NBSIR 81-2301

Field Circuit Breaker Tester

U.S. DEPARTMENT OF COMMERCE
National Bureau of Standards
National Engineering Laboratory
Center for Electronics and Electrical Engineering
Electrosystems Division
Washington, DC 20234

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Final Report

Prepared for
Consumer Product Safety Commission
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U.S. DEPARTMENT OF COMMERCE, Malcolm Baldrige, ***Secretary***
NATIONAL BUREAU OF STANDARDS, Ernest Ambler, ***Director***

Foreword

The equipment and procedures described in this report were developed in conjunction with, and for use by, the Consumer Product Safety Commission (CPSC) to investigate the performance of circuit breakers in residential installations. This report is intended to serve only as an instruction/maintenance manual for use by qualified CPSC staff in operating and maintaining the test equipment. Neither the equipment nor the test procedures are intended for general use.

Prior to conducting tests at a given site, test personnel are required to unplug the electricity meter and plug a substitute meter base assembly into the meter socket. With the substitute meter base properly installed, the 240-V ac lines are disconnected from the circuit breaker panel and connected through appropriate protective devices to the input unit of the test equipment. During subsequent tests of the circuit breakers, low voltage, constant-current ac voltage is supplied by the test equipment through the meter socket to the circuit breaker panel.

The particular meter base supplied with the test equipment mates with one type of meter socket that is commonly used in residential installations. However, test personnel should be aware that other socket configurations may be encountered in the field and should determine the compatibility of components before arranging the tests.

Since the conduct of the tests involves breaking the seal and removal of the meter, the use of unmetered electricity during the tests, and the subsequent re-installation and sealing of the meter, each test must be planned with the full knowledge and approval of the local utility company and other relevant authorities. Furthermore, to ensure the validity of the test data, all phases of the tests should be carried out by qualified personnel who have a thorough understanding of residential electrical systems and equipment and of the procedures and equipment used in the tests. Finally, and most importantly, since removal of the meter exposes terminals with hazardous voltages, all general safety precautions plus those specifically discussed in this manual must be rigorously observed.

In developing the equipment and test procedures, every effort has been made to ensure the safety of operating personnel and to avoid damage to the equipment under test. However, without direct supervision of the tests, NBS cannot be held responsible for the accuracy of test results nor for any damage or injuries that might be incurred.

It should be noted that the procedures are intended to be carried out by a two-person crew. Even though the individual components of the test apparatus can be manipulated by an average individual, prudent operating practice requires the presence of a second person.

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FIELD CIRCUIT BREAKER TESTER

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1. INTRODUCTION

Overcurrent protection devices are required within an electrical distribution system to minimize the possibility of electrically initiated fires caused by circuit overloads. Circuit breakers are the most commonly used form of overcurrent protection in new and recent residential construction. However, the complexity of the circuit opening mechanism typical of these devices makes them susceptible to mechanical deterioration, which can affect their operation. A circuit breaker so affected may perform its intended function for a direct short type of fault but may not respond adequately to a less severe circuit overload condition.

The possibility that an unknown number of installed circuit breakers might not perform as intended under certain overload conditions prompted the Consumer Product Safety Commission (CPSC) to initiate an investigative testing program. The program will include visiting various field locations, subjecting installed circuit breakers to controlled overcurrent conditions, and evaluating their performance. In order to obtain valid field performance data, the testing will be accomplished without removing or otherwise disturbing the circuit breakers.

Test equipment developed at NBS for the CPSC to evaluate the performance of single-pole circuit breakers in residential installations is described in this report, along with instructions for its use. The procedures are intended to be carried out by a test crew of at least two persons.

2. GENERAL DESCRIPTION

The field circuit breaker tester is designed to permit on-site testing of installed single-pole circuit breakers[1] - primarily those used in residential applications with 125-A (ampere) or smaller frame size. The circuit breakers can be tested as already installed without disturbing any of their connections. Testing is preceded by interrupting the 240-V (volt) utility power to the panel board containing the circuit breakers, then using the utility power to operate the circuit breaker tester. The tester generates a constant test current for checking the breakers of interest or all of them in sequence.

Interruption of utility company power is achieved at the service entry by pulling the electric power meter. The meter is temporarily replaced by a modified meter base assembly which feeds incoming 240 V ac from the upper jaws in the power company meter socket to the circuit breaker tester by means of connecting wires. Constant current generated by the tester is returned to the lower jaws of the meter socket through the same meter base assembly and fed from there to the circuit breaker panel board via the power company service entry cables.

The circuit breaker tester is basically a source of low voltage, moderately high, constant current, the output duration of which is accurately indicated by a self-contained timer. The output current is adjusted to the desired value with all connecting wire resistance (but not breaker resistance) in the circuit. The unit is started after the breaker to be tested is added into the circuit. When the circuit breaker trips, output current from the tester is automatically shut off. Elapsed time is indicated and held on a digital panel meter (DPM) until the next test is started.

The unit has two ranges of output (10 to 100 A and 30 to 300 A), which permits increased instrumentation accuracy over the entire range.[2] The maximum voltage output from the instrument is approximately 11.5 V ac.

The required output voltage depends on the impedance through which the circuit breaker current must flow. For example, if a test current of 200 A is desired (e.g., to test a 100-A circuit breaker at twice its rated current) and the connecting wires and circuit breaker itself offer a combined total impedance of 20 mΩ (milliohms), then the tester must supply a voltage of 200 x 0.02 or 4 V to drive the current through the circuit impedance.

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[1]With certain additional accessory equipment, the tester could also be used to test double-pole breakers.

[2]The unit will supply up to 250 A continuously. Currents between 250 and 300 A should be drawn for limited duration only - say an hour when slightly above 250 A down to 20 minutes at 300 A. OFF-time after operation at these higher currents should be at least one-tenth the ON-time, and as much as one-half the ON-time at 300 A.

For portability, the tester is divided and packaged into three separable sections or units. The two heavier Generator Units contain the constant current generating equipment and range selection switch. These units are designed to mount on a portable hand truck which will generally remain outside the house in the area of the electrical service entry during testing. The Control Unit includes the digital panel indicating meters and the stop-start and current adjust controls. It is joined by cables to the other two units and is designed to be carried inside the house to the vicinity of the service entry panel board.

3. SYSTEM OPERATION

The field circuit breaker tester utilizes the 240-V ac input power from the electric utility company to generate a low voltage ac constant current for testing the calibration of residential circuit breakers, in situ. Before testing begins, the connection between utility power and the circuit breakers to be tested is interrupted; the constant test current is introduced at this juncture. The tester is composed of several parts which are described in this section. A block diagram of the system is shown in figure 1 and more detailed schematics in figures 2, 3, and 4.

Figures 5 and 6 show the three portable cabinets which contain components for generating, controlling, and measuring the constant current and for measuring circuit breaker characteristics when subjected to this current. For convenience in describing them, they are labeled Generator Input Unit (GIU), Generator Output Unit (GOU), and Control Unit (CU). When in use, two Generator Units are normally mounted side by side on a portable hand truck (as shown in fig. 7) and located near the power company electric utility meter. A 4-ft long, 13-conductor cable connects one unit with the other. The CU, located in the vicinity of the circuit breaker panel board, is connected to the GOU via a 30-ft long, 13-conductor cable.[3] The two cables are not interchangeable.

The incoming 240-V ac utility supply is shifted from its normal path (that is, to the service entry panel) in order to supply power for the Generator Units. This is accomplished by pulling the electricity meter and substituting an assembly (fig. 8) which plugs into the same meter socket. The 240-V ac utility input power normally passes through the upper socket connectors through the electricity meter to the lower socket connectors and thence to the service entry panel board. Once the substitute meter assembly has been inserted however, the 240-V ac (120-V ac each side of neutral) input power passes from the upper socket connectors into the substitute assembly, through a pair of fast acting safety fuses and out via a three-wire 15-ft cable to the GIU. The neutral connection is picked up by a threaded brass rod in the center of the substitute meter base assembly: this rod is screwed down manually

[3]The panel board is generally located inside a building as close as possible to the service entrance power usage meter. A 35-ft extension cable is available if the distance between electric meter and panel board or the location of building openings through which to pass the cable necessitate a longer cable length.

until it contacts the neutral connection in the power company meter socket. (If, because of its location, the neutral connection in the meter socket cannot be contacted by the rod, the tests cannot be completed without modifying the means of connecting to the neutral.) This neutral line is carried to the GIU by the third wire in the cable. The three-wire 15-ft cord from the substitute meter assembly has a female cord connector on its end which plugs into a motor base receptacle on the rear of the GIU.

At the GIU the 240-V ac is directed through a ground fault circuit interrupter (GFCI) and a master control relay, or contactor, to the primary windings of a motor-driven variable transformer. The 120-V ac developed between one side of the 240-V ac input and the neutral connection is sent through a second GFCI and used to provide operating power for the digital panel meters, the autotransformer driving motor, and other devices within the test equipment. It also furnishes power for auxiliary lighting, since normal building power is usually cut off when the electric meter is removed.

Output from the motor-driven variable autotransformer is directed through 10-A slow blow fuses (replaceable on the front panel) to the primary winding of a high current transformer located in the GOU. This transformer has an input-to-output turns ratio of approximately 25, hence its output voltage is much lower than the input, but its output current is much higher. The output current, which is the circuit breaker test current, flows through one or the other of two pairs of instrument transformers (also located in the GOU): the selection depends on the position of the large front panel switch on the GOU. This switch (composed of five ganged double pole, double throw toggle switches) selects the desired output test current range - either 10 to 100 A or 30 to 300 A. The first instrument transformer in the chosen path generates a lower level (5 A max.) alternating current which is proportional to the output test current. This current is sent back to the regulator controller, located in the GIU. The second instrument transformer in the test current path generates a similar low level proportional ac current which is sent to the CU where it is manipulated by a current transducer and various electronic circuits to produce an accurate indication of the output test current and the length of time during which it is flowing.

At the regulator controller, the ac current from the first instrument transformer (proportional to the output test current) is converted to a voltage and compared with an internally generated voltage whose value is set by the position of the current control knob located on the CU front panel. If the two voltages are not equal, the regulator controller directs the motor driven autotransformer output to change and cause the voltages to become equal.

Adjustment of the current control knob to produce a higher test current causes a rise in the internally generated comparison voltage. To make the voltages equal again, the regulator controller drives the motor in a direction to increase the autotransformer output voltage. This causes an increase in the high current transformer output voltage and, assuming constant output resistance, an increase in the output circuit breaker test current.

The control loop just described also serves to keep the output test current constant when changes in output circuit resistance occur. If output circuit resistance should increase (as it tends to do when current flow causes wire temperature to rise), the resulting tendency for output current to decrease is counteracted by the feedback loop which increases the motor driven autotransformer output sufficiently to maintain the test current at its preset value. Sensitivity of the feedback loop can be adjusted by a potentiometer (covered by a screw-on cap) on the regulator controller. This control should be adjusted to just below the point where the feedback loop tends to "hunt."

Black and red (or yellow) output connectors, located on the front panel of the GOU, provide the test current to the line and load sides, respectively, of the circuit breakers. The black terminal is common to both ranges of the instrument and is connected by a 15-ft long, high current, single-conductor cable (AWG #1) to one of the two short cables hanging from the substitute meter base assembly. Each short cable is connected to one or the other of the two lower bayonets on the substitute meter base. These lower bayonets, when inserted into the power company meter socket, make connection with the panel board bus bars via the utility service entry cable. The line side of each circuit breaker is connected to one or the other of these bus bars.

The red (or the yellow) terminal on the GOU is connected to the load terminal of the circuit breaker to be tested by means of a spring-loaded probe assembly which is described in more detail below. Connection between the probe assembly and the GOU is made by a 30-ft long, high current, flexible, single-conductor cable (AWG #1) routed through the same building opening as the multiconductor cable connecting the CU and GOU. As with the instrument interconnecting cable, an extension is available should the cable run be longer than 30 ft.

Test current will not flow unless the switch between the red and yellow terminals on the GOU is set in the direction of the selected output terminal. However, internal wiring is designed to prevent damage if the switch is not correctly set.

The spring-loaded probe assembly (see fig. 9) can be adjusted to clamp onto the frame of most common panel boards once the cover plate has been removed. Precise placement of the probe to coincide with the desired circuit breaker load terminal, as well as adjustment of spring tension, are accomplished after the assembly has been attached to the panel board.

