

# **MISCELLANEOUS ELECTRICAL VOLUMES I**

## **FIST VOLUMES 3-11 THROUGH 3-15**

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Facilities Engineering Branch  
Denver Office**

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May Differ From the Original, but the Contents Do Not*

**UNITED STATES DEPARTMENT OF THE INTERIOR**

**BUREAU OF RECLAMATION**

## MISCELLANEOUS ELECTRICAL VOLUMES I

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**FACILITIES INSTRUCTIONS, STANDARDS,  
& TECHNIQUES**

**Volume 3-11**

**GENERATOR THRUST BEARING  
INSULATION AND OIL FILM  
RESISTANCE**

## Generator Thrust-bearing Insulation and Oil Film Resistance

The thrust and upper-guide bearings of large vertical generators are insulated from the frame to prevent circulating current from passing through the bearing surfaces which might damage them. Test terminals are provided for periodic ohmmeter checks across the thrust bearing insulation. Some generators have three terminals A, B, and G (fig. 1), which permit checking the insulation on both sides of the metal plate separately, as well as measuring the thrust bearing oil film resistance. Other generators have only the terminal A, which only permits checking the thrust-bearing insulation to ground.

This bearing insulation test should be performed annually on all Reclamation generators. If the insulation resistance is abnormally low, the cause of the trouble should be investigated. Before concluding that the insulating sheets under the bearing supports are causing the low resistance, check the RTD leads, temperature device tube, or high pressure oil connection to the bearing shoes. On machines with a B terminal it is possible to determine when the bearing shoes are grounded through these accessories by measuring the resistance between terminals B and G with the machine running (provided there is a high oil film resistance, and the bearing support insulation is good). The insulation on both sides of the metal plate can be checked separately by connecting the ohmmeter between terminals A and G, and between A and B. The thrust-bearing insulation resistance should measure from about 10,000 ohms to infinity. Low resistance can indicate mechanical damage or damp insulation from leaky cooling coils. Dampness in the oil pot, due perhaps to a very slow cooling-coil leak, can cause serious corrosion damage or saturation of insulation, if allowed to persist. These problems are difficult to detect except by this test.

An additional test may be periodically made on the thrust-bearing oil-film resistance while the generator is running, and with the ohmmeter connected across terminals B and G. Although not entirely reliable, this test has indicated metal-to-metal contact where the bearing was slightly wiped, or a high spot had developed.

When there is very high resistance with the machine running, it is a good indication that the bearing surfaces are free of high spots or roughness, and the bearing is not grounded. This test can also be used when establishing an oil film with a high pressure lubrication system or to determine how quickly a complete oil film is established on starting a unit, or how long it persists on stopping.

The insulation resistance between the bearing shoes and the frame should be checked first, before the oil film resistance is checked; because, since these resistances are in parallel, a false impression of oil film resistance could be obtained if the bearing insulation resistance is relatively low. When the generator is stationary, the oil having been squeezed from between the bearing surfaces allows metal-to-metal contact, and zero resistance between terminals B and G. When operating at normal speed the oil film resistance should be from 100,000 to 500,000 ohms.

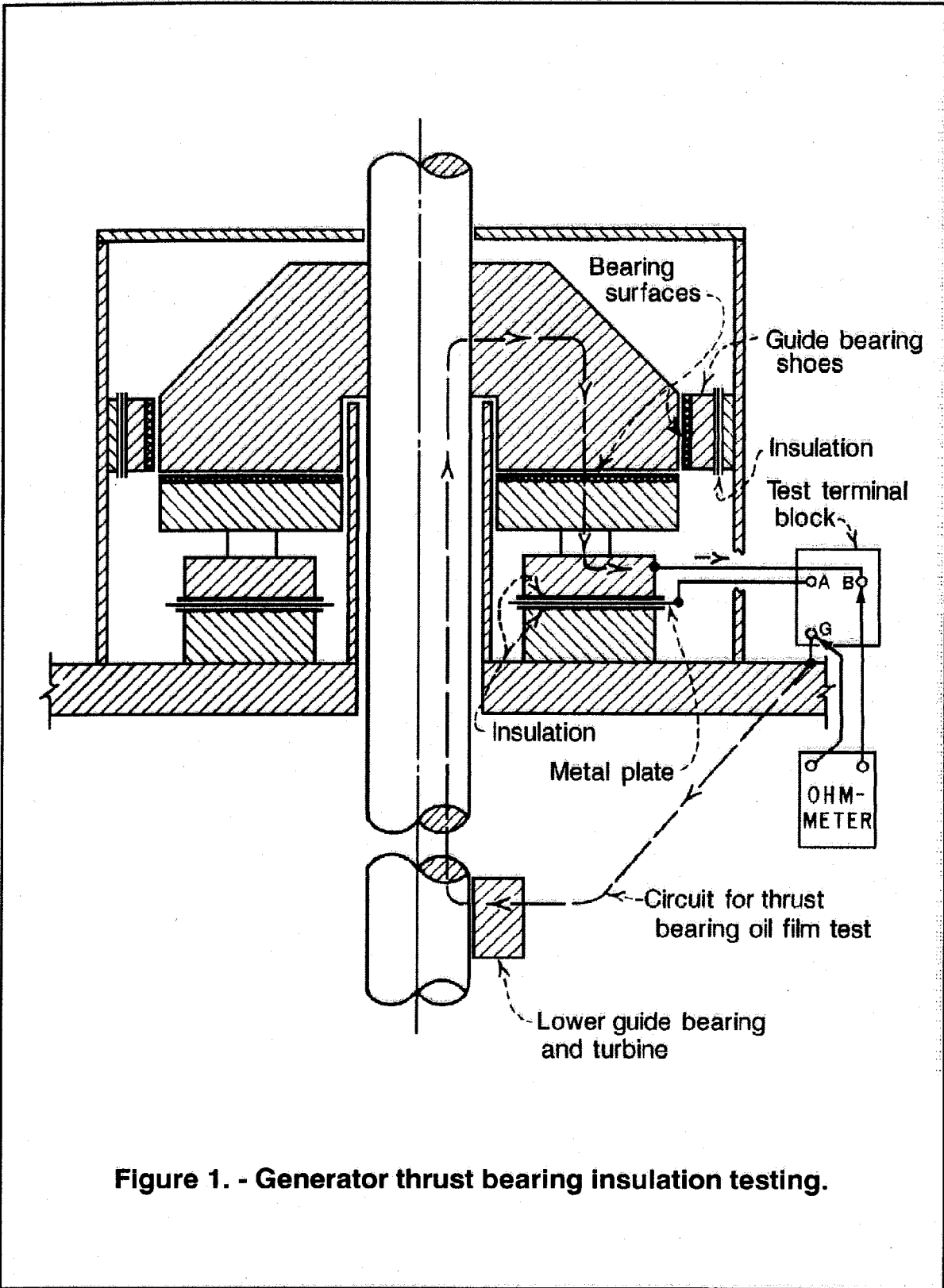
Measurements of oil film or bearing insulation resistance should be made using an ohmmeter operated from batteries of not more than 9 V d-c, and connected only long enough to take the reading. Under no circumstances should an a-c or d-c power circuit be connected to the test terminals, because damage could occur to bearing surfaces if high current should pass through them. As an added precaution, generators provided with the B terminal connected to the bearing shoes, should have a red nameplate mounted adjacent to the terminals with the following inscription:

