

# TDR9000™ Circuit Breaker Test System User's Guide

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# Preface

## Structure of This Guide

This guide consists of four chapters and nine appendices.

Chapter 1. "Getting Started"

Chapter 2. "Introducing the TDR9000™ Circuit Breaker Test System"

Introduces the features and available options of the TDR9000™.

Chapter 3. "TDR9000™ Front Panels"

Describes the TDR9000 Physical and Virtual Front Panels and how they interrelate.

Chapter 4. "Setup and Operation"

Details the physical installation, configuration and use of the TDR9000.

Appendix A "TRXField™ Software and Circuit Breaker Testing Theory"

Explains the basics of circuit breaker operation, testing theory and the relationship between TDR9000 Test Plan items and tabulated Test Results.

Appendix B "Troubleshooting and Parts Replacement"

Contains troubleshooting, including the Self-Diagnostics test, for the TDR9000.

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Appendix C "Software Field Upgrades"

Contains the field procedures for:

- Installing new software
- Updating firmware
- Updating the Pentax® printer drivers

Appendix D "Concepts of Operation"

Explains the theory of operation for the TDR9000.

Appendix E "Maintenance"

Contains procedures for cleaning and general maintenance.

Appendix F "Glossary"

Contains a description of commonly used terms.

Appendix G "Error Messages"

Lists the error messages for the TDR9000.

Appendix H "TDR9000™ Circuit Breaker Test System Specifications"

Contains the physical, operational and environmental specifications for the TDR9000.

Appendix I "Application Notes"

Contains a compilation of Application Notes useful for optimizing the operation of the TDR9000.

## Document Conventions

Buttons, Picklist Items, Menu Items, etc.

Items that are selected by the user – buttons, menu items, etc. – are shown in **this text**.

Windows

Windows referenced in the text are shown in **this text**.

User-entered text

Text entered into TRX or TRXField fields is shown in *this text*.

Field Names/Displayed text

Messages displayed on windows and field names are shown in *this text*.

**NOTE**



**The NOTE icon signifies information that is important to the user.**

**WARNING**



**The WARNING icon signifies information that is necessary in order to properly perform a function. Failure to follow information contained in WARNINGS could cause a hazardous condition.**



# 1. Getting Started

Getting Started provides the minimum information required to make connections between a circuit breaker and the Doble® TDR9000 Circuit Breaker Test System, configure the TDR9000, run a test and save the Test Results for Dead Tank and Live Tank tests. When necessary, page references to detailed explanations are provided.

Information in this chapter is split into *Site Preparation* and *Running the Test*, and can be accessed by an individual task, or an entire circuit breaker test can be performed by executing both sets of tasks.

## Site Preparation

Site Preparation consists of the following steps:

1. Circuit Breaker Preparation
2. TDR9000™ Connections
3. Circuit Breaker Connections
4. Laptop and TDR9000 Test Plan Configuration

### Step 1: Circuit Breaker Preparation

#### NOTE



**Safety issues are different for First Trip/Close tests. Refer to "Safety Considerations: First Trip/Close Tests" on page 4-2 for a specific discussion.**

Circuit Breaker  
Preparation:  
Offline Testing

Figure 1.1 on page 1-4 shows how the Circuit Breaker Control Cabinet looks once preparation is complete.

Preparation of the circuit breaker includes the following sub-steps:

1. Opening the circuit breaker
2. Opening, locking and tagging the circuit breaker isolating disconnect switches
3. Connecting safety grounds to a cleaned (brushed) spot on the ground grid and then to each bushing of the circuit breaker to be tested
4. Removing DC power from the Trip and Close circuits on the circuit breaker control panel

5. Connecting the Breaker Control cable to the control circuit of the circuit breaker
6. Connecting the:
  - a. Trip leads across the terminals of the manual Trip switch on the circuit breaker control panel
  - b. Close leads across the terminals of the manual Close switch on the circuit breaker control panel

Alternately, connect the two trip leads between the +DC voltage and the trip coil and the two close leads between the +DC voltage and the close coil.

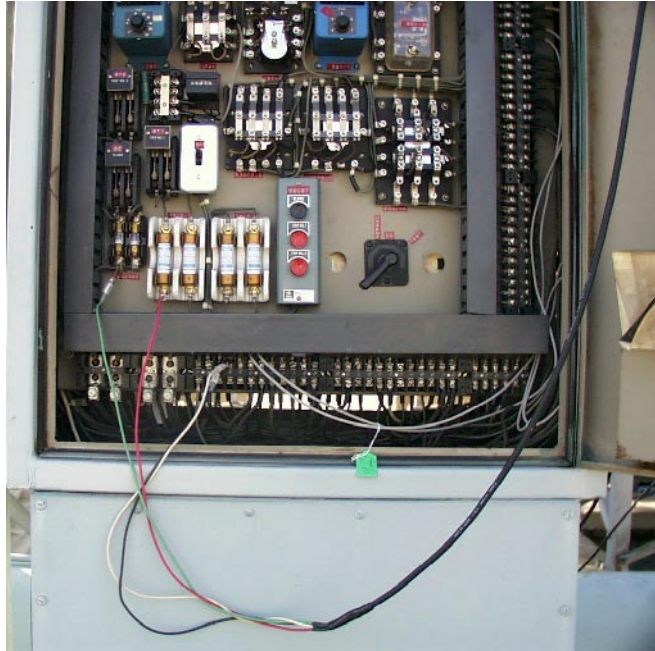
7. Connect either:
  - An OCB Contact Monitor cable to the appropriate circuit breaker bushings as listed in Table 1.1or
  - The EHV Contact Monitor cables to the appropriate circuit breaker bushings as listed in Table 1.2.

**Table 1.1 OCB Dead Tank Connections**

Alligator Clip Color	Phase	Bushing
Red	A	1
Yellow	B	3
Blue	C	5
Black	COM	2, 4, 6

**Table 1.2 EHV Dead Tank Connections**

Alligator Clip Color	Phase	Contact
Yellow	Red	1
Red	Red	2
Black	Red	COM
Yellow	Red	3
Red	Red	4
Black	Red	COM
Yellow	Yellow	1
Red	Yellow	2
Black	Yellow	COM
Yellow	Yellow	3
Red	Yellow	4
Black	Yellow	COM
Yellow	Blue	1
Red	Blue	2
Black	Blue	COM
Yellow	Blue	1
Red	Blue	2
Black	Blue	COM



**Figure 1.1 Step 1: Circuit Breaker Control Cabinet Preparation**

Circuit Breaker  
Connections:  
First Trip/Close Test

The connections to the breaker are outlined in the steps below:

**NOTE**



**Once this is complete skip to "Step 4: Laptop and TDR9000™ Test Plan Configuration" on page 1-15.**

1. Connect the TDR9000 ground connection to circuit breaker ground.
2. Connect a Doble current probe to a CT secondary for each phase being measured, to record the Main Contact currents.
3. Connect Doble current probes to selected relay coil circuits and then to TDR9000 event module.
4. Connect a set of Analog cables across the DC supply switch to monitor the DC bus voltage. Set up the channel for voltage sense and range.
5. Connect Auxiliary Contact cables across the selected contact and connect to an Aux contact.

6. Connect channels on the Event module:

- If the TDR9000:
  - Has the Trigger option and Trigger In set as the trigger source in the Test Plan, connect Trigger In cables across the:
    - 52CS/T contacts for Trip
    - 52CS/S contacts for Close
  - Does not have the Trigger option, ensure that Aux Contact is set as the trigger source in Test Plan, connect Auxiliary Contact cables across the:
    - 52CS/T contacts for Trip
    - 52CS/S contacts for Close

## Step 2: TDR9000™ Connections

Figure 1.2, Figure 1.3 and Figure 1.4 on page 1-8 show the TDR9000 Physical Front Panel wirings for an EHV, OCB/Motion and Event Trigger test, respectively.

### NOTE



**For First Trip/Close tests complete steps 1 through 4 and then proceed to "First Trip/Close Tests" on page 4-1.**

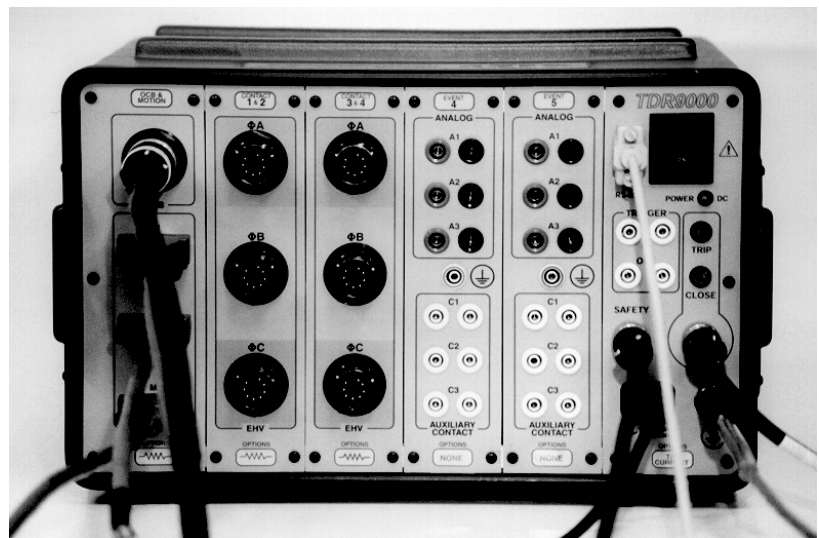
To connect the TDR9000:

1. Remove the front protective cover and store it in a safe place for reuse.  
If the printer option is available, locate the cover/printer assembly near the laptop.
2. Plug the ground cable into the system ground receptacle and ground the other end.
3. Plug the Safety Switch cable into the **SAFETY** receptacle of the System module. The Safety Bypass flag is used for First Trip/Close tests.
4. Ensure that the line voltage is correct (100 - 240 VAC, 50 or 60 cycles).
5. Connect the female end of the Motion Transducer cable to one of the **MOTION** connectors on the TDR9000 OCB/Motion module, if present.
6. Connect the male end of the Motion Transducer cable to the transducer.
7. Connect the Breaker Control cable to the **TRIP/CLOSE** connector on the TDR9000 System module.
8. Connect either:
  - An OCB Contact Monitor cable to the **OCB** connector on the TDR9000 OCB/Motion module.or
  - The EHV Contact Monitor cables to the **EHV** connectors on the TDR9000 EHV modules.

Refer to "Connecting the TDR9000™ Physical Front Panel" on page 4-30.



**Figure 1.2 Step 2: Physical Front Panel for EHV Test**

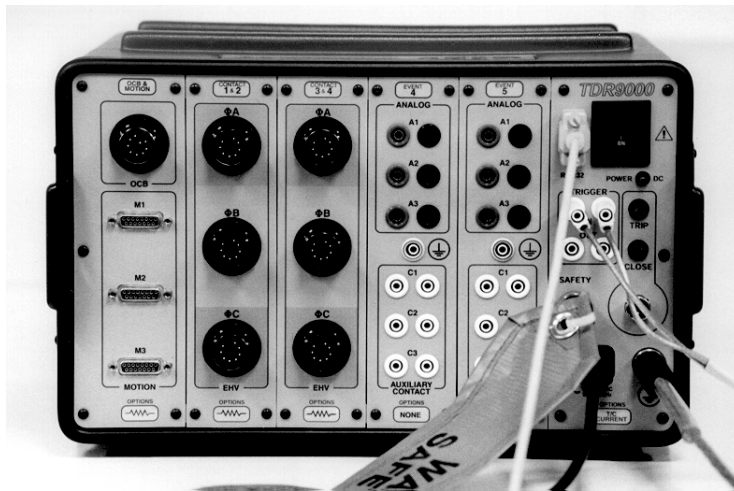


**Figure 1.3 Step 2: Physical Front Panel for OCB/Motion Test**

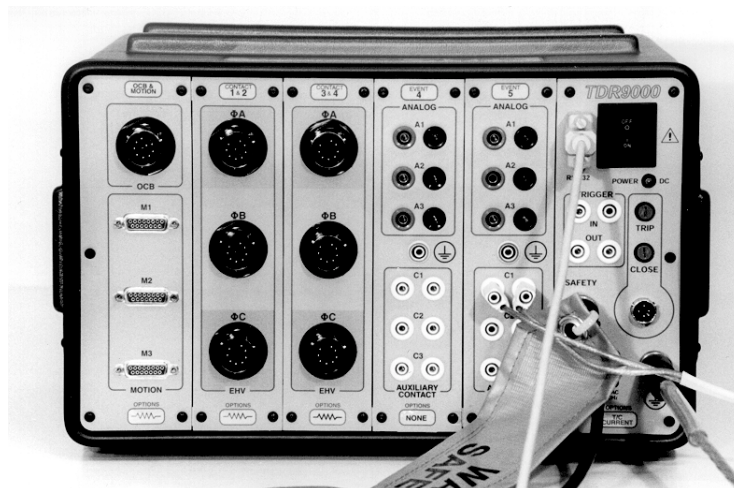
## Analog and Auxiliary Setup

The discussions that follow relate to setup issues for the Event and System modules (Figure 1.4 and Figure 1.5).

- Refer to "Monitoring Auxiliary Channels" on page 4-32 to connect an Auxiliary Contact.
- Refer to "Monitoring Analog Channels: Current and Voltage" on page 4-33 to connect a voltage input.
- Refer to "Current Probes" on page 4-34 to connect and zero a current probe on the Virtual Front Panel.
- Refer to "Current Shunt" on page 4-37 to connect a current shunt.



**Figure 1.4 Step 2: Physical Front Panel for Trigger In Test**



**Figure 1.5 Step 2: Physical Front Panel for Auxiliary Input Trigger Test**

TDR9000™  
Connections:  
First Trip/Close  
Test

Table 1.3 and Table 1.4 list the connections to the TDR9000 required for both a minimum set of channels and the recommended set of channels, respectively. Since this is an external trigger test, no control cable is used.

**Table 1.3 TDR9000™ Using a Minimum Set of Channels**

Item	Signal	Type	TDR9000 Module Connection
1	Main Contact (from CT secondary)	Analog	Event
2	Trip relay coil current	Analog	Event
3	DC Supply voltage	Analog	Event
4	52CS/T contact state (for Trigger In source)	Auxiliary Contact	Event or Trigger In*

\*Connect to an Event module if using the Aux Contact trigger source, and to the Trigger In connectors on the System module if using the Trigger In source. *Table 1.3 applies to a TDR9000 with one Event module.*

**Table 1.4 TDR9000™ Using Recommended Set of Channels**

Item	Signal	Type	TDR9000 Module Connection
1	Main Contact A (from CT secondary)	Analog	Event
2	Main Contact B (from CT secondary)	Analog	Event
3	Main Contact C (from CT secondary)	Analog	Event
4	Trip relay coil current	Analog	Event
5	DC Supply Voltage	Analog	Event
6	52X or 52Y relay coil current	Analog	Event
7	52A contact state	Aux Contact	Event
8	52B contact state	Aux Contact	Event
9	52X contact state	Aux Contact	Event
10	52Y contact state	Aux Contact	Event
11	52CS/T contact state (for Trigger In source)	Aux Contact	Event or Trigger In*

\* Connect to an Event module if “Aux Contact” is the trigger source in the Test Plan, and to the Trigger In receptacles if “Trigger In” is the trigger source. **Table 1.4 applies to a TDR9000 with two Event modules.**

## Step 3: Circuit Breaker Connections

Figure 1.6 on page 1-12 schematically shows how the installation looks once preparation is complete.

Preparation of the installation includes the following sub-steps:

1. Perform the connections as shown in Figure 1.6 for the Dead Tank test or in Figure 1.7 on page 1-12 for the Live Tank test.
2. Mount the transducer as explained in "Rotary/Linear Transducer Installation" on page 1-14.