An additional terminal on the probe facilitates measurement of ac voltage across the circuit breaker while it is undergoing a calibration test. This voltage, together with the test current value, can be used to calculate circuit breaker ac resistance.[4]

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[4]Circuit breaker ac resistance in ohms equals the voltage measured across the circuit breaker in volts divided by the current flowing through the breaker in amperes.

The GIU and the GOU, which house the constant current generating equipment just described, are normally located in the area of the service entry electric meter during a test. Initial turn-on of the equipment and selection of the test current range must be done at these units. Test current adjustment, the starting and stopping (if necessary) of a test, and all voltage, current, and time readings are performed in the vicinity of the circuit breakers to be tested via the separate, lightweight CU which is connected to the GOU via a multiconductor cable.

The front panel of the CU includes four digital panel meters, a stop/start control, a current adjust control, an input connector for the ac voltage measurement, and an indicating light to signal that test current is flowing. A 120-V ac outlet (7.5 A max.) is also available should it be necessary to provide additional illumination in the work area. Activation of switches on the GIU, which place the tester in a "stand-by" condition, is indicated on the CU by the appearance of numbers on the digital panel meters.

The top panel meter indicates the ac voltage developed across the circuit breaker during a test (provided the voltmeter leads are connected), the third one from the top reads the ac test current flowing through the circuit breaker, and the bottom one reads the time between starting the test and the end of current flow. The latter indication remains displayed until the next test has started. The second panel meter from the top duplicates the peak reading of the test current meter and holds this reading for a few minutes after the test has been completed. Thus, confirmation of the test current value is available in those situations where the circuit breaker opens very quickly.

The ac current and elapsed time indications are both derived from the output of an instrument transformer located in the GOU. As explained previously, the circuit breaker test current flows through two instrument transformers before leaving the GOU. The output of these transformers is an ac current proportional to the circuit breaker test current, but of lower value (<5 A). The output of the first is part of the constant current feedback loop as described earlier. The ac current output of the second instrument transformer is supplied to the CU, where it is converted to a proportional low level dc current by a current transducer. A change in circuit breaker test current thus results in a proportional change in the low level dc current from this transducer.

The actual change in dc current produced for a given change in circuit breaker test current depends on the output range selected on the GOU. The instrument transformers each have a 60-to-1 turns ratio, but the one in the path of the 10- to 100-A range has more turns of the test current conductor through its primary. The instrument transformer in the path of the 30- to 300-A range has only one turn of the test current conductor through its primary and thereby produces a 5-A ac output for a 300-A circuit breaker test current (or a 0.05-A output change for a 3-A test current change). The 5-A ac output is converted to 1-mA dc current by the transducer and the 0.05-A change to a 0.01-mA dc current change. The instrument transformer in the path of the 10- to 100-A output has three turns of the current conductor through its primary and thereby produces the same 5-A ac output for only a 100-A test current.

As seen from the above discussion, the additional output range provides increased resolution at the lower circuit breaker test currents, i.e., the change in transducer dc output current, which is proportional to a change in circuit breaker test current, is the same for a 1-A test current change when using the 10- to 100-A range as it is for a 3-A test current change when using the 30- to 300-A range.

The front panel ac current indicators are actually dc millivolt meters which measure the voltage developed across a stable precision resistor by the proportional dc transducer current. The precision resistor is switched with the range selected so that the correct scale factor is maintained, i.e., 1 mA must produce an indication of 100.0 when using the 10- to 100-A range, whereas 1 mA must produce an indication of 300 when using the 30- to 300-A range.[5] The voltage developed across a second resistor in the dc transducer current path is sent to a comparator circuit which is used to activate the elapsed time indicator.

The elapsed time indicator is a gated electronic counter which counts the level changes of a derived square wave during the presence of an enabling positive dc input voltage. The period of the square wave is adjustable by front panel controls so that the count can correspond to seconds, minutes, or hours. The enabling positive voltage is obtained from a comparator circuit (see fig. 10) within the CU. If the dc voltage input to this comparator circuit is above a preset trigger value, the comparator sends a positive enabling voltage of about 4.6 V to the counter. The comparator trigger point is adjusted by R3 so that any circuit breaker test current in excess of approximately 2 A causes the comparator input to be above its trigger value. Thus, the electronic counter starts when the circuit breaker test current starts and stops when the current stops. The counter indication is the time elapsed during current flow.

The comparator output, which is present only during test current flow, is also used to activate two solid-state control relays - one within the GIU and one within the CU. The first is wired in series with the 115-V ac required by the motor which drives the variac. The second is wired as a "lock-in" for the START switch on the CU. The dc voltage

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[5]The dc voltmeter used has a range of 0-200.0 mV. For the 10-100-A output range the resistor value selected is 100 Ω so that 1-mA dc (corresponding to a 100-A ac test current) will produce a voltage across the resistor of 100 mV and a 100.0 reading on the meter. For the 30-300-A test range, the resistor value selected is 30 Ω so that 1-mA dc (corresponding to a 300-A ac test circuit) will produce a voltage of 30 mV and a 300 reading on the meter. (Connections are available at the rear of the meter for eliminating the decimal point and are so used in this range.)

between 3 and 32 V at the control terminals of these relays activates the relay and closes any circuit connected to the normally open relay output terminals.

The purpose of the control relay wired in series with the autotransformer driving motor is to break the constant current feedback loop when the circuit breaker under test opens or when the stop button on the CU is operated. This prevents the motor from driving the autotransformer to maximum output in a futile attempt to keep test current constant.

The purpose of the relay in the CU is to hold the GIU main contactor closed after the START button is pushed if test current is flowing, and to release the contactor if current ceases or is not flowing. (As explained earlier, 240-V ac input to the motor driven variac primary is supplied through this contactor.) Thus, the contactor will remain closed after the START button is released only if the test circuit is complete. Opening of the circuit breaker under test, pushing the STOP switch, or breaking any connection in the current path causes this contactor to open and thereby remove voltage from the test equipment output terminals.

Also, included in the CU is circuitry to cause resetting of the peak-and-hold ammeter approximately 3 seconds after a test is started. This prevents an abnormally large turn-on transient from being registered and held by this meter. The reset pulse is obtained from a duo-monostable multivibrator integrated circuit (see fig. 11) which is activated by the comparator circuit. When current starts flowing, the comparator output goes positive and activates the first monostable multivibrator. After a time determined by capacitor C3, the first multivibrator returns to its original condition. This event activates the second monostable multivibrator to produce a pulse the length of which is determined by capacitor C4. This pulse is used to reset the peak-and-hold meter. The meter may also be reset manually by pressing the small pushbotton "reset" switch directly under the CU operating light.

A three-pole, double-throw relay located in the CU chooses the precision resistor corresponding to the output test current range. This relay also changes decimal point location on the digital ammeters so it corresponds to the test current range selected. The relay accomplishes this by switching certain connections on the rear of the test current indicating meters. The relay coil is connected to its 120-V ac energizing source by a switch which is ganged with those that select desired test current range.

Four low voltage dc power supplies are located in the CU, one for each of the two digital current indicators and two to supply dc voltages to the comparator and monostable multivibrator circuits. Each of these supplies is operated from 120 V ac.

4. PREPARATIONS FOR TEST

Some advance planning and a number of setup procedures must be accomplished before actual testing can begin. This section discusses those needs. Note that the test procedures are intended to be carried out by a crew of at least two persons.

Permission to pull the electricity meter at each test site should always be obtained from the electric utility company. If a number of test sites are located in a particular area, a prior agreement with the local utility company may permit a simple notification of test site and date. The power company may choose to have a representative present during the test. In addition, someone from the company will have to reseal the electric meter once the tests have been completed.

Utility power will not be restored until the electric meter is replaced following testing. In some situations, therefore, a portable generator may be necessary to supply temporary power for heating equipment or food freezers for the duration of the circuit breaker tests. In such cases, the auxiliary power must be supplied directly to the desired equipment, not through the circuit breaker panel. This is necessary for the safety of test personnel and to avoid any possible interference with the subsequent tests.

The parts necessary to test circuit breakers in the field are given in table 1. Photographs of the various parts are shown in figures 7, 8, 9, and 12. Operating personnel should be certain that all parts are on hand before proceeding to the test location.

The Control Unit (CU) and most of the necessary cables can be placed on the hand truck along with the Generator Units (as shown in fig. 13) while moving the equipment from its storage area to the vehicle used for travel to the test site. Separation of the units from the hand truck will generally be necessary before they can be loaded into the transporting vehicle, however. Weights of various units and interconnecting cables are given in table 2.

At the test site, the equipment should be unloaded and repositioned on the hand cart for transport to the actual test location. Precautions should be taken during transport to avoid moisture or dust contamination through the ventilation openings of the Generator Units. The hand cart and Generator Units must be located within 15 ft of the electric meter, whereas the CU should be placed near the panel board housing the circuit breakers to be tested. If more than one electric meter is present, it must be determined which one serves the panel board in question.

The CU is most easily used if placed on the ground or floor with the front panel facing upwards. The meters are easily read from above in this position and the wide metal legs keep the unit away from any dirt and moisture on the floor in the test area.

Once at the test site, the various interconnections between units can be made. The 4-ft multiconductor cable should be connected between the rear panels of the two Generator Units and the longer (30-ft) multiconductor cable connected between the rear panel of the Generator Output Unit (GOU) and the rear of the CU. The connector pins on the longer cable can be easily bent, hence the connector should not be forced into the socket. The guide bar on the bottom and the guide pins on the exterior of the plug shell should be lined up with their couterparts on the socket and then the connector plug shell gently turned. The cable should mate easily; if not, the components are not lined up, and forcing may bend one or more of the connector pins. Following this, one end of the 30-ft long, high current, single-conductor cable with the red connectors should be connected into the red or yellow terminal on the GOU (only one end of this cable will fit into the GOU), and then the range switch located between the terminals should be set in the direction of the terminal selected. The other end of the cable should be located near the CU at the panel board.

The electric meter is typically located outside the building and the panel board inside (usually in close proximity to the electric meter), hence the two 30-ft cables must be routed through an opening in the building, e.g., window, door, etc. Should a convenient opening be lacking or the panel board be located at some distance from the meter, 35-ft extensions are provided for each cable to enable total cable runs of as much as 65 ft.

Following the above steps, the connection from the substitute meter base assembly to the Generator Input Unit (GIU) can be connected. After checking to be certain that both front panel switches of the GIU are in the OFF (down) position, the longer cable coming from the substitute meter base assembly can be inserted into its mating, three-terminal motor base receptacle on the rear panel of the GIU.

The next step is to prepare for pulling the utility company electric meter and inserting the substitute meter base assembly. <u>Prior to pulling the electric meter, any load on branch circuits served from that meter should be disconnected to eliminate arcing and possible damage to the contacts when the meter is pulled. Note that the circuit breakers to be tested must not be opened to remove the load since exercising these breakers prior to testing may affect the test results. If there are master breakers for the panel, and they are not to be tested themselves, they should be switched off. Otherwise, all lights and appliances, etc., connected to branch circuits served from the panel board in question should be turned off.</u> The rotation of the meter disk should be observed to verify that the loads have been disconnected.

REMOVAL OF THE UTILITY COMPANY ELECTRIC METER SHOULD BE DONE CAREFULLY, USING THE PROCEDURES APPLICABLE TO THE PARTICULAR METER TYPE. REMOVAL OF THE METER LEAVES ELECTRICALLY LIVE TERMINALS EXPOSED AT THE METER SOCKET. <u>DO NOT COME IN CONTACT WITH THESE TERMINALS</u>. The exposed meter socket should be observed, however, to note whether the socket contacts are spaced to accept the substitute assembly and whether contact can be made with the power company neutral at the center of the socket. (The neutral connection needed by the circuit breaker tester is obtained after the substitute meter assembly has been installed: a threaded brass rod in the center of the assembly is rotated until it makes contact with the utility company neutral. Contact between the brass rod and the meter socket case may also be sufficient for obtaining the neutral connection. If the neutral connection cannot be made with the brass rod, the tests should be cancelled.)

