PRIMARY INJECTION CIRCUIT BREAKER TEST SET
STANDARD RETROFIT PACKAGE
Memory Ammeter Controller
MAC-21

INSTRUCTION MANUAL

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TABLE OF CONTENTS

SECTION I

GENERAL INFORMATION

SECTION I

GENERAL INFORMATION

WARNING

WARNING - READ THIS ENTIRE MANUAL AND THOROUGHLY FAMILIARIZE YOURSELF WITH THE UNIT OPERATION PRIOR TO CONNECTING THE UNIT TO A SOURCE OF POWER. HIGH CURRENT TEST SETS ARE NORMALLY POWERED FROM HIGH CAPACITY 208 VOLT TO 575 VOLT SERVICES, AND IMPROPER CONNECTION OR OPERATION COULD CAUSE DAMAGE TO THE TEST SET AND EQUIPMENT UNDER TEST, AS WELL AS CREATE AN UNSAFE CONDITION FOR PERSONS OPERATING THE SET.

ABOUT THIS MANUAL

This manual consists of completely new descriptive, operational, and technical information, based on many years of experience in the design, manufacturing, and operation of electrical protective device test equipment. It is intended to provide useful, up-to-date and complete information for safe and efficient operation of the test set.

CHANGES FROM ORIGINAL TEST SETS

Several changes have been made in the design of high current test sets since early models such as the EIL BTS-50, many of which are important for safety and convenience of operation. Some of these may have been incorporated with the modifications associated with the upgrade to the MAC-21 metering and control system.

A new indicator panel has been installed which provides test (output ON/OFF) indicators, interlock indicators, and a power on indicator.

The EIL BTS-50, BTS-30 and BTS-20 units used the old Duffers current meter for current and time measurement. The newer BTS-500, BTS-300, and BTS-200 used the improved Accu-Amp. Units manufactured by other companies used other instrumentation for this purpose. In all cases covered by this manual, the old current meter and timer have been replaced with the MAC-21 microprocessor based measurement and control unit.

The test sets covered by this manual include the following:

1. EIL BTS-20
2. EIL BTS-200
3. EIL BTS-30
4. EIL BTS-300
5. EIL BTS-50
6. EIL BTS-500
7. GE Big I
8. Hipotronics 9025
9. Hipotronics 9050
10. Multi-Amp CB-225
11. Multi-Amp CB-225-66
12. Multi-Amp CB-7130
13. Multi-Amp CB-7150
14. Multi-Amp CB-7745
15. Multi-Amp CB-8130
16. Multi-Amp CB-8160

TRADEMARKS

1. "Duffers" refers to a device manufactured by Duffers Corporation
2. "Accu-Amp" is a trademark for a device originally made by EIL Instruments, Inc.
3. "SmartCore" is a trademark of ZWorld Engineering, Davis, CA.

INTRODUCTION

A high current test set, such as the EIL BTS-50, may consist of two pieces known as a "control unit" and an "output unit", or these functions may be combined in a single package. These two functions, when connected by external or internal power cables and control cables, form a test system with high current, low voltage outputs used for primary injection testing of direct acting low voltage circuit breakers. The indicator panel provides simple display of control power, output ON, and interlock conditions. The MAC-21 has replaced the old current metering system and timer, and also provides enhanced output control functions.

GENERAL DESCRIPTION

The MAC-21 microprocessor-based measurement and control unit features digital readout of current and time enhanced by digital signal processing. Pulse (memory) mode provides fast and accurate automatic evaluation of output current pulses as short as one half cycle.

The MAC-21 incorporates a precision A/D converter and special firmware for true-RMS continuous and pulse current reading with much greater accuracy. It also utilizes a sophisticated current sensing system for more reliable current latch mode operation and better timing accuracy. An LED digital readout for current in four ranges from 1000 A to 100 KA reduces the chance of operator error. An integral autoranging timer with LED readout provides four digits in seconds or cycles mode, with a resolution of 0.001 second or 0.5 cycle. A preset function allows you to set a maximum ON time in seconds or cycles, for convenient "jogging" of output to desired current. The entire metering and control package is designed to be removed and replaced very easily, so that it may be transported separately.

The complete retrofit package also includes wiring changes to the original unit to accommodate the MAC-21, and may also require an additional or modified control panel to accomplish tap changes and vernier control. The retrofit is designed to simplify the basic control functions for reliability and ease of troubleshooting.

SECTION II

DETAILED DESCRIPTION

SECTION II

DETAILED DESCRIPTION

THEORY OF OPERATION

High Current Test Sets

High current test sets generally consist of the following:

1. One or more coarse taps accomplished by:
   (a) A tapped autotransformer providing several equal steps of voltage or
   (b) A multi-section output transformer
2. A continuously variable vernier adjustment between coarse taps by means of:
   (a) A variable autotransformer and boost transformer, or
   (b) A variable autotransformer connected to a section of the output transformer.
3. An output transformer with one or more isolated low voltage, high current secondary.
4. Power control circuitry consisting of switches, relays, protective devices, etc.
5. Current measurement circuitry consisting of sensors, current meter, and timer.

In general, a primary voltage is selected by means of a combination of coarse tap and vernier adjustment. This voltage is stepped down by the output transformer to provide the desired current into the load impedance.

For test sets using an electromechanical contactor, an AC-controlled solid-state relay with zero-crossing detection is often used to energize the main contactor. This provides some consistency of output waveform, since the contactor will always pull in at some fixed time after the zero crossing, and hopefully not at a multiple of a half-cycle. This tends to minimize the DC offset which results when an inductive load is energized at or near the voltage zero-crossing.

Many modern test sets use solid-state SCR controllers, with electronic circuitry to provide precise phase control of initial firing angle. Solid state contactor replacement is a retrofit option that is highly recommended.

MAC-21 Unit Circuitry

The current measurement function of most breaker test sets is based on the principle of an air core inductor, which may be used to sense a magnetic field, which is proportional to the rate of change of current flowing in an adjacent conductor. The output voltage of the inductor is therefore proportional to the rate of change of current in the conductor. For practical purposes, the sensing inductor is usually made in the form of a split core, or "fork", which fits closely around the current-carrying buswork.

In the measurement system, in this case the MAC-21, the signal from the current sensor (typically about 240 mV for 1000 Amperes), is connected to an integrator, consisting of precision resistors and a capacitor. This signal is processed by a variable-gain instrumentation amplifier, and a digitally programmable gain circuit. An analog to digital converter (ADC), under microprocessor control, reads this.

Retrofit Indicator Panel

The retrofit indicator control panel replaces the original control panel, and performs the functions of indicating POWER ON, OUTPUT ON, and INTERLOCK.

The POWER ON lamp is connected across the 120 VAC high and low circuits, and should light whenever power is applied to the test set and the main power switch or circuit breaker is turned on.

The OUTPUT ON lamp indicates that the SCR or contactor is energized.

The INTERLOCK lamp indicates that the interlock circuit is open. This may occur when an interlock switch on an access door is open, the push-to-turn tap switch is engaged, the interconnecting cable is not properly in place, or a thermal switch is open. The initiate circuit is disabled by relay contacts.

