the lights. The following defects may be the cause of the malfunction.

(1) No Light:

(a) Burned-out Lamp. Replace the lamp according to the manufacturer's instruction book. Replace the fused disc cutout 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 chapter 3.

(2) Dim Light:

(a) Dirty Light. The exposed optical surface of the semiflush light gets dirty from exposure to aircraft traffic and weather. Periodically, clean the lights as described in paragraph 2-10.

(b) Light Aiming. Shallow base semiflush light fixtures sometimes are twisted out of alignment by aircraft landing or turning. Visually check any dimly burning lights to see if they are merely misaligned. The alignment procedure is discussed in paragraph 2-10.

(c) Water in the Fixture. Examine the lens for standing water or condensation behind the lens. If water is present, remove the fixture and service according to paragraph 2-10.

(d) Improperly Sized Bulb. Check for proper bulb.

b. Quarterly Checks:

(1) Bolt Torque. The impact of aircraft wheels can loosen mounting bolts, cause misalignment of fixture and foreign object damage (FOD) to aircraft. This is particularly troublesome in the touchdown zone. Check cover assembly and optical base assembly holddown bolts every 3 months and when servicing. Ensure that bolts are properly torqued: 15 foot-pounds on light cover assemblies and 15 foot-pounds on optical base assemblies. Use a commercial bolt thread compound to keep bolts tight. If a bolt is stripped, retap and install a larger bolt until a new unit can be installed. If a bolt cannot be properly torqued, replace the unit.

(2) Specifications. All securing hardware must meet FAA requirements and manufacturer's recommendations. FAA Advisory Circular 150/5345-46, Specification for Semiflush Airport Lights, requires holddown bolts used for fastening the top assembly to the base to be 3/8-inch x 16 N.C., 7/8-inch in length, and in addition requires 3/8-inch external tooth lock washers to be used under the bolt heads. The bolt and lock washers must be fabricated of 410 stainless steel.

(3) Fixture Bases. Reset Loose fixture bases as soon as possible using a compound comparable to FAA Circular AC-150/5370-10, Item P-606 for sealing wire and lights in pavement.

c. Semiannual Checks:

(1) Remove light, and clean and service according to paragraph 2-10. If an intensity check reveals that the light has enough brightness, do not disassemble it; but do remove the light from its base and examine the base and cable connections.

(2) Check the base for the presence of water. If water is found, remove it and seal the base to prevent its reentry. Make this check more frequently in winter months. Freezing can cause damage to the fixture by shearing the fixture holddown bolts or rupturing the base.

Maintenance Requirement Checklist

	*	W	Q	SA	U
1. Repair or replace defective lights.		X			
2. Clean lights with dirty lenses.					X
3. Check the intensity of selected lights.					X
4. Check the torque of mounting bolts.			X		
5. Clean and service light; check electrical connections.				X	
6. Check for water in the light base.				X	
7. Remove snow from around fixtures.					X
8. Check wires in saw kerfs.					X

*LEGEND

Q = Quarterly

SA = Semiannually

U = Unscheduled

W = Weekly

Table 2-7. Recurring Work Program Schedule for Centerline & Touchdown Zone Lighting System.

d. Unscheduled Maintenance:

(1) After snow removal operations, inspect all lighting fixtures and replace any damaged light assemblies. If snow removal is a frequent winter job, install high-strength steel light fixtures to better withstand the impact of snow plowing.

(2) Check wireways in saw kerfs. If wires are floating out, reinstall using wedges for assembling wires. Space wedges 2 feet (60 cm) on center. Seal wireways with a sealer referenced in b(3) above.

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

(4) Intensity Checks. To complement the cleaning process, check the light output of several fixtures located on different parts of the field, particularly near the ends and in the touchdown zone. Measure the light output with a photographic 1 degree spotmeter. Do this:

(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. Schedule lights that are below minimum levels for removal and servicing.

2-10. Centerline and Touchdown Zone Lighting Systems Maintenance Procedures. Service semiflush lighting when anticipating the minimum disruption of normal airfield operations. Keep spare fixtures on hand to replace defective fixtures. By replacing the defective light with a spare unit, minimum time is spent on the runway. Repair the defective light in the shop. The procedures below are a generalized approach to repair. For more specific information about a particular light, consult the manufacturer's instruction book.

a. Light Removal. Remove the light fixture 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.

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

(1) Use commercially available cleaning detergents and pads to manually remove deposits from the lighting fixture lens, unless prohibited by the manufacturer. Do not use abrasive materials such as sandpaper or emery cloth as they will scratch the glass. Solvents are available that will clean the lens. Make sure the solvent used is 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) Clean the light fixture using 20/30 grade, clean, ground walnut or pecan shells, and clean, dry compressed air or nitrogen (nozzle pressure 85 psi), unless prohibited by the manufacturer. Figure 2-1 shows a typical example of how to clean the lighting fixture with shells. It also shows a worker operating the nozzle sitting on the vehicle tail gate with feet hanging. Personnel must not be in this position while vehicle is in motion.

(a) Cleaning the external surface of the lens takes an average time of 10 seconds.

(b) The cleaning system shown is not available as an assembled unit; but use a commercially available air compressor with controls and gauges, a sandblaster unit, and abrasive resistant hoses.

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

(d) After removing deposits from the lens, clean the fixture's light channel of shells with a blast of air, and wipe off the remaining dust with a clean cloth.

(3) Use an abrasive brush to clean rubber deposits by mounting it on a rotary hand tool powered by air pressure or electricity. The average cleaning time is 30 seconds per lens. Be careful not to remove the lens-sealing material in the cleaning process; use a shield.