Before installation of the substitute meter assembly, the threaded brass rod should be rotated counterclockwise to move it upwards into the meter base and the assembly positioned so that the wires emerge from it at the bottom. Following this the substitute meter assembly can be inserted into the meter socket and the brass rod rotated clockwise until it contacts the utility neutral. Connection to the two short cables coming from the substitute meter assembly or procedure with other steps must not be made until the correctness of the substitute meter assembly installation has been verified.

A correct meter assembly installation is verified if the small red light above the left-hand switch on the GIU lights when that switch is moved to the ON position. There is no danger in operating this switch because no voltage is available at any of the instrument output terminals unless the START button on the CU is depressed and held. Should the light fail to come on, either (1) the substitute meter may have been installed incorrectly, (2) the neutral connection may not have been engaged, or (3) the lamp may have burned out. To determine whether the neutral has been engaged and the lamp is operable, the right-hand switch on the GIU should be briefly moved to the ON position and the large white lamp above that switch observed along with the digital panel meters on the CU. If the large white lamp comes on but the meters don't light up, then the neutral connection at the meter socket has not been properly made. If both the lamp and the panel meters light up, then the small red lamp is probably defective and should be replaced. If neither the lamp nor the meters light up, then the substitute meter assembly has probably been installed incorrectly and should be removed immediately.

Once it has been confirmed that the substitute meter assembly has been installed correctly, both switches on the GIU should be turned off and the 15-ft long, high current, single-conductor cable with the black connectors connected between the GOU black terminal and either one of the two short cables hanging from the substitute meter assembly.

The next step is to select a specific single-pole circuit breaker in the panel board for test. This requires that the circuit breaker ultimately be connected between a pair of terminals on the GOU, either the yellow and black or the red and black.

If proper connections have been made, the line side for one of two groups of circuit breakers is already connected to the GOU black terminal. As just described, the black terminal is connected by a high current, single-conductor cable to one of the lower bayonets in the substitute meter assembly. From there it is connected through the meter socket to one of the main bus bars in the panel board by means of the utility company service entry wires. (The other lower bayonet in the substitute meter base assembly is connected by the same method to the other bus bar in the panel board.)[6] The line side of each single-pole breaker is connected to one or the other of main bus bars depending upon its location in the panel board. Thus, some circuit breakers have been connected with the black GOU terminal. Either the red or yellow GOU terminal must now be connected to the load terminal of the selected circuit breaker.

Contact with the load terminal of a specific circuit breaker in the panel board is achieved by means of the probe assembly pictured in figure 9. FOR INCREASED SAFETY TO OPERATING PERSONNEL, THIS ASSEMBLY SHOULD BE SET UP AFTER THE UTILITY COMPANY POWER METER HAS BEEN PULLED AND THE SUBSTITUTE METER ASSEMBLY INSTALLED. (Safety is enhanced since the utility company's 240 V ac is removed from the panel board when its meter is removed. Only 11.5 V ac is available from the tester, and even this is not present until a test is started.)

In most houses, removal of the electricity meter will result in loss of electric lighting in the panel board area. A 120-V ac outlet (7.5 A max. current) has therefore been installed on the front panel of the CU for connection of auxiliary lighting. Of course, the substitute meter assembly must be installed for power to be supplied at the CU.

The circuit breakers to be tested should not be switched nor otherwise disturbed during the following setup operation. The panel board cover plate must be removed to gain access to the circuit breaker terminals and to provide a surface on which to clamp the probe assembly. The probe itself is a spring-loaded brass rod which is positioned, by means of various clamps, rods, etc., so that its major axis is perpendicular to the plane of the circuit breaker load terminal (see fig. 14). In the usual installation, the only accessible portion of the load terminal (without disturbing any connections) is the head of the screw which clamps the branch circuit wire to the circuit breaker. Accordingly, the probe must be positioned to contact that screw head.

After the probe tip has been placed in contact with a surface, spring tension on the probe can be reduced by turning the white plastic knob at the rear of the threaded section (see fig. 14) counterclockwise within the threaded U-shaped metal clamp. Alternatively, the tension can be eliminated by pulling back on the knurled metal handle surrounding the wire leading to the probe connector and inserting the dark-colored "Y-shaped" fork between the white plastic knob and the knurled metal handle (see fig. 9). This fork should be in place (i.e., eliminating spring tension) while adjusting the clamping assembly to position the probe correctly. Spring tension should then be adjusted so that moderate

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[6]Access to both bus bars in the circuit breaker panel cannot be made with a single connection because the two lower bayonets of the meter base assembly are purposely not connected together. This was done as a safety precaution to prevent the extremely hazardous situation that could otherwise result if the meter base were incorrectly installed in the inverted position, thereby causing a short circuit across the incoming 240-V lines.

pressure will be placed on the circuit breaker load terminal (screw head) when the fork is removed. This pressure can be increased later, if necessary, by rotating the white plastic knob clockwise.

The configuration of the probe clamping assembly can be varied somewhat in order to conform to the physical characteristics of a given panel board. Individual probe assembly parts are shown in figure 15, and their configuration for a typical panel board is depicted in figure 9. The vise-grip clamps at either end of the assembly are locked onto the upper and lower edges of the panel board, as shown in figure 16. The probe itself is attached to a one-half-inch rod which is 26 in. long. A 48-in. rod is available for use when larger panel boards are encountered.

The real world may present more difficult situations than illustrated by the mock-up in the photograph. As an example, wires and cables emerging from the panel board may limit the area available for placing the vise-grip clamps. Clamping arrangements within the assembly may have to be adjusted to compensate for this. In some cases, the edges of the panel board may have lips which prevent fastening the vise-grip clamps. Accessory wooden blocks of various thicknesses and shapes will be needed to fit into the area and provide a clamping surface.

Once the probe clamping assembly is correctly positioned, movement of the probe to test any circuit breaker in the same vertical column can be achieved by raising or lowering the U-shaped clamp, which holds the probe, along the vertical rod. To do this, the spacer fork should be inserted to remove the probe from contact with the breaker just tested, the probe clamp thumb screws loosened to permit rotation of the probe away from the circuit breaker and reposition of it at the next circuit breaker to be tested, the probe clamp thumb screws re-tightened, and then the spacer fork removed to bring the probe back into contact with the (next) screw head.

The high current, single-conductor cable end (red color-coded) previously left in the vicinity of the CU will eventually be inserted into the connector at the rear of the probe. This will complete the connection between the GOU red or yellow terminal and the circuit breaker load terminal. Refer to the operating procedures for further details.

5. OPERATING PROCEDURES

After the initial setup procedures (as described above) have been completed, circuit breaker testing can begin. <u>It should be emphasized here that, even though the maximum tester output voltage of 11.5 V ac is much less than that thought capable of presenting a shock hazard to humans, operating personnel should avoid contact with exposed terminals throughout the testing.</u> Once test current stops flowing, there is no voltage at the output terminals until the START button is pushed again. (Voltage is available while the START button is being pushed. Voltage remains after the button is released only if a test current in excess of 2 A is flowing.) The equipment is configured with both fast-acting fuses and ground fault circuit interrupters to protect operating personnel in the event of malfunction. Avoiding unnecessary contact with exposed terminals provides increased assurance of safety for the operation.

Before a test can begin, the spring-loaded probe assembly (pictured in fig. 9) must be positioned so that the tip of the probe will be perpendicular to the plane of the load terminal screw head (see figs. 14 and 16) of the circuit breaker to be tested. (Details of this procedure were provided above.) During initial and all subsequent position adjustments, the probe tip should be restrained from the test position (i.e., there should be no contact between probe and circuit breaker) by insertion of the one-half-inch thick fork-shaped spacer between the knurled metal probe handle and the white plastic knob used to adjust probe spring tension (see fig. 9). The probe spring tension should be initially set at its minimum by rotating the threaded white plastic section counterclockwise within the metal probe clamp.[7]

After the probe is correctly positioned and before the spacer fork is removed, the test unit must be preadjusted to deliver the approximate value of test current desired. This must be done without the circuit breaker in the current path so that the very large currents which may occur during adjustment will not pass through the circuit breaker.

As a first step in presetting the test current, it must be determined which panel board bus bar connects to the line terminal of the circuit breaker to be tested. Contact with this bus bar must be made later in the preset sequence. If observation and knowledge of panel board construction are not sufficient to determine this information, a continuity tester (ohmmeter) may be used.[8] Next, the connections and switches on the GOU must be set for the desired output current range. For test currents equal to or less than 100 A, the yellow output connector (10-100 A) should be used. For currents exceeding 100 A, the red output connector (30-300 A) must be used. The switch between the yellow and red connectors should be set in the direction of the output to be used.

Long-term continuous operation at currents exceeding 250 A is not recommended. However, at 260 A the unit can be operated continuously for periods up to one hour provided an OFF period of at least one tenth the

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[7]The actual pressure exerted on the circuit breaker load terminal when the spacer fork is removed will, of course, depend upon how close the probe tip was to the terminal while the spacer fork was in place. A prior spacing wider than the fork width will obviously allow no contact between the probe and the terminal when the fork is removed, while a very small spacing would allow the probe to exert maximum pressure on the terminal. Starting with the probe body rotated counterclockwise back in its clamp, pressure can be increased substantially if necessary (e.g., to reduce contact resistance) by turning the white plastic probe body clockwise within the probe clamp.

[8]Ohmmeter tests will be unambiguous only if all loads are disconnected.

ON period is observed. At 300 A operation should be limited to 20-minute periods separated by an OFF time of at least 10 minutes. In no case should the current exceed 300 A.

The next step is to verify that the switches on the GIU are activated. Both the auxiliary ac switch and the main ac switch should be placed in the "up" position. A small red pilot light on the GIU indicates that auxiliary ac power is available. These switches may be left ON for the duration of all testing because no current or voltage is present at the output terminals until the START button on the CU is pushed. Voltage and current are removed as soon as the circuit is broken (whether the circuit breaker under test opens, a test wire becomes disconnected, or the STOP button is pushed).

The range of the digital timer (lower DPM on the control unit) should be set to correspond to the estimated length of circuit breaker ON time. If current through the breaker will be less than 150 percent of its rated current, the thumbwheel switches on the meter face should be set to read 0000600 and the time will be indicated in tenths of a minute up to 99999.9 minutes maximum (approximately 1667 hours or 69 days). If current through the breaker will be 150 percent or greater of its rated current, the thumbwheel switches should be set to read 0000010 and the time will be indicated in tenths of a second up to 99999.9 seconds maximum (approximately 1667 minutes or 27 hours).

Next, the accessory tip (pictured at the right in fig. 12) should be placed on the end of the red color-coded, high current, single-conductor cable. The other end of this cable should already be connected to the GOU red or yellow terminal via passage through a convenient building opening. This tip is then placed and held in contact with the desired panel board main bus bar, during which time the CU START button is pushed and held for one to two seconds before releasing. If all connections have been made correctly, the ammeters will indicate current flow and the CU current regulator knob can be adjusted for the desired current[9] as read on the lower ammeter.

If current does not flow when the START button is pushed, the GOU common is probably connected to the opposite panel board bus bar at the substitute meter base assembly. In this event, the high current, single-conductor cable should be disconnected from the short wire emerging from the substitute meter base assembly and reconnected to the other short

[9]The Generator Units have been adjusted for maximum resolution (i.e., smallest change of current for a given movement of the control knob) under normal operating conditions. Should circuit resistance be less than normal, the unit will tend to "hunt" and sensitivity must be reduced by means of the sensitivity adjustment on the GIU front panel.

wire.[10] The GIU switches do not need to be turned OFF for this operation provided that the START button on the CU is not operated during the transfer.

The timer (lower right DPM) will be operating during the preadjustment period, but its reading may be ignored other than to note whether it is set for the desired units (seconds or minutes). If it is not, the thumbwheel switches must be reset.

Once the current has been preadjusted to the desired value, either the STOP button can be activated for approximately 2 seconds or the connection to the main bus bar can be removed. The lower ammeter should now read approximately zero and the timer will indicate the length of time that the test current was flowing.

After test current preadjustment is complete, the accessory tip can be removed from the red color-coded cable and the cable inserted into the connector at the rear of the probe. The probe spacer fork should be removed with one hand, while the other hand holds the knurled metal handle to prevent the probe from suddenly lurching forward. The probe should be allowed to come gently into contact with the circuit breaker load terminal.