MAJOR PARTS IDENTIFICATION AND OPERATION

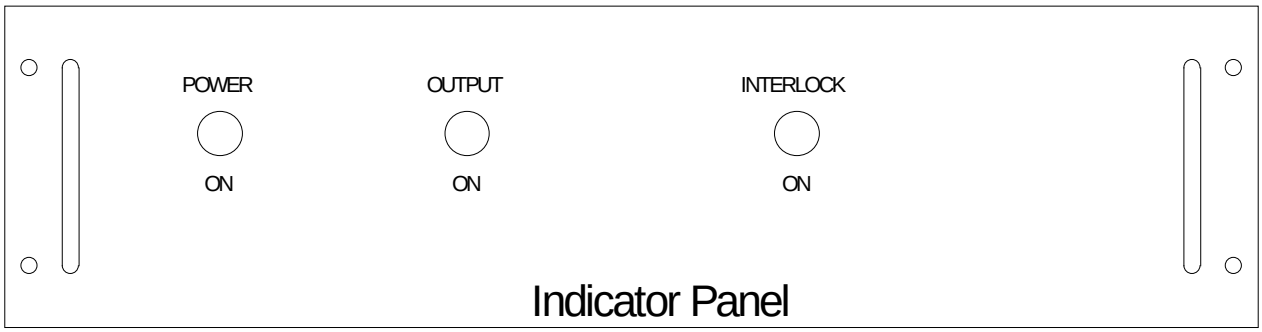
Retrofit Indicator Panel

POWER ON indicator: This amber neon lamp lights when power is applied to the test set.

OUTPUT ON indicator: This red neon lamp lights when the SCR firing circuit is energized, indicating that the output should be ON.

INTERLOCK ON indicator: This red neon lamp lights when one of the test set interlocks are ON, which inhibits output initiation.

Figure II-2 - Retrofit Indicator Panel



SECTION III

MAC-21 Monitor and Controller

MEMORY AMMETER CONTROLLER
MAC-21

INSTRUCTION MANUAL

Firmware Version 3.06 and above

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MAC-21 Specifications

INPUT POWER:

120 VAC, SINGLE PHASE
50/60 HZ, 20 VA Max

CURRENT RANGES:

0-1,000 / 5,000 / 25,000 / 100,000 Amperes

CURRENT ACCURACY:

+/- 0.5% Reading + 0.5% Range + 1 Digit (Continuous)
+/- 1.0% Reading + 1.0% Range + 1 Digit (Pulse > 0.01 sec)

TIMER RANGES:

0-9.999 / 0-99.99 / 0-999.9 / 0-9999 Seconds
0-999.9 / 0-9999 Cycles

TIMER ACCURACY:

+/- 0.005 sec +/- 0.005% of reading +/- 1 count

DIMENSIONS AND NET WEIGHT

Height:	7.0 in. (178 mm)
Width:	19.0 in. (483 mm)
Depth:	2.0 in. (51 mm)
Weight:	3.7 lb. (1.68 kg)

STANDARD ACCESSORIES

Remote Initiate cable	1	S-B143
Contact Leads	1 pair	S-A108

MAJOR PARTS IDENTIFICATION AND OPERATION

MAC-21 Control Panel

TIME DISPLAY: This 4 digit LED display normally indicates the elapsed time of a current pulse. In SECONDS mode, it displays time up to 9.999 seconds, then autoranges to 99.99 seconds, 999.9 seconds, and 9999 seconds. In CYCLES mode, it reads time (based on 60 Hz), up to 999.9 cycles, then autoranges to 9999 cycles. If time exceeds maximum display capacity (10,000 seconds or 10,000 cycles), the display will read "OVER". In PRESET mode, the display indicates the maximum time of initiation (ON time), in either cycles or seconds. A reading of zero disables the PRESET function, and allows any time.

CURRENT DISPLAY: This 4 digit LED display indicates the output current. In CONTINUOUS mode, as well as in MEMORY mode before and during a test, the display indicates true-RMS output current in real time. After completion of a test, in MEMORY mode, the display shows the true-RMS value as computed over the entire length of the pulse. This mode is indicated by a flashing LED on the MEMORY key. If a reading exceeds the maximum value for the selected range, the display will read "OVER".

This display is also used When the timebase is in SECONDS mode, press the STOP key to display the last average RMS value displayed in CONTINUOUS mode. This is useful for pickup tests. It may not be accurate for times less than 1 second.

INITIATE key: This key is used to turn ON the output of the test set. The LED in the key indicates that the MAC-21 is attempting to turn the output ON, but other conditions (such as interlocks) could keep the output from actually turning on. In MOMENTARY mode, the key must be held to keep output current on. In MAINTAIN mode, once current is detected, the output will stay on until the breaker trips, or the STOP or RESET button are pressed. The MAC-21 must be RESET in order to initiate output, and in N.C. or N.O. contact modes, the contact status (continuity) must indicate that the breaker is closed. If the output on time exceeded the PRESET time, as indicated by flashing of the PRESET key LED, the INITIATE key will automatically reset the MAC-21 and turn the output on.

STOP key: This key is used to turn the output of the test set OFF. Its LED indicates that output is not being turned on by the MAC-21, but other conditions could cause output voltage to be ON. Use of this key is usually necessary only when in MAINTAIN mode, and it is necessary to abort the test before the breaker trips. **NOTE:** It is important to realize that the interlock system of the circuit breaker test set may also turn the output off, but it will turn back ON when the interlock condition is cleared (in N.O. and N.C. modes only).

RESET key: This key resets the displays on the MAC-21, and arms the pulse reading system. The LED on the key indicates that the system is reset and armed. RESET also takes the unit out of PRESET ADJUST mode.

MAINTAIN key: This key toggles the MAINTAIN mode for initiation; its LED indicates that this mode is enabled. When in MAINTAIN mode, the INITIATE key need only be pressed briefly to turn output on. MAINTAIN must be set in order to read pulse current when output is initiated by means other than the MAC-21.

For test sets with motorized vernier, the MAINTAIN key may be pressed while output is ON to provide automatic current hold. The LED in the MAINTAIN key will blink while this mode is set, and the vernier motor will be activated whenever the current varies more than 5 amperes from the value displayed when the key was pressed. The key may be pressed again to return to normal mode. STOP or RESET will also discontinue current hold.

N.O. key: This key is used to set the Normally Open contacts mode. In this mode, lack of continuity on the CONTACTS binding posts indicates that the protective device under test is in its normal (non-tripped) mode, and ready to accept current. In N.O. mode, after the INITIATE key is pressed, the timer starts when current (about 3% of range) is detected. The timer stops when the STOP key is pressed or continuity is sensed at the CONTACTS binding posts. Timing accuracy in this mode is typically +/- 0.01 seconds.

N.C. key: This key is used to set the Normally Closed contacts mode. In this mode, continuity on the CONTACTS binding posts indicates that the protective device under test is in its normal (non-tripped) mode, and ready to accept current. This mode may be used for testing multi-pole breakers by connecting the CONTACTS binding posts to an unused pole. In N.C. mode, the timer starts as soon as current (about 3% of range) is detected after the INITIATE key is pressed, and stops when the STOP key is pressed or a break in continuity is sensed at the CONTACTS binding posts. Timing accuracy in this mode is typically +/- 0.01 seconds.