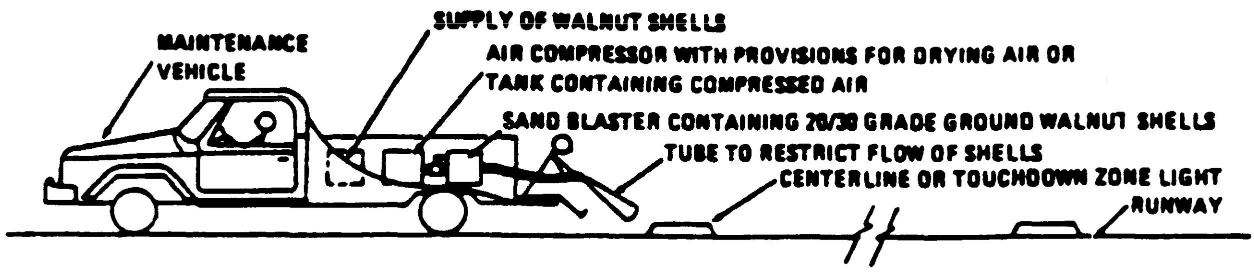

Figure 2-1. Cleaning Centerline and Touchdown Zone Lights.

c. Light Aiming. Aim the semiflush lights as part of the installation procedure. The lights on top of transformer housings are pre-aimed and cannot be adjusted. For lights installed on glue-in bases, the aiming may come out of alignment due to twisting of the light bases. Align the runway centerline lights to within 2 degrees of a line parallel to the runway centerline. When reinstalling the base, use an adhesive compatible with the type of pavement. Recommend the adhesive product conform to specifications listed in Federal Aviation Administration (FAA) Circular AC-150/5370-10 Item P-606. Be sure to choose the correct mixture. Check the aiming of semiflush lights by turning the lights on during foggy weather. The fog makes the light beam visible and it is easy to tell if a light is properly oriented. For touchdown zone lights, offset the light beam 4 degrees toward the runway centerline. Judge the aiming of touchdown zone lights by viewing the barettes on either side of the runway while standing on the centerline. When viewing the barettes on either side of the runway from some distance, check all light appearing dimmer or brighter than the lights next to it, and make sure it is properly aimed.

d. Light Cleaning and Sealing. Semiflush lights gradually get dirty internally. Clean the internal optical surfaces when the light is disassembled for relamping or maintenance. Use sandblasting to clean rubber deposits off the casting after removing all removable parts. Use a cleaning solution that does not leave a residue after drying. When relamping a light, especially quartz, use clean gloves or handle the lamp by the leads only; fingerprints on the glass assembly shorten lamp life. Mount lamps in brackets according to manufacturer's recommendations. Using the wrong lamp or improperly mounting it can drastically reduce the light output of the fixture. When reassembling the light, carefully examine all gaskets and O-rings for cracks. tears, or malformation that prevent them from resealing properly. Examine the optical prism to make sure that the sealer around the edges is in good condition. If the optical prism is cracked or badly pitted, replace it.

e. Reinstallation. When mounting a semiflush unit on its base, be sure to seal it watertight. Seal the fixture connections to the series circuit with two layers of plastic tape or with heat-shrinkable sleeving. Also varnish the connection with a heat-resistant varnish to further improve the sealing of the gasket. Make sure its mating surface is free of sand or grit. This is a common fault in servicing that allows moisture to enter. Use a graphite compound or gasket cement on the gasket surfaces to ensure a watertight seal. Securely tighten all fixtures to the manufacturer's specified torque. Clean the bolts and threads; coat the threads with a securing compound.

f. Water Removal. The procedure for removing water from the base of semiflush lights and preventing reentry is similar to that described in paragraph 3-7 for runway edge lights. If the fixture itself leaks, install new gaskets and sealants.

2-11. Visual Approach Slope Indicator System (VASI): (See RWP table 2-8)

a. Daily Checks. Check that all lamps are burning and are of equal brightness. Adequate spare lamps should be available to permit complete replacement of all lamps in the system. Stock spare bypass (grasshopper) fuses, if used. Immediately replace lamps if they burn out or become darkened. If the Visual Approach Slope Indicator (VASI) uses bypass fuses, check the associated fuse before replacing a lamp.

b. Monthly Checks:

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

(2) Check for damage by mowers or snowplows.

(3) Clean lamps and filters.

Maintenance Requirement Checklist

	* D	M	SA	BE
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 insulation resistance of underground cables.			X	
13. Check resistance of grounding system.				X

*LEGEND

BE = Biennially

D = Daily

M = Monthly

SA = Semiannually

Table 2-8. Recurring Work Program Schedule for Visual Approach Slope Indicator (VASI) System.

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

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

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

(7) Check for burrows or other signs of rodent activity in vicinity of cables; take steps to discourage their presence to reduce chances of cable damage.

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

(9) Check the horizontal and lateral alignment of the light boxes, and check the aiming (vertical angle) with the VASI aiming bar (see paragraph 2-12 for procedures). Coordinate the correct horizontal and lateral alignment with airfield management. Record the date and angle setting. Check the aiming frequently when the soil freezes or thaws or has a change in moisture content (especially clay soils).

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

c. Semiannual Checks. Check insulation resistance of underground cables and record the results.

d. Biennial Checks. Perform a ground resistance measurement of ground rod every 2 years using a vibraground test meter. If the resistance is greater than 25 ohms, lower the resistance.

2-12. VASI Maintenance Procedures:

a. Adjusting the Vertical Aiming. This is normally done with an aiming bar, calibration bar, and small (machinist's) level. Carefully handle these precision instruments. Make sure the aiming bar is the one with the VASI light units. When checking the VASI:

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

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

(3) Turn the small level 180 degrees to check for centering of the bubble. If it does not check when reversed, adjust the small level so that the bubble will remain centered when the small level is reversed.

(4) Place the aiming bar on the calibration bar and check that its spirit level remains centered in the 0 degrees, 3 degrees, and 6 degrees positions and settings. Adjust spirit level if necessary to center the bubble. If the bubble cannot be centered at each of the three angles, replace the aiming bar.

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

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

(7) Set the proper angle on the aiming bar (usually 2 1/2 degrees for light bar No. 1, closest to runway end, and 3 degrees for light bar No. 2) and insert through the aperture so the end of the aiming bar resets on the transition bar.