If an indication of ac voltage developed across the circuit breaker while it is undergoing test is desired, the meter connections should be made at this time. Connections to the top DPM, which indicate ac voltage, are made through the male microphone latch lock panel connector located to the right of this meter and above the current adjustment knob. A grey-colored, two-wire, shielded cable (the upper center cable of fig. 12) fits into this connector. The white wire emerging from the other end of this cable has a small pin on its end which plugs into a small red jack located at the rear of the threaded white plastic portion of the probe.

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[10]One other situation could prevent current flow. It should be investigated if switching the meter base connectors does not rectify the situation. If the previous test location required a high-voltage output from the autotransformer (e.g., to drive the desired test current through a higher than normal resistance), the output voltage will be at this same high level when the unit is first activated again. If the present circuit resistance is low, however, high current will flow until the autotransformer motor has time to readjust the voltage output to a lower value. During this time the 10-A slow-blow fuses at the bottom of the GIU front panel may blow. (These fuses have a relatively low rating because they protect the input to the high current transformer - not its output.) If such is the case, the fuse should be replaced and resistance added into the test circuit temporarily. This can be done by using the 35-ft, single-conductor extension cable. Then the equipment can be activated and the current adjust control turned counterclockwise. Once the autotransformer has adjusted downward, the normal procedures can begin again. If the 35-ft extension is unavailable or does not add sufficient resistance, the autotransformer can be turned by hand. Remove all power from the equipment and take off one of the perforated sides. Rotate the autotransformer arm counterclockwise by placing a finger in one of the holes in the plate attached to the arm and turn.

The black lead has a larger plug on its end which fits into one of two supplied accessory alligator clips. The appropriate alligator clip is then attached to the panel board bus bar which feeds the breaker to be tested.

The voltmeter will indicate to 1.9999 V ac, but as much as 100.0 V ac may be applied without damaging the meter. Resolution of the meter is 0.1 mV.

The circuit breaker test can begin after (1) the test current has been preadjusted to the desired value, (2) the probe assembly is in place with the probe contacting the circuit breaker load terminal, and (3) the ac voltmeter leads have been connected. To start the test, the CU START button must be pushed and held for approximately 2 seconds. The tester will shut off automatically when and if the circuit breaker trips, with time to trip indicated on the timer. This reading will remain until another test is started or the tester is turned off. For currents no greater than the circuit breaker rating, the breaker should not trip, hence the test will have to be terminated by pushing the STOP button after some predetermined length of time.

The second meter from the top on the CU front panel is a peak-and-hold ammeter. Approximately 4 seconds after a test is started, this meter resets and thereafter indicates the maximum current flow through the breaker during that test. This reading is held for a short time after the test is terminated. This meter is most useful at currents which are 200 percent or more of the circuit breaker rating: at these current levels, breaker trip time can be quite short and current readings may be difficult to observe. The peak-and-hold ammeter provides reassurance that the circuit breaker test current was at the desired value.

When the test on a circuit breaker has been completed, the spacer fork should be replaced into the probe assembly to back the probe away from contact with the circuit breaker load terminal.[11] Then the probe clamp thumb screws should be loosened and the probe raised or lowered along the rod to contact the next circuit breaker to be tested.

6. CONSTRUCTION

The circuit breaker tester is divided into three separable units to facilitate portability. These units have been designated: (1) Generator Input Unit (GIU), (2) Generator Output Unit (GOU), and (3) Control Unit (CU). A schematic diagram for each unit is shown in figures 2, 3, and 4, respectively. Two subassemblies are located with the CU - the Comparator and the Duo-monostable multivibrator. Schematics for these subassemblies are shown in figures 10 and 11.

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[11]Because the circuit breaker tripping mechanism responds to the heat generated by current flow, consecutive tests should not normally be conducted on the same circuit breaker. Some "cooling-off" time is necessary to avoid affecting the results of the next test on that circuit breaker.

A parts list and photographs showing various views of the interior layout are included for each of the three major units and for the modified meter base and probe assemblies. Parts for the GIU, GOU, and CU are listed in tables 3, 4, and 5, respectively.[12] Parts for the modified meter base, the probe assembly, and the interconnecting cables are listed in tables 6 and 7.[12] Construction details are shown in the photographs of figures 17 through 26.

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[12]Certain commercial equipment, instruments, or materials are identified in this paper in order to adequately specify the experimental procedure. In no case does such identification imply recommendation or endorsement by the National Bureau of Standards, nor does it imply that the material or equipment identified is necessarily the best available for the purpose.

TABLE 1. Parts Necessary to Test Circuit Breakers *In Situ*

1 Generator Input Unit

1 Generator Output Unit

1 Control Unit

1 substitute meter base assembly and attached cables

1 hand cart and attached rubber tie-down cords

1 probe assembly including:

- 1 probe
- 1 probe clamp (u shaped)
- 2 vise grip sheet metal clamps
- 1 spacer fork
- 2 long 1/2" rods (26" and 48")
- 4 short 1/2" rods (8")
- 2 swivel clamps
- 2 rod clamps

7 cables

- 1 multiconductor cable - 4 feet long (female cable plugs)
- 1 multiconductor cable - 30 feet long (female cable plugs)
- 1 multiconductor cable extension - 35 feet long (one male and one female cable plug)
- 1 welding cable - 15 feet long (black connectors)
- 1 welding cable - 30 feet long (red-coded connectors)
- 1 welding cable extension - 35 feet long (red-coded connectors)
- 1 shielded 2 wire cable - 25 feet long (microphone latch lock connector at one end)

Miscellaneous

- 1 open end wrench (7/16") for use with probe assembly
- 1 red-coded adaptor for attachment to red-coded welding cable
- 2 alligator clip assemblies for attachment to shielded 2 wire cable
- 1 trouble light
- Miscellaneous wooden spacer blocks: 1/2" x 3/4" x 3", 1/2" x 5/8" x 3", 5/8" x 3/4" x 3"

TABLE 2. Weight of the Various Field Circuit Breaker Tester Parts

1 Generator Input Unit	61 lb
1 Generator Output Unit	75 lb
1 Control Unit	14 lb
1 substitute meter base assembly and attached cables	10 lb
1 hand cart (unloaded)	38 lb
1 probe assembly including extra rod	7 lb
2 multiconductor cables (not including extension)	5 lb
2 welding cables (not including extension)	14 lb
All cables (including extensions)	34 lb
Total weight of equipment including cable extensions	239 lb

TABLE 3. Parts List for the Generator Input Unit (GIU)

Part	Manufacturer	Part Number
Aux. GFCI switch (1 pole, 15A)	Square D Co.	Q0-115GF1
Main GFCI switch (2 pole, 20A)	Square D Co.	Q0-220GF1
Master control contractor (Definite purpose contractor; 50A res., normally open)	Cutler Hammer, Inc.	9560H1416-49
Control relay (Normally open; 120 vac controlled by 3-32 vdc)	International Rectifier, Crydom Div.	D1210
Regulator controller	Superior Electric Co.	FR501B
Motor driven variable transformer	Superior Electric Co.	15MD236BU
Male chassis mount receptacle (AWG #16 contacts)	Amphenol North America Div. Bunker Ramo Corp.	MS3102A 20-27p

TABLE 4. Parts List for the Generator Output Unit (GOU)

Part	Manufacturer	Part Number
High current transformer	Signal Transformer Co., Inc.	9-250
Control Transformer	Superior Electric Co.	T6304
Instrument Transformers (4)	Instrument Transformer Co. through Pyttronic Industries of Savage, Maryland	Model 7 Part #7ASFT301
Pin receptacles (3):	Superior Electric Co.	
Red		RP250 GR
Yellow		RP250 GY
Black		RP250 GB
Male chassis mount receptacle (fourteen AWG #16 contacts)	Amphenol North America Div. Bunker Ramo Corp.	MS3102A 20-27P
Male chassis mount receptacle (twenty-four AWG #20 contacts)	Amphenol North America Div. Bunker Ramo Corp.	165-27

TABLE 5. Parts List for the Control Unit (CU)

Part	Manufacturer	Part Number
Start, stop pushbutton switch	Westinghouse Electric Corp.	SD2EØS
Control relay (normally open; 120 vac controlled by 3-32 Vdc)	International Rectifier, Crydom Div.	D1210
Current control potentiometer kit	Superior Electric Co.	26602-G-8
Current transformer	Scientific Columbus Unit Esterline Corp.	CT510A2
Relay 3PDT (120 vac coil)	Potter and Brumfield, AMF	KRP14AG
AC voltmeter	Non-linear Systems, Inc.	Model RM-450-TB-AC-115
Timer (programmable factoring timer)	United System Corp. (Digitec)	Model 8159
Peak and hold ammeter (DC voltmeter)	International Microtronics Corp.	Model A3183112
Ammeter (DC voltmeter)	International Microtronics Corp.	Model A3183002
Comparator circuit	See schematic of figure 10	
Duo-monostable multivibrator circuit	See schematic of figure 11	
Supply #1 (5vdc)	International Microtronics Corp.	supplied with model A3183112
Supply #2 (5vdc)	International Microtronics Corp.	supplied with model A3183002
Supply #3 (-5vdc)	Semiconductor Circuits, Inc.	SQ55500
Supply #4 (5vdc)	Semiconductor Circuits, Inc.	SQ55500
Male chassis mount receptacle (Fourteen AWG #16 contacts)	Amphenol North America Div. Bunker Ramo Corp.	MS3102A 20-27p
Male panel receptacle	Switchcraft, Inc.	B3M

TABLE 6. Parts List for the Meter Base Assembly and the Probe Assembly

Meter Base Assembly Parts	Manufacturer or Supplier	Part Number or Description
Base plate	Duncan Electric Co., Inc.	55809
Lexan cover	Duncan Electric Co., Inc.	50689
Contact blade assemblies (4)	Duncan Electric Co., Inc.	55457-16
Cotter pins (4)	Duncan Electric Co., Inc.	36453
Female cable connector for short cables (2)	Lenco Inc.	One half of LC-10 (includes both male and female)
Fuse holder - 250V, 30A	Bussmann Mfg. Div. of McGraw-Edison Co.	1B0003
Fuses - class RK5, 250V, 30A (2 per unit)	Bussmann Mfg. Div. of McGraw-Edison Co.	LPN-R 30
Center brass screw assembly	NBS	-
Cable (3 conductor)	-	AWG #12/3, type SO
Cable (1 conductor)	-	AWG #1 welding cable
Probe Assembly Parts		
Spring loaded probe and probe clamp	NBS	-
Female cable connector	Lenco, Inc.	One half of LC-10 (includes both male and female)
Vise-grip sheet metal clamps (2) (modification necessary)	McMaster-Carr Supply Co.	2445 All
Swivel holder castoloy clamps (2)	Fisher Scientific	5-762
Rod clamps (2)	Fisher Scientific	

TABLE 7. Parts List for the Interconnecting Cables

Part	Manufacturer	Part Number or Description
Multiconductor cable - 4 feet long: Wire (13 separate wires)	-	Stranded: 2 AWG #14, 3 AWG #18, 8 AWG #20
Female cable plug (2)	Amphenol North America Div. Bunker Ramo Corp.	MS3106A 20-27S with MS3057 cable clamp and AN3420 bushings
Multiconductor cable - 30 feet long: Wire (13 separate wires)	-	Stranded: 2 AWG #18, 11 AWG #20
Female cable plug (2)	Amphenol North America Div.	165-26
Multiconductor cable extension -35' feet long: Wire (13 separate wires)	-	Stranded: 2AWG #18, 11 AWG #20
Female cable plug	Amphenol North America Div.	165-26
Male cable receptacle	Amphenol North America Div.	165-27-1005
Single conductor cable - 15 feet long: Wire	-	AWG #1 welding cable
Male cable socket plug (black)	Superior Electric Co.	RP250 GB
Male cable plug (black)	Lenco, Inc.	One half of LC-10
Single conductor cable - 30 feet long: Wire	-	AWG #1 welding cable
Male cable socket plug (red)	Superior Electric Co.	RP250 GR
Male cable plug (black with red coding)	Lenco, Inc.	One half of LC-10
Single conductor cable extension -35' feet long: Wire	-	AWG #1 welding cable
Male and female connectors	Lenco, Inc.	LC-10
Shielded cable - 25 feet long: Wire	-	Flexible stranded microphone, 2 conductor shielded, AWG #22
Female cable plug	Switchcraft, Inc.	A3F