C.L. key combination: When the N.O. and N.C. keys are pressed simultaneously, both LEDs light, indicating C.L. mode (Current Latch). This is the normal power-up default mode for the test set, and is recommended for all tests, unless there is a good reason for using contacts to sense trip. In this mode, current is continuously sampled, and when it exceeds approximately 10% of the current range value, the timer starts, and calculation of pulse current begins. When current stops (or drops below a dynamically determined threshold value), the timer stops running, and the final value for pulse current is calculated and displayed. If the output was initiated by the MAC-21, it is turned OFF. **NOTE:** in C.L. mode only, the contacts jacks may be used for remote initiation (see below).

PRESET key: This key toggles the PRESET ADJUST mode, indicated by illumination of its LED. When PRESET ADJUST is active, the adjacent SECONDS and CYCLES keys respectively lower and raise the preset time in seconds or cycles, depending on the timebase that was selected. Both keys may be pressed simultaneously to reset the

time limit to zero, which disables the time limit function. When not in PRESET mode, the LED will flash if the displayed time exceeds the preset limit.

SECONDS key: This key normally selects the SECONDS timebase. If the PRESET mode is selected, this key is used to LOWER the preset time limit by decrements of 1.000 second (5.000 seconds above 10.00) with the SECONDS timebase, or 1.0 cycles with the CYCLES timebase. If it is held, the reading will decrease at a rate of about 5 intervals per second. If a preset time limit was set in SECONDS mode, the output will be turned off within 200 milliseconds of the limit. SECONDS or CYCLES timebase may be selected at any time before, during, or after a test.

CYCLES key: This key normally selects the CYCLES timebase. If the PRESET mode is selected, this key is used to RAISE the preset time limit by increments of 1.000 seconds (5.000 seconds above 10.00) with the SECONDS timebase, or 1.0 cycles with the CYCLES timebase. If it is held, the reading will increase at a rate of about 5 intervals per second. If a preset time limit was set in CYCLES mode, the output will be turned off within several milliseconds after the limit has been reached. SECONDS or CYCLES timebase may be selected at any time before, during, or after a test.

MEMORY key: This key toggles the MEMORY mode, indicated by illumination of its LED. When in CONTINUOUS mode (LED off), the current display always reads the real-time continuous output current of the test set. In MEMORY mode (LED on), the current display will read the continuous output current until the test is complete. At this time, the LED will flash, and the display will read the computed true-RMS value of the entire current pulse for the duration indicated on the TIME display. This key may be pressed at any time before, during, or after the test, to toggle between the two modes.

As described above, pressing the STOP key provides access to display of peak RMS and last average RMS current.

1000 A range key: This key selects the 1000 ampere range, which provides best accuracy of readings up to about 1000 amperes. Nominal currents close to this limit, when applied to the device under test, will sometimes cause higher peak currents, causing the display to read "OVER", indicating an overrange condition. If this happens, select the next higher range. Pressing any range switch will also RESET the MAC-21.

5 KA range key: This key selects the 5.000 KA range, for output currents up to about 5,000 amperes. See above for information common to all ranges.

25 KA range key: This key selects the 25.00 KA range, for output currents up to about 25,000 amperes. See above for information common to all ranges.

100 KA range key: This key selects the 100.0 KA range, for output currents up to about 100,000 amperes. See above for information common to all ranges.

CONTINUITY lamp: This LED lights when continuity is detected at the CONTACTS binding posts in N.O. and N.C. modes. The beeper will also sound whenever contacts

change state.

CONTACTS/REMOTE jacks: These jacks provide a low-power AC signal which detects continuity in N.O. and N.C. modes, or is used with a pushbutton cord switch for remote initiate function (see below). A resistance of about 200 ohms or less will be interpreted as continuity. Although the signal is low power and transformer isolated, it is good practice to avoid touching any conductive surface connected to these terminals. **CAUTION: NEVER CONNECT THESE TERMINALS TO ANY LIVE CIRCUIT!**

REMOTE INITIATE: In C.L. mode only, the CONTACTS jacks provide a remote initiate function. For safety reasons, this function is disabled in MAINTAIN mode, unless a preset value is set in CYCLES timebase.

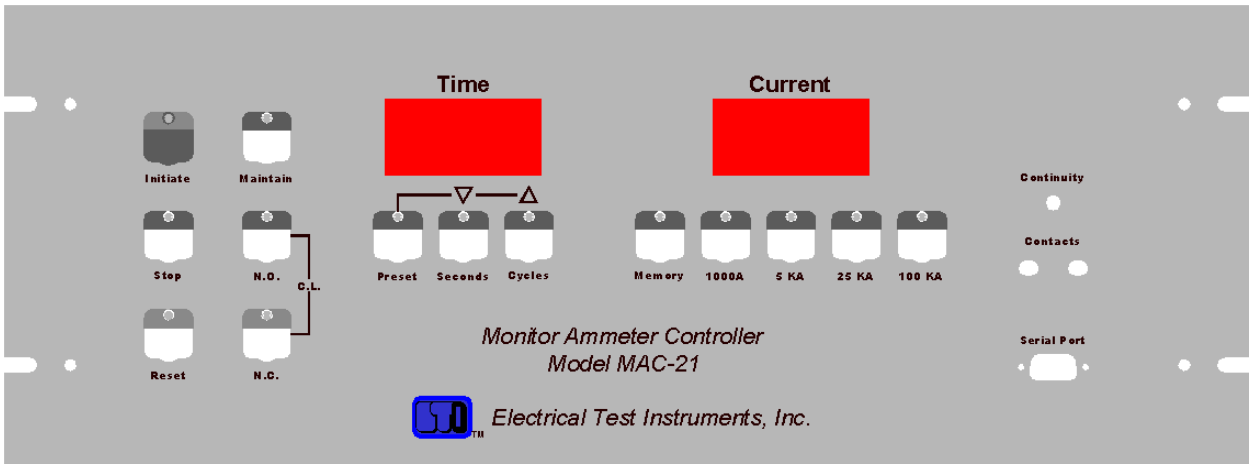
SERIAL port: This standard serial port may be connected to a printer, computer, or other device to print or store time and current values of test results in ASCII format. It is set for 9600 baud, 8 bits, 1 stop bit, no parity, no flow control. This information is sent at the end of each test, or by pressing the Stop and Reset keys.

Report Generator Software Option: we also offer a software package for a Windows based computer that takes the data from the serial port and inserts time and current values into an excel document. Must have Microsoft office installed for this software to function properly. This can be custom tailored to Your excel document or use the generic document that is provided with the software

MAC-21 Internal Parts

INPUT CONNECTOR: This connector, located on the upper rear corner of the MAC-21, provides 120 VAC control power, and connects to the air core CT (current sensor), and initiate circuitry of the test set. The wiring of this connector is essentially compatible with that of the EIL Accu-Amp, and is designed to facilitate removal of the MAC-21 for service or shipment. Additional pins are used to provide isolated logic level control for motorized vernier raise and lower for the current hold feature.