**NOTE**



**During test setups, it is important to perform connections in the following order:**

1. **Connect grounds**
2. **Complete TDR9000 connections**

**NOTE**

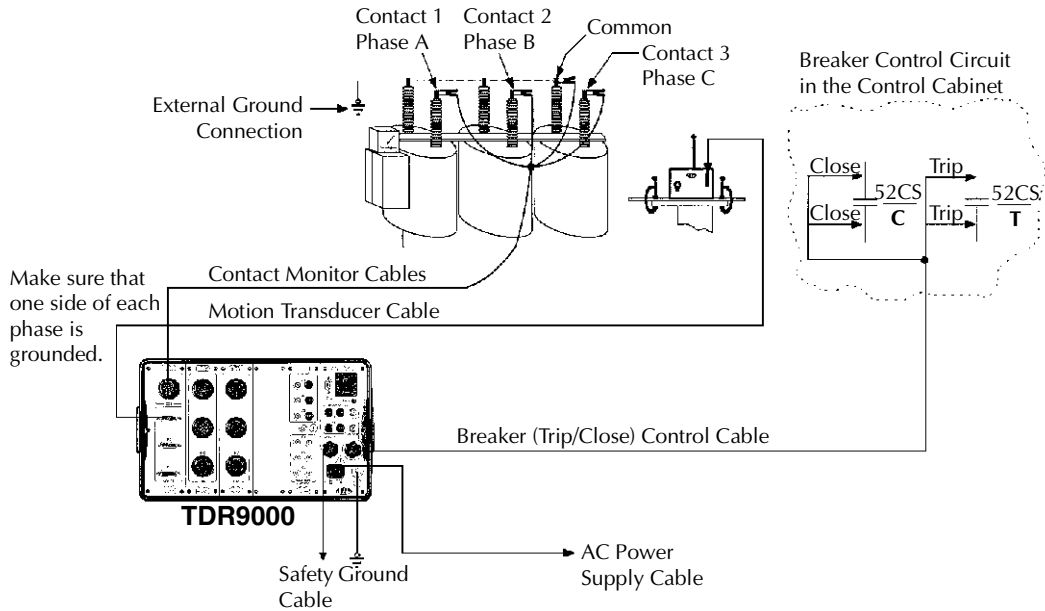


**To optimize TDR9000 isolation, make sure the Instrument is off.**

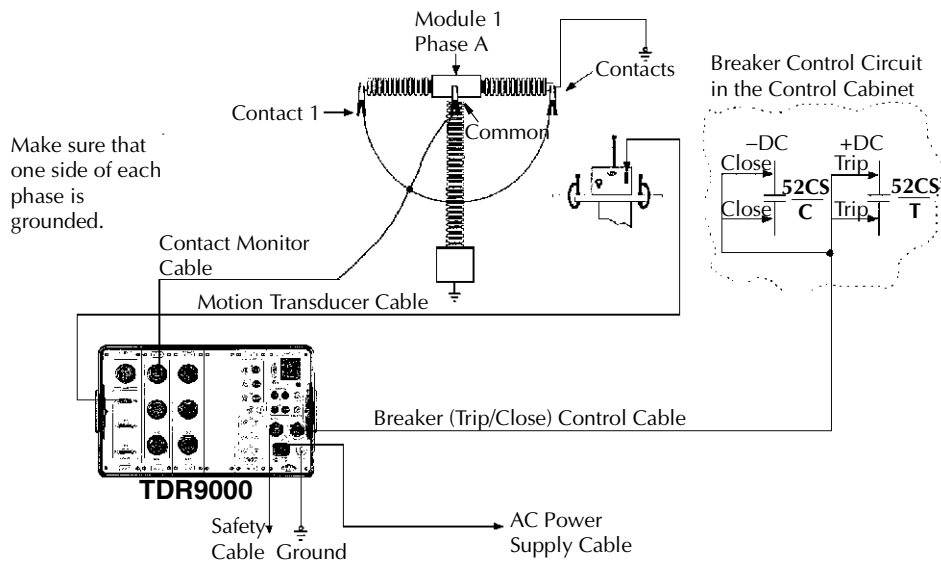
3. **Complete connections to the circuit breaker being tested**

Refer to "Dead Tank Circuit Breaker" on page 4-11 and "Live Tank Circuit Breaker" on page 4-14 for specific installation instructions.

Step 3: Circuit Breaker Connections



**Figure 1.6 Step 3: Dead Tank Test Setup**



**Figure 1.7 Step 3: Live Tank Test Setup**

Figure 1.8 shows an installation with Live Tank circuit breaker contact monitor cabling in place.



EHV Contact Monitor Cabling

**Figure 1.8 Installation with Circuit Breaker Contact Monitor Cabling**

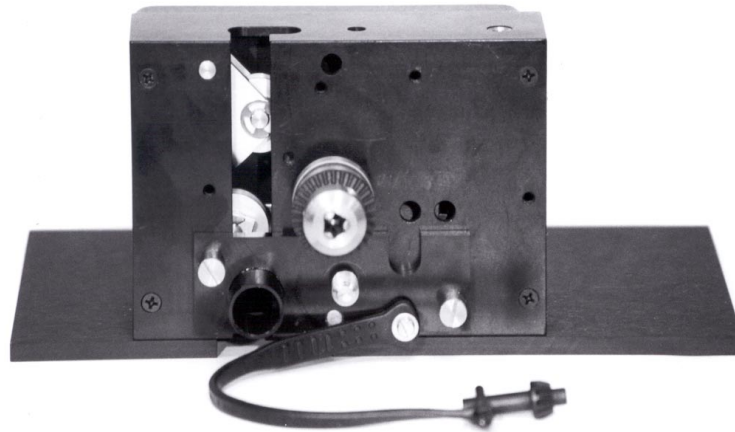
Rotary/Linear  
Transducer  
Installation

**WARNING**



Figure 1.9 and Figure 1.10 show the rotary and linear transducers, respectively.

**When using a linear rod, make sure that the circuit breaker is in a *safe* position before beginning transducer installation. A safe position exists when an accidental circuit breaker operation draws the rod into the circuit breaker. This is usually the closed position.**



***Figure 1.9 Step 3: Rotary Motion (Transducer with Rotary Adapter)***



***Figure 1.10 Step 3: Linear Motion (Transducer with Rod)***

For the TR3190 Digital Rotary/Linear Transducer:

- Rotary Motion setup, refer to "Rotary Motion" on page 4-18.
- Linear Motion setup, refer to "Linear Motion" on page 4-24.

For the TR3160:

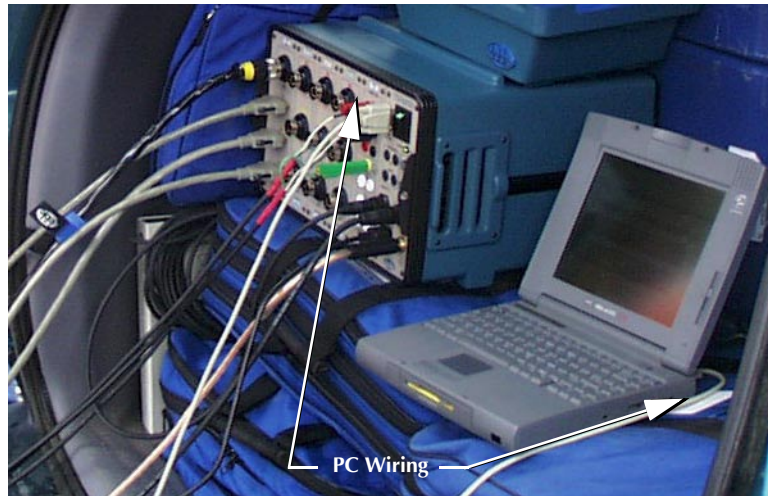
- Linear Transducer setup, refer to "Linear Motion" on page 4-24.
- Motion Transducer Rotary setup, including the TR3165 Rotary Adapter, refer to "Rotary Motion" on page 4-24.

## Step 4: Laptop and TDR9000™ Test Plan Configuration

Figure 1.11 shows how the TDR9000 looks once the laptop is set up, Figure 1.12 on page 1-17 shows a partial TRXField™ Test Plan, and Figure 1.13 on page 1-18 shows the Virtual Front Panel once the software is configured.

Preparation of the TDR9000 includes the following sub-steps:

1. Connect the laptop to the serial port of the TDR9000, power up the laptop and the TDR9000, and run the TRXField™ software.  
Refer to "Connecting to the Laptop, Printer and Powering Up" on page 4-27.
2. Import a Test Plan from TRX™ or configure a new one.  
Refer to "Connecting the TDR9000™ Physical Front Panel" on page 4-30.
3. Configure the Virtual Front Panel.  
Refer to "Setting Up a Test Plan Manually with TRXField™" on page 4-43.

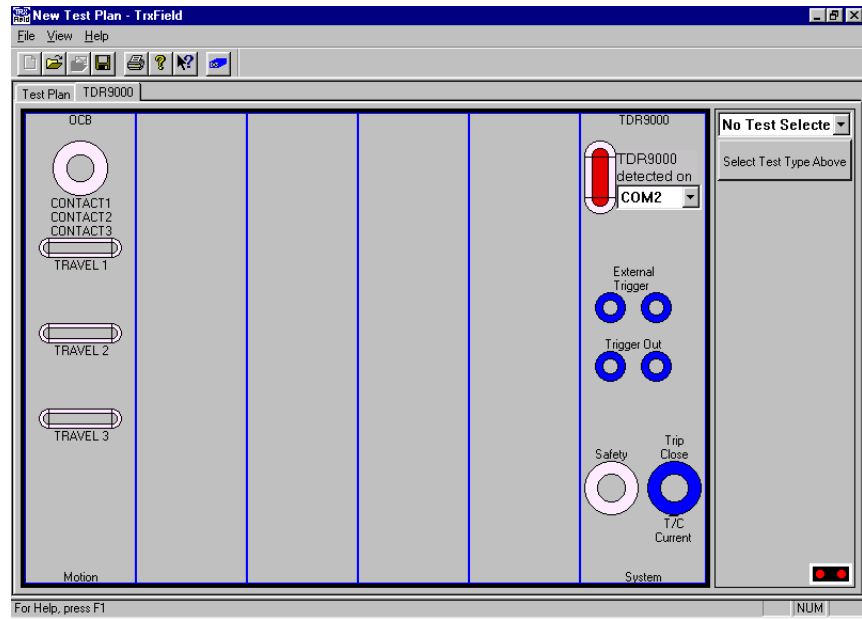


**Figure 1.11 Step 4: TDR9000™ and PC Wiring**

Breaker Test Plan		
Required Information		
Information Required for Library Plans	Information Required for Breaker Plans	
Manufacturer: <b>General Electric</b>	Location:	
Model Number: <b>FK-121-2C000</b>	Special Id:	
Version Description:	Serial Number: <b>0202A9405 701</b>	
Optional Information		
Inst. Book Number:	Operator:	
Mech. Number: <b>MA-13-5D</b>	Circuit:	
Mech. Book Number:	User 1:	:
Operation Counter:	User 2:	:
Command Parameters		
Trip Current Range: <b>100.0 A</b>	Close Current Range: <b>200 A</b>	Timing Measurement: <b>Seconds</b>
Trip Parameters:	Trip-Free Parameters:	O-C-O Parameters:
Trip Pulse: <b>66.6 ms</b>	Close Pulse: <b>133.3 ms</b>	O-C-O: <b>Standing</b>
	Trip Free: <b>Standing</b>	Trip Pulse: <b>66.6 ms</b>
		Close Pulse: <b>133.3 ms</b>
		Delay Length: <b>113.3 ms</b>
Close Parameters:	Reclose Parameters:	Trigger Input Parameters:
Close Pulse: <b>133.3 ms</b>	Trip Pulse: <b>66.6 ms</b>	Trigger Source: <b>None (Internal)</b>
Timing Event: <b>Test Initiation</b>	Reclose: <b>Standing</b>	
Trigger Output Parameters:	Main Contact Digital Discriminator:	Test Duration Parameters:
Trigger State: <b>Off</b>	Digital Discriminator: <b>Auto</b>	Recording Length: <b>1600 ms</b>
		Sample Rate: <b>10 kHz</b>

Figure 1.12 Step 4: TRXField™ Test Plan (Partial)

## Step 4: Laptop and TDR9000™ Test Plan Configuration



**Figure 1.13 Step 4: Virtual Front Panel**

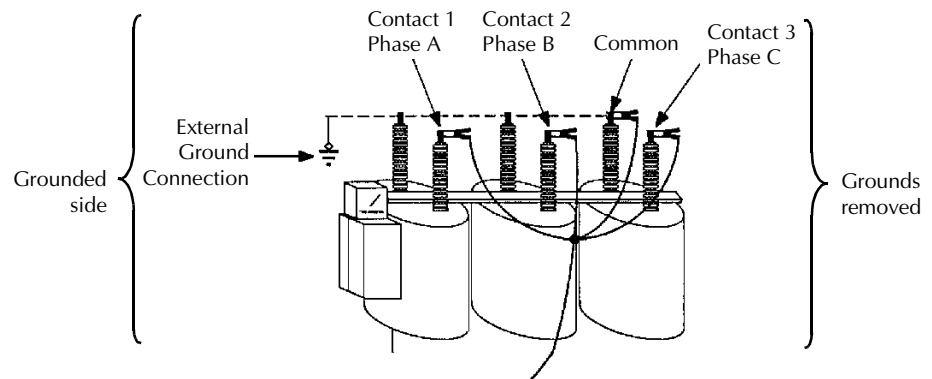
## Running the Test

The steps in this section list the procedures for running the test. These are:

- Removing Safety Grounds
- Running Self Diagnostics (Optional)
- Running the Continuity Test (Recommended)
- Performing the Pretest Checklist
- Running a Test
- Saving Test Results

### Step 1: Removing Safety Grounds

Figure 1.14 shows a breaker with the safety grounds removed from one side of the circuit breaker in preparation for the test.



**Figure 1.14 Breaker with Safety Grounds Removed**

### Step 2A: Running the Self-Diagnostic Test (Optional)

Refer to "Self-Diagnostics Test" on page B-1.

## Step 2B: Running the Continuity Test (Recommended)

**NOTE**

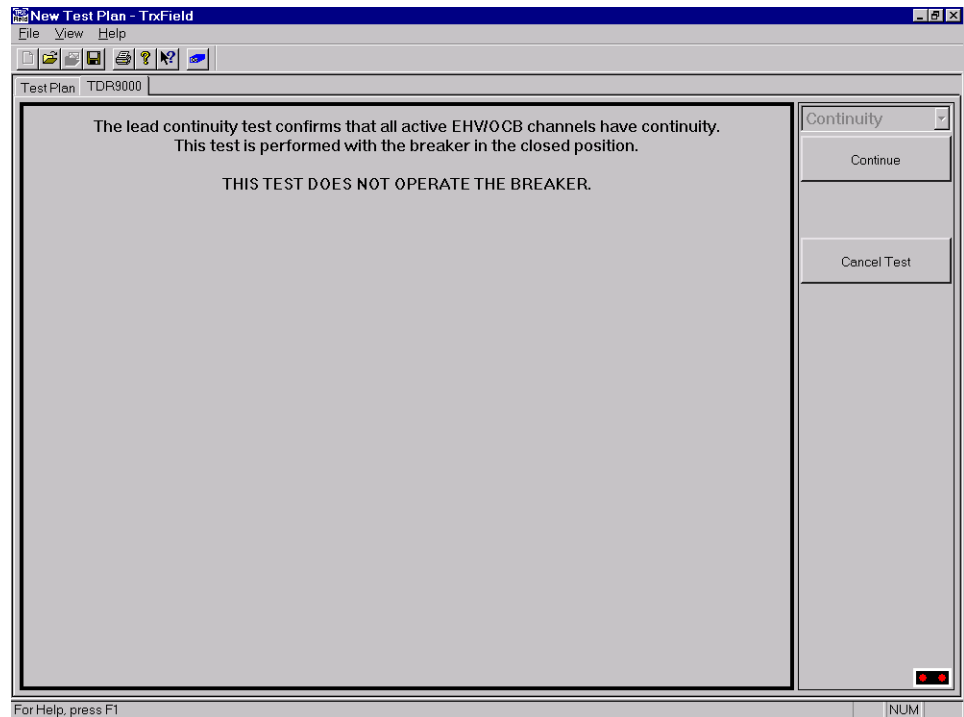


Figure 1.15 shows the initial **Continuity Test** window.

**The Continuity Test must be run with the circuit breaker in the closed position.**

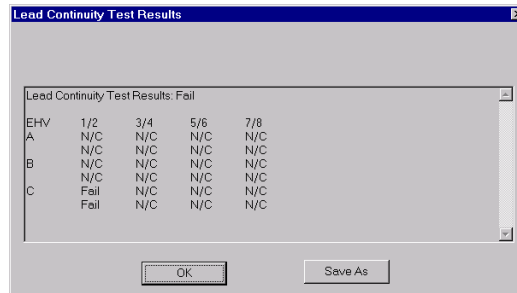
If the Continuity Test fails, check all test connections starting with the connections to the circuit breaker, then the connections to the TDR9000 Physical Front Panel.

For instructions on performing this test, refer to "Running the Continuity Test" on page 4-71.



**Figure 1.15 Continuity Test**

Running the Continuity Test produces the Test Results window shown in Figure 1.16.



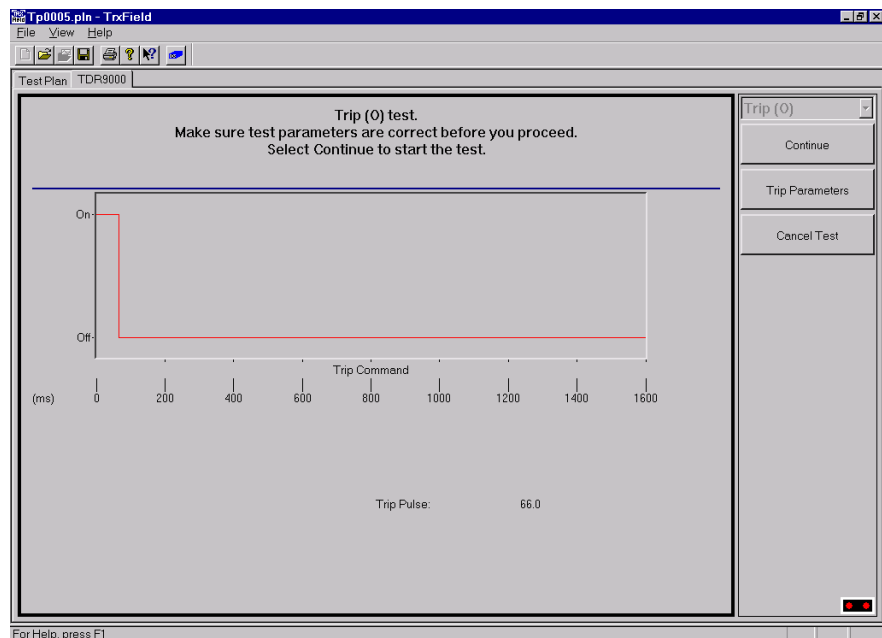
**Figure 1.16 Continuity Test Results**

### Step 3: Performing the Pretest Checklist

Use the checklist given in Table 4.8 on page 4-70 to ensure that the system is safely configured for testing, then reapply DC power to the circuit breaker Trip and Close circuits.