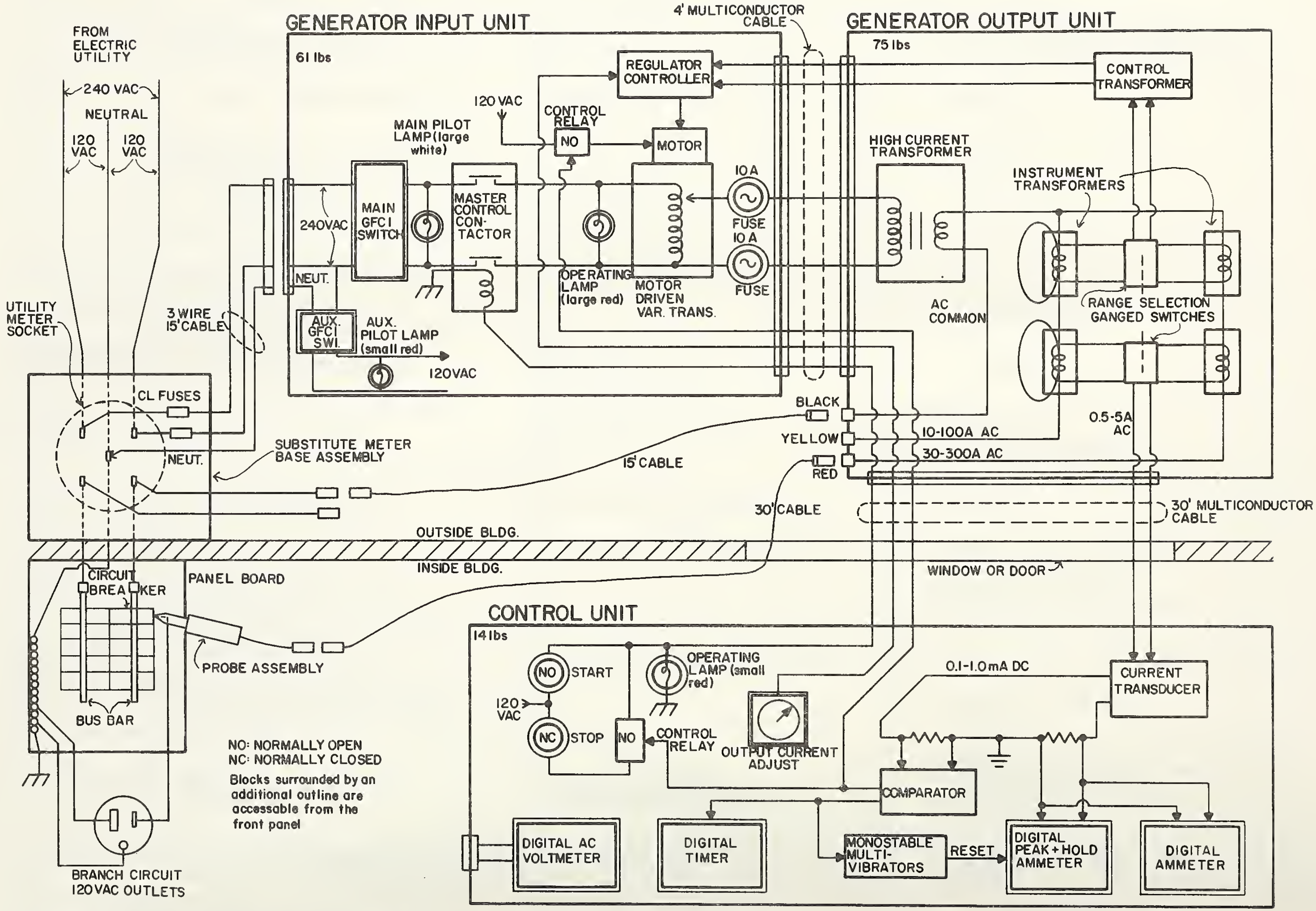


FIGURE 1. Block Diagram of the Field Circuit Breaker Tester

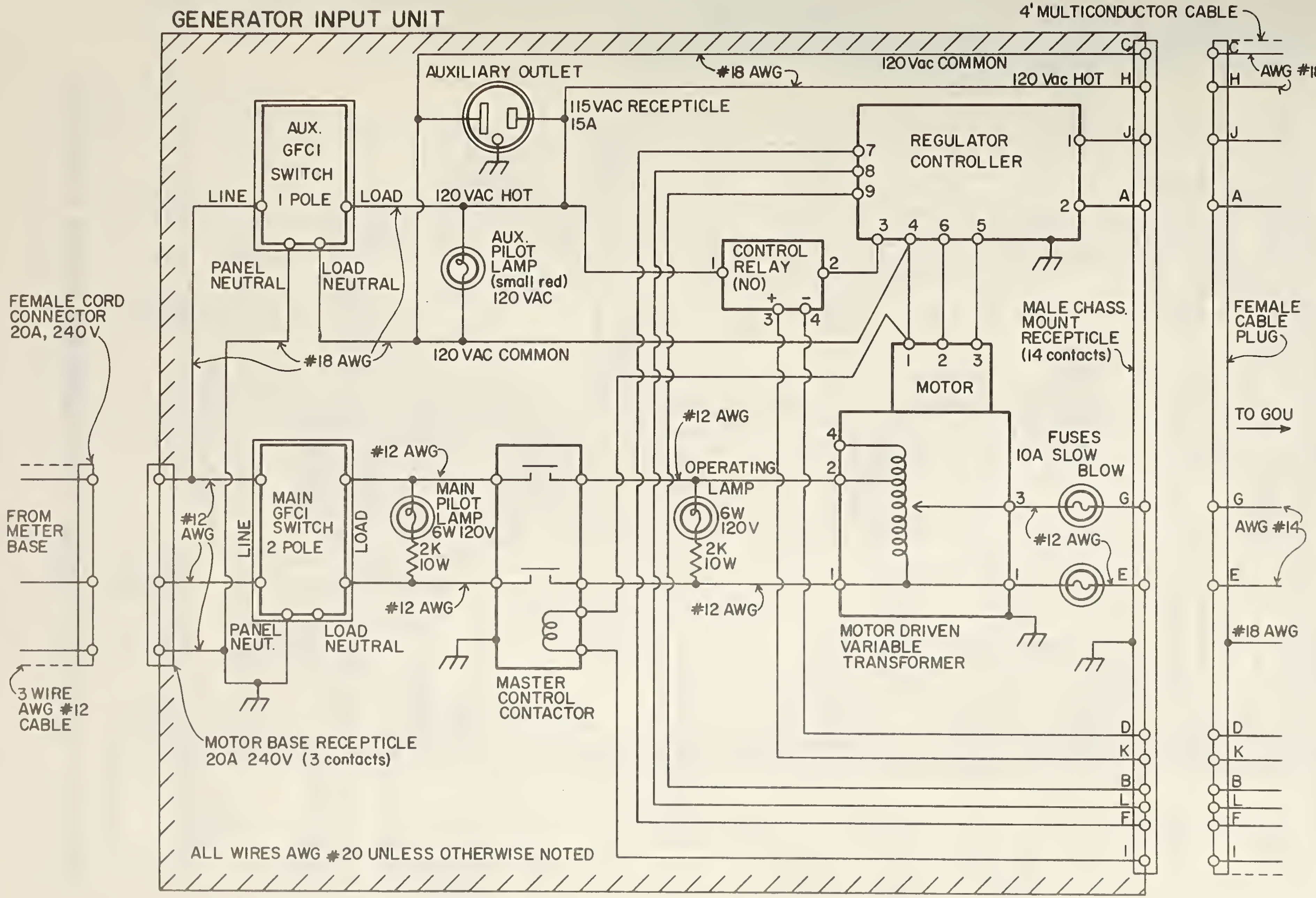


FIGURE 2. Schematic Diagram of the Generator Input Unit (GIU)

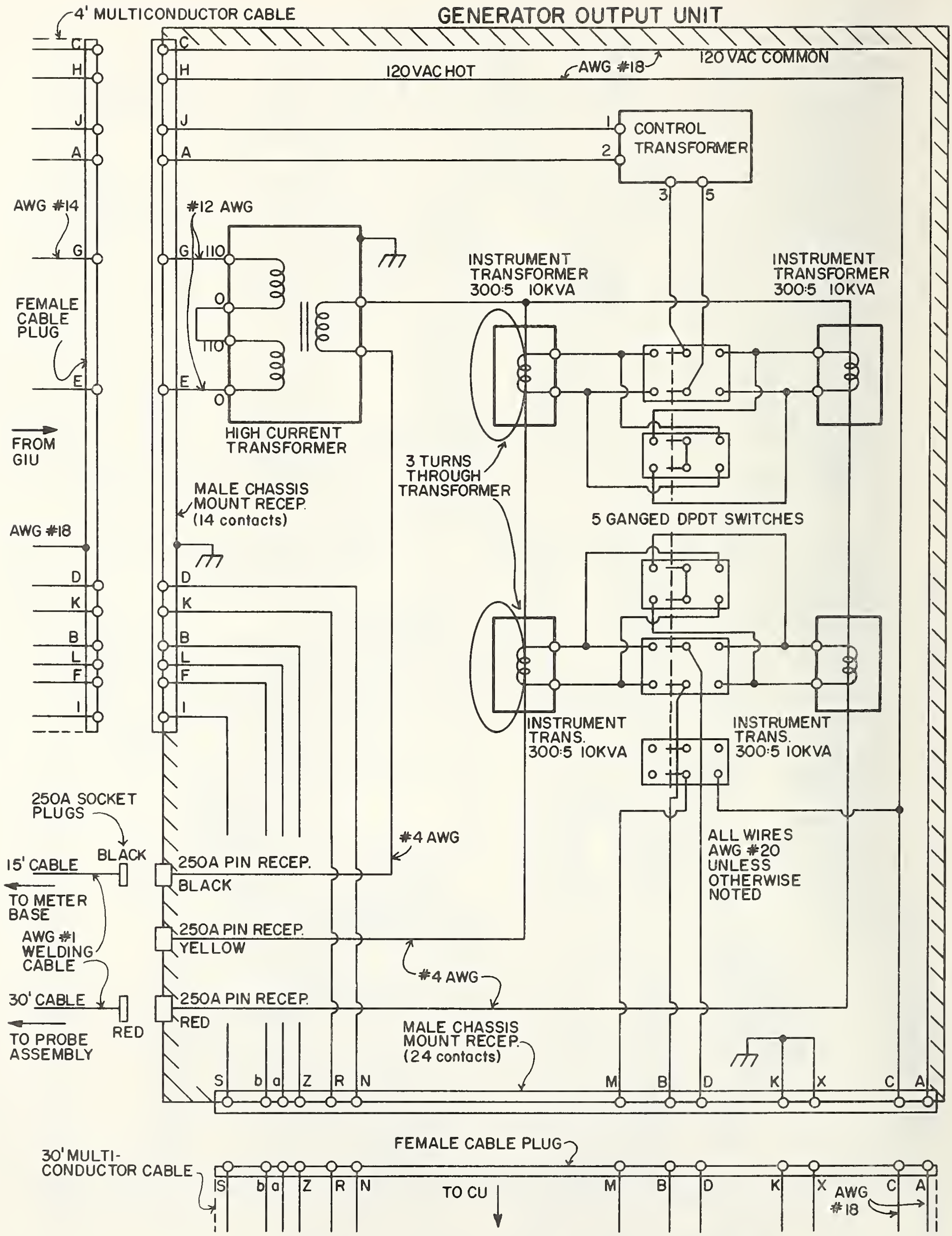


FIGURE 3. Schematic Diagram of the Generator Output Unit (GOU)