Figure II-2: MAC-21 Front Panel



SERVICE INFORMATION AND DOCUMENTATION

MAINTENANCE AND CALIBRATION OF THE MAC-21

The MAC-21 is manufactured using solid state components that should not require extensive maintenance. However, the accuracy of the MAC-21 is critical to the testing of circuit breakers, and is dependent upon the output of an air-core current sensing coil, which could change due to movement caused by shock or vibration encountered in transporting the test set. Other factors which may affect calibration are contact resistance in the control cable, unusual magnetic fields, insulation leakage, and aging of electronic components in the MAC-21. Therefore, proper operation and calibration should be checked at regular intervals, and adjusted if proper equipment is available.

The inherently delicate nature of electronic circuitry and metering make it generally inadvisable to leave the MAC-21 fastened into the breaker test set while it is being transported, and subject to shock and vibration. The standard rack-mount hardware and twist-lock connector make it simple to remove the MAC-21 and carry it separately.

Field calibration of the MAC-21 may be performed as follows:

1. Obtain a current measuring calibration standard capable of reading TRUE-RMS current up to at least 1000 Amperes to an accuracy of at least 0.25%. This may consist of a shunt or current transformer, in conjunction with a digital multimeter or laboratory grade AC ammeter.
2. Set up the breaker test set for normal breaker testing. If adjustments are anticipated, remove the MAC-21 from the test set .
3. Connect the calibration standard to the desired output tap. If cables are used, it is recommended that they be twisted so as to minimize radiation and pickup of stray magnetic fields.
4. Apply power to test set, and allow at least one minute for circuits to stabilize.
5. Check ammeter zero in all ranges. If reading on current meter is greater than 1% of range, internal zero adjustment may be required.
6. Set MAC-21 Range to 1000 A, and adjust output of breaker test set to exactly 800 Amperes. If Coarse Tap is 1, and Output Control Vernier is less than 50%, additional resistance must be added to output circuit. This is important, because waveform distortion is more prevalent at lower levels.
7. If the MAC-21 reading differs from the standard by more than rated accuracy, adjust the gain potentiometer on the analog board for proper reading. If an error of more than 5% is noted, and unit has been in service, the accuracy and validity of previous tests may be questionable; otherwise, there may be a problem in the test

setup.

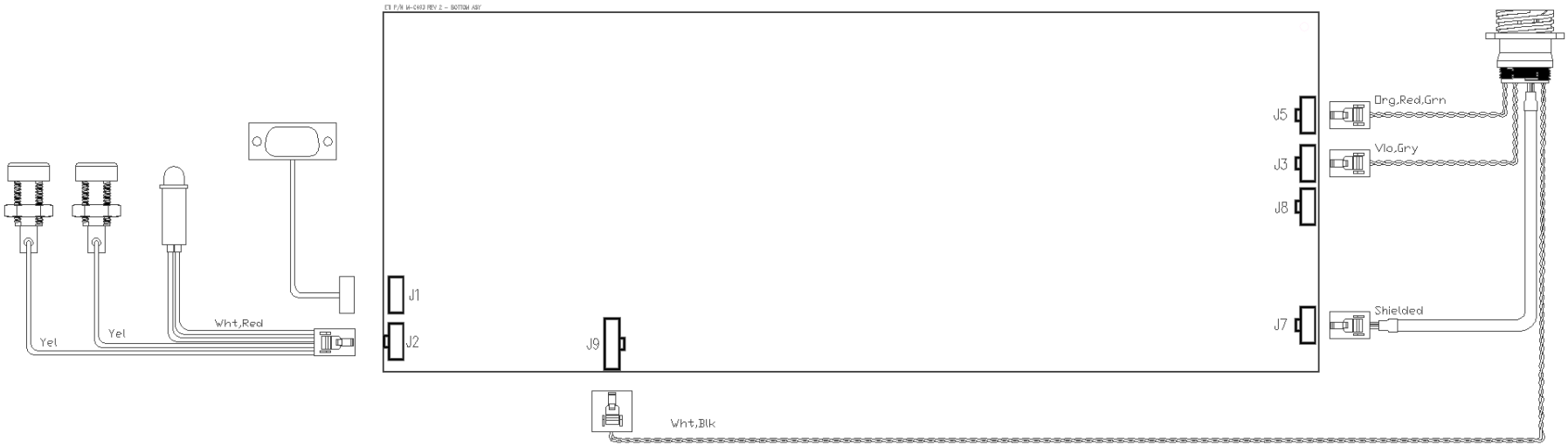
8. Check calibration at 200, 400, 600, and 1000 Amperes.
9. Adjust the current to zero, and press RESET key.
10. Raise the current slowly, until the timer begins to run. This is the Current Latch Threshold, which should be about 10% of range.
11. Set the current at 50% of full scale (500 A), and stop the current.
12. Set the MAC-21 to MEMORY mode, and press the RESET Switch.
13. Initiate a fast momentary pulse of no more than 6 cycles (0.1 Sec) duration. The meter should read the same value, within 1% of reading + 1% of range, that was set in step 11 above.
14. Check pulse reading operation in this manner for currents of 200, 400, 600, and 1000 Amperes, and varying duration.
15. Set Timer Timebase to SECONDS. Press Master Reset Switch. Set N.O. mode. Using a stopwatch, initiate for exactly ninety (90) seconds. Timer should read 90.00 Seconds, +/- 0.01 Seconds. (Note: actual reading may vary because of inability to control and measure pulse length.)
16. If everything checks out, the MAC-21 can be assumed to be in calibration, and no other adjustments are required.

PARTS LIST (MAC-21):

The overall schematic is on the following pages. The parts list is provided below. Please refer to both when ordering replacement parts.

ITEM	QTY	DESCRIPTION	Part Number
1	1	MAC-21 Contact/LED Harness	S-B369
2	1	MAC-21 Rear Panel Harness	S-B368
3	1	MAC-21 Metal Cage	M-D464
4	1	MAC-21 Main PCB	M-C492
5	1	MAC-21 Membrane Switch Panel	M-D462
6	6	LOCKWASHER, INT TOOTH #4	M-A116
7	6	SCREW, PH, 4-40x1/4	M-A118
8	2	HANDLES, BRASS, NICKEL PLT, 4"	M-C103
9	4	SCREW, RH, 10-32x1/2	M-A158
10	4	FLATWASHER, #10	M-A159
11	4	LOCKWASHER #10	M-A160
12	4	SCREW, PH, 10-32X3/4	M-A191
13	4	NYLON WASHERS #10	M-A155
14	2	JACKSCREW, .312, W/HARDWARE	M-A125
15	4	SCREW, PH, 6-32x1/4	M-A139
16	1	COMMUNICATION CABLE	S-A106

Connections (MAC-21):



WARRANTY

Electrical Test Instruments, Inc., will for two years after date of purchase of any Electrical Test Instruments product, correct any defect in workmanship or material. Such corrective measures will be limited to repairing or replacing the unit, at Electrical Test Instruments' option. This limited warranty shall not apply to equipment which has been subjected to negligence, accident or damage by operation, maintenance or storage, or to other than normal use or service. This limited warranty does not cover reimbursements for transportation, removal, installation, repair or replacement, except as may otherwise be specifically agreed to in writing by Electrical Test Instruments. The foregoing is in lieu of all other warranties expressed or implied, and all other obligations or liabilities whether arising under contract, negligence or otherwise, on the part of Electrical Test Instruments. In no event shall Electrical Test Instruments be liable for consequential or special damages, including but not limited to loss of use, loss of income, loss of profit or cost of replacement.