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

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

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

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

b. Checking Adapter Unit Current Output:

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

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

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

2-13. Precision Approach Path Indicator System (PAPI): (See table 2-9)

a. Purpose of PAPI. A PAPI system consists of four identical light units (FAA Type L-880). Normally, these light units are positioned to the left side of the runway and provide the aircraft pilot approaching the runway with the correct glide slope. When on a correct glide slope the pilot can see two red and two white lights in a bar. If the aircraft is below the glide slope, the pilot can see a progressively increasing number of red lights. Conversely, if the aircraft goes above the glide slope, the pilot will see the number of white lights increase.

b. Optics Operation. A PAPI unit contains two or three projector modules. When viewed from a distance, the projected light beams appear as a short horizontal bar. Each projector contains a lamp, reflector, color filter, baffle, and lens. The edge of the color filter is precision ground. It provides a very sharp transition between the red and white portions of the beam. If it becomes necessary to change the filter or lens, refocus the filter.

c. Tilt Switch. Each light unit contains a tilt switch mechanism. This mechanism is factory adjusted to open circuit if the light unit becomes misaligned more than 1/2 degree down or 1 degree up.

2-14. PAPI Maintenance Procedures:

a. Daily. Inspect for burned-out bulbs and replace if necessary.

b. Weekly. Clean and inspect lens filters and reflectors.

c. Monthly:

(1) Verify light unit elevations.

(2) Check tilt switch system by pulling on tilt switch cord. System should not stay on for more than 30 seconds.

(3) Verify tilt switch mechanism alignment.

d. Semiannually:

(1) Verify complete base casting alignment.

(2) Check power and control unit for loose connections, broken or missing parts.

(3) Operate unit in brightness steps; first by local control; then by remote control (if used).

(4) Remove dust buildup from power and unit.

Maintenance Requirement Checklist	* D	W	M	SA
1. Inspect burned out bulbs.	X			
2. Clean and inspect lens filters and reflectors.		X		
3. Verify light unit elevations.			X	
4. Check tilt switch system.			X	
5. Verify tilt switch mechanism alignment.			X	
6. Verify base casting alignment.				X
7. Check power and control unit.				X
8. Operate unit in brightness steps.				X
9. Clean Equipment.				X

*LEGEND

D = Daily

M = Monthly

SA = Semiannually

W = Weekly

Table 2-9. Recurring Work Program Schedule for Precision Approach Path Indicator (PAPI).

2-15. Pulse Light Approach Slope Indicator (PLASI): (See table 2-10)

a. Purpose of PLASI. A PLASI system, when properly installed and oriented, furnishes the pilot with precise visual approach slope information for safe descent guidance to an airfield. The PLASI provides this visual vertical glide path information by projecting a beam of light along the desired descent path to the touchdown point. PLASI is a ground installed self-contained device housed in a single box. From the pilots view the device generates and projects four horizontal bands of light, only one of which can the pilot see at a given instant.

Maintenance Requirement Checklist

Maintenance Requirement Checklist	*	SA	U
1. Inspect external beam index mark.		X	
2. Inspect air inlet filter.		X	
3. Inspect drive chain.		X	
4. Check upper and lower shutter chains.		X	
5. Check oil level.		X	
6. Check photocell operation.		X	
7. Replace failed lamps, adjust positions and clean surfaces.			X

*LEGEND

SA = Semiannually

U = Unscheduled

Table 2-10. Recurring Work Program Schedule for Pulse Light Approach Slope Indicator (PLASI)

b. Functional Characteristics of Lighting. The center light band is a steady white light projected at a 0.35 $\pm$0.02 degrees high angular wedge, 16 degrees wide with the apex at the PLASI. This center band defines the correct glide path. The upper band of white light pulsing at 2.2 pulses per second is a wedge approximately 2.5 degrees high by 16 degrees wide,which gives "above glide path" indication. A similar lower band of pulsing red light provides the "below glide path" information. In between the steady white on-glide path signal and the pulsing red below-glide paths signal is a solid red sector of .175 degree height by 16 degrees width which is the slightly below glide path signal and advises the pilot that he is at 2.65 degrees (for 3 degrees approach) when at the lower edge of the steady red. The pulses of the white "above" and red "below" lights vary in length continuous at the edge of the glide path to zero length at the "off-glide path" limit of visual contact. This variation in light pulse length, long near the path, and becoming shorter and shorter as deviation from glide path increases, gives the pilot quantitative information on deviation. Rate of change of pulse length provides rate of deviation from or closure with the glide path. Figure 2-2 is a pictorial representation of the pulse light signals. The visual presentation is accomplished through the use of optical components, a moveable shutter and red filter. One tungsten-halogen lamp is positioned behind a condenser lens. For reliability, an automatic lamp changer inserts a new lamp within 1 to 4 seconds if the one in use should fail.

2–16. PLASI Maintenance Procedures:

a. Semiannual Checks. Always turn the power off before opening the housing.

(1) Open housing top and securely latch. Make sure the external level beam index mark is set to the desired approach scale on the degree scale, and that the bubble in the beam level is centered. Adjust if necessary.

(2) Inspect the air inlet filter to the dual fan motor. If the filter is corroded or damaged, replace with a new filter. If filter is dirty, remove and clean with a water and detergent solution. Rinse thoroughly, air dry, and replace.

(3) Check the drive chain for proper tension with the power on and the chain running, it should be possible to deflect the top strand of the chain approximately 3/8 inch. Adjust if necessary after turning the power back off. Lubricate the chain sparingly with SAE 50 weight nondetergent oil. Check the tightness of all sprocket set screws (6 locations).

(4) Check the upper and lower shutter chains for correct tension. With the power on and the chains running, the chain sag should be approximately one-eighth of an inch. Turn the power off and adjust if necessary. Check tightness on all six sprocket set screws. Lubricate sparingly the chains and sprocket teeth with SAE 50 weight nondetergent motor oil. Do not contaminate the red filter or condenser lens with oil.

(5) Remove oil plug on the shutter motor and check oil level in the gear case. Add SAE 50 weight nondetergent oil as required.