### Step 4: Running the Test

Figure 1.17 shows the initial window for running a Trip (O) test.



**Figure 1.17 Run Test**

To run a test:

1. Select a test type from the picklist on the upper right corner of the window.
2. Click **Run XXX Test**, where **XXX** designates the type of test.
3. Click **Continue**.



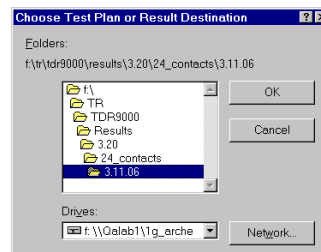
**The test is run after step 3 for Slow Close and externally triggered tests. In these cases, the Safety Bypass flag is used instead of the switch. For a Slow Close test, manually close the circuit breaker within the selected time (thirty seconds or one minute). For externally activated tests, activate the trigger.**

4. Press the button on the Safety Switch cable until the alarm ceases.

After test data is collected, the test results appear in graphic form. Refer to "Running Tests" on page 4-75 for specific instructions on how to run the test.

## Step 5: Saving Test Results

Figure 1.18 shows the initial window for saving Test Results.



**Figure 1.18 Saving Test Results**

To save Test Results while in either the tabulated or graphical test results of TRXField:

1. Click **Save** on the **File** menu.

If a test has been run and the **Tabulation** or **Graphics** tab is selected, the data is saved as a Test Result File.

The **Save TDR9000 Test Result** window appears.

2. Navigate to the desired folder and click **Save**.

For instructions on closing without saving, refer to "Closing Without Saving" on page 4-97.

**NOTE**



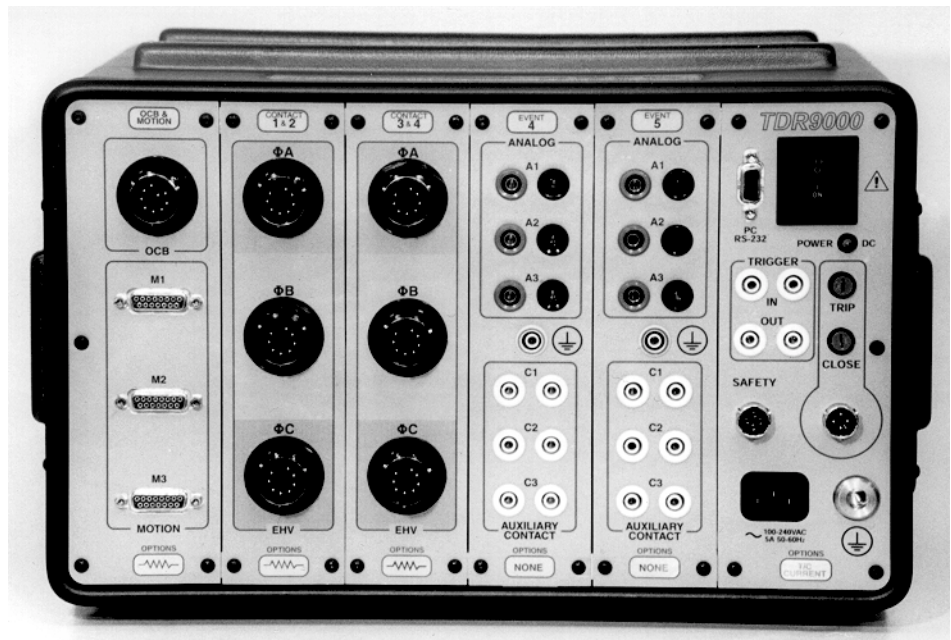
**Autosave disables Save in the File menu and the Save Toolbar icon.**



## 2. Introducing the TDR9000™ Circuit Breaker Test System

The TDR9000 measures, analyzes and records the electrical and mechanical performance of circuit breakers in the field. It accomplishes this through the use of its modular design and user-friendly interface.

Figure 2.1 shows the TDR9000 in one of its more comprehensive configurations. This configuration is used for Live Tank and Dead Tank circuit breaker testing.



**Figure 2.1 TDR9000™ Circuit Breaker Test System**

The modular design of the TDR9000 allows for a wide array of configuration possibilities. The Instrument can be configured to perform both on-line and off-line Live Tank and Dead Tank circuit breaker tests, as well as read inputs from a varying set of external data collection devices connected through its Event module channels.

---

The TDR9000, in conjunction with the TRXField software, offers flexible testing capabilities through a combination of **TDR9000** tab access to test command parameters coupled with **Test Plan** tab access to all circuit breaker specifications used for comparative purposes. The configuration of these parameters, and the operation of the test from the same interface, makes the performance of multiple tests under varying test conditions easy.

After the test is complete, the results can be viewed in the field using the **Tabulation** and **Graphics** tabs. The TRXField software, which operates the TDR9000, has the ability to overlay the results from different tests for comparison. The TDR9000 compares Test Results against circuit breaker specifications and presents a *Pass* or *Fail* determination on the **Tabulation** tab for each measurement for which a comparative value is set in the Test Plan. The data accumulated in the field can be transferred to a computer running the TRX software, which stores the Test Results in a database format for record keeping and test interpretation.

**WARNING**



**To avoid operating conditions hazardous to personnel, or harmful to the TDR9000, carefully follow all procedures, paying specific attention to Notes and Warnings.**

Figure 2.2 shows the topology of the TDR9000 in the test environment.

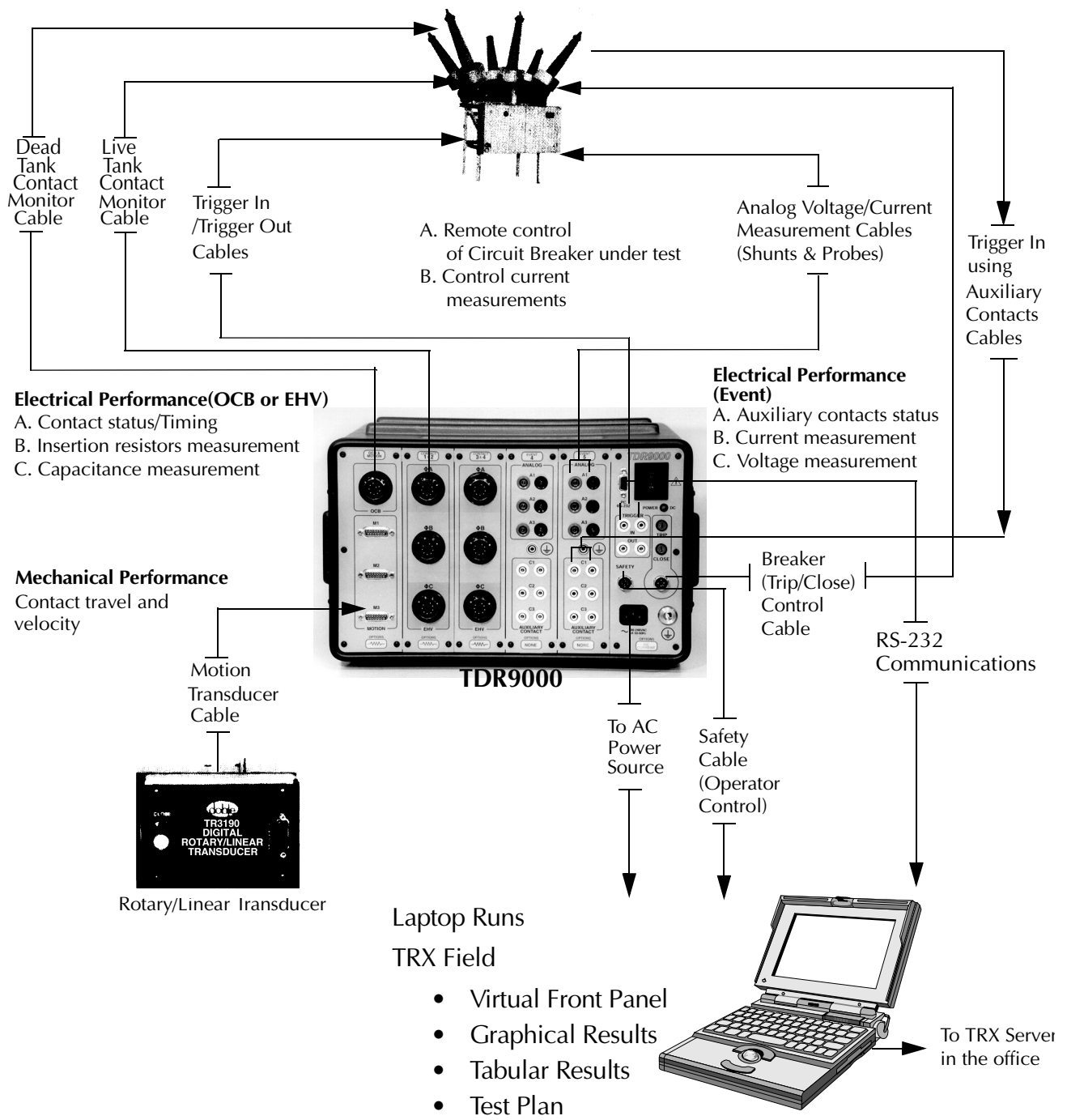
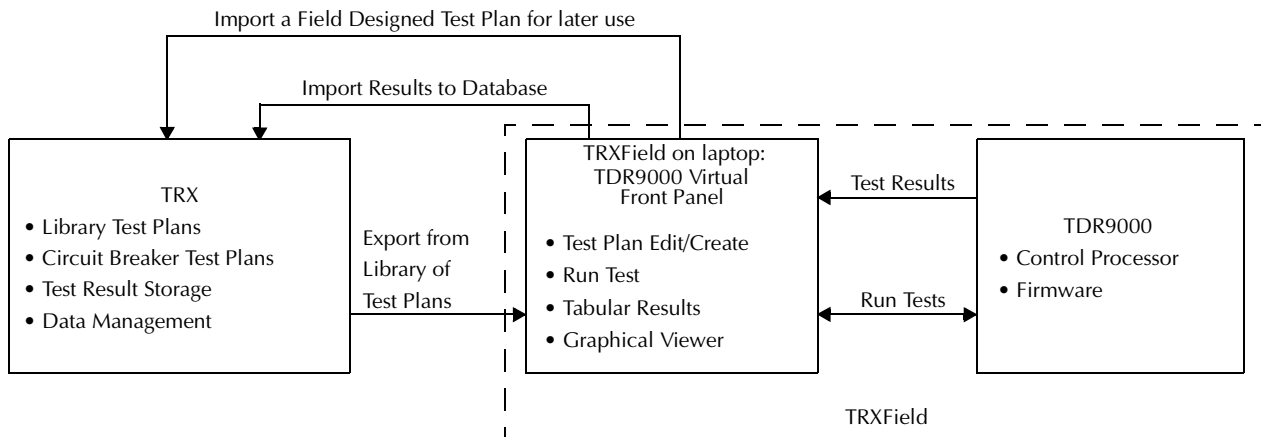


Figure 2.2 TDR9000™ System Topology

## TRX™ and TRXField™ Software

Figure 2.3 shows the working relationship between the TRX software (with database components) and the TRXField software (control and data collection), which is used to run tests. TRXField is included with the TDR9000, and is also provided with the TRX installation.



**Figure 2.3 TDR9000™ System Information Flow Diagram**

The features of both software programs are discussed below:

### TRX

TRX is installed on an office computer or network server that is responsible for data storage and performing historical data analysis of circuit breakers.

TRX offers the following features:

- The ability to design a library of circuit breaker Test Plans from which an editable, circuit breaker specific Test Plan can be created.
- The storage of test data.
- The evaluation of circuit breaker test data from single and multiple tests and overlay comparisons of Test Results from the same or similar breakers.

The complete functionality of TRX software is explained in the *TRX User's Guide*. Refer to "TDR9000™ TRXField™ Software and Test Plan Dynamics" on page A-28 for a discussion of the TRXField software used to run the TDR9000.

## TRXField

TRXField is installed on any laptop, or other computer that is used to perform tests. It contains the functionality to take existing Library Test Plans and run them as individual Circuit Breaker Test Plans.

TRXField offers the following capabilities:

- The creation of individual Circuit Breaker Test Plans using a Library Test Plan as its basis. Once completed, Individual circuit breaker tests can be imported into the TRX software. Each circuit breaker test adds to the database of Test Results available for analysis using TRX. These completed individual circuit breaker tests contain not only the Test Results gathered, but also a record of the Circuit Breaker Test Plan used.
- The ability to view the results of an individual circuit breaker test graphically and then tailor the presentation of results to highlight behaviors of interest.
- The ability to view the results in a tabular form, then toggle back to the **Test Plan** tab where changes to the editable fields are actively reflected on the **Tabulation** tab.

The main body of this guide explains the operations of the TRXField software as it pertains to use with the TDR9000. Refer to "TDR9000™ TRXField™ Software and Test Plan Dynamics" on page A-28 for a complete explanation of TRXField fields and their uses.

## Modules

There are four modules available that are installed in various combinations by Doble when the system is ordered. The positions that these modules occupy dictate the configuration of the boards in the system backplane that support their operation. Once this configuration is set, any field installation of newly purchased modules must be done in accordance with Doble provided instructions.

The discussions that follow explain the module types, their purposes, and their possible configurations.

## OCB/Motion

OCB and Motion are independent functions that are packaged together for convenience.

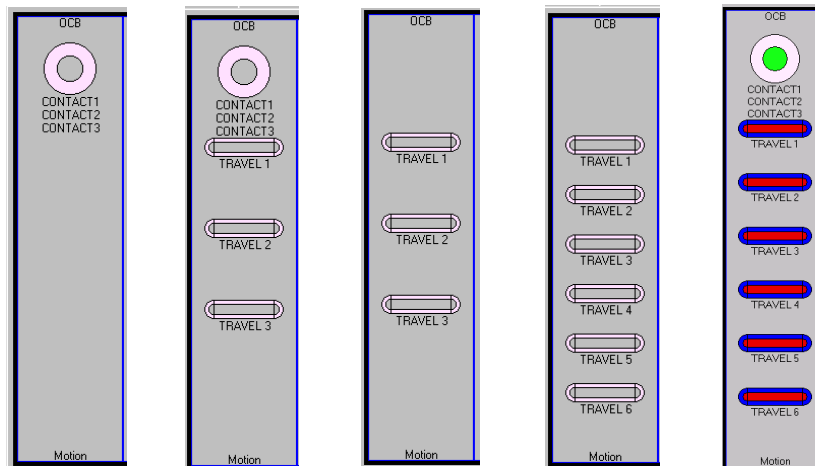
The OCB portion of this module measures:

- Main Contact timing of Dead Tank circuit breakers
- Pre-insertion resistor switch timing
- Ohmic value of pre-insertion resistors (optional)

The Motion channels measure the linear or rotary movement of up to six TR3190, 3160 motion transducers. The software accommodates:

- User-defined zones of measurement for calculating average velocities
- Indirect contact measurements on transducers via a Linear Transfer Function scaled by user-defined inputs
- English or Metric units

Figure 2.4 shows the available configurations for the OCB/Motion module.



**Figure 2.4 OCB/Motion Module Configurations**

## EHV

The EHV module measures:

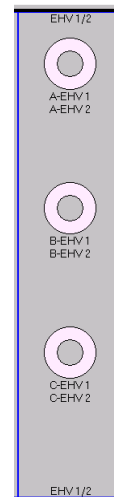
- Main Contact timing of a Live Tank circuit breaker
- Pre-insertion resistor switch timing
- Capacitance of grading capacitors (optional)
- Ohmic value of pre-insertion resistors (optional)

The software supports two configuration choices:

*EHV* Measures two breaks per phase on all three phases (6 contacts).

*Split* Tests breakers with odd numbers of interrupters per phase, or activates and tests one contact at a time in a module.

Figure 2.5 gives the available configurations for the EHV module.



**Figure 2.5 EHV Module Configuration**

## Event

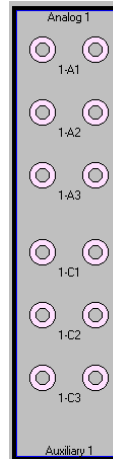
The Event module is split into two parts:

- Analog channels
- Auxiliary contacts

A combination of these channels is used to monitor the characteristics of the circuit breaker's operating mechanism. All the channels are used when performing First Trip/Close tests.