SECTION IV

OPERATING INSTRUCTIONS

SECTION IV

OPERATING INSTRUCTIONS

PRE-TEST INSTALLATION AND SET-UP

1. The following components of the test set should be available and in good condition:
   a) Main Control Unit and Output Unit (if applicable).
   b) MAC-21
   c) Stab set to match breaker to be tested
   d) Input power plugs
   e) Input ground lead
   f) Interconnecting power cables (If applicable)
   g) Interconnecting ground cable (If applicable)
   h) Interconnecting control cable (If applicable)
   i) Contact lead set (If applicable)
   j) Remote initiate cable (optional)
2. Additional requirements for testing are as follows:
   a) Breakers to be tested
   b) Manufacturers' curve data
   c) Test log and/or report forms (See examples at end of section)
   d) Basic hand tools (wrench, screwdriver, etc.)
   e) Safety equipment (safety glasses, gloves, etc.)
   f) Reliable and sufficient power source
   g) Clean, spacious, and well-lit work area.
3. The MAC-21, which may be transported separately, must be installed as follows:
   a) Inspect the interior of the Main Control Unit or Panel Enclosure through the 19 inch opening.
   b) Pull out the circular plug and fasten it to the mating connector on the MAC-21.
   c) Carefully place the MAC-21 into the opening, and secure it by means of screws.
4. Calculate KVA requirements for the source per manufacturer’s manual.
5. Locate a suitable earth ground, and connect it to the Main Control Unit with at least #6 AWG wire.
6. Ground the Main Control Unit to the Output Unit with the supplied ground cable (If applicable).

7. Connect the two power cables between the Main Control Unit and the Output Unit, observing polarity (If applicable).
8. Connect the interconnecting control cable between the Main Control Unit and the Output Unit (If applicable).
9. Make sure that the controls on the test set are adjusted as follows:

   a) Main Power Switch (Circuit Breaker): OFF

   b) Output Tap Switch: 1 (lowest tap)

   c) Output Control Vernier: 0 (minimum position)
10. Remove rear access cover of Main Control Unit, (If applicable), to be sure input tap matches supply voltage. Replace panel. Failure to set input voltage tap properly could cause a serious accidental overvoltage and DAMAGE TO TEST SET OR INJURY TO OPERATOR COULD RESULT.
11. If possible, TURN OFF power at source.
12. Connect power source to input of Main Control Unit, using connectors supplied.
13. If Remote Initiate Cable will be used, install NOW, before power is turned on.
14. Turn on power at source, if turned off in step 11 above.
15. Connect breaker under test to appropriate output tap, using stabs or cables as required.
16. Make sure that breaker is CLOSED.
17. Turn Main Power Switch (Circuit Breaker) ON.
18. If everything is OK, POWER ON light will glow, INTERLOCK indicator will be OFF, and the MAC-21 will perform its power on sequence.
19. Follow Step-by-Step procedures below, as required, for testing.
20. When tests are completed, turn TAP SWITCH to 1, VERNIER to 0, and MAIN POWER switch OFF.
21. Turn off supply power, if possible, and disconnect input power cables.
22. Remove interconnecting power and control cables (If applicable).
23. Remove interconnecting ground cable (If applicable).
24. Remove ground cable from Main Control Unit to earth ground.
25. If unit is to be transported, under rough conditions, remove MAC-21 and carry separately.

BASIC GUIDELINES AND SUGGESTIONS

1. Best timing and current accuracy will be obtained with the MAC-21 in current latch (C.L.) mode.
2. Current Latch modes are preferred for most testing purposes. Exceptions are:
   a) Non-series-connected devices such as motor overload relays or shunt-trip breakers.
   b) Ratioing of current transformers.
   c) Heat runs of cables, buswork, etc. (Connect contacts to thermostat).
   d) Use of MAC-21 as a manually operated timer.
3. If Contacts Mode is selected, use caution when connecting continuity sensing cables. Although the voltage and current are minimal, under some conditions it could cause electrical shock. ALWAYS connect one clip at a time, and NEVER rest the other hand on any current-carrying parts of the breaker while the test set is powered up.
4. Always choose an ammeter range that allows the test current to be read in the area from 20% to 80% of the maximum. This provides greatest accuracy of readings, least chance of overrange, and optimum current latch operation.
5. To obtain maximum output current from the test set, especially when using output cables, it is important to minimize both input and output impedance. This can be accomplished by using the largest cable size possible, or using multiple cables in parallel, to reduce resistance, and by keeping cables close together by tying or twisting, to reduce inductance.
6. For all breaker test sets, much better output current waveform and stability can be achieved when the controls of the test set are in their higher positions. To test smaller breakers, it is helpful to introduce additional output impedance, by using some length of adequate, but lighter gauge, wire to connect the breaker to the output connections. When using tap 1, the vernier control should always be at least at 30% to produce desired test current.

SINGLE POLE MOLDED CASE CIRCUIT BREAKERS

Timing Test

1. Consult breaker manufacturer's literature to determine any necessary precautions and expected test results. A test current of three times the rating of the breaker should be used for this test.
2. Follow steps 1 through 18 in pre-test installation and setup, as required, to set up the breaker test set.
3. Setup MAC-21 for C.L. MOM.
4. Set MAC-21 RANGE to lowest range that is greater than desired test current.
5. Set TIMEBASE to CYCLES.
6. Press PRESET key. Adjust preset time to 4.0 cycles. This value may be set higher or lower, depending on trip characteristics of breaker.
7. Press PRESET again to return to normal mode.
8. Select MEMORY mode.
9. Repeatedly jog the INITIATE button, while adjusting the OUTPUT CONTROL higher, until the desired test current is read on the ammeter. If insufficient current is obtained at maximum position of the vernier, set the OUTPUT TAP control to the next higher tap, return the vernier to zero, and continue.
10. Press RESET button.
11. Set TIMEBASE to SECONDS.
12. Select LATCH mode.
13. Press and release INITIATE key; CLOSE or OUTPUT ON light should glow, timer should run, and current display should read desired output current.
14. While test is running, observe current reading. If necessary, adjust to correct value by using vernier control.
15. When breaker trips, the test set output should de-energize, timer should stop, and OUTPUT ON light should turn off.
16. Read and record trip current and trip time. Compare to manufacturer's time/current curve.
17. If test is to be repeated, make sure that breaker cools completely.
18. Shut down test set, disconnect breaker, and prepare for subsequent testing or relocation according to steps 20 through 25 in pre-test installation and setup outlined above.