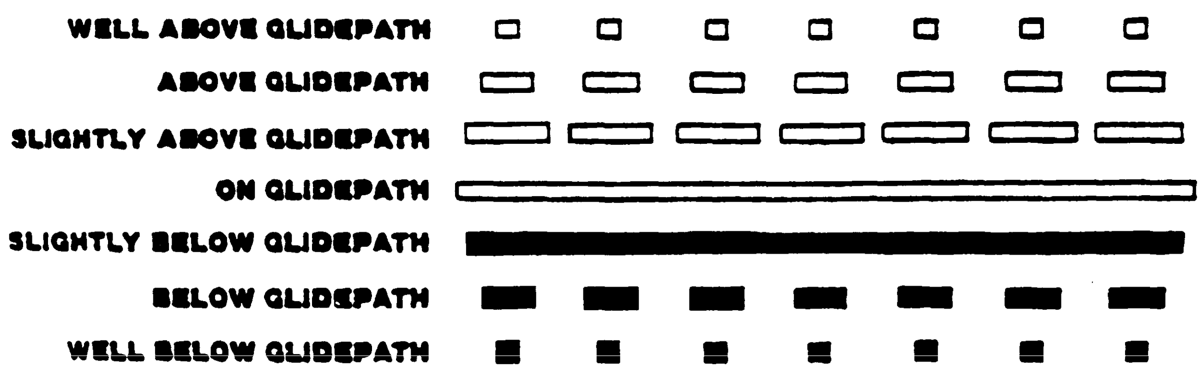

Figure 2-2. Pictorial PLASI Pulse Signals.

(6) Check for correct photocell operation with the system operating on daytime lamp voltage, cover the photocell. Within 3 minutes the photocell should reduce lamp voltage to the night setting (approximately 30 to 40 volts). Uncover the photocell and within 3 minutes full voltage should return to the lamps.

b. Unscheduled Checks:

(1) Replace failed lamp when so indicated by the illumination of the red indicator lamp. Move the lamp in service to the number 1 socket and install new lamps in all other sprockets. Do not touch lamps with bare fingers as body chemicals will cause lamp to become opaque. Use a clean cloth or gloves when handling lamps. If lamp surfaces are touched clean with alcohol. Reset the lamp table so that the number 1 lamp is in the service position and turn on the power. Trigger the lamp table through all positions. Check for proper operation of all the lamps and that the table seats in the detent roller at each position. External red lamp should be illuminated when lamp number 5 is operating. Turn off the power and reset lamp table to the number 1 position.

(2) When replacing a lamp, clean the inside and outside of the front window, condenser lens, the objective lens and the red filter with a high quality lens cleaning fluid. Replace any damaged optical component.

2-17. Hazard Beacons and Obstruction Lights: (See table 2-11)

a. 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.

b. Annual Checks:

(1) Check the condition of the wire, insulation, splices, switches, connections and fuses. Check the fuse size (should not be more than 120 percent of rated load). The fuseholder should be tight with clean uncorroded contacts. Check the wiring for loose connections and the insulation for breaks or fraying. 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 using a booster transformer, check the input and output voltage levels.

(3) Check gaskets and seals for leaks. Adequate weatherproofing is necessary for the protection of lights. Replace all cracked or deteriorated gaskets. 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, coat both gasket and seal with cement and permit to dry until tacky before placing the gasket 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 missing mounting brackets. Repair as required.

(5) When obstruction lights are mounted on disconnect hangers equipped with lowering devices, clean and lubricate the wire guides, pulleys, fittings, supports, and cables. Also, clean the contact surfaces of the electrical disconnect.

(6) Service the duplex obstruction lights as described above. If using a changeover relay, clean it and keep the relay housing gasket in good condition. Replace all missing cover screws to prevent water, moisture, and dust from entering the relay enclosure. A transfer relay (when installed) allows only one light in the double obstruction light to be energized at a time. When the first lamp fails, the relay transfers power to the standby lamp. The transfer relay is usually mounted in the fixture base. Also, the light assembly usually has a remote pilot lamp conspiciously located to signal that a lamp has burned out. Check the operation of this remote lamp.

(7) Annually or when replacing a lamp, clean and recondition the beacon following 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.

Maintenance Requirement Checklist

	* M	SA	A
1. Check flash rate of hazard beacons.	X		
2. Check operation of photocell.	X		
3. Check insulation resistance and ground resistance.		X	
4. Check wire and connections.			X
5. Check voltage at lamp socket.			X
6. Check weatherproofing of the fixture.			X
7. Check lightning protection system.			X
8. Check power meter.		X	
9. Service lowering device and other supporting hardware.			X
10. Check changeover relay in dual fixture.			X
11. Clean and recondition beacon.			X

*LEGEND

A = Annually

M = Monthly

SA = Semiannually

Table 2-11. Recurring Work Program Schedule for Hazard Beacons and Obstruction Lights.

(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 deenergized.

c. Unscheduled Maintenance. Change the lamps as necessary. Make certain that the correct lamp is in place. Allow the new lamp to burn for a few minutes to make certain that the lamp is not defective.

2–18. Runway End Identification Lights (REIL) and Omnidirectional Approach Light System (ODALS): (See table 2-12)

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

b. Quarterly Checks:

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

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

(3) Check for damage or misaligned lights.

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

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

c. Semiannual Checks:

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

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

(3) Check and adjust alignment and level of light units. For omnidirectional units, check only the level. For unidirectional REILs, check alignment and elevation using figure 2-3 and 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) Follow the procedure below to align the unidirectional REIL:

(a) To check for 15 degrees toe-out, hold the triangle horizontally with the 15 degrees angle pointed toward the other light unit. Do this by aligning the outside edge of the triangle to point at the opposite light unit, 15 degrees toe-out.

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

(5) Check level of ODALS optical heads.

(6) Check baffles, if used on REIL. Where baffles are installed, aim the light units at an angle of 3 degrees vertical and toe out 10 degrees. Slope down the louvers 10 degrees toward the runway and 5 degrees down toward the approaching aircraft. Paint the louvers black to lower the reflected light.

d. Annual Checks:

(1) Carefully inspect all power distribution equipment and protective devices at terminal pole and lights.

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

(3) Repaint as required.

