NATIONAL BUREAU OF STANDARDS REPORT

5243

Maintenance of Airfield Lighting Systems

Part III

Troubleshooting Procedures for Series Circuits

By

John W. Simeroth
James E. Davis

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

THE NATIONAL BUREAU OF STANDARDS

Functions and Activities

The functions of the National Bureau of Standards are set forth in the Act of Congress, March 3, 1901, as amended by Congress in Public Law 619, 1950. These include the development and maintenance of the national standards of measurement and the provision of means and methods for making measurements consistent with these standards; the determination of physical constants and properties of materials; the development of methods and instruments for testing materials, devices, and structures; advisory services to Government Agencies on scientific and technical problems; invention and development of devices to serve special needs of the Government; and the development of standard practices, codes, and specifications. The work includes basic and applied research, development, engineering, instrumentation, testing, evaluation, calibration services, and various consultation and information services. A major portion of the Bureau's work is performed for other Government Agencies, particularly the Department of Defense and the Atomic Energy Commission. The scope of activities is suggested by the listing of divisions and sections on the inside of the back cover.

Reports and Publications

The results of the Bureau's work take the form of either actual equipment and devices or published papers and reports. Reports are issued to the sponsoring agency of a particular project or program. Published papers appear either in the Bureau's own series of publications or in the journals of professional and scientific societies. The Bureau itself publishes three monthly periodicals, available from the Government Printing Office: The Journal of Research, which presents complete papers reporting technical investigations; the Technical News Bulletin, which presents summary and preliminary reports on work in progress; and Basic Radio Propagation Predictions, which provides data for determining the best frequencies to use for radio communications throughout the world. There are also five series of nonperiodical publications: The Applied Mathematics Series, Circulars, Handbooks, Building Materials and Structures Reports, and Miscellaneous Publications.

Information on the Bureau's publications can be found in NBS Circular 460, Publications of the National Bureau of Standards ($1.25) and its Supplement ($0.75), available from the Superintendent of Documents, Government Printing Office, Washington 25, D. C.

Inquiries regarding the Bureau's reports should be addressed to the Office of Technical Information, National Bureau of Standards, Washington 25, D. C.

NATIONAL BUREAU OF STANDARDS REPORT

NBS PROJECT		NBS REPORT
0201-20-2327	May 1957	5243

Maintenance of Airfield Lighting Systems

Part III

Troubleshooting Procedures for Series Circuits

By
John W. Simeroth
James E. Davis

Project No. TED NBS AE-10011
of the
Ship Installations Division
Bureau of Aeronautics
Department of the Navy
Washington 25, D.C.

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

Table of Contents

		Page
Abstract		1
1.0	General Information	2
1.1	Step-by-Step Procedures	2
1.2	Troubleshooting by Symptoms	2
1.3	Precautions for Troubleshooting Series Circuits	3
1.4	Equipment Covered by This Troubleshooting Procedure	3
1.5	Making Repairs	4
2.0	The Detailed Step-by-Step Procedure	5
A.	Locating Faults in the Field	
	Initial Isolation of Fault	7
	Locating Grounds in the Field Circuits	8
	Locating Ungrounded Shorts in Field Circuits	11
	Locating Opens in Field Circuits	11
	Locating Overloads in Series Circuits	13
B.	Locating Faults in the Vault	
	Isolation of Faults in the Regulator and Controls to Specific Circuits	15
	Locating Faults in the Input Power Circuits	16
	Locating Faults in the Protective Relays and the Remote-Energizing Controls	19
	Locating Faults in the Brightness Control Circuits	21
	Locating Faults in the Circuit- (Runway-) Selector Control Circuits	23
3.0	Troubleshooting Charts	26
	Isolation of Faults	27
	Location of Grounds in Field Circuits	28
	Locating Ungrounded Shorts in Field Circuits	29
	Locating Opens in Field Circuits	30
	Locating Overloads and High-Series-Resistance Faults in Field Circuits	31

		Page
	Isolation of Faults in the Regulator Controls to Specific Circuits	32
	Locating Faults in the Input Power Circuits	33
	Locating Faults in the Protective Relays and the Remote Energizing Controls	34
	Locating Faults in the Brightness Control Circuits	35
	Locating Faults in the Circuit-(Runway-) Selector Control Circuits	36
4.0	Brief Step-By-Step Troubleshooting Procedure	37
5.0	Troubleshooting by Symptoms	46
5.1	Symptoms	47
5.2	Checks	49

Maintenance of Airfield Lighting Systems

Part III

Troubleshooting Procedures for Series Circuits

Bv
John W. Simeroth
James E. Davis

Abstract

This report is the first of a series of reports covering the maintenance of airfield lighting systems and related equipment. The theory of operation of these systems, preventive maintenance procedures, and general maintenance will be discussed in subsequent reports. It is contemplated that these reports will constitute a complete airfield lighting maintainance manual.

This report includes four types of troubleshooting procedures for series airfield lighting systems. The several procedures are offered for consideration and evaluation. It is not intended that all will be included in the final draft of the maintenance manual. The troubleshooting procedures included are (1) a detailed step-by-step procedure, (2) a complete troubleshooting chart, (3) a brief step-by-step procedure, and (4) a procedure for troubleshooting by symptoms.

1.0 GENERAL INFORMATION

1.1 Step-by-Step Procedures

A step-by-step troubleshooting procedure is a method of isolating and locating faults by performing a predetermined set of checks and measurements in sequence to locate a fault rapidly and reliably. Of the possible methods of locating faults in series circuits of airfield lighting systems, this method generally obtains the best results. The skilled troubleshooter generally uses a step-by-step procedure, often developing it as he works. Use of a well developed step-by-step procedure requires a minimum of experience and covers a maximum of possible situations. The purpose in developing the procedures given in this report is to systematize and generalize the steps used so that one will go directly to the fault with a minimum of time and effort.

Three types of step-by-step procedures are given here. The first is a detailed procedure given in the form of instructions for a test or check, the possible results of this test or check, and the probable cause or corrective procedure for each result. The complete procedure covering a number of systems is quite lengthy when given in detail, but in practice the number of steps required to locate any given fault is not great. Generally only four or five steps are required to locate the fault.

The second procedure is in the form of troubleshooting charts based on the detailed step-by-step procedure but presented more briefly and in a block diagram form.

The third procedure is an abbreviated form of the first which assumes that the maintenance personnel is familiar with general maintenance and testing procedure and is familiar with the operation of the individual circuits.

1.2 Troubleshooting by Symptoms

The fourth method of troubleshooting given is troubleshooting by symptoms. The usefulness of the symptoms method for troubleshooting will depend on the ability of the maintenance personnel and their familiarity with the circuits and equipment involved. Certain types of troubles may be located directly from the indicated symptoms, but many of the faults in airfield lighting require some form of step-by-step procedure in combination with the indicated symptoms to locate the fault. The troubleshooting procedure by symptoms given in this report is such a combination.

1.3 Precautions for Troubleshooting Series Circuits

Series lighting equipment and some of the troubleshooting tests involve voltages which are dangerous. For the protection of personnel and equipment, certain precautions must be observed when troubleshooting these circuits. In general these are the usual high-voltage safety rules. The step-by-step procedures are designed to avoid measurements or handling of high voltages except when there is no satisfactory alternative. Personnel doing testing and troubleshooting <u>must</u> be experienced in high-voltage techniques or must be adequately supervised. All maintenance personnel should be <u>adequately</u> trained in giving artificial respiration and in the emergency procedures for treatment of electric shock. Use suitable precautions, even when handling low voltages (120-480 volts); they, too, are dangerous.

1.4 Equipment Covered by this Troubleshooting Procedure

This procedure is applicable to all of the various types of series lighting circuits commonly used for runway, over-run, approach, boundary, or taxiway lighting, with or without isolating transformers. The treatment is general enough for all series-type fixtures and units, all types of wire and cable, whether direct-burial or in ducts. The procedure is based on the types AN-R-17 and NC-3 regulators, Type II airport-lighting control panels, specification AN-C-109 runway-selector cabinets, and type R-C-O-C oil switches. The instructions and results are stated in terms general enough to apply directly to nearly all other types of equipment and can easily be adapted for any other equipment.

1.5 Making Repairs

Methods of making repairs after the fault is located have not been included because the method of repair will usually be obvious to maintenance personnel. Repairs of many faults are routine matters of cleaning, adjusting, or replacing; but some repairs require special handling. Make temporary repairs only when necessary and then make permanent repairs as soon as possible.

1.5.1 Repairing Cable. When a wire or cable is faulty, replace the entire section between adjacent fixtures, manholes, or handholes, if practicable. When it is necessary to splice a cable, make the splice in an easily accessible location (hand-holes or fixtures) if possible. When it is necessary to bury a splice, mark the location of the splice, and indicate its location on circuit drawings or records. If a cable has been opened for test purposes, it must be as carefully re-spliced as if a fault had been repaired at this point.

1.5.2 Repairing Regulators. Make or obtain regulator repairs as instructed in the appropriate Technical Order or instruction manual. Never attempt to repair a regulator without experience with that type of regulator. When a fault occurs within the tank of a regulator, it is usually necessary to return the unit to the shops, depot, or factory for repair. Most adjustments inside the tank are factory made for each individual unit and tinkering may create more damage. If it is necessary to open the tank, use extreme care to prevent foreign matter or moisture from entering the tank. The capacitors in the resonant-network circuit may be charged to very dangerous voltages and must be carefully discharged before these capacitors or other circuits to them are handled. Replace faulty components only with replacement parts specified in the Technical Order. After closing the tank, pressure test the unit to check the seal.

2.0 THE DETAILED STEP-BY-STEP PROCEDURE

The troubleshooting procedure given below provides a detailed step-by-step procedure for locating faults in series airfield-lighting systems. It is based on the assumption that the only available information about the trouble is a report of which circuit is not operating satisfactorily. This information may have been obtained from routine or preventive maintenance checks, tower operator or pilot reports, or acceptance testing results. To keep the procedure general and to prevent unnecessary repetition, any additional information in the malfunction report or further information which may have been obtained before starting the troubleshooting has not been considered. The tests are started from a check in the vault rather than a visual check of operations because at many fields where the circuits are distant from operations and transportation and communications facilities are limited, the saving in time and effort may be considerable.

The basic method used in this procedure is to determine first whether the fault is in the field circuits or in the regulator or control circuits. If the fault is in the field circuits, the type of fault is then determined, and the fault is then located by a suitable method. If the fault is in the regulator or control circuits, it is isolated to one of the control circuits, to the input voltage, or to the regulator. By inspection and measurement the fault is then located.

To obtain satisfactory results, the step-by-step procedure must be followed carefully, not hit or miss. Begin with Step 1.0 and proceed as directed from that Step. Make the "Check or Test Procedure" indicated, considering all possible "Results" as the check is performed. Understand how the check or test is to be performed and what results may be expected before starting the check. Most "Checks" have two or more possible "Results", one or more indicating that a fault exists and frequently one "Result" indicating that operation during this check is satisfactory. When more than one "Result" indicating a fault is given, choose the "Result" which best describes the operation observed. For the "Result" obtained, consider the corresponding "Probable Cause and/or Corrective Procedure" indicated and proceed as directed.

If more than one "Probable Cause" is given for the "Result" proceed as directed for the "Cause" first listed, then for the subsequent "Causes" if necessary. When more than one method is given for locating the same fault, the methods will be listed in the order of greatest practical application considering saving in time, simplicity, reliability, and least possibility of confusion. Such factors as lack of equipment or experience may make it desirable to try one of the other methods first. After a given "Check" and "Corrective Procedure" have been considered, proceed to the next step unless directed otherwise. Make "Checks" in the order given and skip "Steps" only when clearly directed to do so in the procedure. The results of some tests can be misleading unless all previous steps were followed correctly. If at any time the instructions appear wrong or doubtful, repeat the steps carefully. As the repairs are made, return to the initial isolating step and repeat it to determine if another fault exists.

It should be emphasized that only a very few of the steps listed are used in locating any one fault. For example, consider a fault caused by a cut in the cable so that the circuit is opened but one side of the line is grounded. The procedure would direct the maintenance man through Steps 1.0, 1.0.3, 1.0.4, 1.3 and any one of Steps 1.1.1, 1.1.2, and 1.1.3. If the fault were a defective open-circuit protective relay cutting off power to the regulator, all lights would again be out and the procedure would use Steps 1.0, 1.0.3, 2.0, 2.2, and either 2.2.2 or 2.2.3.

STEP-BY-STEP TROUBLESHOOTING PROCEDURE FOR AIRFIELD LIGHTING SYSTEMS

A. Locating Faults in the Field

Step No.	Check or Test Procedure	Results	Probable Cause and/or Corrective Procedure
<u>Initial Isolation of Fault</u>			
1.0	Select the circuit to be tested and brightness step B5 (100% intensity), energize the regulator and measure the load current.	The load current is too high, too low, or zero.	Proceed to Step 1.0.3.
		The load current is normal (about 6.6 or 20 amperes).	Proceed to the next step.
1.0.1	With the circuit energized, visually check the operation of the lights in this circuit.	Some or all of the lights are dim or out.	After the regulator is de-energized, beginning with the first unlighted or dim unit from each end of the faulty section of the circuit, check each faulty light progressively along the circuit for each of the following routine maintenance faults. If the faulty lights at each end of the faulty section are found without these faults, the remainder of the units in this section need not be checked. Make the required repairs as each fault is located. a. Burned out lamps. b. Wrong type of lamps. c. Blown or omitted film cutouts. d. Water in bases of units not using isolating transformers. e. Shorts or grounds in the isolating transformer or in the wiring of the unit. If some of the units in the faulty sections of the circuit were repaired, repeat this step. If some of the lights are still dim or out, there are grounds or shorts in the circuit between the lights of satisfactory intensity and the adjacent lights of unsatisfactory intensity. Repair by replacing this section of cable. If replacing this section of cable is not practical, and locating the position of the ground(s) more exactly is required, proceed to Step 1.1. If all of the lights are still dim or out, proceed to the next step.
		All the lights operate satisfactorily.	High-resistance grounds or a single low-resistance ground may still exist. To check for the presence of, and to locate these faults, proceed to Step 1.1.
1.0.2	Carefully check the relay and wiring in the runway-selector cabinet to make certain that only the proper circuit is being selected and is not being shorted out in the selector cabinet.	A relay or the wiring in the runway-selector cabinet is faulty and the circuit is not being energized.	Repair or replace the faulty component. If the circuit-selector controls have failed and the repairs are not obvious, proceed to Step 2.4 to locate the fault in the controls.
		The proper circuit is being selected but the lights do not operate.	A short or ground is in the feeder cables of this circuit. To locate the grounds or short in the feeder cable, proceed to Step 1.1.

Step No.	Check or Test Procedure	Results	Probable Cause and/or Corrective Procedure
1.0.3	Short circuit the output of the regulator on the load side of the runway-selector cabinet for the circuit being tested. Energize the regulator at brightness step B5 (100% intensity) and measure the short-circuit output current.	The short-circuit output current is not appreciably different from the load current.	The fault is in the input voltage, in the control circuits, or in the regulator. Proceed to Step 2.0.
		The short-circuit current is normal, but the load current was too high.	The load is affecting the regulator output, probably from too much reactance in the circuit. Check for the following routine-maintenance faults at any lights which are not operating and replace or repair as required. a. Burned out lamps. b. Opens in the secondary circuit of isolating transformers. c. Faulty isolating transformers. If the high load current has not been cleared up when all lamps are back in operation, check for series-multiple transformers connected into this circuit. If these transformers can not be removed from the circuit, reset the tap-selector switch so that the load current is correct. See Step 2.1.4.a.
		The short-circuit current is normal, but the load current was too low.	The regulator is overloaded. Proceed to Step 1.4.
		The short-circuit current is normal, but the load current was zero.	There is an open fault in the field circuit, or the regulator is greatly overloaded. Proceed to the next step.
1.0.4	To determine if a fault is an open or an overload, disconnect the field circuit from the output terminals of the runway-selector cabinet and with an ohmmeter on <u>a low-resistance range</u>, measure the continuity of the field circuit.	The circuit does not have continuity, or it has a resistance of several thousand ohms.	The field circuit has an open fault. Proceed to Step 1.3.
		The circuit has continuity.	The regulator is overloaded. Proceed to Step 1.4.

<u>Locating Grounds in the Field Circuits.</u>

Step No.	Check or Test Procedure	Results	Probable Cause and/or Corrective Procedure
1.1	When grounds or shorts are indicated and the location is not readily apparent from the appearance of the lights, disconnect the field circuit from the runway-selector cabinet and measure the insulation resistance of each feeder. To measure insulation resistance use a high-voltage, limited-current insulation test set, a low-voltage insulation test set, or an ohmmeter, with the preference in the order listed. As each fault is cleared repeat this insulation resistance measurement for the circuit to determine if other grounds exist. If a combination of faults exists, clear the grounds first because these faults are usually easier to locate and often occur in conjunction with opens, overloads, or shorts. Then clear any high-resistance grounds. Then locate any remaining opens, overloads,	The resistance of each feeder to ground is low.	There are one or more ground faults. To locate grounds by: a. Cable Test-Detecting Set (TSM-11), proceed to Step 1.1.1; b. Insulation resistance measurements, proceed to Step 1.1.2; c. Intentional grounds and energizing the circuit, proceed to Step 1.1.3.
		The resistance of each feeder to ground is fairly high (between 1000 ohms and 10 megohms) but is not adequate for a good circuit.	There are one or more high-resistance grounds. To locate high-resistance grounds by: a. Cable Test-Detecting Set (TSM-11), proceed to Step 1.1.1; b. Insulation resistance measurements, proceed to Step 1.1.2.
		The resistance of each feeder to ground is very high or infinite (above 10 megohms).	If the intensity of all the lights was satisfactory, the regulator and this field circuit have been proven satisfactory. To complete the check of the regulator and controls, proceed to Step 2.0. If some or all of the lights are out, there is an ungrounded short. Proceed to Step 1.2.

