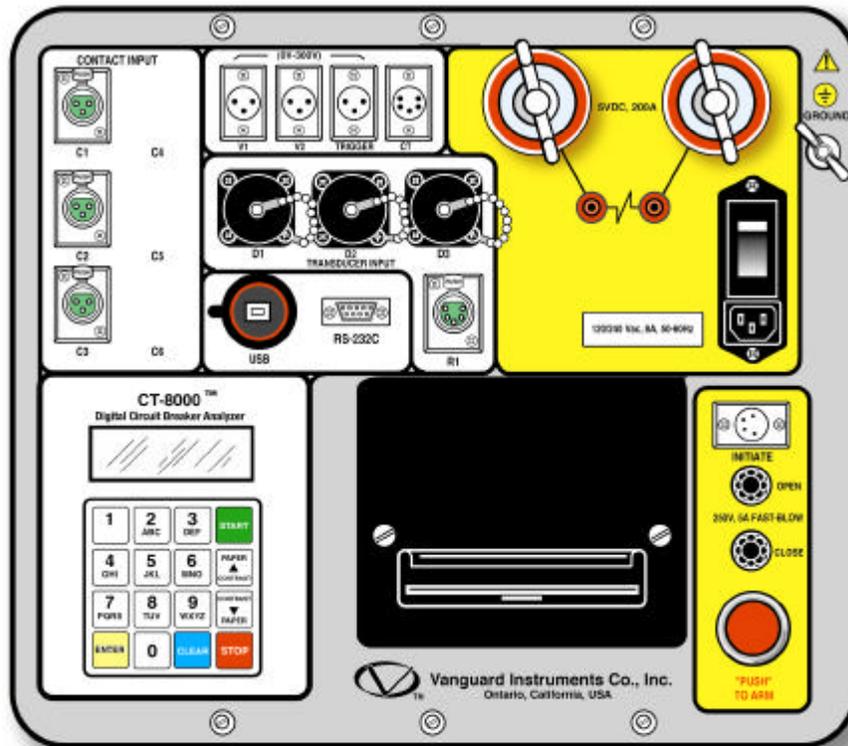# OPERATING INSTRUCTIONS
for the
CT-8000
Digital Circuit Breaker Analyzer

070721CT8K642A

Vanguard Instruments Company
1520 South Hellman Avenue
Ontario, California 91761, USA

SAFETY WARNINGS AND CAUTIONS

Only trained operators shall use the device. All circuit breakers under test shall be **off line and fully isolated.**

DO NOT SERVICE OR TEST ALONE

Do not perform test procedures or service unless another person is also present who is capable of rendering aid and resuscitation.

DO NOT MODIFY TEST EQUIPMENT

Due to the added risk of introducing additional or unknown hazards, do not install substitute parts or perform any unauthorized modifications to any CT-8000 test unit. To ensure that all designed safety features are maintained, it is recommended that repairs be performed only by Vanguard Instruments Company's factory personnel or by an authorized repair and service center. Unauthorized modifications can cause serious safety hazards and will nullify the manufacturer's warranty.

FOLLOW EXACT OPERATING PROCEDURES

Any deviation from the procedures described in the operator's manual may create one or more safety hazards, damage the CT-8000, the test circuit breaker or cause errors in the test results. Vanguard Instruments Company, Incorporated assumes no liability for unsafe or improper use of the CT-8000.

WARRANTY

The CT-8000's warranty is only valid to the original purchaser to be free from defects in material and workmanship for a period of one year. The warranty does not apply to normal wear or damage from misuse, abuse, improper storage, installation, accident, unauthorized repair or alterations.

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1.0 Introduction

The CT-8000 is the fifth generation microprocessor-based, digital time travel circuit breaker analyzer developed by Vanguard Instruments Co. The CT-8000 design combines the circuit breaker time travel analyzer with a 200 amperes micro-ohm meter in one package. The CT-8000 can fully analyze a utility circuit breaker's performance by measuring: the contact time, stroke, velocity, over-travel, bounce-back and contact wipe. The same device can be used as a 200A micro-ohm meter. A unique feature of the CT-8000 allows the user to measure the circuit breaker contact resistance during the circuit breaker operation (Dynamic Contact Resistance Test). This Dynamic Contact Resistance Test can detect the circuit breaker contact problems (i.e. contact erosion) which is not detected easily in the conventional circuit breaker test.

The contact motion analysis includes: Open, Close, Open-Close, Close-Open and Open-Close-Open operations. A timing window of one second, ten seconds or twenty seconds can be selected. The ten and twenty second timing windows allow the user to record long timing events such as circuit switcher contact activities.

The CT-8000 can also be used as an on-line timing device (in Quick-shot mode). An AC clamp-on current probe connected to the circuit breaker bushing CT lets the CT-8000 measure circuit breaker switching time (While the circuit breaker is still in service). The CT-8000 times an OPEN operation by measuring the time between the OPEN coil being energized and the bushing CT current returning to zero. CLOSE time is measured between the close coil being energized and the bushing CT current being detected.
This "On-line Timing" or "Quick-shot mode" provides a quick way to diagnose circuit breaker performance and thus provide savings in maintenance cost.

The conventional Time-Travel test mode allows the user to fully analyze the circuit breaker contact time and contact travel information. Additional circuit breaker information such as: Operating-coil current reading, breaker DC coil power supply voltage reading are also available.

Dynamic Contact Resistance test mode allows the user to measure the contact resistance during a circuit breaker operation. This resistance graph allows the user to analyze the circuit breaker contact condition.

Static Resistance test mode allows the user to use the CT-8000 as a 200 amperes micro-ohm meter.

The CT-8000 is available with the following configurations:
CT-8000-3:
- Three Contact-Input channels
- Three Digital Travel Transducer Input channels
- One Resistor Type Transducer Input Channel
- One On-line Timing Test Channel
- One Dynamic Resistance Channel
- One Analog Voltage Monitor Input channel
- One Digital Voltage Monitor Input channel
- One Trip/Close Current Monitor channel

CT-8000-6:
- Six Contact-Input channels
- Three Digital Travel Transducer Input channels
- One Resistor Type Transducer Input Channel
- One On-line Timing Test Channel
- One Dynamic Resistance Channel
- One Analog Voltage Monitor Input channel
- One Digital Voltage Monitor Input channel
- One Trip/Close Current Monitor channel

There are two different modes of operation for the CT-8000 which are Stand Alone Mode and Computer Control Mode. The manual will focus on the Stand Alone Mode. The Computer Control Mode is covered under the Circuit Breaker Analyzer Software Series 2 manual.

2.0 CT-8000 Description

2.1 Contact Timing Channels

A breaker's interruption of contacts are timed with the dry-contact input channels. Each contact channel can detect the main contacts and the insertion resistor contact times in milliseconds and cycles.

The CT-8000 applies a test voltage of 35Vdc to each of the contact channels thus allowing an analog to digital converter (A/D) to determine if a close, an open or an insertion resistor was the state of the contact. The CT-8000 records into the memory 20,000 readings from the A/Ds and the transducer position counters. The contact time, circuit breaker stroke and velocity is then derived from the data that was stored in the memory.

NOTE

The CT-8000 can detect insertion resistors ranging from 10 to 7,000 Ohms. Resistances over 7,000 Ohms are detected as an open contact.

2.2 On-line CT Timing Channel

A clamp-on AC current transducer is available to perform circuit breaker on-line tests. Circuit breaker Open time is detected by measuring the time between the OPEN coil being energized and the bushing CT current returning to zero. CLOSE time is measured between the close coil being energized and the bushing CT current being detected.

2.3 Analog Voltage Monitoring Channel

One analog voltage, input channel, "V1" is dedicated to monitoring the breaker's DC power supply or coil voltages from 0 to 255Vdc or peak Vac.

NOTE

Maximum input voltage is 300Vdc or peak Vac. Recording voltage readings are from 0 to 255Vdc.

2.4 Digital Voltage Monitoring Channel

One digital voltage, input channel, "V2" monitors the status voltage as "ON" or "OFF." Voltages from 30 to 255Vdc are considered as "ON" status. Voltages less than 30Vdc are considered as "OFF" status.

2.5 Trip/Close Current Monitoring

A built-in, hall-effect, current sensor measures the trip and close coil current levels and duration. The coil current waveform can be graphically plotted onto a printout. The coil current reading is also printed in the tabulated report. The CT-8000 initiate circuit is capable of carrying up to 30 amperes. Maximum coil current reading is 20 amperes.

2.6 Travel Transducer Input Channels

Each CT-8000 has three digital transducer input channels. The CT-8000 uses up-down counters to sense the breaker's transducer reading. The CT-8000 travel transducer employs optical encoders to send quadrature signals to the CT-8000's counters. With the use of digital transducers and counters, the need to set up or calibrate the transducers is eliminated.

The CT-8000 will interface with a linear, a rotary and other special transducers developed by Vanguard Instruments Company. Please refer to Appendix I for more details.

2.7 Resistor Type Transducer Input channel

One resistor type transducer input channel is also available with the CT-8000. The resistor range is from 200 to 10,000 Ohms.

2.8 Dynamic Contact Resistance Channel

One channel for Dynamic Contact Resistance testing is also available. A built-in 200-ampere power supply provides test current for this application. Resistance measurement ranges from 1 micro-ohm to 1999 micro-ohms (accuracy: ?2%, ?5 micro-ohms). The Dynamic Contact Resistance test allows the users to monitor the circuit breaker contact resistance during circuit breaker operation. The feature allows the user to detect circuit breaker contact erosion, or contact problems that can not be detected in a static resistance test. The CT-8000 can also be used as a 200-ampere, micro-ohm meter to check circuit-breaker contact resistance, bus connection, or other applications of low resistance measurements.

2.9 Breaker Initiate Capability

A built-in, solid-state, initiate device allows the user to operate the circuit breaker from the CT-8000. Operational modes include: Open, Close, Open-Close, Close-Open and Open-Close-Open. The multiple operations of: Open-Close, Close-Open and Open-Close-Open can be initiated with a programmable delay time or by sensing the breaker's contact state.

The solid-state switching implemented in the initiate circuitry allows the CT-8000 to switch a breaker's AC or DC control circuit. . The CT-8000 initiate circuit is capable of carrying up to 30 amperes. Separate 5 Ampere, fast-blow fuses protect each trip and close circuit. An interlock "ARM" switch action is required by the operator to operate the initiate circuit.

2.10 Built-in Thermal Printer

The breaker's contact analysis results can be printed in both tabular and graphical formats by a built-in, 4.5 inch wide, thermal printer. Refer to paragraph 7.5 for ordering thermal paper.

2.11 Computer Interface Capabilities

Built-in, RS-232C and USB ports allow the CT-8000 to be interfaced with an IBM-compatible personal computer. A Windows XP Circuit Breaker Analyzer software is supplied with each CT-8000. The software allows the user to:

- Control CT-8000 from a personal computer.

- Retrieve timing records stored in the CT-8000.
- Transfer circuit-breaker test plans to CT-8000.
- Recall timing records from a hard drive for re-analysis at an office PC.

2.12 Timing Records Storage Capabilities

The CT-8000 uses Electrically Erasable Programmable Read-Only-Memory (EEPROM) to store timing-shot data. Unlike other media, EEPROMs are immune to temperature, shock and humidity. Stored shots can be recalled to reanalyze the test data, to reprint test reports or to transfer data to a personal computer for record keeping. Up to 100 timing records can be stored in the EEPROMs. The number of test records stored in the EEPROMs may vary depending upon the size of the records.

2.13 Breaker Test Plan Storage Abilities

Up to 99 breaker's test plan can be stored in the CT-8000. Test plans comprise breaker specifications (i.e., stroke, velocity, contact-time). By recalling and using a test plan, operators can immediately test breakers and view a pass/fail report (made by comparing test performance with specifications in the test plan.

Circuit breaker test plans are created using the Circuit Breaker Analyzer software. Test plans are then loaded into the CT-8000 via the RS-232C serial port or USB port.

2.14 Diagnostic Capabilities

The CT-8000 is designed with self-diagnostic capability to check the integrity of the electronics. Self testing of the contact cable hook-up and transducers permits the user to examine the CT-8000's components whenever verification is required.

2.15 CT-8000 Display and Control Switches

An alphanumeric keypad enables the users to operate the CT-8000 and to enter the breaker's nameplate data such as: the substation name, breaker model and other descriptions. A 4-line by 20-character LCD readout displays user messages and menus. The LCD is back-lighted to allow messages to be viewed in low light conditions.

3.0 Test Result Tabulation

3.1 Timing Test Measurement Results

In the Time Travel Mode, each CT-8000 contact channel provides the following test results:
- Contact Close time
- Contact Open time
- Insertion Resistor Contact Open and Close times
- Contact Bounce time
- Resistor On time
- Contact Spread time

NOTE
The CT-8000 can detect insertion resistors ranging from 10 to 7,000 Ohms.
Resistances over 7,000 Ohms are detected as an open contact.

3.2 On-line Timing Results

The CT-8000 provides one channel of on-line timing test results. The CT-8000 times an OPEN operation by measuring the time between the OPEN coil being energized and the bushing CT current returning to zero. CLOSE time is measured between the close coil being energized and the bushing CT current being detected.

3.3 Mechanical Measurement Results

Under the Time Travel Mode, the digital transducer channels provide the following test results:
- CB contact stroke
- CB contact over travel
- CB Contact bounce back
- CB Contact wipe
- CB Contact velocity

Breaker contact speed calculations are based upon a contact's travel distance over a period of time, which is defined by the manufacturer's specifications.

NOTE
When the resistor type transducer channel is used, the test results are shown as transducer channel 1.
CB contact mechanical measurement can be shown in "English" or "Metric" units.

A CT-8000 not only calculates simple distance over-time speeds, but can also support other formulas. An example is the Siemens SPS2 breaker calculation formula:

$$V = 12.2 \times a/b$$

The formula and analysis point can be stored in a test plan for use later in the field.

NOTE

If operators use a breaker test plan (See paragraph 9.18) during testing, the test report will also indicate a Pass/Fail condition for each test parameter (i.e contact time, stroke, velocity, etc.).

3.4 Analog Voltage Input Results

The analog voltage, input channel, "V1" measures the breaker's DC control voltage during an operation. Printed voltage readings include nominal voltage (when the supply voltage has no load) and minimum voltage (when the supply voltage is under load or when a coil is energized). The "V1" connection allows the user to monitor the DC power supply's voltage fluctuations during a breaker operation. This feature is effective in detecting breaker power supply problems, which normally can not be seen by using a voltmeter.

NOTE

Printed voltage readings can range from 0 to 255Vdc.

3.5 Digital Voltage Input Results

The digital voltage, input channel, "V2" monitors the voltage status as "ON" or "OFF" conditions and graphs the result. A voltage level above 30Vdc is considered as the "ON" state. The input channel is dedicated to monitor the breaker's auxiliary switch action during a breaker operation.

NOTE

Maximum input voltage is 300Vdc or peak Vac.

3.6 Initiate Current Results

The CT-8000 not only plots the trip or close current waveforms, but also prints the steady-state current readings of the trip and close coils during an operation. A typical circuit breaker timing report is shown in Figure 14.0.

3.7 Slow-Close Test Results

A Slow-Close test determines the contact touch distance and penetration by using the travel transducer and dry contact channels. See section 9.22 for Slow-Close test Procedure.

3.8 Static Resistance Test

Static resistance test mode allows the CT-8000 to be used as a 200A micro-ohm meter. Resistance measurement ranges from 1 micro-ohm to 1999 micro-ohms (accuracy: ?2%, ?5 micro-ohm). Static Resistance Test results can be stored in the CT-8000 Flash EEPROM. See section 9.4 for Static Resistance Test procedure.

4.0 Test Result Graphics

4.1 Thermal Printer Graphic Printout

A 4.5 inch wide, built-in, thermal printer can output graphic waveforms of the contact channels, travel curves and actuator-coil currents. Using the Zoom Graphics Mode, the user can enlarge the graphical outputs by specifying the timing zone. Typical graphical results are shown in Figures 15.0 and 16.0.

5.0 CT-8000 Controls and Display

Before using the CT-8000, users should become familiar with all of the controls and display indications. The keypad and display are used to operate the CT-8000. Figure 1.0 represents the control panel and the numbered lines pointing to each control and indicator refer to Table 1.0, which describes the function of each control and indicator.

Figure 1.0 CT-8000 Control Panel

Table 1.0 CT-8000 Controls and Displays

Fig. 1.0 Index no.	PANEL MARKING	FUNCTIONAL DESCRIPTION
1, 6, 7	D1, D2, D3 TRANSDUCER INPUT	16-pin connectors. Digital travel transducer input channels.
2	0-300V V1	3-pin connector. V1 voltage input channel is dedicated to monitor circuit breaker DC power supply or coil voltages. Voltage sensing range is from 0-255 volts, dc or peak ac.
3	0-300V V2	3-pin connector. V2 voltage input channel is dedicated to detect voltage on/off status (present or absent) of an A/B switch. Voltage input ranges from 0-300 volts, dc or peak ac.
4	0-300V TRIGGER	3-pin connector. Triggers voltage input for external trigger application. Voltage levels ranging from 30 to 300 V, dc or peak ac.
5	CT	CT Input channel. Detect CB load current for Quick-Shot application.
8, 11	5VDC, 200A	200A Micro-Ohm Meter current output terminals.
9, 10	RESISTOR SYMBOL	Micro-Ohm Meter sense inputs.
12	GROUND	Safety, ground terminal. 5/16-18 thread stud, with wing nut.
13	120/240Vac, 8A, 50-60Hz	3-wire power plug. 12 Ampere circuit breaker. The ON/OFF switch is a 2-pole rocker.
14	INITIATE	4-pin connector used for the switching circuit for operating the circuit breaker under test.
15	CLOSE 250V, 5A FAST-BLOW	Close circuit fuse: 5 Ampere, 250V, Fast-Blow.
16	OPEN 250V, 5A FAST-BLOW	Open circuit fuse: 5 Ampere, 250V, Fast-Blow.
17	"PUSH" TO ARM	Spring-loaded, pushbutton switch. Press and hold to complete the Trip or Close circuits for breaker tests.
18	(Printer; No panel marking)	Thermal printer. Microprocessor controlled printer that uses specially treated, 4.5 inch wide paper.

Table 1.0 CT-8000 Controls and Displays (Continued)

19	R1	Five pin connector. Resistor Type Transducer input channel
20	1-9, 0, ENTER, START, STOP, CLEAR, ? PAPER LCD, ? PAPER LCD	16 button keypad. The keys are momentary-contact, pushbutton switches. Allows users to make menu selections, enter alphanumeric data, adjust the LCD contrast and reposition the printer paper.
21	RS-232C	RS-232C serial computer interface port.
22	(Display; no panel marking)	4-line by 20-character, backlit LCD. Displays menus, options, prompts and test result data.
23	USB	Computer interface, USB Port.
24,25,26	CONTACT INPUT (C1–C6)	Female connectors for the contact channels.

6.0 CT-8000 Analyzer Specifications

PHYSICAL SPECIFICATIONS	16" W by 11"H by 14"D (40.6 cm x 29.9 cm x 35.6 cm) Weight: 25lbs (11.3Kg).
INPUT POWER	8 Amperes, 90-120Vac or 200-240Vac (selectable), 50/60 Hz.
DRY-CONTACT INPUT	3 or 6 contact channels. All contact inputs are grounded until testing is started. Each contact detects main and insertion resistor contacts.
TIMING WINDOW	Selectable between: 1, 10, or 20 second.
TIMING RESOLUTION	±50 microseconds at 1 second duration. ±0.5 millisecond at 10 second duration. ±1.0 millisecond at 20 second duration.
TIMING ACCURACY	0.05% of reading, ?50 micro-seconds at 1-second duration.
CONTACT DETECTION RANGE RANGE	CLOSED: less than 20 Ohms. OPEN: greater than 10,000 Ohms.
RESISTOR DETECTION RANGE	Ranges from 10 to 7,000 Ohms.
CT CURRENT SENSOR	One, Non Contacting, 1-150 Amp.
EXTERNAL TRIGGER INPUT	Open/Close: 30 to 300Vdc, peak Vac.
VOLTAGE SENSING INPUTS	V1: analog input, 0-255V dc or peak ac. Sensitivity: ?1V; V2: voltage detector (present/absent).Input: 30-300V, dc or peak ac.
BREAKER OPERATION	Open, Close, Open-Close, Close-Open, and Open-Close-Open.
BREAKER INITIATE CAPACITY	30A/250V ac/dc max (100A inrush).
INITIATE CURRENT READING RANGE	One, Non-contact, hall-effect sensor ranging from 0-20 Amperes, DC to 5 kHz.
TRAVEL TRANSDUCER INPUT	3 travel-transducer channels. Linear motion from 0.0 to 30.0 inches (±0.01) inch. Rotary ranges from 0 to 360° (± 0.36º).
RESISTOR TRANSDUCER INPUT	One channel. Resistance range: 200 Ohms to 10K Ohms.
BREAKER SLOW-CLOSE TEST	Measures "Slow-Close" the contact point distance (hard copy printout).
RESISTANCE TEST CURRENT	200 Amperes typical.
RESISTANCE READING RANGE	1-1999 micro-ohm, Accuracy: ?2% of reading, ?5 micro-ohm.
DISPLAY	Back-lit LCD screen, 4-lines by 20-characters, sunlight viewable.
PRINTOUT	Both graphic contact-travel waveforms & tabulated results are printed on 4.5 inch thermal paper.

STORAGE CAPABILITIES Store 99 Circuit Breaker Test Plans.
Store up to 100 timing records.

COMPUTER INTERFACE RS-232C Port, USB Port.

PC SOFTWARE (included) Furnished Circuit Breaker Analyzer PC software. Windows XP and Windows Vista compatible. The analysis software can be installed on an IBM-compatible computer for graphical display, numerical reports and database utility for office use.

SAFETY Designed to meet UL 61010A-1 Certification and CAN/CSA C22.2 No 1010.1-92.

ENVIROMENT Operating: -10?C to 50?C (+15?F to +122?F).
Storage: -30?C to 70?C (-22?F to +158?F).

OPTIONS Hard shipping case for CT-8000.
Hard shipping case for Travel Transducers.

WARRANTY One year warranty on parts and labor.

7.0 CT-8000 Special Features

7.1 CT-8000 Supplied Cables

Table 2.0 CT-8000 Cable set

ITEM	DESCRIPTION	QTY
1	GND Cable	1
2	Power Cord	1
3	Contact Cable	3 or 6
4	Contact Extension Cable	3 or 6
5	Transducer cable	1
6	Voltage & Trigger Leads	3
7	Voltage & Trigger Extension cables	3
8	AC Current Sensor	1
9	Resistor type transducer cable	1
10	Micro-Ohm Meter Current Cables	2
11	Micro-Ohm Meter Sense Cables	2
12	Initiate Lead	1
13	Initiate Extension Cable	1
14	USB Cable	1
15	RS-232C Cable	1

7.2 CT-8000 Operating Voltages

   The CT-8000 operating voltage is selectable between 110-120Vac, 50/60 Hz or 220-240Vac, 50/60 Hz. Operating voltage is set by the voltage selection switch as shown in figure 2.0.

To change the voltage setting, remove the CT-8000 from the case, locate the voltage setting switch and set the new operating voltage.
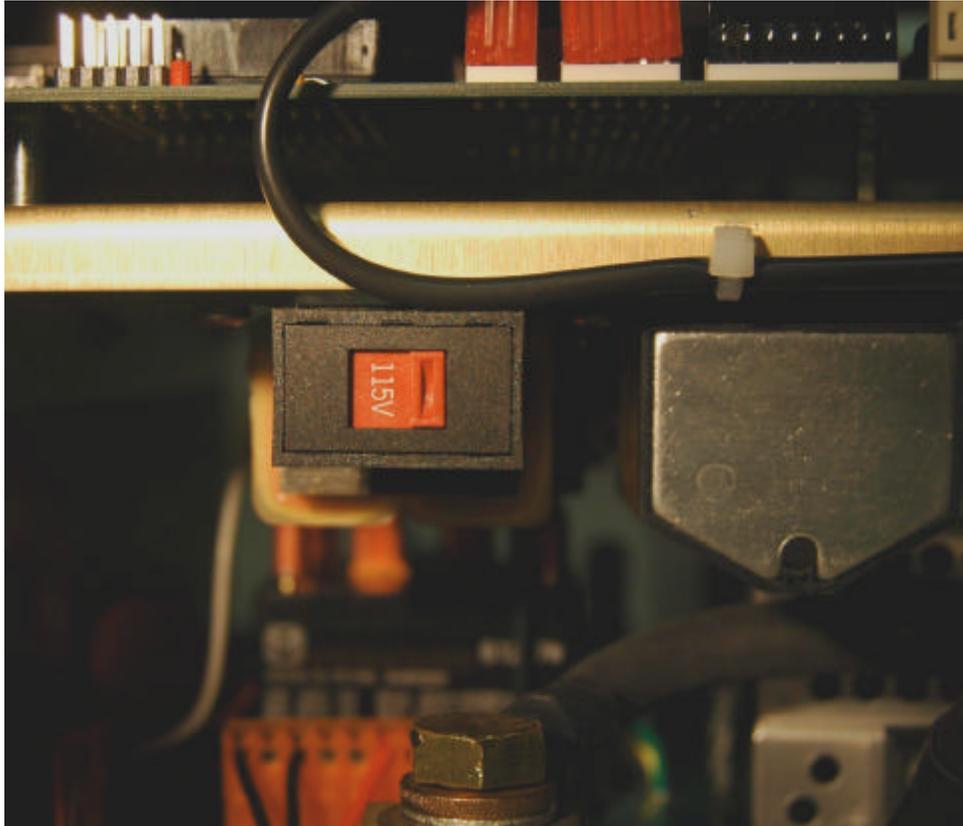
Figure 2.0 CT-8000 Operating Voltage Setting

7.3 CT-8000 Main Power Switch & Circuit Breaker

   The CT-8000 uses an AC input module that contains the AC receptacle, power switch and circuit breaker.

7.4 Initiate Circuit Protection Fuses

   The OPEN and CLOSE initiate circuits are protected by 5 Ampere fuses (3AG, 250Vac, fast-blow types).

7.5 CT-8000 Printer and Printer Paper

The built-in, thermal printer uses 4.5 inch wide, thermal paper for printing test results. To maintain the highest, quality printing and to avoid paper jamming, it is highly recommended that the thermal paper be supplied by the factory. Additional paper can be ordered from either of the two sources listed below:

Vanguard Instruments Co, Inc.
1520 S. Hellman Ave.
Ontario, CA 91761
Tel: 909-923-9390
Fax: 909-923-9391
Part Number: TP-4 Paper

BG Instrument Co.
13607 E. Trent Avenue
Spokane, WA 99216
Tel: 509-893-9881
Fax: 509-893-9803
Part Number: TP-4 paper

7.6 Replacing CT-8000 Thermal Paper

The roll of thermal paper resides inside a pocket underneath the printer cover. To replace the paper, follow the steps below:
- Remove the printer cover.
- Remove the leftover thermal paper roll from the paper holder.
- Unroll the new thermal paper.
- Feed the thermal paper into the slot between the paper pocket and the rubber roller. The printer will automatically pull the paper under the thermal head.
- Place the paper roll into the paper holder.
- Lift the thermal head and align the thermal paper if necessary.
- Replace the printer cover back.