- Analog Channels      The analog section of the Event module has three general purpose analog inputs configurable to read voltages directly or to read currents from Doble current shunts and probes (401-0055).
- Auxiliary Contact      The Auxiliary Contact section of the Event module monitors the state of up to three sets of auxiliary contacts.

Figure 2.6 shows the available configurations for the EVENT module.



**Figure 2.6 Event Module Configurations**

## System

The System module is minimally comprised of:

- Power switch/Circuit Breaker
- PC RS-232 communications connector
- Safety switch input connector
- AC power supply plug
- System ground connector

Two options are available which add to the functionality of the TDR9000:

- Automatic Trip/Close Control – with or without internal current measurement on Trip/Close control leads
- Triggers

## Trip/Close Module

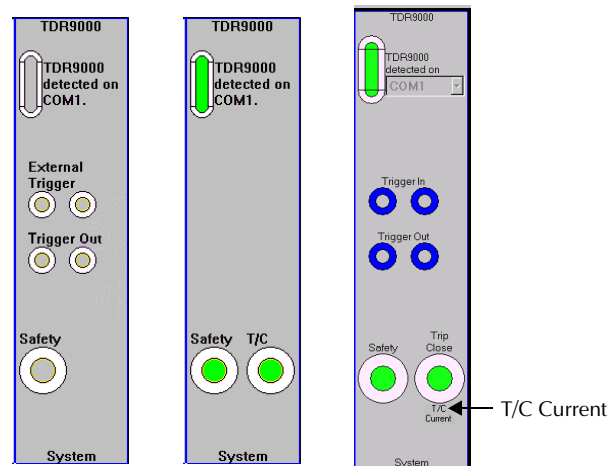
This module enables all of the system's Trip/Close test control functionality, including:

- Trip (O)
- Close (C)
- Trip Free (C-O)
- Reclose (O-C)
- O-C-O

Trip/Close  
Current Isolation  
Option

The Trip/Close module can be outfitted with an optional internal current isolation measurement capability for the Trip and Close control leads. When this option is resident in the system, *T/C Current* appears below the Trip/Close connector on the Virtual Front Panel.

Figure 2.7 shows the available configurations for the System module.



**Figure 2.7 System Module Configurations**

Triggers                      The TDR9000 comes with Trigger Input and Trigger Output capabilities.

*Trigger Input*              Trigger Input has three possible sources, selected in the Trigger Source field, that begin recordings:

None(Internal)

AUX Contact                  An input that comes in through an Auxiliary Contact triggers the test.

Trigger In                    An input that comes in through the Trigger In connection of the System module and is conditioned by a delay time, starts the TDR9000 test.

*Trigger Output*            Trigger Output enables the user to operate a circuit breaker using an input generated by the TDR9000, as connected through the Trigger Out connectors of the System module.

Serial Interface              Serial communication is via the electrically-isolated PC RS-232 connection and the RS-232 connection on the IBM compatible laptop. The baud rate of this connection is set at 38.4 kbits/sec. Doble supplies a twenty-five foot, double-shielded cable for connecting this interface.

Printer                        The TDR9000 can be ordered with a Pentax® PocketJet II™ thermal printer. The printer provides print outs of Test Plans, tabular results and graphical results in the field. For easy storage and transport, the printer is mounted in the Instrument cover. When in use, the printer is connected to the PC's parallel port.

## TDR9000™ Physical Front Panel Configurations Supported

Table 2.1 lists the configurations possible for the Physical Front Panel. Some configurations require that different boards be used in the backplane slots.

**Table 2.1 Physical Front Panel Configurations**

Location 1	Location 2	Location 3	Location 4	Location 5	Location 6
Motion/OCB or Empty	Empty	Empty	Empty	Empty	System
Motion/OCB or Empty	EHV 1-2	Empty	Empty	Empty	System
Motion/OCB or Empty	EHV 1-2	EHV 3-4	Empty	Empty	System
Motion/OCB or Empty	EHV 1-2	EHV 3-4	EHV 5-6	Empty	System
Motion/OCB or Empty	EHV 1-2	EHV 3-4	EHV 5-6	EHV 7-8	System
Motion/OCB or Event	EHV 1-2	EHV 3-4	EHV 5-6	EHV 7-8	System
Motion/OCB or Empty	Empty	Empty	Empty	Event 5	System
Motion/OCB or Empty	Empty	Empty	Event 4-6	Event 5	System
Motion/OCB or Empty	EHV 1-2	Empty	Event 4	Event 5	System
Motion/OCB or Empty	EHV 1-2	Empty	Empty	Event 5	System
Motion/OCB or Empty	EHV 1-2	EHV 3-4	Event 4	Event 5	System
Motion/OCB or Empty	EHV 1-2	EHV 3-4	EHV 5-6	Event 5	System

## Tests Supported

The TDR9000 supports the following circuit breaker and ancillary tests:

- Trip (O)
- Close (C)
- Reclose (O-C)
- Trip Free (C-O)
- O-C-O
- First Trip
- First Close
- Slow Close
- Continuity
- Capacitance
- Self-Diagnostics

Table 2.2 lists the nine circuit breaker tests that the TDR9000 performs, and gives a state description of the sequencing that comprises the test. The Instrument stores the data when a test is run and displays it on the **Graphics** and **Tabulation** tabs. The contents of both of these tabs can be printed to the optional printer in the field or to a printer in the home office. Figure 2.8 through Figure 2.12 on page 2-17 give examples of the test waveforms used for each test, with callouts to explain the Command Parameters that affect test operation. For a detailed explanation of these test parameters, refer to "Test Plan Items" on page A-33.

Trigger Input and Trigger Output are available for all tests except Continuity and Self-Diagnostics.

**NOTE**

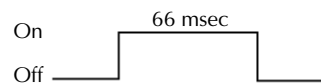
**For the First Trip or First Close test, if the Trigger Input parameter is set to None(Internal), a dialog box appears stating that only AUX Contact and Trigger In are valid trigger types.**

**Table 2.2 Circuit Breaker Test Types**

Test	Initial State	Intermediate		Final State
		State 1	State 2	
Trip (O)/First Trip (O)	Closed	—	—	Open
Close (C)/First Close (C)	Open	—	—	Closed
Reclose (O-C)	Closed	Open		Closed
Trip Free (C-O)	Open	Closed	—	Open
O-C-O	Closed	Open	Closed	Open
Slow Close (C)	Open	—	—	Closed
Continuity	This test checks the continuity of contact connections. The circuit breaker is not operated.			
Capacitance	This test checks the capacitance characteristics of the grading capacitors connected across the Main Contact of a circuit breaker. The circuit breaker must be open, but is not operated during the test.			
Self-Diag.	This test checks Instrument measurement channel operation by performing test emulations. The circuit breaker does not operate.			

**Trip (O)**

Figure 2.8 shows a simplified version of the test waveform generated for the Trip/First Trip test.

**Figure 2.8 Trip Command Pulse**

Command  
Parameter

*Trip Pulse*

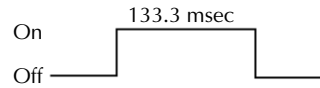
This time setting determines the duration of the Trip Pulse sent to operate the trip circuit of the circuit breaker.

*Recording Length*

This setting determines the recording length and implicitly sets the sampling rate at which recording is performed.

## Close (C)

Figure 2.9 shows a simplified version of the test waveform generated for the Close test.



**Figure 2.9 Close Command Pulse**

Command Parameter	<i>Close Pulse</i>	This time setting determines the duration of the Close Pulse sent to operate the close circuit of the circuit breaker.
	<i>Recording Length</i>	This setting determines the recording length and implicitly sets the sampling rate at which the recording is performed.

In addition to *Close Pulse*, *Timing Event* and *Timing Trigger* command parameters exist. They are accessed via the **Test Plan** tab and the test parameters button, and are used to determine if a test result tabulation is based on a Timing Event other than Test Initiation.

### *Timing Event and Timing Trigger*

The following parameters determine when Close test timing calculations start:

#### **Test Initiation**

Immediately upon the start of the test (default)

#### **Close Current**

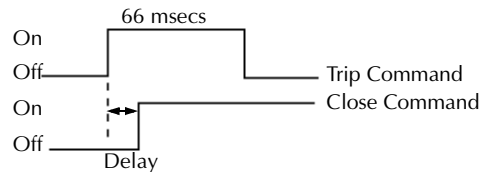
When a percentage, in ten percent increments, of the full scale Close current is reached (requires T/C Current option)

#### **Contact/Current/Voltage**

When a percentage, in ten percent increments, of the full scale current or voltage is reached on a particular channel or when a change of state is detected for a contact on an auxiliary channel (requires an Event module)

## Reclose (O-C)

Figure 2.10 is a simplified representation of the test waveform generated for the Reclose test.

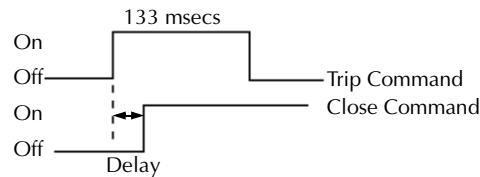


**Figure 2.10 Reclose Command Pulse**

Command Parameters	<i>Trip Pulse</i>	This time setting determines the duration of the Trip Pulse sent to operate the trip circuit of the circuit breaker.
	<i>Close Pulse</i>	This pulse, initiated after the Trip Pulse, operates the close circuit and performs the Reclose function.
	<i>Reclose and Delay</i>	<p>These parameters determine when the Close Pulse is initiated:</p> <p><b>Standing</b> Initiates a Close .5 cycles (8.3 ms at 60 Hz) after the test starts. This occurs when <b>Standing</b> is selected in the <i>Reclose</i> field.</p> <p><b>Delay</b> Initiates a Close after the time entered in the <i>Delay Length</i> field that appears when <b>Delay</b> is selected in the <i>Reclose</i> field.</p>
	<i>Recording Length</i>	This setting determines the recording length and implicitly sets the sampling rate at which the recording is performed.

## Trip Free (C-O)

Figure 2.11 is a simplified representation of the test waveform generated for the Trip Free test.

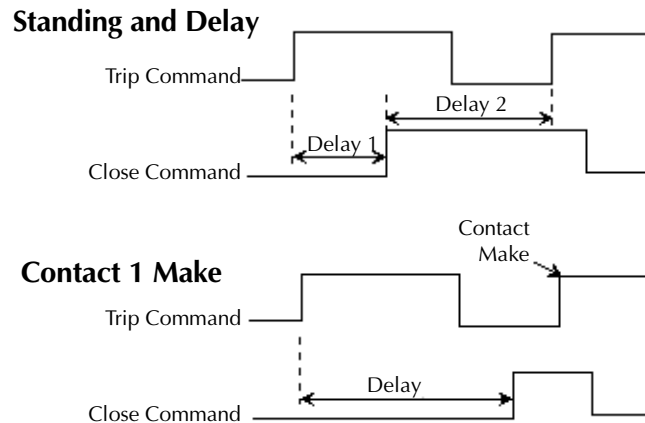


**Figure 2.11 Trip Free Command Pulse**

Command Parameters	<i>Close Pulse</i>	This time setting determines the duration of the Close Pulse sent to operate the close circuit of the circuit breaker.
	<i>Trip Free and Delay</i>	These parameters determine when the Trip Pulse is initiated: <ul style="list-style-type: none"> <li><b>Standing</b> Initiates .5 cycles (8.3 ms at 60 Hz) after the test starts.</li> <li><b>Delay</b> Initiates after the time entered in the <i>Delay Length</i> field.</li> <li><b>Contact 1 Make</b> Initiates when the TDR9000 senses that a contact make has occurred on the first of the Main Contacts.</li> </ul>
	<i>Recording Length</i>	This setting determines the recording length and implicitly sets the sampling rate at which the recording is performed.

## O-C-O

Figure 2.12 gives a simplified representation of the test waveform generated for the O-C-O test.



**Figure 2.12 O-C-O Command Pulse**

### Command Parameters

*Trip Command* This time setting determines the duration of the first Trip Pulse sent to operate the trip circuit of the circuit breaker.

*Close Command, Delay 1 and Delay 2*

These parameters determine when the Close Pulse is initiated:

#### Standing

Initiates .5 cycles (8.3 ms at 60 Hz) after the Trip Pulse. The second Trip Pulse occurs – measured from the start of the Close Pulse – after the time specified in *Delay 2*.

#### Delay

Initiates a Close after the time entered in *Delay 1* that appears when **Delay** is selected. *Delay 2* also appears, which determines when the second Trip Pulse is sent. Both delays are measured from the start of the Close Pulse.

### Contact 1 Make

Initiates the Close Pulse after the time specified in *Delay 1*. The second Trip Pulse occurs when the TDR9000 senses that a contact make has occurred on the first of the Main Contacts.

### Recording Length

This setting determines the recording length and implicitly sets the sampling rate at which the recording is performed.

## Continuity

The Continuity test is a system check of the TDR9000's contact monitor cable connections to the circuit breaker. This test is run as part of the Pretest Check List completed just prior to running the test. Refer to "Using the Pretest Checklist" on page 4-70.

## Capacitance

The Capacitance Measurement test is used to measure EHV grading capacitors. These capacitors are located in parallel with the main contacts and can be measured through the EHV modules/cables when the contacts are open. The test consists of measuring capacitance, in the range of 75 to 10,000 pF, between each of the two EHV leads and the common lead for each phase and each module. The test measurement accuracy is in the range of  $\pm 5\%$ . Since the circuit breaker is not operated during the test, no waveform is sent through the system

## Slow Close

A combination of the OCB and Motion modules is used to monitor performance during a Slow Close test. The purpose of the Slow Close test is to accurately measure Contact Wipe. No external trigger is used. The circuit breaker is usually operated manually by field personnel using a hydraulic jack.

### NOTE



**As there is no triggering mechanism, for recording to occur, the software must be initiated from the Virtual Front Panel by field personnel prior to operating the circuit breaker.**

## Self-Diagnostics

The Self-Diagnostics test performs a two-tiered analysis of machine functionality. This test determines the validity of both the Physical Front Panel and the internal operations based on the results from the processing of pre-determined signals. These signals are designed to emulate the signal flow that occurs on all measurement channels during various tests. Refer to "Self-Diagnostics Test" on page B-1.

## First Trip/Close Tests

Use a First Trip/Close to capture operational data for circuit breakers that have been idle. To preserve the integrity of data, and to study the characteristics of long dormant circuit breakers, these tests are performed on circuit breakers without removing them from operation. Main Contact timing test results appear as waveforms instead of the usual contact state, trip, resistor level/bounce, and close, because a CT secondary is used as the signal source instead of the main contact cables, since the Main Contacts are energized.

### NOTE



- **Compare the First Trip/Close Test Results with subsequent operations of the same type.**
- **These tests are useful for long idle spare breakers as well.**

### First Trip/Close Test Measurements

The TDR9000 can be used for First Trip/Close testing on IPO circuit breakers as well as those with a single mechanism for the three phases. Any number of signals are measurable, including motion and velocity. A First Trip/Close Test Plan can be designed to quickly test a distribution breaker of relatively low system importance, while another may include a complete set of tests on a circuit breaker that is rarely removed from service. The former requires a Test Plan designed for quick testing and a minimum set of channels, while the latter setup requires a recommended set of channels. In this guide, the process is described using an external trigger. After the first Trip test, a Close test should also be run followed by a second Trip and Close test for comparison purposes.

