Civil Aviation Authority of Nepal

Guidance Material
on
Airport Visual Aids Facilities Maintenance

2019

Record of Amendment

Revision/ Version Number	Chapter Changed	Pages Replaced	Signature	Date

Table of Contents

page

Record of Amendment 2

Table of Contents ………………………………………………………………………... 3

Foreword ………………………………………………………… …………….. 5

Chapter 1. General ……………………………………………………………………….. 6

1.1 Aim of the manual ………………………………………………………………. 6

1.2 Personnel ………………………………………………………………. 6

1.3 Spare Parts ………………………………………………………………. 6

1.4 As-built drawing ……………………………………………………………… 6

Chapter 2. Organization of the Maintenance ….…………………………………………. 7

2.1 Requirement of Workshop ………………………………………………………... 7

2.2 Categories of Maintenance ……………………………………………………… ……. 7

Chapter 3. Safety ……………………………………………………………………… 8

3.1 Common Causes of Accident ………………………………………………………… 8

3.2 Safety Procedure and Guidelines …………………………………………………… 8

3.3 Electrical Hazards of Series Lighting Circuits……………………………………….. 9

3.4 Safety Practices ……………………………………………………………………… 10

Chapter 4. Maintenance Management ……………………………......................... 16

4.1 Maintenance Schedule ………………………………………………………. 17

4.2 Maintenance Records ………………………………………………………………. 17

4.3 Preventive Maintenance Program ………………………………………………… 18

4.4 Record Retention ………………………………………………………… .. 19

4.5 Reference Library ………………………………………………………………. 19

4.6 Spare Parts Provisioning ……………………………………………………… 20

4.7 Test Equipment……………………………………………………….. ……… 21

Chapter 5. PREVENTIVE MAINTENANCE OF VISUAL AIDS FACILITIES … 25

5.1 Airfield Lighting Room ………………………….. 26

5.2 Constant Current Regulators(CCRs) ……………………………………………. 31

5.3 Light Fixture And Base Maintenance ……………………………………………. 34

5.4 Illuminated Runway and Taxiway Guidance Signs ……………………………… 40

5.5 Rotating Beacons ……………………………………………………………….. 40

5.6 Illuminated Wind Direction Indicator ……………………………………….. ... 42

5.7 Precision Approach Path Indicator (PAPI) System ……………………………. 44

5.8 Runway Threshold Identification Lights (RTILs) ……………………………… 46

5.9 Approach Lighting System ……………………………………………………….. 48

5.10 Hazard Beacons and Obstruction Lights …………………………………….. 49

5.11 Airport Lighting Control and Monitoring Systems ………………………….. 51

5.12 Transformer Stations For Electric Power Supply ……………………………. 53

5.13 Relay and Switch Cabinets …………………………………………………… 54

5.14 Control Cables, Monitoring Units, Remote Control Desk …………………… 54

5.15 Apron Floodlighting ……………………………………………………..... 55

Chapter 6. Troubleshooting Procedures For Series Lighting Circuits …………. 56

6.1 Initial Fault Investigation ……………………………………………………. 56

6.2 Locating Ground Faults in the field ………………………………………… 58

6.3 Locating Open Circuit Faults ……………………………………………….. 59

6.4 Interconnected Circuit Faults ……………………………………………… 60

6.5 Intentional Ground Test …………………………………………………… 61

6.6 Grounded Output Test For Locating Open Circuits ………………………. 62

6.7 Using Heat Sensing Equipment To Locate Ground Faults ………………… 64

6.8 Using Cable Fault Locating Equipment To Locate Ground Faults ………… 64

FOREWORD

To maintain safety, efficiency and regularity of aircraft operations at an airport the facilities that are in place should be in good operational condition. Proper maintenance is the only key to keep facilities of an airport in good condition. This Maintenance Manual is intended to give guidance in conducting airport visual aids facilities maintenance. The manual has been developed on the basis of related ICAO Documents.

Proper maintenance of airport facilities is important both for the safe operation of aircraft arid extending the life of the facilities. Nevertheless, maintenance is frequently overlooked or reduced when establishing budgets for airport. The manual attempts to overcome this by identifying the various types of maintenance required for airport visual aids facilities. It remains for each airport to decide if a particular maintenance check is appropriate for its airport and to establish the appropriate maintenance schedule. It is hoped that this manual will establish the proper position of maintenance in the overall airport program.

Director General
Civil Aviation Authority of Nepal
Babar Mahal, Kathmandu, Nepal 2019

CHAPTER 1. GENERAL

1.1 Aim of Manual

This manual is intended to give guidance on planning and conducting maintenance work on the airport. The guidance has been developed on the basis of related ICAO Documents which, in turn, were developed from various airport operators' practices and reflects long-term experience in the field of airport operation. Since wear and sensitivity of any technical component depend on material, utilization, age, climate and other environmental conditions, none of the recommendations on the type and intervals of maintenance action described in this manual should be considered a specification. Maintenance work shall be planned on the basis of local needs, experience and recommendations of manufacturers of components and be carried out as per the approval of the appropriate authority.

However this Manual is limited to execution of maintenance works only. The Manual has to be complemented to Annual Airport Maintenance Plan (AAMP) as a planning tool. The AAMP as a planning tool is ineffective without having a strong Airport Management Information System, where data are to be collected for the management decisions on such aspects:

- Assessing current levels of airports and their conditions
- Determining appropriate levels of investment in airport based on needs
- Prioritizing capital investments and investment in maintenance
- Simulating the effects on any improvements on the future condition and performance of the airport network
- Estimating the cost of improvement
- Identify the life cycle cost impact of preventative works in delaying the need for major works
- Controlling on-going expenditures.

Therefore this manual has to be supplemented by AAMP and Management Information System, planning tools to perform the maintenance activities in a systematic manner.

1.2 Personnel

The task of maintaining lighting aids should be entrusted only to reliable and skilled electrical personnel who have had experience with high voltage series circuits and lighting. These individuals should be present or on call during the operating hours of the airport to correct any deficiencies that might develop. Training programmes should be established to maintain the competence of maintenance personnel and to keep them abreast of new developments.

1.3 Spare Parts

An adequate stock of spare parts should be available. The level of stock will vary depending on the time required to re-supply a particular item and its shelf

1.4 As-built drawing

A set of as-built drawings shall be kept readily available in the Maintenance unit. The as-built drawings shall be kept in the following manner:-

a. Drawings shall be kept in the Maintenance unit and in the concerned Engineer’s office;
b. Drawings must be kept up to date and any changes at site shall be reflected immediately on these drawings.
b. The completeness and the accuracy of all circuit diagrams, drawings and descriptions shall be checked at least annually.

CHAPTER 2 ORGANIZATION OF THE MAINTENANCE

2.1 Requirement of workshops

To ensure the whole airport's smooth operation the provision of workshops at the airport is necessary from both an operational and economic standpoint. The size of the workshop and types of equipment to be available will of course depend on:

a. the volume of maintenance to be done at the airport;
b. the availability of skilled maintenance personnel; and
c. availability of close-to-airport workshops or craftsmen that may be used for maintenance work on contract basis;
d. compliance with airport emergency plan; and
e. economic aims.

A sound balance between the capacity of the airport's basic maintenance workforce and their system to comply with peak and emergency workloads is important for an economic airport operation.

2.2 Categories of Maintenance

There are two categories of maintenance, namely-
a) Regular/ Corrective /Maintenance,
b) Preventive Maintenance.

2.2.1 Regular/Corrective Maintenance

Corrective maintenance can be defined as the maintenance which is required to bring an item back to working order when it has failed or worn out. Corrective maintenance shall be carried out on items where

a) the consequences of failure or wearing out are not very significant, and
b) the cost of corrective maintenance is not greater than preventive maintenance.

Corrective Maintenance activity will consist of repair, restoration or replacement of equipment/ item. This activity will be the result of a regular inspection, which identifies the failure in time for corrective maintenance to be planned, scheduled and effected.

2.2.2 Preventive Maintenance

Preventative maintenance is the maintenance which is carried out to prevent an item failing or wearing out. Preventive maintenance shall be implemented by providing systematic inspection, detection and prevention of incipient failure. Preventive maintenance shall be carried out on items where

a) the consequences of failure or wearing out are significant, and
b) the cost of corrective maintenance is greater than preventive maintenance.

CHAPTER 3. SAFETY

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

3.1 Common causes of Accidents

Some common causes of accidents are listed below:

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

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

c. Failure to follow instructions in equipment manuals.

d. Failure to follow safety precautions.

e. Failure to properly lock-out equipment.

f. Using unsafe equipment.

g. Becoming lax due to working in a familiar environment.

h. Poor housekeeping of work areas.

i. Working at unsafe speeds.

The number one cause of accidents is working at unsafe speeds. This is often the main contributing factor in failing to follow proper safety guidelines in all the other causes outlined in the list above. The perception that there is not enough time to take proper safety precautions or think through the proper procedures has the potential for causing an accident. Even in emergency repair situations, care must be taken to make the time to follow proper safety procedures to avoid injury or death.

3.2 Safety Procedures and Guidelines

Most visual aids are exposed to weather and moisture and may develop electrical shock hazards through damage from lightning or insulation deterioration from exposure. Begin maintenance procedures only after a visual inspection has been made for possible hazards. Due to the danger of lightning, lighted navigational aids should not be serviced during periods of local thunderstorm activity. Develop and implement a set of action plans to follow in the event of an accident occurring. Ensure that positive responsive actions take place within moments of accident notification by establishing and having in place a known set of predetermined responses. Precious seconds are saved getting medical assistance to those in need when action plans are in place. Rehearse and review action plans regularly.

3.3 Electrical Hazards of Series Lighting Circuits

Airport lighting circuits, by their nature, are very dangerous. This is especially true for the uninformed electrical technician with little or no experience working on constant current series circuits. Airport lighting circuits can operate at potentials of several thousand volts depending on the size of the regulator driving the circuit and the load.

3.3.1 Basic Rules

There are three basic rules to remember when working on and around airport lighting circuits:

a) ALWAYS assume that the circuit is energized until you have proven otherwise. ALWAYS check for current before disconnecting the series circuit connector, removing the cutout, or opening the primary series circuit by any other means. Make it a required practice to check the circuit with an ammeter prior to breaking the connection . NO EXCEPTIONS. Never attempt to measure voltage in a series lighting circuit using ordinary volt meters. An inductive voltage measuring device such as AC Proximity Voltage Tester may be used to detect the presence of induced voltage on a series lighting cable after checking for the presence of current. Always use a true RMS clamp-on type ammeter to verify if the circuit is energized. ALWAYS check the operation of the test equipment on a known live circuit before and after measurements are taken.

b) NEVER under any circumstances break a live series circuit. The voltage generated in the circuit can reach levels many times normal before the regulator's open circuit protection can shut it down. As long as a current flow can be maintained, even if it is through you, the regulator will continue to operate. This is one of the reasons that series circuits can be so hazardous to work around. By their nature, there is no personnel protection provided such as might be found on parallel interior wiring.

c) NEVER enter a manhole with energized conductors and never handle cables or transformers while there is current present. Cables or connectors can have cracked insulation where it is not visible or may be deteriorated and fall apart.

3.3.2 Induced Voltages

Series circuits are typically run from the transformer vault in duct banks where the wires are lying parallel to each other in close proximity. Voltages may be induced in an otherwise un-energized conductor and may be a hazard when troubleshooting and testing. Circuits that have a load that varies due to flashing action of runway guard lights or REIL strobes are particularly prone to induce voltages in other conductors due to the pulsing characteristics of the voltage and current in these circuits. Always check for induced voltages before handling an airfield lighting series circuit conductor.

3.3.3 Re-lamping

The most common lighting maintenance task on the airfield is re-lamping of runway and taxiway lighting fixtures. Depending on the type of fixture, this may be accomplished in the field or, as in the case of most inset lights, the entire fixture is removed, replaced, and brought to the maintenance shop for refurbishing. The greatest unseen danger to you is re-lamping or removing the fixture with the circuit energized. This has always been a common practice by airport electricians for convenience and the dangers are often overlooked. There are two primary hazards associated with this practice. The first occurs when an isolation transformer has a primary to secondary short in the windings. Remember that even though these are referred to as isolation transformers, they were not designed for personnel protection. They are merely designed to isolate the secondary from the primary circuit to allow the circuit to continue to operate with a lamp burned out. A transformer with a primary to secondary short may not cause a circuit malfunction and could therefore remain unnoticed in normal operation with a live primary. This exposes you to the full voltage present on the primary circuit and can be especially dangerous if another short is present on the primary circuit. When that happens, you can become the path to ground for the full primary current, a circumstance which is almost always fatal. This condition is especially dangerous when working with inset lights and removing them from the light base can while the circuit is energized. As soon as the fixture is unbolted and lifted from the can, you become the path to ground. Some have tried to alleviate this hazard by attaching a ground wire from the bottom of the light fixture to a grounding lug on the inside of the can. However, you cannot know if the wire is truly connected until you remove the fixture, at which time it is too late.

The second hazard encountered when re-lamping an energized light fixture is from the open circuit voltage present at the secondary of the transformer. The open circuit voltage present on the secondary of the transformer is proportional to the size of the transformer. The peak voltages can create an unsafe condition for maintenance personnel. Therefore, it is recommend that you perform re-lamping of the series lighting circuits with the circuits de-energized, especially during the re-lamping of fixtures with exposed contacts. If this is not practical, wear appropriate insulating gloves during re-lamping procedures. A final hazard that is present when re-lamping any type of fixture, whether in the field or at the maintenance shop, is the danger of cuts from broken lamps. Many times when an airfield lamp fails, the glass envelope becomes cracked or brittle and can break during the removal process. Always wear leather gloves when removing lamps to prevent your hands from being cut in the event of a lamp shattering.

3.4 Safety Practices

When you perform maintenance on airport visual aids, use the following safety practices:

a. Ensure that workers are trained and familiar with electrical safety.

b. Strictly observe safety rules.

c. Ensure that the test equipment is rated for the voltage under test or for the application.

d. Prior to beginning any maintenance work on airport lighting circuits, coordinate the work schedule with the control tower and security personnel. Make sure circuits will not be energized during maintenance by observing strict lock-out tag-out procedures for the equipment and obtain authorization for local control if equipment is normally operated from a remote control point.

e. Where maintenance work is to be accomplished on a high-voltage circuit, assign at least two electrical technicians, with at least one having a thorough knowledge of the layout of all airport high-voltage circuits.

f. Because performing maintenance on many lighted visual aids requires workers to traverse the active airfield, all workers shall be fully knowledgeable of air traffic control and radio communication procedures. Workers shall be fully familiar with airport runway and taxiway layout to avoid any possibility of runway incursions.

3.4.1 Personal Safety Precautions.

Every electrical technician should adopt the following common sense safety precautions as standard procedure:

a. Know the location of main power disconnect devices.

b. Know how to summon medical aid.

c. De-energize circuits by removing necessary fuses using properly insulated fuse pullers or by turning off and locking out circuit breakers or other disconnecting means. Consult circuit diagrams to identify all fuses, breakers or disconnects involved. Discharge all capacitors.

d. Do not depend on interlocks to remove power or on indicating lights to signal that power is off. Verify that power is off by using a voltmeter and/or ammeter on the component after opening the power switch. Verify operation of voltmeter (or ammeter) on known live circuit before and after measurements are taken.

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

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

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

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

i. Ground test equipment to the equipment under test unless otherwise specified in instruction manuals.

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

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

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

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

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

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

3.4.2 Safety Boards

Locate a plywood board for posting safety procedures and a pegboard for mounting safety equipment in the airport lighting room, switchgear rooms, engine generator rooms, and other appropriate locations. In addition, provide a telephone for emergency use as well as regular communications use. Recommended safety procedures and safety items to be included on or adjacent to safety boards are as follows:

a. Accident and fire procedures.

b. Emergency telephone numbers, such as hospital, fire station, airport operations, police and Control Tower.

c. Resuscitation instructions.

d. First-aid kit.

e. High-voltage disconnect (hot) stick.

f. Non-conductive body rescue hook.

g. Rubber gloves rated for maximum voltage present with leather gloves and protective storage bag.

h. Insulated fuse puller, if applicable.

i. Non-metallic flashlight

j. Grounding stick.

k. Safety posters and bulletins.

l. Portable non-conductive warning signs with non-conductive hangers.

m. Fire extinguisher of proper type rating for electrical fires.

3.4.3 Safety Checklist

Complete a safety inspection on a monthly basis to ensure that the safety boards contain all required items and that test equipment is in a safe operating condition. Retain the completed checklist on file for at least one year.

3.4.4 Safety Equipment in Vehicles

All vehicles operated on the airfield should have a properly sized fire extinguisher and first aid kit. Equip all vehicles and/or personnel with radio communication to be available to summon help in an emergency. Mark and register all vehicles appropriately. Equip all vehicles with a lighted warning beacon.