Step No.	Check or Test Procedure	Results	Probable Cause and/or Corrective Procedure
1.1 (cont.)	or ungrounded shorts.	The resistance to ground of one feeder is low or unsatisfactory, and the resistance of the other feeder is much higher or infinite.	The faults are a combination of grounds and opens or overloads. To locate the ground faults in the grounded sections of the circuit by a. Cable Test-Detecting Set (TSM-11), proceed to Step 1.1.1; b. Insulation resistance measurements, proceed to Step 1.1.2; c. Intentional grounds and energizing the circuit, proceed to Step 1.1.3. If the open or overload is not found with the grounds, return to Step 1.0.4.
1.1.1	In locating grounds by using the Cable Test-Detecting Set (TSM-11) equipment, study carefully the instructions for this Set in the Operations Handbook (NAVAER 08-20-501). Disconnect the feeders from the runway-selector cabinet, connect a feeder that indicates a ground to one terminal of the output of the signal generator, and connect the other terminal of the signal generator to a good ground. Energize the signal generator and determine the optimum impedance matching of the signal generator to the cable by checking for maximum output current or for maximum signal strength as shown by the amplifier-indicator as the OUTPUT IMPEDANCE switch selects the LO, MED, and HI positions. Use the signal generator with the power switch in the TEST position if the cable is easily followed; but if the cable is hard to follow or if other noise creates difficulty, use the ON position to obtain the interrupted signal. Then with the amplifier-indicator and the detecting element, follow the path of the cable as indicated by the tone in the headphones and/or by the meter reading. Adjust the GAIN control low enough for peaks in signal amplitude to be recognized as the cable is crossed. (Keep the meter reading no greater than one-half scale at maximum deflection for ease in reading.) Swing the loop of the detecting element sufficiently to note the change in signal strength as the detecting element is moved from the cable. Proceed along the path of the cable noting carefully any changes in signal strength. CAUTION Do not handle the cable after energizing the signal generator because the output voltage may be as great as 300 volts.	A strong signal-generator signal (250 cycles steady or interrupted tone) is indicated by the meter or the headphones.	The detecting element is over the cable being tested and following the proper path. Proceed until a change in signal is noticed.
		The signal strength continues steady, then suddenly decreases in strength or fails.	The ground is located within the immediate area. Repair the fault. Then continue the check until the entire circuit is clear of grounds.
		The signal changes tone.	A signal of another frequency is being picked up, probably from another cable. Return to a known location of the cable being tested and follow this cable carefully. Use the interrupted signal from the signal generator if desired.
		The signal strength suddenly decreases and continues at the decreased strength.	This may be caused by deeper cable, by the cable entering metallic duct or other shielding, or by a high-resistance ground fault. Check for each of these possibilities, and if the change is caused by a high-resistance ground, repair the cable. Then continue the check until the entire circuit is clear of grounds.
		The signal strength decreases gradually for a considerable distance along the cable to a very low signal strength.	There is general leakage to ground or a series of high-resistance grounds in this section of the cable. Repair this section of the cable. Then continue the check until the entire circuit is clear of grounds.
		No signal or only a very weak signal is detected.	The cable is lost, the cable is looped back upon itself, a ground fault has been passed, or this section of the cable is extremely well shielded. Investigate for each of these possibilities or follow the cable more carefully.
		The ground faults were not located with this test.	Sectionalize the circuit by opening it at several points and check each section with the TSM-11. If the faults can not now be located, use the method of insulation resistance measurements. Proceed to Step 1.1.2.

Step No.	Check or Test Procedure	Results	Probable Cause and/or Corrective Procedure
1.1.2	To locate grounds by insulation resistance measurements, use a high-voltage insulation test set, a low-voltage insulation test set, or an ohmmeter (listed in the order of most dependable results). Disconnect the feeders of this circuit from the runway-selector cabinet in the vault. At a selected test point open the circuit and measure the insulation resistance of each section of the circuit.	The insulation resistance is satisfactory in one direction only.	This section of the circuit contains no ground faults.
		The insulation resistance is zero or lower than desired for the circuit. (This may be the case in only one or both directions.)	One or more grounds are on these sections of the circuit as indicated. Proceed to the next step.
		The insulation resistance is satisfactory in both directions.	An open fault exists between the test point and the ground fault(s). Proceed to Step 1.1.2.2.
1.1.2.1	After reconnecting the circuit at this test point, continue moving the test point in the direction of the ground fault(s) and measuring the insulation resistance at each new test point as outlined in Step 1.1.2 above until all ground faults are located.		Make the repairs. Then repeat the resistance checks until the circuit has been cleared of ground faults. If Steps 1.1.2 or 1.0.4 indicated an open fault and if the open was not located with a ground, proceed to Step 1.3.
1.1.2.2	After reconnecting the circuit at the test point, continue moving the test point toward the feeder indicating unsatisfactory insulation resistance and measuring the insulation resistance at each new test point as outlined in Step 1.1.2 above until all ground faults are located.		Make the repairs. If Steps 1.1.2 or 1.0.4 indicated an open fault and the open was not located with a ground, proceed to Step 1.3.
1.1.3	To locate grounds by using an intentional ground and energizing the circuit with the load connected to the regulator, ground one of the feeders in the vault. Energize this circuit with the regulator and make a visual check of the operation of each of the lights in this circuit.	Some of the lights are out or dim.	There is a ground fault between the last light operating satisfactorily and the adjacent light that is operating unsatisfactorily. Repair this section of cable. If necessary to locate the position of the fault more exactly, use the methods outlined in Steps 1.1.1 or 1.1.2.
		All of the lights are out or dim.	The ground fault is in the feeder without the intentional ground. Repair this section of the circuit. If necessary to locate the position of the fault more exactly, use the methods outlined in Steps 1.1.1 or 1.1.2.
		All of the lights appear to operate satisfactorily.	Proceed to the next step.
1.1.3.1	Move the intentional ground to the other feeder, repeat, energizing the circuit, and making the visual check of operation of the lights as outlined in Step 1.1.3.	Some of the lights are out or dim.	A ground fault exists between the last light operating satisfactorily and the adjacent light operating unsatisfactorily. Repair this section of cable. If necessary to locate the position of the fault more exactly, use the methods outlined in Steps 1.1.1 or 1.1.2.
		All of the lights are out or dim.	A ground fault is in the feeder which was intentionally grounded first. Repair this section of the circuit. If necessary to locate the position of the fault more exactly, use the methods outlined in Steps 1.1.1 or 1.1.2.
		The lights appear to operate satisfactorily when each feeder is tested with the intentional ground.	The fault may have too high resistance for the change in intensity to be recognized. Use the methods outlined in Steps 1.1.1 or 1.1.2 to locate the ground.

Step No.	Check or Test Procedure	Results	Probable Cause and/or Corrective Procedure
Locating Ungrounded Shorts in Field Circuits.			
1.2	When ungrounded shorts are indicated, energize the circuit and make a careful visual inspection of the operation of the lights (if not previously made) to determine which, if any, are operating.	Some of the lights are operating satisfactorily, but others are out.	The short is between the lighted and the adjacent unlighted units. Repair by replacing the faulty cable between these lights. If it is not practical to replace this section of cable, locate the fault more closely by: a. The hook-on ammeter. See Step 1.2.1; b. Open-circuit test. See Step 1.2.2.
		All of the lights are out.	The short is in the feeders. Locate it by using: a. The hook-on ammeter. See Step 1.2.1; b. Open-circuit test. See Step 1.2.2.
1.2.1	To locate ungrounded shorts using a hook-on ammeter, select a test point. Connect the ammeter about the conductor of the circuit. Energize the circuit with the regulator and read the current in the circuit at the test point. CAUTION Do not come in contact with the cable or meter while the circuit is energized. If the meter must be handled or attached to the circuit while the circuit is energized, use a hot-line clamp-stick.	The current in the circuit at the test point is approximately normal.	The test point is between the short and the regulator. Proceed to the next step.
		The current in the circuit at the test point is very low or zero.	The short is between the test point and the regulator. Proceed to the next step.
1.2.1.1	Continue moving the test point toward the short and repeat Step 1.2.1 until the fault is located.		Repair both sections of cable which contain the short.
1.2.2	To locate ungrounded shorts by open-circuit tests, select a test point. Open the circuit. Keep the open clear of the ground and personnel clear of the circuit. Energize the circuit with the regulator and check to see if the protective relays turn off the regulator. NOTE: If the regulator is turned off, do not energize the circuit again until the open at the test point has been reconnected and a new test point has been selected.	The protective relays turn off the regulator.	The test point is between the ungrounded short and the regulator. Proceed to the next step.
		The protective relays do not turn off the regulator.	The ungrounded short is between the test point and the regulator. Proceed to the next step.
1.2.2.1	Reconnect the circuit at the test point. Continue moving the test point toward the short and repeating Step 1.2.2 until the short is located.		Repair both sections of cable which contain the short.
Locating Opens in Field Circuits.			
1.3	If an open circuit is indicated and the possibility of grounds on the circuit has not already been checked, disconnect both feeders from the runway-selector cabinet and with an insulation tester measure the insulation resistance of each feeder to determine if any grounds exist also.	The insulation resistance of one or both feeders is unsatisfactory.	A combination of open and ground faults is indicated. Since grounds are easier to locate and are likely to occur at the open, locate the grounds in the grounded section of circuit by using: a. The Cable Test-Detecting Set (TSM-11). See Step 1.1.1; b. Insulation resistance measurements. See Step 1.1.2;

Step No.	Check or Test Procedure	Results	Probable Cause and/or Corrective Procedure
1.3 (cont.)			c. Intentional grounds, and energizing the circuit. See Step 1.1.3. After the grounds have been cleared, repeat Step 1.0 to determine if the open fault still exists, and, if so, repeat this step.
		The insulation resistance of both feeders is satisfactory.	To locate ungrounded open faults by using: a. Intentional grounds and open circuit test, see Step 1.3.1; b. Insulation resistance measurements, see Step 1.3.2; c. The Cable Test-Detecting Set (TSM-11), see Step 1.3.3.
1.3.1	To locate ungrounded opens by using intentional grounds and open-circuit test, intentionally ground one of the feeders of the circuit in the vault and then, by energizing the circuit with the regulator, determine if the circuit will break down to ground at the open fault. Check the operation of the regulator as it is energized to see if the protective relays turn it off.	The protective relays do not turn off the regulator.	The circuit has become grounded beyond the open from the intentionally grounded feeder. Locate this ground, using the methods outlined in Steps 1.1.1, 1.1.2, or 1.1.3. After locating the ground and making the repairs, repeat Step 1.0 to determine if the open fault still exists, and, if so, repeat this step.
		The protective relays turn off the regulator.	The circuit beyond the open from the intentionally grounded feeder does not break down to ground. Proceed to the next step.
1.3.1.1	Move the intentional ground to the other feeder and repeat Step 1.3.1.	The protective relays do not turn off the regulator.	The circuit has become grounded beyond the open from the intentionally grounded feeder. Locate this ground and repair the circuit using the methods outlined in Steps 1.1.1, 1.1.2, or 1.1.3. Then repeat Step 1.0 to see if the open fault still exists, and, if so, repeat this step.
		The protective relays turn off the regulator when either feeder is grounded.	The circuit does not break down to ground. (At this point it may be more practical to use the methods outlined in Steps 1.3.2 or 1.3.3 rather than to continue this method.) Otherwise, proceed to the next step.
1.3.1.2	Sectionalize the circuit, using intentional grounds by grounding one feeder in the vault, and at a selected test point also ground the conductor of the circuit without breaking continuity. Energize the circuit and check the operation of the regulator to see if the protective relays turn it off.	The protective relays do not turn off the regulator.	The open fault is between the intentional grounds. Proceed to the next step.
		The protective relays turn off the regulator.	Both intentional grounds are on the same side of the circuit from the open fault. Proceed to the next step.
1.3.1.3	Continue moving the test point and the intentional ground in the field toward the open fault and checking the regulator operation as in Step 1.3.1.2 until the fault is located.		Make the repairs.

Step No.	Check or Test Procedure	Results	Probable Cause and/or Corrective Procedure
1.3.2	To locate ungrounded opens by resistance measurements, disconnect the feeders from the runway-selector cabinet and intentionally ground one feeder of the circuit in the vault. Then at a selected test point, maintaining continuity of the circuit, measure the resistance between the conductor and ground. NOTE: The ground at the selected test point must provide adequate continuity to the system ground. If desired, the circuit may be grounded at the selected test point and the measurements made in the vault.	The resistance is very high or infinite.	The open fault is between the test point and the grounded feeder. Proceed to the next step.
		The resistance to ground is low or zero.	The test point is between the open fault and the grounded feeder. Proceed to the next step.
1.3.2.1	Continue moving the test point toward the open and repeating Step 1.3.2 until the fault is located.		Make the repairs.
1.3.3	To locate ungrounded opens with the Cable Test-Detecting Set (TSM-11), study the instructions. given in the Operations Handbook (NAVAER 08-20-501) for locating open faults. The signal generator should be operated with the OUTPUT IMPEDANCE switch in the HI position and the amplifier gain will have to be much higher than that required for the same response from a grounded cable. The characteristics of the signal at the fault may also be much different from the indications at a ground fault.	The open fault is located.	Make the repairs.
		The open fault can not be located by using this equipment.	To locate the ungrounded open by: a. Resistance measurements, see Step 1.3.2; b. Intentional grounds and open-circuit tests, see Step 1.3.1.

<u>Locating Overloads in Series Circuits.</u>

Step No.	Check or Test Procedure	Results	Probable Cause and/or Corrective Procedure
1.4	If an overload is indicated and the possibility of grounds on the circuit has not already been investigated, disconnect both feeders from the regulator and check the insulation resistance of each feeder with an insulation tester to determine if any grounds exist.	The insulation resistance of the circuit is not satisfactory.	Some combination of grounds and an overload exists, such as high-resistance grounds on each side of an open fault or a high-series resistance and ground fault. To locate the grounds by: a. The Cable Test-Detecting Set (TSM-11), see Step 1.1.1; b. Insulation resistance measurements, see Step 1.1.2; c. Intentional grounds and energizing the circuit, see Step 1.1.3. After the grounds have been cleared, repeat Step 1.0 to determine if the overload still exists; if so, repeat this step.
		The insulation resistance of the circuit is satisfactory.	The circuit is clear of grounds. To locate the overload by: a. Sectionalizing and load current measurements, see Step 1.4.1; b. Comparison of actual load to the normal circuit load, see Step 1.4.2.

Step No.	Check or Test Procedure	Results	Probable Cause and/or Corrective Procedure
1.4.1	To locate overloads (particularly those caused by high-series-resistance faults or by open faults which have become partially grounded) by sectionalizing, turn off the regulator; remove a section of the load from the circuit by shorting it out with a jumper or length of cable. Energize the remainder of the circuit and remeasure the output load current. NOTE: In case the circuit is normal but the load is sufficient to overload the regulator, the overload may not be indicated by sectionalizing and measuring load current.	The load current is still low, or the protective relays continue to turn off the regulator. The load current is now normal.	The fault is in the section of the circuit still being energized by the regulator. Proceed to the next step. The fault or overload is in the section of the circuit which is short circuited. Proceed to the next step.
1.4.1.1	Continue sectionalizing by moving the jumper toward the fault or overload and repeating Step 1.4.1 until the fault or overload is located.		Make the repairs. If the overload can not be located by sectionalizing and measuring the load current, proceed to the next step.
1.4.2	To locate overloads by comparing the actual load on the regulator to the normal load of the circuit, determine the actual load by accurately measuring the output voltage of the regulator and the load current at brightness step B5. Compute the actual load as the product of the output voltage and current. Compute the normal load of the circuit including losses and any recent additions to the circuit. Compare the actual load to the normal load of the circuit and to the nameplate of the regulator. NOTE: If the protective relays turn off the regulator or the load current is more than 10% below rated value, do not use this method to obtain the actual load but use the method outlined in Step 1.4.1 to locate the fault.	The normal load and the actual load are approximately the same, but they exceed the rating of the regulator. The actual load exceeds the normal load and the rating of the regulator.	Redistribute the load to other regulators, or replace this regulator with a regulator of adequate capacity. The circuit has a high-series resistance fault. Proceed to the next step.
1.4.2.1	Sectionalize by connecting a suitable jumper or length of cable between convenient test points of the circuit. Compute and compare the actual load and the normal load for the section of the circuit still being energized by the regulator, as outlined in Step 1.4.2.	The actual load and the normal load for this section of the circuit are approximately the same. The actual load exceeds the normal load for this section of the circuit.	The fault is in the section of the circuit that is now shorted out and is not being energized. Proceed to the next step. The fault is in the section of the circuit still connected to and being energized by the regulator. Proceed to the next step.
1.4.2.2	Continue sectionalizing by moving the jumper toward the fault and computing and comparing the actual load and the normal load of the section of the circuit still connected to and being energized by the regulator, as outlined in Step 1.4.2, until the fault is located.		Make the repairs.

B. Locating Faults in the Vault

Step No.	Check or Test Procedure	Results	Probable Cause and/or Corrective Procedure
	Isolation of Faults in the Regulator and Controls to Specific Circuits.		
2.0	When trouble is indicated in the regulator controls, or if a check of this equipment is desired, turn off the regulator and short circuit all load circuits on the load side of the runway-selector cabinet. Connect an accurate ammeter into the output circuit of the regulator and carefully determine the short-circuit current for each brightness setting as the regulator is energized from one of the control panels.	The current is satisfactory for each brightness setting.	The regulator, the incoming primary voltage, and the input voltage circuits are functioning properly. The protective and brightness controls from this control panel are satisfactory. To check the other control panels, proceed to Step 2.0.3.
		The current is satisfactory for one or more brightness settings, but it is too high, too low, or zero for other settings.	The input voltage and the protective controls are satisfactory. To check the individual brightness controls, proceed to Step 2.3.
		The current is appreciably higher or lower for all brightness settings than is normal for short-circuit current, but is not zero for any setting.	The tap-selector switch is set improperly, the input voltage has changed, or the regulator is not operating properly. Proceed to Step 2.1.4.a.
		The current reads momentarily and then becomes zero for all brightness settings.	The remote-energizing controls, the protective relays, or the regulator are unsatisfactory. Proceed to Step 2.2.
		The current is zero at all times for all brightness settings.	Proceed to the next step. If the input voltage is known to be satisfactory, proceed to Step 2.2.
2.0.1	Move the short circuit to the output terminals of the regulator and repeat the short-circuit current measurements as outlined in Step 2.0. NOTE: Make certain that the protective relays are not bypassed by the short circuit.	The current is still zero at all times for all brightness settings.	The fault is in the incoming primary voltage, the input-voltage circuits, the energizing, controls, or the regulator. Proceed to Step 2.1.
		Current is present on one or more brightness settings.	There is an open in the output circuit between the regulator and the load terminals of the runway-selector cabinet. Proceed to the next step.
2.0.2	Carefully inspect the wiring in the runway-selector cabinet, the wiring from the regulator to the selector cabinet, the contacts of the runway-selector relays, and the series-plug cutouts, until the open fault is located.		Make the repairs. Then repeat Step 2.0.
2.0.3	When the output current of the regulator for each brightness setting is satisfactory for one control panel, transfer control to another control panel and repeat Step 2.0 for each control panel.	The current is satisfactory for each brightness setting from each control panel.	The regulator, the input power, and the brightness controls are satisfactory. To check the runway-selector controls, proceed to Step 2.4.
		The current is too high, too low, or zero, for one or more brightness settings from one or more of the other control panels, but it is not zero for all settings.	The brightness controls from this panel are not operating satisfactorily. Proceed to Step 2.3.
		The current is zero at all times for all brightness settings from one or more control panels.	The energizing controls from this control panel are not operating properly. Proceed to Step 2.2.