NOTE
The paper should feed from the bottom of the roll. The thermal paper will show a colored stripe in the margin to indicate that the roll is about to run out of paper.

7.7 CT-8000 Printer Paper Control

To advance the paper from the printer, press and release the "? PAPER LCD" button.
To retract the thermal paper from the printer, press and release the "? PAPER LCD" button.

7.8 CT-8000 LCD Contrast Control

To darken the LCD screen, press and hold the "? PAPER LCD" button. To decrease the contrast of the LCD screen, press and hold the "? PAPER LCD" until the desired contrast is reached.

8.0 Test Hook-up Connections

8.1 Contact Cable Hookup

A typical, contact cable connection to a circuit breaker is shown in Figure 3.0. Red and black clips are connected across the circuit breaker contact phase A, B and C.

A typical circuit breaker with series contacts is shown in figure 4.0. In the example below, the circuit breaker has 2 contacts in series per phase. Contact timing channel 1 and 2 are used in the illustration.

NOTE

It is advisable to ground one side of the contacts for most testing purposes. If a breaker is floating or ungrounded, ensure that the contact channel inputs are protected against static discharge.
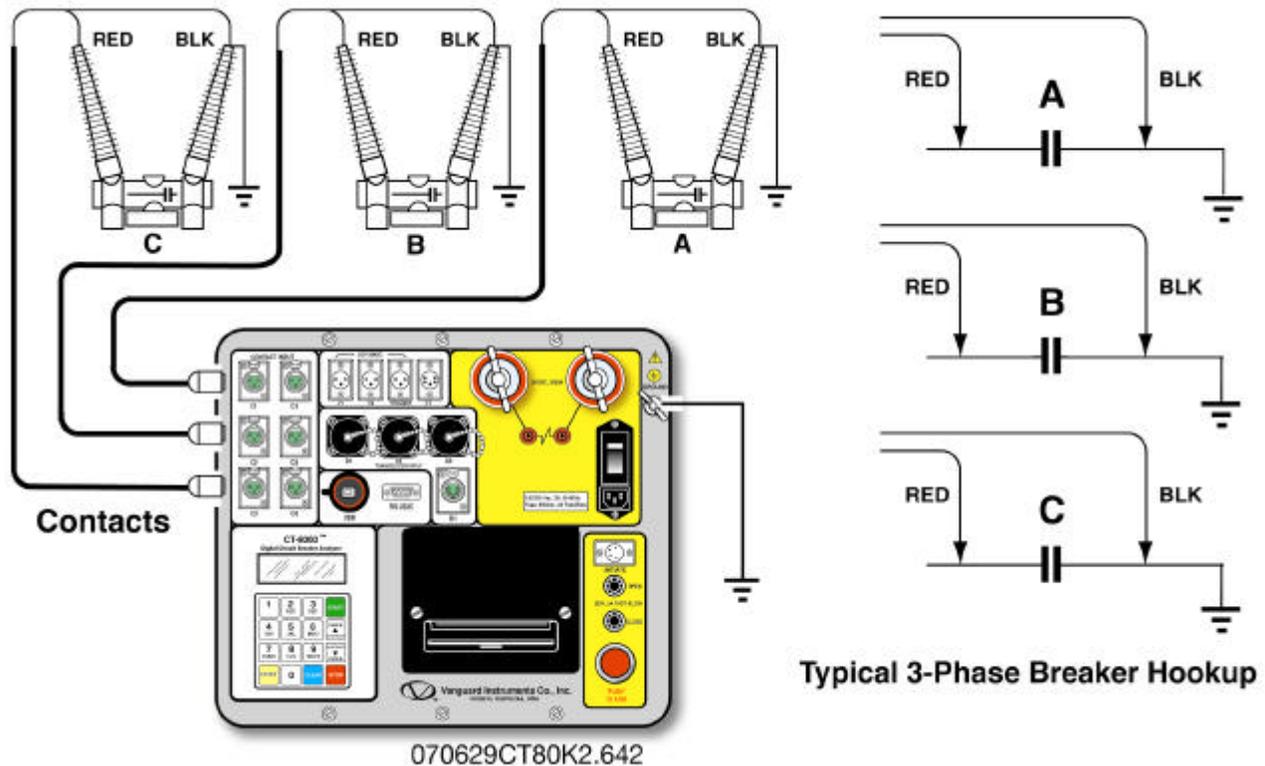
Figure 3.0 Contact Cable Connection
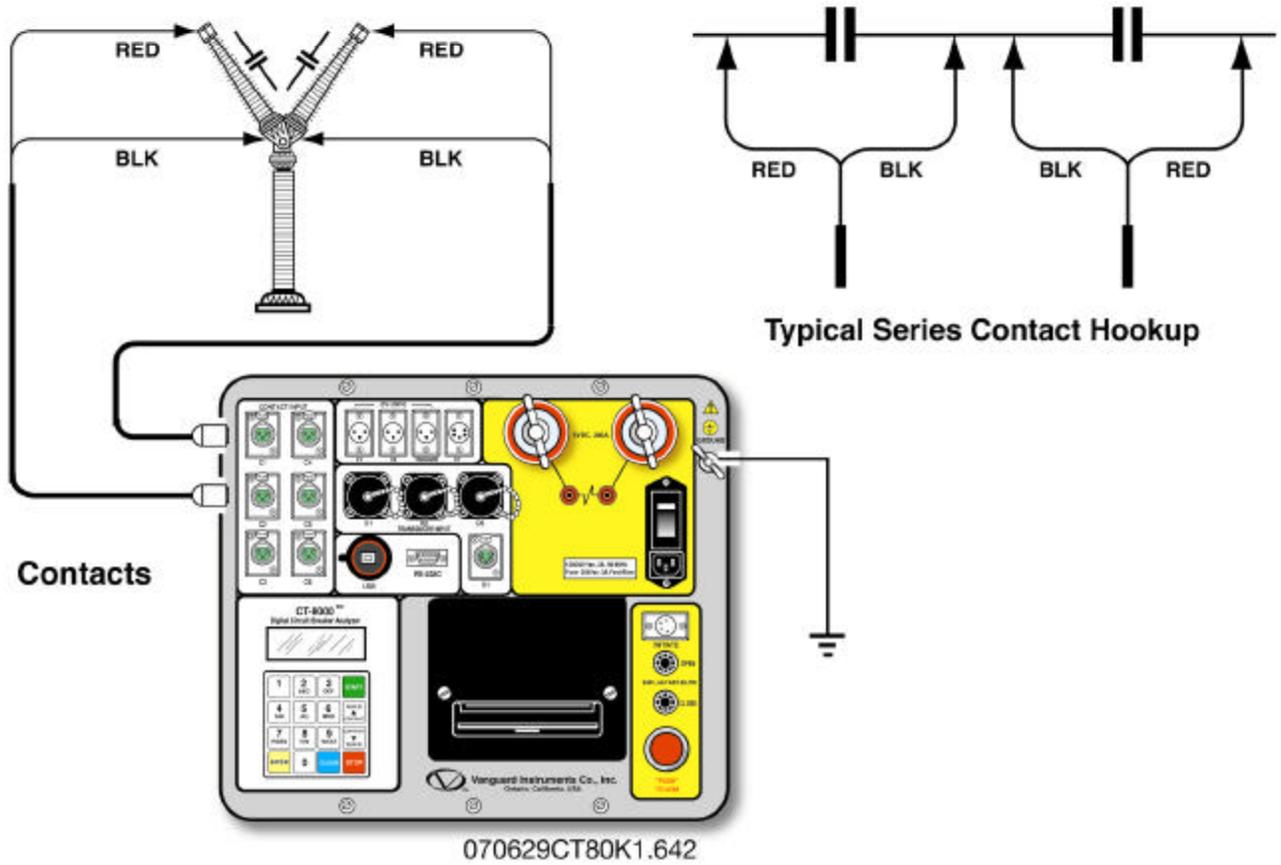
Figure 4.0 Series Contact Cable Connection

8.2 Initiate Cable Hookup

The CT-8000 will trip or close breakers through a solid-state device, which will operate on any AC or DC control voltage ranging from 10 to 300 Volts. Both the trip and close circuits are protected by 5 Ampere fuses.

A typical DC trip and DC close, control circuit test hookup is shown in Figure 5.0.

A typical DC trip and AC close, control circuit test hookup is shown in Figure 6.0.
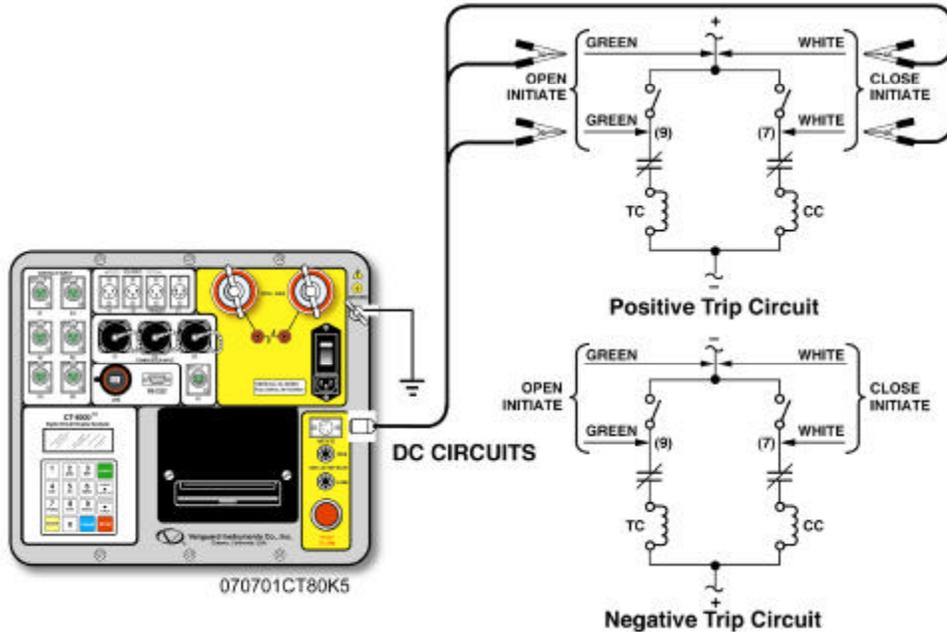
Figure 5.0 DC Trip and DC Close, Initiate Circuit Cable Hook-Up
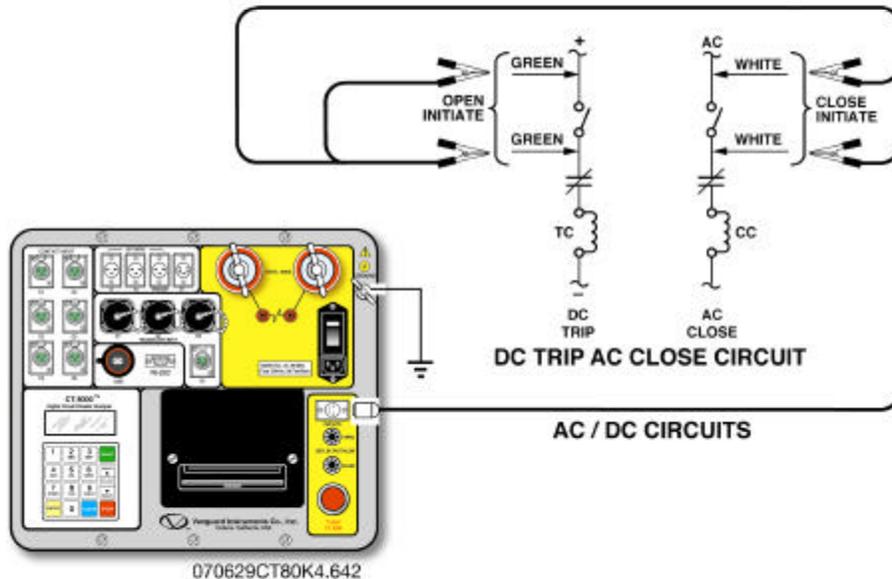
Figure 6.0 DC Trip and AC Close, Initiate Circuit Cable Hook-Up

8.3 Analog Voltage Monitor Hookup

The analog voltage input, "V1" permits the user to monitor a breaker's DC control voltage during an operation.   The analog voltage input will record the nominal DC voltage at no load and the minimum DC voltage while the Trip or Close coil is energized.

The nominal and minimal voltage readings will be printed on a tabulated report. Analog waveforms will also be plotted in a graphical format. Thus, the user is able to see the breaker's DC control voltage "dip" under load conditions. Problems, such as a poor connection or an excessive voltage drop, during the circuit breaker operation can be easily detected.

A typical voltage monitoring hook up scheme is shown on Figure 7.0.

NOTE
The maximum voltage that can be recorded is 255 Vdc.
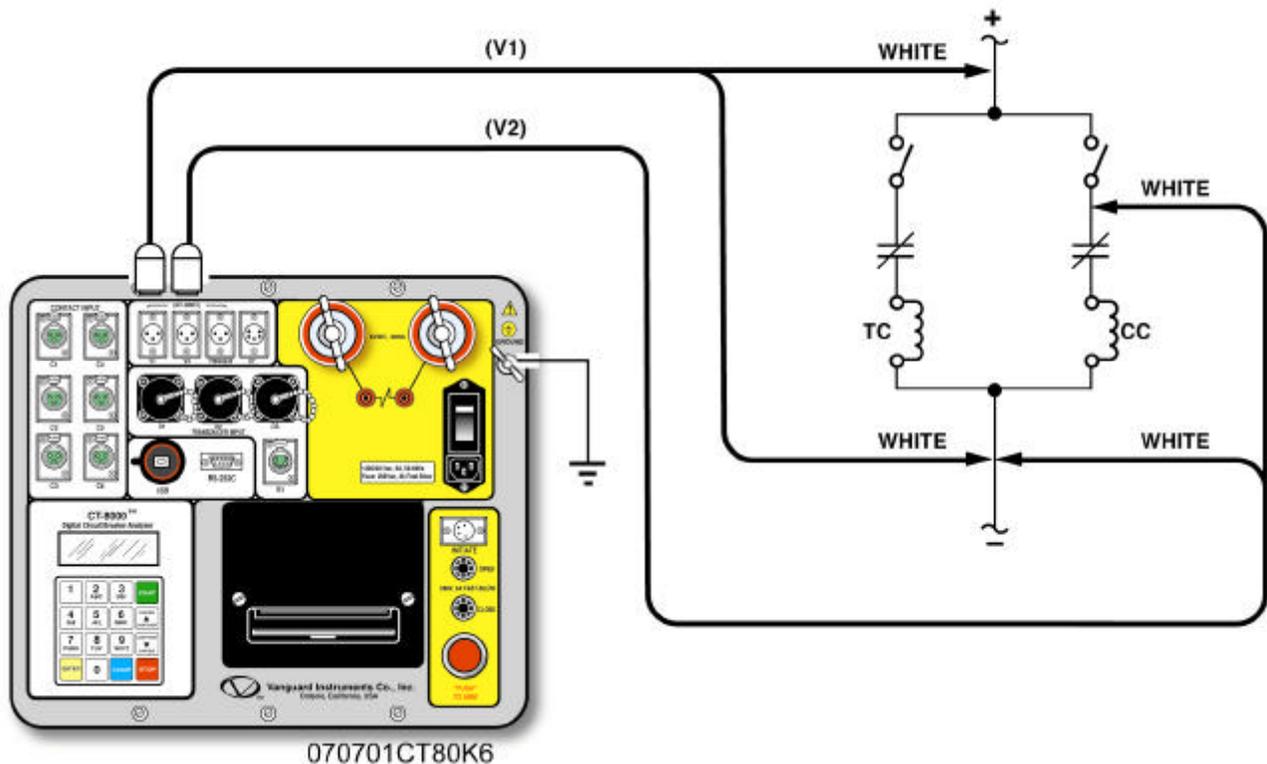
Figure 7.0 Voltage Monitoring Cable Hook-Up

8.4 Digital Voltage Monitor Hookup

The digital, voltage input channel, "V2" permits the user to monitor the voltage status as "ON" or "OFF" states. The voltage "ON" or "OFF" states will be plotted on the graphical report. A typical hook up is shown in Figure 7.0.

8.5 External Trigger Input

The External Trigger Mode enables the user to start recording data when the CT-8000 senses a voltage. A typical application for the External Trigger Mode is to time a circuit breaker in a close operation and to start timing only when the close coil is energized, thus bypassing the 52X relay delay time.

Since the 52X relay carries the close coil current, the user will need to connect the CT-8000's initiate cable to the close terminal shown in Figure 5.0. The CT-8000 will energize the 52X relay to start the close operation, which will then start the timing when the CT-8000 senses the voltage across the closing coil. See Figure 8.0 for a typical test hookup. Another application for external trigger is to start timing the breaker when the user trips or closes the breaker remotely.

NOTE

Minimum trigger voltage is set for 30 Vac/dc. Maximum, continuous voltage is limited to 300 Vac/dc. Different trigger voltages can be set at the factory, based upon specific requests.

The CT-8000 will start looking for the external trigger voltage when the message, "AWAITING TRIGGER…" is shown on the LCD screen. The external trigger voltage needs to be sensed by the CT-8000 within 15 seconds after the initiate sequence has begun. The CT-8000 will return to the main menu if no voltage is sensed.
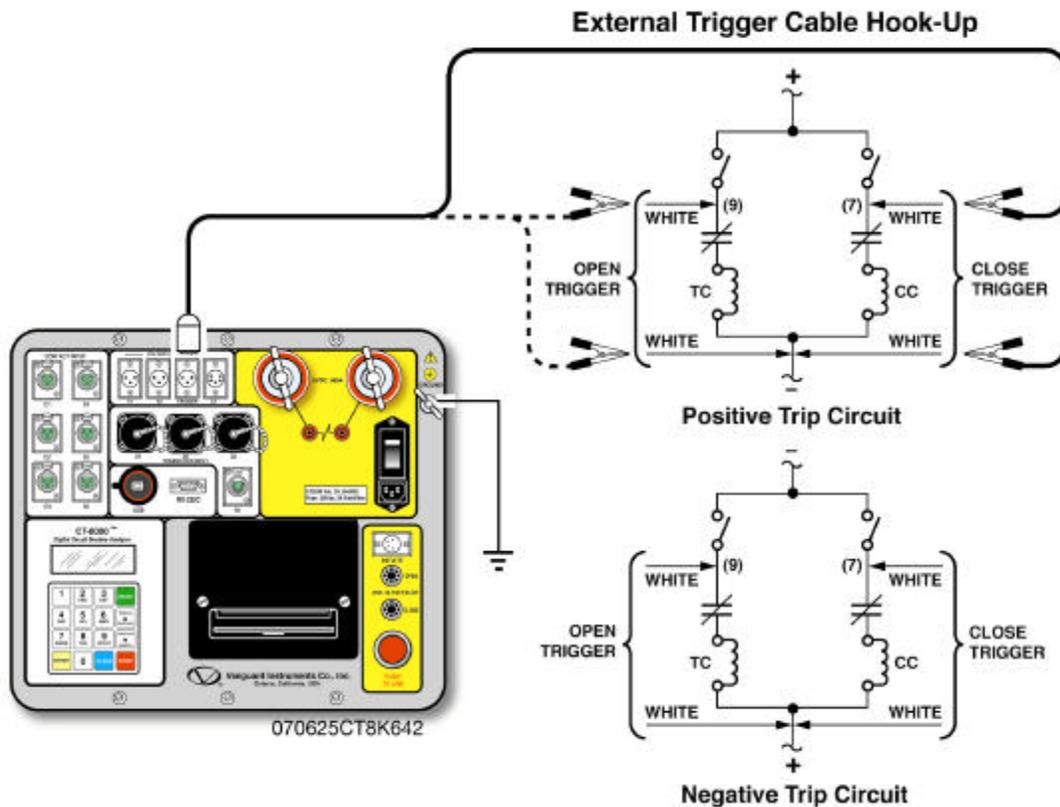
Figure 8.0 External Trigger Cable Hook-Up

8.6 Digital Transducer Connection

A typical digital transducer connection is shown on Figure 9.0. See Appendix I for more transducer connections.
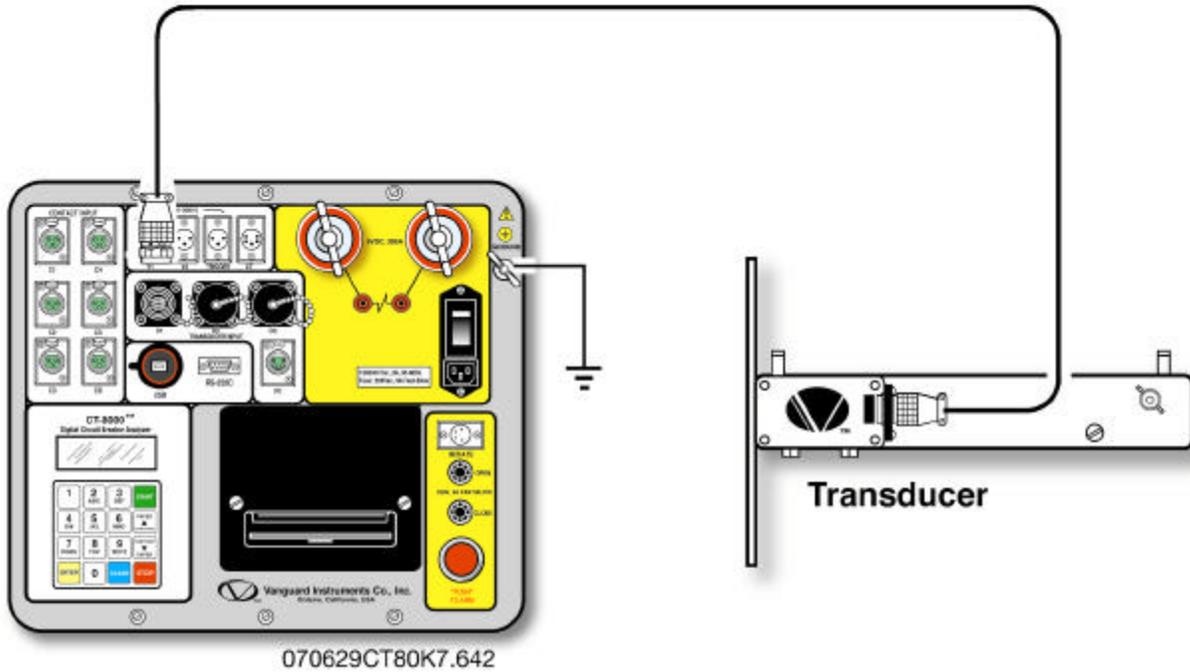
Figure 9.0 Transducer Connection

8.7 Resistor type transducer Connection

The CT-8000 will support one channel of resistor type transducers. The transducer resistance input ranges from 200 Ohms to 10K Ohms.

The CT-8000 supplies a 5 Vdc reference voltage to power the resistor type transducers. The sense voltage will be translated into a travel distance based on the transducer calibration parameters. The user is required to set up the resistor transducer before performing a test (see section 9.15). Up to 9 transducer setups can be stored in the CT-8000 memory. Once the transducer setup is stored; the user can simply recall a transducer setup before running a test.

A typical resistor type transducer connection is shown in figure 10.0

NOTE

When a resistor type transducer is used, the test result is shown as travel transducer channel 1 (see figure 28).

070624CT8K642B
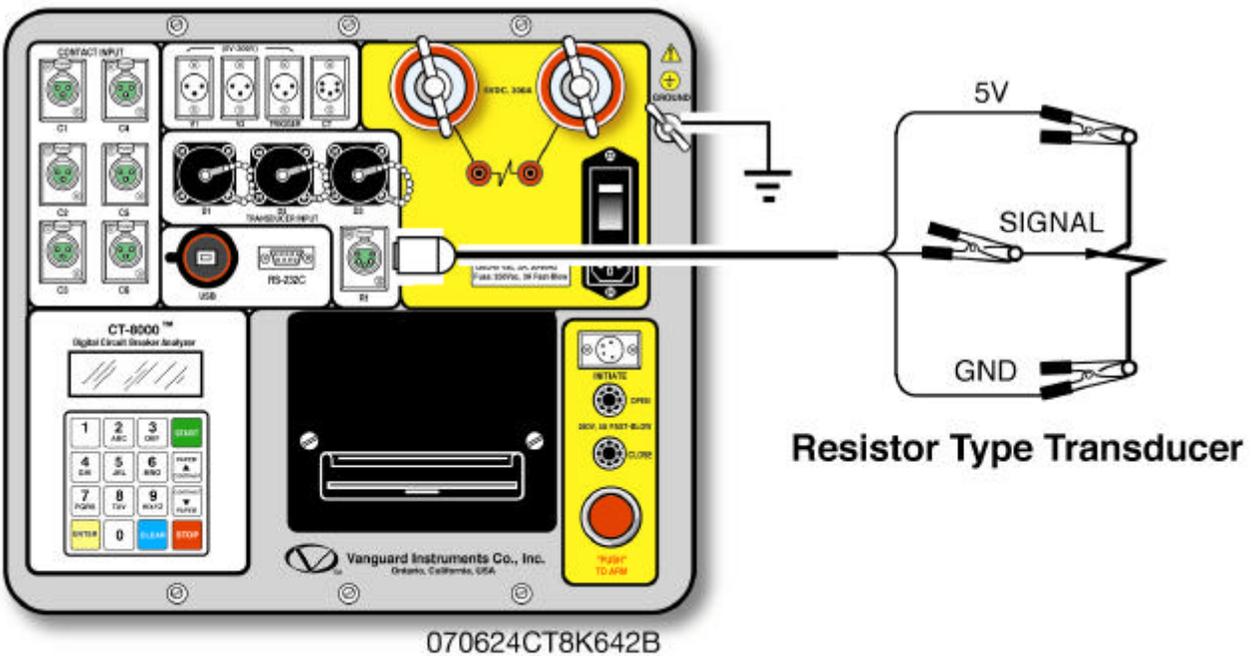
Figure 10.0 Typical Resistor Type Transducer Connection

A 15ft transducer cable with 3 quick disconnect clips is provided with each CT-8000. The 3 clips are labeled: +5V, Signal and GND.

8.8 Micro-Ohm Meter Connection

A typical CT-8000 micro-ohm meter (for Dynamic Contact Resistance or Static Resistance Test) connection to a circuit breaker contact is shown in figure 11.0. The CT-8000 is supplied with two 40 ft, #4 AWG current cables with quick disconnect alligator clamps. Two 40 ft sense cables are also supplied with each CT-8000.