3.4.5 Electric Shock

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

a. Voltages between 200 and 1000 volts at commercial powerline frequencies are particularly harmful since, under these conditions, heart muscle spasm and paralysis of the respiratory center occur in combination. However, lower voltages can also prove fatal, as evidenced by records of deaths caused by even 32 volt lighting systems. The body response to current is a follows:

   - 5 to 15 mA stimulates the muscles
   - 15 to 19mA can paralyze the muscles and nerves through which it flows
   - 25 mA and above may produce permanent damage to nerve tissues, blood vessels
   - 70 mA and above may be fatal.

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

3.4.6 Safety Training

Establish a safety training course and present to all employees. Present follow-up training on a periodic basis to ensure that employees are safety motivated. Include first aid and CPR (Cardio-Pulmonary Resuscitation) training in the safety training course.

3.4.7 Safety Warning Signs / Danger Tags

The following discusses the use of warning signs on high voltage equipment. Permanently place “DANGER – - HIGH VOLTAGE” signs on all fixed electrical equipment where potentials of 500 volts or more terminal-to-ground are exposed. Place signs in a conspicuous location, usually on the outside of the equipment.

Figure 3-1 "Danger – High Voltage" Sign

3.4.8 Lock-Out/Tag-Out and Danger Tags.

Each airport electrical maintenance units should have a written lock-out/tag-out procedure. Equipment or circuits should never be worked on unless locked out and tagged by the person performing the work. Never trust anyone but yourself. Have your partner check behind you to make sure the proper equipment is turned off. The lock-out tag should only be removed by the person who signed it except in some circumstances when verbal permission has been granted to another person or when the worker who signed the tag is on vacation, etc. Never rely on the tower controllers to assure electrical safety. The controllers in the tower are relieved periodically and the next person may not know of the work that is going on. Always take whatever time is necessary to make sure that the circuit or equipment you are working on is safe. One of the primary reasons for accidents is when workers get in too great a hurry and don't take proper precautions and follow proper safety procedures. The other main reason is when the electrical technician lets his/her guard down because they are working in a familiar environment and becomes negligent about safety procedures.

Figure 3-2 Danger Tags

3.4.9 Locks and Padlocks.

Use built-in locks on switchgear and disconnecting switches whenever the equipment is tagged, and return the keys to the supervisor responsible for their control. Padlocks need not be used if it is decided that use and control of such locks would be difficult because of the type of switchgear and its location. However, use padlocks with "DANGER" tags when equipment or electrical lines remain out of service or when electrical work has been discontinued until a later date.

3.4.10 Grounding and Bonding

Never remove, alter, or attempt to repair conductors or conduit systems providing grounding or electrical bonding for any electrical equipment until all power is removed from equipment. Warn all personnel of the ungrounded/unbonded condition of the equipment. Display appropriate warning signs, such as danger tags, to warn personnel of the possible hazards.

3.4.11 Lightning

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

NOTE: IF ADMINISTERED IN TIME, FIRST-AID TREATMENT, ESPECIALLY ARTIFICIAL RESPIRATION OR CARDIO-PULMONARY RESUSCITATION MAY PREVENT DEATH FROM ANY DIRECT CHARGES.

Observe the following rules for personal safety, if possible, during any thunderstorm:

a. Remain indoors unless absolutely unavoidable. Remember, when on the airfield YOU are the tallest object and therefore vulnerable to lightning strikes. Stay within a dry area of a building, preferably away from all metal objects.

b. If there is a choice of shelter, select the type of shelter in the following order:

- Large metal or metal-frame building
- Dwellings or other buildings which are protected against lightning
- Vehicles
- Large unprotected buildings.

c. If remaining out-of-doors is unavoidable, keep away from the following:

- Small sheds and shelters in an exposed location; in particular, any that house power equipment.
- Wire fences, antennas, supporting structures, or lines; whether telephone, electric, or otherwise.
- Hilltops and wide-open spaces.
- Isolated trees.

3.4.12 Toxic Agents

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

a) Carbon Tetrachloride.

Never use carbon tetrachloride. Contact with liquid carbon tetrachloride destroys the natural oils of the skin, producing a whitish appearance on skin surfaces that are exposed. Continuous skin exposure may cause skin eruptions. Carbon tetrachloride fumes are highly toxic.

b) Trichloroethylene.

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

c) Battery Acids.

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

All locations where lead-acid batteries are used or housed should have, as a minimum, an emergency eyewash station installed. If water is not readily available, portable emergency eyewash stations consisting of a wall mountable water bottle should be made readily available.

3.4.13 Fire Extinguishers.

Conveniently locate fire extinguishers of the proper type and in good working condition, near all high-voltage equipment.

3.4.14 First Aid

First aid is what to do before the doctor comes. It is never a substitute for the medical help. The maintenance technician should take the lifesaving measures necessary in emergencies, but avoid doing harm. Many first-aid measures are quite simple and do not require “split-second speed” in their application. Haste without knowing what one is doing can be worse than doing nothing at all. At other times, immediate action is essential to save a life or prevent serious complications; this action can only be taken by someone who is on the scene when minutes are vital.

CHAPTER 4. MAINTENANCE MANAGEMENT

The purpose of the maintenance management system is to ensure the maximum availability of any given system at a minimum cost in man-hours or funds. “Availability” and “costs” are relative terms; they must be interpreted for each airport. For example, a CAT I runway may still be considered operational with 15% of the edge lights out, while a PAPI system may be unserviceable with more than one lamp out per box. By the same reasoning, the cost of maintaining a spare regulator may be considered cost prohibitive, while stocking

replacements for 10% of the runway edge lights may be considered a normal practice. In addition, operational factors are a major consideration in determining what maintenance is required. Airports with heavy traffic may require more frequent maintenance servicing than those used only by light traffic. The maintenance operations include maintenance planning, preventive maintenance inspection, visual inspection, repair, installation, calibration, and unscheduled maintenance procedures. Maintenance procedures, including the work order and documentation required, may vary between airports. The purpose of this manual is to provide the minimum maintenance procedures required for safe and efficient movement of aircraft during takeoff, landing, and taxiing operations.

Regardless of the actual maintenance routines decided upon, the following elements are essential to any controlled maintenance program. The maintenance procedures in this manual are considered minimum guidelines:

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

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

c. Document repairs and troubleshooting performed on each piece of equipment and the results of those actions as well as the symptoms related to the malfunction. This allows for more rapid troubleshooting of similar problems at a later date.

4.1 Maintenance Schedule

Documenting the maintenance schedule by spelling out each item of routine maintenance is beneficial in several ways:

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

b. It helps to establish spare part stock levels.

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

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

4.2 Maintenance Records

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

4.3 Preventive Maintenance Program

Reliable functioning of airport lighted visual aids is essential to airport safety, capacity, and operation especially for low visibility operations. Therefore, it is essential that a preventive maintenance program be established to ensure reliable service and proper equipment operation. Properly scheduled inspections, testing, and calibrations are essential to the proper functioning of these systems. Particularly airport lighting systems are designed to be dependable and may continue to operate for long periods of time even if maintenance is neglected. Eventually a failure will occur and, if the failure occurs at a critical time, safety may be jeopardized. Lighted visual aid maintenance should receive high priority to prevent equipment failure, false signals, and deterioration of the system.

4.3.1 Installation and Material.

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

4.3.2 Personnel.

The second element in a preventive maintenance program is trained experienced personnel. Maintenance personnel should have a thorough knowledge of the equipment, should have experience with high voltage, and should be able to make careful inspections and necessary repairs. Considerable experience with the equipment and its operation is desirable. These individuals should be present, or on-call, during the operating hours of the airport to correct any deficiencies that may develop.

4.3.3 Tools and Test Equipment

The third element in a preventive maintenance program is the tools and test equipment required to perform the maintenance. This includes specialized tools and test equipment, adequate working space, adequate storage space, spare parts, and applicable technical manuals.

4.3.4 Preventive Maintenance Inspection Program

The fourth element in a preventive maintenance program is an effective preventive maintenance inspection schedule for each equipment and visual aid . This schedule should also include all cable systems. The Preventive Maintenance Inspection (PMI) schedule is the foundation for the successful maintenance of the equipment. If the PMI is performed properly and at the scheduled time, it will ensure top system performance and will minimize unscheduled interruptions and breakdowns. Review of the inspection records, checks, tests, and repairs provides a constant awareness of the equipment condition and gives maintenance personnel advanced warning of impending trouble.

4.3.5 Preventive Maintenance Inspection Schedule

Scheduled inspections and tests are those accomplished on specific types of equipment on a periodic basis. The schedule may be based either on calendar or on hourly-use increments. The PMI schedules, based upon recommendations from the manufacturers and users of the equipment, are considered to be the typical requirements to keep the equipment in good condition. Adjust the frequency of a particular PMI after experience is gained under local operating conditions.

4.4 Record Retention

There is no set period of time that maintenance records should be kept, but in keeping within the goals mentioned above, a period of twice the longest period recorded would appear to be the minimum (i.e., 2 years in the case of annual maintenance action). Records of daily inspection will, of course, lose their significance much sooner, probably within a month. It should be noted however, that maintenance records should be retained permanently, if possible, as situations may develop years later in which those records can prove invaluable.

4.5 Reference Library

Establish a reference library to maintain a master copy of all Equipment Technical Manuals (ETMs), Maintenance Manuals, as-built drawings, and other useful technical data. The electrical supervisor should establish and maintain responsibility for maintaining the technical reference library and ensure that technical manuals and drawings are kept up to date and not lost or damaged.

4.5.1 Equipment Technical Manuals (ETMs)

ETMs and other manufacturer’s literature form an important part of the reference library. Obtain two copies of all technical manuals and related manufacturer’s literature. Retain a master copy in the reference library, and provide a separate copy for the workshop. In addition, keep a copy of each equipment manual at the equipment location. This facilitates troubleshooting and repairs without the necessity of traveling back to the workshop location to retrieve the manual. Do not remove the master copy of the technical manual from the reference library as it can easily become misplaced or lost. In the event the workshop copy is lost, make another photocopy of the technical manual from the reference library instead of releasing the master copy.

4.5.2 Other Technical Data

Other reference information that is occasionally useful should also be added to the library. This might include engineer's handbooks, test equipment manuals, and other general information publications.

4.5.3 As-Built Drawings

Maintain the master copy of all as-built (record) drawings as part of the reference library. Incorporate modifications to any equipment into the drawings as soon as the modification is completed. Give a copy of the "as-built" lighting plan, showing the location of all cable runs, runway lights, etc., and including the wiring diagrams for the airfield lighting, building lighting engine generator, and the visual aid system, to the maintenance personnel as a working copy. Install or identify test points at appropriate locations in the field circuitry and record locations of these test points on the "as-built" drawings. Immediately update any notations regarding test points or discrepancies in the drawings made in the field on the master set in the reference library.

4.6 Spare Part Provisioning

This paragraph contains guidelines on how to establish a stock of spare parts to be used for quick repair of lighting and other equipment that fails unexpectedly. The purpose of a spare parts system is to have the necessary part on hand when a piece of equipment fails; this will minimize the time the system is out of operation. However, the greater the number of spare parts stored, the greater the inventory costs. The optimum spare part system balances the cost of system downtime (lost operation, tenant inconvenience, safety, etc.) with the cost of purchasing and storing spare parts. A small airport with few operations may suffer little inconvenience with the loss of their lighting system and may, therefore, choose to stock few spare parts. A large airport may rely heavily on its lighting system for low visibility operations and would, therefore, require a substantial quantity of spare parts. In the case of a large airport, the funds lost by the tenants due to interrupted operations and the impact on the safety and security of the traveling public must also be taken into consideration. A malfunction at a major airport can have a far reaching effect on the national airspace system. When establishing a spare parts inventory, two questions must be answered:

(1) What parts should be stocked?

(2) How many of each part?

When new construction occurs or a project is funded for replacement of existing systems, fund and include a quantity of spare parts (fixtures, lamps, fuses, relays and spare CCR control boards, etc.) in the equipment furnished by the contractor. This gives the maintenance department a built-in stock of spare parts and lessens the time required to procure parts for the new equipment. This is especially true if the equipment being installed is different from what is currently in use.

4.6.1 Choosing Spare Parts

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

4.6.2 Failure Rate

The failure rate (or replacement rate) is the product of the expected life of an item and the number of items in the system. For instance, if a lamp is expected to last one year, and we have 100 lamps in the system, then an average of 100 lamps will be replaced every year or approximately two per week. Accurate records of parts used over time will help immensely in determining a failure rate.

4.6.3 Part Availability

Part availability refers to the time it takes to secure a replacement part. This usually means procurement lead time. If a part can be readily procured from shelf stock of a local supplier, it might not be necessary to add the part to the spare parts inventory; as it could be purchased when needed or the number of spare parts in the inventory could be reduced. However, if there is a twenty four-week lead time required by the supplier, then stock twenty four times the weekly failure rate (48 lamps in the example above). Spare parts for constant current regulators and other special equipment fall into this category. For instance, a replacement printed circuit board or other assembly typically has a twenty four week lead time and unless a spare regulator is maintained for emergency use, the loss of a circuit could have a serious effect on airport operations.

4.6.4 Effect of the Failure

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

4.6.5 Part Identification

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

4.7 Test Equipment

An average electrical technician may have little day-to-day use for anything more than a voltmeter; however, when maintaining airport lighting series circuits, the equipment needs become more demanding. An airport electrical technician needs to be able to perform many tasks involving troubleshooting and calibration that are typically out of the norm for the average technician. Series circuits operate at potentially high voltages and are prone to develop shorts and opens that require an advanced knowledge of the use of ohmmeters and insulation resistance testers (meggers) to properly trace the problem and get the lighting circuits back up and operating in a minimum of time. There is also a need for current measurements at relatively low currents (<20 amps) that require highly accurate and calibrated equipment. A small change in the output current in a series circuit can have a large effect on light output and lamp life. At maximum output of 6.6 amps at the lamp, a current change (increase or decrease) of 1% can change the light output of the lamp by as much as 5%. That same 1% change (increase) can result in a 20% decrease in lamp life. It is therefore obvious from these facts that accurate test equipment and proper knowledge of its usage are vital to the maintenance of the airfield lighting system.

For maintenance purposes it is therefore recommended that every airport acquire at least a volt-ohm-meter, an insulation tester and an accurate true RMS measuring clamp-on AC ammeter or true RMS digital multimeter with an accurate clamp-on ammeter probe. These units are useful for various maintenance routines and are necessary for troubleshooting and calibration of constant current regulators and series lighting circuits.

4.7.1 Types of Equipment and Usage

4.7.1.1 Volt-Ohm-Milliammeter (VOM).

An analog VOM is a highly versatile piece of test instrument that is capable of measuring AC/DC voltages, resistance, and low values of DC current. The better quality units offer reasonable accuracy and ruggedness and are useful for making a large variety of measurements. The most common use of this instrument is for making resistance measurements on series circuits for the purpose of troubleshooting when a fault has occurred. An analog VOM is useful because of its ability to show fluctuating trends and rates and the ease with which it offers a go, nogo check when rapid troubleshooting is required. An analog VOM does have limitations however. Its relatively low-input impedance and susceptibility to interference make it unsuitable for some measurements, especially when dealing with electronic circuits or when working in an environment with RF (radio frequency) energy present. Also it must be remembered that a typical VOM should not be used for making current measurements in an airfield lighting series circuit because it does not possess the ability to make true RMS, high accuracy measurements.

Safety must always be considered when using a VOM. Know the voltage levels and shock hazards related to all equipment to be tested. General recommendations for specific uses of a VOM are contained in the manufacturer’s manual supplied with the equipment.

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

b) Switch settings. When making voltage measurements on power and control circuits, be sure that the meter selector and range switches are in the correct position for the circuit under test before applying test leads to the circuit conductors. To prevent damage to the meter movement, always use a range that ensures less than full-scale deflection of the pointer. A 1/3 to mid-scale deflection of the pointer assures the most accurate readings.

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

4.7.1.2 Digital Multimeter (DMM).

A digital multimeter is another piece of essential test equipment for the airport electrical technician’s toolbox. This versatile instrument can deliver high accuracy and, through the use of various accessories, the ability to make a wide range of measurements.

A DMM with a good quality amp-clamp accessory is a good combination for measuring the output current of constant current regulators. It is sometimes difficult to know whether the instrument you are using is accurate or not. Even though the DMM is rated as a true RMS instrument and has a high rated accuracy, the accessories may not be as accurate.

All safety precautions listed for VOMs also apply to DMMs.