Step No.	Check or Test Procedure	Results	Probable Cause and/or Corrective Procedure
Locating Faults in the Input Power Circuits.			
2.1	In checking for input voltage, first check lights or other equipment in the vault that is connected to the same phase of power for their ability to operate.	Lights and/or other equipment are on this circuit but do not operate.	The incoming primary voltage or the input power circuits have failed. Proceed to Step 2.1.2.
		Lights and other equipment on this circuit are operating, or no other equipment is connected to this circuit.	Proceed to the next step.
2.1.1	With the switches, relays, and contactors set in the required positions for energizing the regulator, check for hum or vibration of the input transformer of the regulator as the remote-control oil switch, the input switch, or the main contactor is <u>momentarily</u> placed in the manual ON position and then returned to OFF or AUTO position. CAUTION Do not leave the regulator energized with the manual ON control because the protective relays may not be able to protect the regulator.	The energizing controls can not be set for energizing the regulator.	The energizing controls have failed. Proceed to Steps 2.2 through 2.2.14. After repairs repeat Step 2.0.
		Hum or vibration occurs.	The input voltage is available, but there is a fault in the remote-energizing control circuits or in the regulator. Proceed to Step 2.1.9.
		No hum or vibration occurs or no manual ON control is included in the control equipment.	Proceed to the next step.
2.1.2	Check the input circuit for blown fuses, tripped circuit breakers, opened cutouts, and switches in the OFF position.	Switches or circuit breakers are in the OFF position, or a cutout is open.	Make certain that no one is or will be working on the circuits. Then close the switch, circuit breaker, or cutout, and repeat Step 2.0.
		Fuses are blown, or a circuit breaker is tripped.	Proceed to Step 2.1.7.
		The switches are in the proper position, and the overcurrent protective devices still provide continuity.	Proceed to the next step.
2.1.3	By inspection or by disconnecting the input circuit from the incoming primary voltage and making continuity measurements with an ohmmeter, check the input circuit for opens, especially at connections, terminals, terminal bushings, switches, circuit breakers, fuse cutouts, and input switch contacts. Also check the tap-selector switch on the regulator input for proper seating and the input winding of the input transformer of the regulator for continuity.	An open circuit is found.	Make the repairs and repeat Step 2.0.
		The tap-selector switch is not seated properly.	Reset the switch to the correct position as indicated in Step 2.1.4.a and repeat Step 2.0.
		The input switch contacts are burned off or fail to close.	The cam for the manual ON control is loose on the shaft, or the input switch has been overloaded or worn. Make the repairs and repeat Step 2.0.
		The input winding of the input transformer of the regulator is open.	The regulator has failed internally. Make or obtain repairs as instructed in the appropriate Technical Order or instruction manual. Then repeat Step 2.0.
		There are no opens in the input circuit.	Proceed to Step 2.1.4.b.

Step No.	Check or Test Procedure	Results	Probable Cause and/or Corrective Procedure
2.1.4.a	To set the tap-selector switch by measuring the output current, turn off the regulator and connect an accurate ammeter into the output of the regulator. With the regulator connected to the normal load at brightness step B5, energize the regulator and measure the output current. Set the tap-selector switch to obtain an output current nearest normal (6.6 or 20 amperes).	The output current is too low.	Set the tap-selector switch to a lower input voltage position until the correct output current is obtained.
		The output current is too high.	Set the tap-selector switch to a higher input voltage position until the correct output current is obtained.
		The output current is satisfactory.	The tap-selector switch is set properly. To check the other controls, repeat Step 2.0.
		Satisfactory adjustment cannot be obtained.	See Step 2.1.4.b.
2.1.4.b	Measure the input voltage at the input terminals of the regulator as follows. Disconnect the input circuit from the primary supply system and connect a suitable potential transformer and/or voltmeter (using adequate leads) to the input terminals of the regulator. Then by setting the controls to energize the regulator and its normal load, determine the input voltage to the regulator. CAUTION Use extreme care in measuring high voltages. Do not come in contact with the potential transformer, the voltmeter, or the leads while the circuit is energized.	Input voltage is present but does not agree with the tap-selector switch setting.	Reset the tap-selector switch to agree with the input voltage when the regulator is energizing its normal load.
		The input voltage is present, but is is not within the range of the tap-selector switch.	Connect the regulator to a suitable source of power by using the required distribution transformers or use a regulator with an input rating suitable for this input voltage. Then repeat Step 2.0.
		The input voltage is present and agrees with the setting of the tap-selector switch.	If the regulator is not operating satisfactorily, the fault is in the brightness controls of in the regulator. Proceed to Step 2.1.6.
		The input voltage is zero.	Proceed to the next step.
2.1.5	Continue moving the potential transformer and/or the voltmeter toward the source of power and repeating the voltage measurements of Step 2.1.4.b until the fault is located.	The point of failure of the input voltage is located.	Make the repairs and repeat Step 2.0.
		The incoming primary voltage is not delivering power.	Restore the incoming primary voltage or report the outage to the proper authorities. After repairs, repeat Step 2.0.
2.1.6	By inspection, check the brightness relays to be certain that one, and only one, relay is closed as the regulator is energized. Also check all auxiliary wiring and interlocking or interconnecting contacts for proper adjustment, as required, between the selected brightness tap and the regulating section of the regulator.	The brightness relay fails to close, or there is an open in the circuit between the selected brightness tap and the regulating section of the regulator.	Adjust, repair, or replace the faulty component. If the brightness relay is not energized or if more than one relay closes, locate the fault in the brightness controls and make the repairs. Proceed to Steps 2.3 through 2.3.6, if necessary. Then repeat Step 2.0.
		The brightness relays and auxiliary wiring are operating satisfactorily.	The fault is within the regulator. Make or obtain repairs as instructed in the appropriate Technical Order or instruction manual. Then repeat Step 2.0.
2.1.7	To check the input voltage circuit when fuses are blown or circuit breakers are tripped, replace the fuse or reset the breaker only once and determine if it now holds as the regulator is energized again.	The fuse or circuit breaker continues to hold.	Probably the trouble is over, but keep this failure in mind should the device open again. Repeat Step 2.0.
		The fuse blows, or the breaker trips again.	The circuit overloads the protective device which opens. Proceed to the next step.

Step No.	Check or Test Procedure	Results	Probable Cause and/or Corrective Procedure
2.1.8	Check for any possible overloads which could cause this protective device to fail; e.g., grounds or shorts on the input circuit, inadequate capacity of the fuse or circuit breaker to handle the total possible load, other loads beside the regulator which could overload this component in normal or faulty operation, or two or more brightness relays closed or energized at the same time creating a short on the transformer in the regulator. Only after other possible causes of this overload have been eliminated, assume that the fault is in the regulator.	There are grounds or shorts on the input circuit.	Make the repairs and repeat Step 2.0.
		The capacity of the protective device is not adequate to handle the maximum possible normal load.	Replace the device with one of adequate rating for the load or redistribute the load to stay within the rated capacity of the device. Then repeat Step 2.0.
		Equipment other than the regulator overloads the protective device.	Repair this equipment, if faulty, or redistribute the load to keep the load within the rating of the protective device. Then repeat Step 2.0.
		Two or more brightness relays are or have been closing at the same time.	Repair the relays and locate the fault in the brightness controls which causes this unsatisfactory operation and make the repairs. If necessary, use Steps 2.3 through 2.3.6 to locate the fault in the brightness controls. Repeat Step 2.0.
		The overload is not in the input circuit, other loads, or the brightness controls.	The fault is in the regulator. Make or obtain repairs as instructed in the appropriate Technical Order or instruction manual. Then repeat Step 2.0.
2.1.9	If input power is available but the regulator does not deliver output current when the regulator is energized with the normal controls, check the energizing controls between the input switch and the terminal block in the regulator control compartment and check all the energizing controls for proper operation.	The remote-energizing controls do not operate satisfactorily to energize the regulator.	Locate faults and make repairs in the energizing controls, proceeding as directed in Steps 2.2 through 2.2.14, if necessary. Then repeat Step 2.0.
		The remote-energizing controls operate satisfactorily.	Proceed to the next step.
2.1.10	With the regulator disconnected from input power and with load circuits (and any short-circuiting jumpers) disconnected from the output terminals of the regulator, check across the output terminals of the regulator with an ohmmeter for continuity.	The output circuit of the regulator does not have continuity.	Check the coil of the series-current relay and all terminals, bushings, and connections in the output circuit of the regulator that are outside the tank for opens and repair. If the open circuit is inside the tank of the regulator, make or obtain repairs as instructed in the appropriate Technical Order or instruction manual. Then repeat Step 2.0.
		The output circuit of the regulator has continuity.	The fault is in the regulator tank. Make or obtain repairs as instructed in the appropriate Technical Order or instruction manual. Then repeat Step 2.0.

Locating Faults in the Protective Relays and the Remote-Energizing Controls.

Step No.	Check or Test Procedure	Results	Probable Cause and/or Corrective Procedure
2.2	To check the protective relays and the remote-energizing controls, with the output of the regulator shorted as instructed in Step 2.0, carefully observe the action of the protector and the series-current relays as the regulator is energized from one of the control stations. NOTE: Normal action of these relays varies with the type of regulator.	The protector relay opens in much less time than required for the series-current relay to operate.	The delay is not adequate for normal operation. Proceed to Step 2.2.3.
		The protector relay and/or the series-current relay fails to operate satisfactorily.	Proceed to Step 2.2.2.
		Both relays operate normally.	Proceed to the next step.
2.2.1	Repeat the visual check of operation of the protective relays as in Step 2.2 as the regulator is energized from each of the other control panels.	One or both relays fail to operate normally from one or more of the other control panels.	Proceed to Step 2.2.4.
		The relays operate satisfactorily from all control panels.	No faulty operation occurred during the test, but if there is intermittent unsatisfactory operation as from too short delay, proceed to Step 2.2.3.
2.2.2	With the control and input voltage turned off, inspect the protector and series-current relays for burned, dirty, pitted, corroded, or poorly adjusted contacts; for opens or crossed connections in the wiring; for binding in the movement of the relays; and with an ohmmeter check for open or shorted coils in the relays. NOTE: In some types of regulators the protector relay operates against a dashpot and is sluggish in its movements.	One or both protective relays have faults.	Adjust, repair, or replace the relay(s) and repeat Step 2.0.
		Both relays are in satisfactory condition.	Proceed to Step 2.2.4.
2.2.3	Check the protective relays for overload (open-circuit) protection by opening the output circuit of the regulator. Check the time required after the regulator is energized before the protective relays turn off the regulator.	The protector relay turns off the regulator after the normal delay. (Delay is 1/2 to 2 seconds, depending on the type of regulator.)	The open-circuit protection is satisfactory, and the protector relay is functioning normally.
		The protective relays do not turn off the regulator, or the delay is much more or less than normal. NOTE: On some types of regulators, such as the NC-3 and C-3 types, there may be no appreciable delay except when the output circuit is opened under load.	Adjust the protector relay to turn off the regulator after the correct delay (1/2 to 2 seconds), or repair or replace the relays, if necessary. If the protective relays do not turn off the regulator, make certain that the output circuit of the regulator is not shorted out or grounded to allow output current to flow.
2.2.4	De-energize the regulator. With a voltmeter measure the voltage at the regulator relay panel between CR and L_NR as the control circuits are energized from a control panel which indicated faulty operation.	The voltage is zero.	Proceed to Step 2.2.6.
		The voltage is approximately 115 volts.	Proceed to the next step.

Step No.	Check or Test Procedure	Results	Probable Cause and/or Corrective Procedure
2.2.5	Check the input switch, the main contactor, and/or the remote-control oil switch, and the control wiring for these units back to the regulator control compartment for burned, pitted, dirty, corroded, or poorly adjusted contacts; grounded, open, shorted, or crossed connections or wiring; sticking, binding, or unsatisfactory operation of movements; and with an ohmmeter check for open or shorted coils.	A switch, contactor, or control circuit is not satisfactory.	Adjust, repair, or replace the faulty component, and repeat Step 2.0.
		The switches, contactors, and control wiring are satisfactory.	The energizing control circuits are satisfactory from this control panel. Check each of the other control panels, repairing or replacing faulty components as necessary. When each control panel energizes the regulator satisfactorily, the energizing controls are satisfactory.
2.2.6	With a voltmeter measure the input voltage to the control distribution panelboard from each side to neutral.	The voltage is approximately 115 volts for each side.	Control voltage is present at this point. Proceed to Step 2.2.8.
		The voltage of one or both sides is zero.	Proceed to the next step.
2.2.7	Check the distribution wiring from the incoming primary voltage to the control distribution panelboard for opens, shorts, grounds, or faulty components.	This wiring has a fault or faulty component.	Make the repairs and repeat Step 2.0. If the faulty component is a blown fuse which continues to blow, locate the overload and repair.
		This wiring and components are satisfactory.	The incoming primary voltage has failed. Repair the incoming primary voltage or report the outage to the proper authorities. After repairs, repeat Step 2.0.
2.2.8	Measure the output voltage of the control distribution panelboard between neutral and L_1 and the transfer-control circuit with the corresponding circuit breakers in the ON position.	The output voltage of each circuit is approximately 115 volts.	Proceed to Step 2.2.10.
		The output voltage of one or both circuits is zero.	Proceed to the next step.
2.2.9	Check the wiring and the circuit breakers in the control distribution panel until the fault or tripped breaker is found.		Make the repairs. If the fault is a tripped breaker, reset it only one time. If the breaker trips again, locate the overload and make the repairs. Then repeat Step 2.0.
2.2.10	Transfer control to the lighting control panel being tested. Then with L_1 on the control distribution panel energized, measure the voltage at the control-panel terminal board between L_1 and ground or neutral.	The voltage is approximately 115 volts.	Control voltage is present to this point. Proceed to Step 2.2.13.
		The voltage is zero.	Proceed to the next step.
2.2.11	By inspection or by ohmmeter or voltmeter measurements, check the L_1 control circuit from the control distribution panel thru the transfer relay panel to the terminal board in this control panel for opens, shorts between circuits, grounds, or crossed connections. Also check the transfer relay for proper position to transfer control to this control panel.	The L_1 circuit has opens, grounds, shorts, or crossed connections.	Make the repairs and repeat Step 2.0.
		The transfer relay has not transferred control to this control panel.	Proceed to the next step.

Step No.	Check or Test Procedure	Results	Probable Cause and/or Corrective Procedure
2.2.12	By inspection or by ohmmeter or voltmeter measurements, check the transfer-circuit controls from the control distribution panel thru the transfer switch to the transfer relays for opens, shorts between circuits, grounds, crossed connections, and check the transfer switch for faults. Check the relay coils for opens or shorts, and the relays for proper operation. Check until the fault is located.		Make the repairs and repeat Step 2.0.
2.2.13	For the control panel and the circuit being tested, set the controls for energizing the regulator and measure the voltage at the control-panel terminal board between the corresponding output terminal (9, 8, or other) and ground or neutral.	The voltage is zero.	Find the open, ground, short, crossed connection, or faulty switch or circuit breaker in the control panel, and make the repairs. If the fault is a tripped circuit breaker which continues to trip and if the overload is not in the control panel, check for grounds or shorts in the energizing controls, the brightness controls, or the circuit-selector controls. Repair. Then repeat Step 2.0.
		The output voltage is approximately 115 volts.	Proceed to the next step.
2.2.14	By inspection or by ohmmeter or voltmeter measurements, check the energizing control circuits from the output terminal (9, 8, or other) in the control panel through the transfer-relay panel to the regulator control compartment for opens, shorts between circuits, grounds, or crossed connections.	There are faults in the energizing control circuits.	Make the repairs and repeat Step 2.0.
		The energizing circuits are satisfactory.	The energizing controls from this control panel are satisfactory. If necessary, check the energizing controls from the other control panels.

<u>Locating Faults in the Brightness Control Circuits</u>

Step No.	Check or Test Procedure	Results	Probable Cause and/or Corrective Procedure
2.3	To check the brightness controls, de-energize the regulator and the control circuits. Visually inspect the brightness relays for welded, burned, pitted, dirty, corroded, or poorly adjusted contacts; for opens, shorts between circuits, grounded or crossed connections in the wiring; for binding or stuck relay movements; or by using an ohmmeter, check for opens or shorts in the relay coils.	One or more relays are not satisfactory.	Adjust, repair, or replace the relay and repeat Step 2.0. CAUTION If the contacts of one or more relays are welded, burned, or pitted from operating under load or if more than one relay is closing at the same time, <u>do not energize the regulator again</u> until Steps 2.3.1 through 2.3.6 have been completed.
		The relays and wiring are satisfactory.	Proceed to the next step.
2.3.1	With the regulator de-energized, transfer control to and operate the remote controls from the panel being tested and measure the brightness control voltage. At the terminal block of the regulator control compartment, simultaneously measure the voltage between L_NR and each of the brightness terminals (B1, B2, B3, B4 and B5) as each of the brightness settings is selected and energized.	For one or more terminals the voltage is not approximately 115 volts when selected, or is 115 volts when not selected.	Proceed to Step 2.3.4.
		The voltage at each selected terminal is 115 volts, but induced or leakage voltage has one or more other terminals not selected well above zero, especially during the switching	Induced or leakage voltage is present. Proceed to Step 2.3.3.

Step No.	Check or Test Procedure	Results	Probable Cause and/or Corrective Procedure
2.3.1 (cont.)		operations; or brightness relay contacts are burned, welded, or pitted.	
		The voltage at each terminal is at or near zero at all times, except that it is approximately 115 volts when the corresponding brightness setting is selected.	The remote brightness controls from this control station are satisfactory. If the regulator does not operate on one or more settings when energized for normal operation, proceed to the next step.
2.3.2	Check the wiring, connections, and bushings in the regulator control compartment, from the brightness relays to the tank of the regulator, for opens, shorts between circuits, grounds, or crossed connections in the wiring and for cracked, broken, or loose bushings.	Faults are present in this wiring.	Make the repairs and repeat Step 2.0.
		This wiring is satisfactory.	The fault is inside the tank of the regulator. Make or obtain repairs as instructed in the appropriate Technical Order or instruction manual.
2.3.3	To check for the presence of or cause of induced or leakage voltage, visually observe the action of the relays for the tendency of any relay not selected to operate, or of any relay that is selected to drop out, and simultaneously check for these voltages with voltmeters as each possible switching operation is performed. Make the checks for the switching of all other equipment as well as of that affecting this regulator. Perform these checks carefully and thoroughly, especially if primary fuses are blown, or if relay contacts are welded, burned, or pitted.	Induced or leakage voltage tends to operate one or more relays, or is indicated, even momentarily.	Eliminate the induced or leakage voltage by: a. Separating the control circuits from high current-carrying conductors in the same or nearby paralleling cables; b. Replacing a circuit with poor insulation with one with adequate insulation; c. Using a shielded cable for the control cable and have a return neutral wire in the cable. If it is not practical to eliminate the induced or leakage voltage, reduce the effects of this voltage by: a. Replacing the relay(s); or b. Shunting the coil of the relay(s) with a low impedance, such as a low-wattage incandescent lamp. Then repeat Step 2.0.
		A fixed (not induced or leakage) voltage is impressed on a relay other than the one selected.	A short between circuits or crossed connection exists in the control circuits. Proceed to the next step.
2.3.4	Check the brightness selections at the control panel being tested by measuring the voltages simultaneously with voltmeters or incandescent lamps at the terminal block in the control panel between the brightness terminals B1, B2, B3, B4, and B5 and ground or neutral as each brightness setting is selected.	The voltage is zero for one or more selected terminals.	Locate the open in the wiring in the control panel or the fault in the selector switch. Make the repairs and repeat Step 2.0.
		The voltage is 115 volts for one or more terminals not selected.	Locate the short between circuits or crossed connection in the wiring in the control panel or in the selector switch. Make the repairs and repeat Step 2.0. If the fault is not in the control panel or selector switch, the fault is a short between circuits in the control cable. Proceed to Step 2.3.6.
		The voltage is 115 volts at each terminal as selected and is zero at all other times.	To check the timing and operation of the interlocks, if any, of the selector switch, proceed to the next step.