070701CT80K8
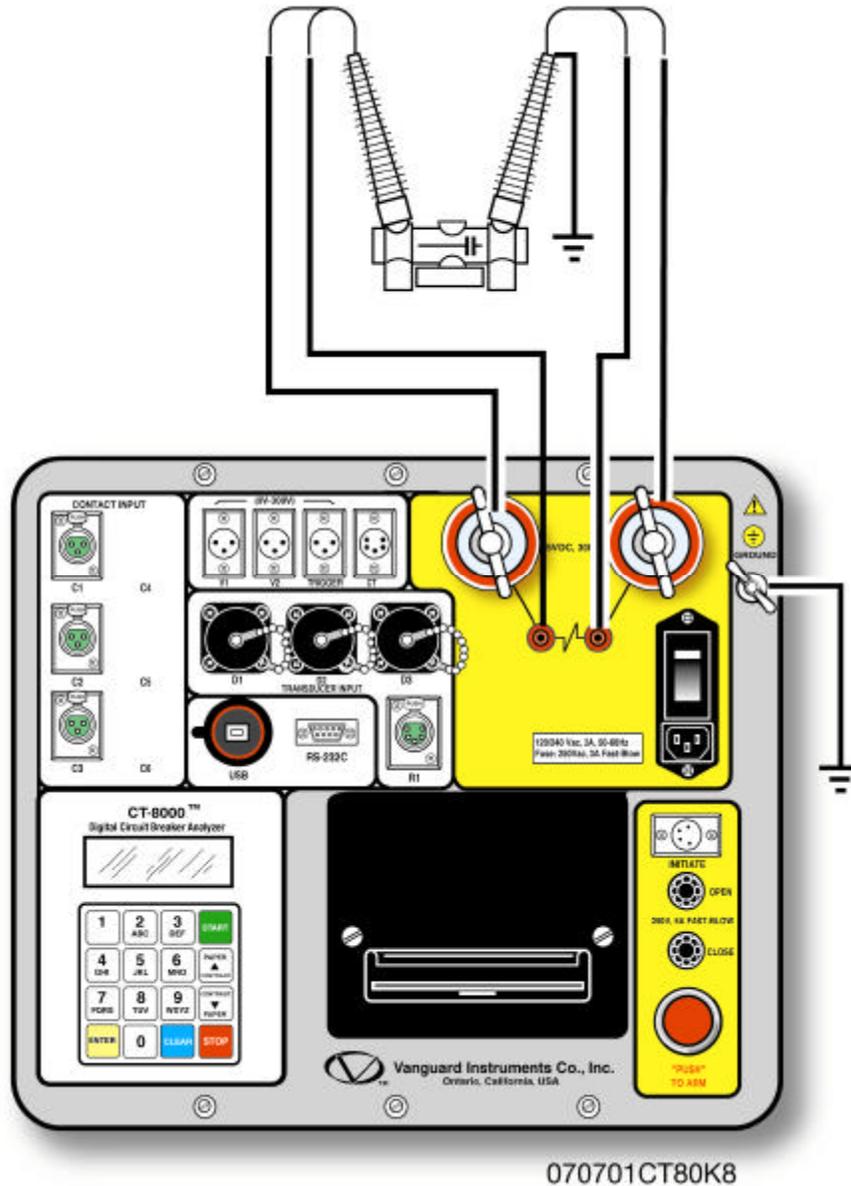
Figure 11.0 Typical Contact Resistance Cable Connection

NOTE
Do not modify the length of the CT-8000 current cables.

8.9 On-line test AC Current Sensor Connection

A typical CT-8000 AC current sensor connection is shown in figure 12.0. The non-contact AC current sensor shall be connected to one of the circuit breaker bushing CT terminals. A minimum current of 100 mA is required for the CT-8000 AC current sensor.
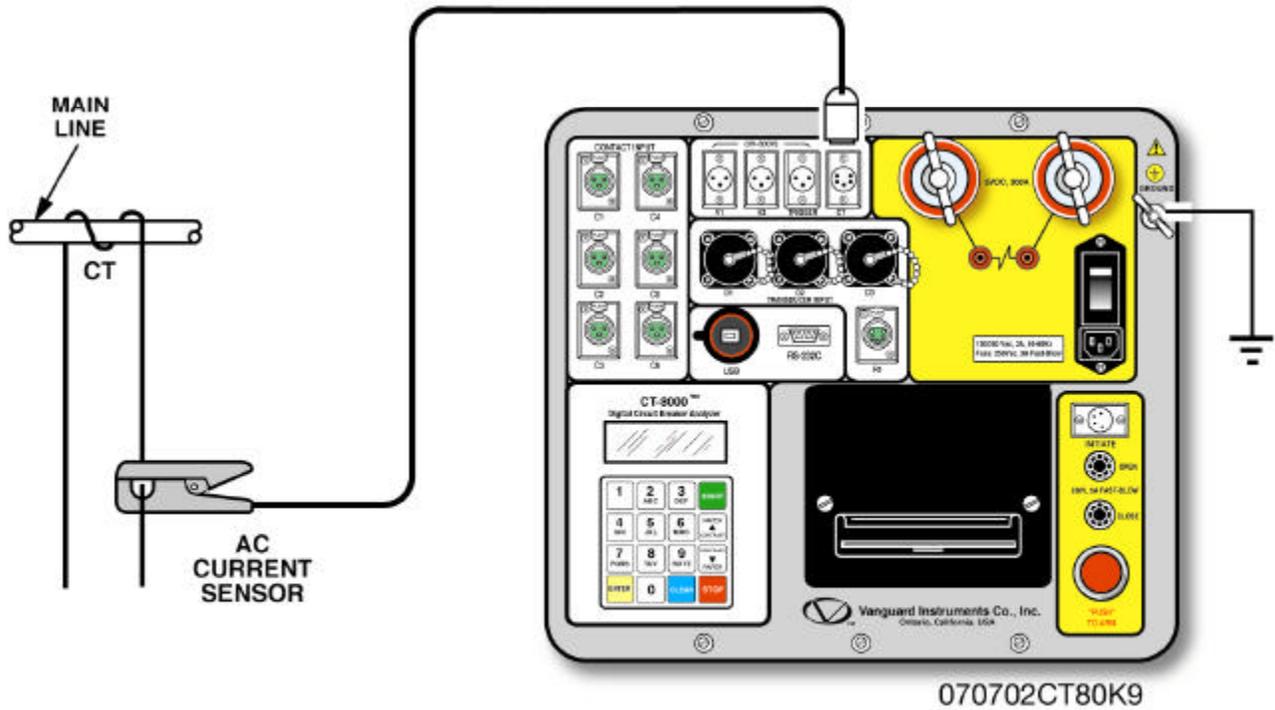
Figure 12.0 AC Current Sensor Connection

9.0 Operating Procedures

The main steps to time a circuit breaker are listed in Figure 13.0.

.

```
┌─────────────────────────────────────────────┐
│            HOOKUP CT-8000                    │
│ 1. GROUND THE CT-8000 (See NOTE)             │
│ 2. CONNECT CT-8000 CABLES TO BREAKER         │
│ 3. INSTALL TRANSDUCER WITH CABLE             │
└─────────────────────────────────────────────┘
                      │
                      ▼
┌─────────────────────────────────────────────┐
│              APPLY POWER                     │
│ 1. TURN THE CT-8000 ON                       │
│ 2. PERFORM SELF TESTS: HOOK-UP TEST,         │
│    CABLE TEST, IF NECESSARY                  │
└─────────────────────────────────────────────┘
                      │
                      ▼
┌─────────────────────────────────────────────┐
│             TIME BREAKER                     │
│ 1. SELECT THE CT-8000 TEST                   │
│ 2. OPERATE THE BREAKER                       │
└─────────────────────────────────────────────┘
                      │
                      ▼
┌─────────────────────────────────────────────┐
│              GET RESULTS                     │
│ 1. READ OR PRINT THE TABULATED RESULTS       │
│ 2. PRINT THE GRAPHICAL RESULTS               │
│ 3. SAVE THE TIMING SHOT                      │
└─────────────────────────────────────────────┘
```
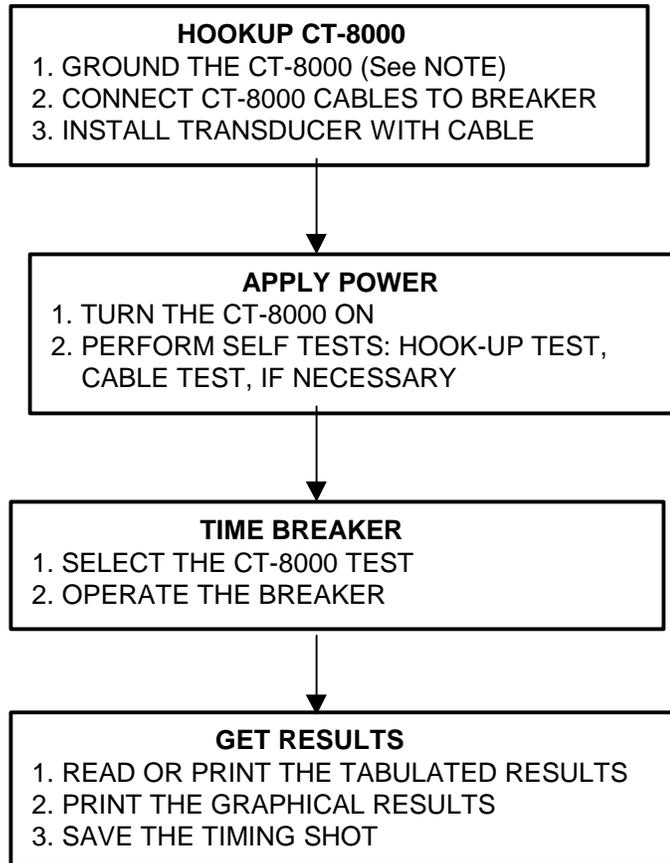
Figure 13.0 CT-8000 Operating Steps

NOTE

To reduce the possibility of damaging the CT-8000 contact channels due to static discharge in the high voltage substations, it is recommend to ground one side of the breaker's bushings.

Always connect the CT-8000 ground stud to the substation ground before connecting any cables to the unit.

9.1 Timing a Circuit Breaker

The CT-8000 will initiate the breaker operation and do a timing test on the following operations:

- OPEN
- CLOSE
- OPEN-CLOSE
- CLOSE-OPEN
- OPEN-CLOSE-OPEN

NOTE

1. The CT-8000 can start the OPEN-CLOSE operations without a delay or by using a programmable delay between the OPEN and CLOSE commands.

2. The CLOSE-OPEN operation can be started by the CT-8000, using several options.
   - Contact #1 Close
   The CT-8000 can initiate a CLOSE command and then an OPEN command after detecting the breaker's contact was closed. The CT-8000 detects that the breaker's contact was closed through contact channel #1. The selection is recommended for the CLOSE-OPEN operation since it truly represents when the circuit breaker closed and then opened.

   - Set DELAY
   The CT-8000 can initiate a CLOSE command and then an OPEN command after a programmable delay that can be set in milliseconds.

   - No DELAY
   The CT-8000 can initiate a CLOSE command and then an OPEN command without any delay. Since the circuit breaker is in the open state, the circuit breaker's 52B contact allows the close coil to be energized, which can start the close command. When the circuit breaker is making the transition from an open state to a closed state, the 52A contact will close allowing the breaker to initiate the open command.

3. The OPEN-CLOSE-OPEN operation can be initiated by the CT-8000, by using a programmable delay between each of the operations, where the delays can be set between the OPEN to CLOSE and between the CLOSE to OPEN commands.

9.1.1 Timing an OPEN Operation (With No Insertion Resistors)

The following example shows the steps for performing an Open Test on a circuit breaker.

Table 3.0 Open Operation With No Insertion Resistors

STEP	OPERATION	ACTION	DISPLAY
1	READY TIMER FOR BREAKER OPERATION.	PRESS #1 KEY.	1.TIME BREAKER 2.STATIC RES TEST 3.DYMANIC RES TEST
2	SELECT "TIME BREAKER".	PRESS #1 KEY.	INSERTION RESISTOR? 1.NO 2.YES
3	SELECT NO INSERTION RESISTOR.	PRESS #1 KEY.	TIMING WINDOWS: 1.WINDOW = 1 SEC 2.WINDOW = 10 SEC 3. WINDOW = 20 SEC
4	SELECT 1-SECOND TIMING WINDOW.	PRESS #1 KEY.	TRIGGER MODE: 1. INTERNAL TRIGGER 2. EXTERNAL TRIGGER
5	SELECT INTERNAL TRIGGER.	PRESS #1 KEY.	TIMING MODE: 1. OPEN 2. CLOSE 3. O-C 4. C-O 5. O-C-O
6	SELECT OPEN OPERATION.	PRESS #1 KEY.	OPEN TIMING Hold "ARM" Switch, Then "START". "STOP" to ABORT
7	INITIATE OPEN COMMAND.	HOLD THE "ARM" SWITCH AND PRESS THE "START" KEY.	TEST IN PROGRESS Hold "ARM" Until Test complete. (Up to 25 seconds)
8	OBSERVE BREAKER OPERATED. ANALYZER IS READY TO OUTPUT RESULTS.	NONE.	1.RUN TEST 06/12/07 2.GET RSLT 19:20:01 3.SET-UP 4.DIAGNOSTIC

Go to section 9.2 to print a test report.

NOTE

One-second timing windows are used for breaker timing. The 10 and 20 second timing windows are used for long timing events (i.e. timing circuit-switchers).

The user can set the CT-8000 to print tabulated and graphical reports automatically after it completes a test. See Paragraph 9.26 for the automatic print setting.

9.1.2 Timing an OPEN Operation With Insertion Resistors

The CT-8000 can time breakers with insertion resistors. The insertion resistor can range from 10 to 7,000 Ohms. Any insertion resistor more than 7,000 Ohms is detected as an open circuit. The timing results will show the main contact time and the insertion resistor contact time. Graphic reports will show the main contact and the resistor contact activities on each of the channels.

Table 4.0 Open Operation With Insertion Resistor

STEP	OPERATION	ACTION	DISPLAY
1	READY TIMER FOR BREAKER OPERATION.	PRESS #1 KEY.	1.TIME BREAKER 2.STATIC RES TEST 3.DYMANIC RES TEST
2	SELECT "TIME BREAKER".	PRESS #1 KEY.	INSERTION RESISTOR? 1.NO 2.YES
3	SELECT INSERTION RESISTOR.	PRESS #2 KEY.	RESISTOR VALUE: 1.LESS THAN 1000 OHM 2.1000 to 2000 OHM 3.MORE THAN 2000 OHM
4	SELECT LESS THAN 1000 OHM RESISTOR RANGE.	PRESS #1 KEY.	TIMING WINDOWS: 1.WINDOW = 1 SEC 2.WINDOW = 10 SEC 3.WINDOW = 20 SEC
5	SELECT 1-SECOND WINDOW.	PRESS #1 KEY.	TRIGGER MODE: 1. Internal Trigger 2. External Trigger
6	SELECT INTERNAL TRIGGER.	PRESS #1 KEY.	TIMING MODE: 1. OPEN 2. CLOSE 3. O-C 4. C-O 5. O-C-O
7	SELECT OPEN OPERATION.	PRESS #1 KEY.	OPEN TIMING Hold "ARM" Switch, Then "START". "STOP" to ABORT
8	INITIATE OPEN COMMAND.	HOLD THE "ARM" SWITCH AND PRESS THE "START" KEY.	TEST IN PROGRESS Hold "ARM" Until Test complete. (Up to 25 seconds)
9	ANALYZER IS READY TO OUTPUT RESULTS.	NONE.	1.RUN TEST 06/12/07 2.GET RSLT 19:20:01 3.SET-UP 4.DIAGNOSTIC

Go to section 9.2 to print a test report.

NOTE

One-second timing windows are used for breaker timing. The 10 and 20 second timing windows are used for slower timing events (i.e. timing circuit-switchers).

The user can set the CT-8000 to print tabulated and graphical reports automatically after it completes a test. See Paragraph 9.26 for the automatic print setting.

9.1.3 Timing CLOSE-OPEN Operation Using Contact Channel #1

The CLOSE-OPEN operation of the breaker simulates a condition where a breaker is closed on a fault. There are 3 choices for the user to setup the CLOSE-OPEN operation:

1. Contact #1 CLOSE

   The CT-8000 will initiate a CLOSE operation. The Open operation is then initiated after contact channel # 1 is closed.

2. Set DELAY

   The user can set a delay from 10 to 500 ms between a CLOSE command to the OPEN command. The CT-8000 will initiate the CLOSE operation and start the delay counter. The OPEN operation will be initiated when the delay time completes.

3. No DELAY

   Both the CLOSE and OPEN commands are initiated by the CT-8000 simultaneously. The OPEN coil is energized when the Open auxiliary switch makes.

NOTE

The CLOSE-OPEN command option "Contact #1 CLOSE" closely simulates the breaker closing on a fault condition in the field.

Table 5.0 Close-Open Operation Using Contact Channel #1

STEP	OPERATION	ACTION	DISPLAY
1	READY TIMER FOR BREAKER OPERATION.	PRESS #1 KEY.	1.TIME BREAKER 2.STATIC RES TEST 3.DYMANIC RES TEST
2	SELECT "TIME BREAKER".	PRESS #1 KEY.	INSERTION RESISTOR? 1.NO 2.YES
3	SELECT NO INSERTION RESISTOR.	PRESS #1 KEY.	TIMING WINDOWS: 1.WINDOW = 1 SEC 2.WINDOW = 10 SEC 3.WINDOW = 20 SEC
4	SELECT 1-SECOND WINDOW.	PRESS #1 KEY.	TRIGGER MODE: 1.INTERNAL TRIGGER 2.EXTERNAL TRIGGER
5	SELECT INTERNAL TRIGGER.	PRESS #1 KEY.	TIMING MODE: 1. OPEN 2. CLOSE 3. O-C 4. C-O 5. O-C-O
6	SELECT CLOSE-OPEN OPERATION.	PRESS #4 KEY.	C-O Second Trigger: 1. Contact #1 CLOSE 2. Set DELAY 3. No DELAY
7	SELECT CONTACT #1 CLOSE.	PRESS #1 KEY.	CLOSE-OPEN TIMING Hold "ARM" Switch Then "START" "STOP" to ABORT
8	INITIATE OPEN COMMAND.	HOLD THE "ARM" SWITCH AND PRESS THE "START" KEY.	TEST IN PROGRESS Hold "ARM" Until Test complete. (Up to 25 seconds)
9	ANALYZER IS READY TO OUTPUT RESULTS.	NONE.	1.RUN TEST 06/12/07 2.GET RSLT 19:20:01 3.SET-UP 4.DIAGNOSTIC

NOTE
1. Users can program a delay from 10 to 500 ms between the CLOSE and OPEN commands. When a delay is used in the operation, it may not represent a true breaker operating condition.

2. Users can also program in no delay for the operation in which case, the CLOSE and OPEN commands are initiated at the same time by the CT-8000.

9.1.4 Timing OPEN-CLOSE-OPEN Operation

The OPEN-CLOSE-OPEN operation requires the user to enter two time-delays between the circuit breaker operations. The time delays are in millisecond intervals. The first delay is from the first OPEN command to the CLOSE command. The second delay is from the CLOSE command to the second OPEN command. Refer to Table 6.0 for setting up the OPEN-CLOSE-OPEN operation.

Table 6.0 Open-Close-Open Operation Using Delay

STEP	OPERATION	ACTION	DISPLAY
1	READY TIMER FOR BREAKER OPERATION.	PRESS #1 KEY.	1.TIME BREAKER 2.STATIC RES TEST 3.DYMANIC RES TEST
2	SELECT "TIME BREAKER".	PRESS #1 KEY.	INSERTION RESISTOR? 1.NO 2.YES
3	SELECT NO INSERTION RESISTOR.	PRESS #1 KEY.	TIMING WINDOWS: 1.WINDOW = 1 SEC 2.WINDOW = 10 SEC 3.WINDOW = 20 SEC
4	SELECT 1-SECOND WINDOW.	PRESS #1 KEY.	TRIGGER MODE: 1.INTERNAL TRIGGER 2.EXTERNAL TRIGGER
5	SELECT INTERNAL TRIGGER.	PRESS #1 KEY.	TIMING MODE: 1. OPEN 2. CLOSE 3. O-C 4. C-O 5. O-C-O
6	SELECT OPEN-CLOSE-OPEN OPERATION.	PRESS #5 KEY.	O-C Delay in mS: (10 – 350) mSec ENTER when done
7	SELECT DELAY BETWEEN OPEN-CLOSE OPERATION.	ENTER DELAY USING 0-9 KEYS, PRESS THE "ENTER" KEY TO CONFIRM.	C-O Delay in mS: (10 – 350) mSec ENTER when done
8	SELECT DELAY BETWEEN CLOSE-OPEN OPERATION.	ENTER DELAY USING 0-9 KEYS, PRESS THE "ENTER" KEY TO CONFIRM.	OPEN-CLOSE-OPEN TIMING Hold "ARM" Switch, Then "START". "STOP" to ABORT
9	INITIATE O-C-O COMMAND.	HOLD THE "ARM" SWITCH AND PRESS THE "START" KEY.	TEST IN PROGRESS Hold "ARM" Until Test complete. (Up to 25 seconds)
10	ANALYZER IS READY TO OUTPUT RESULTS.	NONE.	1.RUN TEST 06/12/07 2.GET RSLT 19:20:01 3.SET-UP 4.DIAGNOSTIC

9.2 Printing Tabulated Timing Results Using the Thermal Printer

The circuit breaker timing results can be printed on the thermal printer by using the steps listed in Table 7.0.

A typical circuit breaker timing result printed from the thermal printer is shown in Figure 14.0.

Table 7.0 Printing Tabulated Results

STEP	OPERATION	ACTION	DISPLAY
1	GET TIMING RESULTS.	PRESS #2 KEY.	1.PRINT TEST RESULTS 2.PLOT FULL CHART 3.PLOT EXPANSION 4.PLOT 0-200 MS
2	PRINT TABULATED RESULTS.	PRESS #1 KEY.	SELECT PRINTER 1.THERMAL PRINTER 2.DISPLAY RESULTS
3	OUTPUT TABULATED RESULTS ON THERMAL PRINTER.	PRESS #1 KEY.	BUSY PRINTING

```
BREAKER TIMING RESULTS — 60 Hz

            SHOT NUMBER: 75
DATE: 05/11/07      TIME: 09:09:49

COMPANY:    VANGUARD
STATION:    ONTARIO
CIRCUIT:    123
MFR:        ITE
MODEL:      14 4KV
S/N:        12345
OPERATOR:   HAI

TEST:   CLOSE

CONTACT TIME
CH   TIME   CYCLE         BOUNCE    WIPE
     <mS>                 <mS>      <in>
 1  187.10  11.21         19.20     0.90
 2  187.70  11.24          4.10     0.84
 3  186.45  11.19         22.80     0.97
DELTA TIME <mS>: 1.25

CT CHANNEL ANALYSIS
  TIME    CYCLE
  <mS>
  0.00    0.00

TRAVEL ANALYSIS   T1
STROKE        in    7.09
SPEED        ft/s   8.42
OVER-TRAVEL  in    0.31
BOUNCE BACK  in    0.27

SPEED ANALYSIS:
POINT 1 = 1.00  in
POINT 2 = 2.00  in

V1 NOMINAL VOLTAGE  =    56 VOLTS
V1 MINIMUM VOLTAGE  =    51 VOLTS
INITIATOR CURRENT   =   5.2 AMPS

SHOT LENGTH:            1 SECOND
INSERTION RESISTOR:    NO
TRIGGER:               INTERNAL
```

Figure 14.0 Typical Tabulated Printout of an Open Operation From the Thermal Printer

9.2.1 Tabulated Results Interpretation

1. Timing Record is time and date stamped by the CT-8000.

2. Timing record header information (Company, Substation name, Circuit, etc) is also saved with test record.

3. Timing test type (OPEN, CLOSE, O-C, C-O, O-C-O) is identified. A CLOSE timing shot is shown in figure14.0.

4. Contact channel #1 time is shown in both milliseconds and cycles. From Figure 14.0, contact channel #1 time was 187.10 ms or 11.21 cycles.

5. Contact channel #1 bounce duration was 19.20 ms.

6. Contact channel #1 wipe was measured as 0.90 inches.

7. The slowest contact and fastest contact differential time is shown as contact delta, 1.25 ms.

8. CT (current transformer) time. This is the circuit breaker open or close time when using the CT-8000 AC current sensor (for on-line test).

9. Breaker contact stroke was measured as 7.09inches.

10. Contact velocity calculation was 8.42 feet per second.

11. Contact over-travel distance was measured as 0.31 inches.

12. Contact bounce-back distance was measured 0.27 inches.

13. Contact velocity calculation was from the two analysis points:
      Analysis point # 1 was 1.00 inch from the fully closed position.
      Analysis point # 2 was 2.00 inches from the fully closed position.

14. The DC power supply was monitored during the test. The nominal voltage was 56 Volts and the minimum voltage was 51 Volts.

15. Initiate current was 5.2 Amperes.

16. Timing shot duration was one second.

17. Trigger mode was internal therefore the timing window starts at the same time when the CT-8000 energized the circuit breaker.

18. There was no insertion resistor in the test, thus no insertion resistor time was measured.

9.3 Printing Graphic Timing Results Using the Thermal Printer

Selecting the "PLOT FULL CHART" command will plot the timing chart as follows:
- Timing chart from 0 to 1000 ms with one second window and 50 ms time markers.
- Timing chart from 0 to 10 seconds with 10 second window and 500 ms time markers.
- Timing chart from 0 to 20 seconds with 20 second window and one second time markers.

Table 8.0 Plot Timing Chart

STEP	OPERATION	ACTION	DISPLAY
1	GET TIMING RESULTS.	PRESS #2 KEY.	1.PRINT TEST RESULTS 2.PLOT FULL CHART 3.PLOT EXPANSION 4.PLOT 0-200 MS
2	PLOT FULL CHART.	PRESS #2 KEY.	SELECT PRINTER 1.INTERNAL THERMAL 2.EXTERNAL INK JET
3	SELECT THERMAL PRINTER.	PRESS #1 KEY.	PLEASE WAIT PLOTTING GRAPH
4	RETURN TO MAIN MENU AFTER PRINT CHART.	NO ACTION.	1.RUN TEST 06/12/07 2.GET RSLT 19:20:01 3.SET-UP 4.DIAGNOSTIC

NOTE

1. Plot Expansion, which is Selection #3, in Step 1, allows the user to expand the graphic results in 100 ms increments.

2. Selecting "PLOT 0-200 MS" will automatically plot the timing chart from 0 to 200 milliseconds in the expansion mode with 10 ms timing markers.