4.7.1.3 Insulation Resistance Tester (MegOhmMeter).

The insulation resistance tester or MegOhmMeter is a necessary tool for maintaining and troubleshooting underground airport lighting cables. Insulation resistance testers come in a variety of styles from the traditional hand-crank models to battery and AC mains powered versions. These instruments are used for testing the insulation resistance-to-ground of underground cables; for testing insulation resistance between conductors; and for testing resistance-to-ground or between windings of transformers, motors, regulators, etc. The battery powered models are the most prevalent and come in all shapes and sizes in both analog and digital readout. Another consideration in selecting an insulation resistance tester is the output voltage. Some battery and line powered units now have selectable output voltages that can range as high as 5000 volts DC. As a minimum, select an insulation resistance tester with an output of 1000 volts DC. If possible, consider using a unit with higher maximum voltage output as this lends more possibilities of finding high resistance faults and more closely approximates the rated voltage of the cables and transformers. However, note that testing old cables in questionable condition and/or circuits that have been operating at much lower voltages may suffer damage from testing at voltages over 1000 volts. Exercise caution when testing older circuits for the first time.

a) When preparing to make an insulation resistance test, first make a complete safety check. Make sure that equipment to be tested is disconnected from all power sources. Open all safety switches and lock out other control equipment so that the equipment cannot be accidentally energized.

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

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

d) Large equipment and cable usually have sufficient capacitance to store a dangerous amount of energy from the test current. After taking resistance readings and before handling the test leads, allow any energy stored in the equipment to discharge by leaving the tester connected for at least 30 seconds before touching the leads. Many new testers will automatically discharge the equipment under test and give the user a visual or audible indication when it is safe to remove the test leads. Consult the equipment manual for information on manufacturer's instructions.

4.7.1.4 Underground Cable/Fault Locators.

A cable locator is an indispensable tool for quickly locating airport lighting cable and ducts. A cable locator normally consists of a transmitter which is either directly, or indirectly by means of an inductive coupler, attached to an underground cable and a receiver which is used to pick up the transmitted signal to follow the path of the cable. These devices are very handy for locating the path of a conductor while troubleshooting cables in PVC conduit and are even more necessary when dealing with direct buried cables. Whenever work on the airport requires digging of any kind it is necessary to utilize a locator to prevent inadvertent cutting of cables. Most of the receivers also incorporate the ability to locate 50 Hz AC cables without the necessity of applying a signal or tone to the conductor. If the airport circuits are supplied by direct-buried conductors or have direct-buried control cables, it is advisable to have a locator which also has the capability of locating ground faults. It should be noted, however, that faults in cables installed in conduit cannot be located using these devices.

When using a direct connection to the conductor to be located or tested, always exercise care to ensure that the circuit supplying the conductor has been de-energized and locked out, and tagged.

4.7.1.5 Clamp-on Ammeter.

The stand-alone clamp-on ammeter is useful for measuring AC and sometimes DC current. Most of the modern instruments of this type are provided with plug-in leads to permit the instrument to be used as a voltmeter or as an ohmmeter. Ensure that the unit is a true-RMS type so as to deal properly with the sometimes distorted waveform output of some constant current regulators. Also the same warnings apply to these devices as to the DMM/clamp on combination when it comes to accuracy of the instrument. Since most of these devices are rated to measure current far in excess of what you need to measure on airport lighting circuits, their accuracy at the low end of the measurement scale may be in question. Clamp-on devices having an accuracy of + or – 2 % or better should be used if at all possible as a small change in current can produce a large change in lamp light output. It may be beneficial to have a calibration check at the lower amp range.

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

4.7.1.6 AC Proximity Voltage Tester.

These small non-contact testers, sometimes referred to as "tickers," can be handy for detecting voltage present in insulated cables. Depending on the model, they may have a wide measurement range. They should not, however, be used to determine if an airfield lighting series circuit is energized. The reason for this is because of the behavior of voltage in a series circuit. The voltage is reduced by the various voltage drops (loads) present in the circuit until at some point near the middle of the circuit there is no measurable voltage although current flow is still present. Breaking the circuit at that point or at any point in the live series circuit can result in serious injury.

Do not rely on these units as the only instrument used to protect oneself from coming into contact with energized conductors. A good quality clamp-on ammeter device is the only safe way to check for an energized series lighting conductor. After checking for the presence of current with a clamp-on ammeter, an inductive proximity voltage measuring device may be used to detect the presence of induced voltage. Also, as with all test instruments used for measuring voltage or current, make sure that you test the device on a known live circuit before and after making any measurement of this kind.

4.7.1.7 Infrared Thermometer.

Infrared thermometers are hand-held devices that can give a direct temperature readout of any surface from several feet away. They can be aimed at the target via a laser target sight. In addition to identifying loose connections in panel boards, these instruments may be used for troubleshooting of ground faults in airfield lighting circuits. By measuring the temperature of different light bases on the runway or taxiway and comparing the temperature differential between light bases, it is possible to find the location of a ground fault if the cable and transformer assembly have been arcing and burning inside a light base.

Since the use of an infrared thermometer requires no contact with the surface of the object to be measured, these devices are generally very safe to use. Follow manufacturer's instructions and avoid direct eye exposure to the laser sighting beam.

4.7.1.8 Ground Rod Resistance Tester.

Ground rod resistance testers come in several styles and are necessary for checking and maintaining the effectiveness of grounding systems and counterpoise systems at the airport. These testers measure the resistance between the grounding system and the earth ground. Some of the newer models are simple clamp-on units capable of giving the resistance-to-ground of ground rods or grounding conductors by measuring the ground leakage current without disconnecting the grounding conductor under test. Follow manufacturer's instructions closely to obtain an accurate ground resistance reading, thus avoiding a false, lower than actual resistance-to-ground measurement that can result from incorrect use. The grounding system in question may be used for AFL Room, engine generators, and for other lighted visual aids, or it may be a counterpoise system for underground cables. The maximum acceptable ground resistance is 25 ohms. It is preferable that the resistance be 10 ohms or less. In many locations, the water table is gradually falling. In these cases, the ground electrode systems that were effective when initially installed are no longer effective. This emphasizes the importance of a continuous program to periodically check the grounding system. It is not sufficient to check the grounding system only at the time of installation.

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

CHAPTER 5. PREVENTIVE MAINTENANCE OF VISUAL AIDS FACILITIES

This chapter discusses the preventive maintenance program for the visual aids facilities and equipment. It contains a Preventive Maintenance Inspection (PMI) schedule for each major item of equipment with step-by-step instructions for performing the PMI. The PMIs establish a recommended routine. General troubleshooting procedures for airport lighting systems and equipment are contained in Chapter 6. Corrective maintenance procedures for specific equipment will be found in the manufacturer's operating and maintenance instructions and are not included in this maintenance manual. The information provided covers the following systems:

- Airport lighting and series lighting circuits
- Constant current regulators
- Runway and taxiway elevated edge lighting systems
- Runway and taxiway inset lighting systems
- Illuminated runway and taxiway signs
- Rotating beacons
- Illuminated wind direction indicator
- Precision Approach Path Indicator (PAPI) system
- Runway Threshold Identification Lights (RTIL)
- Approach Light System
- Sequence Flashing Lights
- Aerodrome beacons
- Obstruction lights
- Control system
- Relay and switch cabinets (including switch cabinets in sub-stations)
- Control cables, monitoring units
- Remote control desk
- Apron floodlighting.
- Lighting and electric equipment

5.1 Airfield Lighting Room

To perform the PMIs, as shown in Table 5-3, proceed as follows:

5.1.1 Daily Checks.

Check the operation of all controls.

5.1.2 Weekly Checks.

a) Cleanliness. Check the general cleanliness of the room. Sweep out the room regularly. Keep it free from dust, dirt, sand, spider webs, insect nests, etc.
b) 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.
c) Air Conditioning. If room is equipped with air conditioning, check for proper operation of system and thermostat control in warm weather months.
d) Storage. Check room for improper use as a storeroom. Avoid storing spare parts, rags,

etc., near the high voltage equipment. If the room has an attached room, use this room for storing spare lamps, fuses, rags, spare parts, etc.

5.1.3 Monthly Checks.

a) Insulation-Resistance Test.

Performing regular preventive maintenance checks on airfield lighting circuits is absolutely necessary for reliable operation of the system. Because of the potential of operating at very high voltages, the components of the series circuit are extremely susceptible to failure.

Perform insulation resistance tests on all airfield circuits on a monthly basis as a minimum. If the airport has circuits that fail regularly due to age or other reasons, consider weekly checks. Many potential failures can be found during daylight hours before they become a problem by making weekly PM insulation resistance checks a habit. Keep records in the regulator room with the circuit identified as well as the date and results of the test. Provide space for notes as to special conditions such as weather conditions at the time of the test, recent lightning activity and to note failure locations and causes when found.

As a minimum, the test set should have an output of 1000 volts DC. Test sets with outputs of 2500 VDC to 5000 VDC are superior at detecting high resistance faults. It should be noted, however, that when testing older circuits, especially circuits that normally operate at lower voltages, use of a 5000 VDC tester may show a fault in an otherwise undetected weak spot in a cable or transformer. It is therefore advisable, when testing at voltages higher than 1000 VDC, to be prepared to make immediate repairs if necessary.

When performing insulation resistance tests for preventive maintenance, it is necessary to be consistent in the way the tests are carried out from one session to the next. Test results may vary due to a number of circumstances. For instance, the test should be administered for the same length of time each time it is performed and at the same test voltage so that the results may be accurately compared.

A very important consideration when performing insulation resistance tests is the time required for the reading of insulation resistance to reach a maximum. The primary cause of delay in reaching full charge is known as the dielectric absorption effect. It may be a matter of several minutes before this is completed and for the reading to reach an absolute maximum. It is best to establish a minimum time for conducting the tests based on experience.

For short time readings of insulation resistance, operate the instrument for a definite length of time, either 30 seconds to 1 minute, and read at the end of that time. Make future tests with the same length of operating time.

Other variables such as moisture, weather, and time of day may affect the readings. Readings should ideally be taken after circuits have been de-energized for several hours. Readings may appear higher immediately after operating the circuit. This is a sign of deteriorating insulation in transformers and possibly cable that is allowing moisture to enter. Operating the circuits raises the temperature and drives moisture from the insulation resulting in an artificially higher reading.

There is no ideal value for insulation resistance readings on series circuits due to factors such as circuit length, age, etc. The best rule here is to base this decision on past experience with your own facility. Each circuit may be different based on age, manufacturer of cable and equipment, installation methods (direct buried or installed in conduit), local weather conditions, and amount of moisture normally present in the system. The decision of when to consider a circuit failing and in need of preventive maintenance repairs may vary from one circuit to another at the same facility. Generally speaking, any circuit that measures less than 1 megohm is certainly destined for rapid failure. The time it takes for a circuit to fail is affected by the output voltage of the regulator, type of fault and presence of moisture at the location of the fault. The larger the circuit size in kW, the higher the output voltage and hence, the more the condition of the insulation becomes critical. The important information is the deterioration of the resistance values from month to month and year to year. The resistance value inevitably declines over the service life of the circuit; a 10-20 percent decline per year may be considered 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 insulation. In this instance the maintenance supervisor should consider performing troubleshooting to locate the problem. A table for typical existing circuit loop resistance is shown in Table 5-1.

It should also be noted that the insulation resistance that is required for new installations will have a great effect on the ability of the maintenance staff to maintain the series lighting circuits after installation and acceptance. With newer cable installations being more frequently installed in conduit and pit as opposed to direct burial, initial resistance values up to and in excess of 500 megohms are normally achievable and should be required.

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 5-1. Suggested Resistance Values for Maintenance

AIRPORT LIGHTING CIRCUIT INSULATION RESISTANCE TEST RECORD

AFL ROOM OR SUBSTATION ___

CIRCUIT IDENTIFICATION____

DATE	OHM	WEATHER CONDITION AND COMMENTS	INITIAL

Figure 5-2 Sample Insulation Resistance Record

a) Input Voltage.

Measure the input voltage to the AFL Room. Take this measurement at various times of the day and/or night since the demand on the commercial power network varies throughout the day. Record the input voltage of each phase for future reference.

5.1.4 Semi-annual Checks.

a) Ground Resistance.

Perform a ground-resistance measurement for each item of equipment using a ground resistance tester. Record the readings and compare with previous readings to discover deterioration in the grounding system. The lower the resistance value, the better a value of 5 to 10 ohms is desirable. If the resistance is greater than 25 ohms, immediate actions must be taken to lower the resistance.

b). Primary High-Voltage Buses and Ground Buses.

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

c) Relays.

Inspect the protective relay, circuit selector switches, and auxiliary relay panels when servicing the AFL Room equipment. Check the operation of these devices, clean the contacts. Replace all unserviceable parts.

d) Power Transfer Switches.

Check operation of power transfer switches. Check contacts for dirt or corrosion.

e) Control Panel or Control Equipment.

Carefully check the operation of all parts of the panel. Clean all contacts and make sure all electrical connections are in good condition. Clean the interior of the panel carefully.

f) 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.

g) Miscellaneous.

Inspect all miscellaneous AFL Room items, such as circuit breakers, terminal blocks, potheads, Room lights, switches, etc. Make sure they are clean and all connections are tight. Inspect all safety board equipment and fire extinguishers.

5.1.5 Annual Checks.

a) Dielectric Checks.

Perform dielectric tests on oil in oil-filled equipment such as circuit breakers, regulators, and transformers.

b). Paint.

Check the condition of the paint on the equipment and vault. Repaint as necessary.

5.1.6 Recommended AFL Room Procedures.

a) Airport Plan.

Permanently post an airport plan in the Room to aid in testing and troubleshooting the field circuit loops. This airport plan shows the field layout, marked with the location of all lights, cable runs, cable splices, and lighted visual aid equipment. Name and telephone number(s) of person(s) responsible for electrical maintenance for the airport should be located adjacent to the airport plan.

b) Schematic Diagram.

Display up-to-date diagrams of all power and control circuits in the Room. 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) Room Security.

Lock the Room, except during maintenance, to keep unauthorized personnel out. Contact with the high-voltage buses in an AFL Room is nearly always fatal. Allow only authorized personnel, experienced in the hazards of high voltage, in the Room.

d) High-Voltage Warning Signs.

Prominently display high-voltage warning signs, as described in Paragraph 5.1.4.7, at appropriate locations.

e) Safety Board.

Install safety boards, as described Paragraph 5.1.4.2, in the AFL Room.

Maintenance Requirement	Daily	Weekly	Monthly	Bi-Monthly	Semi Annually	Annually	Unscheduled
1. Check control operation	●						
2. Check general cleanliness				●			
3. Check Insulation-Resistance Test			●				
4. Check Input Voltage			●				
5. Check Ground Resistance					●		
6. Inspect and Clean Buses					●		
7. Check Relay and Contactor Operation					●		
8. Check Power Transfer Switches Operation					●		
9. Check Control Panel					●		
10. Check Lightning Arrestors					●		
11. Check Miscellaneous Electrical Devices					●		
12. Check Oil Dielectric						●	
13. Paint Equipment as necessary						●	

Table 5-3. Preventive Maintenance Inspection Schedule for AFL Room

5.2 Constant Current Regulators (CCRs)

Constant current regulators come in two basic types, air cooled and liquid filled. The two basic types of regulators can be further classified as either magnetic or electronic. Magnetic types typically utilize either a resonant circuit or a saturable reactor principle. In a resonant network circuit, the current output is proportional to the input voltage and therefore any change in input voltage will cause a corresponding change in output current. The manufacturer’s literature on the operation, theory of operation, and recommended maintenance procedures for the particular regulator(s) being used should be obtained and kept on hand in the AFL Room and maintenance workshop for reference.

Unlike other elements in the electrical system that use commonly available parts, when a failure occurs of a component in a CCR, it is most likely an entire PC board that will have to be replaced and manufacturers may not have parts readily available. As a minimum, keep one type of each board and critical component such as silicon controlled rectifiers (SCRs) on hand for each type and size of CCR in use at the airport. This task has been made easier by some manufacturers as they make CCRs that use common control boards and components regardless of size, style, or type.

5.2.1 Daily Checks.

a) Check all control equipment for proper operation.

b) Check remote control operation on each brightness step.

5.2.2 Weekly Checks.

a) Check for cleanliness and general condition in the AFL Room.

b) Visit the Room while the circuits are in operation so as to notice any unusual noises or smells that could lead to discovering a problem with one of the CCRs.

5.2.3 Monthly Checks.

a) Check and record input voltage and current. If the voltage is not within + or –5% of the design voltage, take action to correct the input voltage.

b) Check and record the output current of each CCR on each brightness step. Compare the values with the tolerances listed in Tables 5-4 & 5-5. Make sure you are using a high accuracy true RMS ammeter when making these measurements. If any are found to be out of tolerance, adjust CCR per manufacturer's instructions.

5.2.4 Semi-annual Checks.

a) If it is suspected that a circuit may be overloaded, a measurement of the output load may be made at this time. Evidence of overloading could be overheating, failure to produce rated current (6.6 A) at maximum brightness setting, or erratic behavior when operated with a transient load such as Runway Threshold Identification Lghts (RTILs).

!!CAUTION!!