Step No.	Check or Test Procedure	Results	Probable Cause and/or Corrective Procedure
2.3.5	For those regulators requiring interlocks, check the operation and timing of the brightness-selector switch to prevent operation of the brightness relays under load. With the voltmeters or incandescent lamps, measure voltage between each brightness terminal, B1, B2, B3, B4, B5, and CR, and ground or neutral, as each setting is selected. Make certain the interlock opens before the switch breaks contact of the present setting and remains open until after contact of the new setting is completed.	The interlock does not open or close the circuit, or the timing is not satisfactory.	Adjust, repair, or replace the selector switch. Then repeat Step 2.0
		The voltage at each terminal selected is approximately 115 volts, and the interlock (CR) opens before and closes after the selected brightness contact.	The interlock and brightness wiring in the control panel is satisfactory. The fault is in the circuit between the relay panel and the inside of the regulator. Proceed to the next step.
2.3.6	By inspection or by ohmmeter or voltmeter measurements, check each of the brightness-control circuits, from the terminals B1, B2, B3, B4, B5 and CR in the control panel through the transfer relay panel to the regulator control compartment, for opens, shorts between circuits, grounds, or crossed connections.	There are faults in the brightness control circuits.	Make the repairs and repeat Step 2.0.
		The brightness-control circuits are satisfactory.	The brightness controls from this control panel are satisfactory. Check the brightness controls from the other control panels.

<u>Locating Faults in the Circuit- (Runway-) Selector Control Circuits.</u>

Step No.	Check or Test Procedure	Results	Probable Cause and/or Corrective Procedure
2.4	To check the circuit-selector controls, remove all short circuits on the output of the regulator and, after connecting the field circuits to the regulator, visually check every circuit as each circuit is selected and energized. (For some types of circuits such as taxiway lights, it may be possible to energize and check more than one circuit, or all circuits, at the same time.)	The selected circuit is not energized, or a circuit not selected is energized.	Proceed to Step 2.4.2.
		Each circuit is energized as selected.	The circuit-selector controls from this control panel are satisfactory. To check the other control panels, proceed to the next step.
2.4.1	Transfer control to and test each of the other control panels by repeating the visual check of operations as in Step 2.4.	From one or more panels the selected circuit is not energized, or a circuit not selected is energized.	There are faults in the selector controls from this panel. Proceed to Step 2.4.4.
		Each circuit is energized as selected from each of the control panels.	The circuit-selector controls are satisfactory.
2.4.2	De-energize the regulator and the control circuits. Visually inspect the wiring, the bushings, and the series-plug cutouts in the runway-selector cabinet for opens, shorts between circuits, grounds, and loose or crossed connections; for welded, burned, pitted, dirty, corroded, or poorly adjusted relay contacts; and check the relays for binding or stuck movements. With an ohmmeter check for opens or shorts in the relay coils.	There are faults in the wiring or components.	Make the repairs and repeat Step 2.4. If the fault is welded, burned, or pitted relay contacts which have been damaged from operating under load, proceed to Step 2.4.4.
		There are no faults in the wiring or components in the runway-selector cabinet.	Proceed to the next step.

Step No.	Check or Test Procedure	Results	Probable Cause and/or Corrective Procedure
2.4.3	Check the output wiring between the output terminals of the regulator and the runway-selector cabinet for opens, shorts between circuits, grounds, or loose connections, and for cracked or broken bushings.	There are faults in this output circuit.	Make the repairs and repeat Step 2.0.
		This output wiring is satisfactory.	The fault is in the circuit-selector control circuits. Proceed to the next step.
2.4.4	With the regulator de-energized, transfer control to and operate the remote controls from the panel being tested and measure the selector-circuit control voltage. At the control terminal block of the runway-selector cabinet, simultaneously measure the voltage between L_NR and each of the circuit-selector control terminals, R1, R2, R3, R4, and CR, etc., as each circuit is selected and energized.	The voltage at each terminal is at or near zero at all times except that it is approximately 115 volts when the corresponding circuit is selected.	The remote circuit-selector controls from this control panel are satisfactory. Repeat the check using other control panels.
		For one or more terminals the voltage is not approximately 115 volts when selected, or is 115 volts when not selected.	The fault is in the control wiring. Proceed to Step 2.4.6.
		The voltage at each terminal selected is 115 volts, but induced or leakage voltage has one or more other terminals not selected well above zero, especially during the switching operations; or the relay contacts were welded, burned, or pitted.	Induced or leakage voltage is present. Proceed to the next step.
2.4.5	To check for the presence or cause of induced or leakage voltages, visually observe the action of the relays for the tendency of any relay not selected to operate, or for any relay that is selected to drop out; and simultaneously measure for these voltages with voltmeters as each possible switching operation is performed. Make the checks for the switching of all other equipment as well as of that affecting these circuits. Perform these checks carefully and thoroughly, especially if primary fuses are blown or circuit breakers are tripped, or if relay contacts are welded, burned, or pitted from operating under load.	Induced or leakage voltage tends to operate or is indicated, even momentarily, for one or more relays.	Eliminate the induced or leakage voltage by: a. Separating the control circuits from high current carrying conductors in the same or nearby paralleling cables; b. Replacing a circuit with poor insulation with one with adequate insulation; or c. Using a shielded cable for the the control cable and having a returnneutral wire in the cable. If it is not practical to eliminate the induced or leakage voltages, reduce the effectiveness of the voltages by: a. Replacing the relay(s); or b. Shunting the coil of the relay(s) with a low impedance, such as a low-wattage incandescent lamp. Then repeat Step 2.4.
		A fixed (not induced or leakage) voltage is impressed on a relay other than the one selected.	A short between circuits or crossed connection exists in the control circuits. Proceed to the next step.
2.4.6	Check the circuit selections at the control panel being tested by measuring the voltages simultaneously with voltmeters or incandescent lamps at the terminal block in the control panel between the circuit-selector terminals R1, R2, R3, R4, etc., and ground or neutral as each circuit is selected.	The voltage is zero for one or more selected terminals.	Locate the open in the wiring in the control panel or the fault in the selector switch. Make the repairs and repeat Step 2.4.
		The voltage is 115 volts for one or more terminals which were not selected.	Locate the short between circuits, or crossed connection in the wiring in the control panel or in the selector switch. Make the repairs and repeat Step 2.4. If the fault is not in the selector switch, the fault is a short between circuits in the control cable. Proceed to Step 2.4.8.

Step No.	Check or Test Procedure	Results	Probable Cause and/or Corrective Procedure
2.4.6 (cont.)		The voltage is 115 volts at each terminal selected and is zero at all other times.	To check the timing and operation of the interlocks and of the selector switch, proceed to the next step.
2.4.7	For those circuit-selecting relays requiring interlocks to prevent operation of the relays while under load, check the operation and timing of the circuit-selector switch. With the voltmeters or incandescent lamps, measure the voltage between each circuit-selector terminal (9, R1, R2, R3, R4, etc.) and ground or neutral at the control panel selector board, as each circuit is selected. Make certain the interlock (9) opens before the switch breaks contact of the present selection and remains open until after contact of the new selection is completed.	The interlock does not open or close the circuit for some selections, or the timing is not satisfactory.	Adjust, repair, or replace the selector switch. Then repeat Step 2.4.
		The voltage at each terminal selected is approximately 115 volts, and the interlock opens before and closes after the selected contact.	The interlock and circuit-selector wiring in the control panel is satisfactory. If the circuit-selection control operation is not satisfactory, the fault is in the circuits between the control panel and the runway-selector cabinet. Proceed to the next step.
2.4.8	By inspection or by ohmmeter or voltmeter measurements, check each of the circuit-selector control circuits, from the terminals (R1, R2, R3, R4, etc.) in the control panel through the transfer-relay panel to the runway-selector cabinet, for opens, shorts between circuits, grounds, or crossed connections.	There are faults in the circuit-selector control circuits.	Make the repairs. Then repeat Step 2.4 or Step 2.0.
		The circuit-selector control circuits are satisfactory.	The circuit-selector controls from this control panel are satisfactory. If necessary, check the circuit-selector controls from the other control panels.

3.0 TROUBLESHOOTING CHARTS

The troubleshooting charts given in this section are based on the Step-by-Step Procedure given in Section 2. For maintenance personnel with considerable experience and familiarity with step-by-step procedures, this briefer and picture-form arrangement may be the more useful method. If the instructions given here are too brief, the corresponding Step in the Step-by-Step Procedure will provide additional details. The method of using these charts is the same as that for the Step-by-Step Procedure. The special instructions given for the Detailed Step-by-Step Procedure also apply for the Troubleshooting Charts. The numbers used in the steps of these charts correspond to the step numbers of the step-by-step procedure. In these charts the rectangular boxes contain check or test instructions or repair information. The oval boxes contain supplementary information such as probable causes or incidental instructions. A star (*) on a line following a check or test identifies the point for which the accompanying result applies. A dot (°) before a particular instruction indicates the location of a fault. Upon completion of the work outlined in the instruction, the major step in the procedure should be repeated to determine if other faults exist or if the circuit is ready to be returned to normal operation. From a given step, the chart branches into a description of each of the results which may be expected. When more than one result or step requiring a similar procedure can be conveniently arranged to join into a succeeding step and thus avoid repetition, a brace (⏟) is used. When a set of loose individual charts is available, they may be mounted together to form a complete troubleshooting chart.

The load current is too high, but the short-circuit current is normal. *

The secondaries of a number of isolating (IL) transformers are open, or too many series-multiple transformers are in the circuit.

overloaded.

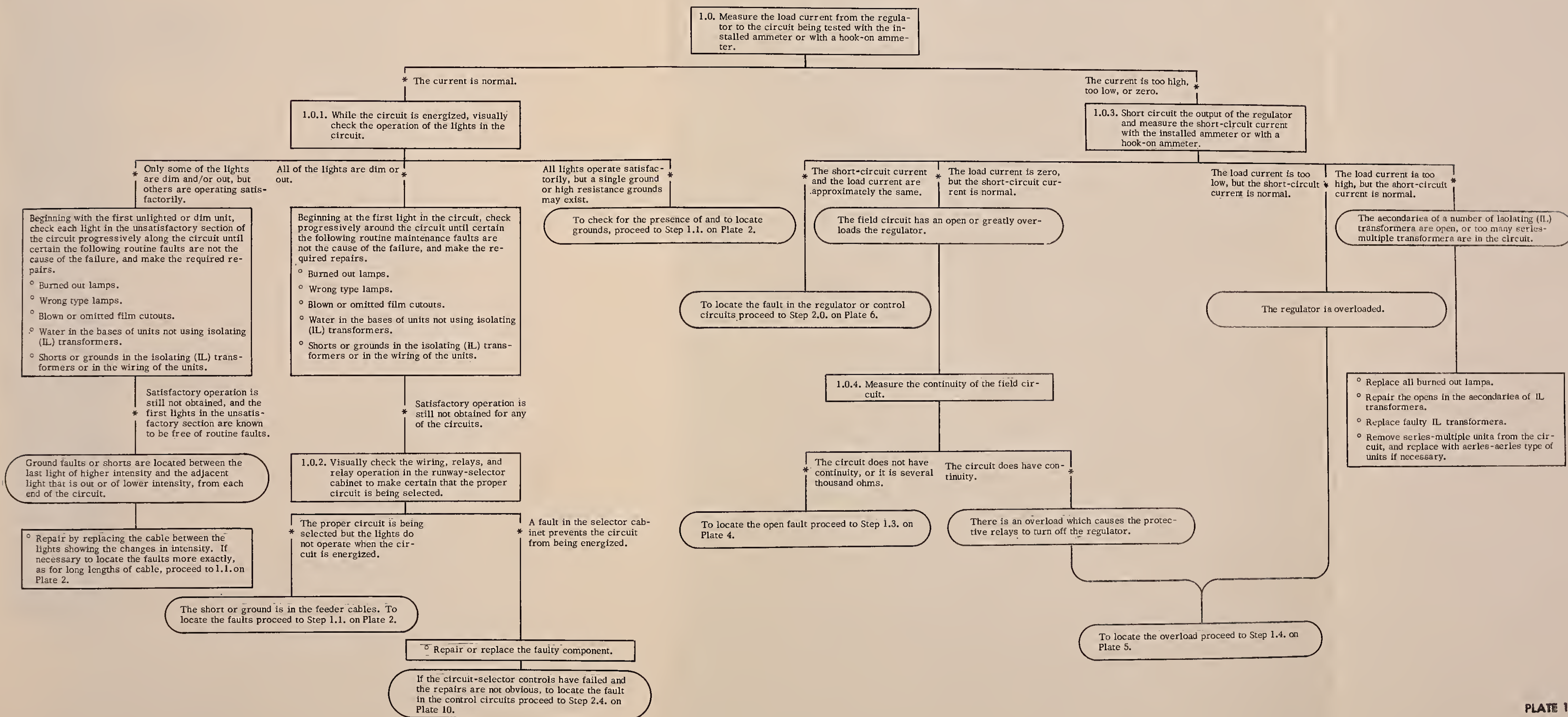
- Replace all burned out lamps.
- Repair the opens in the secondaries of IL transformers.
- Replace faulty IL transformers.
- Remove series-multiple units from the circuit, and replace with series-series type of units if necessary.

PLATE 1

3.0 TROUBLESHOOTING CHARTS

The troubleshooting charts given in this section are based on the step-by-step procedure given in Section 2. For maintenance personnel with considerable experience and familiarity with step-by-step procedures, this briefer and picture-form arrangement may be the more useful method. If the instructions given here are too brief, the corresponding Step in the step-by-step procedure will provide additional details. The method of using these charts is the same as that for the step-by-step procedure. The special instructions given for the Detailed Step-by-Step Procedure also apply for the Troubleshooting Charts. The numbers used in the steps of these charts correspond to the step numbers of the step-by-step procedure. In these charts the rectangular boxes contain check or test instructions or repair information. The oval boxes contain supplementary information such as probable causes or incidental instructions. A star (*) on a line following a check or test identifies the point for which the accompanying result applies. A dot (○) before a particular instruction indicates the location of a fault. Upon completion of the work outlined in the instruction, the major step in the procedure should be repeated to determine if other faults exist or if the circuit is ready to be returned to normal operation. From a given step, the chart branches into a description of each of the results which may be expected. When more than one result or step requiring a similar procedure can be conveniently arranged to join into a succeeding step and thus avoid repetition, a brace (⏟) is used. When a set of loose individual charts is available, they may be mounted together to form a complete troubleshooting chart.

These charts are based on an assumed report that certain circuits or sections of series lights are not operating properly. To keep the chart general and to prevent unnecessary repetition, any additional information in the malfunction report or further information which may be obtained before starting the troubleshooting has not been considered in preparing these charts. These charts are started from a check in the vault rather than a visual check of operations, because at many fields where the circuits are distant from operations and transportation and communication facilities are limited, the saving in time and effort may be considerable. For those thoroughly familiar with troubleshooting procedures for series circuits a simplified procedure is given in the section on Troubleshooting by Symptoms, but if difficulty is encountered in locating faults by thia procedure, return to these charts or the Step-by-Step Procedure and follow instructions carefully. The numbers used in the steps of these charts correspond to the Step numbers in the Step-by-Step Procedure. The Step-by-Step Procedure contains more detailed instructions and references. On these charts the rectangular boxes contain instructions on things to do, the ovals contain supplementary information, a (*) on a line following a procedure identifies the point for which the accompanying result applies, and the dot (°) before a particular instruction indicates the location of a trouble or fault and indicates that upon completion of the instruction the major step in the procedure should be repeated to check for other symptoms or the circuit should be restored to normal operation. When a step is performed the chart branches into each of possible results to be expected. When mora than one result or step requiring a similar procedure can be conveniently arranged to join into a succeeding step and avoid repetition a brace (⏟) is used.