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### WARNING

Do not connect any source of power over 9 V d-c to these terminals. To check resistance, use an ohmmeter operated from d-c batteries of not over 9 V, and connect only long enough to take the reading.

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**Figure 1. - Generator thrust bearing insulation testing.**

**FACILITIES INSTRUCTIONS, STANDARDS,  
& TECHNIQUES**

**Volume 3-12**

**CORRECTING THE RATIO AND PHASE  
ANGLE CHARACTERISTICS OF  
BUSHING CURRENT TRANSFORMERS**

# CORRECTING THE RATIO AND PHASE ANGLE CHARACTERISTICS OF BUSHING CURRENT TRANSFORMERS

Fairly accurate current, watt, or var readings or recordings from a circuit where the only current transformers available are of the bushing type, may be obtained by the addition of ratio and phase-angle compensators. Several Reclamation facilities have these compensators installed, and operators find them satisfactory and that they give good results at a moderate cost. The ratio and phase angle compensator (fig. 1) consists of one each of the following components for each phase, A, B and C:

- T2 - current balancing autotransformer, Westinghouse1 Style 608A938G01
- T3 - auxiliary autotransformer rated 5 V\*A capacity 1.5/9.0/24 V (special design by Standard Transformer Company)<sup>2</sup>
- Thyrite disk - GE3 No. 3952481
- Capacitor - 100 V or larger; 1/2, 1, or 2FF as needed (any manufacturer)

The compensators are not available complete from any single manufacturer, but can be readily assembled. The thyrite disk, the capacitor, and T3 can be mounted to the side of T2,

and makes a compact assembly complete with terminals for all external connections. The current-balancing autotransformer is used to increase the bushing current transformer secondary current slightly higher than the correct value. The thyrite shunt then drains off this excess current in a nonlinear relationship, to bring the resultant current to the correct value. Capacitors may be used as necessary to correct the phase angle.

The ratio error of a standard multi-ratio bushing-type current transformer may be from approximately 5 to 20 percent and the phase angle error may be up to approximately 5 degrees, depending on the secondary current and burden. Except as described, the use of this compensator will correct the ratio error to within 1 percent, and the phase angle error to within 1 degree. This makes the bushing current transformers suitable for operating the recording wattmeters or varmeters. The range of this correction is only from 1 to 5 A and is not to be used to correct relay currents at high values of fault current and is not recommended for use with revenue watt-hour meters. An example of the results obtained on a 150-V, 5-A, 69-kV bushing current transformer with and without the compensator is shown (fig. 2). The compensators must be adjusted for the burden and bushing current transformer characteristics that exist on each installation.

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<sup>1</sup>Westinghouse Electric Corporation, P. O. Box 4239, Grand Central Station, New York, N.Y. 10164

<sup>2</sup>Standard Transformer Company, 212 Dana Street, NE, Warren, Ohio 44481

<sup>3</sup>General Electric Company, 1635 Broadway, Bldg. 18-5, Fort Wayne, Ind. 46804