MEASUREMENTS OF THE OUTPUT LOAD OF A CCR REQUIRE TAKING VOLTAGE MEASUREMENTS AT THE LOAD OUTPUT TERMINALS OF THE CCR. NEVER ATTEMPT TO MEASURE THE VOLTAGE ACROSS THE OUTPUT OF A REGULATOR WITHOUT A LOAD CONNECTED. IN OPEN CIRCUITED CONDITIONS, THE VOLTAGE CAN REACH EXTREMELY HIGH VALUES BEFORE OPEN-CIRCUIT SHUT DOWN OF THE REGULATOR OCCURS. ONLY QUALIFIED ELECTRICAL TECHNICIANS EXERCISING EXTREME CAUTION AND USING THE CORRECT INSTRUMENTS AND SAFETY PRECAUTIONS SHOULD ATTEMPT THESE MEASUREMENTS.

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

b) Visually inspect the regulator for any signs of loose connections or overheating. Be aware that many of the connections should be inspected are not visible by merely opening the front or rear access panel on the regulator. De-energize and lock out power to the regulator and remove the top, sides, or back panels depending on the type of CCR to access and inspect the connections. Pay special attention to line and load connections where high current is present; and inspect connections on capacitors closely. Look for any signs of discoloring that would indicate overheating and a loose connection and physically test any and all connections for tightness.

5.2.5 Annual Checks.

a) For regulators that are oil filled, make a dielectric strength test of the oil. If the oil is dirty or black, this is usually a sign of a major electrical problem within the tank which will require major work. If the oil dielectric strength is low, it should be replaced or filtered and dried to restore its dielectric strength. Wash out sludge deposits on the core and coil assembly and in the tank with clean dry oil. Fill with oil to the proper level with the type oil approved by the regulator manufacturer. Dielectric strength (kV) for new oil should be 30kV+. A normal range for oil being tested should be 26-30 with 22 kV as the minimum acceptable level.

b) Remove dust accumulated in the cabinet, electronic cards.

c) Check that the power connection are correctly tightened.

d) Perform a short circuit test as follows:

Turn off power to the regulator. Short the output terminals using No. 10 SWG wire (or larger) across the output terminals. Turn on the regulator and advance intensity through each step. Read the output current on each step using an accurate true RMS ammeter. The output current should be within the tolerances shown in Tables 5-4 & 5-5.

e) If the current output is not within limits, check the voltage input to the regulator. It should be within +/-5 percent of rated input voltage. Be sure the correct voltage tap is used (on dry-type transformers). Turn off the regulator and lock out and tag out the input supply. Disconnect the short and reconnect output cables. Compare the short circuit values with those obtained from the monthly output current readings. If necessary, adjust output current according to the manufacturer’s equipment maintenance manual.

f) Perform an open circuit test as follows:

Perform this test only on those regulators with open circuit protective devices. Turn off power to the regulator and lock out the primary supply circuit. Disconnect cables from output terminals. Turn on power to the regulator. Advance the brightness selector switch to any step. The open-circuit protective device should automatically operate within two seconds to turn off the regulator. Turn off the selector switch. Reset the open-circuit protective device. If the test is satisfactory, turn off regulator power and lock out primary supply and reconnect the output cables. Re-energize primary power to the regulator and set selector switch for automatic (remote) operation.

g) Perform an over-current test:

If the regulator is equipped with over-current protection, follow the manufacturer's recommendations and procedures as outlined in the regulator manual for performing an over-current test.

Standard CCR Output Currents vs. Allowable Range

Output Step	Nominal Output	Allowable Range
3	6.6 amps	6.40-6.70
2	5.5 amps	5.33-5.67
1	4.8 amps	4.66-4.94

Table 5-4. 3-Step CCR Output Tolerances

Output Step	Nominal Output	Allowable Range
5	6.6 amps	6.40-6.70
4	5.2 amps	5.04-5.36
3	4.1 amps	3.98-4.22
2	3.4 amps	3.30-3.50
1	2.8 amps	2.72-2.88

Table 5-5. 5-Step CCR Output Tolerances

Maintenance Requirement	Daily	Weekly	Monthly	Bi-Monthly	Semi Annually	Annually	Unscheduled
1. Check control circuits on all brightness steps	●						
2. Check condition and operation of regulator		●					
3. Check input voltage and current			●				
4. Check output current on each brightness step			●				
5. Check output load on regulator if needed				●			
6. Check relays, wiring and insulation				●			
7. Check dielectric strength of cooling oil (if used)					●		
8. Perform a short-circuit test					●		

9. Perform an open-circuit test (only on regulators with open circuit protection.					●		
10. Clean rust spots and repaint as necessary.							●

Table 5-6. Preventive Maintenance Inspection Schedule for CCRs

5.3 Light Fixture And Base Maintenance

5.3.1 Introduction.

Airport lighting fixtures for runway and taxiway use are divided into two broad categories: elevated and in pavement. The maintenance requirements for each of these types are quite different. In-pavement lights generally require more maintenance than elevated lights to provide consistent performance and uniformity of light output. Elevated runway edge lights require more care in alignment so that the light output is aimed properly to meet photometric requirements. But in this manual only elevated lights will be discussed.

5.3.2 Runway and Taxiway Elevated Edge Lighting Systems.

Elevated lights, particularly taxiway lights, generally require less maintenance attention than the runway edge lights. Taxiway edge lights normally only require periodic relamping. However, they are probably the most likely candidates for other types of damage on the airfield. Aircraft and ground vehicles and mowers seem to have a particular affinity for running over elevated taxiway edge lights. The primary problems and hazards associated with the repair of elevated lights, when they have been run over or damaged, is from the glass and bare electrical conductors that may be exposed. Be sure to take proper safety precautions when handling these items (i.e. proper gloves and other safety equipment). Glass from broken taxiway globes is extremely sharp and poses a hazard both to the maintenance electrician and also as a significant Foreign Object Damage (FOD) hazard for aircraft. Probably the single biggest problem with repairing damaged elevated taxiway or runway lights is the removal of the existing frangible coupling.

Runway edge lights and threshold lights require more maintenance than taxiway lights. Runway edge lights may require periodic cleaning to remove dirt, mud, bird droppings, etc. The lenses of elevated runway edge lights can also become pitted and sand-blasted from jet blast and require replacement. When re-lamping or repairing runway edge lights, care must be taken to make sure that all lenses and filters are in their proper orientation and that the fixture itself is in the proper orientation relative to the runway. Proper orientation of the fixture is necessary for this toe-in and required photometric output to be maintained. When relamping any type of fixture, always check the lamp before installing to make sure that it is the correct type and wattage. Many lamps look alike. Never re-lamp fixtures with the circuit energized.

5.3.2.1 Preventive Maintenance Inspection Procedures

To perform the PMIs contained in Table 5-6, proceed as follows:

5.3.2.2 Daily Checks.

a) Perform a visual inspection of the system at twilight or night each day. This inspection consists of a driving patrol to visually check for dimly burning bulbs, burned-out lamps, and fixtures out of alignment. Record the locations of such fixtures and make corrections as soon as possible. Replace dimly burning lamps and burned out lamps when the system is deactivated.

b) Check lenses for cleanliness and clean as required.

5.3.2.3 Monthly Checks.

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

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

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

5.3.2.4 Semi-annual Checks.

a) Check the ground elevation around lighting fixtures. Maintain the elevation of all lights the same height above the runway/taxiway pavement edge..

b) 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.

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

5.3.2.5 Annual Checks.

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

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

c) Check condition of all connections.

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

5.3.3 Maintenance Procedures

The following paragraphs discuss general maintenance procedures for the runway and taxiway units that are not functioning:

5.3.3.1 Lamp Replacement.

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

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

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

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

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

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

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

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

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

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

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

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

e) When closing the light, confirm that the gaskets are positioned for proper sealing. Tighten all screws, clamps, and fasteners.

f) Check frangible couplings for cracks.

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

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

5.3.3.2 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.

5.3.3.3 Inspection.

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

5.3.3.4 Cleaning.

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

5.3.3.5 Cleaning Schedule.

The cleaning schedule will vary at each location depending on such factors as environment, geographical location, and the types of lighting units. Clean each light thoroughly at least once a year. Regular photometric measurements may indicate a need for a more aggressive cleaning schedule.

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

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

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

(d) 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.

5.3.3.7 Moisture.

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

(b) 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 pumped out. Drain holes should be drilled or cleaned out if already present. Gaskets, seals, and clamps that may admit water should be checked. Chipped, cracked, or broken glassware should be replaced. If water cannot be eliminated from light bases, ensure all electrical connections and insulation are watertight and above the waterline. New conduit and base installations should be designed to drain and have a separate drainage system installed at low elevation points in the system.

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

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

(3) Strikes and Blast Damage. Light units damaged by strikes from aircraft or vehicles, or by propeller or jet blasts, should be repaired or replaced immediately. Areas where this damage recurs should be checked frequently. A careful check should be made following damage of this type because the attaching cable may also be damaged. At locations where damage is frequent due to vehicular traffic, consider replacing elevated lights with approved in-pavement types.

(c) Repair and Replacement. When possible, replace the entire damaged unit. Simple repairs usually consist of the following:

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

(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.

(d) Frangible Coupling Replacement. Frangible couplings are used primarily to reduce damage to aircraft in case of a strike. They provide an intentional weak point and aid in preventing damage to other components. An open-end wrench, pipe wrench, cold chisel, and punch and hammer are usually sufficient to remove and install frangible coupling.

Maintenance Requirement	Daily	Weekly	Monthly	Semi Annually	Annually	Unscheduled
1. Inspect for outages; repair as necessary	●					
2. Check cleanliness of lenses	●					
3. Check light alignment and orientation			●			●
4. Re-align lights as needed			●			●
5. Clean fixtures and sockets						●
6 Check for moisture in lights				●		
7. Inspect fixture for rust, deterioration					●	
8. Check lamp fitting and clean contacts					●	
9. Check gaskets					●	
10. Vegetation from around lights						●

Table 5-7 Preventive Maintenance Inspection Schedule for Runway and Taxiway Elevated Edge Lights.

5.4 Illuminated Runway And Taxiway Guidance Signs

5.4.1 Cleaning

Most signs require minimal maintenance aside from lamp replacement. However, with the intrusion of dust, dirt and water it is necessary to inspect and clean the interior of signs periodically to ensure proper light output. Inspect and clean airfield guidance signs at least twice a year.

5.4.2 Lamp Replacement

As with all airport lighting systems, re-lamping should be accomplished with the sign de-energized to prevent the possibility of electric shock. In some Model, the act of re-lamping has also been made easier and quicker by designs of both incandescent and fluorescent types that allow re-lamping without the use of tools.

5.4.3 Current Check

At least twice a year, the current through the lamp circuit should be checked to verify that it is correct for the sign in question.

5.5 ROTATING BEACONS

5.5.1 Preventive Maintenance Inspection Procedures

The rotating beacon normally needs less maintenance than runway and taxiway lights. When performing the PMI contained in table 5-7 the following should be followed.

5.5.2 Preventive Maintenance Inspections.

5.5.2.1 Daily Checks.

Check the operation of the beacon and lamp, replace if necessary.

5.5.2.2 Bi-Monthly Checks.

(a) Lamp Changer (if equipped): Check the operation of the lamp changer. De-energize the beacon circuit and remove the operating lamp from its receptacle. Energize the beacon circuit and observe that the beacon changes to the reserve lamp. De-energize the beacon circuit and re-install the lamp previously removed.

(b) Slip Rings (if equipped): Check the condition of the slip rings and brushes. Clean the slip rings and brushes as per manufacturer's instructions. If sparking or pitting has occurred, smooth rings according to manufacturer's instructions. Avoid sanding as this 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) Lens Retainer: Check the clamps or screws that secure the beacon lens and filter (or cover) in place to be sure they are tight and the lens is properly seated.

(d) Clean glassware if necessary:

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.

Glassware: Clean and polish all glassware, both inside and outside, using a type of non-abrasive cleaner that will not scratch the lens.

5.5.2.3 Semi-annual Checks.

(a) Input Voltage: Check the input voltage and record the reading. It should be within 5 percent of the rated lamp voltage. Voltage levels higher than a lamp's nominal rating will prematurely reduce the lamp's life proportionally to the increased voltage. Conversely, voltage levels lower than a lamp's nominal rating will reduce the lamp's light output proportionally to the reduced voltage. Make the measurement at the beacon lamp terminals, with all field equipment energized, so the voltage reading will reflect operating conditions. Beacon lamps are very sensitive to voltage changes. A drop of 10 percent will reduce the light output by 31 percent while a rise of 10 percent will shorten the lamp life 72 percent.

(b) Lamp Focus and Beam Elevation: Verify that beacon beam is narrow, well defined and projects horizontally. Check that the elevation setting has not slipped and it with elevation set at the time of installation. Beam elevation can normally be adjusted by lowering the lamp mounting position to elevate the beam or raising the lamp position to lower the beam.

(c) Lubrication: Beacons with a grease fitting on the vertical main shaft should be lubricated twice a year under ordinary operation or as directed by the manufacturer. Ring gears should have a small amount of grease applied per manufacturer's recommendation. Caution: Using an excessive amount of grease will result in its dropping down upon the slip rings and causing poor contact and arcing.

(d) Lightning Protection System: Check the earthing connection for tightness and check the condition of the conductor for corrosion or damage. Check and record the ground resistance. Compare the reading with the previous ground resistance checks. Reading must be less than 25 ohms. If the reading exceeds 25 ohms, immediate action must be taken to correct the grounding problem.

5.5.2.4 Annual Checks

(a) Base Level: Check the level of the beacon in four directions. Make corrections as necessary.

(b) Gears: Clean the old grease from the gears. When installing new grease, observe the caution statement above.

(c) Wiring: Inspect all wiring, electrical connections and relays for abrasions, breaks and loose connections. Check terminal lugs for tight electrical connection. Inspect conduit for loose supports and connections. Replace broken brackets.

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

Maintenance Requirement	Daily	Weekly	Bi-monthly	Semi Annually	Annually	Unscheduled
1. Check operation of beacon	●					
2. Check operation of lamp-changer			●			
3. Check slip rings and brushes			●			
4. Check clamps and filter			●			
5. Clean glassware and filter			●			
6 Check operation of relays			●			
7. Check and record input voltage				●		
8. Check lamp focus and beam elevation				●		
9. Lubricate main shaft, motor and ring gear				●		
10. Check grounding system				●		
11. Check level of base					●	
12. Clean and re-grease the gears					●	
13. Inspect wiring, lugs and conduit					●	

14. Check weatherproofing and gaskets					●	

Table 5-8. Preventive Maintenance Schedule for Rotating Beacons

5.6 ILLUMINATED WIND DIRECTION INDICATOR

5.6.1 Preventive Maintenance Inspections

5.6.1.1 Daily Checks.

(a) Visually check to see that the light is burning properly. If the lamps burn dimly, the voltage is probably too low. If the lamps burn out too frequently, the voltage is probably too high. Some of these supplemental wind direction indicators are fed from the runway edge light series circuit via a power adapter and consequently, the voltage to the lamps and the brightness of the lamps may vary slightly with a change in runway light intensity.

(b) Check the obstruction light, replace lamp if necessary

5.6.1.2 Monthly Checks.

(a) Check the cone assembly to see that it swings freely throughout the 360 degree travel.

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

(c) Check to make sure that the movement of the wind cone is not impeded by vegetation.

5.6.1.3 Semi-annual Checks.

(a) Check the ball joint to see if they need lubricating. An application of light grease should be sufficient.

(b) Take an insulation reading on the underground feeder if wired from a parallel source and record the results. Compare results to previous readings to look for signs of insulation deterioration. If powered from a power adapter connected to a series lighting circuit, check the voltage at each output step of the series circuit to make sure the power adapter is still functioning within manufacturer’s parameters.

5.6.1.4 Annual Check.

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

(b) Check the wiring at power supply collectors. If frayed, loose, or pitted, repair or replace.

(c) Check the ground system for loose connections.

(d) Test the resistance of the grounding system. It should measure 25 ohms to ground or less.

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

Maintenance Requirement	Daily	Weekly	Monthly	Semi Annually	Annually	Unscheduled
1. Check lamp operation	●					
2. Check obstruction light	●					
3. Check cone assembly			●			
4. Check condition of wind cone fabric			●			
5. Clean movement of wind cone			●			
6 Check ball joint				●		
7. Check and record insulation reading				●		
8. Check the assembly base					●	
9. Check wiring at power supply collectors					●	
10. Check grounding system for loose connections					●	
11. Test the resistance of grounding system					●	
12. Clean and re-grease the gears					●	
13. Inspect the condition of paint, repaint if necessary						●

Table 5-9. Preventive Maintenance Schedule for Illuminated Wind Direction Indicator

5.7 Precision Approach Path Indicator (PAPI) System

5.7.1 Preventive Maintenance Inspection Procedures

Precision Approach Path Indicator (PAPI) System preventive maintenance inspection should include checking and, if necessary, taking the indicated corrective action, as follows:

5.7.1.1 Daily Checks.

Confirm all lamps are burning and are of equal brightness. Adequate spare lamps should be available to permit a complete replacement of all lamps in the system. Lamps should be replaced immediately if they burn out or become darkened.