The minimum set of channels is:

- One Main Contact current (analog measurement from CT secondary)
- Trip (or Close, if performing the First Close test) coil current (analog measurement)
- DC supply voltage (analog measurement)
- 52CS/T (or 52CS/C if performing the first Close test) contact state for Trigger In (Aux Contact measurement)

The *recommended set of channels* is:

- Three Main Contact currents (analog measurements from CT secondaries)
- Trip (or Close if performing a First Close) coil current (analog measurement)
- DC supply voltage (analog measurement)
- 52 X or Y coil current (analog measurement)
- 52 X relay contact state (Aux Contact measurement)
- 52 Y relay contact state (Aux Contact measurement)
- 52A relay contact state (Aux Contact measurement)
- 52B relay contact state (Aux Contact measurement)
- 52CS/T (or 52CS/C if performing the first Close) contact state for Trigger In (Aux Contact measurement)

Test System  
Component  
Requirements

The following components are required to perform a First Trip/Close test using an external trigger for the minimum set of channels:

- An Event module (T9433)
- System module with Trigger In/Out (T9003, T9004, T9005)
- Two Doble current probes (P/N 401-055)

The following components are required for the recommended set of channels:

- Two Event modules (T9433)
- System module with Trigger In/Out (T9003, T9004, T9005)
- Five Doble current probes (P/N 401-0055)

## 3. TDR9000<sup>TM</sup> Front Panels

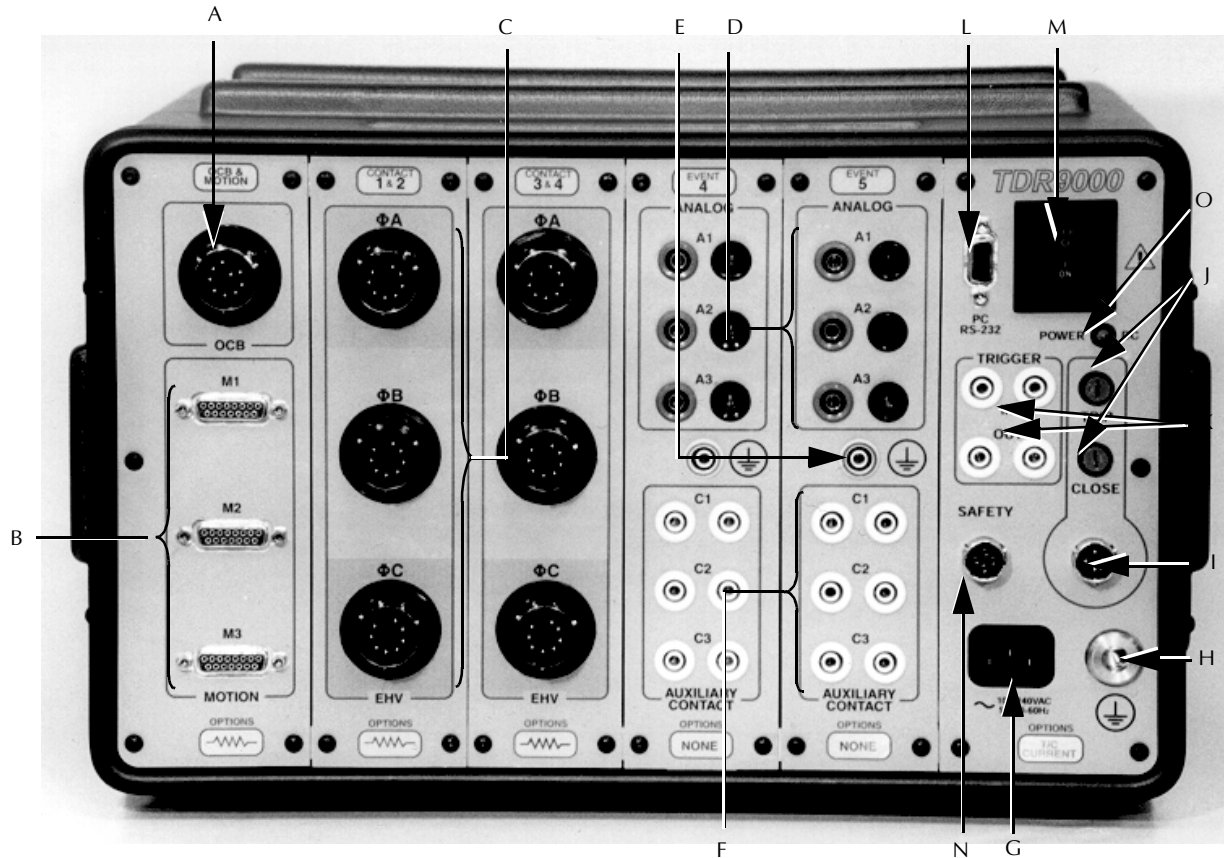
This chapter explains the TDR9000 Physical Front Panel and the use of the TRXField Virtual Front Panel. Topics discussed include:

- Basic characteristics of the TDR9000 front panel and the virtual interface
- Types of modules available and the relationship between the physical and virtual front panels

### Physical and Virtual Front Panel Characteristics

Figure 3.1 on page 3-2 shows a TDR9000 Physical Front Panel containing

- One OCB/Motion module with three Motion channels installed
- Two Main Contact EHV modules
- Two Event modules with three analog and three auxiliary channels installed
- The required System module with the Trip/Close and Trigger In/Out options installed



**Figure 3.1 TDR9000™ Physical Front Panel Connections**

Table 3.1 describes the connections and switches present on the Physical Front Panel. For the specifications of each channel, refer to "TDR9000™ Circuit Breaker Test System Specifications" on page H-1.

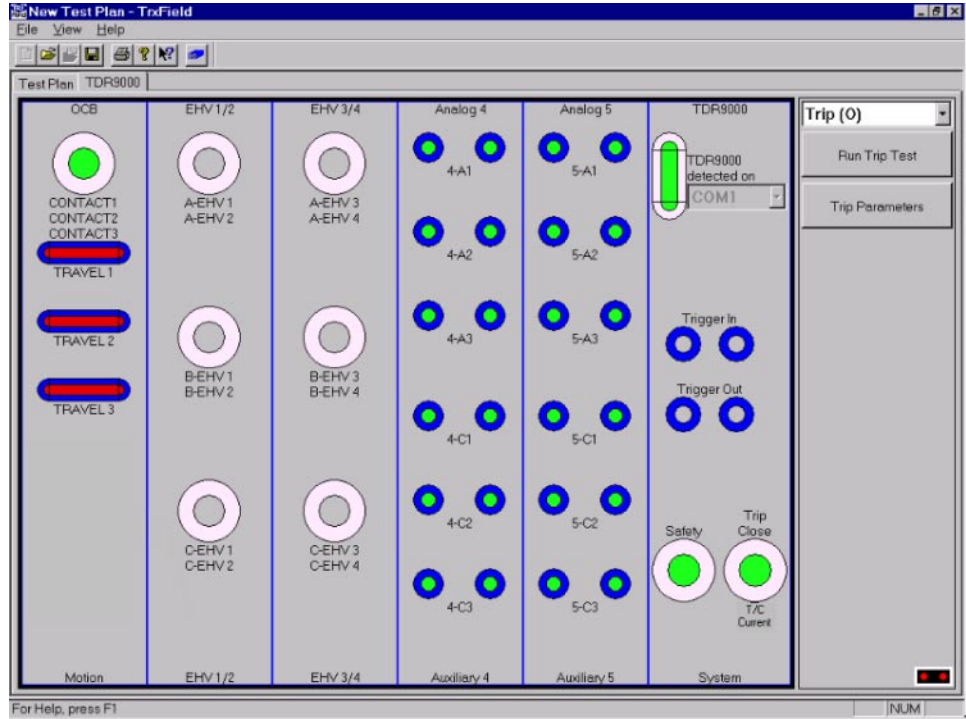
**NOTE**

**Throughout this guide, "banana jack" refers to a banana jack connector that is shrouded.**

**Table 3.1 TDR9000™ Physical Front Panel Connections/Switches**

<b>Callout</b>	<b>Description</b>
A	Circular 12-pin male connector for an OCB Contact Monitor cable
B	15-pin female connectors for Motion Transducer cables
C	Circular 12-pin male connectors for EHV Contact Monitor cables
D	Banana jack connectors for completing general purpose analog measurements (voltage, current shunt and current probe inputs)
E	Banana jack connector for connecting the shield lead of analog test cables to the chassis ground
F	Banana jack connectors for completing auxiliary contact timing measurements
G	3-pronged male connector for use with an IEC standard power cord
H	Twist-Jack connector used to establish the system safety ground through the ground cable
I	5-pin male connector for establishing Trip/Close control connections
J	Trip and Close fuses
K	Banana jack connections for the Trigger In and Trigger Out functions
L	9-pin female connector for the Doble supplied RS-232 serial communications cable
M	Power ON/OFF switch/circuit breaker
N	4-pin male connector for the Doble-supplied Safety Switch cable or Safety Bypass flag
O	DC power sources valid operation LED

Figure 3.2 shows the Virtual Front Panel that appears when the Instrument bearing the modules (Figure 3.1 on page 3-2) is powered up. The modules that appear on the Virtual Front Panel are dictated by the TDR9000 firmware, which polls the TDR9000 Instrument and adds the modules it detects to the Virtual Front Panel and, if a Test Plan is selected, indicates the active channels.



**Figure 3.2 TDR9000™ Virtual Front Panel**

## Basic Virtual Front Panel Functionality

The Virtual Front Panel provides general functionality used to operate the Instrument and to interpret the tests being configured or run. This section covers:

- Navigating the TDR9000 Virtual Front Panel tab in TRXField
- Module level vs. connector level configuration
- Understanding connector indications
- TDR9000 Physical and Virtual Front Panel Numbering

## Tab Navigation

Figure 3.3 and Figure 3.4 show the tabs that comprise TRXField operations. By navigating these tabs, data is entered, edited or viewed. Figure 3.3 shows the tabs that appear when beginning a new Test Plan. Figure 3.4 shows the tabs that appear when an existing Test Result is opened or after a test is run. A description of each tab follows.



*Figure 3.3 Navigating Tabs I*



*Figure 3.4 Navigating Tabs II*

The Test Plan and TDR9000 tabs are used to configure Test Plans as follows:

**Test Plan** All data can be configured here. This includes channel activation and the input of the performance specifications. The data fields present on this tab are fully explained in Appendix A "TRXField™ Software and Circuit Breaker Testing Theory".

**TDR9000** This tab contains the Virtual Front Panel. Channel activation and labeling can be set. Refer to "Setting Up a Test Plan Manually with TRXField™" on page 4-43 for configuration information.

The Edit Specs., Tabulation and Graphics tabs are used to work with Test Results as follows:

**Edit Specs.** This tab displays all of the parameters that were configured when the test was run. Some of these fields are active and editable. When these fields are edited, the data displayed on the Tabulation and Graphics tabs change to reflect the effect new parameter settings have on the data gathered during the test. This is a useful way in which to study and compare data on circuit breaker operations.

**NOTE**



**The Edit Specs. functionality does not change the specifications in the original Test Plan, nor does it change the actual data gathered during that test.**

**Tabulation** Tabular Test Results are viewed on this tab.

**Graphics** Graphical Test Results are viewed on this tab. The presentation characteristics of the results are tailored, using the operations explained in "Working with Test Results" on page 4-81.

The contents of the **Test Plan**, **Tabulation** and **Graphics** tabs are printable using the optional printer, or any other connected printer.

**NOTE**



**TRXField also supports a functionality that displays multiple Test Results together on a Graphics Overlay tab. This function is performed using the Overlay Graphics selection of the File menu.**

## Configuration Levels

The Virtual Front Panel has two configuration levels for each module:

- Module
- Connector

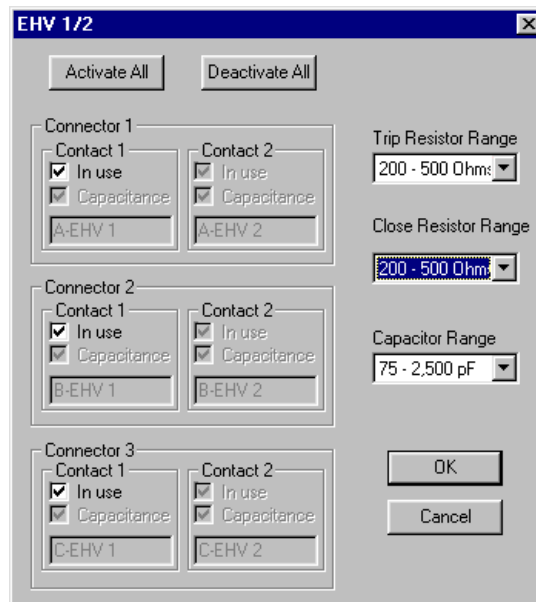
### NOTE



**The System module does not include a module level configuration capability. To configure a parameter, click the virtual image associated with it.**

### Module

The module level configures all fields associated with a connector type. This includes fields associated with individual connectors and those associated with overall module behavior. Figure 3.5 shows the module level window for an EHV module.



**Figure 3.5 Module Level Configuration**

For the EHV module, this window sets the following parameters that affect all the active channels:

- Activate/Deactivate All
- Trip Resistor Range
- Close Resistor Range
- Capacitor Range

On the same window, the following parameters affect only individual connectors that are configured:

- In Use
- Capacitance
- Label (Not editable in EHV)

The OCB/Motion Virtual module (leftmost panel, location one, in Figure 3.2 on page 3-4), contains an OCB connector and a Motion connector. This module is effectively split in two, with the overall Motion parameters window accessed by clicking **Motion** on the bottom of the virtual module, and the overall OCB parameters accessed by clicking **OCB** on the top of the virtual module. This behavior holds true for the Event module (panel locations four and five of Figure 3.2 on page 3-4) as well.

## Connector

The connector level accesses only those fields that dictate the behavior of individual connectors. To open this window for a particular connector, click its virtual image.

Figure 3.6 shows the connector level window for an EHV connector.





**Figure 3.6 Connector Level Configuration**

Using this window, the following parameters that affect individual connectors can be configured:

- In Use
- Capacitance
- Label (Not editable in EHV)

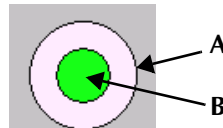
### Smart Cursor

To assist in configuring Virtual Front Panel modules, the TRXField program includes a specialized *Smart Cursor*. When the mouse pointer is located near a configurable item, the Smart Cursor appears with text indicating the module associated with the cursor. The cursor has two different appearances:

-  Clicking the mouse when this cursor appears opens the Module level configuration window, as explained in "Module" on page 3-7.
-  Clicking the mouse when this appears opens the Connector level configuration window, as explained in "Connector".

### Connector Indications

Figure 3.7 shows an example of an OCB connector with callouts to its various components (shown as rings). All connectors on the Virtual Front Panel use the same basic functionality, where color designates status.



**Figure 3.7 Sample Connector**

**A**

Indicates the channel activation status. Channels are activated or deactivated using the **In Use** checkbox on the various connector configuration windows or on the **Test Plan** tab. For this component:

- White indicates an active channel
- Blue indicates an inactive channel

**B**

Indicates that the firmware has confirmed that a measurement channel has been detected, and that it is ready for use. This means that all connections that can be detected (transducers and certain cables) have been made and that all operations required prior to a test, such as probe zeroing, have been completed. For this component:

- Red indicates the channel is not ready for use.
- Green indicates the channel is ready for use.
- If all the connectors on the Virtual Front Panel have a gray center, there is no communication between the Instrument and the laptop via the serial port.
  - Check the serial port connections.
- Component B is gray when:
  - Channels are activated in the Test Plan, but there is no communication with the TDR9000.
  - There is communication with the TDR9000, but channels are activated for a module that is not physically present in the instrument. Modules not present on the Virtual Front Panel appear gray.

**NOTE**

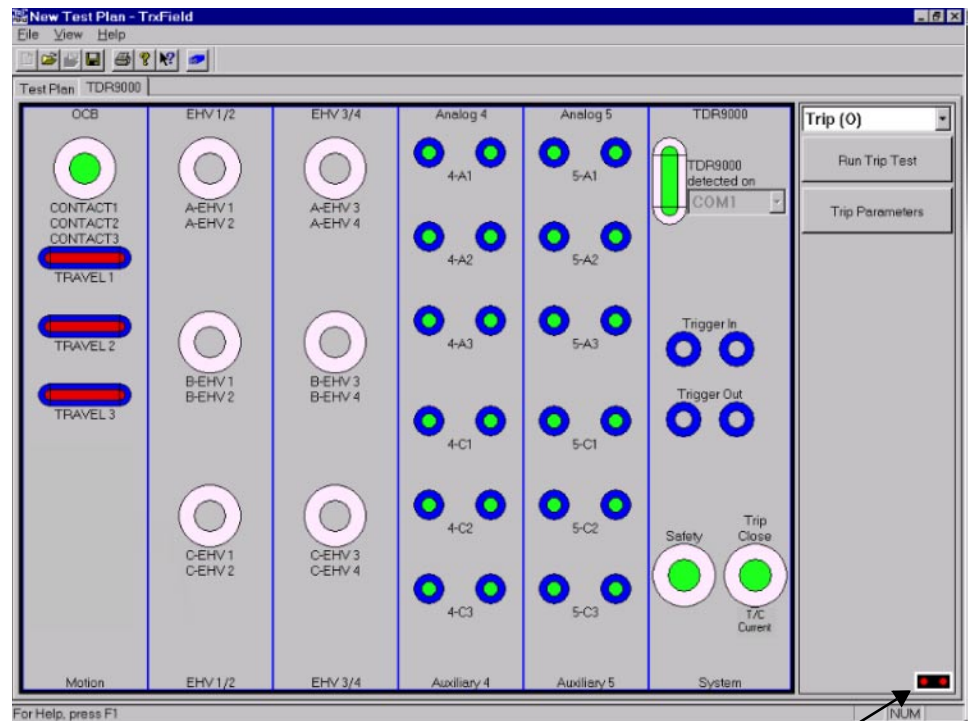


**The entire Virtual Front Panel, except for the System module, is gray if there is no communication with the TDR9000 and there are no channels activated in the Test Plan.**

**If the Instrument does not support the current Test Plan, the channels not supported must be de-activated via the Test Plan or TDR9000 tab.**

## Transmit/Receive

Figure 3.8 shows the transmit/receive indicators located on the lower right side of the Virtual Front Panel. These indicators flash green when data is being transmitted or received through the communications port of the laptop or computer running TRXField; left and right indicators, respectively.



Transmit/Receive Indicators

**Figure 3.8 Transmit/Receive Indicators****NOTE**

If both indicators are gray, there may be a communications port conflict that makes the selected port on the PC or laptop unavailable to the TRXField software. This is not a TDR9000 failure.