Pick-Up of Instantaneous Element

1. Consult breaker manufacturer's literature to determine any necessary precautions and expected test results. Check the breaker's instantaneous setting. Pickup should occur at about that current.
2. Follow steps 1 through 18 in pre-test installation and setup, as required, to set up the breaker test set.
3. Setup MAC-21 for C.L. MAINTAIN (default).
4. Set MAC-21 RANGE to lowest range that is greater than desired test current.
5. Set TIMEBASE to CYCLES (default).
6. Press PRESET key. Adjust preset time to 5.0 cycles (default). This value may be set higher or lower, depending on trip characteristics of breaker.
7. Press PRESET again to return to normal mode.
8. Select MEMORY mode (default).
9. Repeatedly jog the INITIATE button, while adjusting the OUTPUT CONTROL higher, until the circuit breaker trips instantaneously. This is the approximate pickup point. If insufficient current is obtained at maximum position of the vernier, set the OUTPUT TAP control to the next higher tap, return the vernier to zero, and continue.
10. Close breaker under test.
11. By repeating the test, determine the MINIMUM SETTING of the OUTPUT CONTROL, at which the breaker under test opens immediately, whenever the INITIATE button is depressed.
12. Read and record ammeter reading as instantaneous pick-up of the breaker.
13. Shut down test set, disconnect breaker, and prepare for subsequent testing or relocation according to steps 20 through 25 in pre-test installation and setup outlined above.

Instantaneous Trip Time Test

1. Perform Instantaneous Pickup Test as outlined above.
2. Adjust controls to obtain current above pickup, at approximate desired multiple of rating.
3. Close breaker under test.
4. Press the INITIATE button. Breaker should trip instantaneously.
5. Read and record timer and ammeter readings as instantaneous trip time and current.
6. Shut down test set, disconnect breaker, and prepare for subsequent testing or relocation according to steps 20 through 25 in pre-test installation and setup outlined above.

MULTI-POLE MOLDED CASE CIRCUIT BREAKERS

Timing Test

1. Consult breaker manufacturer's literature to determine any necessary precautions and expected test results. A test current of three times the rating of the breaker should be used for this test.
2. Follow steps 1 through 18 in pre-test installation and setup, as required, to set up the breaker test set.
3. Connect appropriate output tap to one pole of breaker under test.
4. Setup MAC-21 for C.L. MAINTAIN (default).
5. Set MAC-21 RANGE to lowest range that is greater than desired test current.
6. Set TIMEBASE to CYCLES (default).
7. Press PRESET key. Adjust preset time to 5.0 cycles (default). This value may be set higher or lower, depending on trip characteristics of breaker.
8. Press PRESET again to return to normal mode.
9. Select MEMORY mode (default).
10. Repeatedly jog the INITIATE button, while adjusting the OUTPUT CONTROL higher, until the desired test current is read on the ammeter. If insufficient current is obtained at maximum position of the vernier, set the OUTPUT TAP control to the next higher tap, return the vernier to zero, and continue.
11. Press RESET button.
12. Set TIMEBASE to SECONDS.
13. Select MAINTAIN mode.
14. If desired, N.C. mode may be used; connect contacts leads to an unused pole of the breaker.
15. Press and release INITIATE key; OUTPUT ON light should glow, timer should run, and current display should read desired output current.
16. While test is running, observe current reading. If necessary, adjust to correct value by using vernier control.
17. When breaker trips, the test set output should de-energize, timer should stop, and OUTPUT ON light should turn off.
18. Read and record trip current and trip time. Compare to manufacturer's time/current curve.
19. Repeat above tests for other poles of the breaker. Allow time for breaker to cool. Note: it is acceptable if all poles of the breaker trip within +/- 15% of the manufacturer's time range for the value of test current chosen. All poles of the breaker need not trip in exactly the same amount of time.
20. Shut down test set, disconnect breaker, and prepare for subsequent testing or

relocation according to steps 20 through 25 in pre-test installation and setup outlined above.

Pick-Up of Instantaneous Element

1. Consult manufacturer's literature to determine any necessary precautions and expected test results. Check the breaker's instantaneous setting. Pickup should occur at about that current.
2. Follow steps 1 through 18 in pre-test installation and setup, as required, to set up the breaker test set.
3. Setup MAC-21 for C.L. MAINT (default).
4. Set MAC-21 RANGE to lowest range that is greater than desired test current.
5. Set TIMEBASE to CYCLES (default).
6. Press PRESET key. Adjust preset time to 5.0 cycles (default). This value may be set higher or lower, depending on trip characteristics of breaker.
7. Press PRESET again to return to normal mode.
8. Select MEMORY mode (default).
9. Repeatedly jog the INITIATE button, while adjusting the OUTPUT CONTROL higher, until the circuit breaker trips instantaneously. This is the approximate pickup point. If insufficient current is obtained at maximum position of the vernier, set the OUTPUT TAP control to the next higher tap, return the vernier to zero, and continue.
10. Close breaker under test.
11. By repeating the test, determine the MINIMUM SETTING of the OUTPUT CONTROL , at which the breaker under test opens immediately, whenever the INITIATE button is depressed.
12. Read and record ammeter reading as instantaneous pick-up of the breaker.
13. Repeat the above test for the other poles of the circuit breaker.
14. Shut down test set, disconnect breaker, and prepare for subsequent testing or relocation according to steps 20 through 25 in pre-test installation and setup outlined above.

Instantaneous Trip Time Test

1. Perform Instantaneous Pickup Test as outlined above.
2. Adjust controls to obtain current above pickup, at approximate desired multiple of rating.
3. Close breaker under test.

4. Press the INITIATE button. Breaker should trip instantaneously.
5. Read and record timer and ammeter readings as instantaneous trip time and current.
6. Repeat the above test for the other poles of the circuit breaker.
7. Shut down test set, disconnect breaker, and prepare for subsequent testing or relocation according to steps 20 through 25 in pre-test installation and setup outlined above.

LOW VOLTAGE POWER CIRCUIT BREAKERS

Nearly all low voltage power circuit breakers are multi-pole devices. The trip units may be either magnetic with a dash pot or solid state electronic devices. Test procedures would be the same for either type. However, electronic trip types may incorporate ground fault protection. If so, it is necessary to either block or by-pass ground fault protection when tests are being conducted on phase fault characteristics. This is because the tests are being conducted on one pole at a time, and the ground fault protection would consider this operation to be a ground fault.

Most low voltage power circuit breakers have either Long Time Delay, and Short Time Delay, and/or instantaneous tripping characteristics. In this case, for test purposes, it is recommended that the instantaneous unit be set in its maximum calibration. This is to prevent an instantaneous trip while trying to set the current for the Short Time Delay characteristic.

Electrical tests to be conducted on low voltage power circuit breakers include timing test on L.T.D.; timing test on S.T.D.; and instantaneous pick-up. It is recommended that the magnitude of test current for the L.T.D. timing test be 3 times coil rating or transformer tap. For timing test on S.T.D. the test current should be about 1.5 times the S.T.D. setting. In both cases, tripping time should be within the manufacturer's published time range. Pick-up of the instantaneous unit should be +/- 10% of the setting for the electronic device and +/- 20% of the setting for the magnetic device.