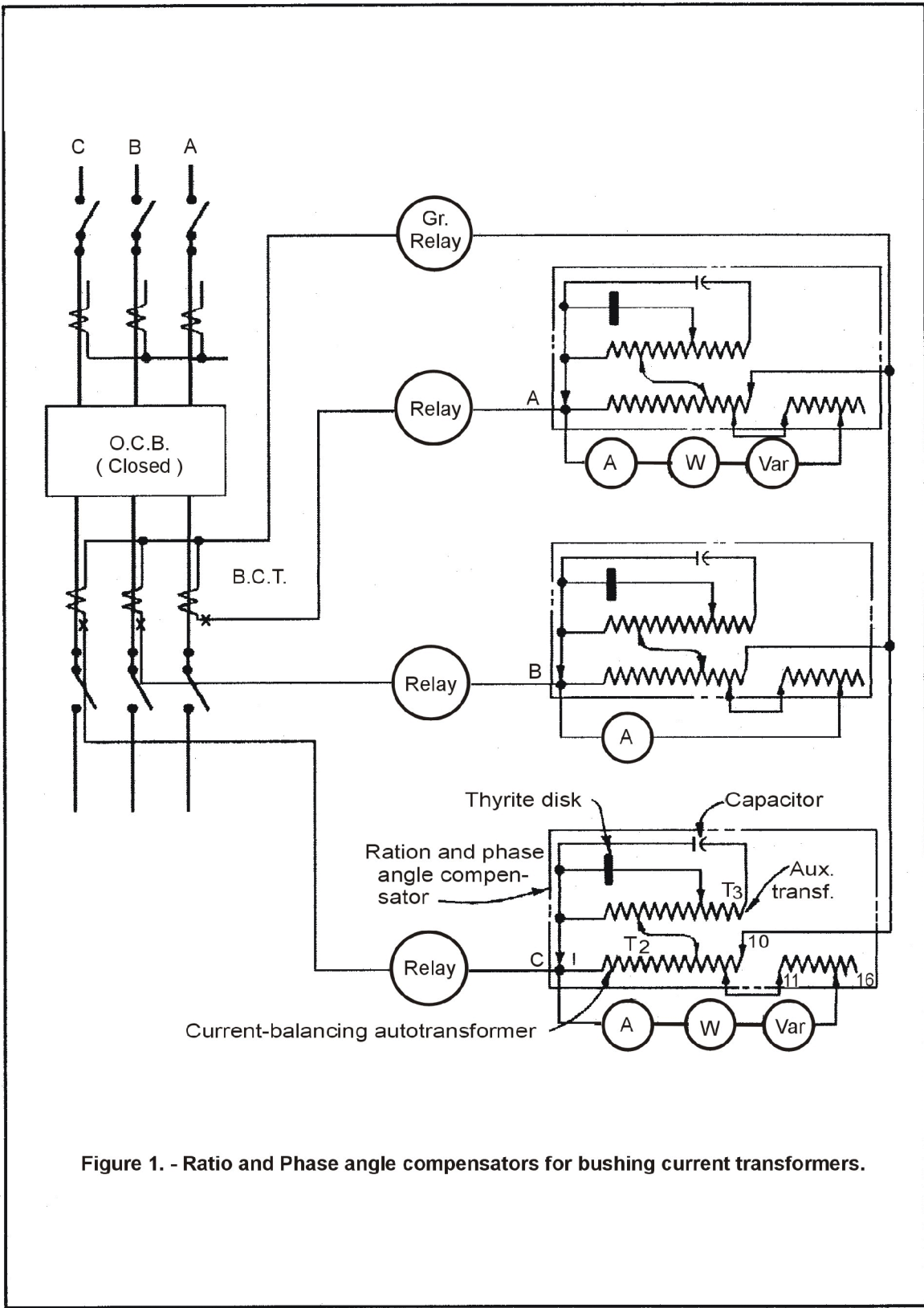
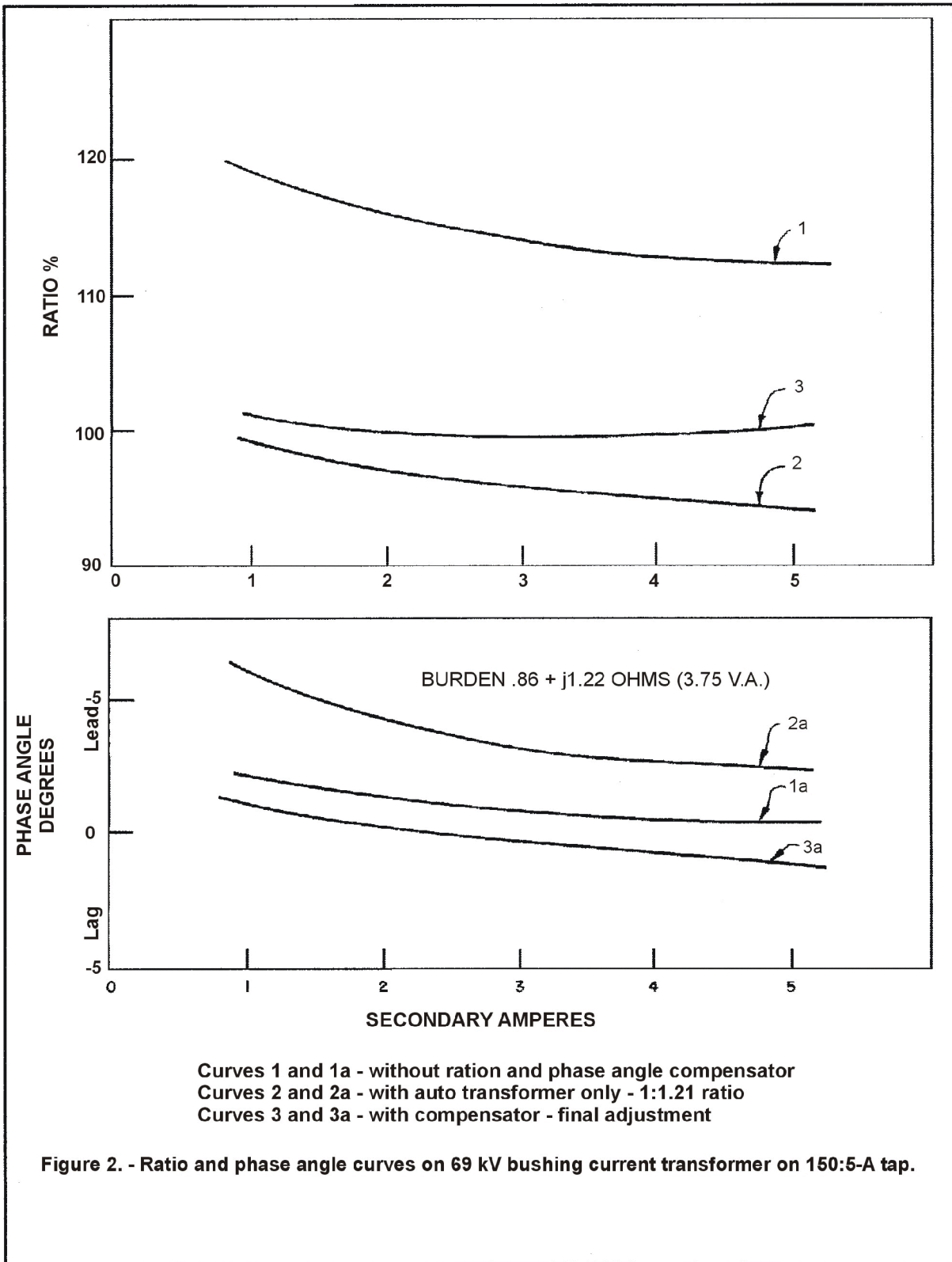