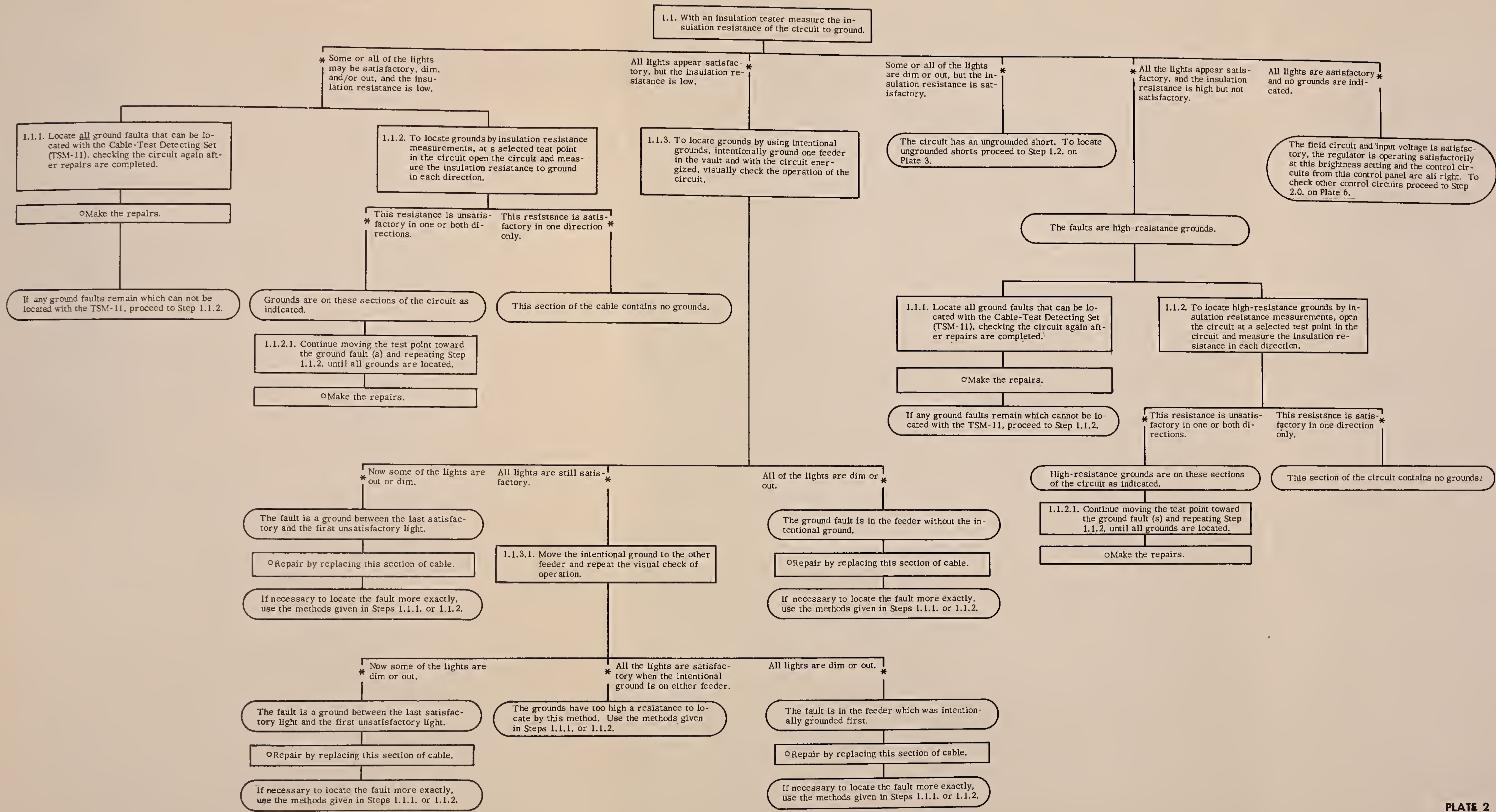

1.1. With an insulation tester measure the insulation resistance of the circuit to ground.
* Some or all of the lights may be satisfactory, dim, and/or out, and the insulation resistance is low.
1.1.1. Locate all ground faults that can be located with the Cable-Test Detecting Set (TSM-11), checking the circuit again after repairs are completed.
○Make the repairs.
If any ground faults remain which can not be located with the TSM-11, proceed to Step 1.1.2.
1.1.2. To locate grounds by insulation resistance measurements, at a selected test point in the circuit open the circuit and measure the insulation resistance to ground in each direction.
* This resistance is unsatisfactory in one or both directions.
Grounds are on these sections of the circuit as indicated.
1.1.2.1. Continue moving the test point toward the ground fault (s) and repeating Step 1.1.2. until all grounds are located.
○Make the repairs.
This resistance is satisfactory in one direction only. *
This section of the cable contains no grounds.
All lights appear satisfactory, but the insulation resistance is low. *
1.1.3. To locate grounds by using intentional grounds, intentionally ground one feeder in the vault and with the circuit energized, visually check the operation of the circuit.
* Now some of the lights are out or dim.
The fault is a ground between the last satisfactory and the first unsatisfactory light.
○Repair by replacing this section of cable.
If necessary to locate the fault more exactly, use the methods given in Steps 1.1.1. or 1.1.2.
All lights are still satisfactory. *
1.1.3.1. Move the intentional ground to the other feeder and repeat the visual check of operation.
* Now some of the lights are dim or out.
The fault is a ground between the last satisfactory light and the first unsatisfactory light.
○Repair by replacing this section of cable.
If necessary to locate the fault more exactly, use the methods given in Steps 1.1.1. or 1.1.2.
* All the lights are satisfactory when the intentional ground is on either feeder.
The grounds have too high a resistance to locate by this method. Use the methods given in Steps 1.1.1. or 1.1.2.
All lights are dim or out. *
The fault is in the feeder which was intentionally grounded first.
○Repair by replacing this section of cable.
If necessary to locate the fault more exactly, use the methods given in Steps 1.1.1. or 1.1.2.
All of the lights are dim or out. *
The ground fault is in the feeder without the intentional ground.
○Repair by replacing this section of cable.
If necessary to locate the fault more exactly, use the methods given in Steps 1.1.1. or 1.1.2.
Some or all of the lights are dim or out, but the insulation resistance is satisfactory. *
The circuit has an ungrounded short. To locate ungrounded shorts proceed to Step 1.2. on Plate 3.
* All the lights appear satisfactory, and the insulation resistance is high but not satisfactory.
The faults are high-resistance grounds.
1.1.1. Locate all ground faults that can be located with the Cable-Test Detecting Set (TSM-11), checking the circuit again after repairs are completed.
○Make the repairs.
If any ground faults remain which cannot be located with the TSM-11, proceed to Step 1.1.2.
1.1.2. To locate high-resistance grounds by insulation resistance measurements, open the circuit at a selected test point in the circuit and measure the insulation resistance in each direction.
* This resistance is unsatisfactory in one or both directions.
High-resistance grounds are on these sections of the circuit as indicated.
1.1.2.1. Continue moving the test point toward the ground fault (s) and repeating Step 1.1.2. until all grounds are located.
○Make the repairs.
This resistance is satisfactory in one direction only. *
This section of the circuit contains no grounds.
All lights are satisfactory and no grounds are indicated. *
The field circuit and input voltage is satisfactory, the regulator is operating satisfactorily at this brightness setting and the control circuits from this control panel are all right. To check other control circuits proceed to Step 2.0. on Plate 6.

PLATE 2

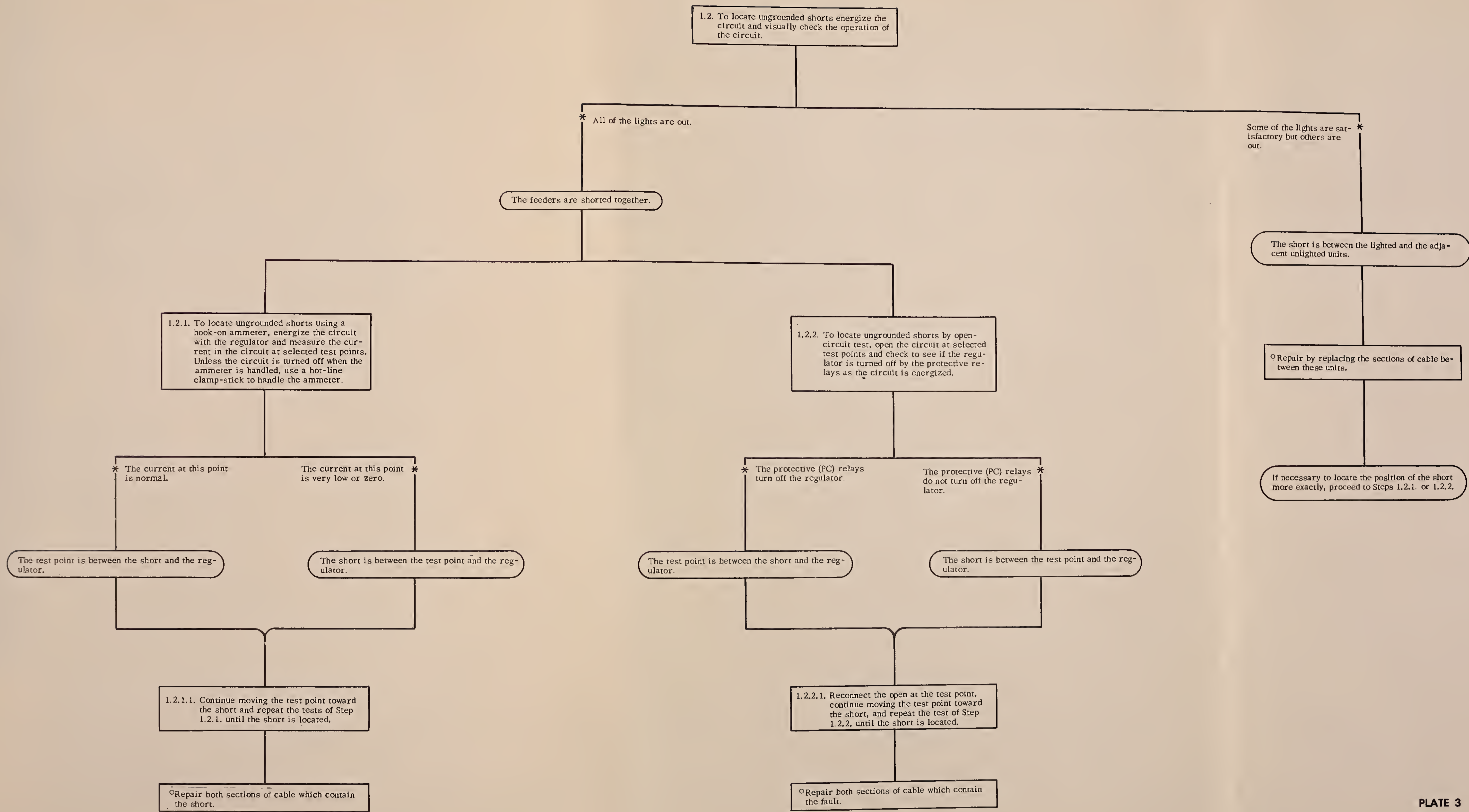
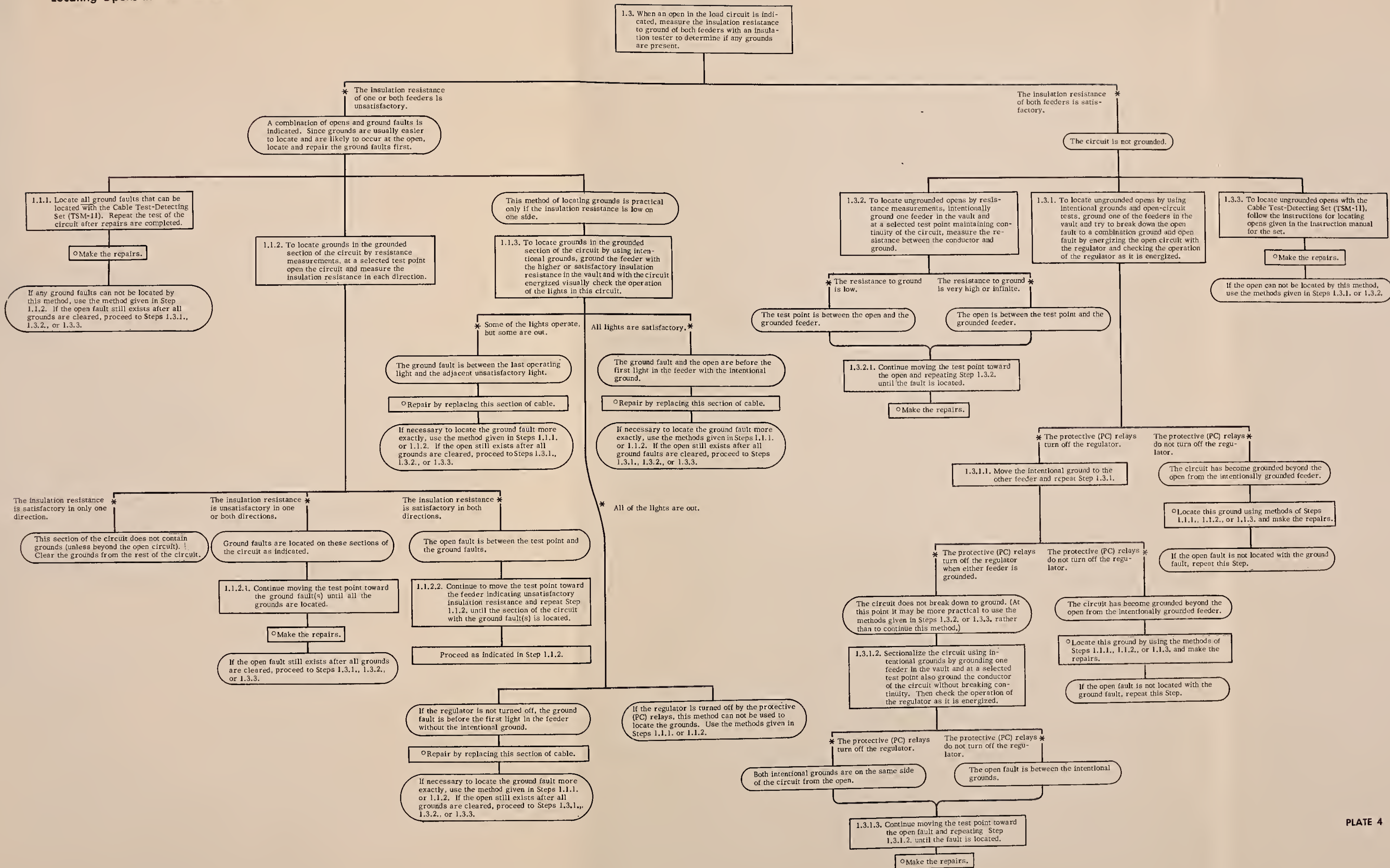

1.2. To locate ungrounded shorts energize the circuit and visually check the operation of the circuit.
* All of the lights are out.
Some of the lights are satisfactory but others are out. *
The feeders are shorted together.
1.2.1. To locate ungrounded shorts using a hook-on ammeter, energize the circuit with the regulator and measure the current in the circuit at selected test points. Unless the circuit is turned off when the ammeter is handled, use a hot-line clamp-stick to handle the ammeter.
* The current at this point is normal.
The current at this point is very low or zero. *
The test point is between the short and the regulator.
The short is between the test point and the regulator.
1.2.1.1. Continue moving the test point toward the short and repeat the tests of Step 1.2.1. until the short is located.
°Repair both sections of cable which contain the short.
1.2.2. To locate ungrounded shorts by open-circuit test, open the circuit at selected test points and check to see if the regulator is turned off by the protective relays as the circuit is energized.
* The protective (PC) relays turn off the regulator.
The protective (PC) relays do not turn off the regulator. *
The test point is between the short and the regulator.
The short is between the test point and the regulator.
1.2.2.1. Reconnect the open at the test point, continue moving the test point toward the short, and repeat the test of Step 1.2.2. until the short is located.
°Repair both sections of cable which contain the fault.
The short is between the lighted and the adjacent unlighted units.
°Repair by replacing the sections of cable between these units.
If necessary to locate the position of the short more exactly, proceed to Steps 1.2.1. or 1.2.2.

PLATE 3


1.3. When an open in the load circuit is indicated, measure the insulation resistance to ground of both feeders with an insulation tester to determine if any grounds are present.
The insulation resistance of one or both feeders is unsatisfactory.
A combination of opens and ground faults is indicated. Since grounds are usually easier to locate and are likely to occur at the open, locate and repair the ground faults first.
1.1.1. Locate all ground faults that can be located with the Cable Test-Detecting Set (TSM-11). Repeat the test of the circuit after repairs are completed.
Make the repairs.
If any ground faults can not be located by this method, use the method given in Step 1.1.2. If the open fault still exists after all grounds are cleared, proceed to Steps 1.3.1., 1.3.2., or 1.3.3.
1.1.2. To locate grounds in the grounded section of the circuit by resistance measurements, at a selected test point open the circuit and measure the insulation resistance in each direction.
The insulation resistance is satisfactory in only one direction.
This section of the circuit does not contain grounds (unless beyond the open circuit). Clear the grounds from the rest of the circuit.
The insulation resistance is unsatisfactory in one or both directions.
Ground faults are located on these sections of the circuit as indicated.
1.1.2.1. Continue moving the test point toward the ground fault(s) until all the grounds are located.
Make the repairs.
If the open fault still exists after all grounds are cleared, proceed to Steps 1.3.1., 1.3.2., or 1.3.3.
The insulation resistance is satisfactory in both directions.
The open fault is between the test point and the ground faults.
1.1.2.2. Continue to move the test point toward the feeder indicating unsatisfactory insulation resistance and repeat Step 1.1.2. until the section of the circuit with the ground fault(s) is located.
Proceed as indicated in Step 1.1.2.
This method of locating grounds is practical only if the insulation resistance is low on one side.
1.1.3. To locate grounds in the grounded section of the circuit by using intentional grounds, ground the feeder with the higher or satisfactory insulation resistance in the vault and with the circuit energized visually check the operation of the lights in this circuit.
Some of the lights operate, but some are out.
The ground fault is between the last operating light and the adjacent unsatisfactory light.
Repair by replacing this section of cable.
If necessary to locate the ground fault more exactly, use the method given in Steps 1.1.1. or 1.1.2. If the open still exists after all grounds are cleared, proceed to Steps 1.3.1., 1.3.2., or 1.3.3.
All lights are satisfactory.
The ground fault and the open are before the first light in the feeder with the intentional ground.
Repair by replacing this section of cable.
If necessary to locate the ground fault more exactly, use the methods given in Steps 1.1.1. or 1.1.2. If the open still exists after all ground faults are cleared, proceed to Steps 1.3.1., 1.3.2., or 1.3.3.
All of the lights are out.
If the regulator is not turned off, the ground fault is before the first light in the feeder without the intentional ground.
Repair by replacing this section of cable.
If necessary to locate the ground fault more exactly, use the method given in Steps 1.1.1. or 1.1.2. If the open still exists after all grounds are cleared, proceed to Steps 1.3.1., 1.3.2., or 1.3.3.
If the regulator is turned off by the protective (PC) relays, this method can not be used to locate the grounds. Use the methods given in Steps 1.1.1. or 1.1.2.
The insulation resistance of both feeders is satisfactory.
The circuit is not grounded.
1.3.2. To locate ungrounded opens by resistance measurements, intentionally ground one feeder in the vault and at a selected test point maintaining continuity of the circuit, measure the resistance between the conductor and ground.
The resistance to ground is low.
The test point is between the open and the grounded feeder.
The resistance to ground is very high or infinite.
The open is between the test point and the grounded feeder.
1.3.2.1. Continue moving the test point toward the open and repeating Step 1.3.2. until the fault is located.
Make the repairs.
1.3.1. To locate ungrounded opens by using intentional grounds and open-circuit tests, ground one of the feeders in the vault and try to break down the open fault to a combination ground and open fault by energizing the open circuit with the regulator and checking the operation of the regulator as it is energized.
The protective (PC) relays turn off the regulator.
1.3.1.1. Move the intentional ground to the other feeder and repeat Step 1.3.1.
The protective (PC) relays turn off the regulator when either feeder is grounded.
The circuit does not break down to ground. (At this point it may be more practical to use the methods given in Steps 1.3.2. or 1.3.3. rather than to continue this method.)
1.3.1.2. Sectionalize the circuit using intentional grounds by grounding one feeder in the vault and at a selected test point also ground the conductor of the circuit without breaking continuity. Then check the operation of the regulator as it is energized.
The protective (PC) relays turn off the regulator.
Both intentional grounds are on the same side of the circuit from the open.
The protective (PC) relays do not turn off the regulator.
The open fault is between the intentional grounds.
1.3.1.3. Continue moving the test point toward the open fault and repeating Step 1.3.1.2. until the fault is located.
Make the repairs.
The protective (PC) relays do not turn off the regulator.
The circuit has become grounded beyond the open from the intentionally grounded feeder.
Locate this ground by using the methods of Steps 1.1.1., 1.1.2., or 1.1.3. and make the repairs.
If the open fault is not located with the ground fault, repeat this Step.
The protective (PC) relays do not turn off the regulator.
The circuit has become grounded beyond the open from the intentionally grounded feeder.
Locate this ground using methods of Steps 1.1.1., 1.1.2., or 1.1.3. and make the repairs.
If the open fault is not located with the ground fault, repeat this Step.
1.3.3. To locate ungrounded opens with the Cable Test-Detecting Set (TSM-11), follow the instructions for locating opens given in the instruction manual for the set.
Make the repairs.
If the open can not be located by this method, use the methods given in Steps 1.3.1. or 1.3.2.