3. Typical graphic results are show in figures 15.0 and 18.0.

3. Graphical result interpretations are shown in Figures 19.0 through 21.0.
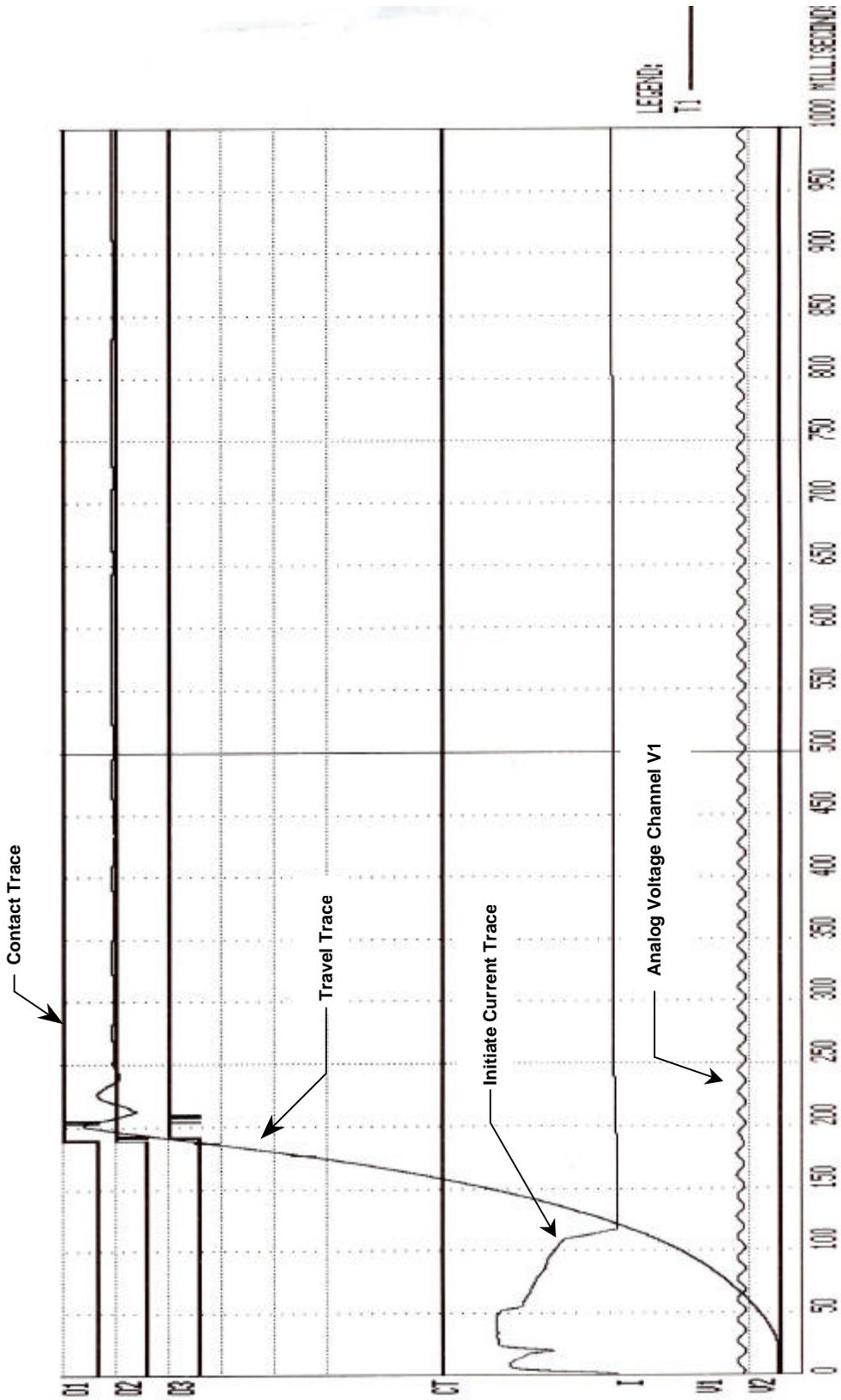
Figure 15.0 Typical Graphic Result Printed on Thermal Printer
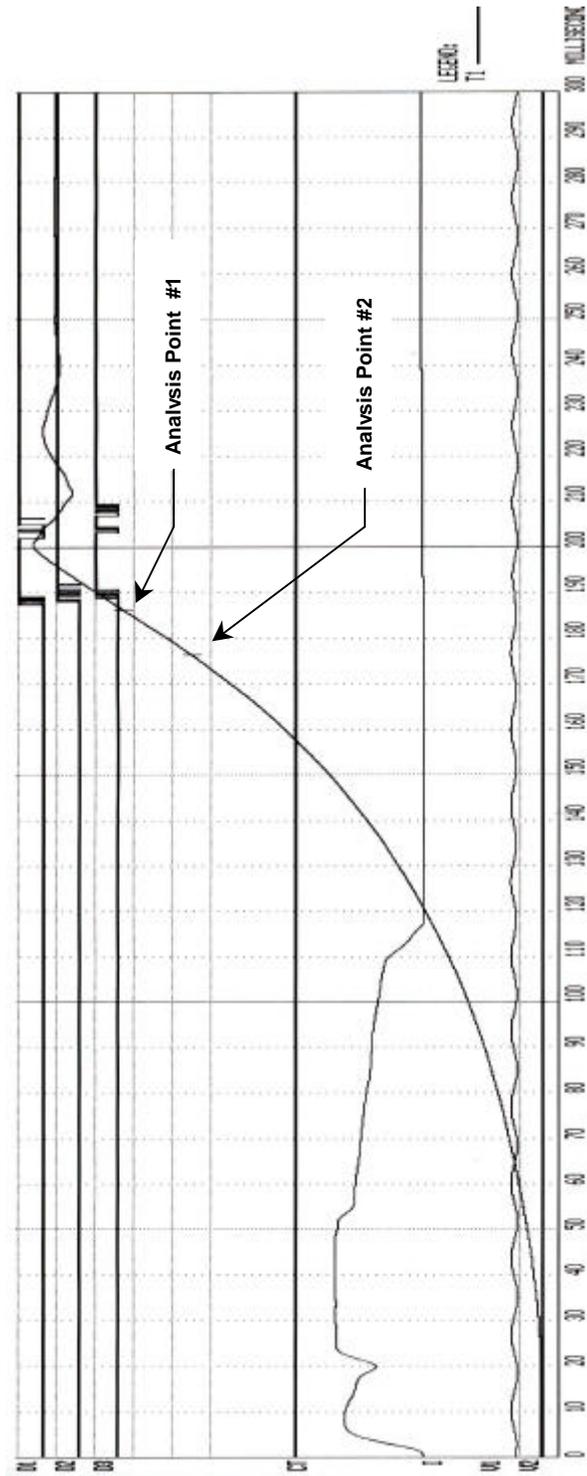
Figure 16.0 Expansion Graph From 0 to 300ms Printed on Thermal Printer
NOTE
Analysis point # 1 and point #2 are shown on chart.

```
┌─────────────────────────────────────────────┐
│ BREAKER TIMING RESULTS - 60 Hz              │
├─────────────────────────────────────────────┤
│          SHOT NUMBER: 1                     │
│ DATE: 06/26/07      TIME: 15:29:18          │
├─────────────────────────────────────────────┤
│ COMPANY:                                    │
│ STATION:                                    │
│ CIRCUIT:                                    │
│ MFR:                                        │
│ MODEL:                                      │
│ S/N:                                        │
│ OPERATOR:                                   │
├─────────────────────────────────────────────┤
│ TEST:   OPEN                                │
├─────────────────────────────────────────────┤
│ CONTACT TIME                                │
│ CH   TIME   CYCLE        BOUNCE    WIPE     │
│      <mS>                <mS>      <in>     │
│  1   0.00   0.00         0.00      0.00     │
│  2   0.00   0.00         0.00      0.00     │
│  3   0.00   0.00         0.00      0.00     │
├─────────────────────────────────────────────┤
│ CT CHANNEL ANALYSIS                         │
│ TIME      CYCLE                             │
│ <mS>                                        │
│ 18.90    1.13                               │
├─────────────────────────────────────────────┤
│ TRAVEL ANALYSIS    T1                       │
│ STROKE       in     0.00                    │
│ SPEED       ft/s    0.00                    │
│ OVER-TRAVEL in      0.00                    │
│ BOUNCE BACK in      0.00                    │
├─────────────────────────────────────────────┤
│ SPEED ANALYSIS:                             │
│ POINT 1 = 1.00 in                           │
│ POINT 2 = 5.00 in                           │
├─────────────────────────────────────────────┤
│ V1 NOMINAL VOLTAGE =      1  VOLTS          │
│ V1 MINIMUM VOLTAGE =      1  VOLTS          │
│ INITIATOR CURRENT  =    4.8  AMPS           │
├─────────────────────────────────────────────┤
│ SHOT LENGTH:           1  SECOND            │
│ INSERTION RESISTOR:    NO                   │
│ TRIGGER:               INTERNAL             │
└─────────────────────────────────────────────┘
```

Current on time

Figure 17.0 On-line Timing Test Report

CT Detect no current

CT detect current
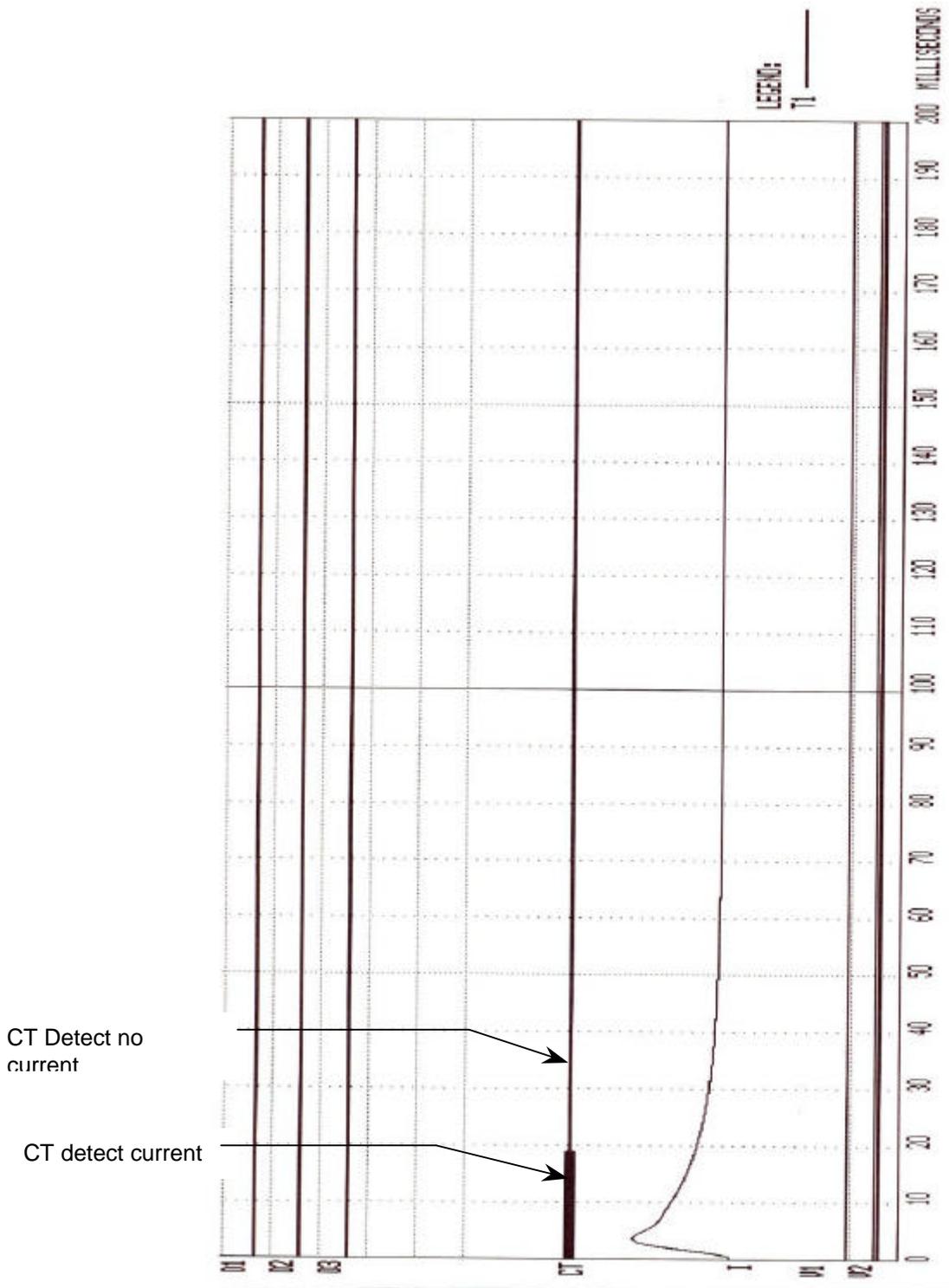
Figure 18.0 On-line Test Graphic Report

CONTACT CLOSED

RESISTOR CLOSED

CONTACT AND RESISTOR OPENED

OPEN

CONTACT OPEN TIME

RESISTOR ON TIME

RESISTOR OPEN TIME
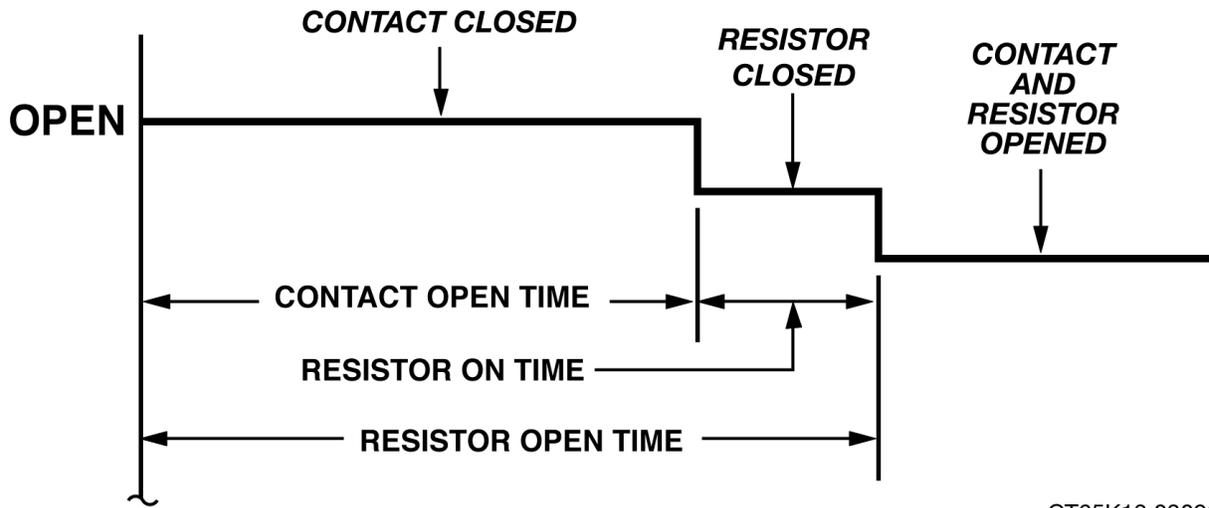
CT65K13.030902

Figure 19.0 Graphical Interpretation of an Open Timing Shot

CONTACT CLOSED

RESISTOR CLOSED

CONTACT AND RESISTOR OPENED

CLOSED

RESISTOR CLOSED TIME

RESISTOR ON TIME

CONTACT CLOSED TIME
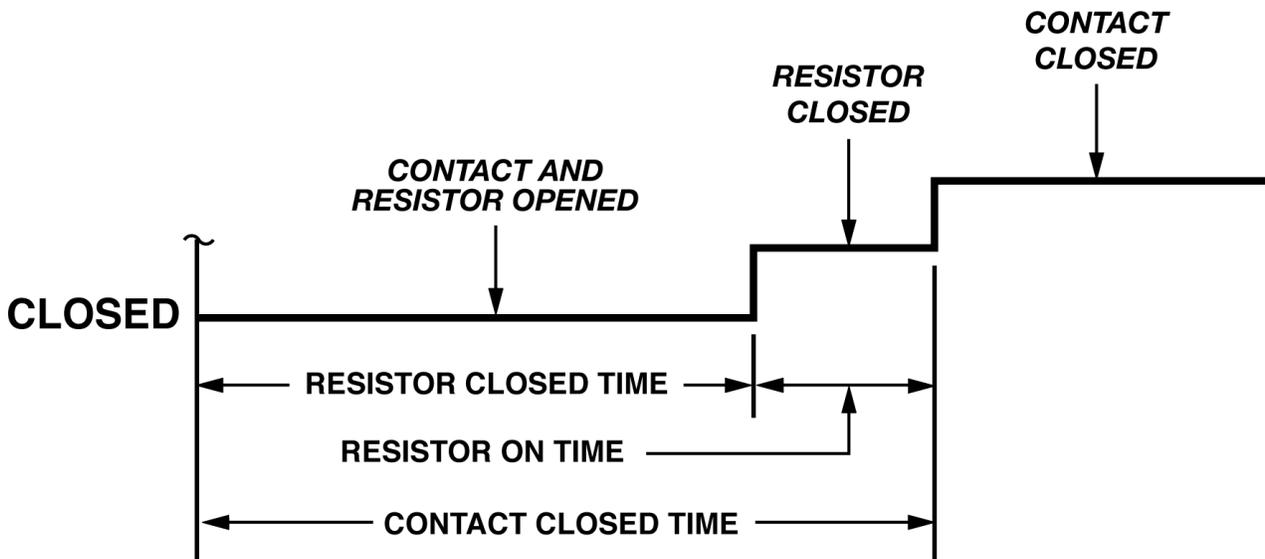
CT65K14.030902

Figure 20.0 Graphical Interpretation of a Close Timing Shot

9ts030606
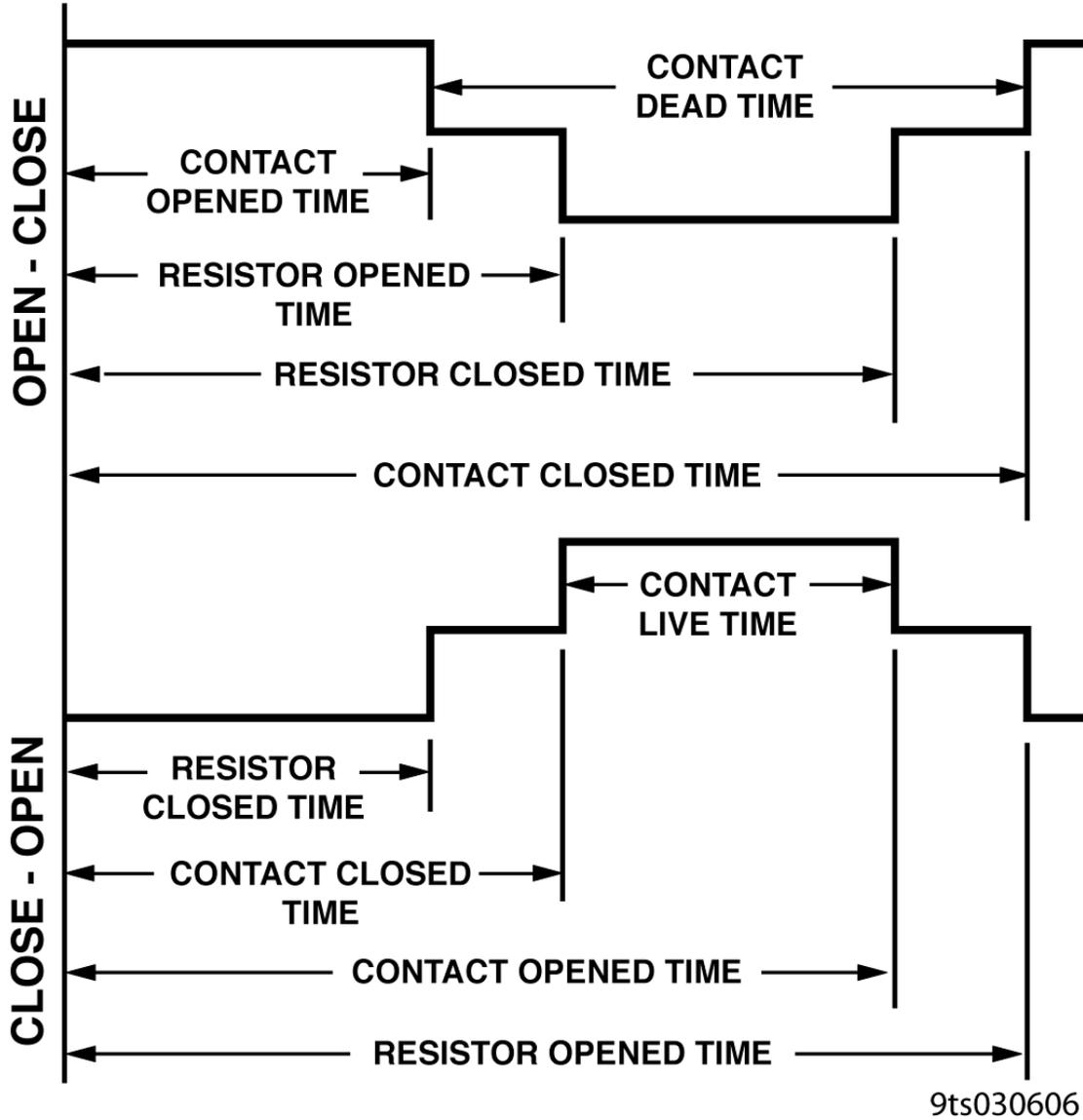
Figure 21.0 Graphical Interpretations of an Open-Close and a Close-Open Timing Shot

9.4 Static Resistance test

The CT-8000 can be use as a 200 Ampere micro-ohm meter. A typical connection for this application is shown in figure 11.0. The following example shows the steps for performing a Static Resistance Test. A typical static resistance test report is shown in figure 22.0.

Table 9.0 Static Resistance Test Procedure

STEP	OPERATION	ACTION	DISPLAY
1	READY CT-8000 FOR STATIC RESISTANCE TEST.	PRESS #1 KEY.	1.TIME BREAKER 2.STATIC RES TEST 3.DYMANIC RES TEST
2	SELECT "STATIC RESISTANCE TEST".	PRESS #2 KEY.	STATIC RESISTANCE TEST CONNECT DCR CABLES THEN "ENTER" TO BEGIN
3	INITIATE TEST.	PRESS "ENTER" KEY	CABLES ENERGIZED
4	CT-8000 MEASURED RESISTANCE OF DUT.	NONE	TEST COMPLETE RES = 291.6 MICRO-OHM CUR = 205.9 A
5	RETURN TO MAIN MENU.	PRESS # "ENTER" KEY.	1.RUN TEST 05/08/07 2.GET RSLT 20:16:00 3.SETUP 4.DIAGNOSTICS
6	PRINT RESISTANCE TEST REPORT.	PRESS #2 KEY.	SELECT PRINTER 1.THERMAL PRINTER 2.DISPLAY RESULTS
7	PRINT REPORT ON THERMAL PRINTER.	PRESS #1 KEY.	1.RUN TEST 05/08/07 2.GET RSLT 20:19:00 3.SETUP 4.DIAGNOSTICS

```
BREAKER TIMING RESULTS — 60 Hz

              SHOT NUMBER: 76
DATE: 05/11/07        TIME: 09:15:51

COMPANY:     VANGUARD
STATION:     ONTARIO
CIRCUIT:     123
MFR:         ITE
MODEL:       14 4KV
S/N:         12345
OPERATOR:    HAI

TEST: STATIC RES TEST

TEST CURRENT:     205.9 AMPS
RESISTANCE:       291.6 u-OHMS
```

Figure 22.0 Typical Static Resistance Report

9.5 Dynamic Contact Resistance Test

The Dynamic Resistance Test allows the user to graph the circuit breaker contact resistance during the CB operation. The feature allows the user to detect circuit breaker contact problems during operation.

Table 10.0 Open Operation with Dynamic Contact Resistance Test

STEP	OPERATION	ACTION	DISPLAY
1	READY TIMER FOR BREAKER OPERATION.	PRESS #1 KEY.	1.TIME BREAKER 2.STATIC RES TEST 3.DYMANIC RES TEST
2	SELECT "DYNAMIC RES TEST".	PRESS #3 KEY.	INSERTION RESISTOR? 1.NO 2.YES
3	SELECT NO INSERTION RESISTOR.	PRESS #1 KEY.	TRIGGER MODE: 1.INTERNAL TRIGGER 2.EXTERNAL TRIGGER
4	SELECT INTERNAL TRIGGER.	PRESS #1 KEY.	TIMING MODE: 1. OPEN 2. CLOSE 3. O-C 4. C-O 5. O-C-O
5	SELECT OPEN OPERATION.	PRESS #1 KEY.	OPEN TIMING Hold "ARM" Switch, Then "START". "STOP" to ABORT
6	INITIATE OPEN COMMAND.	HOLD THE "ARM" SWITCH AND PRESS THE "START" KEY	Test in Progress Hold "ARM" until Test Complete. (Up to 25 Seconds)
7	OBSERVE BREAKER OPERATED. CT-8000 IS READY TO OUTPUT RESULTS.	NONE	1.RUN TEST 06/12/07 2.GET RSLT 19:20:01 3.SET-UP 4.DIAGNOSTIC

9.5.1 Dynamic Contact Resistance Test Report

The Dynamic Contact Resistance graph can be printed with a 0 to 400 micro-ohm linear scale or a 0 to 2000 micro-ohm linear scale or a 0 to 2000 micro-ohm semi-log scale.
The following example shows steps to print the Dynamic Contact Resistance graph (from 0 to 400 micro-ohm linear scale) on the thermal printer.