Figure 1. - Ratio and Phase angle compensators for bushing current transformers.





**FACILITIES INSTRUCTIONS, STANDARDS,  
& TECHNIQUES**

**Volume 3-13**

**AN ELECTRICAL METHOD OF MOVING  
A GENERATOR ROTOR**

# An Electrical Method of Moving an Generator Rotor

It is sometimes desirable to rotate a large generator rotor a small amount to accomplish several maintenance tasks such as the four-wire rotation check during unit alignment, matching up couplings, working on particular turbine runner. It is extremely difficult to move a rotor physically, especially vertical machines not equipped with high pressure thrust-bearing lubrication. This method uses the electrical characteristics of the generator operated as a motor, which can be accomplished by using external excitation current (fig. 1 and 2). This excitation current can be provided from a spare exciter set, or any source of direct current other than the directly connected exciter of the machine itself. An ordinary d-c welder should be sufficient to move the rotor of medium size generators as only one sixth of the normal field current of the generator will usually be necessary.

**THE ROTOR MUST BE RESTRAINED HORIZONTALLY TO PREVENT IT FROM BEING PULLED INTO THE STATOR IRON AS CURRENT IS APPLIED. ADEQUATE THRUST BEARING LUBRICATION MUST BE PROVIDED AT ALL TIMES DURING ROTATION.**

If the unit cannot be raised with jacks to provide lubrication, the thrust bearings should be coated with a mixture of petroleum jelly and lubricating oil. If the work continues for several days, applications may have to be repeated. If there is a field contactor with discharge resistor available, connections should be made as shown (fig. 1 and 2). If not, the spare exciter set, or d-c welder field contactor may be used to deenergize the circuit. In some cases the welder must be stopped to safely deenergize the circuit.