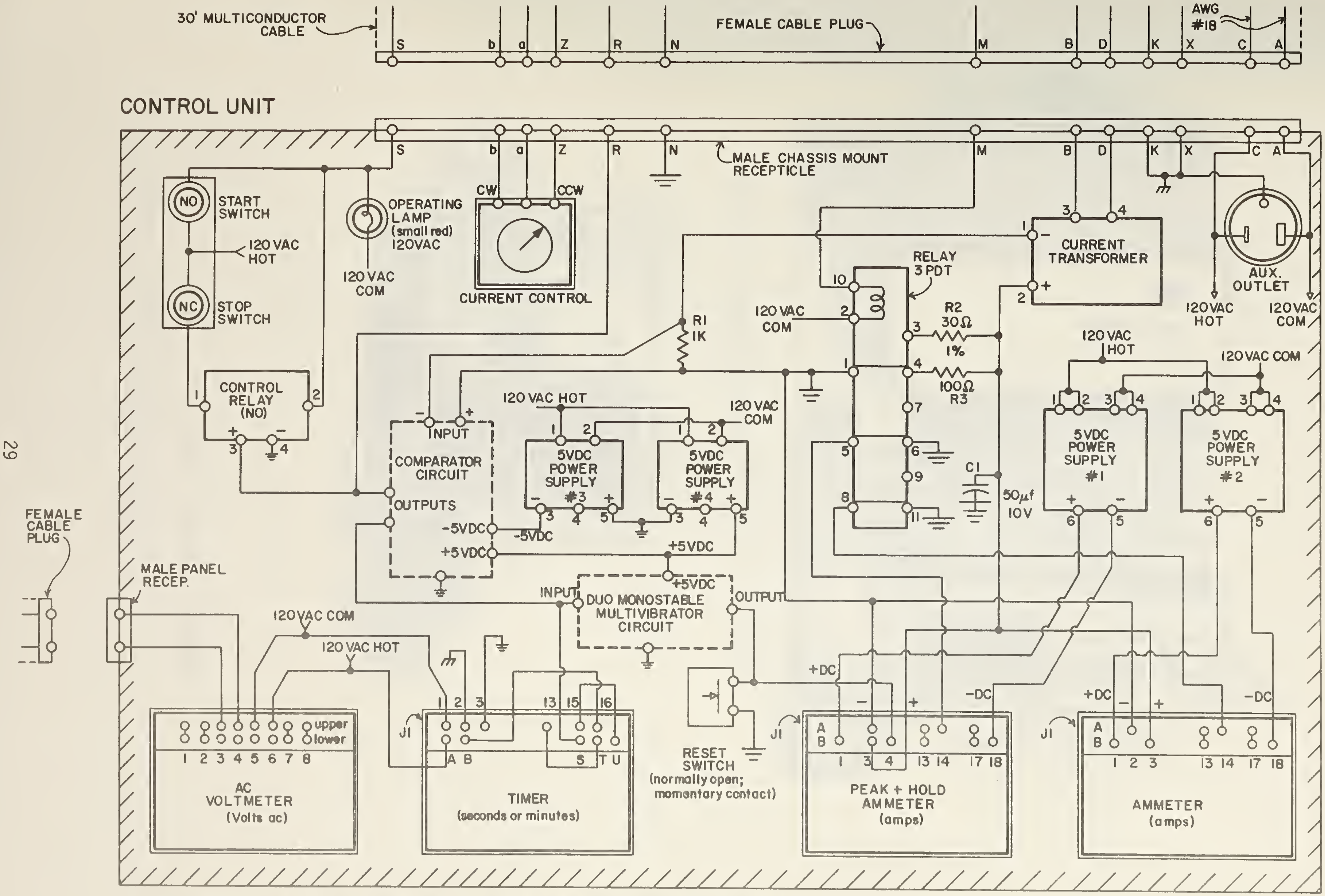


FIGURE 4. Schematic Diagram of the Control Unit (CU)

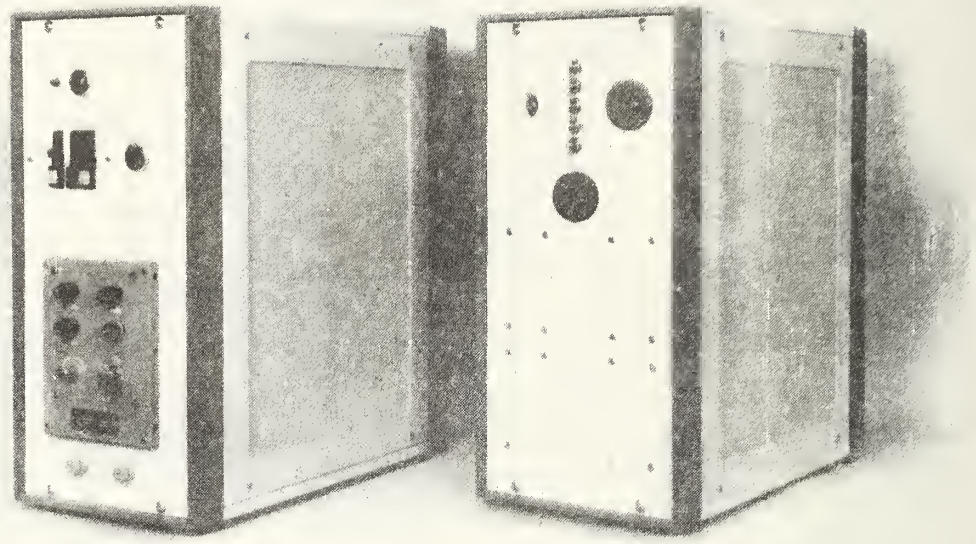


FIGURE 5. Generator Input and Generator Output Units

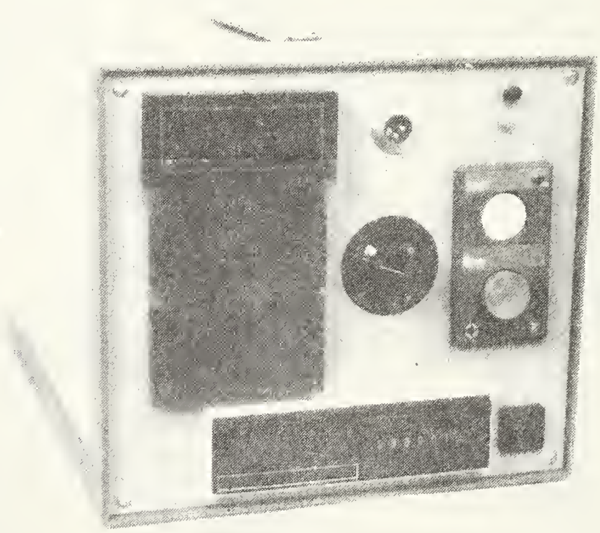


FIGURE 6. Control Unit

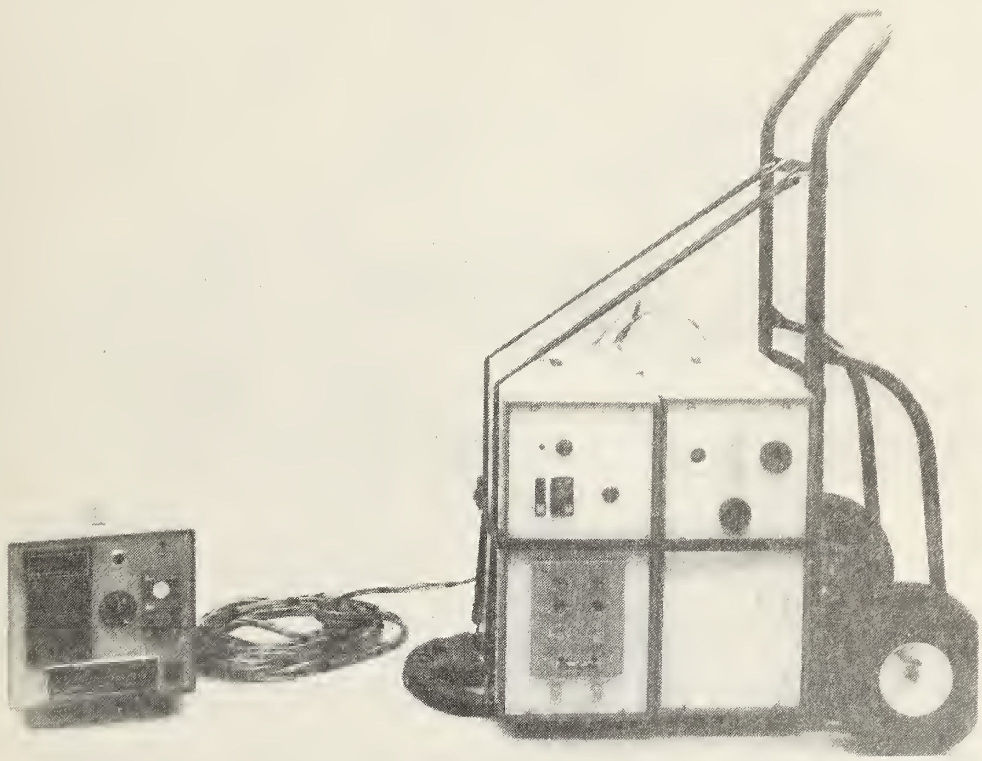


FIGURE 7. Generator Units Mounted on a Portable Hand Truck

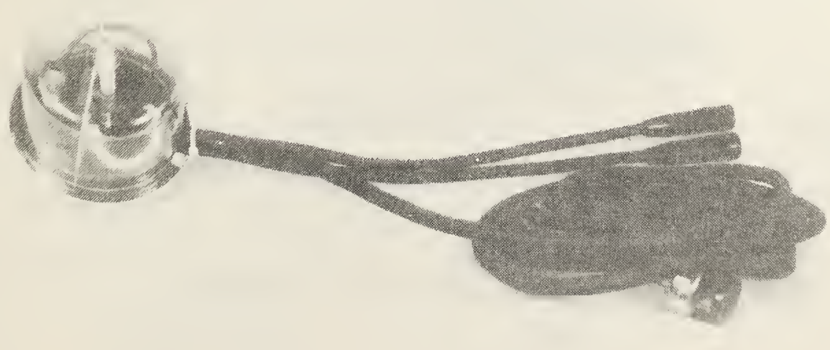
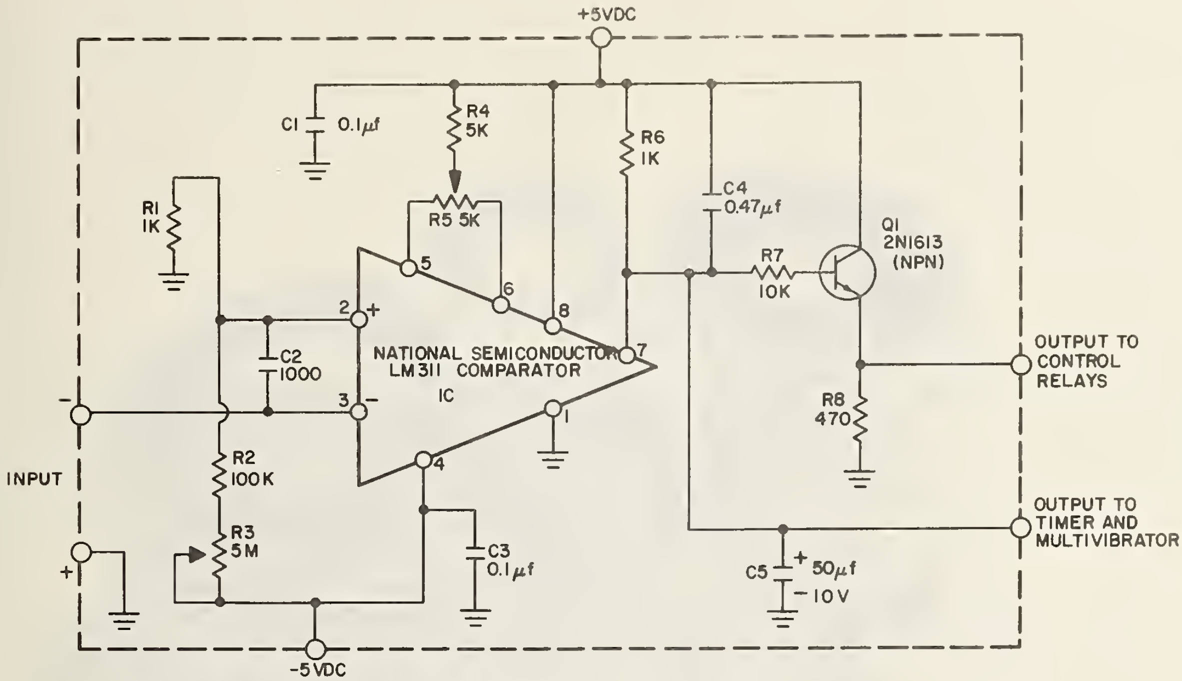