Testing the instantaneous trip on very large circuit breakers set at or near maximum calibration may sometimes exceed the capacity of the test set. In most cases, the instantaneous element has several calibration marks between "LO" and "HI". In such cases, it may be necessary to perform the test at one of the lower calibration marks. Always be sure to record the "AS FOUND" settings, and return the adjustments to these settings after testing. To perform testing, adjust the screw to a lower setting that allows the test set to verify that the unit will pick up. If the instantaneous unit picks up at the proper current at a lower calibration point, it may be assumed that the unit will operate properly at higher calibration points. This has been verified by manufacturers and by means of field tests.

Specific test procedures for all electrical tests are outlined on the following pages.

Timing Test, Long Time Delay

1. Consult breaker manufacturer's literature to determine any necessary precautions and expected test results. A test current of three times the rating of the breaker should be used for this test.
2. Follow steps 1 through 18 in pre-test installation and setup, as required, to set up the breaker test set.
3. Connect appropriate output tap to one pole of breaker under test.

4. Setup MAC-21 for C.L. MAINTAIN (default).
5. Set MAC-21 RANGE to lowest range that is greater than desired test current.
6. Set TIMEBASE to CYCLES (default).
7. Press PRESET key. Adjust preset time to 5.0 cycles (default). This value may be set higher or lower, depending on trip characteristics of breaker.
8. Press PRESET again to return to normal mode.
9. Select MEMORY mode (default).
10. Repeatedly jog the INITIATE button, while adjusting the OUTPUT CONTROL higher, until the desired test current is read on the ammeter. If insufficient current is obtained at maximum position of the vernier, set the OUTPUT TAP control to the next higher tap, return the vernier to zero, and continue.
11. Press RESET button.
12. Set TIMEBASE to SECONDS.
13. Select MAINTAIN mode.
14. If desired, N.C. mode may be used; connect contacts leads to an unused pole of the breaker.
15. Press and release INITIATE key; OUTPUT ON light should glow, timer should run, and current display should read desired output current.
16. While test is running, observe current reading. If necessary, adjust to correct value by using vernier control. (For motorized vernier, press MAINTAIN key to activate automatic current hold)
17. When breaker trips, the test set output should de-energize, timer should stop, and OUTPUT ON light should turn off.
18. Read and record trip current and trip time. Compare to manufacturer's time/current curve. If necessary, adjust the trip unit and repeat the test.
19. Repeat the above tests for the other poles of the breaker, allowing time for breaker to cool. Note: Results are acceptable if all poles of the breaker trip within the manufacturer's time range for the value of test current chosen. All poles of the breaker need not trip in exactly the same amount of time.
20. Shut down test set, disconnect breaker, and prepare for subsequent testing or relocation according to steps 20 through 25 in pre-test installation and setup outlined above.

Timing Test, Short Time Delay

Note: The breaker's trip time for short time delay will always be less than 30 cycles and may be as low as 4-5 cycles. Therefore, setting test current will require some practice. However, the magnitude of the test current is not critical; for instance, if the S.T.D. is set for 1000 amperes, there will be little or no difference in timing if a test current of

1500, 2000 or 2500 amperes is used.

Set up of controls is the same as for timing test L.T.D. Consult breaker manufacturer's literature to determine any necessary precautions and expected test results.

1. Follow steps 1 through 8 under Timing Test Long Time Delay.
2. Repeatedly jog the INITIATE button, while adjusting the OUTPUT CONTROL higher, until the desired test current is read on the ammeter. If insufficient current is obtained at maximum position of the vernier, set the OUTPUT TAP control to the next higher tap, return the vernier to zero, and continue.
3. Press RESET button.
4. Set TIMEBASE to SECONDS.
5. Select MAINTAIN mode.
6. If desired, N.C. mode may be used; connect contacts leads to an unused pole of the breaker.
7. Press and release INITIATE key; OUTPUT ON light should glow, timer should run, and current display should read desired output current.
8. Breaker should trip within 30 cycles (0.5 seconds). When breaker trips, the test set output should de-energize, timer should stop, and OUTPUT ON light should turn off.
9. Read and record trip current and trip time. Compare to manufacturer's time/current curve. If necessary, adjust the trip unit and repeat the test.
10. Repeat the above tests for the other poles of the breaker, allowing time for breaker to cool. Note: Results are acceptable if all poles of the breaker trip within the manufacturer's time range for the value of test current chosen. All poles of the breaker need not trip in exactly the same amount of time.
11. Shut down test set, disconnect breaker, and prepare for subsequent testing or relocation according to steps 20 through 25 in pre-test installation and setup outlined above.

Pick-Up of the Instantaneous Unit

1. Consult breaker manufacturer's literature to determine any necessary precautions and expected test results. Note: If the instantaneous setting is such that the expected test result is above that which may be easily produced by the test set, a valid test may be performed by adjusting the setting to its minimum value. At the end of the test, restore the instantaneous setting to its specified value.
2. Follow steps 1 through 18 in pre-test installation and setup, as required, to set up the breaker test set.
3. Setup MAC-21 for C.L. MAINTAIN (default).
4. Set MAC-21 RANGE to lowest range that is greater than desired test current.

5. Set TIMEBASE to CYCLES (default).
6. Press PRESET key. Adjust preset time to 5.0 cycles (default). This value may be set higher or lower, depending on trip characteristics of breaker.
7. Press PRESET again to return to normal mode.
8. Select MEMORY mode (default).
9. Repeatedly jog the INITIATE button, while adjusting the OUTPUT CONTROL higher, until circuit breaker trips instantaneously. This is the approximate pickup point. If insufficient current is obtained at maximum position of the vernier, set OUTPUT TAP control to next higher tap, return the vernier to zero, and continue.
10. Close breaker under test.
11. By repeating the test, determine the MINIMUM SETTING of the OUTPUT CONTROL, at which the breaker under test opens immediately, whenever the INITIATE button is depressed.
12. Read and record ammeter reading as instantaneous pick-up of the breaker.
13. Repeat the above test for the other poles of the circuit breaker.
14. If trip settings were modified for test purposes, restore them to their original values.
15. Shut down test set, disconnect breaker, and prepare for subsequent testing or relocation according to steps 20 through 25 in pre-test installation and setup outlined above.

Instantaneous Trip Time Test

1. Perform Instantaneous Pickup Test as outlined above.
2. Adjust controls to obtain current above pickup, at approximate desired multiple of rating.
3. Close breaker under test.
4. Press the INITIATE button. Breaker should trip instantaneously.
5. Read and record timer and ammeter readings as instantaneous trip time and current.
6. Repeat the above test for the other poles of the circuit breaker.
7. Shut down test set, disconnect breaker, and prepare for subsequent testing or relocation according to steps 20 through 25 in pre-test installation and setup outlined above.

MOTOR OVERLOAD RELAYS

The motor overload relay is designed to provide overload protection for a motor; therefore, it offers only one time/current characteristic, which is essentially a long time delay. It may be multi-pole, however, most relays are single pole. In the case of a multi-pole device each pole is tested individually as in the case of a multi-pole direct acting circuit breaker.

The motor overload relay contains two separate circuits. The current carrying circuit which contains the relay's operating coil or heater. The control circuit which contains a set of contacts; these contacts open when the relay "operates". It is the opening of these control circuit contacts that deenergizes the motor starter holding coils, thus allowing the starter contactors to open, shutting down the motor.