5.7.1.2 Monthly Checks.

(a) Check operation of controls. Check remote control switch brightness control.

(b) Check for damage by mowers etc.

(c) Clean lamps and filters.

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

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

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

(g) Check the horizontal and lateral alignment of the light boxes, and check the aiming (vertical angle) with the PAPI aiming instrument. Record the angle setting and the date in a maintenance log.

(h) Check leveling and operating of tilt switch - if applicable.

(i) Check the change from red to white is coincident for all element in a unit

5.7.1.3 Semi-annual Checks.

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

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

5.7.1.4 Annual Check

(a) Check the system from the air. Adjust, if required, and record the result.

(b) Check supporting structure and foundation of each unit and repair, if required.

Maintenance Requirement	Daily	Weekly	Monthly	Semi Annually	Annually	Unscheduled
1. Check lamp operation	●					
2. Check operation of remote control			●			
3. Check for damage			●			
4. Visually check mechanical parts for cleanliness			●			
5. Check the PAPI boxes for any damage			●			
6 Check for cable damage from rodent			●			
7. Check for horizontal and lateral alignment			●			
8. Check leveling and operation of tilt switch			●			

9. Check the change from red to white is coincident			●			
10. Check insulation resistance of underground cables				●		
11. Check resistance of grounding system				●		
12. Check the system from the air					●	
13. Check supporting structure and foundation of each unit					●	

Table 5-10. Preventive Maintenance Schedule for PAPI (Precision Approach Path Indicator).

5.7.2 Maintenance Procedures

5.7.2.1 Adjustment of the Vertical Aiming.

This adjustment is performed by using a clinometer. Clinometers are normally supplied with the PAPI. Handle these precision instruments carefully. Make sure the aiming device is the one supplied with the PAPI light units.

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

(b) Stand in front of the PAPI units (approximately 15 m away) and check that the light changes color simultaneously along the whole width of each unit. If not, horizontal leveling was not done properly, the red filters are out of position, or the box is warped.

(c) Check the tilt switch on all units (where provided) by placing the small level on the marked top surface of the tilt switch and adjusting the tilt switch if necessary. If the tilt switch shuts off the power when it is level, the tilt switch should be replaced. The main switch may have to be toggled off and on to reset tilt switch circuit. For tolerances, refer to the manufacturer's installation manual.

5.8 Runway Threshold Identification Lights (RTILs)

5.8.1 Preventive Maintenance Inspection Procedures

Runway Threshold Identification lights (RTILs) System preventive maintenance inspection should include checking and , if necessary, taking the indicated corrective action, as follows:

5.8.1.1 Daily Checks.

Check that lamps are operating and are flashing in proper sequence.

5.8.1.2 Bi-monthly Checks.

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

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

(c) Check for damage or misaligned lights.

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

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

5.8.1.3 Semi-annual Checks.

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

(b) Check electrical contacts and connections to ensure tightness.

(c) Check and adjust alignment and elevation of light units. For unidirectional RTILs, check alignment and elevation using the following tools:

1. A plywood triangle cut to angles of 15 degrees, 80 degrees, and 85 degrees.

2. A 4-inch line level.

The procedure to align the unidirectional RTIL is as follows:

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

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

5.8.1.4 Annual Checks.

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

(b) Check insulation resistance of power cables.

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

(d). Repaint as required.

Maintenance Requirement	Daily	Weekly	Bi-monthly	Semi Annually	Annually	Unscheduled
1. Check operation of lamps	●					
2. Check operation of controls			●			
3. Check cleanliness of optical system			●			
4. Check for mechanical damage or misaligned parts			●			
5. Check operation of interlocks.			●			
6 Check for vegetation around lights.			●			
7. Check cabinets for cleanliness and moisture.				●		
8. Check electrical connections.				●		
9. Check alignment and elevation of unidirectional RTIL.				●		
10. Realign unidirectional RTILs, as required.				●		
11. Check power distribution equipment.				●		
12. Check insulation resistance of cable.					●	
13. Check resistance of grounding systems.					●	
14. Check need for painting					●	

Table 5-11. Preventive Maintenance Schedule for RTIL (Runway Threshold Identification Lights)

5.9 Approach Lighting System

5.9.1 Preventive Maintenance Inspection Procedures

To perform PMIs contained in Table 5-11, proceed as follows:

5.9.1.1 Daily Check.

(a) Check and record burned-out lamps.

5.9.1.2 Weekly Checks.

(a) Request tower personnel to turn on the system and cycle through each brightness step from the remote control panel. During the sequence, the maintenance technical personnel should be in a position to observe the system operation.

(b) Replace burned-out lamps as necessary .

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

5.9.1.3 Monthly Checks.

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

(b) Clear vegetation or obstructions from the front of all lights to ensure adequate visibility. Approved chemicals can be used to help control the growth of vegetation around the lights.

5.9.1.4 Semi-annual Checks.

(a) Check light fixtures for alignment.

(b) Check structures carefully for hidden corrosion.

(c) Check the approach area for new structures or for growth of vegetation which may violate the approach clearance criteria. A clear line-of-sight is required from any point on a plane 1/2 degree below the glide slope extending feet 75 m from each side of centerline for a distance up to 500 m in advance of the outermost lights in the system. If objects block a view of the lights and cannot be removed, refer the problem to appropriate airport authorities.

5.9.1.5 Annual Checks.

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

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

Maintenance Requirement	Daily	Weekly	Monthly	Semi Annually	Annually	Unscheduled
1. Check for burned-out lamps	●					
2. Check operation of controls		●				
3. Replace burned-out lamps.		●				
4. Record input and output voltages of control cabinet			●			
5. Clear any vegetation obstructing the lights.			●			
6 Check angle of elevation of lights.				●		
7. Check structures for integrity..				●		
8. Check approach area for new obstructions.				●		

9. Check electrical distribution equipment.					●	
10. Check insulation resistance of cable					●	
11 Check fuse holders, breakers, and contacts.					●	

Table 5-12. Preventive Maintenance Schedule for Approach Light System

5.10 Hazard Beacons and Obstruction Lights

5.10.1 Preventive Maintenance Inspection Procedures

To perform the PMIs contained in Table 5-12, proceed as follows:

5.10.2 Daily Checks.

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

5.10.3 Monthly Checks.

(a) 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.

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

5.10.4 Semi-annual Checks.

Test the insulation resistance of feeder cables and ground resistance of the grounding system.

5.10.5 Annual Checks.

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

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

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

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

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

(f) The duplex obstruction lights should be serviced as described above. In addition, if a changeover relay is used, it should be cleaned and the relay housing gasket should be kept in good condition. Replace all missing cover screws to prevent water, moisture, and dust from entering the relay enclosure.

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

1. 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.

2. 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.

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

5.10.6 Unscheduled Maintenance.

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

Maintenance Requirement	Daily	Weekly	Monthly	Semi Annually	Annually	Unscheduled
1. Check operation of lamps	●					
2. Check flash rate of hazard beacons			●			
3. Check operation of photocell.			●			
4. Check insulation resistance and ground resistance.				●		
5. Check wire and connections.					●	
6. Check voltage at lamp socket.					●	
7. Check weatherproofing of the fixture.					●	
8. Check lightning protection system.					●	

9. Service lowering device and other supporting					●	
10. Check changeover relay in dual fixture.					●	
11. Clean and recondition beacon.					●	
12. Install new lamp after 80 percent of rated life.						●

Table 5-13. Preventive Maintenance Inspection Schedule for Hazard Beacons and Obstruction Light

5.11 Airport Lighting Control And Monitoring Systems (ALCMS).

5.11.1 Maintenance

There are certain basic provisions of the control system that may be addressed, particularly at the time of installation. These provisions will make the task of maintaining these systems ultimately easier for the maintenance staff.

5.11.2 Maintenance Training

When installing a new system, the control system designer should specify the amount and length of training classes required for the electrical maintenance and other airport personnel (i.e. Operations). All persons who may be called upon to troubleshoot or maintain the system should be properly trained. The training material should be reviewed at a minimum once per year. Training classes for maintenance personnel should be limited to a maximum of 4-6 people per class in order to insure hands-on training. The key to successful training is the availability of well-written comprehensive manuals from the manufacturer that assume that maintenance personnel do not retain a day-to-day knowledge of key maintenance procedures. Today’s control systems are fairly maintenance-free and the maintenance person does not get to use his or her expertise on a daily basis. The maintenance manual and training should, at a minimum, include the following subjects.

(a) System block diagram – - Theory of Operation

(b) System drawing package - System assemblies and wiring diagrams

(c) Overall system maintenance

(d) Hands-on troubleshooting

(e) Procedure in transferring control from Air Traffic Controllers (ATC) to maintenance personnel and return to ATC.

(f) System reporting capabilities

(g) Control and monitoring capabilities

5.11.3 Technical Support

It is very important that the airport maintenance people have adequate technical support from the system manufacturer. This support is not just needed during the warranty period but for the years after that. It is in the best interest of the airport to always have back-up support available. This support should include the following:

(a) Technical phone assistance

(b) On-site technical field service as required

5.11.4 ALCMS Maintenance Manuals

The ALCMS manufacturer shall have supplied the necessary copies of the operation and maintenance manuals that are hard-covered and suitable for the daily operation and maintenance of the system.

5.11.5 As-Installed Drawing Package

The airport should possess a complete set of As-Installed drawings from the ALCMS manufacturer. The As Installed drawings should reflect the final installation design of the ALCMS including System Block Diagram (single line drawings), System External Wiring Diagrams, Assembly Drawings, and Assembly Wiring Diagrams.

5.12 TRANSFORMER STATIONS FOR ELECTRIC POWER SUPPLY

5.12.1 Preventive Maintenance Inspection Procedures.

To perform the PMIs contained in Table 5-14, proceed as follows:

5.12.2 Weekly Checks.

(a) Check over-all condition visually.

5.12.3 Semi-annual Checks.

(a) Clean insulators and check electrical connection for tightness, taking preventive measure
(b) Clean station of any dirt and moisture
(c) Check for lock serviceability, repair

5.12.4 Annual Checks.

(a) Check protection relay, adjust if necessary

(b) Check insulation resistance of high voltage cable; record and compare with previous reading taking preventive measures

(c) Check earthing and measure its resistance;

(d) Check transformer for noise, repair if necessary

(e) Check for rust, corrosion or defective coating; clean and paint accordingly

Maintenance Requirement	Daily	Weekly	Monthly	Semi Annually	Annually	Unscheduled
1. Check over-all condition visually		●				
2. Clean insulator and check connection				●		
3. Check for lock serviceability.				●		
4. Check protection relay					●	
5. Check insulation resistance of high voltage cable					●	
6. Check earthing resistance					●	
7. Check transformer for noise					●	
8. Check for rust, corrosion					●	

Table 5-15. Preventive Maintenance Inspection Schedule for Transformer Station

5.13 Relay And Switch Cabinets

5.13.1 Preventive Maintenance Inspection Procedures.

To perform the PMIs contained in Table 5-15, proceed as follows:

5.13.2 Semi-annual Checks.

(a) Check relays for positive closing of contacts, clean and replace as necessary

(b) Check contacts for corrosion and wear, clean replace as necessary

(c) Check monitoring relay of series circuit for proper feedback, repair as necessary

(d) Check condition of cabinet including weather seal, clean and repair as necessary

5.13.3 Annual Checks.

Check outer condition of cabinet for dirt, moisture, clean as necessary

Maintenance Requirement	Daily	Weekly	Monthly	Semi Annually	Annually	Unscheduled
1. Check relay for positive closing				●		
2. Check contacts for corrosion and wear				●		

3 Check monitoring relay				●		
4. Check condition of cabinet				●		
5. Check outer condition of cabinet					●	

Table 5-16. Preventive Maintenance Inspection Schedule for Relay and Switch Cabinet

5.14 CONTROL CABLES, MONITORING UNITS, REMOTE CONTROL DESK

5.14.1 Preventive Maintenance Inspection Procedures.

To perform the PMIs contained in Table 5-16, proceed as follows:

5.14.2 Weekly Check

(a) Check control voltage and battery charger

(b) Check voltage and ammeter reading, adjust if necessary

(c) Check electrolyte level in battery, add distilled water as necessary

5.14.3 Monthly Check

Check functions of the monitoring unit; clean and repair or replace as necessary.

5.14.4 Semi-annual Check

Replace lamps in monitoring units.

5.14.5 Annual Check

(a) Check cables and clean
(b) Check relays for cleanness and clean.
(c) Check control and monitoring units and replace as necessary.
(d) Check the connection and tighten as necessary.

Maintenance Requirement	Daily	Weekly	Monthly	Semi Annually	Annually	Unscheduled
1. Check control voltage and battery charger	●					
2. Check voltage and ammeter reading	●					
3 Check electrolyte level in battery	●					
4. Check functions of the monitoring unit		●				
5. Replace lamps in monitoring units				●		
6. Check cables and clean						
7. Check relays for cleanness and clean						
8. Check control and monitoring units						

9. Check the connection						

Table 5-17. Preventive Maintenance Inspection Schedule for Control Cable, Monitoring unit and Remote Control Desk

5.15 APRON FLOODLIGHTING

5.15.1 Preventive Maintenance Inspection Procedures.

To perform the PMIs contained in Table 5-17, proceed as follows:

5.15.2 Daily Check

(a) Check switching operation from remote control

(b) Check lamp outage: replace as necessary

5.15.3 Annual Check

(a) Check relay for positive closing; clean or replace as necessary
(b) Check contacts for corrosion and wear, clean or replace as necessary
(c) Check condition of cabinet and weather seal; replace as necessary
(d) Check outer condition of cabinet; clean or paint as necessary.

Maintenance Requirement	Daily	Weekly	Monthly	Semi Annually	Annually	Unscheduled
1. Check switching operation from remote control	●					
2. Check lamp outage	●					
3. Check relay for positive closing					●	
4. Check contacts for corrosion and wear					●	
5. Check condition of cabinet					●	
6. Check outer condition of cabinet					●	

Table 5-18 Preventive Maintenance Inspection Schedule for Apron Floodlighting

CHAPTER 6. TROUBLESHOOTING PROCEDURES FOR SERIES LIGHTING CIRCUITS

6.1 INITIAL FAULT INVESTIGATION

6.1.1 SAFETY:

(a) Troubleshooting tests contained in this chapter may involve voltages that are dangerous. Safety precautions must be exercised for the protection of personnel and property.

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

(c) Series circuits are subject to two primary types of malfunctions, shorts to ground or opens. Keep in mind that an airfield lighting series circuit powered by a constant current regulator is an ungrounded circuit. Therefore, the circuit and CCR will function normally with one ground on the circuit. It is only when two or more grounds appear and a "short circuit" path is created that the current begins to flow through the earth, around the lighting load, and a section of lights appears out. In the case of an open in the primary field circuit, no current can flow and the entire circuit goes out.

(d) Constant current regulators larger than 10kW are required to have open circuit protection that will shut the CCR down within two seconds after current flow has been interrupted. Most manufacturers, however, provide this protection on all their CCRs. When in doubt, check your CCR's operating manual. Open circuits can exist in conjunction with grounds and if the CCR can develop enough voltage to overcome whatever resistance exists in the circuit, it will establish current flow and continue operating.

(e) In most instances, we learn of a malfunctioning lighting circuit from a report made by the control tower or through an operations report. Sometimes it is noticed by an electrical technician making a routine daily runway inspection or light check. Either way, the complaint may consist of a section of lights out or an entire circuit not functioning. The first step in an initial fault investigation is to make a quick visual inspection of the affected lighting on the airfield. This will provide information as to whether an entire circuit is out or just a portion of the lighting on a specific circuit is affected. This gives an electrical technician a good idea as to the possible cause of the malfunction. If an entire circuit is out, the problem could be an open circuit in the field wiring or a malfunctioning CCR. If only a portion of the lights on a circuit is out, the problem is most likely due to a short to ground at each end of the affected section. Keep in mind that if the malfunction is due to a short to ground in the field circuit, the longer the circuit remains energized, the more damage will result at the location of the ground faults due to arcing.

(f) In the AFL Room, once the exact malfunctioning circuit has been determined, the regulator supplying the circuit can be located. Turn the regulator local control to the "OFF" position and shut down and lock out the power supply to the regulator. Disconnect the field circuit. This will allow you to check both the continuity and insulation resistance in the field circuit. After separating the ends of the field circuit by disconnecting at least one end of the field circuit from the regulator, prepare to take a measurement for continuity in the circuit.