Table 11.0 Output Dynamic Contact Resistance Graph to Printer

STEP	OPERATION	ACTION	DISPLAY
1	GET TIMING RESULTS.	PRESS #2 KEY.	1.PRINT TEST RESULTS 2.PLOT FULL CHART 3.PLOT EXPANSION 4.PLOT 0-200MS
2	SELECT PLOT FROM 0 TO 200MS.	PRESS #4 KEY.	DYNAMIC RES PLOT: 1. 0-400 ?-Ohms 2. 0-2000 ?-Ohms 3. 10-2000?-Ohms SemiLog
3	SELECT 0-400 ?-OHM LINEAR SCALE.	PRESS #1 KEY.	PLEASE WAIT PLOTING GRAPH
4	RETURN TO MAIN MENU AFTER PRINT CHART.	NO ACTION.	1.RUN TEST 06/10/07 2.GET RESULTS 20:10:01 3.SETUP 4.DIAGNOSTIC

A 0 to 400 micro-ohm Dynamic Contact Resistance graphic test report is show in figure 23.0 below.
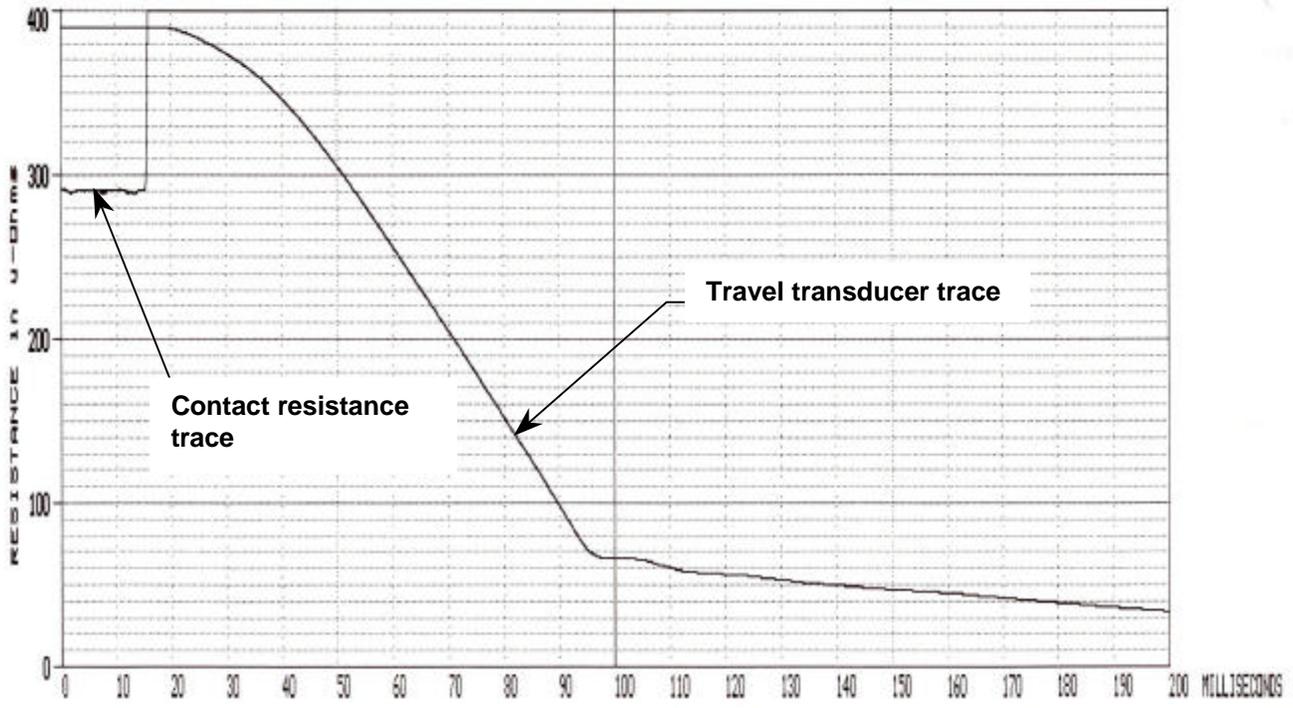
Figure 23.0 Dynamic Contact Resistance Graph (0 – 400 micro-ohm linear scale)
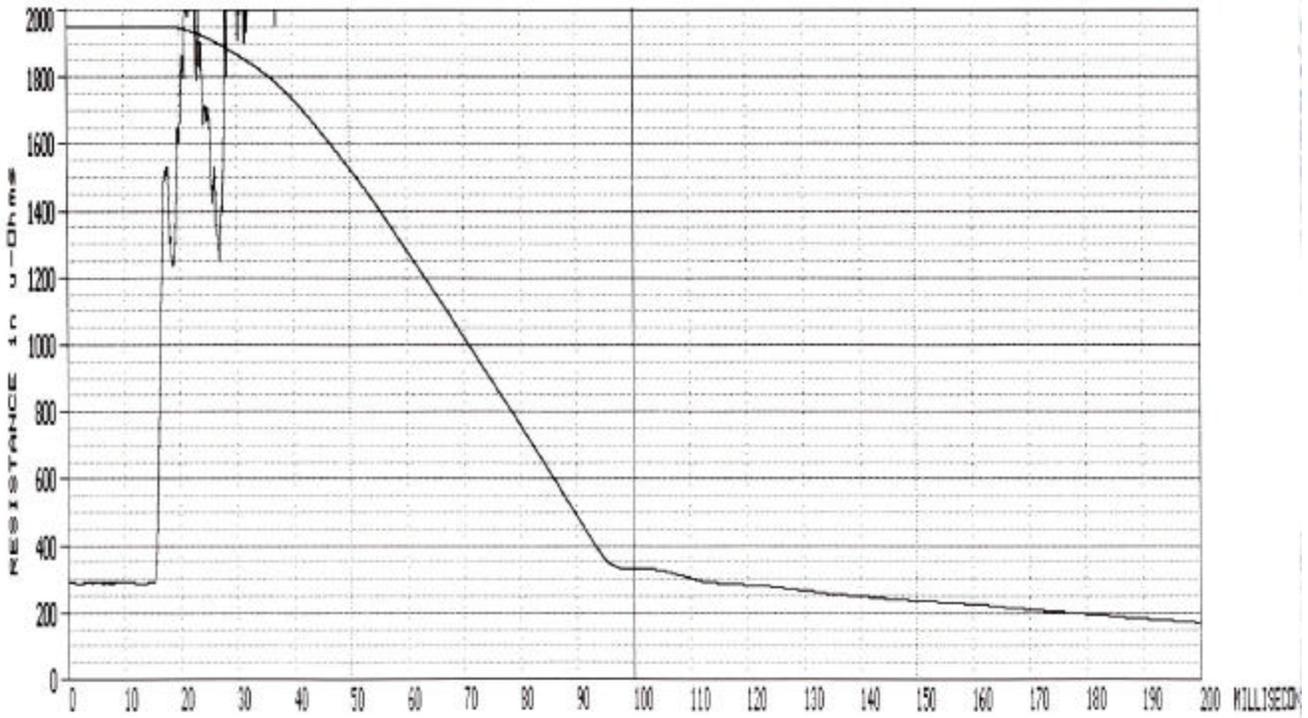
Figure 24.0 Dynamic Contact Resistance Graph (0 – 2000 micro-ohm linear scale)
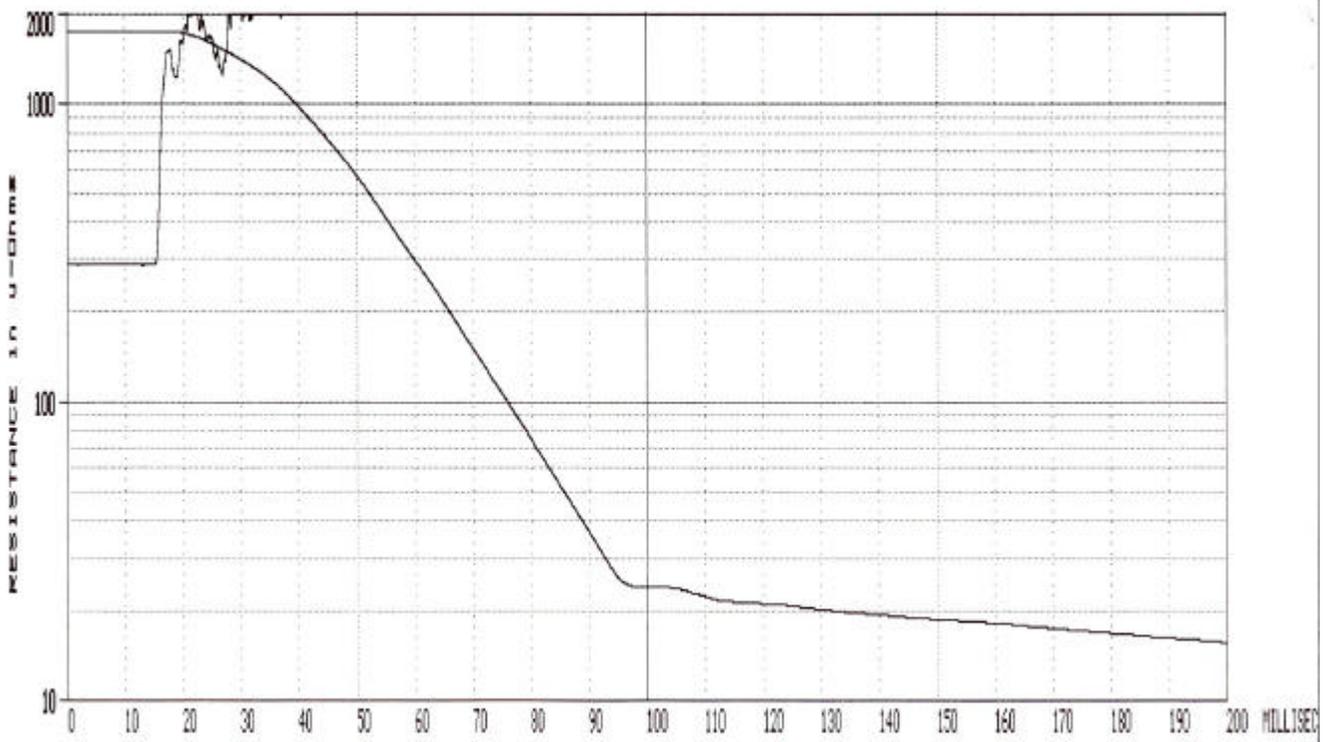
Figure 25.0 Dynamic Contact Resistance Graph in Semi-Log Scale

9.6 Saving Timing Records in the EEPROM

Use the steps in Table 12.0 to save a timing record in the FLASH EEPROM.

Table 12.0 Saving Timing Record in EEPROM

STEP	OPERATION	ACTION	DISPLAY
1	SELECT SETUP MENU.	PRESS #3 KEY.	1.ANALYSIS POINTS 2.MEASUREMENT UNITS 3.SAVE / RESTORE 4.NEXT PAGE
2	SELECT SAVE MENU.	PRESS #3 KEY.	1.SAVE SHOT 2.RECALL SHOT 3.SHOT DIRECTORY 4.ERASE SHOT
3	SELECT SAVE SHOT.	PRESS #1 KEY.	SAVE SHOT # 002 TEST: CLOSE DATE: 05/23/07 12:36 "ENTER" TO PROCEED
4	CONFIRM SAVING SHOT.	PRESS THE "ENTER" KEY.	SAVE IN PROCESS PLEASE WAIT
5	OBSERVE SHOT BEING SAVED.	NONE.	SHOT SAVE
6	RETURN TO MAIN MENU.	PRESS ANY KEY.	1.RUN TEST 06/10/07 2.GET RESULTS 20:10:01 3.SETUP 4.DIAGNOSTIC

NOTE

Timing record storage capability varies, depending upon the size of the shots.
The CT-8000 will assign an identification number for each of the shots stored in the EEPROM.
Shot ID #2 was assigned in the example above.

9.7 Printing Timing Record Directory Stored in the EEPROM

The user can obtain a timing-record directory that was stored in the CT-8000's FLASH EEPROM by using the steps in Table 13.0.

Table 13.0 Print Timing Record Directory

STEP	OPERATION	ACTION	DISPLAY
1	SELECT SETUP MENU.	PRESS #3 KEY.	1.ANALYSIS POINT 2.MEASUREMENT UNITS 3.SAVE / RESTORE 4.NEXT PAGE
2	SELECT SAVE/RESTORE MENU.	PRESS #3 KEY.	1.SAVE SHOT 2.RESTORE SHOT 3.SHOT DIRECTORY 4.ERASE SHOT
3	SELECT SHORT DIRECTORY.	PRESS # 3 KEY.	1.SHORT DIRECTORY 2.FULL DIRECTORY "STOP" TO QUIT
4	SELECT SHORT DIRECTORY.	PRESS #1 KEY.	PRINTING ABBREVIATED DIRECTORY "STOP" TO QUIT
5	RETURN TO MAIN MENU.	NO ACTION.	1.RUN TEST 06/10/07 2.GET RESULTS 20:10:01 3.SETUP 4.DIAGNOSTIC

NOTE

1. If the "Short Directory" was selected, the CT-8000 will print out the shot identifications of the last ten timing shots stored in the EEPROM.

2. If the "Full Directory" was selected, the CT-8000 will print out the shot identifications of all the timing shots stored in the EEPROM.

3. A typical shot directory printout is shown in Figure 26.0.

```
TIMING  SHOT  ABBREVIATED  DIRECTORY

SHOT  NUMBER:      78
DATE    : 05/11/07          TIME   : 09:39:19
COMPANY : VANGUARD          MFGR   : ITE
STATION : ONTARIO           MODEL  : 14 4KV
CIRCUIT : 123               SERIAL : 12345
OPERATOR: HAI               TEST   : OPEN

SHOT  NUMBER:      77
DATE    : 05/11/07          TIME   : 09:16:39
COMPANY : VANGUARD          MFGR   : ITE
STATION : ONTARIO           MODEL  : 14 4KV
CIRCUIT : 123               SERIAL : 12345
OPERATOR: HAI               TEST   : DCR OPEN

SHOT  NUMBER:      76
DATE    : 05/11/07          TIME   : 09:15:51
COMPANY : VANGUARD          MFGR   : ITE
STATION : ONTARIO           MODEL  : 14 4KV
CIRCUIT : 123               SERIAL : 12345
OPERATOR: HAI               TEST   : STATIC RES TEST

SHOT  NUMBER:      75
DATE    : 05/11/07          TIME   : 09:09:49
COMPANY : VANGUARD          MFGR   : ITE
STATION : ONTARIO           MODEL  : 14 4KV
CIRCUIT : 123               SERIAL : 12345
OPERATOR: HAI               TEST   : CLOSE

SHOT  NUMBER:      74
DATE    : 04/15/07          TIME   : 10:19:06
COMPANY :                   MFGR   : Manufacturer 1
STATION :                   MODEL  : Model 1
CIRCUIT :                   SERIAL :
OPERATOR:                   TEST   : STATIC RES TEST

SHOT  NUMBER:      73
DATE    : 03/31/07          TIME   : 09:59:11
COMPANY :                   MFGR   : Manufacturer 1
STATION :                   MODEL  : Model 1
CIRCUIT :                   SERIAL :
OPERATOR:                   TEST   : DCR CLOSE

SHOT  NUMBER:      72
DATE    : 03/31/07          TIME   : 09:51:48
COMPANY :                   MFGR   : Manufacturer 1
STATION :                   MODEL  : Model 1
CIRCUIT :                   SERIAL :
OPERATOR:                   TEST   : DCR O-C-O

SHOT  NUMBER:      71
DATE    : 03/31/07          TIME   : 08:21:31
COMPANY :                   MFGR   : Manufacturer 1
STATION :                   MODEL  : Model 1
CIRCUIT :                   SERIAL :
OPERATOR:                   TEST   : STATIC RES TEST

SHOT  NUMBER:      70
DATE    : 03/30/07          TIME   : 06:04:31
COMPANY :                   MFGR   : Manufacturer 1
STATION :                   MODEL  : Model 1
CIRCUIT :                   SERIAL :
OPERATOR:                   TEST   : DCR CLOSE

SHOT  NUMBER:      69
DATE    : 03/29/07          TIME   : 10:43:14
COMPANY :                   MFGR   : Manufacturer 1
STATION :                   MODEL  : Model 1
CIRCUIT :                   SERIAL :
OPERATOR:                   TEST   : DCR OPEN
```

Figure 26.0 Printout of the Timing Shot Directory From the Thermal Printer

9.8 Recalling a Timing Record

The steps in Table 14.0 are used to recall a timing record stored in the EEPROM to the working memory. Once a timing record is recalled, the user can get a printout of the test results from the thermal printer.

Table 14.0 Recalling a Timing Record

STEP	OPERATION	ACTION	DISPLAY
1	SELECT SETUP MENU.	PRESS #3 KEY.	1.ANALYSIS POINT 2.MEASUREMENT UNITS 3.SAVE / RESTORE 4.NEXT PAGE
2	SELECT SAVE/RESTORE SHOT.	PRESS # 3 KEY.	1.SAVE SHOT 2.RESTORE SHOT 3.SHOT DIRECTORY 4.ERASE SHOT
3	SELECT RESTORE SHOT.	PRESS #2 KEY.	ENTER SHOT NUMBER TO BE RESTORED XXXX "ENTER" TO CONFIRM
4	ENTER SHOT NUMBER "1" TO BE RESTORED.	PRESS KEYS 0-9 FOR SHOT ID THEN PRESS THE "ENTER" KEY.	ENTER SHOT NUMBER TO BE RESTORED 0001 "ENTER" TO CONFIRM
5	CONFIRM SHOT TO BE RESTORED.	PRESS THE "ENTER" KEY.	RESTORING SHOT # 0001 TEST: OPEN DATE: 06\12\07 09:12 "ENTER" TO CONFIRM
6	CONFIRM TEST RESTORED.	NONE.	RESTORE COMPLETE
7	RETURN TO MAIN MENU.	PRESS ANY KEY.	1.RUN TEST 06/10/07 2.GET RESULTS 20:10:01 3.SETUP 4.DIAGNOSTIC

9.9 Deleting a Timing Record

Users can delete a specific timing record or all of the timing records from the CT-8000's EEPROM by using the steps in Table 15.0.

Table 15.0 Deleting a Timing Record

STEP	OPERATION	ACTION	DISPLAY
1	SELECT SET UP MENU.	PRESS # 3 KEY.	1.ANALYSIS POINTS 2.MEASUREMENT UNITS 3.SAVE / RESTORE 4.NEXT PAGE
2	SELECT SAVE / RESTORE MENU.	PRESS # 3 KEY.	1.SAVE SHOT 2.RESTORE SHOT 3.SHOT DIRECTORY 4.ERASE SHOT
3	SELECT ERASE SHOT.	PRESS # 4 KEY.	1.ERASE SHOT 2.ERASE ALL SHOTS!
4	SELECT ERASE SHOT.	PRESS # 1 KEY.	ENTER SHOT NUMBER TO BE ERASED XXXX "ENTER" TO CONFIRM
5	ENTER SHOT NUMBER "1" TO BE ERASED.	PRESS KEYS 0-9 TO SELECT SHOT NUMBER, PRESS THE "ENTER" KEY TO CONFIRM.	ERASE SHOT # 0001 TEST: OPEN DATE: 03\12\07 09:12 "ENTER" TO CONFIRM
6	CONFIRM TO ERASE SHOT.	PRESS THE "ENTER" KEY.	ERASE IN PROCESS PLEASE WAIT
7	WAIT FOR SHOT BEING ERASED.	NO ACTION.	ERASE COMPLETE
8	RETURN TO MAIN MENU.	PRESS ANY KEY.	1.RUN TEST 06/10/07 2.GET RESULTS 20:10:01 3.SETUP 4.DIAGNOSTIC

9.10 Test Record Description

The CT-8000 has the capability for users to enter the breaker and other identification information.   The data usually consists of the name of the company, station, circuit and manufacturer. Other information could be the breaker's model, serial number and the operator's name. The identification data will print out in the header section of the tabulated report.

If the user saves the timing shot, the identification data will also be saved with the timing shot, along with the time and date.

The user can input letters of the alphabet by utilizing the alphanumeric keys. To select the letter "A," the user will need to press key numbered "2," twice. To select the letter "C," the user will need to press the key numbered "2," four times and so on.

To move the cursor forward, press the "UP ARROW" key. To move the cursor backwards, use the "DOWN ARROW" key. Use the "CLEAR" key to enter a space.

Table 16.0 Entering Test Record Identification Header

STEP	OPERATION	ACTION	DISPLAY
1	SELECT SET UP MENU.	PRESS #3 KEY.	1.ANALYSIS POINTS 2.MEASUREMENT UNIT 3.SAVE / RESTORE 4.NEXT PAGE
2	SELECT NEXT PAGE.	PRESS # 4 KEY.	1.SHOT DESCRIPTION 2.NUMBER OF CHANNELS 3.SET DATE & TIME 4.NEXT PAGE
3	SELECT SHOT DESCRIPTION.	PRESS # 1 KEY.	COMPANY: XXXXXX ?/? TO POSITION "ENTER" TO ACCEPT
4	ENTER COMPANY NAME.	PRESS KEYS 0-9 AND PRESS "ENTER" KEY.	STATION XXXXXX ?/? TO POSITION "ENTER" TO ACCEPT
5	ENTER STATION NAME.	PRESS KEYS 0-9 AND PRESS "ENTER" KEY.	CIRCUIT XXXXXX ?/? TO POSITION "ENTER" TO ACCEPT
6	ENTER CIRCUIT NAME.	PRESS KEYS 0-9 AND PRESS "ENTER" KEY.	MANUFACTURER XXXXXX ?/? TO POSITION "ENTER" TO ACCEPT
7	ENTER MANUFACTURER NAME.	PRESS KEYS 0-9 AND PRESS "ENTER" KEY.	BREAKER XXXXXX ?/? TO POSITION "ENTER" TO ACCEPT

Table 16.0 Entering Test Record Identification Header (Continued)

STEP	OPERATION	ACTION	DISPLAY
8	ENTER BREAKER MODEL.	PRESS KEYS 0-9 AND PRESS "ENTER" KEY.	SERIAL XXXX ? /? TO POSITION "ENTER" TO ACCEPT
9	ENTER SERIAL NUMBER.	PRESS KEYS 0-9 AND PRESS "ENTER" KEY.	OPERATOR XXXX ? /? TO POSITION "ENTER" TO ACCEPT
10	RETURN TO MAIN MENU.	NO ACTION.	1.RUN TEST　　　06/10/07 2.GET RESULTS　20:10:01 3.SETUP 4.DIAGNOSTIC

9.11 Computer Interface

Each CT-8000 has one RS-232C and one USB port. The Circuit Breaker Analyzer Software Series 2 package provided with each CT-8000, enables an IBM-compatible personal computer to communicate with the unit. The software operating under Windows XP environments allows the user to transfer timing records stored in the EEPROM into the computer. From the user's computer, the user can now reanalyze the breaker's timing shots and then print the timing reports through an office printer. Since timing shots are stored in the office computer, users can create a database of a breaker's timing history.

This PC program allows the user to generate and transfer circuit breaker test plans to the CT-8000 EEPROM. Up to 99 circuit breaker test plans can be stored in the CT-8000 EEPROM.

Using the PC program, the user can control the CT-8000 to time circuit breakers.

Note

1. There is no requirement to place the CT-8000 under computer control to access the RS-232C or USB port.

2. An interconnect cable must be run between the CT-8000's RS-232C port or USB port to the user's PC.

3. The CT-8000's RS-232 connector pin layout is shown in table below.

Table 17.0 RS-232C Connector Pin Definition

Pin No.	Signal Name
2	Tx
3	Rx
5	Gnd

9.12 Breaker Travel Analysis

The CT-8000's travel analysis includes the breaker's stroke, over-travel, bounce-back, contact-wipe distances and contact velocity calculations.

9.12.1 Breaker Stroke

The CT-8000 uses a digital transducer to measure a breaker's contact stroke, over-travel and bounce-back. The digital transducer output is 200 counts per linear inch of travel, therefore the resolution is accurate to about 1/200 inch. The output resolution is ±0.01 inch of the test result report.

Unlike slide-wire transducers, the CT-8000's digital transducer needs no calibration or setup. A user verifies the transducer's functionality by selecting a diagnostic test for the transducer, which is further explained in Paragraph 9.23.

9.12.2 Breaker Over-Travel Distance

Over-travel is the distance the contact moves beyond the resting position. Over-travel is typically found in the close operation. (See Appendix A for more details).

9.12.3 Breaker Bounce-Back Distance

Bounce-back is the distance the breaker contact moves before the resting position after the over- travel. Again, bounce-back is typically found in the close operation. (See appendix A for more details).

9.12.4 Contact Wipe

Contact wipe is the distance measured from the close position to the contacts touching or parting positions. In the close operation, contact wipe is measured from the contacts touching position to the final close position.

In the open operation, the contact wipe is measured from the close position to the contact break or parting position.

NOTE

Contact wipe is measured during an operation. The measurement may not be as accurate as the measurement done using the Slow-Close Mode. It is recommended that the user use the Slow-Close Test to verify the contact wipe measurement, if required. Please refer to Paragraph 9.22 for further information on the Slow-Close Mode.

9.12.5 Breaker Velocity

When used with a travel transducer, the CT-8000 can calculate the breaker contact velocity through the arc zone. Users will need to program the calculation points or analysis points on the travel curve for the unit to calculate the contact velocity. Analysis point selections and setup are discussed in the following paragraphs.

9.12.6 Analysis Point Selections

Analysis points are used to calculate the average contact speed through the contact's arc zone. The analysis points are usually specified by the breaker's manufacturer. The analysis points can be programmed into the CT-8000 by the user. The CT-8000 will store the two setup points for calculating velocity one set each for the open and another set for the close operations. These setups remain in the CT-8000's memory until it is changed by the user.

9.12.7 Analysis Point No.1 (AP1)

Three selections are available to the user for setting analysis point No. 1:

1. PERCENTAGE OF STRK
2. DISTANCE FROM CLOSE
3. CONTACT #1

a. Percentage of Stroke

Percentage of stroke is the distance based upon the percentage of the total breaker's stroke distance. ***The distance is always measured from the starting point at the fully closed position of the breaker contacts***. See appendix A for more detail.

b. Distance From Close

Distance from Close range is selectable from 00.0 inch to 99.99 inches or from 0.0 centimeter to 99.90 centimeters. ***Again, the distance is referenced from the contact's closed position.*** See Appendix A for more detail.

c. Contact Point #1

Contact point is the distance from the contact's closed position to the point where it is in transition from the close-to-open or the open-to-close position. ***Contact channel #1 will be used for the selection.***

9.12.8 Analysis Point No. 2 (AP2)

There are three selections for analysis point 2:

1. PERCENTAGE OF STRK
2. DISTANCE FROM CLOSE
3. CONTACT +/- TIME

a. See Paragraph 9.12.7.a for "PERCENTAGE OF STROKE" description.

b. See Paragraph 9.12.7.b for "DISTANCE FROM CLOSE" description.

c. "CONTACT +/- TIME", is available for both OPEN and CLOSE operation under analysis point #2 only. For "CONTACT + TIME", the user enters the millisecond time after the contact channel #1 made the transition from OPEN to CLOSE or CLOSE to OPEN to define the Analysis Point No. 2.
For "CONTACT – TIME", the user enters the millisecond time before the contact channel #1 makes the transition from OPEN to CLOSE or CLOSE to OPEN to define the Analysis Point No. 2.

NOTES

1. Average velocity through the arc zone is calculated by using the following formula:

$$V_{avg} = \text{Distance} \div \text{Time}$$

2. The breaker contact velocity can be recalculated based upon the data stored inside the memory after any new analysis points were selected. The user does ***not*** need to operate the breaker again to acquire new contact velocity data after changing the analysis points because the new velocity is then calculated from the travel data stored in memory from the last operation.