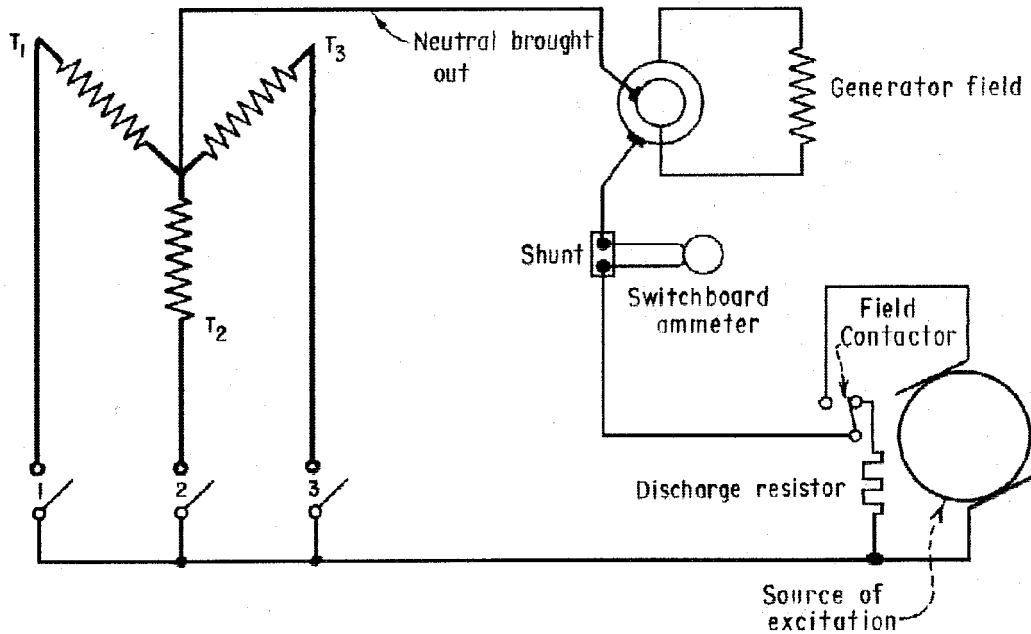
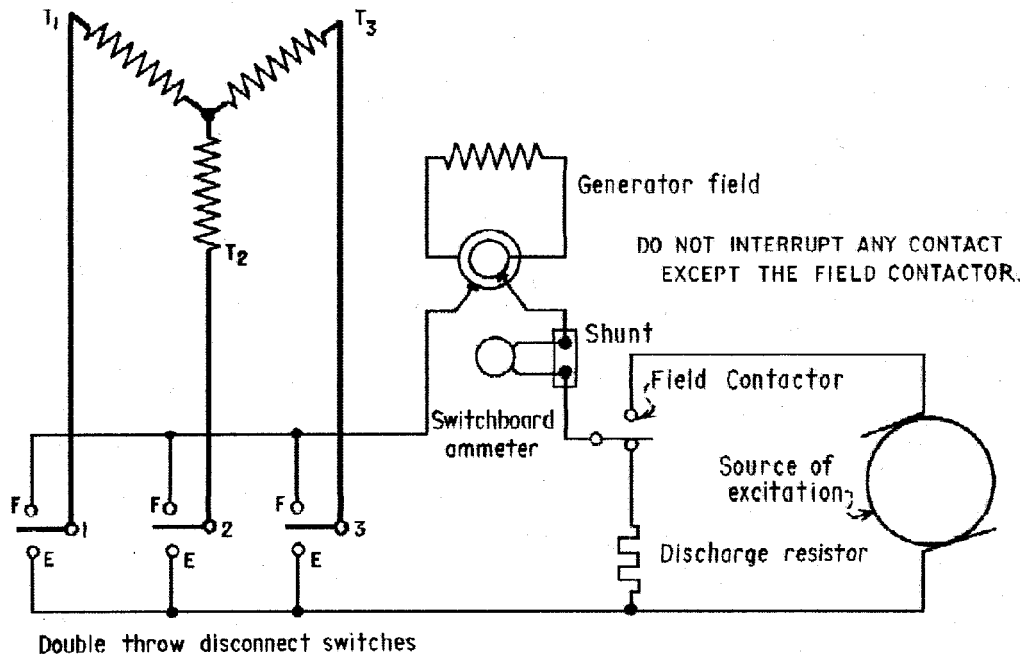


Figure 1 - External excitation current source connected to generator with neutral brought out.



**Figure 2 - External excitation current source connected to generator with double throw disconnect switches.**

A generator designed with the neutral brought out (fig. 1), provides the easiest connecting arrangement; however, it does not allow the full torque available when connections are made directly to the terminals (fig. 2). When the neutral is available (fig. 1), leads are extended from the terminals T1, T2, and T3 to the disconnecting switches. The other switch terminals are connected together, and extended to the other side of the source of excitation. If the inductance of the stator winding is not too great, it is possible to rotate the rotor to the required position 60 electrical degrees at a time, by operating the disconnecting switches alone, without at any time opening the field contactor, then close phase 2, open phase 1, close phase 3, open phase 2, close phase 1, open phase 3, and continue until the rotor moves around to the proper location. The circuit is then completely deenergized by means of the field contactor.

**DO NOT INTERRUPT THE FIELD WITH ANY CONTACT EXCEPT THE FIELD CONTACTOR**

This method enables positioning the rotor to within plus or minus 30 electrical degrees of its required position. This is usually close enough,

but if not, a movement of 30 electrical degrees in either direction may be obtained by shifting the field cable from the neutral to one or the other of the phases which is not closed through the disconnecting switches. Thus, if phase 3 is closed shifting the field cable from the neutral to T1 or T2 will produce the smaller final movement. By following this procedure, the field circuit is not opened and it is usually possible to operate the disconnecting switches without particularly bad sparking if it is done slowly. If the arcing starts to damage the disconnecting switches, use the field contactor or otherwise deenergize the d-c source. Connections can be made consecutively to phases 1, 2, and 3, closing and opening the rotor around 120 electrical degrees at a time. In the older installations, this method may not involve any special switches. It is sometimes possible to open the generator breaker and the generator.

If the generator neutral is not available, or the ampere turns in one leg of the stator winding are not sufficient to pull the rotor around, another method (fig. 7b) can be used. However, this method requires double-throw disconnect switches, which may not be as readily available as the single throw disconnect switches. This connection permits

rotation of the rotor, 30 electrical degrees at a time by operating the switches without opening the field circuit. Starting with 1-F, close 1-E, open 3-E, close 3-F, open 2-F, close 2-E, open 1-E, close 1-F, open 3-F, and continue this sequence until the rotor is at the required location, and then open the field contactor. If this operation causes too much arcing at the switches, an alternate switching sequence can be used which is similar to the previous system: Throw the disconnect switches consecutively to positions 1-E, 2-F, 2-E, 3-F, 3-E, and 1-F, while closing and interrupting the circuit through the field contactor. With this method it is possible to come within plus or minus 15-electrical degrees. The last few degrees may have to be obtained physically with a hydraulic jack, or block and tackle. Some generator circuit breakers are the draw-out type where no disconnecting switches are provided. At this type of installation, connections have been made by making up plug terminals to the welding cables to fit the generator terminal sockets in the switchgear. (When this is done a barrier is recommended to cover the bus-side sockets in the circuit breaker

cubicle.) Switching among the phases is then done by moving the plugs and deenergizing the d-c source each time.