(g) If using a volt-ohm-meter (VOM), the first step is to set the meter to the R x 1 scale and "zero" the meter (if using a digital multimeter, these steps are not necessary). This is accomplished by setting the meter to the desired scale (R x 1 in this case) and touching the two meter leads together. Make sure the leads are plugged into the correct sockets in the meter (on most VOMs, this is the + and common sockets) and adjust the "zero ohms" knob until the meter needle is at the zero point (usually on the right side of the meter scale). After this adjustment has been made, take a reading of the resistance in the field circuit by checking between the two separated conductors of the field circuit. If no continuity can be read in the circuit, check for a short to ground in each side of the circuit and then proceed to Section 6.2, "Locating Open Circuit Faults." If the circuit shows continuity (a measurable amount of resistance) normally between 20 to 70 ohms, the circuit is not open. If a much higher resistance is measured (1000 ohms +), then a high resistance open circuit fault has occurred. Many times this is indicative of a transformer with a faulty primary winding that has not completely burned open yet. It could also be due to a cut cable which has both ends in contact with the earth.

(h) If the resistance in the circuit checks normal, proceed to check the resistance to ground from each end of the circuit to ground. If any resistance can be read to ground with the meter set at R x 1, then one or more low resistance shorts to ground exist and troubleshooting procedures are moved to the field (see Section 6.1). If the meter reads no continuity (no meter movement) when the circuit is checked to ground, set the meter for the R x 100 and R x 10,000 scales respectively and, after zeroing the meter, check for a short to ground on these two scales. Remember that the positive (red) lead should always be connected to the circuit or conductor under test and the negative (black) lead should be connected to ground. Also be aware that on the R x 10,000 scale, merely touching the meter leads with your fingers will produce a reading. Most ground faults serious enough to cause the lights to go out will be reading less than 1000 ohms to ground, usually less than 100 ohms to ground and will be easily indicated on the R x 1 scale. If no ground fault is detected on the circuit with the VOM or DMM, use an insulation resistance tester to test the circuit. Insulation resistance testers operate at much higher voltages, 500 to 5000 volts, and are more useful in locating a high resistance ground fault.

(i) If no problems are detected in the field circuit, the next step is to try to energize the CCR using the manual control on the front of the CCR. After reconnecting the field circuit to the CCR, and turning the primary power back on to the regulator, begin by putting the switch in the step 1 position and note if the CCR comes on. If it does not, the problem may be as simple as a tripped breaker or blown fuse and you should proceed to check for proper input voltage to the CCR. If the CCR energizes for about 2 seconds and then shuts off, the fault is likely a malfunction of the open circuit or over current protection circuitry in the CCR. If the field circuit appears normal, disconnect and lock out the primary power source to the CCR and perform a short circuit test by shorting the output of the regulator with a #10 or larger wire, and test the operation of the regulator again. If the regulator still shuts off after a few seconds, there is an internal problem with the regulator or its controls. Consult the operation and maintenance manual for the CCR for specific troubleshooting instructions.

(j) If the CCR remains on and appears to be operating normally on the lowest brightness setting, continue switching the CCR up through the brightness steps while noting the increase in current output on the meter until the maximum brightness is reached, either step 3 or step 5 depending on the style of the regulator. If the regulator has a normal output on the lower steps, but the output is low on the highest step, the regulator may be overloaded or there may be too much inductance in the field circuit. Perform a short circuit test of the regulator by turning the regulator off and disconnecting and locking out the primary power to the regulator. Then connect a #10 wire across the output and re-energize the regulator. If the regulator operates normally with the output shorted, this would indicate an overload is present in the field circuit. If there have been no additional loads added to the field circuit, check for burnt out lamps or otherwise open secondary connections on the field transformers. Newer regulators are required to withstand up to 30% open-circuited isolation transformers. Older regulators may only tolerate 10%. When a large number of open-circuited transformers exist on the output of a regulator, it increases the inductive loading on the regulator and will cause the regulator to act strangely and many times appear overloaded. One cause of this condition may be a lightning strike that has blown out a large number of lamps in the circuit.

6.2 LOCATING GROUND FAULTS IN THE FIELD

(a) Once it has been established that the circuit is shorted to ground, the troubleshooting procedures can be moved to the field. Keep in mind that if there is a section of lights out othe circuit, there will ALWAYS be at least two shorts or ground faults in the circuit. At this time the circuit may be energized and a visual inspection can be made to try to locate the faults. If the circuit is a simple loop configuration, a visual inspection can sometimes be an effective means to find the problem. It is best to have someone at the AFL Room with a walkie talkie so that as soon as the good to bad transition areas in the circuit are located, word can be sent to the AFL Room to shut off the regulator and lock it out so that repairs can be made. Drive the circuit looking for any section of lights that are out or appear to be extremely dim and mark this area by putting a surveyor’s flag or a paint mark at the locations of the last light burning and the first light out as shown in Figure 6-2. After the circuit has been de-energized and locked-out, check the lights at each end of these “transition areas” for burned transformers, connectors, etc. Always remember that there will be at least two shorts in the circuit and both must be repaired. In some instances, especially in the case of direct buried cables or when the circuit has been energized for a long period of time while ground faults are present, more than two shorts to ground may have occurred.

(b) The best method for finding ground faults after the initial visual inspection has been made is to locate them using the VOM. Leave the ends of the circuit separated at the AFL Room and suspend the ends of the cables in free air if disconnected from the CCR terminal. Refer to as-built plans if available to locate the center of the circuit and break the circuit at that point by disconnecting the cable at one side of the transformer. (See Figures 6-3a & 6-3b). Take a reading to ground in both directions from this point and determine which way the fault is located. It is entirely possible that the meter may indicate a fault in both directions from this point or only in one direction as there may be two or more faults in the same section of cable. Leaving this connection open (if possible), proceed to a point in the circuit approximately halfway between the midpoint and the AFL Room in the direction of the fault and break the circuit again. As before, take a reading on the circuit in each direction to determine the location of the fault. Continue until each fault is located and corrected.

(c) During the course of troubleshooting, you may find that when you remove a transformer from the ground that the fault seems to disappear. When this happens the fault is located at that transformer; normally you can visually see the burned transformer. However, in the case of an internal primary to secondary short in the transformer, there may not be anything readily apparent. Look at the fixture attached to the transformer and check to see if the socket or secondary plug is burned. This is usually a good sign of a primary to secondary short. A short of this nature can be confirmed by touching one lead of the VOM to one of the primary leads of the transformer and touching the other to one of the sockets on the secondary connector. If the transformer is shorted, continuity will be indicated on the meter. Sometimes checking between one of the primary connectors and the outside body of the transformer will indicate a transformer with a significant leak to ground. This can be performed with an insulation resistance tester for better results. If checking the insulation integrity of transformers, you can also submerge the transformer in a bucket of water and connect the positive lead of the Megger to one of the primary leads and the negative lead to a bare wire dropped into the bucket. If any leakage is shown, the transformer is suspect or bad depending on the reading. Reasonably new transformers should read over 1000 megohms, with readings decreasing with age.

6.3 LOCATING OPEN CIRCUIT FAULTS

(a) Open circuits can be successfully located using similar tactics as those used for locating short circuits or ground faults. If the circuit appears to be grounded in conjunction with an open, the troubleshooting procedure used for finding ground faults may be used since the open and ground will likely be located at the same place. Many times a cable will burn in two if left operating after a short to ground has developed. If the initial fault investigation has revealed an open in the field circuit and the circuit does not appear to be grounded, de-energize the regulator and lock out the regulator power supply and proceed to the field and locate the approximate center of the circuit.

Note: Any time an open circuit is indicated, the first question to ask is: “Has anyone been doing any excavating in the vicinity of the airfield?” If so, go out and look for a pile of fresh dirt and you will likely find your problem.

(b) For this type of troubleshooting where you are looking for continuity, it is helpful to have the ends of the circuit connected together at the AFL Room --- see Figure 6-5. That way, when the problem is corrected, it can be verified by being able to read a loop from any point in the circuit. Proceed to the approximate midpoint of the circuit and disconnect the circuit at the transformer and ground the circuit in both directions. Check for continuity to ground at another point in the circuit by disconnecting the transformer. If the circuit is connected together at the AFL Room and you have only one open in the circuit, you should read continuity in one direction but not the other back to the grounded midpoint of the circuit. When the grounded conductor is identified, have someone at the midpoint connection make and break the connection to ground in one direction and then the other until you have established which section of the circuit is open. Then proceed to a point halfway between your present location and the grounded midpoint in the section of the cable that is open and take another reading. If this time you can read to ground in the direction of the midpoint of the circuit, then you know that the open is behind you or between you and the last point you tested. By moving the intentional ground point and looking for continuity in each section of the circuit, the open(s) can be quickly located. See Figure 6-5 for details.

6.4 INTERCONNECTED CIRCUIT FAULTS

(a) It is common for airfields with multiple circuits to experience interconnecting faults. There are two main types of interconnecting faults. The first occurs when two or more circuits contain grounds and/or opens in a manner that electrically connects the circuits together. The second type occurs when two or more circuits do not contain any faults, but they become capacitively coupled together.

(b) When multiple circuits contain faults that connect them together, a section of primary cable is common to all circuits involved. (See Figures 6-6 & 6-7.) Multiple ground faults are the most common cause of this problem. A continuity check between the suspected circuits will confirm if they are electrically connected. To troubleshoot this condition, disconnect and isolate the output leads of regulator "B," then locate the circuit fault on regulator "A" circuit. This will usually locate the common fault area of both circuits.

(c) A capacitive coupling fault occurs when two or more series circuits run parallel and in close proximity to each other. This situation becomes a problem if the circuits have monitors on them because the induced currents can simulate field faults. A continuity check between the suspect circuits confirms they are not electrically connected together. To correct a capacitive coupling fault, simply swap the output leads of one of the regulators involved. This will cancel the capacitive coupling effect.

(d) The troubleshooting methods and procedures outlined in the following paragraphs involve dangerous voltages and should only be attempted by qualified personnel using appropriate safety procedures. Also, while sometimes helpful or necessary, be aware that these methods are by their nature "destructive testing" and if performed indiscriminately can result in more damage occurring in the field circuit.

(e) The following troubleshooting methods are best described as "destructive testing." These methods can be used when either time constraints or difficulty testing using an ohm meter or insulation resistance tester makes traditional troubleshooting impractical. One such instance might be in the case of direct buried circuits where traditional troubleshooting is difficult and time consuming due to having to dig up each connection to perform testing. Another case when this type of troubleshooting might be considered is when a runway circuit is out of service, and time is of the essence due to disrupting air traffic operations at your facility. These methods do require that the circuit have a significantly low resistance to ground at the point of the fault, preferably less than 1000 ohms to ground, the less the better. It should also be noted that small regulators (10kW or less) may not develop sufficient voltage to be effective.

6.5 INTENTIONAL GROUND TEST

(a) The Intentional Ground Test is another method used to find a single ground fault. (See Figures 6-8a & 6-8b.) If an insulation resistance test indicates a ground in the circuit, but a visual inspection is inconclusive, this test method will help locate the problem.

(b) First, shut off and lock out the regulator. Next, label the two regulator output leads "1" and "2." Connect a 45-watt isolation transformer and light fixture between regulator output "1" and ground as shown in Figure 6-8a. The ground resistance of the test connection must be very small. Next, energize the regulator. Keep away from the test setup. If the test lamp illuminates, there is at least one ground fault on the circuit. The brighter the test lamp glows, the lower the resistance of the ground fault(s). With the regulator energized, conduct a visual inspection of the circuit.

(c) If there is a section of dim or out light fixtures, a ground fault exists between the last light operating properly and the first dim or out light. Mark this area.

(d) If all the lights are dim or out, the ground fault is between output “2” and the first light fixture on that side of the circuit.

(e) If all the lights appear to be OK, the ground fault is between output “1” and the first light fixture on that side of the circuit.

(f) De-energize and lock out the regulator. Switch the test transformer/light assembly from output “1” to output “2” (See Figure 6-8b). Energize the regulator. The test lamp should illuminate. Conduct a visual inspection of the circuit.

(g) If there is a section of dim or out light fixtures, and the location of the “good to bad” lights is in the same spot as marked in Paragraph 6.5.2, the circuit has a single ground fault at that location. (The transition area is the same, but the lights that were on in Paragraph 6.5.2 should now be off, and the lights that were off in Paragraph 6.5.2 should now be on.) De-energize and lock out the regulator. Check the connector kits, cable splices, etc., between the two adjacent light fixtures of the marked area and repair or replace suspected faults as necessary. At this point a VOM or insulation resistance tester may be used to verify faulty transformers, etc. Once the single ground fault is cleared, the test lamp will not illuminate when the regulator is energized. Remember, stay away from the primary cable while the regulator is on.

(h) If there is a section of dim or out light fixtures and the location of the “good to bad” lights is not in the same spot as marked in Paragraph 6.5.2, there are at least two ground faults on the circuit. Mark this new transition area. De-energize and lock out the regulator. Check the connector kits, cable, transformer, etc., between the two adjacent light fixtures of the newly marked area and repair or replace suspected faults as necessary. As each fault is cleared, energize the regulator and perform a visual inspection of the circuit. Keep away from the energized primary cable and always lock out the regulator when handling the cable. The “good to bad” transition area should move toward the spot marked in Paragraph (b). Continue troubleshooting the faults in this manner until the last ground is repaired and the test lamp does not illuminate when the regulator is energized.

(i) If all the lights appear to be operating correctly, the ground is between output “2” and the first light on that side of the circuit. (The same as found in Paragraph 6.5.3.) De-energize and lock out the regulator. Work from the light fixture towards output “2.” Check the cable, connector kits, splices, etc., and repair or replace suspected faults as necessary. The ground fault has been fixed when the test lamp does not illuminate when the regulator is energized.

(j) If all the lights are dim or out, the ground fault is between output “1” and the first light fixture on that side of the circuit (the same as found in Paragraph 6.5.4). De-energize and lock out the regulator. Work from the light fixture towards output “1.” Check the cable, connector kits, splices, etc., and repair or replace suspected faults as necessary. The ground fault has been fixed when the light fixtures operate properly and the test lamp does not illuminate when the regulator is energized. Remove the fault marker(s) from the field.

(k) If a Megger is not available, the intentional ground test can be modified to become a valuable preventive maintenance tool. (See Figure 6-9.) Connect the transformer/light assembly to the regulator output through an S-1 cutout, as shown in Figure 6-9. When the

S-1 handle is removed, the intentional ground is connected to the circuit. Once a month, shut off the regulator and pull the S-1 handle out. Energize the regulator to the high step and observe the test lamp. If the circuit has developed a ground fault, the lamp will illuminate. The lower the resistance of the fault, the brighter the lamp will glow. The main advantage of performing this check regularly is that a single ground fault can be detected and located easily, before multiple faults affect the visual appearance of the circuit. The general rule of thumb is, if the test lamp glows, the ground needs to be located and repaired. Add this procedure to your preventive maintenance routine and you will always stay one step ahead of grounding troubles.

6.6 GROUNDED OUTPUT TEST FOR LOCATING OPEN CIRCUITS

(a) The grounded output test is similar to the intentional ground test used to locate ground faults (Paragraph 6.5 (d). In order for this test to work, the open fault needs to be grounded. (See Figure 6-10.) If the open is not grounded or the ground resistance of the fault is too great, this method may only work with large kW rated regulators. Make sure the regulator is off. Refer to Figure 6-10a & b. Mark the regulator leads “1” and “2.” Remove lead “1” from the regulator. Cap or tape the bare end of lead “1.” Make sure it does not touch anything, and stay away from it when the regulator is energized. Next, connect the regulator output terminal, from which “1” was removed, to earth ground. Once again, the ground resistance of this connection must be as low as possible. Energize the regulator to the highest step. Stay away from the test connection to ground.

(b) If the regulator trips off on open circuit protection, do not attempt to energize the regulator a second time. Either the regulator is too small or the ground resistance of the fault is too large. In most cases, 4 and 7.5 kW regulators do not have enough power to drive a grounded output test that has any ground resistance at the fault location. If the circuit cannot be turned on, troubleshoot the open fault with the ohm meter/megohm test.

(c) If the regulator stays on and is registering output current, the open circuit fault can be found using the grounded output test. It is common for the regulator output current to fluctuate with this test set up. This condition will not damage the regulator, but continue to operate the regulator only long enough to locate the fault. Once the fault is cleared, the regulator should return to normal operation. With the regulator energized, conduct a visual inspection of the field circuit. There should be a section of lighted fixtures and a section of out fixtures. Mark the “good to bad” transition area. The open fault will be between the last light fixture operating and the first nonilluminated fixture. If all the lights are on, the open is between output “1” and the first fixture on that side of the circuit. If all the lights are out, the open is between output “2” and the first fixture on that side of the circuit. Deenergize and lock out the regulator.