Maintenance Requirement Checklist

	* D	Q	SA	A
1. Check operation of lamps.	X			
2. Check the operation of controls.		X		
3. Check cleanliness of optical systems.		X		
4. Check for mechanical damage of 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.			X	
10. Check level of optical heads for ODALS.			X	
11. Check baffles on REIL (if used).			X	
12. Check power distribution equipment.				X
13. Check resistance of grounding system.				X
14. Service timer motor and contacts (if used).				X
15. Check need for painting.				X

*LEGEND

A = Annually

D = Daily

Q = Quarterly

SA = Semiannually

Table 2-12. Recurring Work Program Schedule for REIL & ODALS.

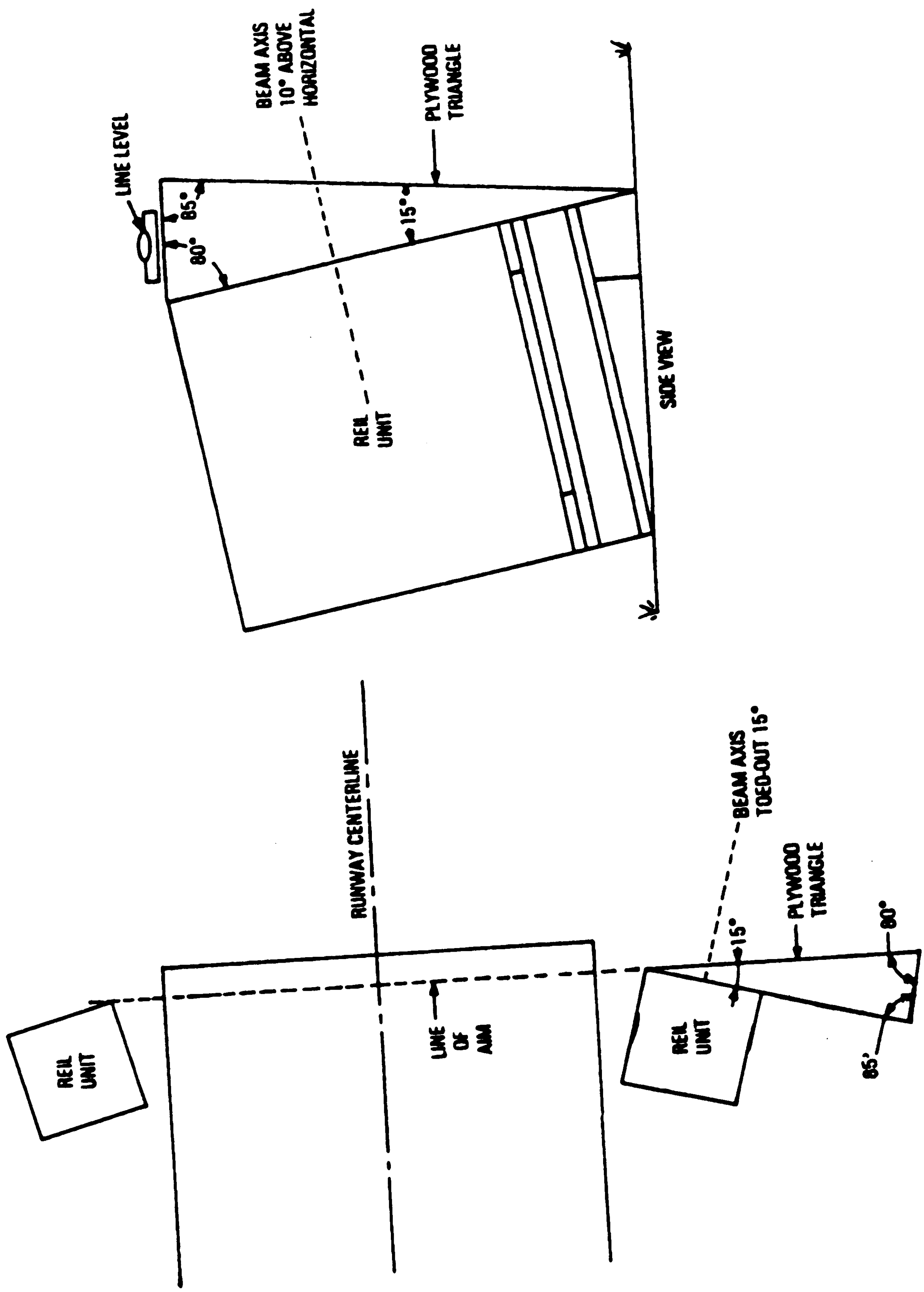

Figure 2-3. REIL Aiming.

2–19. High Intensity Approach Lighting Systems: (See table 2-13)

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

b. Weekly Checks:

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

(2) Replace burned-out lamps as necessary.

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

c. Monthly Checks:

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

(2) Clear vegetation or obstructions from the front of semiflush and ground-mounted lights to ensure adequate visibility. The Roads and Grounds Section has approved chemicals to help control the growth of vegetation around the lights.

d. Semiannual Checks:

(1) Check all light fixtures for alignment. (See AFR 88-14.) 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 all 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 foot-candles and to turn off at 58 foot-candles. If the unit is properly adjusted, the system will operate on the high brightness position on a relatively clear day from approximately 1/2 hour after sunset to 1/2 hour before sunrise. Also, check the orientation of the photoelectric cell. Orient the cell by aiming at an angle of 25 degrees from the vertical pointing toward the ground. 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 all 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 fuseholders, 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.

Maintenance Requirement Checklist	* D	W	M	SA	A
1. Check for burned-out lamps.	X				
2. Check system operation.		X			
3. Replace burned-out lamps.		X			
4. Check semiflush 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 photoelectric controls (if used).				X	
10. Check electrical distribution equipment.					X
11. Check insulation resistance of cable.					X
12. Check fuseholders, breakers, and contacts.					X
13. Lubricate sequenced flasher position timer				X	

*LEGEND

A = Annually

D = Daily

M = Monthly

SA = Semiannually

W = Weekly

Table 2-13. Recurring Work Program Schedule for High Intensity Approach Lighting Systems.