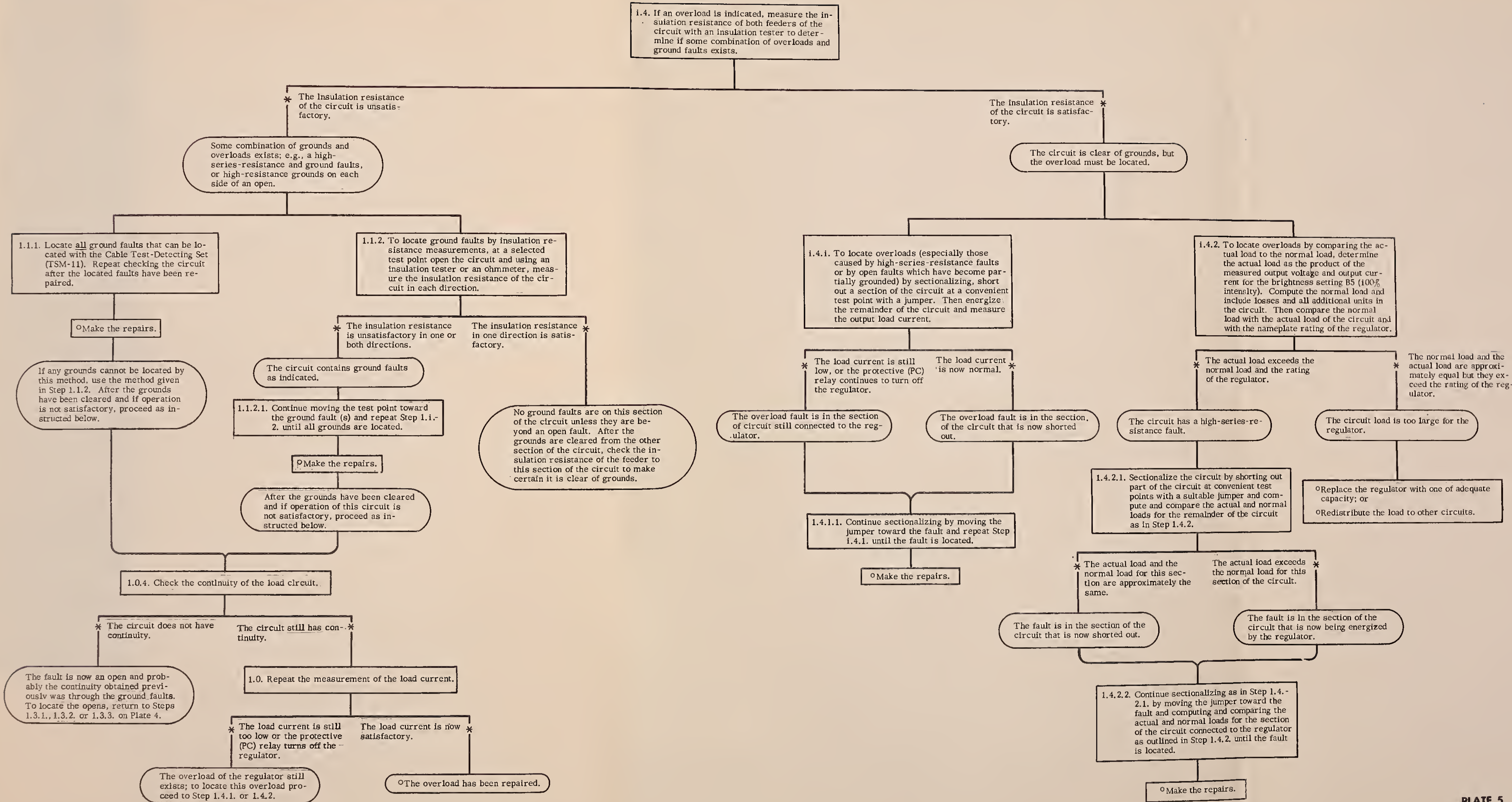

1.4. If an overload is indicated, measure the insulation resistance of both feeders of the circuit with an insulation tester to determine if some combination of overloads and ground faults exists.
* The insulation resistance of the circuit is unsatisfactory.
Some combination of grounds and overloads exists; e.g., a high-series-resistance and ground faults, or high-resistance grounds on each side of an open.
1.1.1. Locate all ground faults that can be located with the Cable Test-Detecting Set (TSM-11). Repeat checking the circuit after the located faults have been repaired.
°Make the repairs.
If any grounds cannot be located by this method, use the method given in Step 1.1.2. After the grounds have been cleared and if operation is not satisfactory, proceed as instructed below.
1.1.2. To locate ground faults by insulation resistance measurements, at a selected test point open the circuit and using an insulation tester or an ohmmeter, measure the insulation resistance of the circuit in each direction.
* The insulation resistance is unsatisfactory in one or both directions.
The circuit contains ground faults as indicated.
1.1.2.1. Continue moving the test point toward the ground fault (s) and repeat Step 1.1.2. until all grounds are located.
°Make the repairs.
After the grounds have been cleared and if operation of this circuit is not satisfactory, proceed as instructed below.
The insulation resistance in one direction is satisfactory. *
No ground faults are on this section of the circuit unless they are beyond an open fault. After the grounds are cleared from the other section of the circuit, check the insulation resistance of the feeder to this section of the circuit to make certain it is clear of grounds.
1.0.4. Check the continuity of the load circuit.
* The circuit does not have continuity.
The fault is now an open and probably the continuity obtained previously was through the ground faults. To locate the opens, return to Steps 1.3.1., 1.3.2. or 1.3.3. on Plate 4.
The circuit still has continuity. *
1.0. Repeat the measurement of the load current.
* The load current is still too low or the protective (PC) relay turns off the regulator.
The overload of the regulator still exists; to locate this overload proceed to Step 1.4.1. or 1.4.2.
The load current is now satisfactory. *
°The overload has been repaired.
The insulation resistance of the circuit is satisfactory. *
The circuit is clear of grounds, but the overload must be located.
1.4.1. To locate overloads (especially those caused by high-series-resistance faults or by open faults which have become partially grounded) by sectionalizing, short out a section of the circuit at a convenient test point with a jumper. Then energize the remainder of the circuit and measure the output load current.
* The load current is still low, or the protective (PC) relay continues to turn off the regulator.
The overload fault is in the section of circuit still connected to the regulator.
The load current is now normal. *
The overload fault is in the section of the circuit that is now shorted out.
1.4.1.1. Continue sectionalizing by moving the jumper toward the fault and repeat Step 1.4.1. until the fault is located.
°Make the repairs.
1.4.2. To locate overloads by comparing the actual load to the normal load, determine the actual load as the product of the measured output voltage and output current for the brightness setting B5 (100% intensity). Compute the normal load and include losses and all additional units in the circuit. Then compare the normal load with the actual load of the circuit and with the nameplate rating of the regulator.
* The actual load exceeds the normal load and the rating of the regulator.
The circuit has a high-series-resistance fault.
1.4.2.1. Sectionalize the circuit by shorting out part of the circuit at convenient test points with a suitable jumper and compute and compare the actual and normal loads for the remainder of the circuit as in Step 1.4.2.
* The actual load and the normal load for this section are approximately the same.
The fault is in the section of the circuit that is now shorted out.
The actual load exceeds the normal load for this section of the circuit. *
The fault is in the section of the circuit that is now being energized by the regulator.
1.4.2.2. Continue sectionalizing as in Step 1.4.2.1. by moving the jumper toward the fault and computing and comparing the actual and normal loads for the section of the circuit connected to the regulator as outlined in Step 1.4.2. until the fault is located.
°Make the repairs.
* The normal load and the actual load are approximately equal but they exceed the rating of the regulator.
The circuit load is too large for the regulator.
°Replace the regulator with one of adequate capacity; or
°Redistribute the load to other circuits.

PLATE 5

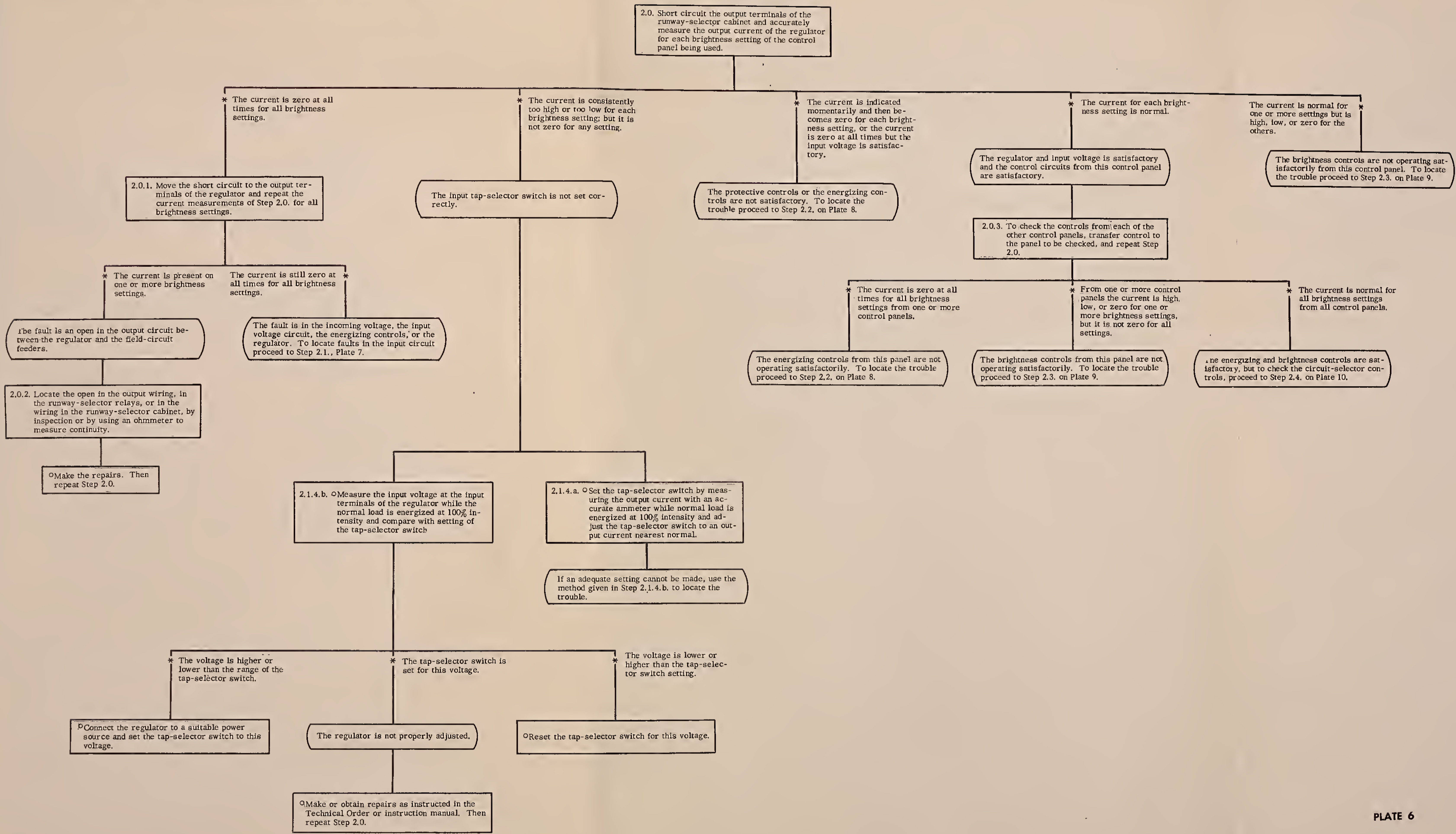

2.0. Short circuit the output terminals of the runway-selector cabinet and accurately measure the output current of the regulator for each brightness setting of the control panel being used.
* The current is zero at all times for all brightness settings.
2.0.1. Move the short circuit to the output terminals of the regulator and repeat the current measurements of Step 2.0. for all brightness settings.
* The current is present on one or more brightness settings.
The fault is an open in the output circuit between the regulator and the field-circuit feeders.
2.0.2. Locate the open in the output wiring, in the runway-selector relays, or in the wiring in the runway-selector cabinet, by inspection or by using an ohmmeter to measure continuity.
○Make the repairs. Then repeat Step 2.0.
The current is still zero at all times for all brightness settings. *
The fault is in the incoming voltage, the input voltage circuit, the energizing controls, or the regulator. To locate faults in the input circuit proceed to Step 2.1., Plate 7.
* The current is consistently too high or too low for each brightness setting; but it is not zero for any setting.
The input tap-selector switch is not set correctly.
2.1.4.b. ○Measure the input voltage at the input terminals of the regulator while the normal load is energized at 100% intensity and compare with setting of the tap-selector switch
* The voltage is higher or lower than the range of the tap-selector switch.
○Connect the regulator to a suitable power source and set the tap-selector switch to this voltage.
* The tap-selector switch is set for this voltage.
The regulator is not properly adjusted.
○Make or obtain repairs as instructed in the Technical Order or instruction manual. Then repeat Step 2.0.
* The voltage is lower or higher than the tap-selector switch setting.
○Reset the tap-selector switch for this voltage.
2.1.4.a. ○Set the tap-selector switch by measuring the output current with an accurate ammeter while normal load is energized at 100% intensity and adjust the tap-selector switch to an output current nearest normal.
If an adequate setting cannot be made, use the method given in Step 2.1.4.b. to locate the trouble.
* The current is indicated momentarily and then becomes zero for each brightness setting, or the current is zero at all times but the input voltage is satisfactory.
The protective controls or the energizing controls are not satisfactory. To locate the trouble proceed to Step 2.2. on Plate 8.
* The current for each brightness setting is normal.
The regulator and input voltage is satisfactory and the control circuits from this control panel are satisfactory.
2.0.3. To check the controls from each of the other control panels, transfer control to the panel to be checked, and repeat Step 2.0.
* The current is zero at all times for all brightness settings from one or more control panels.
The energizing controls from this panel are not operating satisfactorily. To locate the trouble proceed to Step 2.2. on Plate 8.
* From one or more control panels the current is high, low, or zero for one or more brightness settings, but it is not zero for all settings.
The brightness controls from this panel are not operating satisfactorily. To locate the trouble proceed to Step 2.3. on Plate 9.
* The current is normal for all brightness settings from all control panels.
The energizing and brightness controls are satisfactory, but to check the circuit-selector controls, proceed to Step 2.4. on Plate 10.
The current is normal for one or more settings but is high, low, or zero for the others. *
The brightness controls are not operating satisfactorily from this control panel. To locate the trouble proceed to Step 2.3. on Plate 9.