## TDR9000™ Physical and Virtual Front Panel Numbering

This section explains the numbering schemes used for the Physical and Virtual Front Panels.

### Physical Front Panel

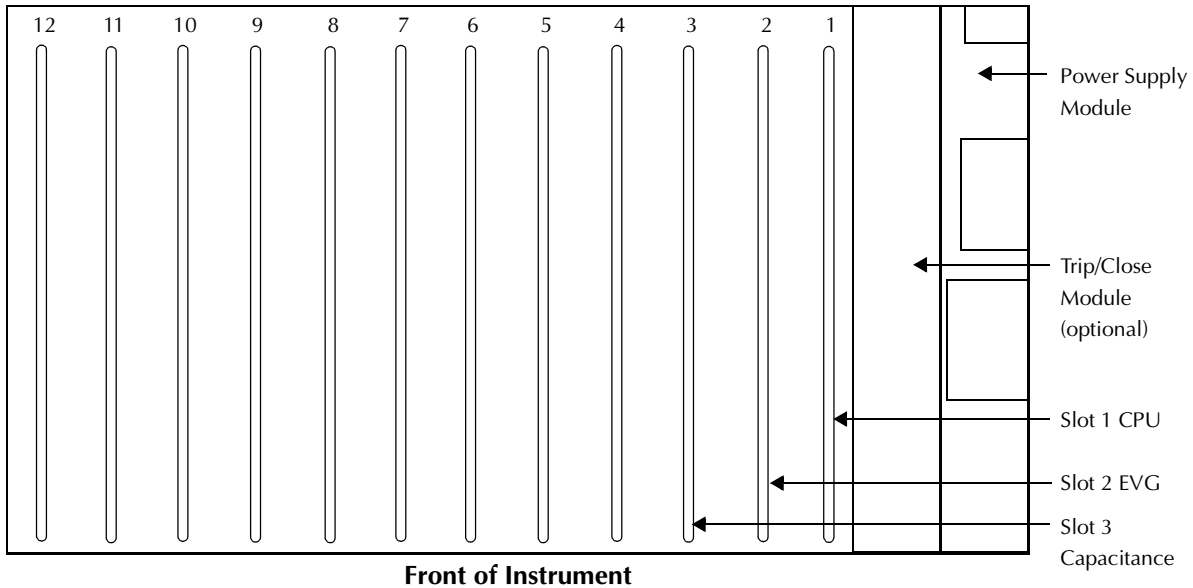
There are two concepts necessary to understand Physical Front Panel numbering: Location and backplane Slot.

A Physical Front Panel Location denotes where a module is plugged into the TDR9000. Figure 3.9 shows how numbering develops for the TDR9000 Physical Front Panel. Six Locations exist, which are numbered from left to right.

OCB/ Motion or Event Module	EHV or Event Module	EHV or Event Module	EHV or Event Module	EHV or Event Module	System Module
Location 1	Location 2	Location 3	Location 4	Location 5	Location 6

**Figure 3.9 TDR9000™ Front Panel Locations**

Figure 3.10 shows how numbering develops for the boards that populate the TDR9000 backplane.



**Figure 3.10 TDR9000™ Backplane Slots - Top View**

Since there are twelve backplane Slots and only six Physical Front Panel Locations for modules, it is apparent that some modules require the use of two individual boards in two backplane slots to operate. This explains, for instance, why once a location is configured for an EHV module, an Event module cannot be placed there. To change module types, when allowed, a backplane card or cards must also be changed.

When a module requires the use of two Slots, one of these Slots contains a Master board and one contains a Slave board.

#### Virtual Front Panel Numbering

There are two instances where module numbering appears on the Virtual Front Panel:

- EHV modules
- Event modules

EHV Module Numbering

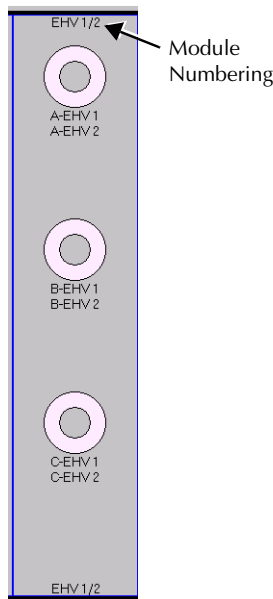
The numbering that appears on the EHV Virtual Front Panel module represents the circuit breaker contacts to be monitored by that module. Figure 3.11 shows an example EHV module. In this example, 1/2 designates that this EHV module should be connected to contacts 1 and 2 of the EHV circuit breaker.

The first available location is Location 2. EHV modules in Location 2 are referred to as EHV1, EHV modules in Location 3 are referred to as EHV2, and so on.

**Note**



**Ensure that the physical connections completed on the Physical Front Panel reflect this numbering order.**



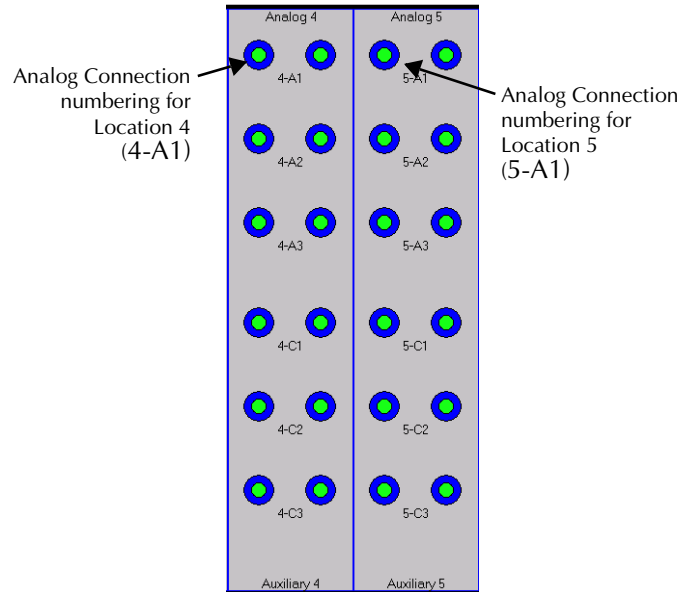
**Figure 3.11 Virtual Front Panel EHV Module Numbering**

Event Module Numbering

The Event module itself is numbered according to the location it populates in the TDR9000. This label appears at the top and the bottom of the module prefaced by Analog and Auxiliary, respectively.

The Analog and Auxiliary connectors, which occur in groups of three per module, are numbered from top to bottom.

Figure 3.12 shows an example with two Event modules side-by-side on the same Virtual Front Panel and explains module numbering syntax.



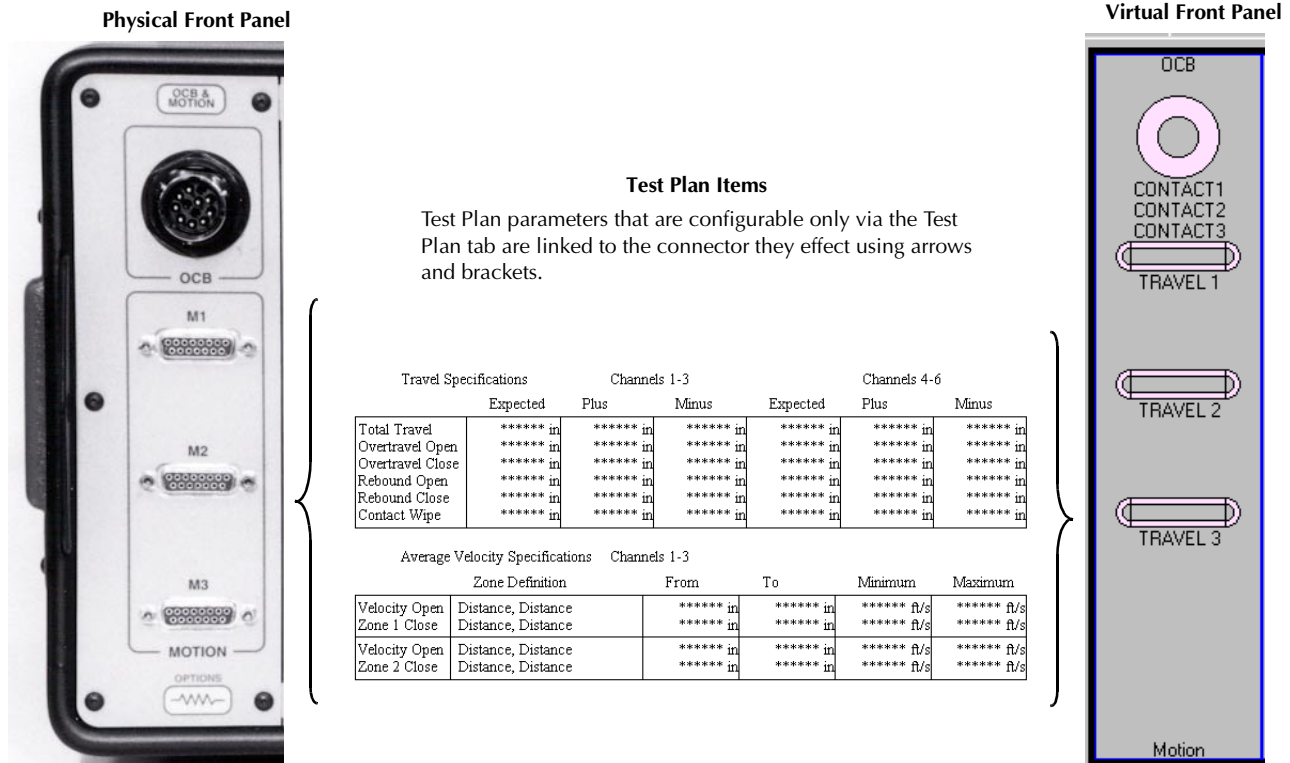
**Figure 3.12 Virtual Front Panel Event Module Numbering**

A discussion of each module type follows. Each discussion contains:

- A description of module functionality.
- A graphic that maps the relationship between the Physical Front Panel and the Virtual Front Panel, using the related TRXField Test Plan parameters as a bridge.

In graphics, bracketed Test Plan items between the Physical Front Panel connector and the Virtual Front Panel are the only configurable using the **Test Plan** tab. These items must be active in a Test Plan imported from the TRX software. If configuring a new plan, they are configurable only on the **Test Plan** tab.

Figure 3.13 shows an example of how this mapping works.



**Figure 3.13 Example Module Mapping**

Refer to "Connecting the TDR9000™ Physical Front Panel" on page 4-30 for specific configuration procedures.

## OCB/Motion

The OCB portion of this module measures main and resistor switch contact operation timing when a Dead Tank or candlestick circuit breaker is closed or opened. Trip and Close pre-insertion resistor value ranges are configurable, and this configuration applies to all three contacts of the OCB connector. Contact status information is available for each individual contact. An option is available (Doble P/N T9120) that measures the Ohmic value of pre-insertion resistors.

The motion portion of this module records the motion of the circuit breaker contacts through a digital rotary or linear transducer attached to the operating mechanism. Possible configurations include three or six motion channels.

Data can be presented in English or Metric units. The TRXField software has the ability to set two user-defined zones for the measurement of velocities and to set a range of expected speeds that should occur in those zones. Additionally, to accommodate the need for indirect measurements on some transducers, TRXField includes a Transfer Function. The Transfer Function performs a linear scaling calculation using two user-entered values that transform a measurement taken at a transducer to one equal to a contact's travel.

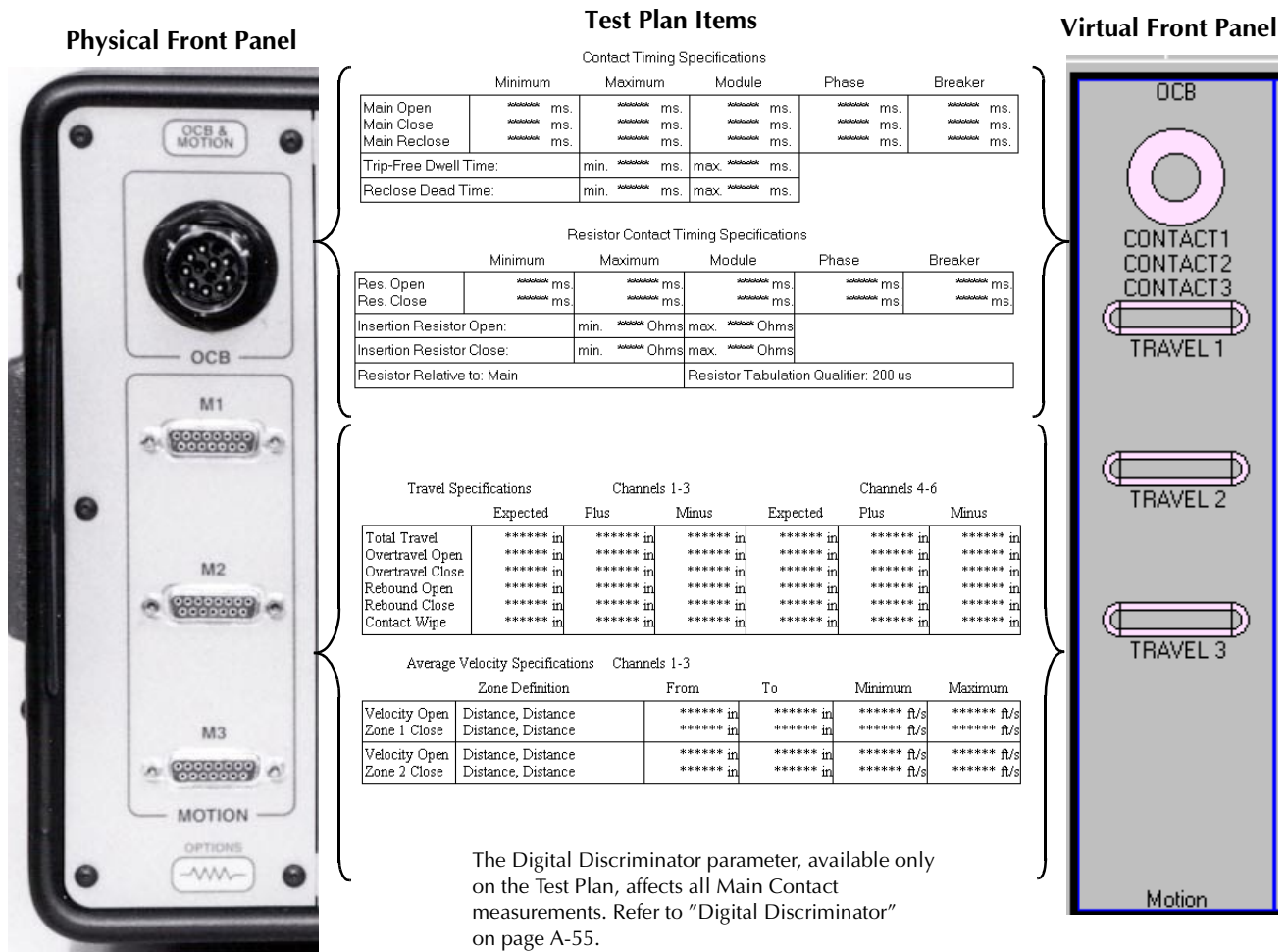
The OCB/Motion module, if used, must reside in Location 1. Its configuration is discussed in "Configuring the OCB/Motion Module" on page 4-45.

Figure 3.14 on page 3-18 maps the relationship between those parameters set only on the Test Plan tab and the Virtual Front Panel connectors they effect.

### NOTE



**OCB and Motion functions are independent, but are packaged individually or in any combination to meet the application requirements.**



**Figure 3.14 OCB/Motion Module Mapping**

## EHV

The EHV module measures the main and resistor switch contact operation timing when a Live Tank circuit breaker opens or closes. An option is available (Doble P/N TR9320) that measures the Ohmic value of pre-insertion resistors.

The TRXField software supports two configuration choices for the contacts as a group:

<i>EHV</i>	Measures two breaks per phase on all three phases.
<i>Split</i>	Tests circuit breakers with odd numbers of interrupters per phase, or activates and tests one channel at a time in a module.

The EHV module, if used, can reside in Locations 2 through 5.

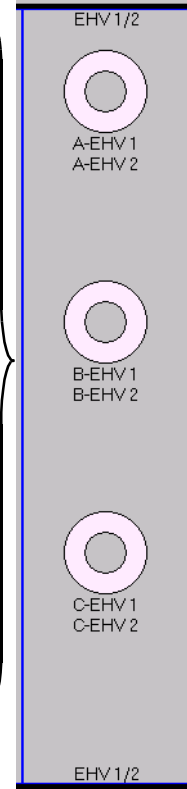
Figure 3.15 on page 3-20 maps the relationship between those parameters set only on the Test Plan tab and the Virtual Front Panel connectors they effect.

Another option is available that measures the capacitance of grading capacitor assemblies installed in parallel with the circuit breaker contacts.