Timing Tests

1. Consult the relay manufacturer's literature to determine any necessary precautions and the expected timing test results. The test current should be 3 to 4 times the rating of the relay operating coil or heater.
2. Follow steps 1 through 18 in pre-test installation and setup, as required, to set up the breaker test set.
3. Setup MAC-21 for C.L. MAINTAIN (default).
4. Set MAC-21 RANGE to lowest range that is greater than desired test current.
5. Set TIMEBASE to CYCLES (default).
6. Press PRESET key. Adjust preset time to 5.0 cycles (default). This value may be set higher or lower, depending on trip characteristics of breaker.
7. Press PRESET again to return to normal mode.
8. Select MEMORY mode (default).
9. Connect the relay operating coil or heater circuit terminals to the breaker test set common terminal and the proper output tap terminal.
10. Repeatedly jog the INITIATE button, while adjusting the OUTPUT CONTROL higher, until the desired test current is read on the ammeter. If insufficient current is obtained at maximum position of the vernier, set the OUTPUT TAP control to the next higher tap, return the vernier to zero, and continue.
11. Press RESET button.
12. Setup MAC-21 for N.C. MAINTAIN.
13. Connect the relay control circuit contacts to the CONTACTS binding posts, and determine that they are closed by observing the CONTINUITY lamp.
14. Press and release INITIATE button; OUTPUT ON light should glow, timer should operate, and current should indicate on display.

15. When the relay control circuit contacts open, the test set output should deenergize and the timer should stop.
16. Read and record the test value of current and the time of the test. Compare the results to the manufacturer's specifications. If possible, adjust the relay. Usually, if the relay time of operation is incorrect, it is necessary to replace the relay heater with one of the recommended size for the motor being protected. If a check test is desired, the relay must be allowed to cool for a period of time (approximately 15 to 30 minutes).
17. For a multi-pole relay, repeat the above tests for the other relay poles.
18. Shut down test set, disconnect breaker, and prepare for subsequent testing or relocation according to steps 20 through 25 in pre-test installation and setup outlined above.

RATIOING CURRENT TRANSFORMERS

To conduct a ratio test on a current transformer, a good multi-range bench ammeter is required in addition to the breaker test set. The breaker test set supplies primary current to the transformer and the bench ammeter is used to read the transformer secondary current. It is suggested that a graph of the test results be plotted. Primary current should be the abscissa and corresponding secondary current the ordinate of the graph.

WARNING: It is extremely important that the secondary circuit of the current transformer never be broken or opened while the primary circuit is energized. Should the secondary circuit of an energized current transformer be opened, the collapsing magnetic field generates an extremely high voltage across the open ends of the circuit until the resultant arc is extinguished. Under these conditions, personal injury and/or damage to the current transformer under test are probable.

1. Follow steps 1 through 18 in pre-test installation and setup, as required, to set up the breaker test set.
2. Connect the current transformer primary terminals to the breaker test set common terminal and the proper output tap terminal.
3. Connect the current transformer secondary terminals to the bench ammeter.
4. Set the MAC-21 to N.O. mode. Set MAINTAIN on.
5. Press and release INITIATE button; OUTPUT ON light should glow, timer should operate, and current should indicate on display.
6. Adjust OUTPUT CONTROL higher until the desired current transformer primary current is read on the MAC-21 ammeter. Adjust OUTPUT TAP switch, if necessary, to obtain required current.
7. Read and record the readings on both the breaker test set (MAC-21) and the bench ammeter.
8. Repeat steps 6 and 7 until the desired number of test points have been obtained. Note: It is suggested that test points be obtained in multiples of the current transformer rating. For instance, for a 200/5 current transformer, test points would be obtained at primary currents of 200, 400, 600, 800 amperes, etc.
9. Shut down test set, disconnect CT, and prepare for subsequent testing or relocation according to steps 20 through 25 in pre-test installation and setup outlined above.

SECTION V

SERVICE INFORMATION AND DOCUMENTATION

SECTION V

SERVICE INFORMATION AND DOCUMENTATION

BASIC MAINTENANCE AND CALIBRATION

Circuit breaker test sets are often subject to conditions in use, storage, and transportation that may affect reliability, safety, and accuracy. Basic preventive maintenance should be performed on a regular basis and as needed due to abnormal conditions. Procedures should include general cleaning, tightening of electrical connections, replacement of worn or damaged components, and a complete functional check. Calibration by certified instruments and personnel should be performed at least annually, or whenever erroneous readings are suspected. The manufacturer's recommended calibration interval is (1) one year.

PARTS LIST: Retrofit with 5" Panel(A), or 2" Panel(B):

The overall schematic is at the end of this manual. The parts list for the retrofit indicator panel and other parts is provided below. Please refer to both when ordering replacement parts.

ITEM	QTY	DESCRIPTION	REF DES	ETI Number
1A	1	Panel, 5.25"		M-D104
1B	1	Panel, 2"		M-D102
2	1	Terminal Block, 8 position	TB1	M-C126
3	1	Terminal Block, 10 position	TB2	M-C127
4	1	Connector, Plug, 16 position	P8	M-C135
5	1	Connector Clamp	XP8	M-C124
6	11	Connector Pin, Female	P8-x	M-A128
7	1	Relay, 120 VAC, DPDT	K1	M-C147
8A	3	Neon Lamp, NE51-H (B2A)	DS1, 2, 3	M-B184
9A	3	Lamp Socket, Neon, B2A	XDS1, 2, 3	M-B196
10A	2	Lens, Red	XXDS2, 3	M-B197
10B	2	Neon Lamp, Red	DS2,3	M-B180
11A	1	Lens, Amber	XXDS1	M-B198
11B	1	Neon Lamp, Amber	DS1	M-B179
12	1	Snubber, 0.1 uF, 400V	RC1	M-B278
13	1	Fuse Block, 30A, 250V	XF1	M-B177
14	1	Fuse, 1.5 A, 250V, Fast, AGC-1.5	F1	M-B200
15	1	Isolation transformer assembly		S-B114
16C	1	SCR Assembly, Large	SCR1	S-B111
16D	1	SCR Assembly, Small	SCR1	S-B112
17	1	SCR Trigger PCB Ass'y	PCB1	S-B110
18	2	Fuse, 5 A, 600 V, FNQ-5	F3,F4	M-C108

WARRANTY

Electrical Test Instruments, Inc., will for two years after date of purchase of any Electrical Test Instruments product, correct any defect in workmanship or material. Such corrective measures will be limited to repairing or replacing the unit, at Electrical Test Instruments' option. This limited warranty shall not apply to equipment which has been subjected to negligence, accident or damage by operation, maintenance or storage, or to other than normal use or service. This limited warranty does not cover reimbursements for transportation, removal, installation, repair or replacement, except as may otherwise be specifically agreed to in writing by Electrical Test Instruments. The foregoing is in lieu of all other warranties expressed or implied, and all other obligations or liabilities whether arising under contract, negligence or otherwise, on the part of Electrical Test Instruments. In no event shall Electrical Test Instruments be liable for consequential or special damages, including but not limited to loss of use, loss of income, loss of profit or cost of replacement.