PLATE 6

Locating Faults in the Input Power Circuits

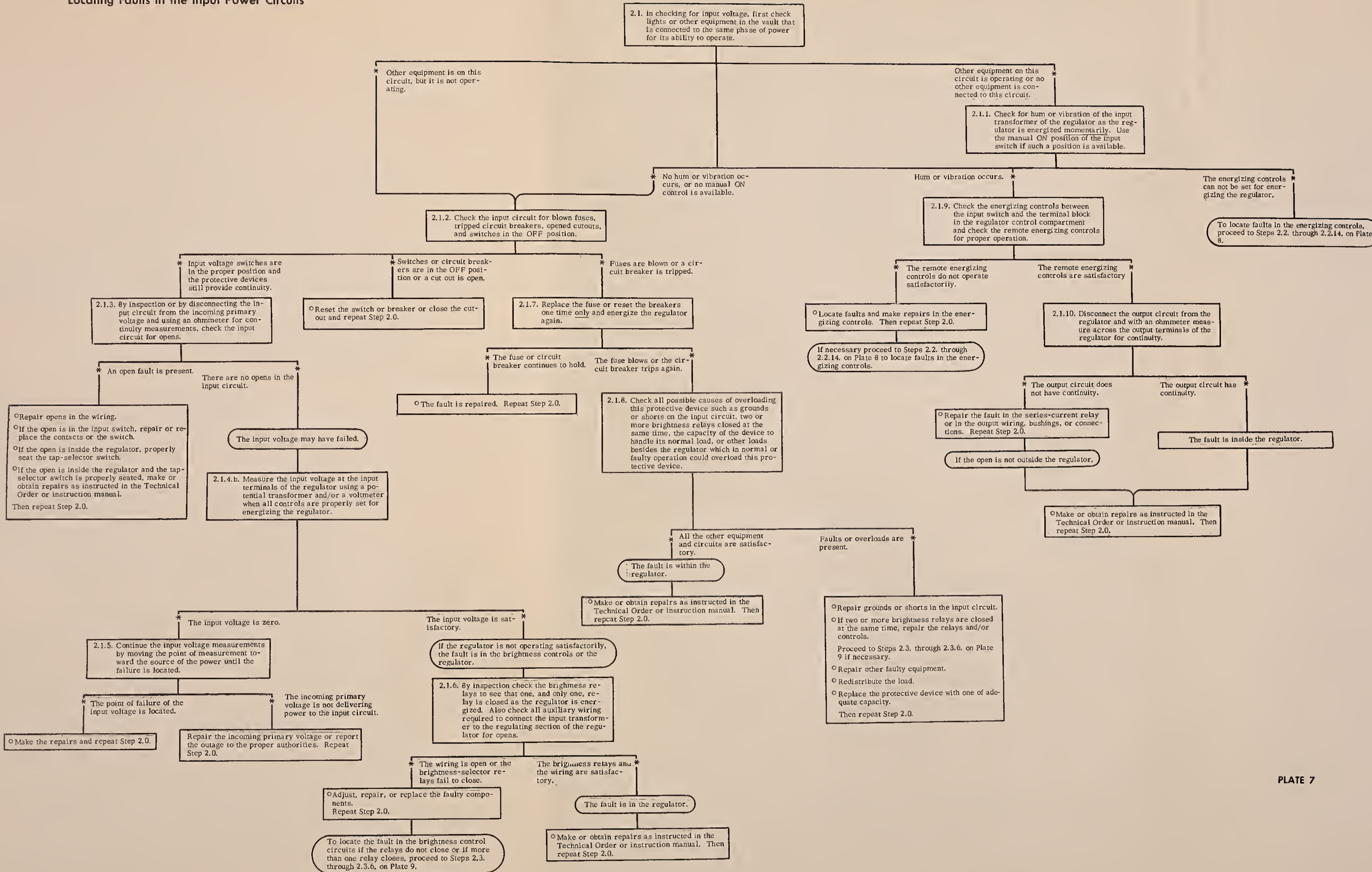


PLATE 7

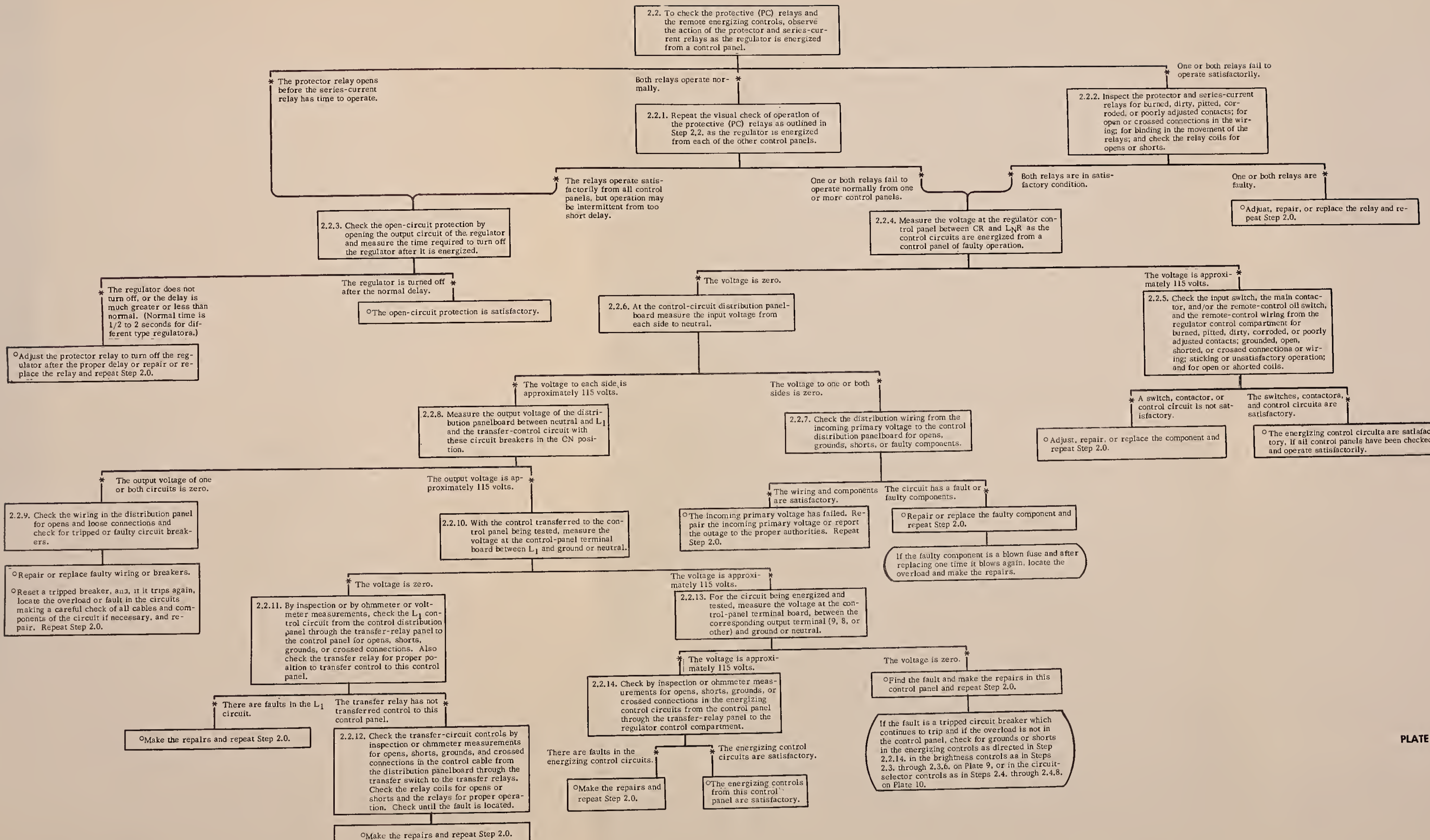

2.2. To check the protective (PC) relays and the remote energizing controls, observe the action of the protector and series-current relays as the regulator is energized from a control panel.
* The protector relay opens before the series-current relay has time to operate.
Both relays operate normally. *
* One or both relays fail to operate satisfactorily.
2.2.1. Repeat the visual check of operation of the protective (PC) relays as outlined in Step 2.2. as the regulator is energized from each of the other control panels.
2.2.2. Inspect the protector and series-current relays for burned, dirty, pitted, corroded, or poorly adjusted contacts; for open or crossed connections in the wiring; for binding in the movement of the relays; and check the relay coils for opens or shorts.
* The relays operate satisfactorily from all control panels, but operation may be intermittent from too short delay.
One or both relays fail to operate normally from one or more control panels. *
* Both relays are in satisfactory condition.
One or both relays are faulty. *
°Adjust, repair, or replace the relay and repeat Step 2.0.
2.2.3. Check the open-circuit protection by opening the output circuit of the regulator and measure the time required to turn off the regulator after it is energized.
2.2.4. Measure the voltage at the regulator control panel between CR and $L_N R$ as the control circuits are energized from a control panel of faulty operation.
* The regulator does not turn off, or the delay is much greater or less than normal. (Normal time is 1/2 to 2 seconds for different type regulators.)
The regulator is turned off after the normal delay. *
°The open-circuit protection is satisfactory.
°Adjust the protector relay to turn off the regulator after the proper delay or repair or replace the relay and repeat Step 2.0.
* The voltage is zero.
The voltage is approximately 115 volts. *
2.2.6. At the control-circuit distribution panelboard measure the input voltage from each side to neutral.
2.2.5. Check the input switch, the main contactor, and/or the remote-control oil switch, and the remote-control wiring from the regulator control compartment for burned, pitted, dirty, corroded, or poorly adjusted contacts; grounded, open, shorted, or crossed connections or wiring; sticking or unsatisfactory operation; and for open or shorted coils.
* The voltage to each side is approximately 115 volts.
The voltage to one or both sides is zero. *
* A switch, contactor, or control circuit is not satisfactory.
The switches, contactors, and control circuits are satisfactory. *
°Adjust, repair, or replace the component and repeat Step 2.0.
°The energizing control circuits are satisfactory, if all control panels have been checked and operate satisfactorily.
2.2.8. Measure the output voltage of the distribution panelboard between neutral and L_1 and the transfer-control circuit with these circuit breakers in the ON position.
2.2.7. Check the distribution wiring from the incoming primary voltage to the control distribution panelboard for opens, grounds, shorts, or faulty components.
* The output voltage of one or both circuits is zero.
The output voltage is approximately 115 volts. *
* The wiring and components are satisfactory.
The circuit has a fault or faulty components. *
°The incoming primary voltage has failed. Repair the incoming primary voltage or report the outage to the proper authorities. Repeat Step 2.0.
°Repair or replace the faulty component and repeat Step 2.0.
If the faulty component is a blown fuse and after replacing one time it blows again, locate the overload and make the repairs.
2.2.9. Check the wiring in the distribution panel for opens and loose connections and check for tripped or faulty circuit breakers.
2.2.10. With the control transferred to the control panel being tested, measure the voltage at the control-panel terminal board between L_1 and ground or neutral.
°Repair or replace faulty wiring or breakers.
°Reset a tripped breaker, and, if it trips again, locate the overload or fault in the circuits making a careful check of all cables and components of the circuit if necessary, and repair. Repeat Step 2.0.
* The voltage is zero.
The voltage is approximately 115 volts. *
2.2.11. By inspection or by ohmmeter or voltmeter measurements, check the L_1 control circuit from the control distribution panel through the transfer-relay panel to the control panel for opens, shorts, grounds, or crossed connections. Also check the transfer relay for proper operation to transfer control to this control panel.
2.2.13. For the circuit being energized and tested, measure the voltage at the control-panel terminal board, between the corresponding output terminal (9, 8, or other) and ground or neutral.
* The voltage is approximately 115 volts.
The voltage is zero. *
°Find the fault and make the repairs in this control panel and repeat Step 2.0.
If the fault is a tripped circuit breaker which continues to trip and if the overload is not in the control panel, check for grounds or shorts in the energizing controls as directed in Step 2.2.14. in the brightness controls as in Steps 2.3. through 2.3.6. on Plate 9, or in the circuit-selector controls as in Steps 2.4. through 2.4.8. on Plate 10.
* There are faults in the L_1 circuit.
The transfer relay has not transferred control to this control panel. *
°Make the repairs and repeat Step 2.0.
2.2.12. Check the transfer-circuit controls by inspection or ohmmeter measurements for opens, shorts, grounds, and crossed connections in the control cable from the distribution panelboard through the transfer switch to the transfer relays. Check the relay coils for opens or shorts and the relays for proper operation. Check until the fault is located.
°Make the repairs and repeat Step 2.0.
2.2.14. Check by inspection or ohmmeter measurements for opens, shorts, grounds, or crossed connections in the energizing control circuits from the control panel through the transfer-relay panel to the regulator control compartment.
There are faults in the energizing control circuits. *
* The energizing control circuits are satisfactory.
°Make the repairs and repeat Step 2.0.
°The energizing controls from this control panel are satisfactory.

PLATE 8

2.3. To check the brightness controls, in the control compartment of the regulator, by inspection check all of the brightness relays: for binding or stuck movements; for opens, shorted, grounded, or crossed connections; for burned, welded, pitted, dirty, corroded, or poorly adjusted contacts, and with an ohmmeter check for open or shorted coils.

* One or more relays are not satisfactory.

°Adjust, repair or replace the relay and repeat Step 2.0.

If the fault is welded, burned, or pitted contacts caused by operation under load or by more than one brightness relay being energized at the same time.

* The relays and wiring are satisfactory.

2.3.1. Keep the regulator disconnected from the input power and with control circuits energized from the control panel being tested, measure simultaneously the voltage at the terminal board in the regulator control compartment between terminals B1, B2, B3, B4, and B5 and L_N as each brightness setting is selected and energized.

* The voltage is zero at all times except that it is approximately 115 volts when the corresponding brightness setting is selected, but the regulator does not operate on one or more settings.

2.3.2. Check the wiring, connections, and bushings in the regulator control compartment for opens, shorts, grounds, or crossed connections and for cracked, loose, or broken bushings for each brightness circuit.

* Faults are present in this wiring.

°Repair and repeat Step 2.0.

* This wiring is satisfactory.

The fault, if any, is within the tank of the regulator.

°Make or obtain repairs as instructed in the Technical Order or instruction manual. Then repeat Step 2.0.

* For one or more terminals the voltage is not approximately 115 volts when selected or is 115 volts when not selected.

2.3.4. Check the brightness selections at the control panel being tested by measuring the voltage simultaneously at the terminal block of this control panel between the brightness terminals B1, B2, B3, B4, and B5 and ground or neutral as each brightness setting is selected.

* The voltage at a terminal is 115 volts, but the corresponding brightness setting is not selected.

°Locate any shorts or crossed connections in the control panel or selector switch. Make the repairs and repeat Step 2.0.

If there are no faults in this wiring in the control panel, the fault is in the control cable

* The voltage is 115 volts as selected, but the timing of the interlock may not be satisfactory.

2.3.5. Check the timing of the interlocks, if any, of the selector switch by measuring the voltage at the brightness terminals as each setting is selected to make certain that the interlock opens before the switch breaks contact of the present setting and remains open until contact at the new setting is completed.

* The voltage and timing are satisfactory for each setting.

2.3.6. Check by inspection or ohmmeter measurements each brightness control circuit for opens, shorts, grounds, or crossed connections from the control panel through the transfer-relay panel to the regulator control compartments.

* There are faults in these brightness control circuits.

°Make the repairs and repeat Step 2.0.

* The brightness control circuits are satisfactory.

°The brightness controls from this panel are satisfactory. If necessary, check the brightness controls from the other control panels.

* The timing is not satisfactory for one or more settings.

°Adjust, repair, or replace the selector switch and repeat Step 2.0.

* The voltage is zero for one or more terminals when the corresponding setting is selected.

°Locate the open in the wiring in the control panel or selector switch. Make the repairs and repeat Step 2.0.

* The voltage at each selected terminal is 115 volts, but when not selected, one or more terminals have appreciable voltage, resulting from induced or leakage voltage; or the contacts of the relays are burned, welded, or pitted.

2.3.3. To check for the presence of or cause of induced or leakage voltage, observe the action of the relays for any tendency to operate from these voltages or simultaneously measure for these voltages on these control circuits during all possible switching or operation of equipment.

* A fixed (not induced or leakage) voltage is impressed on a relay other than the one selected.

A short or crossed connection exists.

* Induced or leakage voltage tends to operate or is indicated for one or more relays.

°Eliminate or reduce the effects of the induced or leakage voltage by:

°Separating the control circuits from high-current-carrying conductors in the same or nearby parallel cables.

°Replacing a circuit with poor insulation with one with adequate insulation.

°Using a shielded cable with a return ground for the control cable.

°Replacing the relay with one of less sensitivity to induced currents.

°Shunting the coil of the relay with a low impedance such as a low-wattage incandescent lamp.

Repeat Step 2.0.

Locating Faults in the Circuit-(Runway-) Selector Control Circuits

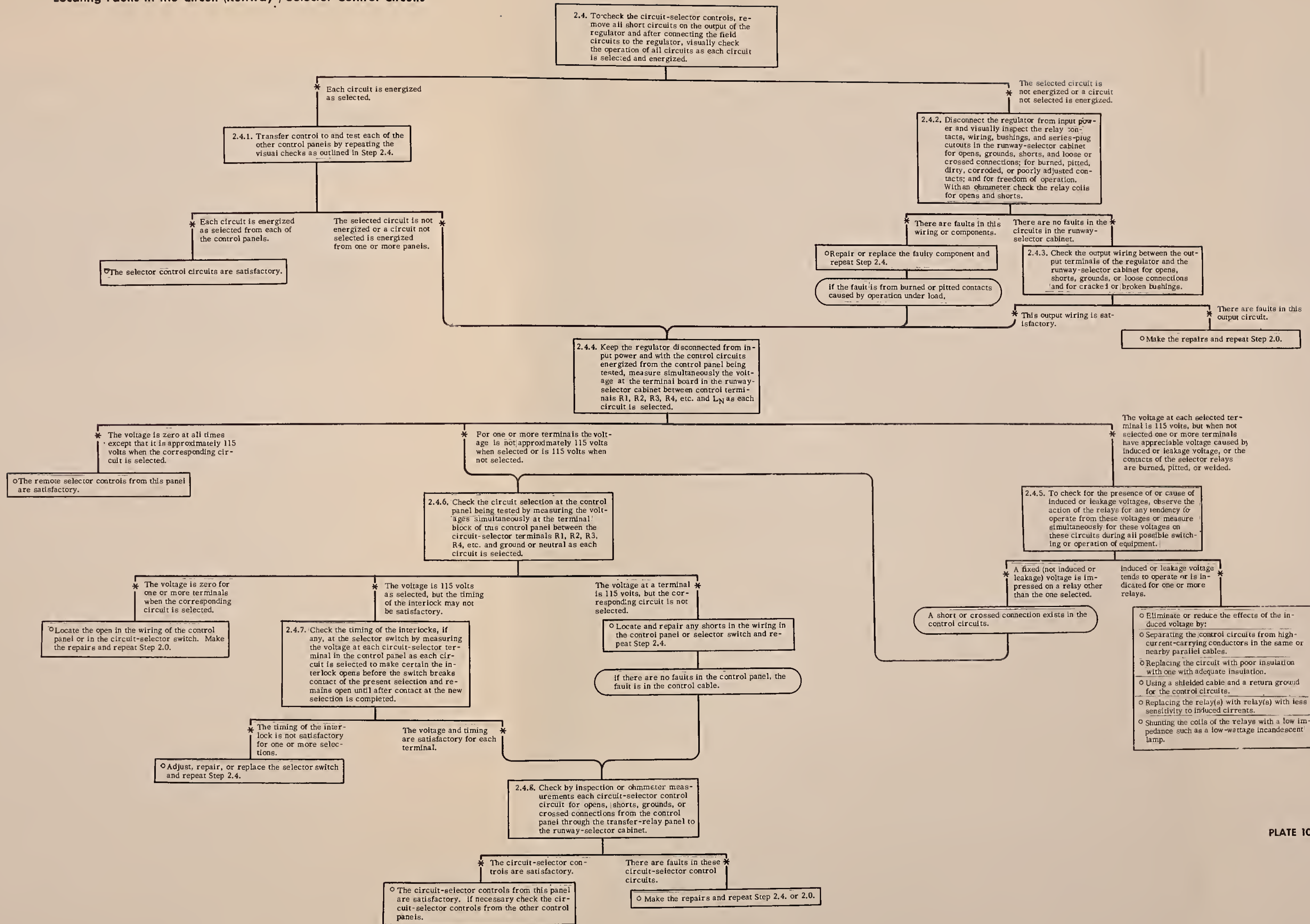


PLATE 10

4.0 BRIEF STEP-BY-STEP TROUBLESHOOTING PROCEDURE

This procedure contains the essential material in outline form of the Detailed Step-by-Step Procedure. Since the minimum of instruction for tests is given, this brief procedure may be satisfactory only for personnel familiar with maintenance procedures and series airfield lighting equipment.

The major steps and tests are indicated by the major divisions. The primary subdivisions indicate the possible results of these tests and the secondary subdivisions indicate the corrective action or direct to the next test to be performed. To avoid confusion or misleading results, carefully make the tests as directed in the procedure starting with Step A and consider each result for the given test before deciding which result is applicable. Three or four major tests should be adequate to locate any fault.

BRIEF STEP-BY-STEP PROCEDURE FOR AIRFIELD LIGHTING SYSTEMS

A. To determine if the fault is in the field or in the vault, measure the output load current from the regulator to the circuit being tested with the intensity on the 100% intensity setting.

1. The current is normal.

   a. To check for grounds or shorts in the field circuit, proceed to Step B.

2. The current is too high, too low, or zero.

   a. To determine if the fault is an open or overload of the field circuits or if it is in the vault, proceed to Step D.

B. To determine what lights are operating, visually check the operation of the circuit while it is energized at a suitable intensity.

1. Some, but not all, of the lights are dim or out.

   a. Replace the burned out lamps or faulty components.

   b. If satisfactory operation is not obtained, locate and repair all grounds or shorts between the satisfactorily and unsatisfactorily operating lights. Use the Cable Test - Detecting set (TSM-11), resistance measurements, or intentional grounds to locate the faults if difficulty is encountered.

2. All of the lights are dim or out.

   a. Replace the burned out lamps or faulty components.

   b. If satisfactory operation is not obtained, proceed to Step C.

3. All of the lights appear to operate satisfactorily, but testing the insulation of the circuit is indicated.

   a. To check for high-resistance grounds or for a single low-resistance ground, proceed to Step C.

C. Measure the insulation resistance of the entire circuit to ground using a limited-current, high-voltage insulation tester (not an impulse-type tester), a megger, or an ohmmeter using a suitable range.

1. Low insulation resistance - less than several megohms - is measured indicating high-resistance grounds or a single low-resistance ground, depending on the value measured.

   a. Locate and repair the ground(s) using the Cable Test - Detecting Set, TSM-11, resistance measurements, or intentional grounds, to locate the fault.