**Physical Front Panel**



**Virtual Front Panel**



**Test Plan Items**

Contact Timing Specifications

	Minimum	Maximum	Module	Phase	Breaker
Main Open	ms.	ms.	ms.	ms.	ms.
Main Close	ms.	ms.	ms.	ms.	ms.
Main Reclose	ms.	ms.	ms.	ms.	ms.
Trip-Free Dwell Time:	min.	ms.	max.	ms.	
Reclose Dead Time:	min.	ms.	max.	ms.	

Resistor Contact Timing Specifications

	Minimum	Maximum	Module	Phase	Breaker
Res. Open	ms.	ms.	ms.	ms.	ms.
Res. Close	ms.	ms.	ms.	ms.	ms.
Insertion Resistor Open:	min.	Ohms	max.	Ohms	
Insertion Resistor Close:	min.	Ohms	max.	Ohms	
Resistor Relative to: Main					Resistor Tabulation Qualifier: 200 us

Live Tank / EHV Channel Activation

Main Contact Configuration:	EHV				
Module	EHV 1	EHV 2	EHV 3	EHV 4	EHV 5
Channel	1 / 2	3 / 4	5 / 6	7 / 8	9 / 10

EHV or Split selection only on Test Plan

The Digital Discriminator parameter, available only on the Test Plan, affects all Main Contact measurement. Refer to "Digital Discriminator" on page A-55.

**Figure 3.15 EHV Module Mapping**

## Event

The Event module is split into two parts:

- Analog channels
- Auxiliary contact channels

### Analog Channels

The analog part of the Event module has three general purpose analog inputs for use in monitoring voltages or currents. These inputs are individually configurable via the software to read inputs from current shunts and probes, as well as voltages. Analog inputs are converted by a high speed 12-bit analog-to-digital converter and then recorded at the Instrument 10 kHz sample rate.

#### NOTE



**For applications where a current probe is used, a probe zeroing process must be completed. Refer to "Current Probes" on page 4-34.**

### Auxiliary Contact Channels

The **Auxiliary Contact** portion of the Event module monitors the state of up to three sets of auxiliary contacts.

These contact circuits ascertain whether a contact is:

- Open or closed
- If open, wet or dry, regardless of the polarity of the excitation voltage

The TDR9000 has an automatic *wetting circuit* that wets a dry contact, which allows the open/closed state of the circuit to be determined.

This module comes with three analog and three auxiliary contact channels. For the present, this module can be used in Locations 1 through 5.

#### NOTE



**Ensure that the physical connections completed on the Physical Front Panel reflect the numbering order of the Event module.**

## System

The System module is mandatory and must be installed in Location 6. It provides basic system functionality such as communications, power and test control.

The System module is minimally comprised of:

- Power switch/circuit breaker
- RS-232 communications connector (to the laptop)
- Safety Switch cable input connector
- AC power supply receptacle
- System ground connector

The System module provides the interface for two optional modules that add to the functionality of the TDR9000:

### **Trip/Close module**

The Trip/Close Current module is an Internal measurement of the Trip and Close currents

### **Trigger In/Trigger Out module**

The Trigger In functionality is used as the trigger input during First Trip/Close tests.

#### **NOTE**



**At least one of these modules is required for the TDR9000 to function. The Instrument can support both.**

## Trip/Close Module

The Trip/Close control function consists of two parts:

- The Trip/Close control module located inside the TDR9000
- The connector, fuses and protection circuits that are part of the TDR9000 System module.

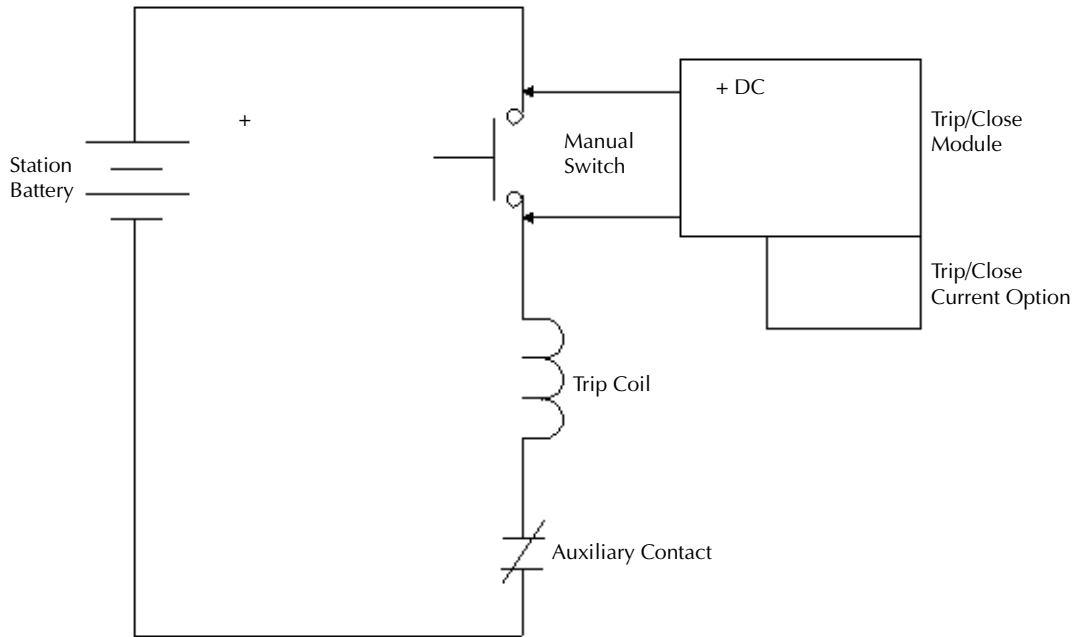
The Trip/Close module enables the TDR9000 to control the following tests:

- Trip
- Close
- Trip Free – Standing
- Trip Free – Delay
- Trip Free – Contact 1 Make
- Reclose – Standing
- Reclose – Delay
- O-C-O Standing
- O-C-O Delay
- O-C-O Contact 1 Make

This module operates the circuit breaker under test through the action of solid-state switches that Trip or Close the circuit breaker and is polarity-insensitive, so that the user need not know lead polarity.

The TDR9000 can be ordered without the Trip/Close module, however, all tests need to be triggered externally to the TDR9000 using a push button or through SCADA.

When included with the TDR9000, the Trip/Close module normally connects across the circuit breaker manual Trip or Close switch, as shown in Figure 3.16.



**Figure 3.16 Trip/Close Module Application**

**Trip/Close Current**

The Trip/Close module can be outfitted with an optional internal current measurement for the Trip and Close circuits. When this option is resident on the system, *T/C Current* appears below the Trip/Close virtual connector.

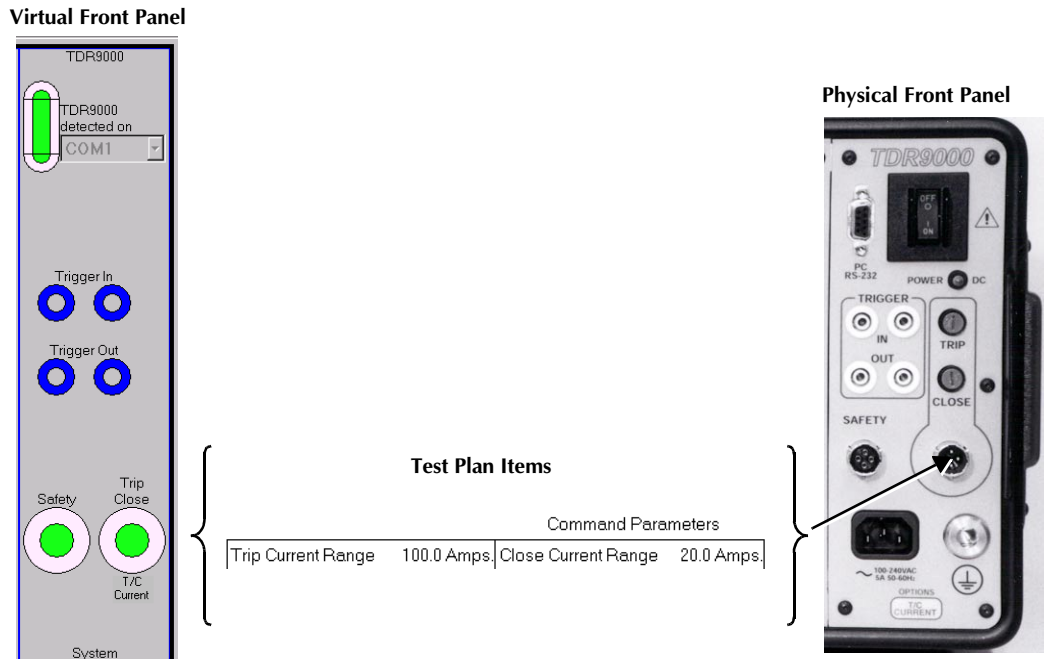
This option measures the Trip and Close circuit current during a Trip/Close test by:

- Shunting the Trip and Close currents through the Trip/Close Current component of the Trip/Close module
- Converting the measured voltage to a digital reading
- Sending the result to the Virtual Front Panel for display on the **Graphics** tab as a current waveform and on the **Tabulation** tab as a peak current value



**If the correct Close currents do not appear, refer to the Doble Application Note: "AN7: Monitoring Closing Coil Current with the TDR9000™ Current Shunt in the Close Circuit" on page I-27 of this guide.**

Figure 3.17 maps the relationship between the System physical module and its virtual counterpart for Trip/Close operations.



**Figure 3.17 System Module Mapping - Trip/Close**

## Triggers

The TDR9000 comes with Trigger Input and Trigger Output capabilities. For a more specific discussion refer to "Configuring the Command Parameters" on page 4-58.

### Trigger Input

Trigger Input has three possible sources, selected in the Trigger Source field, that begin recordings:

None(Internal)      The TDR9000 triggers the circuit breaker and the recording.

AUX Contact      An input that comes in through an Auxiliary Contact triggers the test. The circuit breaker must be triggered by other means; local control. The trigger can be one of four types:

- Open to Close
- Close to Open
- On to Off (Voltage)
- Off to On (Voltage)

Trigger In      An input that comes in through the Trigger In connection of the System module and is conditioned by a delay time, starts the TDR9000 test.

The trigger itself can be one of two types:

- Open to Close
- Close to Open

Although the System module Trigger In channel is a tri-state channel like the Aux Contact channels, it is not a measurement channel. For each of the two settings, it detects the state change, but only the fact that a trigger event has occurred is sent to the firmware. Unlike the Aux Contact channel trigger input, however, the Trigger In channel does not allow a test to begin if the trigger input is detected as already being in the *active* condition.

## Trigger Output

Trigger Output enables the user to operate a circuit breaker using an input generated by the TDR9000, as connected through the Trigger Out connectors of the System module. The pulse width can be set, along with a trigger delay. The Trigger Output parameters pertain to only one thing: the TDR9000 Trigger Out channel (on the System module). The Trigger Output is essentially a solid state switch output (dry contact), that can be used to control an accessory, or trigger another TDR9000. The Trigger can operate in circuits up to 300 V peak, 0.5 A maximum.

There are two Trigger State conditions:

- Off
- On

The following fields are active when the Trigger State is On:

- Pulse Width
- Trigger Delay
- Polarity



## 4. Setup and Operation

This chapter contains sections that discuss the following:

- Safety recommendations for use with the TDR9000
- Site preparation, including:
  - Setting up the circuit breakers being tested
  - Configuring the TDR9000 Test Plan
  - Configuring TDR9000 connections
- Running a test

This chapter also discusses test safety recommendations, wiring, and running First Trip/Close tests. Since First Trip tests require that the circuit breaker be *energized*, references to discussions of test setup are found in "First Trip/Close Tests". Once test setup is complete, move to "Using the Pretest Checklist" on page 4-70 and proceed with the rest of the chapter to run the test and disconnect after the test is complete.

### First Trip/Close Tests

Specific discussions for First Trip/Close tests occur in the following places:

- "Safety Considerations: First Trip/Close Tests" on page 4-2
- "First Trip/Close Virtual Front Panel Configuration" on page 4-2
- "Configuring Analog/Auxiliary Channels for First Trip/Close Tests" on page 4-4
- "Running a First Trip/Close Test: Special Considerations" on page 4-75
- "Disconnecting After a First Trip/Close Test" on page 4-101

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## Safety Considerations: First Trip/Close Tests

First Trip/Close testing involves connecting control cabinet cables to a live circuit breaker. Under no circumstances are Contact Monitor cables (EHV or OCB) used during First Trip/Close tests.

For a First Trip/Close test, connections are made in the circuit breaker control cabinet while the breaker is still energized. During a time when the circuit breaker is de-energized, it is desirable to make some adjustments that facilitate First Trip/Close connections, such as adjusting wiring to accommodate clip-on probes. Doble does not recommend connecting a motion transducer to an energized breaker. To include the measurement of the motion characteristics of a circuit breaker in the First Trip/Close tests, Doble does, however, recommend finding a spot on the circuit breaker's mechanism and permanently installing a motion transducer *while the breaker is de-energized*.

For safety reasons, Doble also recommends that the circuit breaker be operated remotely and that the tester be set up to use the external trigger feature of the TDR9000. This guide outlines the First Trip/Close Test using an external trigger only.

## First Trip/Close Virtual Front Panel Configuration

Some special considerations exist when configuring for a First Trip/Close test. The following areas of the Test Plan or Virtual Front Panel must be configured:

- The Nameplate information must include at least the Manufacturer, Model Number, Serial Number, Special ID, if any, and Location. A note in the Version Description field indicating that the Test Plan is for use with First Trip/Close tests is recommended so as not to confuse this Test Plan with an offline Test Plan for the same circuit breaker.

- In the Command Parameters on the Virtual Front Panel, select the:

**Trigger source:**

- Aux Contact if using an Auxiliary Contact channel on the Event module
- Trigger In if the TDR9000 System module has the Triggers option

**Trigger event:**

- Close
- Open

The trigger event is the change of state the TDR9000 is expecting to see before recording the test data. During a First Trip Test, the closing of the 52CS/T contacts initiates the recording. During a First Close Test, the closing of the 52CS/C contacts initiates recording.

- If using the “Aux Contact” trigger source, select the trigger channel where the trigger signal is received. Select the pre-trigger time, or leave it at the default, zero (see page 4-65).
- For each relay contact state measured, an Auxiliary Contact channel must be activated, given a label and a phase. If the relay contact state is measured using a Trigger In channel (the Triggers option must be present on the System panel), there is no need to activate an Auxiliary Contact channel for it. Activate only the channels being used. When performing a First Close test, both the 52CS/T label in the Test Plan must be changed to 52CS/C and the cables must be transferred, since this contact is being used to trigger the Close operation.
- For each current or voltage waveform to be measured, an Analog Channel must be activated, given a label and a phase. All Analog currents are measured using Doble probes, except for the DC supply voltage. Activate only the channels being used. When performing a First Close test, the Trip Coil label must be changed to Close Coil.
- If Motion transducers are permanently installed, the motion channels must be activated, and a label and phase selected.

## Configuring Analog/Auxiliary Channels for First Trip/Close Tests

Connecting leads for a First Trip/Close test consist of:

- TDR9000 Connections
- Circuit Breaker Connections

### Connecting the TDR9000™

Table 4.1 and Table 4.2 list the connections to the TDR9000 required for a minimum set of channels and a recommended set of channels, respectively. Since this is an external trigger test, no control cables are used.

**Table 4.1 TDR9000™ Using a Minimum Set of Channels**

Item	Signal	Type	TDR9000 Module Connection
1	Main Contact (from CT secondary)	Analog	Event
2	Trip relay coil current	Analog	Event
3	DC Supply voltage	Analog	Event
4	52CS/T contact state (for Trigger In source)	Auxiliary Contact	Event or Trigger In*

\*Connect to an Event module if using Aux Contact trigger source, and to the Trigger In jacks on the System module if using the Trigger In source.

**Table 4.2 TDR9000™ Using Recommended Set of Channels**

Item	Signal	Type	TDR9000 Module Connection
1	Main Contact A (from CT secondary)	Analog	Event/ D
2	Main Contact B (from CT secondary)	Analog	Event
3	Main Contact C (from CT secondary)	Analog	Event
4	Trip relay coil current	Analog	Event
5	DC Supply Voltage	Analog	Event
6	52X or 52Y relay coil current	Analog	Event
7	52A contact state	Aux Contact	Event
8	52B contact state	Aux Contact	Event
9	52X contact state	Aux Contact	Event
10	52Y contact state	Aux Contact	Event
11	52CS/T contact state (for Trigger In source)	Aux Contact	Event or Trigger In*

\* Connect to an Event module if “Aux Contact” is the trigger source in the Test Plan, and to the Trigger In receptacles if “Trigger In” is the trigger source. This table applies to a TDR9000 with two Event modules.

## Connecting the Circuit Breaker

Leads for measuring the Main Contact current are connected via a clip-on probe to the current transformer secondary of the phase being measured. If testing a live tank breaker, where a separate free-standing CT is used, it should be possible to position the TDR9000 so that cable lengths suffice to make the connection. The connections to the breaker are:

1. Connect the test set ground connection to the circuit breaker ground.
2. Connect a Doble current probe (Doble P/N 401-0055) to a CT secondary for each phase being measured to record the Main Contact currents and then connect the current probe leads to the analog channels on the TDR9000 Event module.
3. Connect the current probes (Doble P/N 401-0055) to selected relay coil circuits and then connect the leads to Doble probes and into the Event module Analog channels, as required.