Rotors as large as 300-ton for a 50,000-kW generator have been rotated within an hour with two men, which had required 6 men about 12 hours to rotate mechanically. Because the static friction of the bearings is much greater than the running friction, it is possible to advance the rotor several pole pitches at a time by changing the connections for a 120-degree advance and closing and quickly opening the field contactor. If the field is left connected, the rotor will usually oscillate in its new position several times before coming to rest, but sometimes with a 120-degree advance, it will jump two pole pitches before coming to rest. Therefore, if the field is interrupted just as the rotor starts to move, it may be possible to make use of the stored energy in the rotor to move it several pole pitches. Small movements may be obtained if the d-c source is quickly deenergized and its polarity changed.

**FACILITIES INSTRUCTIONS, STANDARDS,  
& TECHNIQUES**

**Volume 3-14**

**COMMUTATOR AND COLLECTOR RING  
PERFORMANCE**

# Commutator and Collector Ring Performance

Commutator and collector ring problems on exciters of hydrogenerators, which have been most prevalent in Reclamation experience, are often misunderstood. This discussion, although by no means a full treatment of this complex and lengthy subject, gives some basic elements of an adequate maintenance program. The literature listed in the bibliography, only a segment of that which has been published, should be available to maintenance personnel on each project. Troubles which cannot be readily corrected should be referred to D-8440 or D-8450.

Good Performance of both commutators and collector rings is mainly dependent upon the formation of the correct thickness of surface film which is tough, glossy, and has low friction. Moisture absorbed from the surrounding air is an important component of the film. If the ambient air is abnormally dry the film dries, causes friction, and the rate-of-wear increases.

Heat increases the formation of oxides, which are also essential to a good low friction film. The most prevalent problem with exciters has resulted from insufficient heat because of insufficient load which has not allowed adequate film formation. Because the exciters are generously rated, the average load is only about half the nameplate rating. The manufacturer customarily equips the exciter with a good grade of electrographic brush according to the nameplate rating. These brushes may have good characteristics and perform excellently at nameplate rating or medium to heavy load, but perform poorly on light load.

## 1. - COMMUTATOR

Recognizing these conditions characteristic of Reclamation operation, it is not surprising that better performance can usually be obtained by removing half the brushes from the commutator surface. This increases the current density and temperature which aids film formation. Most electrographic brushes are recommended for current densities of 0.093 to 0.109 A/mm<sup>2</sup> (60 to 70 A/in<sup>2</sup>), but will usually form film satisfactorily for densities down to 0.062 A/mm<sup>2</sup> (40 A/in<sup>2</sup>).

Although this is an approximate guide, the brush manufacturer's specific recommendations should be used.

**DO NOT INTERFERE WITH PROPER BRUSH STAGGER WHILE OPERATING A COMMUTATOR WITH SOME OF THE BRUSHES LIFTED. AN EQUAL NUMBER OF POSITIVE AND NEGATIVE BRUSHES MUST COVER EXACTLY THE SAME PATH ON THE COMMUTATOR.**

It is usually easiest to avoid disturbing this stagger pattern by removing brushes toward one end of the commutator, and concentrating current on the other portion. Wear can be distributed by periodically alternating portions of the commutator being used.

## 2. - COLLECTOR RINGS

Unlike commutator performance, collector ring performance can seldom be improved by removing brushes. The most common trouble is excess film formation on one ring. Film is formed principally under the positive brush. The negative ring frequently shows the most wear, which is variously explained as lack of film or as transfer of metal in the direction of current flow.

Less film is required on rings, but excess film results eventually in punctured film, uneven distribution on current, sparking, roughness and rapid brush wear. While commutator brush film is easily controlled by equalizing the brushes; nearly as much benefit can be obtained on a collector by frequently changing polarity. If the ring polarities can be changed as often as from 1 to 3 months the film can usually be maintained on both rings.

Longer intervals may serve only to distribute the roughness which develops. This type of frequent maintenance is sometimes impractical, and other types of film control can be used such as daily or weekly burnishing with canvas pads, frequent use of light flexible abrasives, or occasional stoning.

It is important that collector rings be given frequent attention because, after film puncture and roughness develop, conditions are apt to become worse at an increasingly rapid rate resulting in proportionate brush wear, and bridging of insulation by brush or metal which finally causes flashover. Other collector ring troubles are quite varied and must be treated as special problems.

### 3. - HUMIDITY

Low humidity, already described as a problem, is usual in most Bureau powerplant locations. The approximate amount of moisture needed is shown by the minimum safe water content line on the humidity chart (fig. 1), which has been fixed at  $3.43 \text{ g/m}^3$  ( $1.5 \text{ gr/ft}^3$ ). Relative humidity is not the indicator to be used here, as less water can be held by air at low temperatures. For example, air at  $-6.7 \text{ }^\circ\text{C}$  ( $20 \text{ }^\circ\text{F}$ ) may be tested to have 30 percent relative humidity but the actual water content would be less than needed for good commutator or ring performance. Warming this air for example to  $21.1 \text{ }^\circ\text{C}$  ( $70 \text{ }^\circ\text{F}$ ) moves you on the chart horizontally to about 12 percent relative humidity, but this does not increase the absolute humidity or water content.