Chapter 3

Troubleshooting Procedures for Series Lighting Circuits

3-1. What This Chapter Covers. This chapter covers general troubleshooting procedures for isolating a fault in all types of airfield series lighting circuits. The troubleshooting procedures in paragraphs 3-3 through 3-11 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 of which circuit is not operating satisfactorily. Start the tests from a check in the vault. It is presumed that the problem is more involved than a burned-out lamp, although these procedures will result in isolating a burned-out lamp if that is the problem.

3-2. Safety Precautions. Troubleshooting tests in this chapter often involve voltages that are dangerous. *Exercise safety precautions for the protection of personnel and equipment. Make sure only experienced personnel in high voltage techniques test and troubleshoot lighting circuits.* All maintenance personnel should be thoroughly trained in emergency procedures for treating electrical shock.

3-3. Initial Fault Isolation Procedures:

a. Preparing To Test Circuit. Select the circuit to be tested and set the brightness switch to 100 percent intensity.

b. Measuring Load Current. Energize the regulator and measure the load current. Be sure current is set to the values given in paragraph 2-8. If the load current is normal, proceed to d below. If the load current is out of tolerance, adjust the current according to the procedure in the instruction manual.

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

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

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

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

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

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

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

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

(a) Burned-out lamps.

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

(c) Faulty isolating transformers.

(d) If the maximum brightness current is still too high when all lamps are back in operation, then perform paragraphs 2-4 and 2-5 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.

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

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

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

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

(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 paragraph need not be checked. Make repairs as required for burned-out lamps, wrong type of lamps, blown or omitted film cutouts (where used), and 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 exactly locating the position of the ground is required, refer to paragraphs 3-4 and 3-5.

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

3-4. 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 correct any other problem. Grounds are usually easier to locate, and often occur in conjunction with opens, overloads, or shorts.

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

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

c. Determining Ground Faults. Low insulation resistance values may be obtained for a circuit even though there is no specific fault in the cable (paragraph 2-4d(2)). Often this is the result of leakage through the insulation of isolating transformers or cable connectors. To determine that the ground fault is exclusively a cable problem, free any suspected sections of all connections and test independently.

d. Fault Characteristics. The type of fault in underground cable may often be inferred from the symptoms and nature of the failure. If the log of insulation resistance readings (paragraph 2-4) shows a gradual decline, the cable insulation or a splice probably failed somewhere. If the circuit catastrophically fails while excavation is going on nearby, it is likely that there is mechanical damage. If a string of lights is dim, it is likely there are two faults in the circuit. Such deductive reasoning may save steps in finding the problem.

3-5. Procedure for Locating Grounds. Grounds or shorts may be present and the location may not be readily apparent from the appearance of the lights. If this happens, disconnect the field circuit from the runway selector cabinet or constant current regulator and measure the insulation resistance of each feeder. To measure insulation resistance use an insulation resistance tester. As each fault is cleared, repeat this insulation resistance measurement for the circuit to determine if other grounds exist. If a combination of faults exists, clear the grounds first because these faults are usually easier to locate and often occur in conjunction with opens, overloads, or shorts. Clear any high resistance grounds and then locate any remaining opens, overloads, or ungrounded shorts.

a. Operating Circuit Tester. After the proper connections have been made between the tester and the circuit, operate the tester for approximately 1 minute. At the end of this time, record the insulation resistance value. If the tester reads zero there are one or more grounds to locate before finding other faults.

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

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

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

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

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

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

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

(3) If all of the lights appear to operate satisfactorily, move the intentional ground to the other feeder; energize the circuit and make a visual check of the operation of the lights as described in (1) and (2) above.

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

3-6. Locating and Isolating Ungrounded Circuit Shorts. When ungrounded shorts are present, make an initial analysis by energizing the circuit and visually determining which lights are operating. Then, further isolate the fault by using a clamp on ammeter or performing a circuit analysis test as described below.

a. Isolating Undergrounded Shorts. Make the initial analysis of underground shorts by inspecting the operation of the lights with the circuit energized.

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

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

b. Using the Ammeter. To locate ungrounded shorts using a clamp on ammeter, select a test point. The lights may reveal where the problem area is; if not, select a test point at the start of one feeder and progress systematically through the field circuit. Connect the ammeter around the conductor of the circuit. Energize the circuit with the regulator and read the current in the circuit at the test point. *WARNING: Do not come in contact with the cable or meter while the circuit is energized.* If the meter must be handled or attached to the circuit while the circuit is energized, use a hot-line clamp stick.

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

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

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

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

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

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

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

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

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

3-7. Isolating Open Circuits. Before checking for open circuits, be sure to remove any grounds as described in paragraphs 3-4 and 3-5. An insulation resistance test provides the quickest test. If the insulation resistance of both feeders is satisfactory, find the ungrounded open fault using the intentional ground and open-circuit test, the insulation resistance tester, or the cable test set.

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

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

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

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

(4) Sectionalize the circuit, using intentional grounds by grounding one feeder in the vault, and at a selected test point. Also ground the conductor of the circuit without breaking continuity. Energize the circuit and check the operation of the regulator to see if the protective relays turn it off.

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

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

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

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

NOTE: The ground at the selected test point must provide adequate continuity to the system ground. If desired, ground the circuit at the selected point and make the measurements in the vault.

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

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

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

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

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

e. Use of the Voltmeter. Use a voltmeter to locate ground faults or open circuits using probes. This technique is not suitable for lights mounted in paved areas. The procedure is described below.

(1) Determine type of faults, such as whether it's an open circuit or grounded. If grounded, lights will burn dimly between grounded points, or there will be a section of lights out. If open circuit, a high-resistance reading will be obtained between ends of the field loop cables at the regulator, and the open-circuit protector at the regulator will be tripped (if so equipped).

(2) If cables are grounded, turn the regulator "ON." If cables have an open circuit, disconnect the cables from the regulator and connect two 300-watt incandescent lamps in parallel with each other and in series with the lighting circuit. Connect to 120 volt AC source (or use two 300 watt lamps in series with each other and in series with the lighting circuit and use 208-volt or 240-volt supply). This will limit the current to 0.8 amperes (120 C) or 0.4 amperes (240 V).

(3) Use a sensitive VOM with an input impedance not less than 20,000 ohms/volt AC. Connect the meter terminals for AC volt measurement to a 1/2-inch- diameter solid-aluminum rod 4 feet long with 25 feet of No. 12 or No. 14 wire.