3. For complex velocity calculations, the user can create a test plan using the CT-8000 Breaker Analysis Software from a PC. The test plan then can be downloaded to the CT-8000. The complex breaker velocity calculation can now be executed easily by recalling the test plan before running the timing test.

9.12.9 Set-Up Open Analysis Points

The following procedure allows the user to set the analysis points to calculate velocity of the circuit breaker in the open operation. The open analysis point #1 is 1.00 inch from the fully closed position of the circuit breaker. The open analysis point #2 is 2.00 inches from the fully closed position.

Table 18.0 Setting Up "OPEN" Analysis Points Using Distance

STEP	OPERATION	ACTION	DISPLAY
1	SELECT SET UP MENU.	PRESS # 3 KEY.	1.ANALYSIS POINT 2.MEASUREMENT UNITS 3.SAVE / RESTORE 4.NEXT PAGE
2	SELECT ANALYSIS POINT.	PRESS # 1 KEY.	1.OPEN TIMING 2.CLOSE TIMING 3.PRINT SETTING 4.TEST PLAN
3	SELECT OPEN TIMING.	PRESS # 1 KEY.	OPEN ANALYSIS PT 1 1.PERCENT OF STROKE 2.DISTANCE FROM CLOSE 3.CONTACT #1
4	SELECT DISTANCE FROM CLOSE.	PRESS # 2 KEY.	OPEN ANALYSIS PT 1 DISTANCE FROM CLOSE VALUE: XX.XX in "ENTER" TO CONFIRM
5	ENTER 1 INCH.	PRESS KEYS 0-9 TO SET 1.00. USE THE "ENTER" KEY TO CONFIRM.	OPEN ANALYSIS PT 1 DISTANCE FROM CLOSE VALUE: 01.00 in "ENTER" TO CONFIRM
6	CONFIRM ENTRY.	PRESS THE "ENTER" KEY.	OPEN ANALYSIS PT 2 1.PERCENTAGE OF STROKE 2.DISTANCE FROM CLOSE 3.CONTACT +/- TIME
7	SELECT DISTANCE FROM CLOSE.	PRESS # 2 KEY.	OPEN ANALYSIS PT 2 DISTANCE FROM CLOSE VALUE: XX.XX in "ENTER" TO CONFIRM
8	ENTER 2 INCHES.	PRESS KEYS 0-9 TO SET 2.00 INCHES.	OPEN ANALYSIS PT 2 DISTANCE FROM CLOSE VALUE: 02.00 in "ENTER" TO CONFIRM
9	RETURN TO MAIN MENU.	PRESS THE "ENTER" KEY.	1.RUN TEST 06/10/07 2.GET RESULTS 20:10:01 3.SETUP 4.DIAGNOSTIC

NOTES

1. If an entry is not correct, re-enter the digits until the screen shows the desired numbers, then press the "ENTER" key.

2. Analysis Point #1 is 1.00 inch from the fully closed position.

3. Analysis Point #2 is 2.00 inches from the fully closed position.

9.13 Select English or Metric Measurement Unit.

The CT-8000 supports and displays both English and Metric calculations from the breaker's travel parameters such as the stroke, velocity and other parameters. The user can switch from one system to the other by following the steps in Table 19.0.

Table 19.0 Select English or Metric Procedure

STEP	OPERATION	ACTION	DISPLAY
1	SELECT SET UP MENU.	PRESS # 3 KEY.	1.ANALYSIS POINT 2.MEASUREMENT UNITS 3.SAVE / RESTORE 4.NEXT PAGE
2	MEASUREMENT UNITS.	PRESS # 2 KEY.	SELECT UNITS 1.ENGLISH 2.METRIC 3.ROT ENC 4.RES ENC
3	SELECT METRIC UNIT	PRESS # 2 KEY.	1.RUN TEST 06/10/07 2.GET RESULTS 20:10:01 3.SETUP 4.DIAGNOSTIC

9.14 Digital Rotary Transducer Selection

A rotary transducer requires the user to enter the defined linear distance in millimeters or inches, per one degree of rotary motion as seen in Table 20.0.

Table 20.0 Select Rotary Transducer

STEP	OPERATION	ACTION	DISPLAY
1	SELECT SET UP MENU.	PRESS # 3 KEY.	1. ANALYSIS POINT 2. MEASUREMENT UNITS 3. SAVE / RESTORE 4. NEXT PAGE
2	SELECT MEASUREMENT UNITS.	PRESS # 2 KEY.	SELECT UNITS 1. ENGLISH 2. METRIC 3. ROT ENC 4. RES ENC
3	SELECT ROTARY TRANSDUCER.	PRESS # 3 KEY.	ROTARY ENCODER: 1. ENGLISH (In./deg) 2. METRIC (MM/deg)
4	SELECT INCH PER DEGREE.	PRESS #1 KEY.	INCHES/DEGREE 0.014 in/deg
5	ENTER 0.50 INCH PER DEGREE.	ENTER 0.50 USING 0-9 KEYS.	INCHES/DEGREE 0.500 in/deg
6	RETURN TO MAIN MENU.	PRESS THE "ENTER" KEY.	1.RUN TEST 06/10/07 2.GET RESULTS 20:10:01 3.SETUP 4.DIAGNOSTIC

9.15 Resistor Type Transducer Setup Procedure

The CT-8000 supports one channel of resistor type transducer. Before the user can use this type of transducer, the transducer must be setup. The following procedure allows the user to setup the transducer before usage. Resistor transducer set up can be stored in the CT-8000 memory. Up to 9 setups can be stored in memory.

Table 21.0 Setup Resistor Type Transducer Procedure

STEP	OPERATION	ACTION	DISPLAY
1	SELECT SET UP MENU.	PRESS # 3 KEY.	1.ANALYSIS POINT 2.MEASUREMENT UNITS 3.SAVE / RESTORE 4.NEXT PAGE
2	MEASUREMENT UNITS.	PRESS # 2 KEY.	SELECT UNITS 1.ENGLISH 2.METRIC 3.ROT ENC 4.RES ENC
3	SELECT RESISTOR ENCODER.	PRESS # 4 KEY.	RESISTIVE ENCODER 1.CREAT NEW SETUP 2.LOAD SETUP 3.PRINT SETUP DIRECTORY
4	CREATE NEW SETUP.	PRESS # 1 KEY.	RESISTIVE ENCODER 1.ENGLISH (IN/Volt) 2.METRIC (MM/Volt)
5	SELECT IN/Volt	PRESS KEYS #1	MOVE RES ENCODER TO REFERENCE POSITION "ENTER" TO CONTINUE
6	SELECT REFERENCE POSITION	PRESS "ENTER" KEY	MOVE RES ENCODER A KOWN DISTANCE ….. "ENTER" TO CONTINUE
7	SELECT KNOW POSITION	PRESS "ENTER" KEY	ENTER THE DISTANCE MOVED: _ IN "ENTER" TO CONTINUE
8	ENTER DISTANCE	PRESS KEY 0-9 TO SET DISTANCE	ENTER THE DISTANCE MOVED: X.XX IN "ENTER" TO CONTINUE
9	CONFIRM DISTANCE	PRESS "ENTER" KEY	ENTER SETUP NOTE _ ?/? TO POSITION "ENTER" TO ACCEPT
10	ENTER SETUP NOTE (UP TO 20 CHARACTERS)	PRESS KEY 0-9 TO ENTER NOTE	ENTER SETUP NOTE SETUP 1 ?/? TO POSITION "ENTER" TO ACCEPT

STEP	OPERATION	ACTION	DISPLAY
11	CONFIRM NOTE	PRESS "ENTER" KEY.	ENTER SETUP NUMBER TO SAVE (1-9):
12	ENTER A SET UP NUMBER FROM 1 TO 9.	PRESS A KEY FROM 1 TO 9. USE KEY #3 IN THIS EXAMPLE.	"ENTER" TO SAVE SETUP NUMBER 3
13	CONFIRM SET UP #3.	PRESS "ENTER" KEY.	SETUP SAVED!
14	RETURN TO MAIN MENU.	PRESS THE "ENTER" KEY.	1.RUN TEST 06/10/07 2.GET RESULTS 20:10:01 3.SETUP 4.DIAGNOSTIC

9.16 Load Resistor Transducer Setup

To use the resistor type transducer, the user is required to setup the transducer (see paragraph 9.15) or load a setup from memory. Use the following procedure to load a resistor transducer setup from CT-8000 memory.

Table 22.0 Use Resistor Type Transducer Setup Procedure

STEP	OPERATION	ACTION	DISPLAY
1	SELECT SET UP MENU.	PRESS # 3 KEY.	1.ANALYSIS POINT 2.MEASUREMENT UNITS 3.SAVE / RESTORE 4.NEXT PAGE
2	MEASUREMENT UNITS.	PRESS # 2 KEY.	SELECT UNITS 1.ENGLISH 2.METRIC 3.ROT ENC 4.RES ENC
3	SELECT RESISTOR ENCODER.	PRESS # 4 KEY.	RESISTIVE ENCODER 1.CREAT NEW SETUP 2.LOAD SETUP 3.PRINT SETUP DIRECTORY
4	LOAD SETUP.	PRESS # 2 KEY.	ENTER SETUP NUMBER TO LOAD (1-9:)
5	LOAD SET UP #1 IN THIS EXAMPLE.	PRESS #1 KEY.	SETUP NUMBER 1 ENGLISH "ENTER" TO CONTINUE
6	CONFIRM SETUP.	PRESS "ENTER KEY".	SETUP LOAD!
7	RETURN TO MAIN MENU.	PRESS THE "ENTER" KEY.	1.RUN TEST 06/10/07 2.GET RESULTS 20:10:01 3.SETUP 4.DIAGNOSTIC

9.17 Print Resistor Transducer Setup Directory

The following steps allow the user to print all the CT-8000 resistor setups stored in memory

Table 23.0 Print Resistor Transducer Setup Directory

STEP	OPERATION	ACTION	DISPLAY
1	SELECT SET UP MENU.	PRESS # 3 KEY.	1.ANALYSIS POINT 2.MEASUREMENT UNITS 3.SAVE / RESTORE 4.NEXT PAGE
2	MEASUREMENT UNITS.	PRESS # 2 KEY.	SELECT UNITS 1.ENGLISH 2.METRIC 3.ROT ENC 4.RES ENC
3	SELECT RESISTOR ENCODER.	PRESS # 4 KEY.	RESISTIVE ENCODER 1.CREAT NEW SETUP 2.LOAD SETUP 3.PRINT SETUP DIRECTORY
4	PRINT SETUP DIRECTORY.	PRESS # 3 KEY.	BUSY PRINTING
5	RETURN TO MAIN MENU.	NO ACTION REQUIRED.	1.RUN TEST 06/10/07 2.GET RESULTS 20:10:01 3.SETUP 4.DIAGNOSTIC


```
RESISTIVE ENCODER SETUP DIRECTORY
SETUP  NUMBER  1
SETUP  NOTE:
UNITS:            ENGLISH
SETTING:          2.465  INCHES/VOLT

SETUP  NUMBER  2
SETUP  NOTE:      ABB
UNITS:            ENGLISH
SETTING:          2.040  INCHES/VOLT

SETUP  NUMBER  3
SETUP  NOTE:      2V  OR5  IN
UNITS:            ENGLISH
SETTING:          0.249  INCHES/VOLT

SETUP  NUMBER  4
SETUP  NOTE:      OR5  V       24  IN
UNITS:            ENGLISH
SETTING:          47.768  INCHES/VOLT

SETUP  NUMBER  5
SETUP  NOTE:      OR5  V       30  IN
UNITS:            ENGLISH
SETTING:          59.874  INCHES/VOLT

SETUP  NUMBER  6
SETUP  NOTE:      1V   10MM
UNITS:            METRIC
SETTING:          10.1  MM/VOLT

SETUP  NUMBER  7
SETUP  NOTE:      1V  50MM
UNITS:            METRIC
SETTING:          49.3  MM/VOLT

SETUP  NUMBER  8
SETUP  NOTE:      5V  305MM  MET
UNITS:            METRIC
SETTING:          62.1  MM/VOLT

SETUP  NUMBER  9
SETUP  NOTE:      ABB  AHMB
UNITS:            ENGLISH
SETTING:          1.622  INCHES/VOLT
```

Figure 27.0 Resistor Transducer Setup Directory Printout

Note

When a resistor transducer is used with the CT-8000, it is shown as transducer #1 on the timing report. The resistive transducer channel is identified as "RESISTIVE ANALOG ENCODER" on the timing report (see figure 28.0 below).

```
BREAKER TIMING RESULTS - 60 Hz

          SHOT NUMBER: 78
DATE:  05/11/07      TIME:  09:39:19

COMPANY:    VANGUARD
STATION:    ONTARIO
CIRCUIT:    123
MFR:        ITE
MODEL:      14 4KV
S/N:        12345
OPERATOR:   HAI

TEST:   OPEN

CONTACT TIME
CH    TIME    CYCLE          BOUNCE    WIPE
      <mS>                   <mS>      <in>
  1   41.70   2.50           0.05      0.90
  2   38.35   2.30           0.10      0.69
  3   42.85   2.55           0.05      0.98

DELTA TIME <mS>:  4.50

CT CHANNEL ANALYSIS
  TIME      CYCLE
  <mS>
   0.00     0.00

TRAVEL  ANALYSIS    T1
STROKE          in    6.97
SPEED           ft/s  7.55
OVER-TRAVEL  in       0.00
BOUNCE BACK  in       0.00
<RESISTIVE  ANALOG  ENCODER>

SPEED  ANALYSIS:
POINT 1  =  1.00  in
POINT 2  =  5.00  in

V1  NOMINAL  VOLTAGE  =    56  VOLTS
V1  MINIMUM  VOLTAGE  =    50  VOLTS
INITIATOR  CURRENT    =   5.7  AMPS

SHOT  LENGTH:            1  SECOND
INSERTION  RESISTOR:    NO
TRIGGER:                INTERNAL
```

Resistive Type Transducer Indicator

Figure 28.0 A typical Resistive Transducer Timing Results Printout

9.18 Circuit Breaker Test Plan

A circuit breaker test plan contains breaker maximum/minimum operating parameters. A typical list of operating parameters is shown as follows:
- Max/Min Contact/Resistor Trip Time.
- Max/Min Contact/Resistor Close Time.
- Max Contact Spread Time.
- Max Resistor Contact Spread Time.
- Max/min Contact Close-Open Time.
- Max/min Contact Open-Close Time.
- Max/min Resistor Close-Open Time.
- Max/min Resistor Open-Close Time.
- Max/Min Breaker Stroke.
- Max/Min Breaker Trip Velocity.
- Max/Min Breaker Close Velocity.
- Max/Min Breaker Over Travel.
- Max/Min Breaker Bounce Back.
- Trip Velocity Analysis Calculation Points.
- Close Velocity Analysis Calculation Points.

The user can create a circuit breaker test plan using the CT-8000 Breaker Analysis Software. Up to 99 circuit breaker test plans can be downloaded into the CT-8000. A test plan can be replaced by simply downloading a new test plan into an existing one.

If a timing test is executed with a breaker test plan, the timing report will also display a Pass/Fail status for each of the parameters tested.

9.19 Recall a Breaker Test Plan To be Used

Recalling a test plan allows the user to store the breaker Pass/Fail parameters or operating limits in memory. Since the breaker test plan contains analysis points and any velocity calculation formula, there is no setting required for the CT-8000.

After recalling the breaker test plan, the user can immediately test a circuit breaker and view the timing report.

Table 24.0 Recalling a Test Plan To Be Used

STEP	OPERATION	ACTION	DISPLAY
1	SELECT SET UP MENU.	PRESS # 3 KEY.	1. ANALYSIS POINT 2. MEASUREMENT UNITS 3. SAVE / RESTORE 4. NEXT PAGE
2	SELECT ANALYSIS POINT.	PRESS # 1 KEY.	1. OPEN TIMING 2. CLOSE TIMING 3. PRINT SETTING 4. TEST PLAN
3	SELECT TEST PLAN.	PRESS # 4 KEY.	1. LOAD TEST PLAN 2. PRINT TEST PLAN 3. PRINT DIRECTORY

STEP	OPERATION	ACTION	DISPLAY
4	SELECT LOAD TEST PLAN.	PRESS # 1 KEY.	TEST PLAN #: 01 BZO-145-20-7 SIEMENS DEMO TEST PLAN 1
5	VIEW TEST PLAN HEADER.	PRESS "?" or "?" KEY TO SCROLL.	TEST PLAN #: 02 ABB 72PM ABB DEMO TEST PLAN 2
6	CONFIRM TEST PLAN TO BE LOADED.	PRESS THE "ENTER" KEY.	1.RUN TEST 06/10/07 2.GET RESULTS 20:10:01 3.SETUP 4.DIAGNOSTIC

Figure 29.0 Typical Test Results With Pass/Fail Printout

9.20 Print a Breaker Test Plan

The user can print a breaker test plan stored in the CT-8000 EEPROM by following the steps in table 25.0.

Table 25.0 Print a Test Plan Procedure

STEP	OPERATION	ACTION	DISPLAY
1	SELECT SET UP MENU.	PRESS # 3 KEY.	1. ANALYSIS POINT 2. MEASUREMENT UNITS 3. SAVE / RESTORE 4. NEXT PAGE
2	SELECT ANALYSIS POINT.	PRESS # 1 KEY.	1. OPEN TIMING 2. CLOSE TIMING 3. PRINT SETTING 4. TEST PLAN
3	SELECT TEST PLAN.	PRESS # 4 KEY.	1. LOAD TEST PLAN 2. PRINT TEST PLAN 3. PRINT DIRECTORY
4	SELECT PRINT TEST PLAN.	PRESS # 2 KEY.	TEST PLAN #: 01 BZO-145-20-7 SIEMENS DEMO TEST PLAN 1
5	VIEW TEST PLAN HEADER.	PRESS "?" or "?" KEY TO SCROLL.	TEST PLAN #: 02 ABB 72PM ABB DEMO TEST PLAN 2
6	CONFIRM TEST PLAN TO BE PRINTED.	PRESS THE "ENTER" KEY.	1.RUN TEST 06/10/07 2.GET RESULTS 20:10:01 3.SETUP 4.DIAGNOSTIC

```
        TEST PLAN NUMBER 1

 MFR:        SPS2 121
 TYPE:       Siemens
 COMMENT:

 CONTACT TIME PARAMETERS
                     OPEN      CLOSE

 MAX <mS>            026.0     063.0
 MIN <mS>            020.0     047.0
 DELTA LIM <mS>      004.0     004.0

 C-O,O-C PARAMS:  LIVE       DEAD

 MAX <mS>            040.0     200.0
 MIN <mS>            020.0     150.0

 RESISTOR ON-TIME PARAMETERS
                     OPEN      CLOSE

 MAX <mS>            000.0     000.0
 MIN <mS>            000.0     000.0
 DELTA LIM <mS>      000.0     000.0

 C-O,O-C PARAMS:  LIVE       DEAD

 MAX <mS>            000.0     000.0
 MIN <mS>            000.0     000.0

 TRAVEL PARAMETERS
             STRK    VEL     O-TVL  BNC-BK
             mm      M/S     mm     mm

 OPEN HI     085.1   04.90   003.0  003.0
 OPEN LOW    074.9   04.20   000.0  000.0

 CLOSE HI    085.1   04.50   004.1  004.1
 CLOSE LO    074.9   03.50   000.0  000.0

 VEL = Cx[DIST(AP1 - AP2)/STROKE]
 C = 12.00 M/S

 OPEN SPEED ANALYSIS POINTS:

 POINT 1 = CONTACT
 POINT 2 = CONTACT PLUS   010.0 mS

 CLOSE SPEED ANALYSIS POINTS:

 POINT 1 = CONTACT
 POINT 2 = CONTACT MINUS 010.0 mS
```

Velocity
Calculation
Formula

Figure 30.0 Typical Test Plan Printout of a Siemens SPS2 on Thermal Printer

Close time parameters
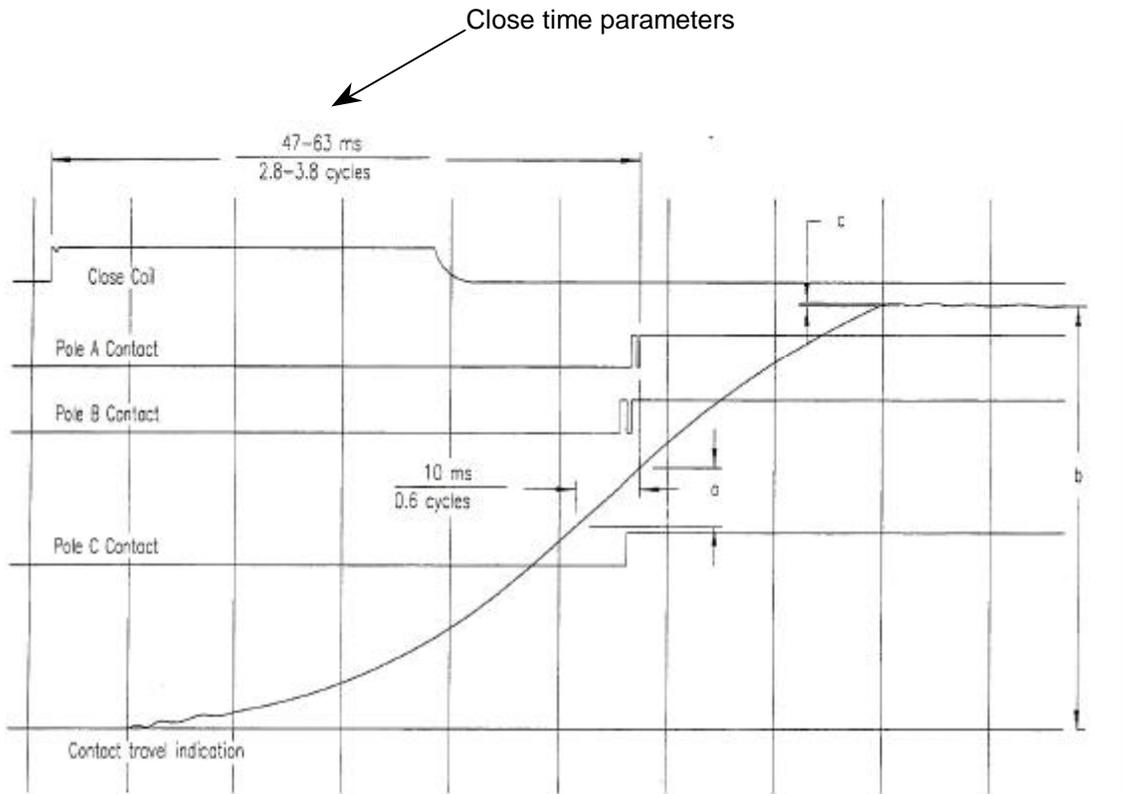
Velocity Calculation Formula

Example of Close Operation Record
Calculation For Contact Closing Velocity
    V=12.0a/b meters/second
Calculation For Overtravel/rebound
    S=120.0c/b millimeters
Note: a,b and c may be measured in any consistent units

Contact Stroke   = 120 mm
Transducer Stroke = 80 mm

Figure 31.0 Siemens SPS2 121 Close Timing Illustration
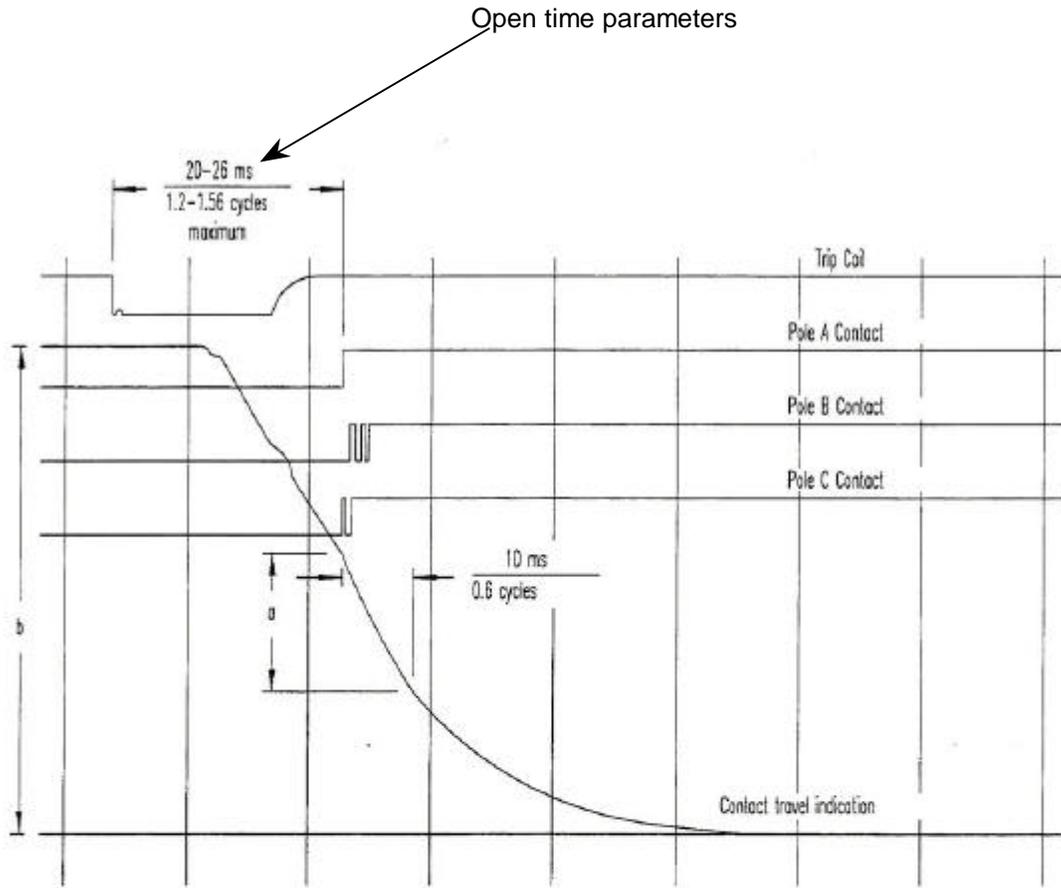
Open time parameters

Example of Opening Operation Record

Calculation For Contact Opening Velocity
V=12.0a/b meter/second

Note: a,b and may be measured in any consistant units

Contact Stroke = 120mm
Transducer Stroke = 80 mm

Figure 32.0 Siemens SPS2 121 Open Timing Illustration

9.21 Print a Breaker Test Plan Directory

The CT-8000 breaker test plan directory stored in the CT-8000 EEPROM can be printed by following the steps below:

Table 26.0 Print a Breaker Test Plan Directory

STEP	OPERATION	ACTION	DISPLAY
1	SELECT SET UP MENU.	PRESS # 3 KEY.	1. ANALYSIS POINT 2. MEASUREMENT UNITS 3. SAVE / RESTORE 4. NEXT PAGE
2	SELECT ANALYSIS POINT.	PRESS # 1 KEY.	1. OPEN TIMING 2. CLOSE TIMING 3. PRINT SETTING 4. TEST PLAN
3	SELECT TEST PLAN.	PRESS # 4 KEY.	1. LOAD TEST PLAN 2. PRINT TEST PLAN 3. PRINT DIRECTORY
4	SELECT PRINT DIRECTORY.	PRESS # 3 KEY.	1.RUN TEST 06/10/07 2.GET RESULTS 20:10:01 3.SETUP 4.DIAGNOSTIC


```
        TEST PLAN DIRECTORY

TEST PLAN #:    1
BRKR TYPE:    SFS2 121
BRKR MFR:     Siemens
COMMENTS:

TEST PLAN #:    2
BRKR TYPE:    121/145PM<HBM Hydrau
BRKR MFR:     ABB121/145pm
COMMENTS:

TEST PLAN #:    3
BRKR TYPE:    CGH-50
BRKR MFR:     McGRAW-EDISON
COMMENTS:
```

Figure 33.0 Typical Test Plan Directory Print Out.