(d) Remove the ground connection from the regulator output terminal. Reconnect lead “1” to the regulator output terminal. Next, remove lead “2” from the regulator. Cap or tape the bare end of lead “2,” making sure it does not touch anything and stay away from it when the regulator is energized. Next, connect the regulator output terminal from which “2” was removed, to earth ground. Energize the regulator to the highest step. Stay away from the test connection to ground. Conduct a visual inspection of the field circuit. This time the fixtures that were on in the last test should be out and the fixtures that were out in the last test should be on. The visual appearance of the circuit now should be the exact opposite of Paragraph 6.5.3 with the “good to bad” transition area in the same location. If this is true, the open is between the two light fixtures adjacent to the fault marker. De-energize and lock out the regulator. Start at one light fixture and work toward the other checking isolation transformer windings, connections, splices, and the primary cable for opens. Repair or replace any defects as necessary. To verify the open fault has been corrected, measure the resistance across output “1” and “2” with an ohmmeter. If the resistance is less than 700 ohms, the circuit is free of all opens. Anything over 700 ohms indicates the presence of an open or high resistance fault somewhere on the circuit. Remember, every circuit will have a different resistance value depending on the number and wattage of the light fixtures, but 700 ohms is the maximum for any airfield circuit. Remove the ground connection from the regulator and reconnect output “2” to the regulator. Energize the regulator to the high step

for approximately thirty minutes. This will double check that the repair work was done correctly. Perform a visual inspection of the circuit and remove the fault marker(s) from the field.

6.7 USING HEAT SENSING EQUIPMENT TO LOCATE GROUND FAULTS

Any time there are two shorts to ground in a series circuit, the current flowing to ground through the breach in the cable or transformer insulation produces heat. This is caused by the arcing that occurs when a good solid connection is not present in an electrical circuit. In the case of series circuits operated by constant current regulators, the regulator can produce very high voltages and damage and heat from arcing can be great. By utilizing economical infrared thermometers, the electrical technician is able to measure the difference between the temperatures of a “normal” light fixture and one that is running an abnormally high temperature. Infrared thermometers are available that use laser sighting and are effective at distances long enough to allow their use from a moving vehicle. Using this equipment, an electrician can drive down the runway or taxiway checking the temperature of each light until one is found that exhibits a higher temperature than the rest and then investigate that light. See Chapter 4, Test Equipment, for more information on this equipment.

6.8 USING CABLE FAULT LOCATING EQUIPMENT TO LOCATE GROUND FAULTS

Cable locating and fault finding technology has improved vastly over the years with many manufacturers offering equipment capable of locating underground cable and ground or shield faults. These units consist of a transmitter and receiver and if equipped for fault finding, usually have an optional A-frame pickup unit for use with the receiver. They are able to detect the location of ground faults in direct buried cables and can be highly accurate. See Chapter 4.7 Test Equipment, for more information on this equipment.

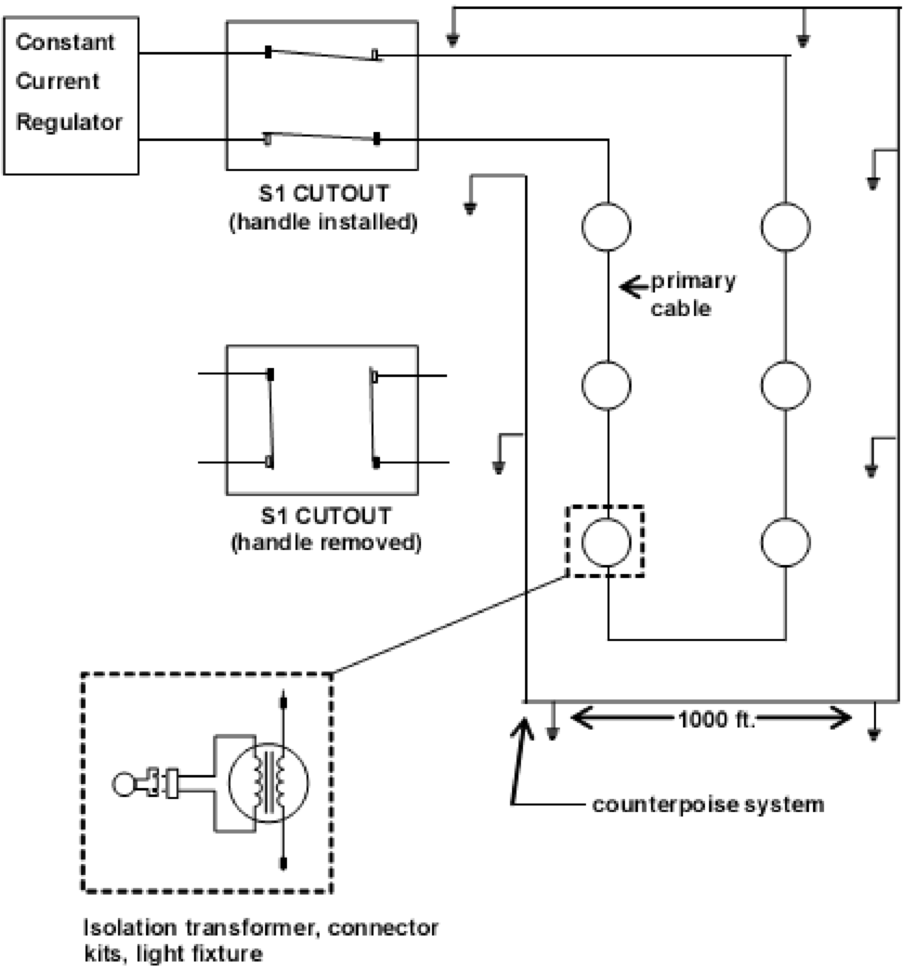


Figure 6-1. Typical Series Lighting Circuit

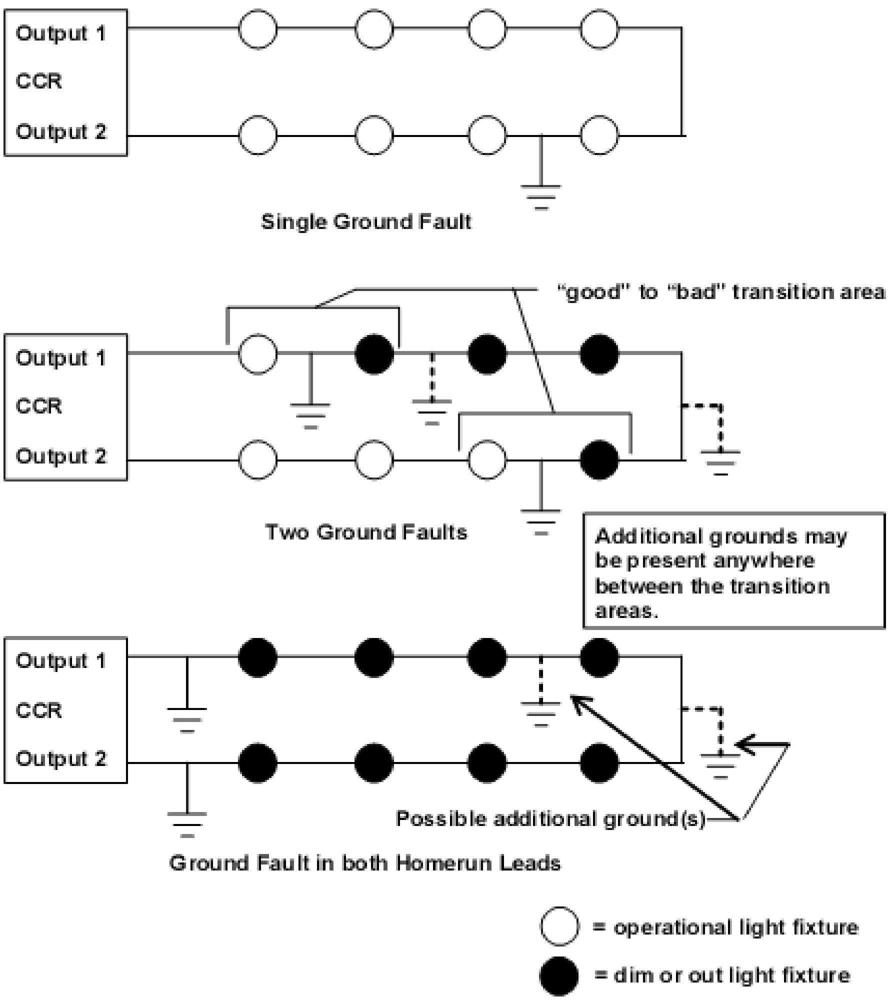


Figure 6-2. Typical Ground Faults

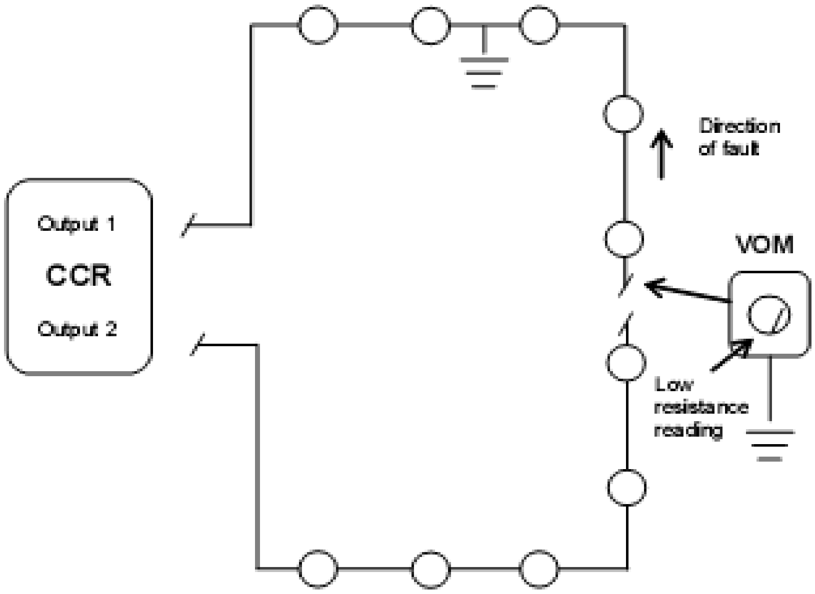


Figure 6-3a. Locating Ground Faults with the VOM

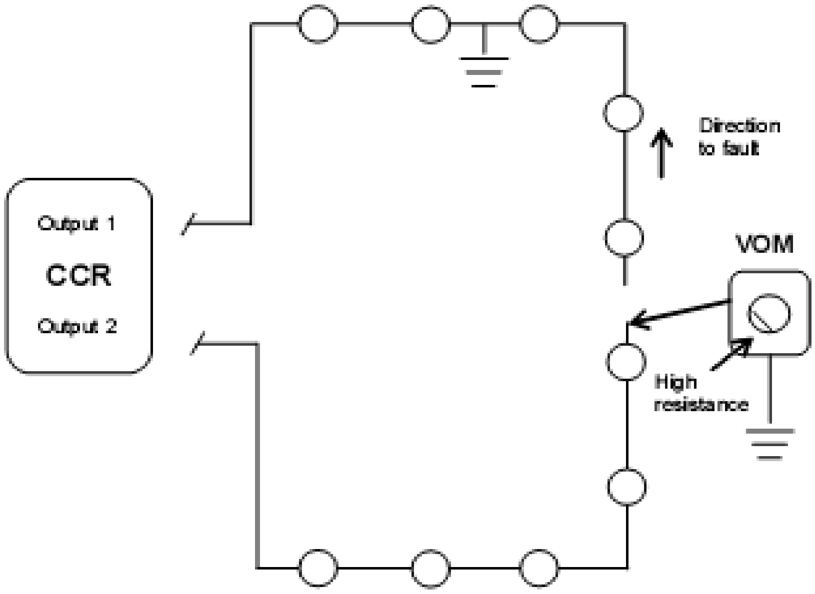


Figure 6-3b. Locating Ground Faults with the VOM

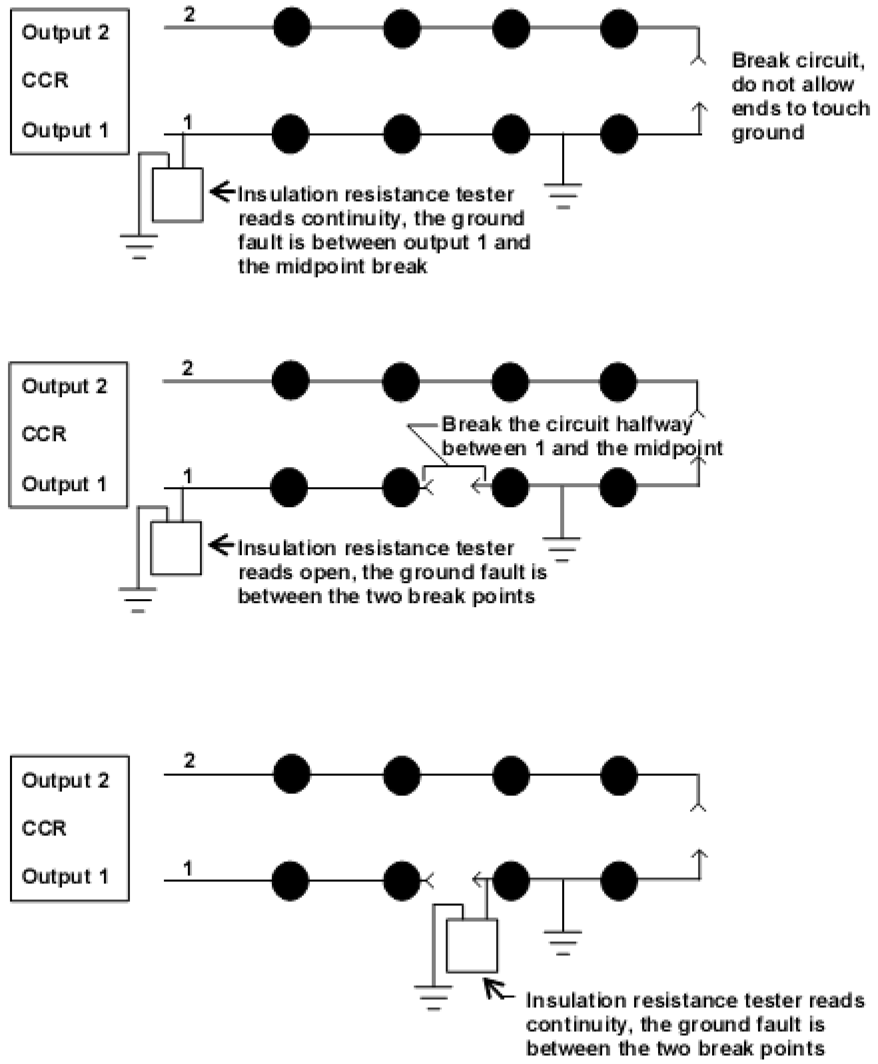


Figure 6-4. Alternative Method of Finding Ground Fault Using VOM or Insulation Resistance Tester