(4) Set the meter on high AC scale and work down to low scale. Starting at home, run

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

f. Example Problems. The following are several examples of finding locations of open circuits in certain lighting circuits.

(1) One Open in the Circuit:

(a) The following conditions exist:

1. There is only one open in the circuit.

2. The circuit is free from grounds, including the location of the open.

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

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

1. Disconnect the series-loop wires from the regulator-output terminals or runway circuit selector. Call these wires L1 and L2. (See figure 3-1.)

2. Ground L1 and the midpoint of the series loop at Gm without breaking continuity.

3. Check with a megohmmeter for continuity across L1 and L2.

4. If there is continuity, the open is between L1 and Gm.

5. If there is no continuity, the open is between L2 and Gm.

6. To double check the above finding, remove ground from L1 and ground L2 and repeat the procedure.

7. Where the open is between L1 and Gm, ground L1 and move ground Gm toward L1 along the circuit to locations (light stations) G1, G2, and G3. Ground one location at a time. (See figure 3-2.)

8. The open is between the last ground location (G2) which will give continuity across L1 and L2 and the first ground location (G3) which will cause no continuity L1 and L2.

9. In case the continuity is obtained with circuit grounded at the last light on the L1 side of the loop (closest to the L2, such as where the home run begins), then the open is on the L1 side of the home run.

10. To verify this, move ground from L1 to L2; leave ground at the last light (as in previous step).

11. When check for continuity is made across L1 and L2, there should be no continuity.

12. Where the open is between L2 and Gm, use steps 7 through 11, but in place of L1, use L2.

(2) Several Opens in the Circuit:

(a) The following conditions exist:

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

2. The circuit is free from all grounds, including at open fault locations.

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

(b) Use the following procedures to locate the opens:

1. Disconnect the series loopwires from the regulator or circuit-selector switch output terminals. Call these wires L1 and L2. (See figure 3-3.)

2. Ground L1 and midpoint of the loop at Gm while maintaining continuity.

3. Check with a megohmeter for continuity across L1 and L2.

4. If there is continuity, there are no opens between L2 and Gm; and therefore, all the opens are between L1 and Gm.

5. If there is no continuity, there are opens between L2 and Gm. This does not mean there are no opens between L1 and Gm.

6. To find out whether there are any opens between L1 and Gm, remove ground from L1 and ground L2. Leave Gm in, and repeat 3, 4, and 5 above.

7. Where the opens are only between L1 and Gm, ground L1 and move ground Gm toward L1 along the circuit to locations (light stations) G1, G2, or G3. Ground one location at a time. (See figure 3-4.)

8. The first open is between the last ground location which will give continuity across L1 and L2 and the first ground location which will cause no continuity across L1 and L2.

9. Repair the open and continue moving the ground toward L1 until all opens are located and repaired.

10. When the opens are only between L2 and Gm, repeat 7 through 9 above, but in place of L1, use L2.

11. Where there are opens between L1 and gm as well as between L2 and Gm (in both halves of the loop), ground L2, leave Gm in. (See figure 3-5.)

12. Ground a point (G1) near L1 (preferably the first light on that side of the loop) and continue moving this ground (G1) to locations

G2 or G3 away from L1. Check the continuity at each position.

13. The first open is between the last ground location which gives continuity across L1 and L2 and the first ground location which gives no continuity across L1 and L2.

14. Repair the open and continue moving the ground toward Gm until all opens between L1 and Gm are repaired.

15. To find opens between L2 and Gm, follow 11 and 14 above, but in place of L1, use L2.

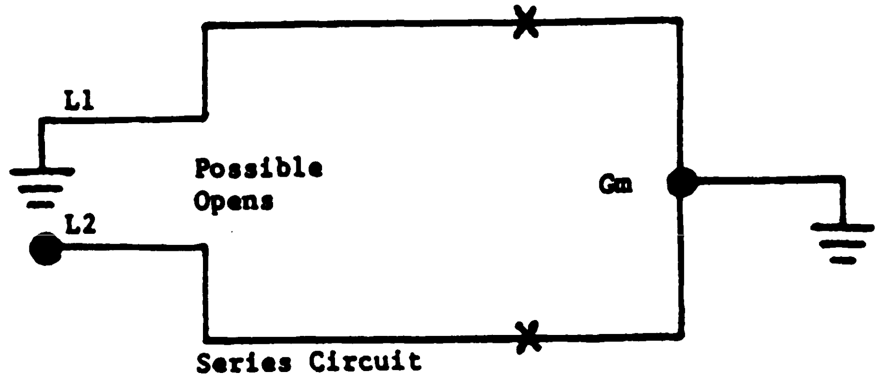

Figure 3-1. One OpenCircuit, Test Example.

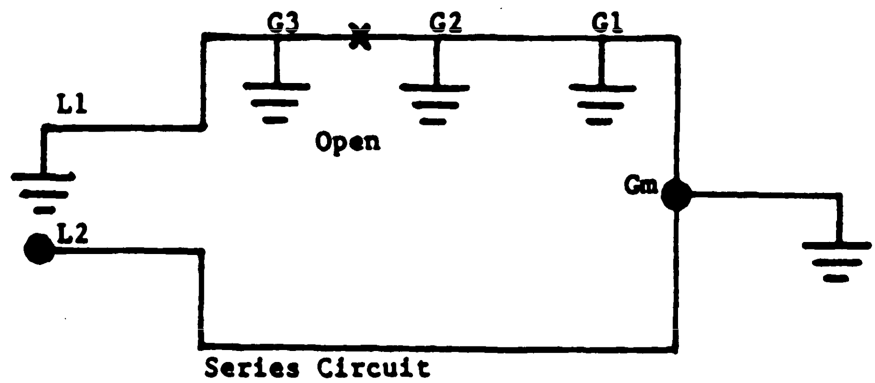

Figure 3-2. Test Grounding With One Open Circuit.