9.22 Slow-Close Test

The CT-8000 offers a unique feature called a "Slow-Close" test. The test permits users to measure the distance a breaker's contact travels from the fully opened position to the point of contact or "touch" position, and the contact wipe or penetration distance. The test requires the operator to manually jack the breaker's contact from the fully open position to the fully closed position.

Contact channel 1, 2, 3 and transducer channel 1 will be used for "Slow-Close" testing. The CT-8000 will measure the contact touch and contact wipe for each contact channel.

Contact touch is the distance measured from the contact being fully open to the first position where the contact channel is electrically closed.

Contact wipe, or penetration, is the distance measured from the contact's first electrically closed position to the final closed, latching position.

Table 27.0 Performing a Slow-Close Test

STEP	OPERATION	ACTION	DISPLAY
1	SELECT DIAGNOSTIC MENU.	PRESS # 4 KEY.	1. SLOW CLOSE TEST 2. CHECK HOOKUP 3. TEST TRANSDUCER 4. NEXT PAGE
2	SELECT SLOW CLOSE TEST.	PRESS # 1 KEY.	BREAKER SLOW CLOSE TEST RMV CB GND (1 SIDE) "ENTER" TO BEGIN
3	START SLOW CLOSE TEST.	PRESS THE "ENTER" KEY.	CONTACT 1:OPEN CONTACT 2:OPEN CONTACT 3:OPEN LIFT TO CLS BREAKER NOW
4	CONTINUE TO CLOSE BREAKER.	NO ACTION.	LIFT BRKR TO CLS POS THEN PRESS "ENTER" TO FIND CONTACT WIPE
5	RETURN TO MAIN MENU.	NO ACTION.	1.RUN TEST 06/10/07 2.GET RESULTS 20:10:01 3.SETUP 4.DIAGNOSTIC

NOTE

The user can also save a Slow-Close test report in the EEPROM. A typical report of a Slow-Close test is shown in Figure 34.0.

```
┌─────────────────────────────────────────────┐
│ BREAKER TIMING RESULTS - 50 Hz               │
├─────────────────────────────────────────────┤
│         SHOT NUMBER: 0006                    │
│ DATE: 12/28/00      TIME: 07:41:30           │
├─────────────────────────────────────────────┤
│ COMPANY:                                     │
│ STATION:                                     │
│ CIRCUIT:                                     │
│ MFR:                                         │
│ MODEL:                                       │
│ S/N:                                         │
│ OPERATOR:                                    │
├─────────────────────────────────────────────┤
│ TEST: SLOW CLOSE                             │
├─────────────────────────────────────────────┤
│          CT TOUCH      CT WIPE               │
│ CH 1     08.23 in      00.86 in              │
│ CH 2     08.41 in      00.68 in              │
│ CH 3     08.40 in      00.69 in              │
└─────────────────────────────────────────────┘
```

Figure 34.0 Typical Slow-Close Test Report

NOTE
The breaker's stroke is the sum of the contact touch and contact wipe distances.

9.23 Transducer Self-Test

The operator can check the transducer electronics by connecting the transducer to the CT-8000 (D1 or D2 or D3) and running a "Test Transducer" diagnostics.

Table 28.0 Performing a Transducer Self Test

STEP	OPERATION	ACTION	DISPLAY
1	SELECT DIAGNOSTIC.	PRESS # 4 KEY.	1. SLOW-CLOSE TEST 2. CHECK HOOKUP 3. TEST TRANSDUCER 4. NEXT PAGE
2	SELECT TRANSDUCER.	PRESS # 3 KEY.	TRANSDUCER TEST 1= 0.00 IN / 000.0? 2= 0.00 IN / 000.0? 3= 0.00 IN / 000.0?
3	MOVE TRANSDUCER SLIDER TO A KNOWN DISTANCE & OBSERVE DISPLAY	MOVE TRANSDUCER SLIDER	TRANSDUCER TEST 1= 5.00 IN / 360.0? 2= 0.00 IN / 000.0? 3= 0.00 IN / 000.0?
2	RETURN O MAIN MENU	PRESS # STOP KEY.	1.RUN TEST 06/10/07 2.GET RESULTS 20:10:01 3.SETUP 4.DIAGNOSTIC

NOTES

1. After selecting the transducer test mode, move the transducer slider and observe the display on the CT-8000 LCD.

2. If the slider is moved 1.00 inch, the CT-8000 LCD should display 1.00 inch.

3. Press the "STOP" key to return back to the main menu.

9.24 Check Cable Hookup

The following steps allow the user to check the CT-8000 contact cable connections to the circuit breaker.

Table 29.0 Checking the Cable Hookup

STEP	OPERATION	ACTION	DISPLAY
1	SELECT DIAGNOSTIC.	PRESS # 4 KEY.	1. SLOW-CLOSE TEST 2. CHECK HOOKUP 3. TEST TRANSDUCER 4. NEXT PAGE
2	SELECT CHECK HOOK UP.	PRESS # 2 KEY.	MAKE SURE BREAKER IS IN CLOSE POSITION, THEN PRESS "START"
3	INITIATE TEST.	PRESS THE "START" KEY.	1 2 3 C - - - "START" to RETEST "STOP" to EXIT
4	RETURN TO MAIN MENU.	PRESS THE "STOP" KEY.	1.RUN TEST 06/10/07 2.GET RESULTS 20:10:01 3.SETUP 4.DIAGNOSTIC

NOTES

1. The CT-8000 will also print a test report with the thermal printer.

2. A contact closure is shown as "C" on the LCD and printout.

3. An open contact is shown as "-" on the LCD and printout.

9.25 Set CT-8000 Time and Date

The CT-8000 has an internal clock with a lithium battery. The clock's time and date is displayed on the LCD screen. When a timing record is stored in the EEPROM, the time and date are also stored along with the record. To set the clock, follow the steps in Table 30.0.

Table 30.0 Set CT-8000 Time and Date

STEP	OPERATION	ACTION	DISPLAY
1	SELECT SET UP MENU.	PRESS # 3 KEY.	1. ANALYSIS POINT 2. MEASUREMENT UNITS 3. SAVE / RESTORE 4. NEXT PAGE
2	SELECT NEXT PAGE.	PRESS # 4 KEY.	1. SHOT DESCRIPTION 2. NUMBER OF CHANNELS 3. SET DATE & TIME 4. NEXT PAGE
3	SELECT SET DATE & TIME.	PRESS # 3 KEY.	ENTER MM-DD-YY HH:MM:SS
4	ENTER MONTH DATE & YEAR.	PRESS KEYS 0-9.	ENTER MM-DD-YY HH:MM:SS 06/10/07
5	ENTER HOUR MINUTES & SECONDS.	PRESS KEYS 0-9.	ENTER MM-DD-YY HH:MM:SS 06/10/07 20:10:00
6	RETURN TO MAIN MENU.	NO ACTION.	1.RUN TEST 06/10/07 2.GET RESULTS 20:10:01 3.SETUP 4.DIAGNOSTIC

NOTE
1. The clock battery is good for three years.
2. Loosing the clock battery will not affect the CT-8000's performance.

9.26 Automatic Print Setting

The CT-8000 can be set to print graphs and tabulated results automatically after each timing shot. To turn on the "Auto Print Results" mode, follow the steps in Table 31.0.

Table 31.0 Automatic Print Setting

STEP	OPERATION	ACTION	DISPLAY
1	SELECT SET UP MENU.	PRESS # 3 KEY.	1. ANALYSIS POINT 2. MEASUREMENT UNITS 3. SAVE / RESTORE 4. NEXT PAGE
2	SELECT NEXT PAGE.	PRESS # 4 KEY.	1. SHOT DESCRIPTION 2. NUMBER OF CHANNELS 3. SET DATE & TIME 4. NEXT PAGE
3	SELECT NEXT PAGE.	PRESS #4 KEY.	1. SET PRINT MODE 2. SET 50/60 Hz
3	SELECT SET PRINT MODE.	PRESS # 1 KEY.	SET PRINT MODE 1. AUTOMATIC PRINT 2. BY REQUEST ONLY
4	SELECT "AUTOMATIC PRINT".	PRESS # 1 KEY.	1.RUN TEST 06/10/07 2.GET RESULTS 20:10:01 3.SETUP 4.DIAGNOSTIC

NOTE

Select print "BY REQUEST ONLY" to disable the "Automatic Print" mode.

9.27 Selecting 50 Hz or 60 Hz for Contact Time Reading

Tabulated contact time is printed in both milli-seconds and cycles. The cycle readings can be in 50 Hz or 60 Hz. The example below shows the steps to set for 60 Hz readings.

Table 32.0 Selecting 50 Hz or 60 Hz for Contact Time Reading

STEP	OPERATION	ACTION	DISPLAY
1	SELECT SET UP MENU.	PRESS # 3 KEY.	1. ANALYSIS POINT 2. MEASUREMENT UNITS 3. SAVE / RESTORE 4. NEXT PAGE
2	SELECT NEXT PAGE.	PRESS # 4 KEY.	1. SHOT DESCRIPTION 2. NUMBER OF CHANNELS 3. SET DATE & TIME 4. NEXT PAGE
3	SELECT NEXT PAGE.	PRESS #4 KEY.	1. SET PRINT MODE 2. SET 50/60 Hz
4	SELECT50 / 60 Hz MODE.	PRESS # 2 KEY.	1. SET 50 Hz 2. SET 60 Hz
5	SELECT "60 Hz".	PRESS # 2 KEY.	1.RUN TEST 06/10/07 2.GET RESULTS 20:10:01 3.SETUP 4.DIAGNOSTIC

Figure 35.0 Typical 50 Hz Tabulated Report

Figure 36.0 Typical 60 Hz Tabulated Report

9.28 CT-8000 Channel Configuration

The CT-8000 is available with 3 or 6 contact inputs. Since most common timing conditions require the user to use only 3 contact timing channels and one travel transducer channel. There is no need to print more than 3 timing channels and one transducer channel on the graphic and tabulated reports. The CT-8000 defaults to printing 3 contact channels (channel 1, 2 and 3) and one transducer channel (transducer channel #1) when the user first turns on the unit. The user can always turn on the rest of the timing channels and transducer channels by following the steps in the table below:

Table 33.0 Channel Configuration

STEP	OPERATION	ACTION	DISPLAY
1	SELECT SET UP MENU.	PRESS # 3 KEY.	1. ANALYSIS POINT 2. MEASUREMENT UNITS 3. SAVE / RESTORE 4. NEXT PAGE
2	SELECT NEXT PAGE.	PRESS # 4 KEY.	1. SHOT DESCRIPTION 2. NUMBER OF CHANNELS 3. SET DATE & TIME 4. NEXT PAGE
3	SELECT NUMBER OF CHANNELS.	PRESS # 2 KEY.	NUMBER OF CHANNELS 1. 3 CONTACT 2. 6 CONTACT
4	SELECT 3 CHANNELS OR 6 CHANNELS OR 12 CHANNELS.	PRESS # 1, OR 2 OR 3 KEY.	1. TRANSDUCER 1 2. TRANSDUCER 1 , 2 3. TRANSDUCER 1 , 2 , 3
5	SELECT 1 TRANSDUCER, OR 2, OR 3.	PRESS #1, OR #2, OR #3.	1.RUN TEST 06/10/07 2.GET RESULTS 20:10:01 3.SETUP 4.DIAGNOSTIC

9.29 Print Test Record Data

The print data command allows the user to print the hexadecimal timing data collected by the CT-8000. This feature is mainly for factory testing. The CT-8000 collects 20,000 data points in the one-second timing window. As a results, each data sample is 0.05 ms apart. By looking at the time marker and the data point, the user can actually find the channel activities vs time in the timing record.

The following steps allow the user to print CT-8000 timing data from memory.

Table 34.0 Print Test Record Data

STEP	OPERATION	ACTION	DISPLAY
1	SELECT DIAGNOSTIC.	PRESS # 4 KEY.	1. SLOW-CLOSE TEST 2. CHECK HOOKUP 3. TEST TRANSDUCER 4. NEXT PAGE
2	SELECT NEXT PAGE.	PRESS # 4 KEY.	1. PRINT DATA 2. ENCODER FILTER 3. CONTACT FILTER
3	SELCT PRINT DATA.	PRESS # 1 KEY.	STARTING ADDRESS?:
4	ENTER ADDRESS BOUNDARY. (See note below)	PRESS KEY # 1 to 9	1. EVERY POINT 2. EVERY 5 POINTS
5	CT-8000 PRINTS DATA.	NONE.	1. EVERY POINT 2. EVERY 5 POINTS
6	RETURN TO MAIN MENU.	PRESS THE "STOP" KEY.	1.RUN TEST 06/10/07 2.GET RESULTS 20:10:01 3.SETUP 4.DIAGNOSTIC

As sample of the CT-8000 timing data print out is shown in figure 37.0.

Note

Pressing key #0 will start printing the data at address location 0 (or the first data point)
Pressing key #1 will start printing the data at address location .10000 second.

Timer marker 0.100000 ms

Time marker 0.10010 ms
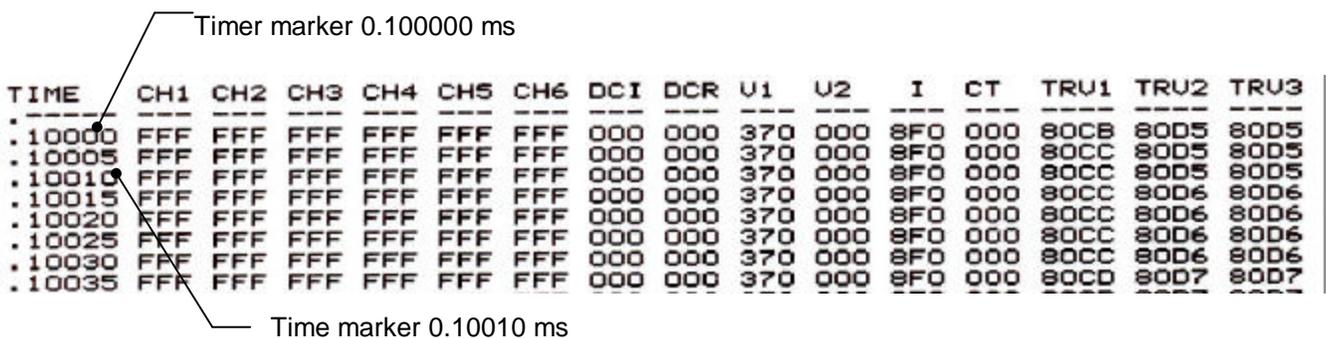
Figure 37.0 CT-8000 Timing Data

9.30 Transducer Encoder filter Setting

In a typical 1 second timing record, the CT-8000 records 20,000 data points for each of the Contact channels (C1-C6), Digital transducer channels (D1-D3), Voltage input channels (V1 & V2), CT channel, DCR channel, Resistor transducer channel and Initiate current channel.

In most circuit breaker timing applications, the breaker activities end after 200 ms. A common problem found in the field was that the CT-8000 recorded erroneous data on the transducer channels (after breaker activities ended) due to vibration. The erroneous data is probably due to the transducer not being properly secured to the mounting plate or a poor linkage problem between the transducer and the circuit breaker mechanism.

The Transducer Encoder Filter setting allows the user to stop recording the transducer channel data after a specific window. This feature allows the user to filter out the unwanted motion picked up by the transducer after the breaker activities have ended.

The following procedure allows the user to stop recording transducer data after 200ms.

Table 35.0 Set Transducer Filter

STEP	OPERATION	ACTION	DISPLAY
1	SELECT DIAGNOSTIC.	PRESS # 4 KEY.	1. SLOW-CLOSE TEST 2. CHECK HOOKUP 3. TEST TRANSDUCER 4. NEXT PAGE
2	SELECT NEXT PAGE.	PRESS # 4 KEY.	1. PRINT DATA 2. ENCODER FILTER 3. CONTACT FILTER
3	SELCT ENCODER FILTER.	PRESS # 2 KEY.	ENTER FILTER TIME (010 - 999)
4	END RECORDING DATA AFTER 200MS.	ENTER "2, 0, 0".	ENTER FILTER TIME (010 - 999) 200
5	SELECT FILTER SETTING.	PRESS "ENTER" KEY.	1.RUN TEST 06/10/07 2.GET RESULTS 20:10:01 3.SETUP 4.DIAGNOSTIC

Note

The Transducer Encoder Filter setting is default to "No Filter" when the CT-8000 is powered on.
The filter setting is available from 10 ms to 999 ms.
A setting of 200 ms requires the user to enter 200 in the "FILTER TIME". This setting makes the CT-8000 not to record any Transducer Encoder data after 200 ms.

9.31 Contact Filter Setting

The contact filter setting is ***applicable for timing shots with insertion resistors only***. The CT-8000 automatically detects the contact time using its own algorithm. However, manual setting for contact time calculation is made available to the user.

The filter setting of 1 allows the CT-8000 to pick up the first contact transition time after the resistor contact activity is detected. The filter setting of 300 allows the CT-8000 to pick up the last contact transition time after the resistor contact activity is detected. Use the steps below to set contact filtering.

Table 36.0 Set Contact Filter

STEP	OPERATION	ACTION	DISPLAY
1	SELECT DIAGNOSTIC.	PRESS # 4 KEY.	1. SLOW-CLOSE TEST 2. CHECK HOOKUP 3. TEST TRANSDUCER 4. NEXT PAGE
2	SELECT NEXT PAGE.	PRESS # 4 KEY.	1. PRINT DATA 2. ENCODER FILTER 3. CONTACT FILTER
3	SELCT CONTACT FILTER.	PRESS # 3 KEY.	ENTER FILTER SETTING (1 – 300) CURRENT SETTING: 1 NEW SETTING?
4	ENTER NEW FILTER SETTING. SELECT 5 SAMPLES.	PRESSS KEY # 5	ENTER FILTER SETTING (1 – 300) CURRENT SETTING: 1 NEW SETTING? 5
5	SELECT FILTER SETTING	PRESS "ENTER" KEY.	1.RUN TEST 06/10/07 2.GET RESULTS 20:10:01 3.SETUP 4.DIAGNOSTIC

Note

The CT-8000 will return to automatic filter setting after power is cycled.
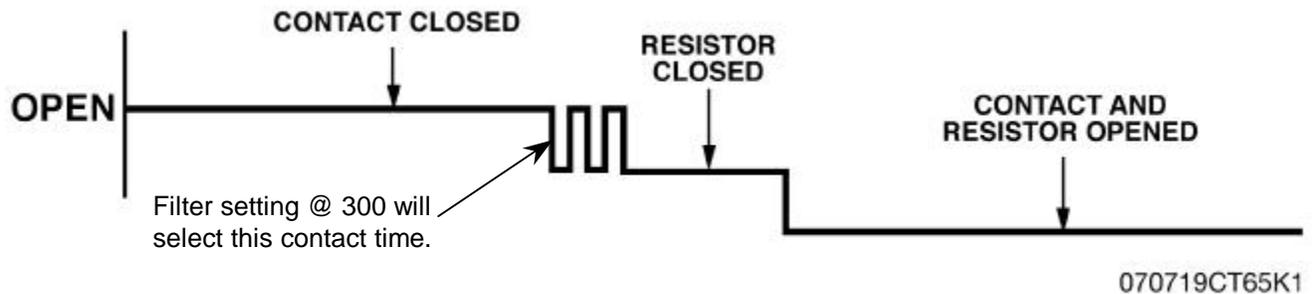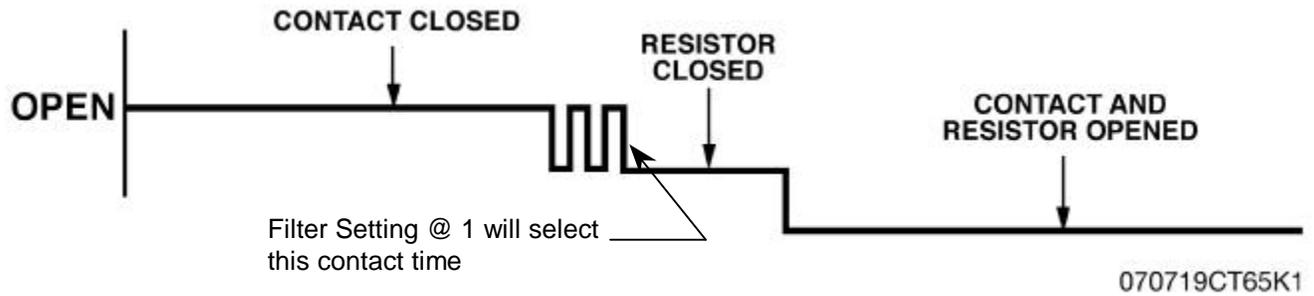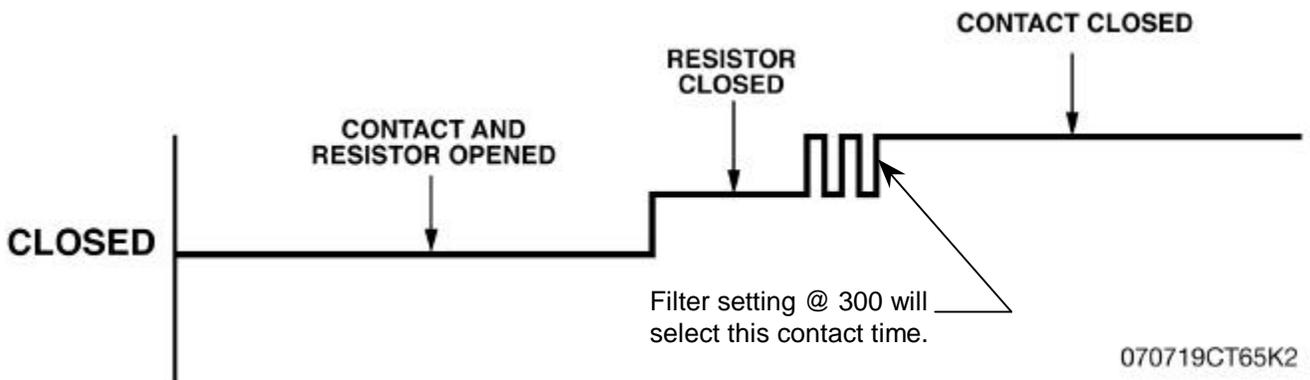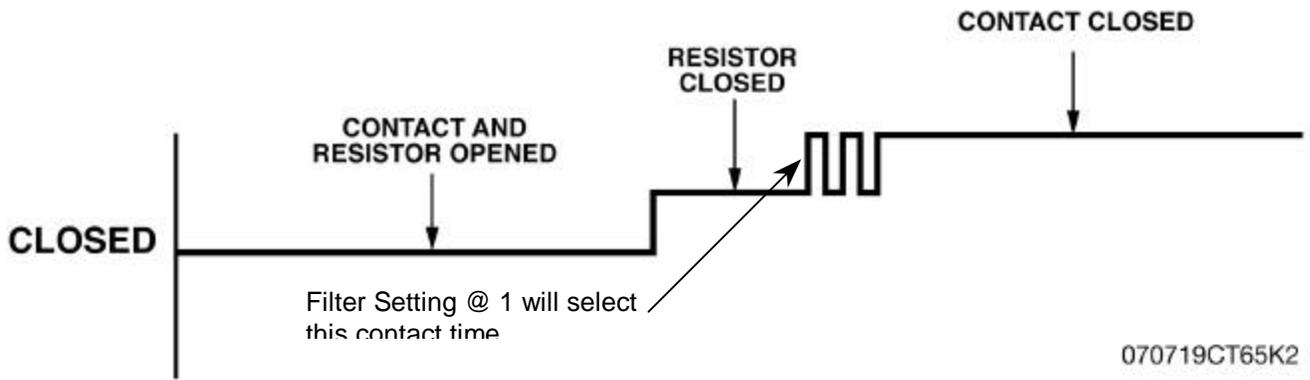
Figure 38.0 Contact Filter Setting Illustration

9.32 Running CT-8000s in Tandem

For timing applications requiring more than 6 timing contact channels, the user can use two or more CT-8000s to time a circuit breaker. A typical application is to use one CT-8000-6 and one CT-8000-3 to create a 9 contact timing application. To time this circuit breaker, the user can use the following steps:

- Connect the CT-8000-6 to phase A and B of the circuit breaker.

- Connect the CT-8000-3 to phase C of the circuit breaker.

- Connect the CT-8000-6 initiate cable to the breaker control circuit. This CT-8000-6 will operate the circuit breaker.

- Connect the CT-8000-3 external trigger cable to the OPEN coil for the OPEN test and CLOSE coil for the CLOSE test. This CT-8000-3 will operate as a slave device.

- Set the CT-8000-3 to start a test using "EXTERNAL TRIGGER".

- Set the CT-8000-6 to start a test using "INTERNAL TRIGGER".

- Hold the "ARM" switch on the first CT-8000-6 to operate the circuit breaker.

The CT-8000-6 will operate the circuit breaker and start the timing sequence. The CT-8000-3 will start its timing sequence as soon as it senses the voltage applied to the breaker coil.

The timing report of the CT-8000-6 will show the contact time of phase A and B. The timing report of the CT-8000-3 shows the contact time for phase C.

If the user downloads the test results of both the CT-8000s to the PC, the user then can combine the 2 test reports to generate a 9-channel test report. This report can now be printed on the PC printer.