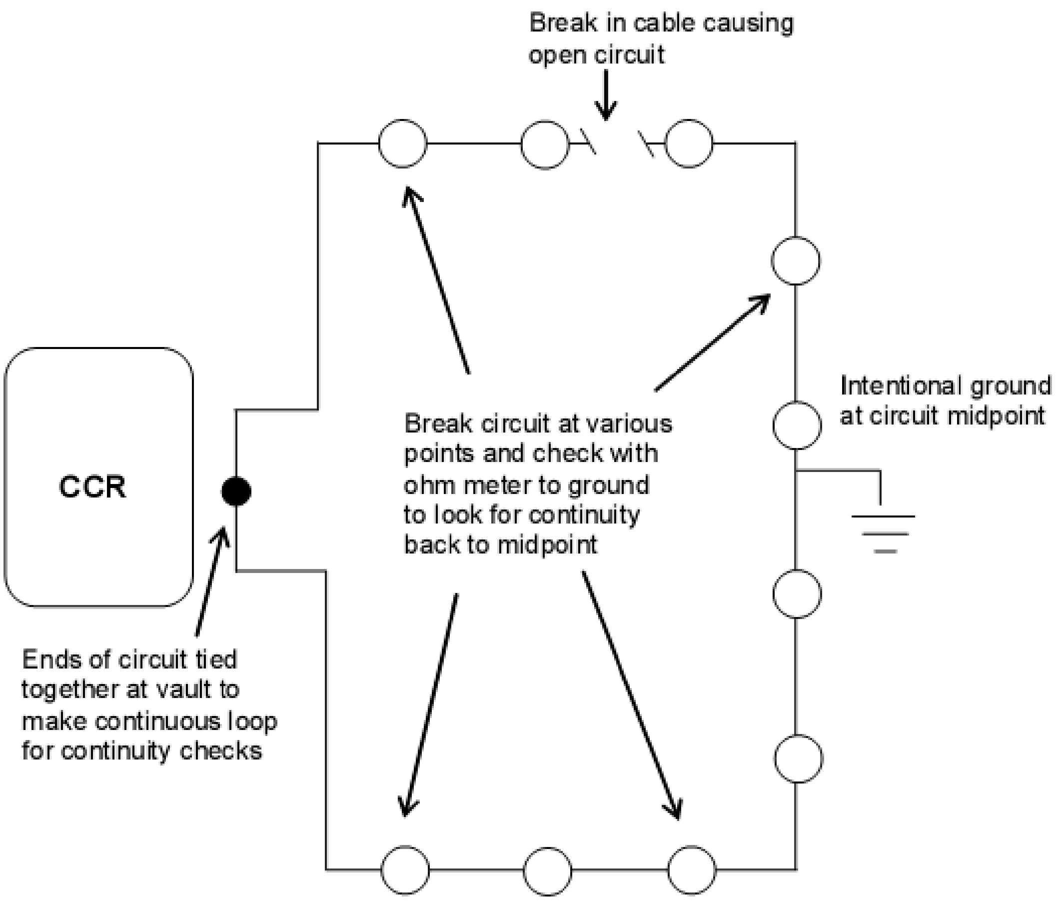
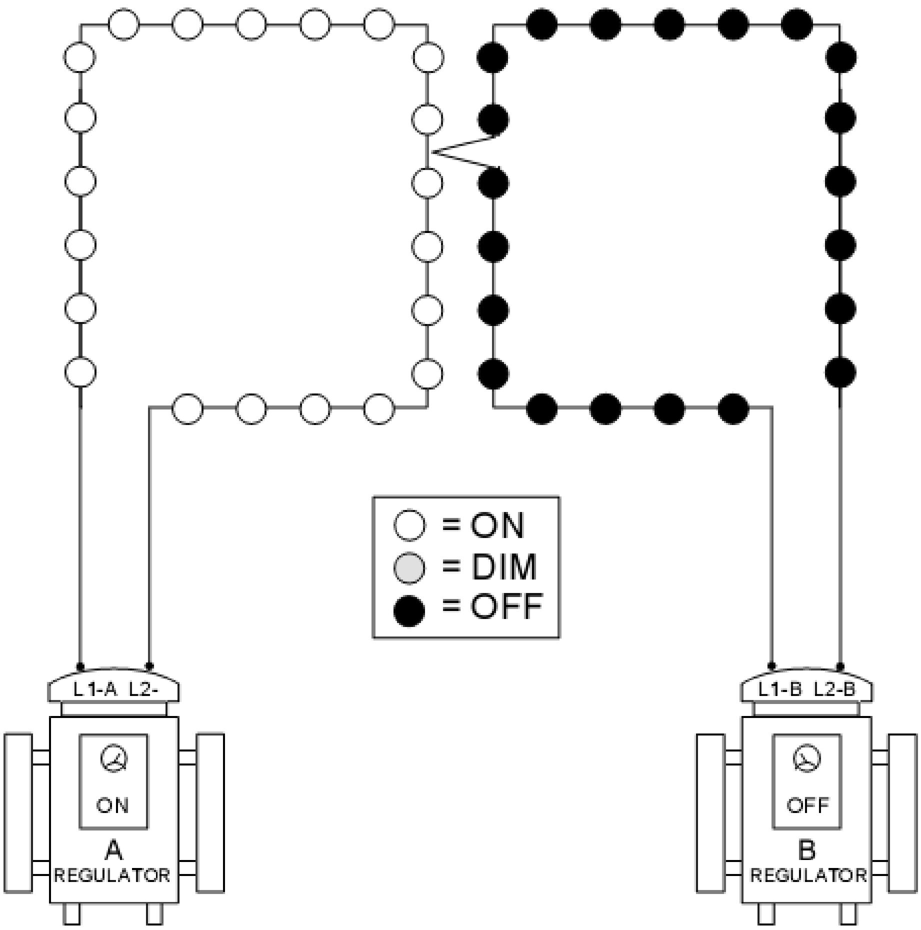


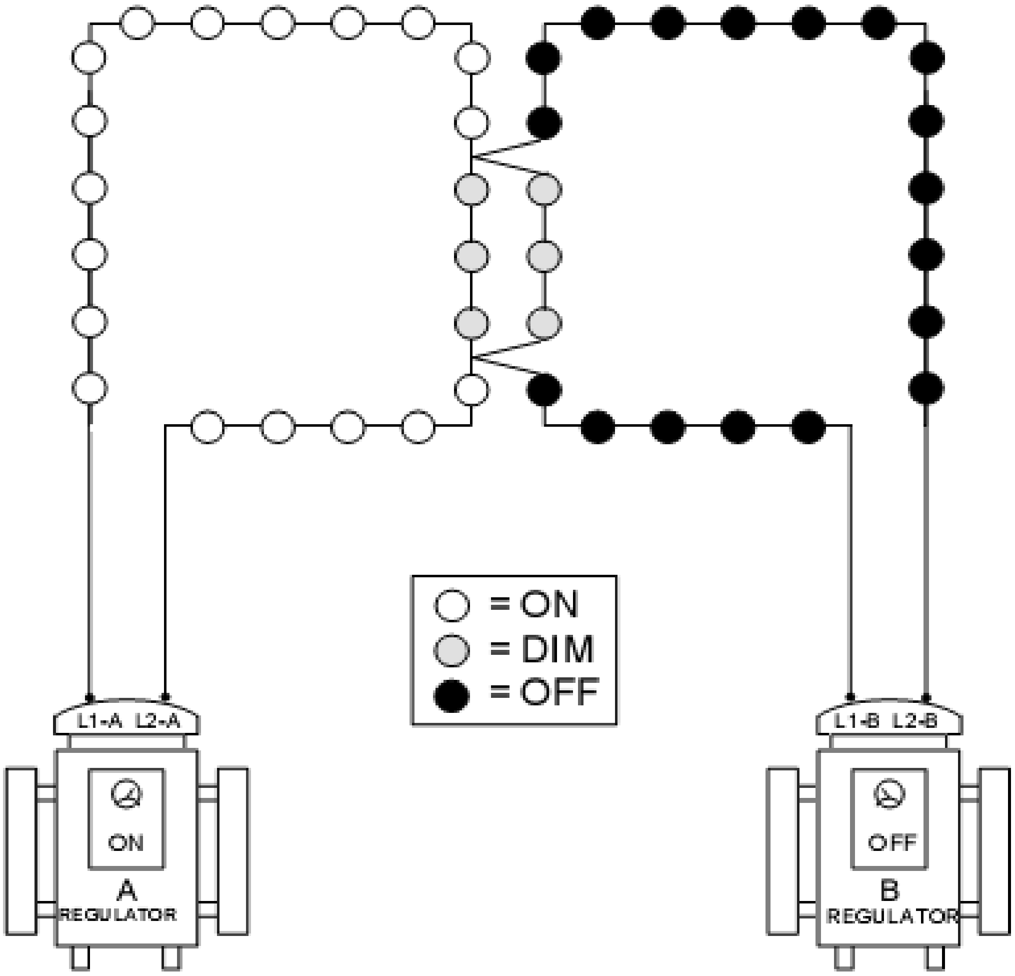
Figure 6-5. Locating Open Circuit Faults



THIS CONDITION CAN BE DETECTED BY OHMMETER TESTING RESISTANCE BETWEEN LOAD “A” AND LOAD “B”.

HAZARD EXISTS TO PERSONNEL WORKING ON EITHER LOAD “A” OR “B” WHEN THE OTHER LOAD IS ENERGIZED.

Figure 6-6. Single Load-to-Load Fault



THIS CONDITION CAN BE DETECTED BY OHMMETER TESTING RESISTANCE BETWEEN LOAD "A" AND LOAD "B."

HAZARD EXISTS TO PERSONNEL WORKING ON EITHER LOAD "A" OR "B" WHEN THE OTHER LOAD IS ENERGIZED.

Figure 6-7. Two Load-to-Load Shorts

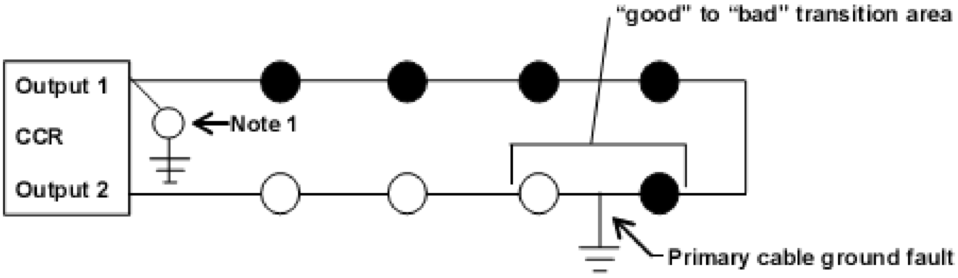


Figure 6-8a

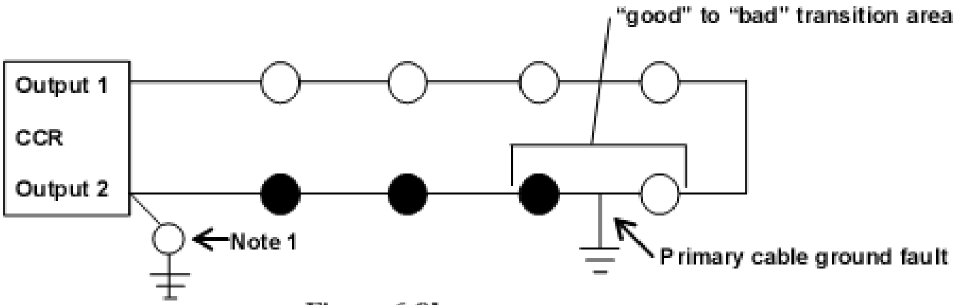


Figure 6-8b

NOTES:

1. 45 watt isolation transformer and light fixture connected between a regulator output terminal and earth ground. The ground resistance of the earth ground connection must be low.
2. When the circuit contains a single ground fault, the "good" to "bad" transition area will be in the same location with the test connection on either output 1 or output 2.

○ = operational light fixture

● = dim or out light fixture

Figure 6-8a, b. Intentional Ground Test

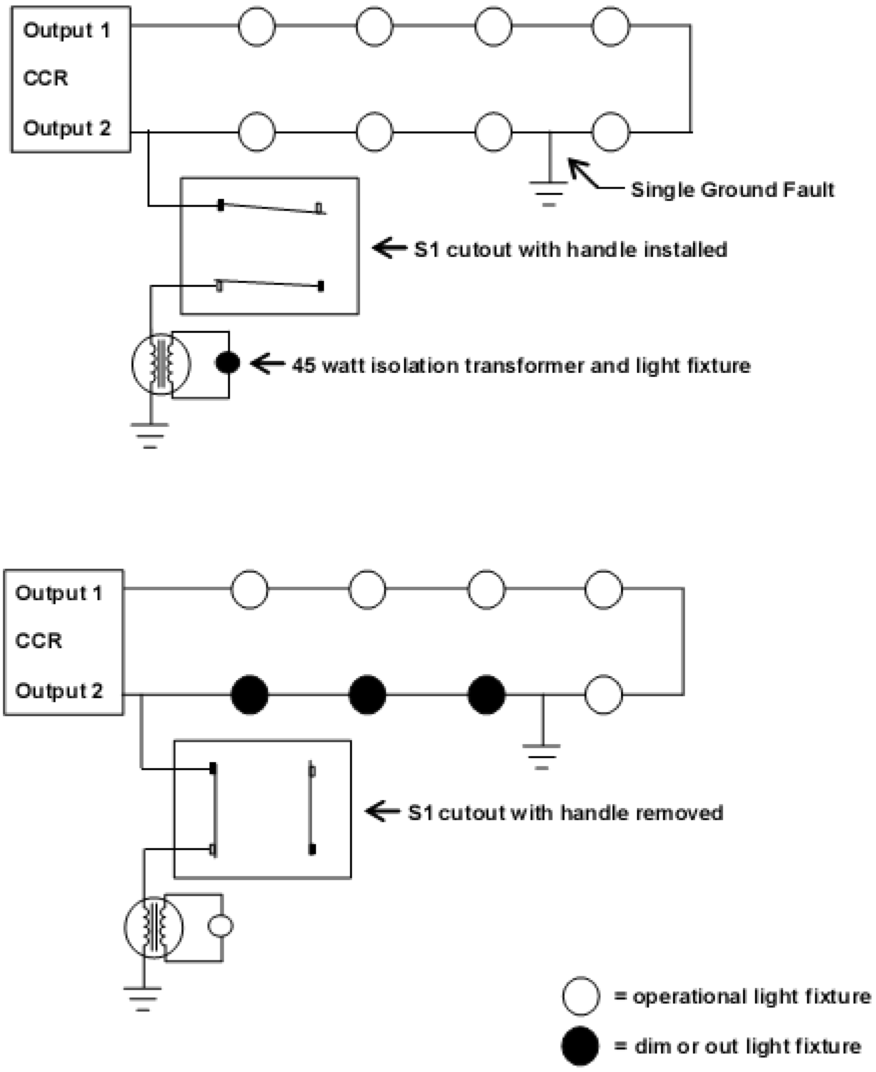


Figure 6-9. Intentional Ground Preventive Maintenance Tool

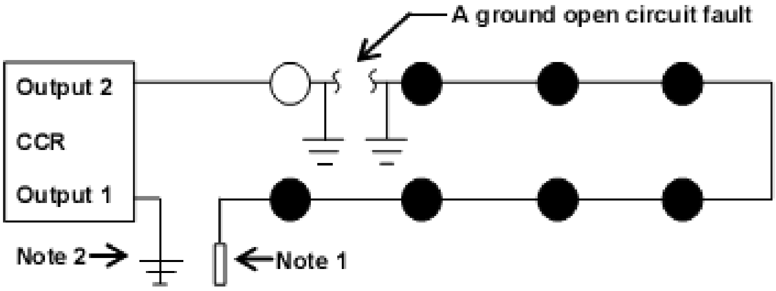


Figure 6-10a. Grounded Output Test on CCR Output 1

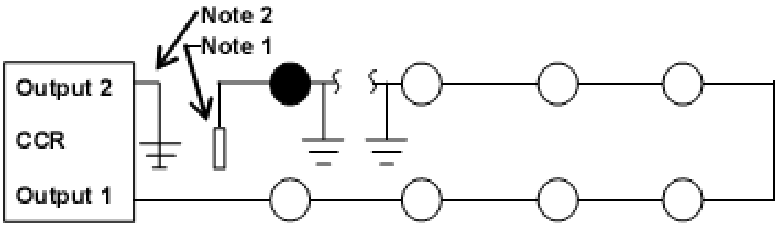


Figure 6-10b. Grounded Output Test on CCR Output 2

NOTES:

1. Insulate and stay clear of the removed primary cable lead, lethal voltages may be present.
2. The ground resistance of this connection must be low.
3. If the regulator trips off on open circuit, the open circuit fault is not grounded or the regulator does not have the power to drive circuit.

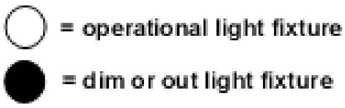


Figure 6-10a, b. Grounded Output Test

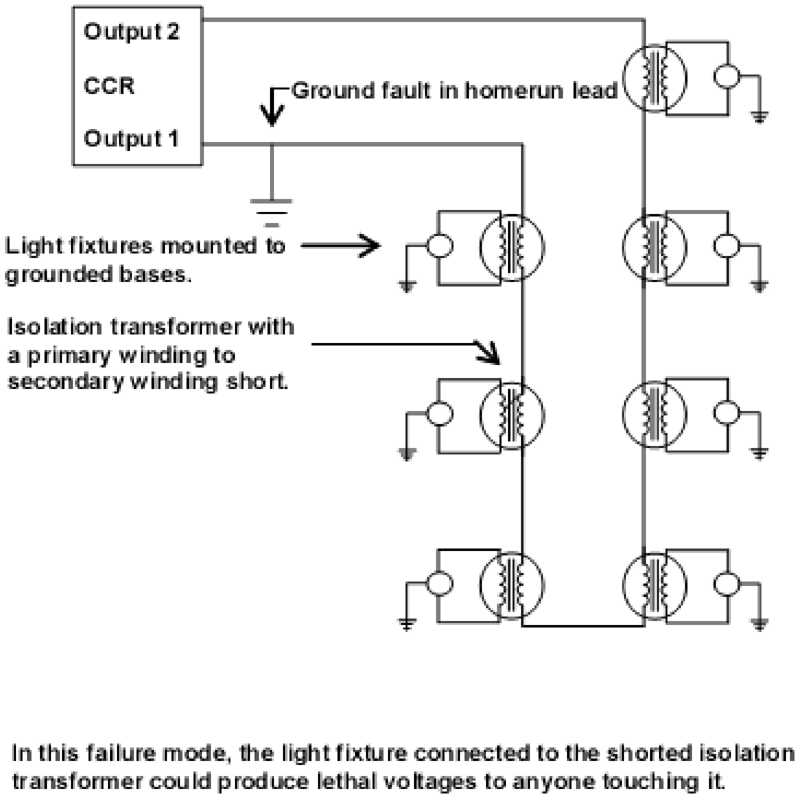


Figure 6-11. Dangerous Isolation Transformer/Circuit Ground Faults