FIGURE 8. Substitute Meter Assembly

FIGURE 9. Spring Loaded Probe Assembly

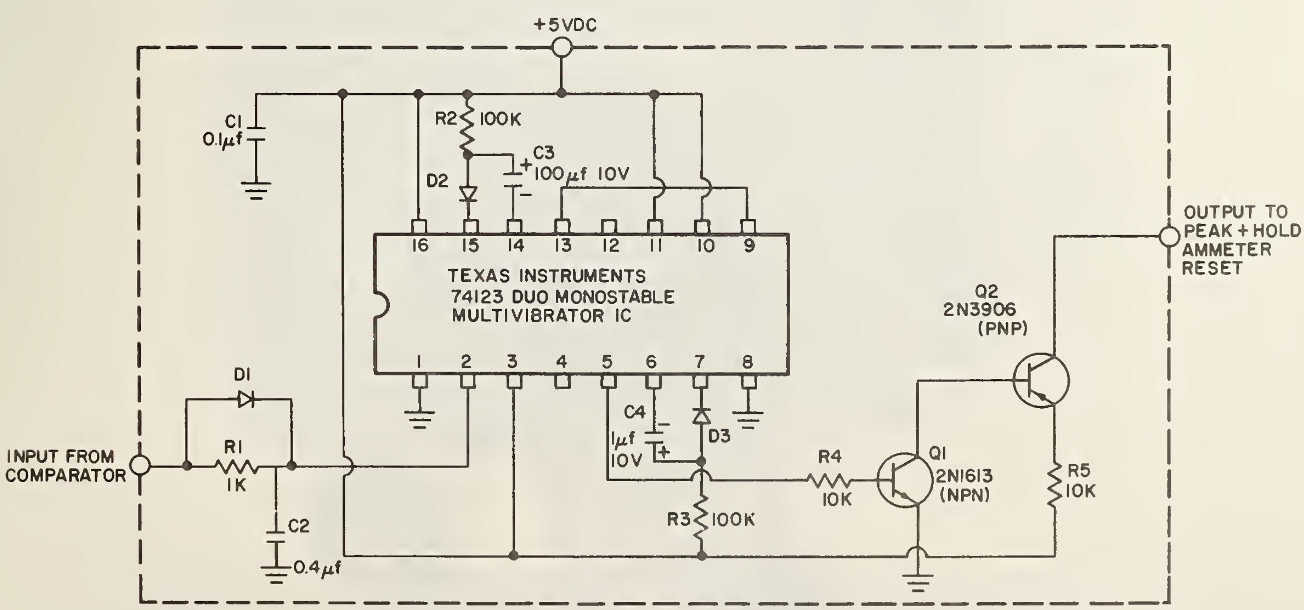


ALL RESISTORS AND POTENTIOMETERS ARE ¼ WATT

Q1 CAN BE ANY MEDIUM GAIN SILICON NPN TRANSISTOR

R3 SHOULD BE ADJUSTED SO THAT A CIRCUIT BREAKER TEST CURRENT OF 2 TO 3 AMPERES PRODUCES A HIGH LEVEL (>3.5 Vdc) OUTPUT, AND ZERO TEST CURRENT RESULTS IN A LOW LEVEL (< 1.0 Vdc) OUTPUT

FIGURE 10. Schematic Diagram of the Comparator Circuit



ALL RESISTORS ARE ¼ WATT

Q1 CAN BE ANY MEDIUM GAIN SILICON NPN TRANSISTOR

Q2 MUST HAVE LOW LEAKAGE CURRENT. USE ANY MEDIUM GAIN SILICON PNP TRANSISTOR

D1 CAN BE ANY GENERAL PURPOSE GERMANIUM DIODE

D2 & D3 CAN BE ANY GENERAL PURPOSE SILICON DIODE

FIGURE 11. Schematic Diagram of the Duo Monostable Multivibrator Circuit

FIGURE 12. Interconnecting Cables (the two extension cables are not shown)

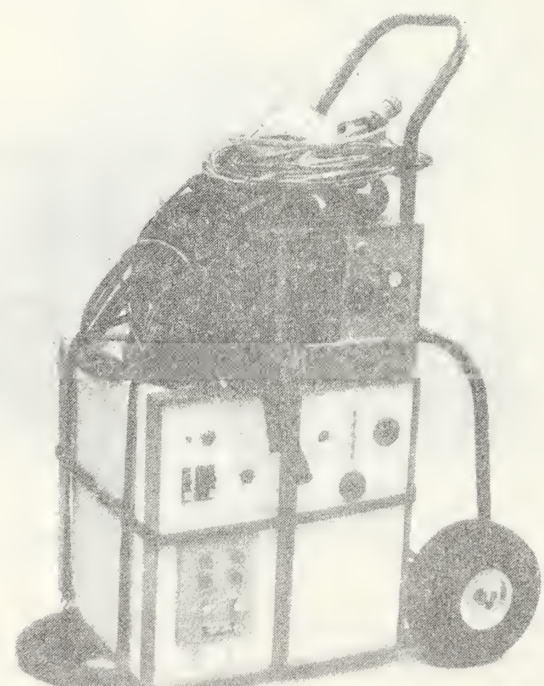


FIGURE 13. Field Circuit Breaker Tester Prepared for Travel

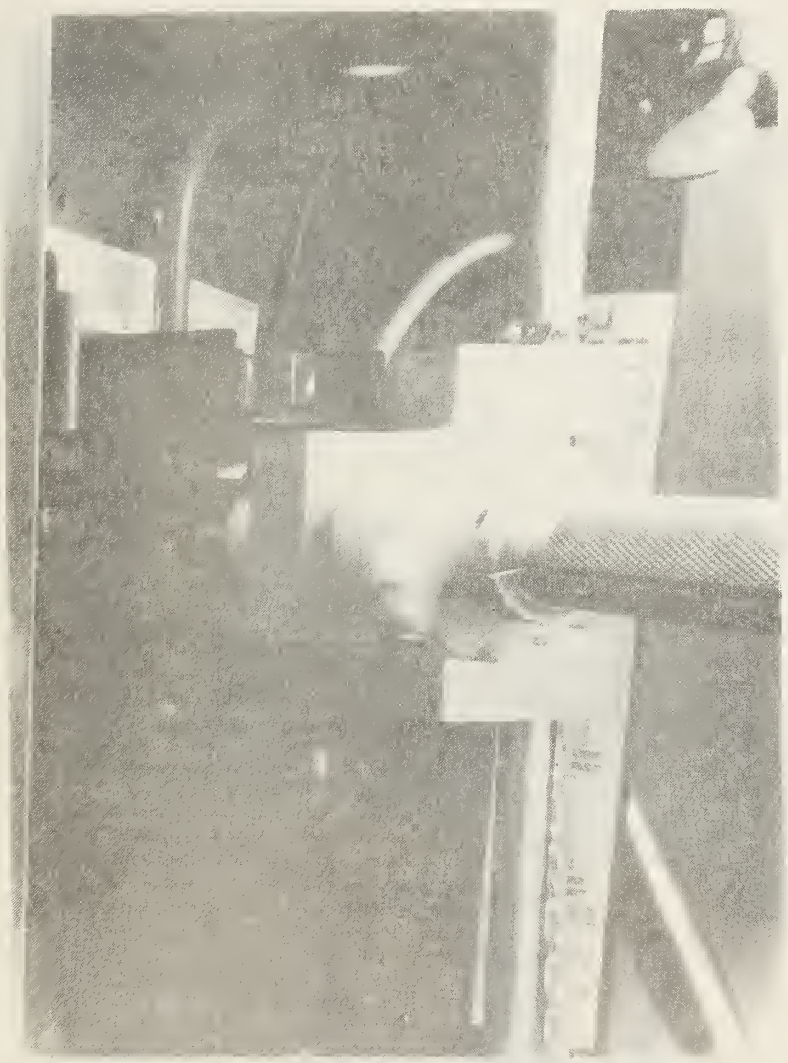


FIGURE 14. Closeup of the Spring Loaded Probe Contacting a Circuit Breaker Load Terminal

FIGURE 15. Individual Probe Assembly Parts

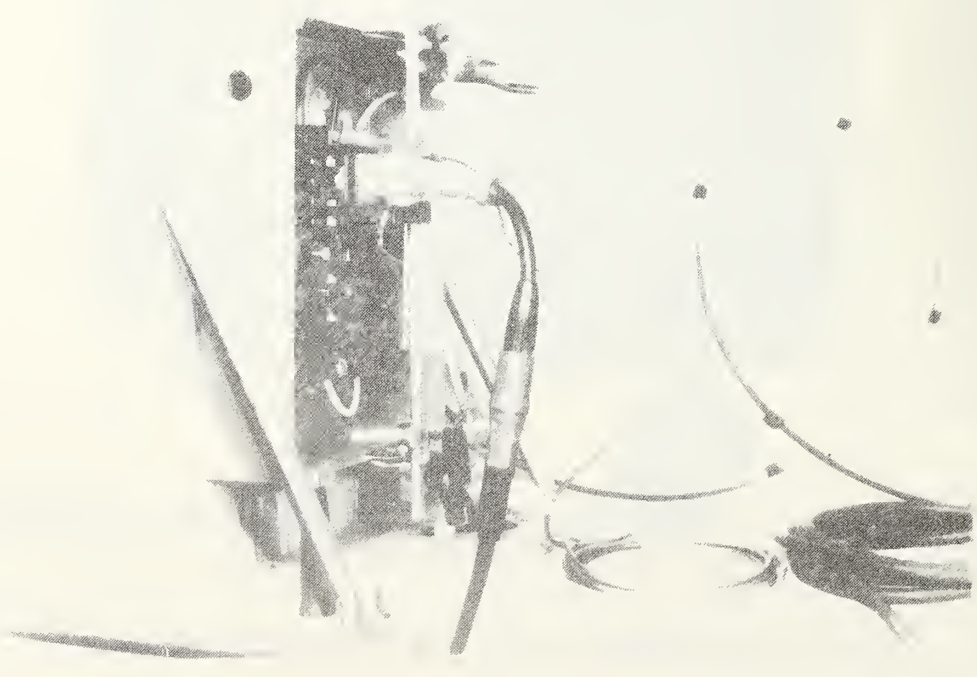


FIGURE 16. Probe Assembly Attached to a Panel Board

FIGURE 17. Interior View of the Generator Input Unit
(left side looking toward rear)

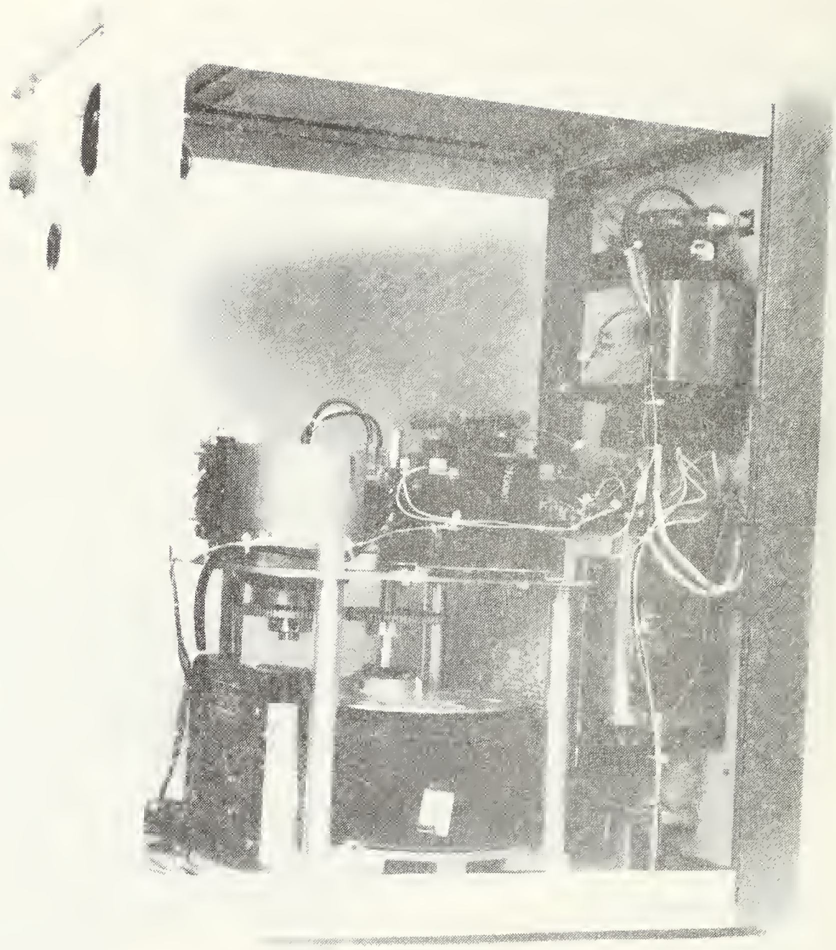


FIGURE 18. Interior View of the Generator Input Unit
(left side looking toward front)