The influence of humidity on brush wear is hard to identify because of the delay in appearance of its symptoms. Once a good film has formed it will last from 1 to 3 months of inadequate

humidity with no adverse results. However, if this persists, increased brush friction could wear through the film, especially if film formation is reduced by light load operation. Current density concentrates at the first bare brush areas, sparking starts, roughness develops, and once started, destruction may occur quickly. Consequently, frequent inspections during cold, dry winter weather are advised. If performance deteriorates, roughness can be controlled by frequent polishing with a light flexible abrasive or occasional stoning. Acceptable performance can be maintained through such a period, even though the ring or commutator may operate for a time without film, until normal conditions are restored.

### REFERENCE MATERIAL

The following reference material was originally used for this volume. Much of this material was not extensive, and is no longer available, but is listed here for general interest. Carbon-graphite and Metal-graphite Brushes, by the Research and Technical Staff of National Carbon Company; Hunter-Brown, Carbon Brushes and Electrical Machines, A.M.I.E.E. published by the Morgan Crucible Company, Ltd., Battersea Works, London; Commutator and Slip-ring Maintenance, by Ideal Industries, Inc., Sycamore Illinois; Carbon Brushes and Commutator Maintenance (B-6150A), Westinghouse Electric Corporation; Better Carbon Performance (GEA-6688), General Electric Company.



**FACILITIES INSTRUCTIONS, STANDARDS,  
& TECHNIQUES**

**Volume 3-15**

**FIBER OPTIC ARC DETECTOR**

# FIBER-OPTIC DETECTOR

Severe arcing from brushes on hydroelectric generator rings has occurred on several Reclamation generators. If this arcing is not detected soon after it develops, the arc travels between the brushes and may cause considerable damage to the collector rings and brush holders. If this situation were to be unnoticed, as it could be in an unattended plant, it could cause a fire in the generator. Therefore, unattended plants need the protection that some method of arc detection could provide.

The following is description of the latest arc detector as of June 1991, prepared by the developer<sup>1</sup>. Figure 1, is a schematic diagram and Figure 2, is a contact copy of the printed circuit card.

## SUMMARY OF DEVELOPMENT AND INSTALLATION OF ARC HYDROELECTRIC GENERATOR EXCITERS

Since the initial development of the exciter arc detectors in 1973, arc detectors have been installed on all hydroelectric generators in the North Platte River Projects and on several generators in other projects. To date, in the North Platte River Projects, several arcing incidents have been detected and the generators successfully shutdown before significant damage occurred.

The arc detector has been modified a few time since it was first developed, and the latest version incorporates some significant changes. The early versions of the arc detector utilized a common photocell or phototransistor and a commercially manufactured fiber optic bundle made to specifications for a specific generator brush layout. These optics worked well for several years, and some original units are still in service. However, due to aging of the fiber optic leads and some damage caused when the fiber

optics were removed and the re-installed during generator maintenance, some fiber optics required repair. Because the common end of the fiber optic bundle was cemented together, it was not possible to replace individual damaged leads, and the entire fiber optic bundle has to be replaced with another commercially manufactured bundle.

The latest of the arc detector utilizes individual Hewlett-Packard "Versatile Link" optical receivers and Hewlett-Packard plastic fiber arc cable. A separate receiver and optical cable is used for each brush on the collector rings. The plastic cable can be cut to length, polished, and terminated in the field with the proper crimping tool and an inexpensive polishing kit. The individual fiber optics plug into the optical receivers that are mounted inside a common chassis. The chassis and associated PC board are designed to accommodate up to 16 fiber optics. The cost of the materials, including fiber optics cable, for a typical 16-circuit detector is approximately \$300.00.

The latest version of the detector had been installed on all of the generators at Guernsey, Glendo, and Alcova Powerplants. These detectors have operated satisfactory for several months. A slightly modified version is being installed at Yellowtail Powerplant. The modified version was designed with more sensitive fiber optic receivers (Hewlett-Packard Model HFBR-2523) that allow one fiber optic to be used for each cluster of brushes. Because of the high sensitivity of these receivers, they can only be used for exciter housings, like Yellowtail's, that do not allow ambient light form the powerplant to enter the exciter housing.

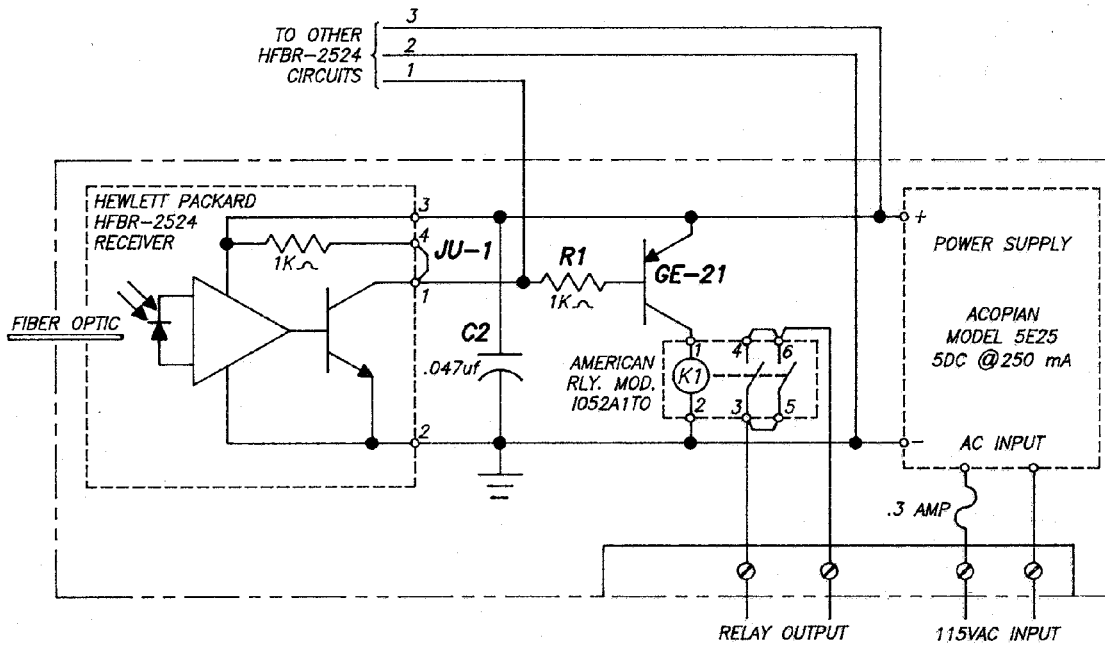
The use of the individual receivers and plastic cable allows any individual cable to be easily replaced if it is damaged. The plastic cable can withstand a long tern bending radius of 35 mm and temperatures up to 70 °C.