2. The insulation resistance is satisfactory, but all of the lights are out.

   a. If the output load current is normal, locate and repair the ungrounded short in the feeder cables. If difficulty is encountered, use a hook-on ammeter to locate the short.

   b. If the brightness setting is not the same as in Step A, check the output load current at this intensity setting, and if it is zero or very much too low, proceed to Step G.

3. The insulation resistance and the operation of the lights is satisfactory.

   a. This circuit is in good shape.

D. To determine if the fault is in the field or vault when the load current is not normal, short the circuit being tested, preferably at the output terminals of the runway-selector cabinet, and measure the short-circuited output current of the regulator with the brightness on the 100% setting. Short-circuited output current as much as 0.2 ampere greater than the load current is considered normal.

1. The short-circuit current is normal but the load current was zero.

   a. The circuit is open or the regulator is greatly overloaded. Proceed to Step E.

2. The short-circuited current is normal but the load current was too low, indicating that the regulator is overloaded.

   a. Redistribute the load to keep within the rating of the regulator or obtain a regulator with adequate capacity for the circuit.

   b. Locate the overload fault by repairing ground faults, sectionalizing the circuit to locate the overload section, or sectionalize and compute and compare the normal and actual loads and make the repairs.

3. The short-circuited current is normal but the load current was too high, indicating a number of isolating transformers with open secondaries.

   a. Replace the burned out lamps or faulty components.

   b. If possible, remove any series-multiple transformers from the circuit.

4. The short-circuited current is not appreciably different from the load current.

   a. The trouble is in the power source, controls or regulator. Proceed to Step F.

E. To determine if a fault in the field circuits is an open circuit or a serious overload, de-energize the regulator and measure continuity of the field circuit.

1. The circuit does not have continuity or its resistance is several thousand ohms, indicating an open circuit.

   a. Locate the open fault by locating grounds, using intentional grounds, resistance measurements, or using the Cable Test - Detecting Set and make the repairs.

2. The circuit has continuity, indicating an overload which causes the protective devices to turn off the regulator.

a. Locate the overload fault by repairing grounds, sectionalizing the circuit to locate the section with the overload, or sectionalize and compute and compare the normal and actual loads and make the repairs.

F. To test the incoming primary voltage, controls, and regulator, short circuit the output terminals of the runway-selector cabinet and accurately measure the short-circuited output current of the regulator at each intensity setting. (Normal short-circuited current may be as much as 0.2 ampere above rated load current.)

1. The current is zero at all times for all brightness settings.

   a. To determine if the fault is in the runway-selector control circuits or in the incoming primary voltage, energizing controls, or regulator, proceed to Step G.

2. The current is proportionately too high or too low for each brightness setting (making allowances for no-load effect on current) but is not zero, indicating improper regulator adjustment.

   a. Properly set the tap-selector switch for the input voltage when the regulator is energizing a suitable field circuit without faults.

   b. Repair or replace the regulator.

3. The current reads momentarily, then becomes zero, indicating that the regulator is being de-energized by the protective relays.

   a. Adjust, repair, or replace the series-current and protector relays, coils, contacts, dashpots, or connections.

4. The current is normal for one or more settings, but is too high, low, or zero for other settings, indicating faults in the brightness control circuit.

a. Adjust, repair, or replace the brightness control relays, contacts, or connections.

b. Check and repair control voltage, contacts, and wiring for each relay in the regulator control panel.

c. Check and repair the control voltages, selector switches, wiring, and connections in the lighting control panel.

d. Check and repair the control cables and connections and the transfer relay panel for opens, shorts, grounds, or crossed connections.

e. Check for and eliminate troublesome induced voltages.

f. Repair the faults in the regulator tank.

5. The current is normal at all times for all brightness settings.

a. To check operation from other control panels, proceed to Step H.

G. To determine if the fault is in the circuit-selector controls or incoming primary voltage, regulator, or other controls, move the short circuit to the output terminals of the regulator and repeat the short-circuited current measurements of Step F for all brightness settings.

1. The current is still zero at all times for all brightness settings, indicating either no input voltage to the regulator, or a faulty regulator.

a. Replace the fuses in the cutouts and check as the circuit is re-energized. Locate and repair the faulty equipment if failure again occurs.

b. Properly set all circuit breakers and selector switches.

c. Check the energizing circuit (L_1 and CR) and repair switches, relays, connections, and cables as required.

d. Check the remote-controlled oil switch coils, contacts, operation, and control wiring, making repairs as required.

e. Locate the fault in the incoming primary voltage to the vault and repair.

f. Properly seat the tap-selector switch or repair the regulator.

g. Check the transfer relays, switch, and transfer control circuit and repair as required, or proceed to Step H.

2. Current is now present at least momentarily for one or more brightness settings, indicating the previous result in Step F was from faulty circuit-selector controls.

a. To check the circuit-selector controls, proceed to Step I.

H. To test operation from other control panels, transfer the controls and repeat the tests of Step F for each control panel.

1. The short-circuited output current on one or more intensity settings is appreciably different from two or more control panels, indicating a fault in the transfer controls or in the controlling components or circuits for the control panel with the faulty operation.

a. Locate the faults in the transfer relays, switch, connections or contacts, or cables, and repair as required.

b. Locate the faults in the control circuits indicating the faulty operation, and repair as required.

2. The faulty operation is the same from all control panels, indicating a fault in the regulator control compartment, transfer relays, control circuits common to the control panels, or regulator.

a. The fault is in the control circuits or regulator and the results of Steps F and G should indicate the location of the fault.

3. The short-circuited current is normal for all intensity settings from all control panels.

a. To determine if intermittent operation may be occurring, proceed to Step J.

I. To determine if the circuit-selector controls are operating satisfactorily, remove the short circuits from all circuits connected to the regulator and with the field circuits connected, check operation of all circuits by measuring the regulator output current as each circuit is selected from each control panel.

1. Output current is present on some circuits from all control panels but is not present on other circuits, indicating a fault in the runway-selector cabinet or control circuits common to the control panels.

a. Locate the faults in the runway-selector relays, cutouts, contacts, controls, or circuits, and repair as required.

b. Locate and repair the faults in the unsatisfactory field circuits, proceeding as in Step A.

2. Output current on the same circuits is present from some but is not present from other control panels, indicating faults in the control circuit from the panel with unsatisfactory operation.

a. Locate the faults in the transfer relays, controls, or control circuits and repair as required.

b. Check and satisfactorily eliminate any troublesome induced voltages.

3. Output current is present and satisfactory for all circuits from all control panels.

a. The control circuits are satisfactory at present but to check for intermittent operation or potential faults, proceed to Step J.

J. Inspect all contacts, connections, and components for arcing, dirt, corrosion, or failures which may cause intermittent or deteriorating performance.

1. Faults or faulty equipment are located.

   a. Repair as required.

2. No faults or faulty equipment are present.

   a. This circuit and equipment should operate satisfactorily.

5.0 TROUBLESHOOTING BY SYMPTOMS

Troubleshooting by symptoms is an efficient and desirable method of locating faults, but the effectiveness of this method depends upon the ability and experience of the maintenance personnel. For some types of faults the symptoms may indicate the location of the fault immediately, but for other faults in a system as complicated as airfield lighting, considerable step-by-step testing may be required to isolate and locate the fault. If the symptoms create confusion or the faults can not be adequately located by using the symptoms method, a step-by-step procedure should be used.

The symptoms method as given in this report not only covers the symptoms which locate the more easily located faults, but also includes briefly the tests and steps required to isolate to the circuits the faults most likely to occur. To locate the fault after isolating it to the circuit, use general maintenance methods. The symptoms given here do not cover all possible faults, but the more probable faults are included.

The basic symptom is given in the heading and the probable faults producing this symptom are listed under this heading. Consider all of the probable causes listed when locating the fault. When the basic symptom is not adequate for identifying the probable cause of the trouble, certain other tests or measurements are given to provide the additional information needed to determine the trouble. Some faults, or causes of troubles, e.g., grounds or opens in field circuits, that may require appreciable effort to locate are treated in Section 5.2, "Checks." Suitable checks and methods of locating the fault closely enough for repair are then indicated. Since it is impractical to prepare a method of troubleshooting by symptoms which includes all possible faults, use step-by-step procedures whenever necessary.

5.1 SYMPTOMS

A. SOME OF THE LIGHTS ON A CIRCUIT ARE DIM OR OUT.

1. Water in bases of lights of a straight series circuit.

2. Two or more grounds in the cable between the lights that operate properly.

3. Lamps or film cutouts burned out, or defective isolating transformers.

4. Wrong wattage lamps or isolating transformers.

B. ALL LIGHTS OPERATE FROM ONE CONTROL PANEL BUT SOME CIRCUITS OR ALL LIGHTS FAIL TO OPERATE FROM OTHER CONTROL PANELS.

1. Faulty switch or contacts in the control cabinet that fail to operate the lights.

2. Contacts or connections in transfer relay improperly adjusted or loose.

3. Cable to inoperative control cabinet open or grounded.

C. ALL OF THE LIGHTS ON ONE CIRCUIT ARE DIM.

1. Feeder cables have two or more grounds.

2. Regulator overloaded.

   a. If a new installation:

      Too many lights on the circuit.
      Wrong wattage lamps.
      Wrong type isolating transformers.

   b. If an old installation:

      New lights added to the circuit causing overload.
      Wrong wattage lamps.

3. Low input primary voltage to the regulator.

    a. Improperly set tap-selector switch.

    b. Incoming power failure.

    c. Brightness selector controls faulty.

D. ALL OF THE LIGHTS ON ONE CIRCUIT ARE OUT.

1. If lights on other circuits from the same regulator will not operate, the fault is either in the regulator or control circuits.

2. If other circuits from the same regulator operate normally, the fault is either:

    a. Grounded or shorted feeder cables.

    b. Open circuit in the feeder cables, field circuit cables, or primary winding of isolating transformers.

    c. Lamps burned out.

    d. The runway-selector controls for this circuit are faulty.

3. If this is the only circuit on the regulator, disconnect the field circuit and place a jumper across the terminals and measure the output current.

    a. If the current is normal for the brightness setting selected, the fault is in the field circuit -- grounds or shorts, opens, or burned out lamps.

    b. If the current is not normal for the brightness setting selected, the fault is in the regulator or the control circuits.

5.2 CHECKS

A. TO DETERMINE IF THE FAULT (ALL LIGHTS ON ONE CIRCUIT ARE OUT) IS IN THE FIELD OR IN THE VAULT AND/OR CONTROL CIRCUITS:

1. Disconnect the field circuit feeder cables from the runway-selector cabinet, or regulator, if no selector cabinet is used, short circuit the output terminals with a suitable jumper, and measure the output current.

   a. If the current is normal for the brightness selected, the fault is in the field circuit.

   b. If the current is not normal for the brightness selected, the fault is in the regulator or controls.

B. TO DETERMINE THE APPROXIMATE LOCATION OF A GROUND IN A FIELD CIRCUIT CABLE:

1. With all of the lamps in the circuit in operating condition, remove any intentional grounds on the circuit and connect a suitable grounding jumper from one leg of the field feeder cable to ground at the runway-selector cabinet, or at the regulator if no selector cabinet is used. Measure the output current of the regulator through the jumper with the circuit turned on at brightness setting B5.

   a. If NO CURRENT is measured in the grounding jumper and output current from the regulator is present, the circuit is usable.

   b. If the CURRENT IN THE JUMPER is approximately the same as for setting B5, the circuit is grounded. The approximate location of the fault can be determined by visually checking the lights in the field while the circuit is turned on and the grounding jumper is still connected.

   If NONE OF THE LIGHTS ARE OUT OR DIM, the fault is in the feeder cable that has the grounding jumper connected to it.

If ALL OF THE LIGHTS ARE OUT, the fault is in the feeder cable that does not have the grounding jumper connected to it.

If SOME OF THE LIGHTS ARE OUT, the fault is between the last light that operates normally and the first light that is out.

If SOME OF THE LIGHTS OPERATE NORMALLY, SOME ARE DIM, AND SOME ARE OUT, there are several partial grounds between the light that operates normally and the first light that is out.

C. TO DETERMINE THE APPROXIMATE LOCATION OF AN OPEN CIRCUIT FAULT IN A FIELD CIRCUIT:

1. With all lamps in the circuit in operating condition, connect a suitable grounding jumper from one leg of the field circuit feeder cable to ground at the runway-selector cabinet, or at the regulator if no selector cabinet is used. At some convenient location near the midpoint of the circuit, connect the circuit cable to a GOOD GROUND and turn on the circuit.

   a. IF NO LIGHTS OPERATE, the open fault is not between the two grounds. Move the grounding jumper in the vault to the other feeder cable. If the lights still do not operate, there are two open faults in the field circuit.

   b. IF HALF OF THE LIGHTS OPERATE with the grounding jumper placed on one of the feeder cables in the vault, the open fault is not in the section of lights that now operate. Move the field grounding jumper to another point in the section of the circuit where the lights do not operate and repeat the test until a point is reached where none of the lights operate. The open fault will be between the point at which the lights operate and the point at which they do not operate. If the field grounding jumper has been moved to the field end of the grounded feeder cable and all of the lights still operate, the open fault is in this feeder cable.

D. REGULATOR AND CONTROL CIRCUIT CHECK:

1. Disconnect all of the feeder cables from the output terminals of the runway-selector cabinet, or from the load side of the protective relay if no selector cabinet is used, and then turn on the circuit from a control panel. Do not disconnect by pulling the series plug cutouts.

   a. The protective relay should operate immediately (in a few seconds) and open the primary input voltage switch.

      If the regulator DOES NOT turn off immediately (in a few seconds), turn it off with the control panel switch. The protective relay is faulty.

      If the regulator is turned off immediately by the protective relay, the protective relays are operating satisfactorily.

2. Short circuit the output terminals of the runway-selector cabinet, or of the regulator if no selector cabinet is used, and with the regulator turned on, measure the output current for each brightness setting.

   a. If the currents are approximately the same as the values shown on the nameplate for each brightness setting, the regulator is operating normally.

   b. If the current reading is the same for two or more brightness settings or the readings are not in order, a cross-connection exists in the control cables, control cabinet, or transfer relay.

   c. If there is no current for one or more brightness settings and the brightness control relays appear to operate normally, there is a fault in the regulator or there are bad contacts on the brightness control relays.

d. If no current is read on one or more brightness settings and the brightness control relays are not operating correctly, there is a fault in the control cable, control cabinet, or transfer relay.

e. If the current is more than 5% above or below the values shown on the regulator nameplate, reconnect all circuits and check the output current again, and if it is still too high or too low, adjust the tap-selector switch in the regulator for an output current nearest 6.6 (or 20) amperes with the control panel selector switch set on brightness setting B5.

f. If the current is zero for all brightness settings, the incoming primary voltage, the regulator, or the controls have failed.

E. SETTING THE REGULATOR TAP-SELECTOR SWITCH:

1. With all lamps on all circuits in operating condition, and no grounds or open faults on any circuit, connect an accurate ammeter to the instrument current transformer output terminals, or if no instrument transformer is in the regulator, connect a suitable transformer and/or accurate ammeter into one of the regulator output cables and measure the output current into each circuit at all brightness settings.

a. Select the most used runway if all of the runway lights on the field are the same type or select the runway with the most high-intensity lights if different types are used, and set the tap-selector switch so that with the brightness-selector switch set on B5 the output current is as nearly 6.6 (or 20) amperes as possible. One or two tenths of an ampere below 6.6 (or20) amperes is preferred rather than above. This does slightly reduce the lamp intensity on brightness B5, but the overcurrent can reduce the lamp life on step B5 significantly.

b. If unable to raise the current to 6.6 (or 20) amperes with the tap-selector switch, check input voltage to the regulator to see if it is within the limits of the tap-selector switch. If so, check by calculations or by current and voltage readings of the output to determine if an overload exists. If no overload exists and the input voltage is within the range of the tap-selector switch, there is a fault in the regulator.

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

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

THE NATIONAL BUREAU OF STANDARDS

The scope of activities of the National Bureau of Standards at its headquarters in Washington, D. C., and its major field laboratories in Boulder, Colorado, is suggested in the following listing of the divisions and sections engaged in technical work. In general, each section carries out specialized research, development, and engineering in the field indicated by its title. A brief description of the activities, and of the resultant reports and publications, appears on the inside front cover of this report.

WASHINGTON, D. C.

Electricity and Electronics. Resistance and Reactance. Electron Tubes. Electrical Instruments. Magnetic Measurements. Dielectrics. Engineering Electronics. Electronic Instrumentation. Electrochemistry.

Optics and Metrology. Photometry and Colorimetry. Optical Instruments. Photographic Technology. Length. Engineering Metrology.

Heat and Power. Temperature Physics. Thermodynamics. Cryogenic Physics. Rheology and Lubrication. Engine Fuels.

Atomic and Radiation Physics. Spectroscopy. Radiometry. Mass Spectrometry. Solid State Physics. Electron Physics. Atomic Physics. Nuclear Physics. Radioactivity. X-rays. Betatron. Nucleonic Instrumentation. Radiological Equipment. AEC Radiation Instruments.

Chemistry. Organic Coatings. Surface Chemistry. Organic Chemistry. Analytical Chemistry. Inorganic Chemistry. Electrodeposition. Gas Chemistry. Physical Chemistry. Thermochemistry. Spectrochemistry. Pure Substances.

Mechanics. Sound. Mechanical Instruments. Fluid Mechanics. Engineering Mechanics. Mass and Scale. Capacity, Density, and Fluid Meters. Combustion Controls.

Organic and Fibrous Materials. Rubber. Textiles. Paper. Leather. Testing and Specifications. Polymer Structure. Organic Plastics. Dental Research.

Metallurgy. Thermal Metallurgy. Chemical Metallurgy. Mechanical Metallurgy. Corrosion. Metal Physics.

Mineral Products. Engineering Ceramics. Glass. Refractories. Enameled Metals. Concreting Materials. Constitution and Microstructure.

Building Technology. Structural Engineering. Fire Protection. Heating and Air Conditioning. Floor, Roof, and Wall Coverings. Codes and Specifications.

Applied Mathematics. Numerical Analysis. Computation. Statistical Engineering. Mathematical Physics.

Data Processing Systems. SEAC Engineering Group. Components and Techniques. Digital Circuitry. Digital Systems. Analogue Systems. Application Engineering.

- Office of Basic Instrumentation
- Office of Weights and Measures

BOULDER, COLORADO

Cryogenic Engineering. Cryogenic Equipment. Cryogenic Processes. Properties of Materials. Gas Liquefaction.

Radio Propagation Physics. Upper Atmosphere Research. Ionospheric Research. Regular Propagation Services. Sun-Earth Relationships.

Radio Propagation Engineering. Data Reduction Instrumentation. Modulation Systems. Navigation Systems. Radio Noise. Tropospheric Measurements. Tropospheric Analysis. Radio Systems Application Engineering.

Radio Standards. Radio Frequencies. Microwave Frequencies. High Frequency Electrical Standards. Radio Broadcast Service. High Frequency Impedance Standards. Calibration Center. Microwave Physics. Microwave Circuit Standards.

NBS