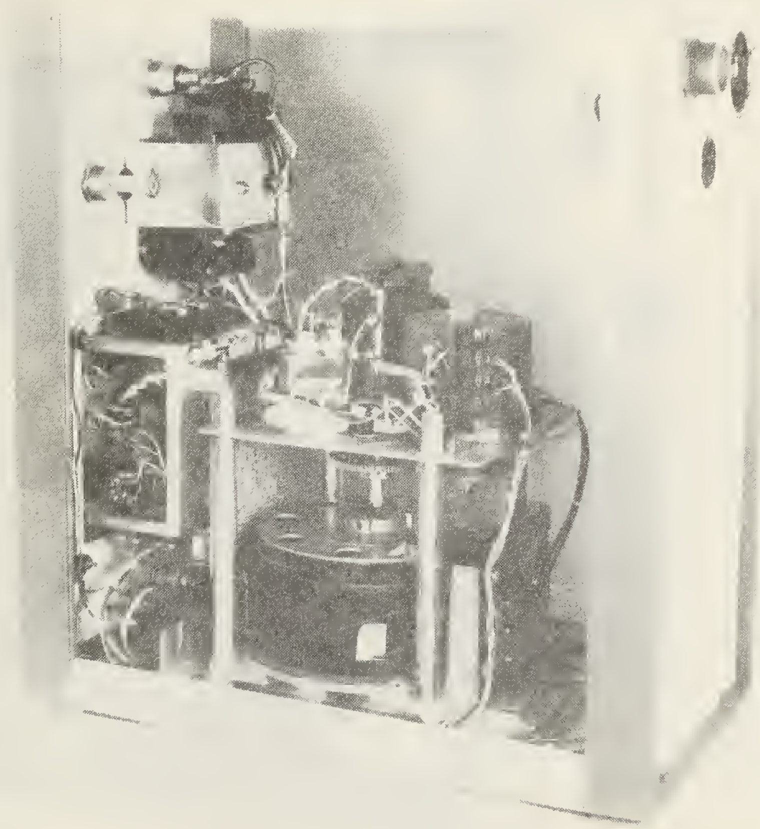


FIGURE 19. Interior View of the Generator Input Unit
(right side looking toward front)

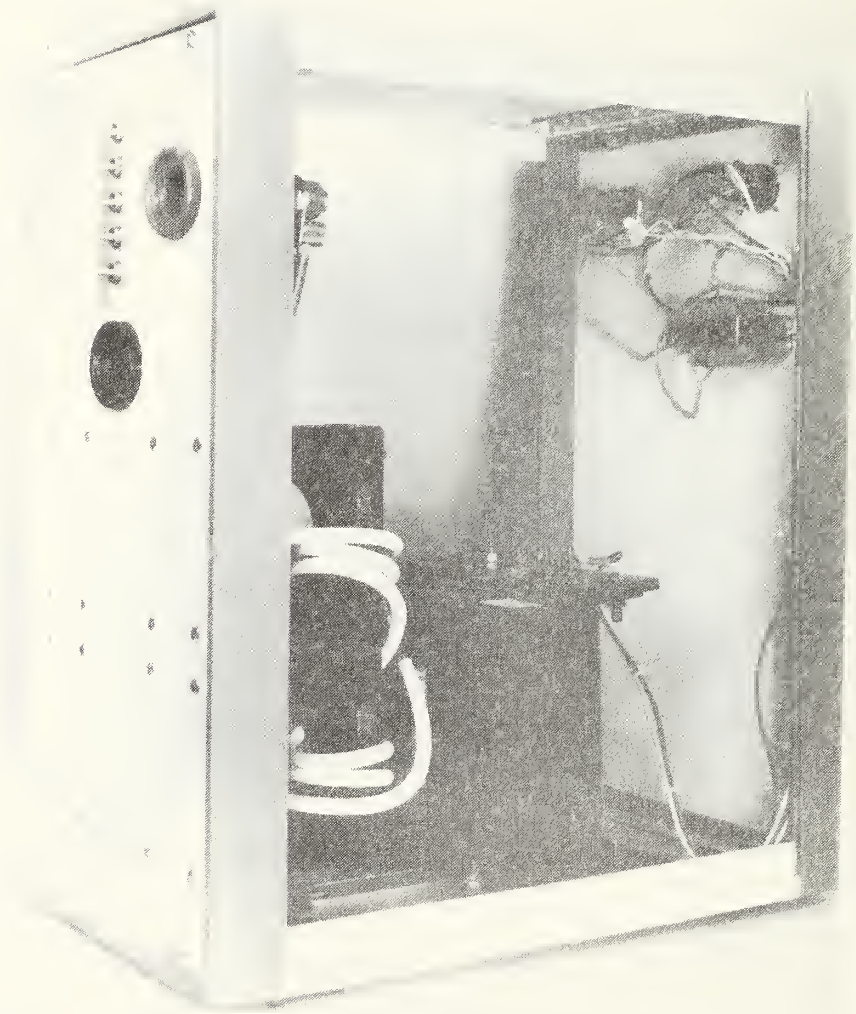


FIGURE 20. Interior View of the Generator Output Unit (right side looking toward rear)

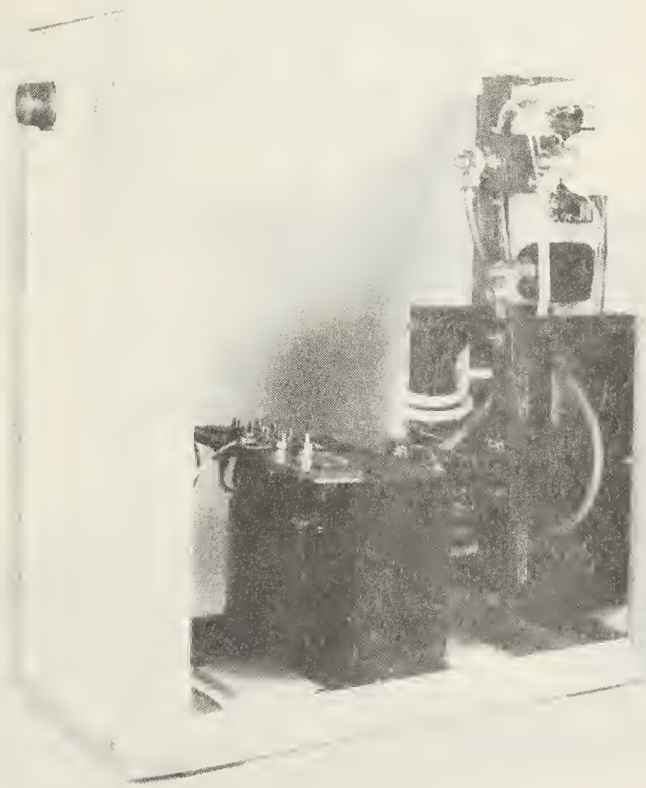


FIGURE 21. Interior View of the Generator Output Unit (left side looking toward front)

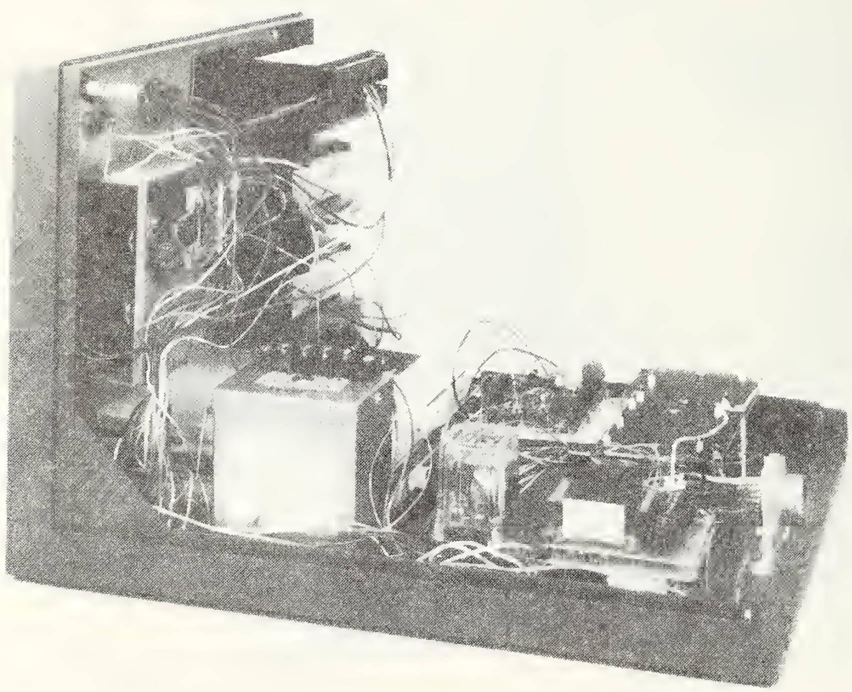


FIGURE 22. Side View of the Interior of the Control Unit

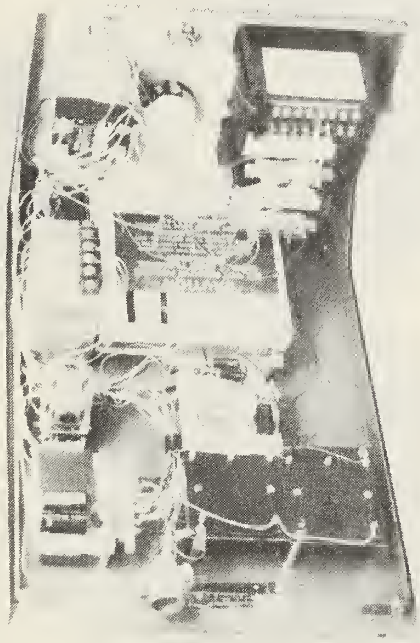


FIGURE 23. Rear View of the Interior of the Control Unit

FIGURE 24. Interior View of the Meter Base Assembly (upper section)

FIGURE 25. Interior View of the Meter Base Assembly (lower section)

FIGURE 26. Rear View of the Meter Base Assembly

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5. AUTHOR(S) P. Michael Fulcomer

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Consumer Product Safety Commission
Washington, DC 20207

10. SUPPLEMENTARY NOTES

☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

11. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here)

Overcurrent protection devices are required within an electrical distribution system to minimize the possibility of electrically initiated fires caused by circuit overloads. Circuit breakers are the most commonly used form of overcurrent protection in new and recent residential construction. However, the complexity of the circuit opening mechanism typical of these devices makes them susceptible to mechanical deterioration, which can affect their operation. A circuit breaker so affected may perform its intended function for a direct short type of fault but may not respond adequately to a less severe circuit overload condition.

The possibility that an unknown number of installed circuit breakers might not perform as intended under certain overload conditions prompted the Consumer Product Safety Commission (CPSC) to initiate an investigative testing program. The program will include visiting various field locations, subjecting installed circuit breakers to controlled overcurrent conditions, and evaluating their performance. In order to obtain valid field performance data, the testing will be accomplished without removing or otherwise disturbing the circuit breakers.

Test equipment developed at NBS for the CPSC to evaluate the performance of single-pole circuit breakers in residential installations is described in this report, along with instructions for its use. The procedures are intended to be carried out by a test crew of at least two persons.

12. KEY WORDS (Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)

circuit breaker; constant current; Consumer Product Safety Commission; electric power meter; on-site testing; overcurrent protection device; portable; residential applications; service entry; test.

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