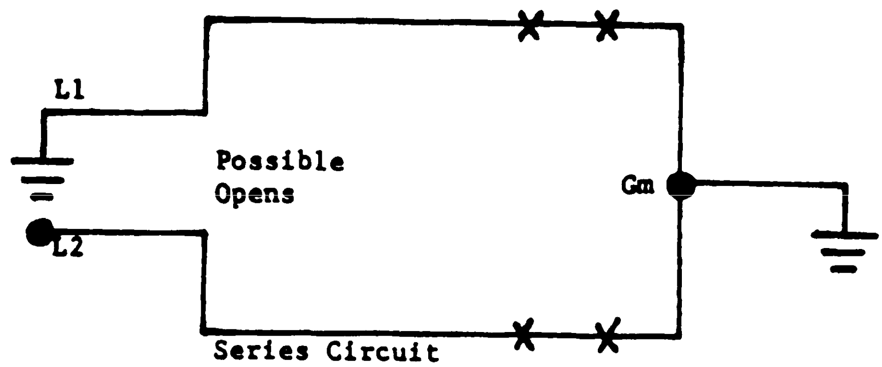

Figure 3-3. Multiple Open Circuits, Test Example.

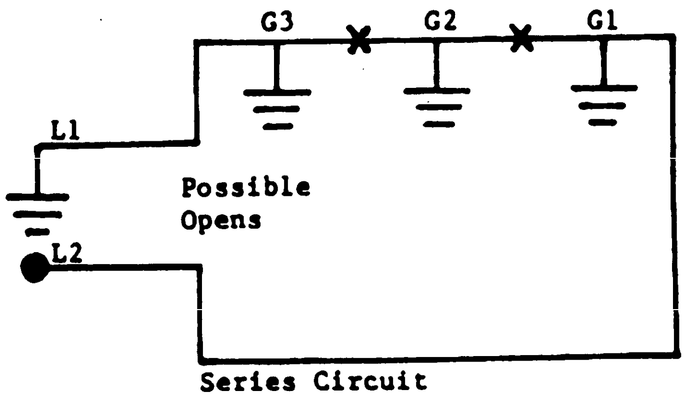

Figure 3-4. Open Circuit With One Leg, Test Example.

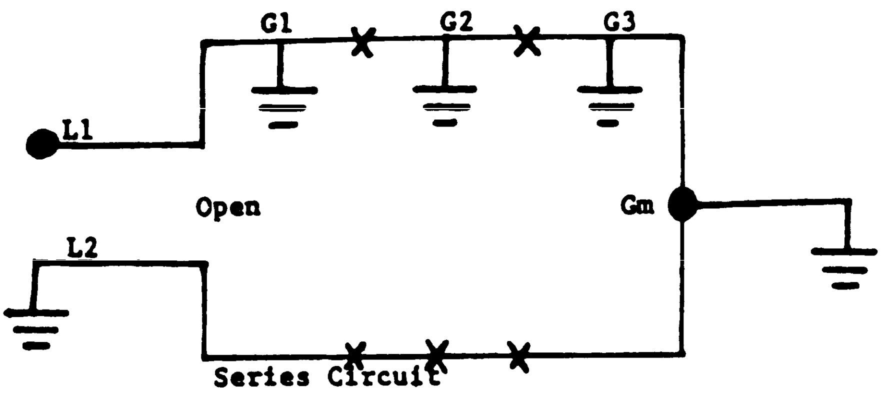

Figure 3-5. Open Circuits in Both Legs, Test Example.

3–8. Isolating Overloads in Series Circuits. A circuit overloads 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 present when the regulator provides reduced current to the field circuit on all steps, yet the regulator current is normal when the outputs are short-circuited. If an overload is present and the possibility of grounds on the circuit has not already been investigated, check for grounds by following the procedure in paragraph 3-5.

a. Unsatisfactory Insulating Resistance. If the insulating resistance of the circuit is not satisfactory, some combination of grounds and an overload exists, 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. Satisfactory Insulation Resistance. If the insulation resistance of the circuit is satisfactory, the circuit is clear of grounds. To locate the overload, sectionalize and take load current measurements, or compare the actual load to normal circuit loads.

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

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

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

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

d. Comparison Procedure. Locate overloads by comparing the actual load on the regulator to the nominal load of the circuit. To do this, determine the actual output voltage load of the regulator and then the load current at brightness step B5. Compute the actual load as the product of the output voltage and current. Compute the nominal load of the circuit including losses and any recent additions to the circuit. Compare the actual load to the normal load of the circuit and to the nameplate of the regulator.

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

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

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

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

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

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

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

3–9. Input Power Circuit Fault Isolation. This paragraph contains step-by-step procedures for locating faults in the input power circuit. *Be certain that no one is working on or near a deenergized circuit before attempting to energize it.*

a. Checking Input Voltage. 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. Energizing the Regulator. If the lights and other equipment on this circuit are operating, set the switches, relays, and contactors in the required positions 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. Absence of Hum or Vibration. 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 keep this in mind should the device open again.

(b) If the fuse blows or the circuit breaker trips again, check for possible overloads which could cause this protective device to fail. Check grounds or shorts on the input circuit. Make sure that the fuse or circuit breaker can handle the total possible load. Other loads beside the regulator could overload this component in normal or faulty operation. Two or more brightness relays closed or energized at the same time can cause a short on the transformer in the regulator. Eliminate all other possible causes of the overload before placing fault in the regulator.

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

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

(b) If the tap-selector switch (if used) is not properly seated, 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 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 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-selection switch setting, reset the taps or tap-selector switch to agree with the input voltage when the regulator is energizing its normal load. Note that regulators larger than 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, use autotransformers 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 agrees with the setting of the taps or tap-selector switch, the regulator is not operating satisfactorily, and the fault is in the brightness controls, in the regulator, or in the load circuit.

(4) If the input is zero, continue moving the potential transformer or the voltmeter toward the source of power and repeating the voltage requirements until the fault is located. Note that the circuit must be deenergized 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 electrical superintendent.

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

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

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

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

(d) 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 lowest 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.

BY ORDER OF THE SECRETARY OF THE AIR FORCE

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WILLIAM O. NATIONS, Colonel, USAF
Director of Information Management
and Administration

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