10.0 CT-8000 Trouble Shooting Guide

Problems	Suggestion
1. CT-8000 will not trip nor close the breaker.	- Make sure you hold the "ARM" switch down during each test. - Check the OPEN or CLOSE fuses. - Check the initiate leads. For a "Positive Trip" circuit, one Close lead and one Open lead should be connected to the Positive side of the power supply. - Check the initiate leads. For a "Negative Trip" circuit, one Close lead and one Open lead should be connected to the Negative side of the power supply.
2. Getting message "TRIGGER FAULT" "No Trigger" When using external trigger.	- Trigger voltage was not detected by the CT-8000. - Check the external trigger input to the CT-8000. - Make sure the external trigger signal is presented when the CT-8000 displays "AWAITING TRIGGER."
3. Missing timing or transducer channels on report and graphic output.	- Timing or transducer channels were not turned on. Turn on channels by going to "SETUP", "NEXT PAGE", "NUMBER OF CHANNELS".
4. No contact time (0 ms) in Trip or Close test.	- Make sure only one side of the breaker is grounded. - Make sure the breaker operates on the Open or Close test only. A dual operation OPEN-CLOSE or CLOSE-OPEN will result in 0 ms reading. - Damaged CT-8000 contact channels or bad cables. Try the "CHECK HOOK-UP" test.
5. No contact time (0 ms) in Close-Open.	- Make sure the breaker contacts complete the transition from the Open (initial state) to the Close, then to the Open (final state). You can see The transition by looking at the timing chart. - Make sure the contact close state is longer than 10 ms. The CT-8000 has a 10ms de-bounce time, any contact state less than or equal to 10ms is invalid, thus the delay time is probably too short. - Try the Close-Open using contact channel #1 option.
6. Select Open-Close test. The breaker opens and will not close.	- Delay between Open to Close is probably too small. Increase delay time.
7. No data or erratic reading on travel transducer.	- Bad transducer. Try "TEST TRANSDUCER" diagnostics. - Transducer slider is not secured to timing rod. - Transducer is not secured properly.
8. No activity on" V2" voltage input channel.	- The "V2" voltage input channel requires a voltage change greater than 30 V, to see activity on the timing chart.

Problems	Suggestion
9. How does one review the current analysis settings?	- Go to SETUP (Press key #3).
	- Select Analysis (Press key #1).
	- Select PRINT SETTING (Press key #3). The CT-8000 will print out the current AP1 & AP2 settings.
10. The CT-8000 will not communicate with the PC.	- Make sure your PC communication port is selected correctly.
	- Make sure your serial or USB cable is connected properly.
11. Turn on Automatic Print Results mode.	- See section 9.26.
12. Where can one get some thermal paper?	- Call the factory at 909-923-9390 or BG Instruments at 509-893-9881. The CT-8000 uses TP-4 thermal paper.
	- In case of an emergency, thermal paper can be purchased at Radio Shack. Radio Shack carries 4.25 inch wide thermal paper. It is not the right size but it will work.
13. How does one darken or lighten the LCD?	- Press and hold the "? PAPER LCD" key will darken the LCD.
	- Press and hold the "? PAPER LCD" key will lighten the LCD.
14. How does one move thermal paper forward or backward?	- Press and release the "? PAPER LCD" key, the thermal paper will advance.
	- Press and release the "? PAPER LCD" key, the thermal paper will retract.

APPENDIX A ITE Circuit Breaker model 14.4K Timing Chart
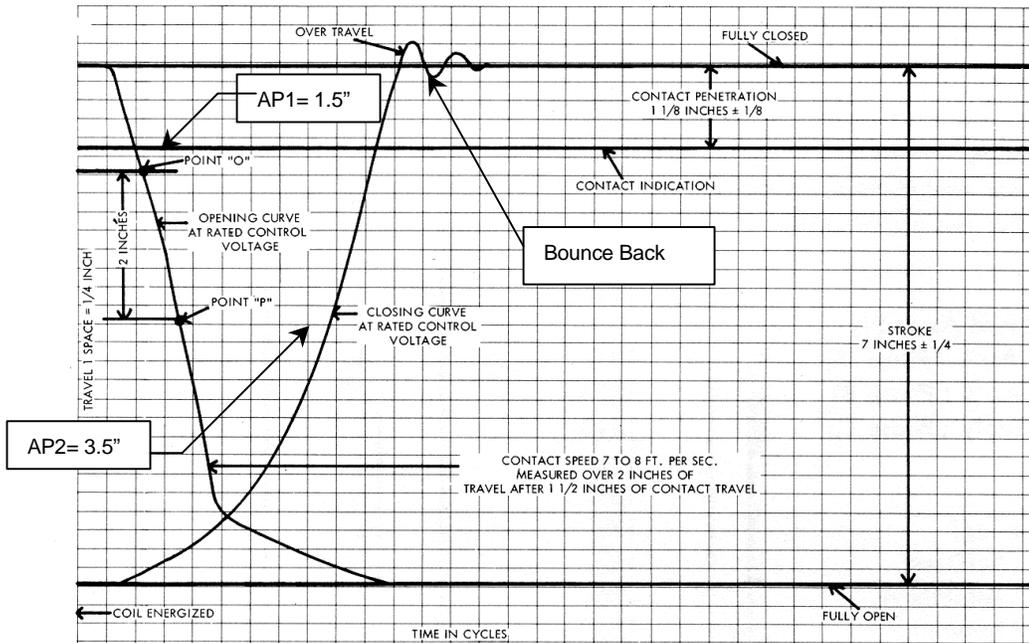
TYPICAL NO LOAD TRAVEL CURVES FOR OPENING AND CLOSING OPERATIONS
AT RATED CONTROL VOLTAGE
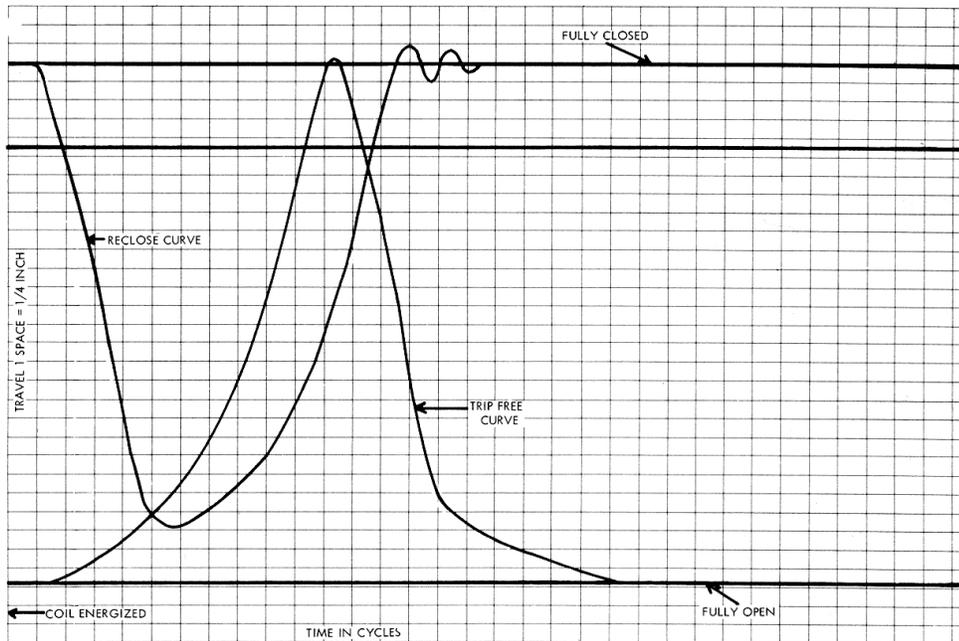
TYPICAL NO LOAD TRAVEL CURVES FOR RECLOSING AND TRIP-FREE OPERATIONS
AT RATED CONTROL VOLTAGE

APPENDIX B CLOSE-OPEN Timing Chart for ITE Circuit Breaker Model 14.4K

Contact Touch Distance

Peak To Peak Travel
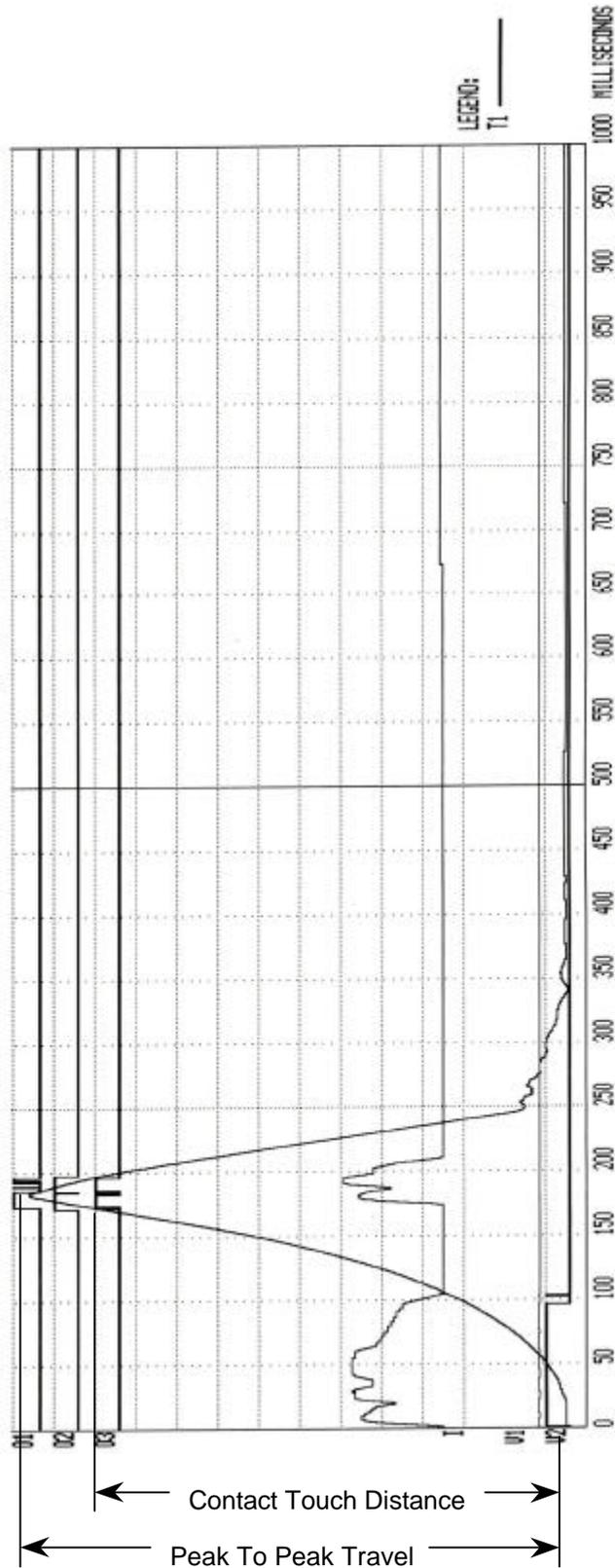
APPENDIX C CLOSE-OPEN Tabulated Report for ITE Circuit Breaker Model 14.4K

```
┌─────────────────────────────────────────┐
│  BREAKER TIMING RESULTS - 60 Hz          │
├─────────────────────────────────────────┤
│         SHOT NUMBER: 0007                │
│  DATE: 09/01/03     TIME: 13:18:42       │
├─────────────────────────────────────────┤
│  COMPANY:    VANGUARD INSTRUMENT         │
│  STATION:                                │
│  CIRCUIT:                                │
│  MFR:                                    │
│  MODEL:                                  │
│  S/N:                                    │
│  OPERATOR:                               │
├─────────────────────────────────────────┤
│  TEST: CLOSE - OPEN                      │
├─────────────────────────────────────────┤
│  CONTACT CLOSE TIME                      │
│                                          │
│  CH    TIME    CYCLES    BOUNCE          │
│        <mS>              <mS>            │
│   1   172.00   10.32    002.50           │
│   2   170.70   10.24    000.30           │
│   3   170.60   10.24    000.00           │
├─────────────────────────────────────────┤
│  CONTACT OPEN TIME                       │
│                                          │
│  CH    TIME    CYCLES    BOUNCE          │
│        <mS>              <mS>            │
│   1   185.00   11.10    013.40           │
│   2   196.70   11.80    000.10           │
│   3   000.00   00.00    196.20           │
├─────────────────────────────────────────┤
│  CONTACT LIVE TIME                       │
│                                          │
│  CH    TIME    CYCLES                    │
│        <mS>                              │
│   1   013.00   00.78                     │
│   2   026.00   01.56                     │
│   3   000.00   00.00                     │
├─────────────────────────────────────────┤
│  PEAK TO PEAK TRAVEL <in>                │
│    T1                                    │
│  07.44                                   │
├─────────────────────────────────────────┤
│  CH1 TOUCH DISTANCE <in>                 │
│   06.49                                  │
├─────────────────────────────────────────┤
│  V1 NOMINAL VOLTAGE = 48 VOLTS           │
│  V1 MINIMUM VOLTAGE = 45 VOLTS           │
│  INITIATOR CURRENT  = 05.6 AMPS          │
├─────────────────────────────────────────┤
│  SHOT LENGTH:          1 SECOND          │
│  INSERTION RESISTOR:   NO                │
│  TRIGGER:              INTERNAL          │
│  DELAY:                CLOSE CH #1        │
└─────────────────────────────────────────┘
```

APPENDIX D OPEN-CLOSE Timing Chart for ITE Circuit Breaker Model 14.4K
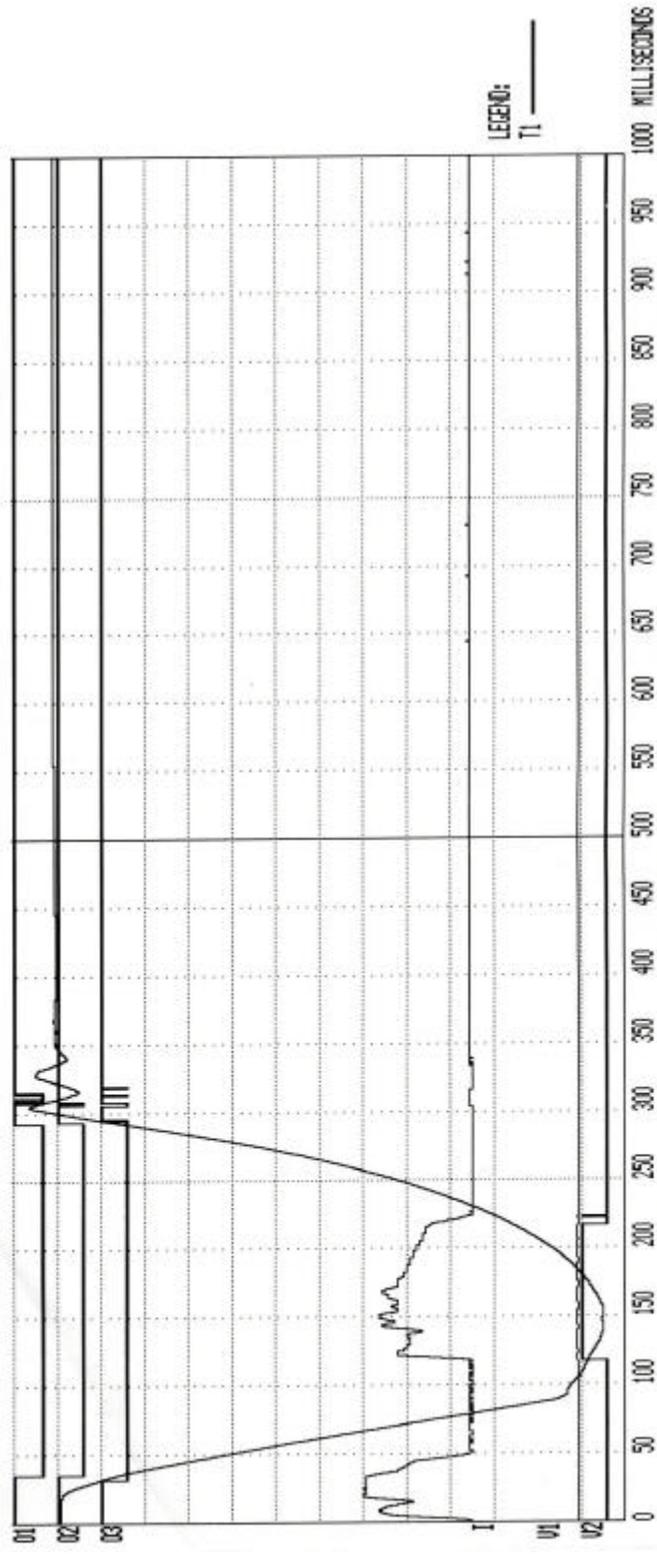
APPENDIX E OPEN-CLOSE Tabulated Report for ITE Circuit Breaker Model 14.4K

```
┌─────────────────────────────────────────┐
│ BREAKER TIMING RESULTS - 60 Hz          │
├─────────────────────────────────────────┤
│         SHOT NUMBER: 0008                │
│ DATE: 09/01/03    TIME: 13:20:37         │
├─────────────────────────────────────────┤
│ COMPANY:   VANGUARD INSTRUMENT           │
│ STATION:                                 │
│ CIRCUIT:                                 │
│ MFR:                                     │
│ MODEL:                                   │
│ S/N:                                     │
│ OPERATOR:                                │
├─────────────────────────────────────────┤
│ TEST: OPEN - CLOSE                       │
├─────────────────────────────────────────┤
│ CONTACT OPEN TIME                        │
│                                          │
│ CH     TIME   CYCLES   BOUNCE            │
│        <mS>             <mS>             │
│  1   034.30   02.06    001.00            │
│  2   034.20   02.05    000.20            │
│  3   030.60   01.84    000.70            │
├─────────────────────────────────────────┤
│ CONTACT RECLOSE TIME                     │
│                                          │
│ CH     TIME   CYCLES   BOUNCE            │
│        <mS>             <mS>             │
│  1   291.10   17.47    023.50            │
│  2   292.30   17.54    015.60            │
│  3   292.80   17.57    025.80            │
├─────────────────────────────────────────┤
│ CONTACT DEAD TIME                        │
│                                          │
│ CH     TIME   CYCLES                     │
│        <mS>                              │
│  1   256.80   15.41                      │
│  2   258.10   15.49                      │
│  3   262.20   15.73                      │
├─────────────────────────────────────────┤
│ PEAK TO PEAK TRAVEL <in>                 │
│   T1                                     │
│  07.21                                   │
├─────────────────────────────────────────┤
│ V1 NOMINAL VOLTAGE  = 48 VOLTS           │
│ V1 MINIMUM VOLTAGE  = 47 VOLTS           │
│ INITIATOR CURRENT   = 05.7 AMPS          │
├─────────────────────────────────────────┤
│ SHOT LENGTH:          1 SECOND           │
│ INSERTION RESISTOR:   NO                 │
│ TRIGGER:              INTERNAL           │
│ DELAY:                100 mS             │
└─────────────────────────────────────────┘
```

APPENDIX F SIEMENS TCP Breaker Velocity Calculation
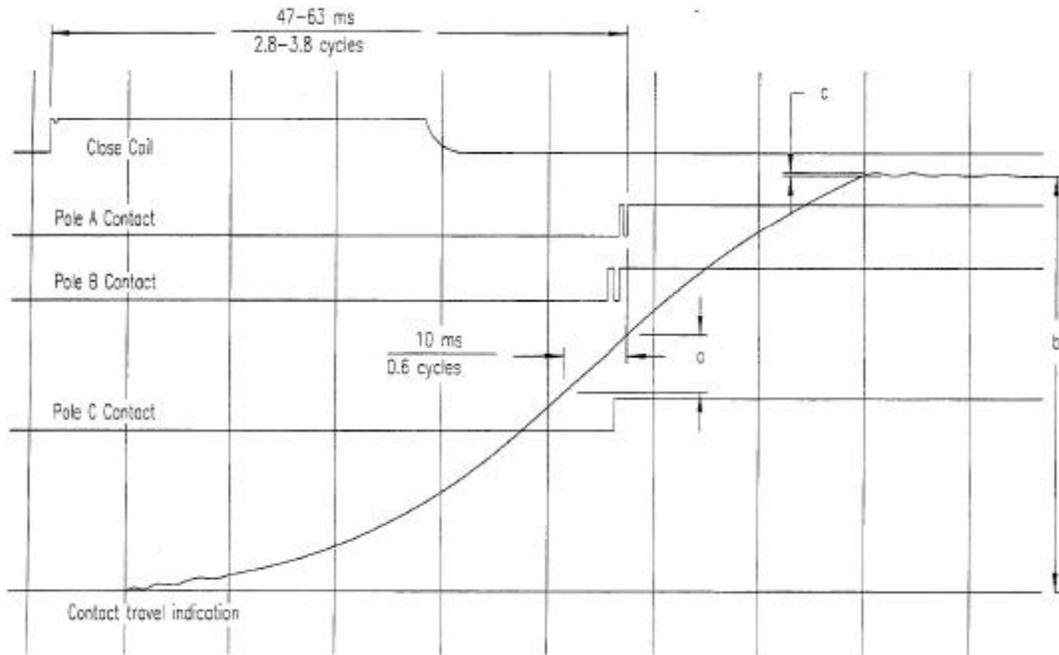
Example of Close Operation Record
Calculation For Contact Closing Velocity
      V=12.0a/b meters/second
Calculation For Overtravel/rebound
      S=120.0c/b millimeters
Note: a,b and c may be measured in any consistent units

Contact Stroke   = 120 mm
Transducer Stroke = 80 mm

APPENDIX G SIEMENS SPS2 Breaker Velocity Calculation

Example of Opening Operation Record

Calculation For Contact Opening Velocity
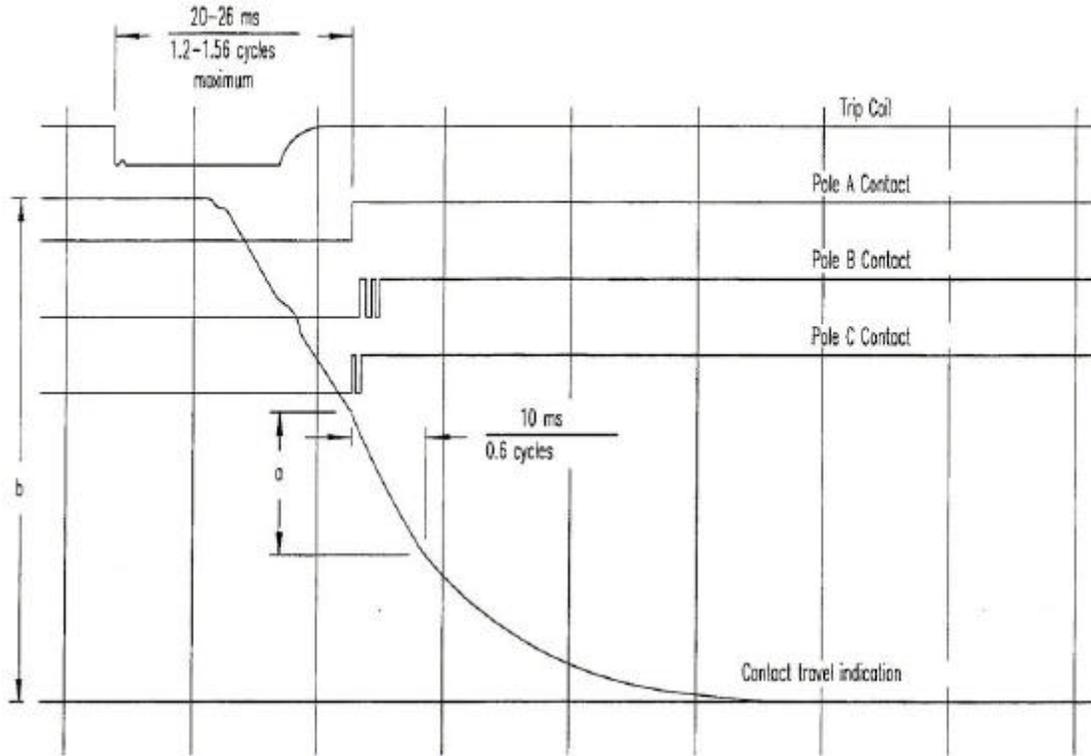$$V = 12.0a/b \text{ meter/second}$$
Note: a,b and may be measured in any consistant units

Contact Stroke = 120mm
Transducer Stroke = 80 mm

APPENDIX H CT-8000 SIEMENS SPS2 Test Plan

```
┌─────────────────────────────────────────────────┐
│           TEST PLAN NUMBER 1                     │
├─────────────────────────────────────────────────┤
│  MFR:          SPS2 121                          │
│  TYPE:         Siemens                           │
│  COMMENT:                                        │
├─────────────────────────────────────────────────┤
│  CONTACT TIME PARAMETERS                         │
│                        OPEN        CLOSE         │
│  MAX <mS>              026.0       063.0         │
│  MIN <mS>              020.0       047.0         │
│  DELTA LIM <mS>        004.0       004.0         │
│                                                  │
│  C-O,O-C PARAMS:  LIVE         DEAD              │
│  MAX <mS>              040.0       200.0         │
│  MIN <mS>              020.0       150.0         │
├─────────────────────────────────────────────────┤
│  RESISTOR ON-TIME PARAMETERS                     │
│                        OPEN        CLOSE         │
│  MAX <mS>              000.0       000.0         │
│  MIN <mS>              000.0       000.0         │
│  DELTA LIM <mS>        000.0       000.0         │
│                                                  │
│  C-O,O-C PARAMS:  LIVE         DEAD              │
│  MAX <mS>              000.0       000.0         │
│  MIN <mS>              000.0       000.0         │
├─────────────────────────────────────────────────┤
│  TRAVEL PARAMETERS                               │
│                 STRK    VEL    O-TVL   BNC-BK    │
│                 mm      M/S    mm      mm        │
│  OPEN HI    085.1   04.90   003.0   003.0        │
│  OPEN LOW   074.9   04.20   000.0   000.0        │
│                                                  │
│  CLOSE HI   085.1   04.50   004.1   004.1        │
│  CLOSE LO   074.9   03.50   000.0   000.0        │
├─────────────────────────────────────────────────┤
│  VEL = Cx[DIST(AP1 - AP2)/STROKE]                │
│  C = 12.00 M/S                                   │
├─────────────────────────────────────────────────┤
│  OPEN SPEED ANALYSIS POINTS:                     │
│                                                  │
│  POINT 1 = CONTACT                               │
│  POINT 2 = CONTACT PLUS   010.0 mS               │
├─────────────────────────────────────────────────┤
│  CLOSE SPEED ANALYSIS POINTS:                    │
│                                                  │
│  POINT 1 = CONTACT                               │
│  POINT 2 = CONTACT MINUS 010.0 mS                │
└─────────────────────────────────────────────────┘
```

APPENDIX I CT-8000 Transducer Illustration

Linear Transducer on an OCB

Rotary Transducer on Alstom HE 1014 Circuit Breaker

Rotary Transducer on ABB HMB Mechanism

Rotary transducer on Federal Pacific Circuit Breaker

Vanguard Instruments Company, Inc.

www.vanguard-instruments.com