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<sup>1</sup> This arc detector was developed by Mr. Donald Jacobson, Electronic engineer, North Platte River Project Office, GP Region, where additional information may be obtained.

# ARC DETECTOR SCHEMATIC DIAGRAM

6/24/91



## - NOTES -

1. USE AS MANY HFBR-2524 RECEIVERS AS REQUIRED, UP TO A MAXIMUM OF SIXTEEN.
2. THE COMPONENTS EXTERNAL TO THE RECEIVERS ARE COMMON TO ALL RECEIVERS, EXCEPT JUMPER JU-1 WHICH MUST BE INSTALLED FOR EACH RECEIVER.
3. CAPACITOR C2 SHOULD BE CONNECTED APPROXIMATELY IN THE MIDDLE OF THE ROW OF FIBER OPTIC RECEIVERS AND THE TOTAL LEAD LENGTH SHOULD NOT EXCEED 20 mm.
4. CONSULT HEWLETT PACKARD OPTOELECTRONICS DESIGNERS CATALOG FOR DETAILS ON THE FIBER OPTIC RECEIVERS AND CABLE.

Figure 1. - Fiber-Optic Schematic Diagram.

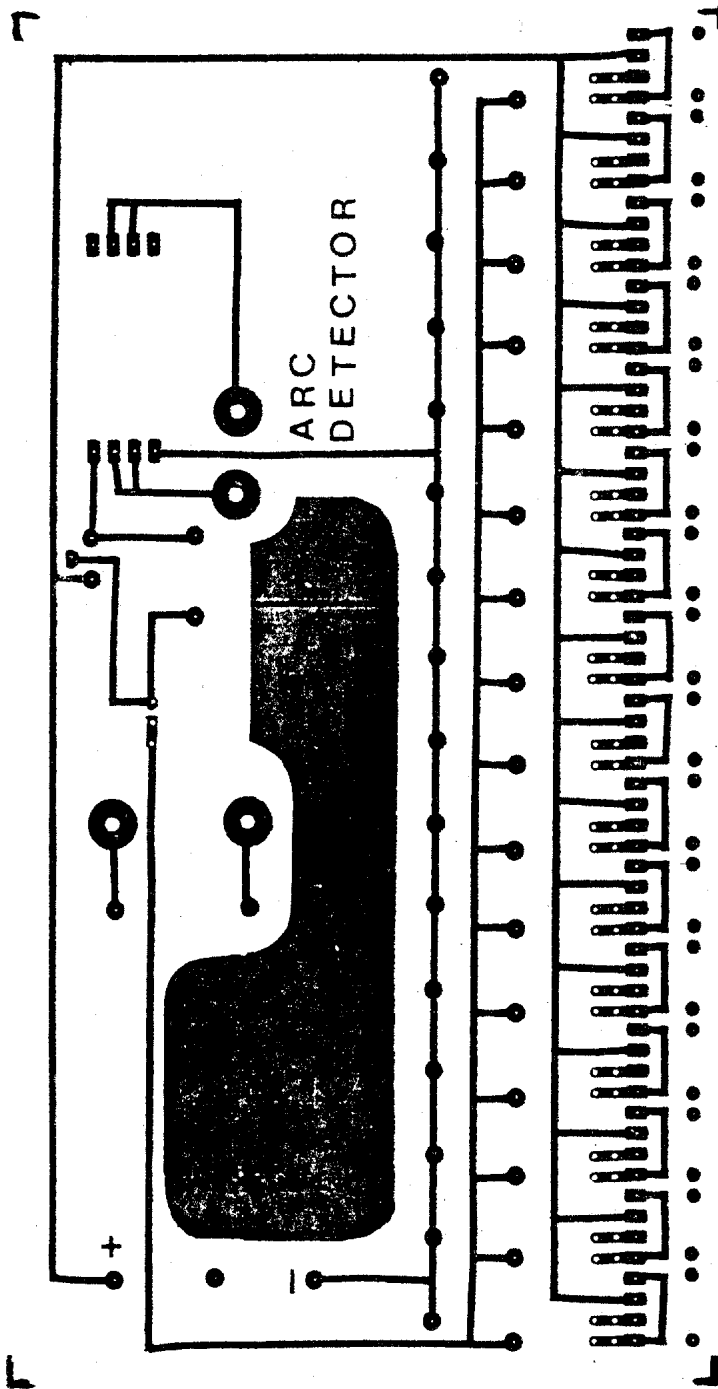


Figure 2. - Fiber-Optic Printed Circuit Board