This records the selected relay coil currents.

4. Connect a set of Analog cables across the DC supply switch and into the TDR9000 Event module Analog connector.

This records the DC supply voltage.

5. Connect Auxiliary Contact cables across the selected contacts and into the TDR9000 Event module Auxiliary connector.

This records the selected contact states.

6. Connect:
  - Trigger In cables across the 52CS/T contacts if using the TDR9000 with a Trigger option and if Trigger In is set as the trigger source in the Test Plan.

Otherwise

- Connect Auxiliary Contact cables across the 52CS/T contacts ensuring that Aux Contact is set as the trigger source in the Test Plan.

When the Trigger In or Connect Auxiliary Contact cable is used as an external trigger signal, it records the 52CS/T contact state.

## Safety

This section discusses principles that must be followed to ensure a safe testing environment.

### Instrument Precautions

- Do not drop or throw the Instrument or transducers.
- Do not use the Instrument or transducers as a step or platform.
- Do not store the Instrument or transducers in temperatures lower than  $-13^{\circ}\text{F}$  ( $-25^{\circ}\text{C}$ ) or greater than  $+158^{\circ}\text{F}$  ( $+70^{\circ}\text{C}$ ).
- Do not operate the Instrument or transducers in temperatures lower than  $32^{\circ}\text{F}$  ( $0^{\circ}\text{C}$ ) or greater than  $+122^{\circ}\text{F}$  ( $+50^{\circ}\text{C}$ ).
- Do not store the Instrument or transducers in excessively humid environments.
- Do not expose the Instrument or transducers to rain, snow, sand, or dust.
- Always transport the Instrument or transducers with their protective covers in place.

### Testing Personnel Required

The TDR9000 should not be operated by a crew of less than two people. Designate one person as the *Test Set Operator*, and the other as the *Safety Observer*.

The role of testing personnel can be defined as follows:

*Test Set Operator*      Supervises the test and operates the TDR9000 using the Safety cable switch provided.

*Safety Observer*      Observes the performance of the test, oversees the test setup, watches for any potential safety hazards, and gives warnings and guidance as required.

## Personnel Safety

Personnel safety considerations include:

- Hold a pre-test meeting for everyone who will be working in proximity to the area where testing will be performed. Frequently, other crews will be working on non-test related tasks in close proximity to the equipment being tested.

Review:

- Tests to be performed
- Apparatus and the voltage test levels involved
- Potential hazards involved with the work, and the individual assignments

Remind personnel to be aware of the work activity taking place around them and be alert to the possibility that non-test personnel may enter the test area.

- Agree on a consistent and uniform set of visual and verbal signals that will be used during testing.
- While making the various types of connections involved in the different tests, it may be necessary for personnel to climb up on the apparatus.

Be sure that no one remains on the apparatus during the test itself.

### NOTE



**Once a test is loaded, never attempt to disconnect the cables from either the test specimen or from the TDR9000 Instrument until the test is completed or cancelled.**

### WARNING



**Do not handle Contact Monitor cable test connections while a test is running. Up to 48 VDC can be present.**

## Safety Practices – General Rules

General safety considerations include:

- Perform all tests with the apparatus under test removed from service and made safe for testing.
- Strictly observe all company rules for safe practice in testing, including tagging during testing and maintenance work.

Always adhere to manufacturer's circuit breaker specifications. State, local, and federal regulations (e.g., OSHA) may also apply. ***Company rules and government regulations take precedence over Doble recommendations.***

## Grounding

Grounding considerations include:

- Solidly ground or earth the apparatus under test, the TDR9000, and any other external equipment being used.
- When the TDR9000 is permanently housed in a vehicle, bind the Instrument ground to the vehicle chassis, which in turn is grounded.

When dealing with capacitors:

1. Close all the grounding switches on the device housing in order to ground the bottom terminals of the capacitor.
2. Make sure capacitor stacks are discharged before personnel come into contact with them.

Internal resistors must not be relied upon for discharging individual capacitor cells; resistors in failed capacitor cells should be considered suspect. For additional protection, Doble recommends that a shorting wand be applied to the terminals of individual cells before personnel come in contact with them.

## Site Preparation

This section covers site preparation for the following tests:

- Dead Tank Circuit Breaker
- Live Tank Circuit Breaker

Preparation can be broken down into the following tasks:

1. Circuit breaker preparation, including safety ground attachment, which is common for Dead Tank and Live Tank tests
2. Rotary/Linear Transducer installation, which varies for Dead and Live Tank tests
3. TDR9000 configuration, which is common for Dead Tank and Live Tank tests
4. Safety Grounds removal, which is common for Dead Tank and Live Tank tests

## Circuit Breaker Preparation

The TDR9000 is designed to test circuit breakers with one side of the circuit breaker at ground potential at all times.

In addition to the circuit breaker itself, the Contact Monitor cables act as excellent antennae for electrostatic or electromagnetic pickup. Since the length of the cables and their relationship to the energized conductors is a determining factor in the level of interference, the TDR9000 system uses shielded Contact Monitor cables. This shielding minimizes the length of the cable that is exposed to electrostatic or electromagnetic pickup.

Although the system successfully performs in the presence of mild electrostatic interference, every effort to minimize the interference should be made.

Preparation of the circuit breaker includes:

1. Opening the circuit breaker
2. Opening, locking and tagging the circuit breaker isolating disconnect switches
3. Connecting safety grounds to a cleaned (brushed) spot on the ground grid and then to each bushing of the circuit breaker to be tested
4. Removing DC power from the Trip and Close circuits on the circuit breaker control panel

## Rotary/Linear Transducer Installation

The separate installation procedures for Dead Tank and Live Tank Circuit Breaker transducer installations follow.

During both Dead Tank and Live Tank test setups, it is important to perform connections in the following general order:

1. Connect grounds
2. Complete TDR9000 connections
3. Complete connections to circuit breaker being tested

Additionally, before beginning transducer installation, make sure that the circuit breaker is closed.

### WARNING



**When using a linear rod, make sure that the circuit breaker is in a *safe* position before beginning transducer installation. A safe position exists when an accidental circuit breaker operation draws the rod into the circuit breaker. This is usually the closed position.**

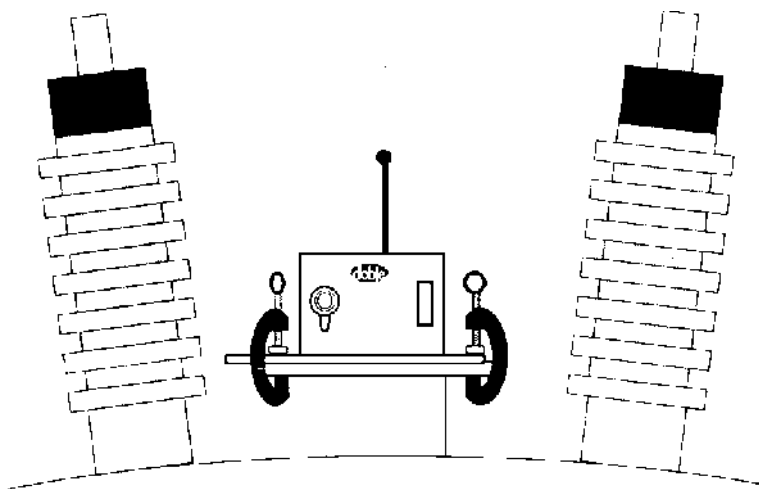
## Dead Tank Circuit Breaker

Since test voltages are below 48 V, it is important to provide good connections between the Contact Monitoring cables and the bushings.

To install the transducer for a Dead Tank Circuit Breaker test:

1. Determine the location for the transducer on the appropriate tank and remove the circuit breaker top cap.

Figure 4.1 shows a typical mounting of the Rotary/Linear Transducer.



**Figure 4.1 Rotary/Linear Transducer**

2. Install the mounting platform for the transducer.

This platform is the same as those used with mechanical timers and is not supplied with the TDR9000. An optional General Purpose Adapter (Doble P/N TR3177) is available. The transducer may also be secured directly to the circuit breaker tank.

3. Insert the Transducer Connecting Rod into the threaded hole in the circuit breaker operating (lift) rod.

A #10 (0.190)-32 UNF-2A thread is standard. Other thread sizes are available from Doble.

**WARNING**



**The transducer rod should be installed and removed while the mechanism is up. In this way, if the circuit breaker is activated accidentally, the rod can only move down.**

4. Mount the transducer on the tank.

All tests on a given circuit breaker can be performed with the customary mounting on Tank 2. If possible, Doble recommends that tests be performed with transducers mounted on Tanks 1 and 3, as well.

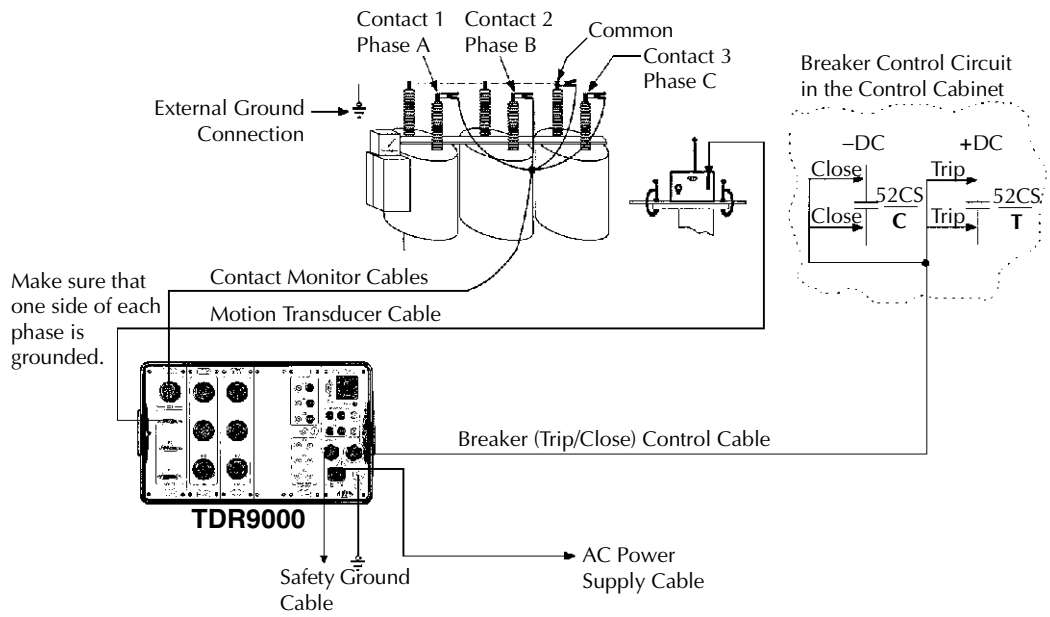
5. Position the transducer on the mounting platform so the Connecting Rod is centered in its pathway.

Verify that the Connecting Rod is clear of the mounting platform.

6. Rotate the transducer clamping knob until the small moving wheels pinch the Connecting Rod against the bull wheel.

7. Secure the 6" x 10" transducer base plate to the mounting platform using two or more C-clamps (See Figure I.18 on page I-19).

Figure 4.2 shows the cable connections for the Dead Tank test.



**Figure 4.2 Cable Interconnection Diagram – Dead Tank**

## Live Tank Circuit Breaker

Since the test voltage for the Main Contacts is between 7.5 V and 15 V, it is important to provide good connections between the Contact Monitoring cables and the bushings. To relieve the clips of cable weight and ensure better contact especially in windy conditions, wrap the cables around the porcelain.

Measuring motion may be difficult for most live tank circuit breakers due to the inaccessibility of the moving components.

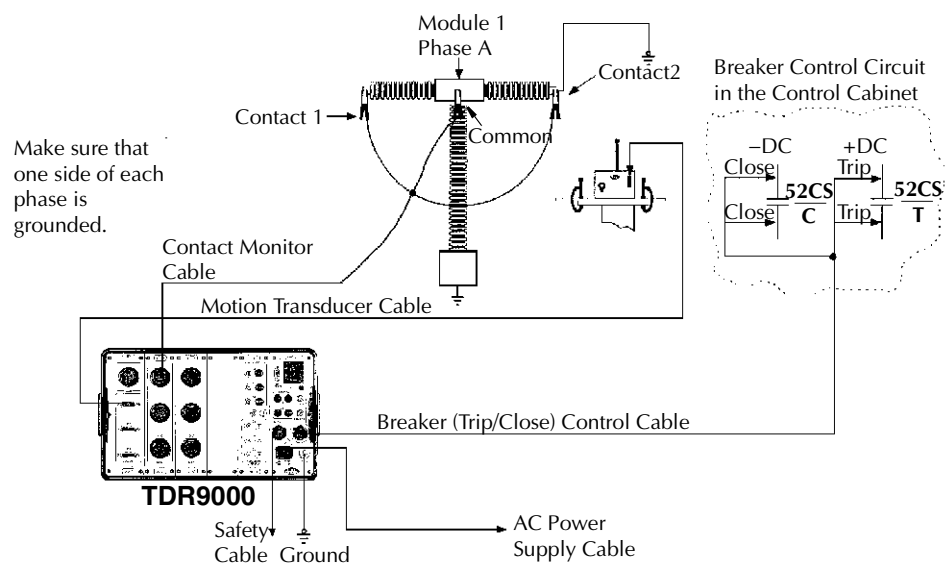
Table 4.3 lists the circuit breaker adapters available.

**Table 4.3 Circuit Breaker Adapters**

<b>Doble Adapter</b>	<b>Circuit Breaker Manufacturer</b>	<b>Circuit Breaker Type</b>
TR3172	Westinghouse	SFA
TR3173	GE	GE Metalclad Air Magnetic Circuit Breakers (specify 13.8 or 4 kV)
TR3174	GE	GE Metalclad Air Magnetic Circuit Breakers (above 2000 A)
TR3175	Hitachi	Independent Pole Operation (IPO)
TR3176	Hitachi	HVB, Ganged operating mechanism
TR3177	N/A	General Purpose Tank Adapter
TR3178	Hitachi	HVB-IPO Spacer
TR3179	GE	Metalclad VB-1 Vacuum Circuit Breakers
TR3180	ABB	HPL Insulator Column
TR3181	ABB	HPL Mechanism Cabinet
TR3182	GEC	Alstom HFG SF6
TR3183	ABB	Coupling 8mmINT x 0.38 lg.
TR3184	Westinghouse	SF Mechanical Interface
TR3185	N/A	Universal Mechanical Transducer Mounting

In many cases the transducer cannot be attached directly to the moving contact portion of a live tank circuit breaker mechanism. In such cases, it should be attached to another part of the mechanism whose movement is related to the one being measured through the Transfer Function. Often, this mounting location is found near the semaphore, which indicates the status of the circuit breaker. For a full discussion of the transducer's Transfer Function, see "Transfer Function" on page A-58. Configuration of transducers is discussed in "Linear Transducer and Rotary Attachments" on page 4-16.

Figure 4.3 shows the cable interconnections for the Live Tank test.



**Figure 4.3 Cable Interconnection Diagram – Live Tank**

## Linear Transducer and Rotary Attachments

### Configuring the TR3190™



This section discusses the configuration procedures for the TR3190 Digital Rotary/Linear Transducer and the TR3160 Motion Transducer.

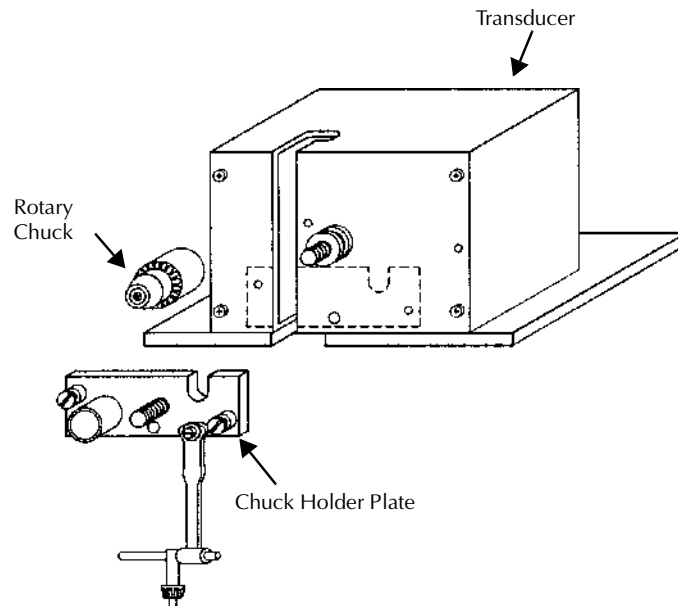
The TR3190 Digital Rotary/Linear Transducer is used to measure Rotary or Linear motion. The setup for each measurement follows.

**Early shipments of the TR3190 were marked externally as TR3160, but were labeled as model TR3160LR on the S/N label.**

Figure 4.4 shows the three components of the TR3190, which include:

- Transducer
- Chuck Holder Plate
- Rotary Chuck

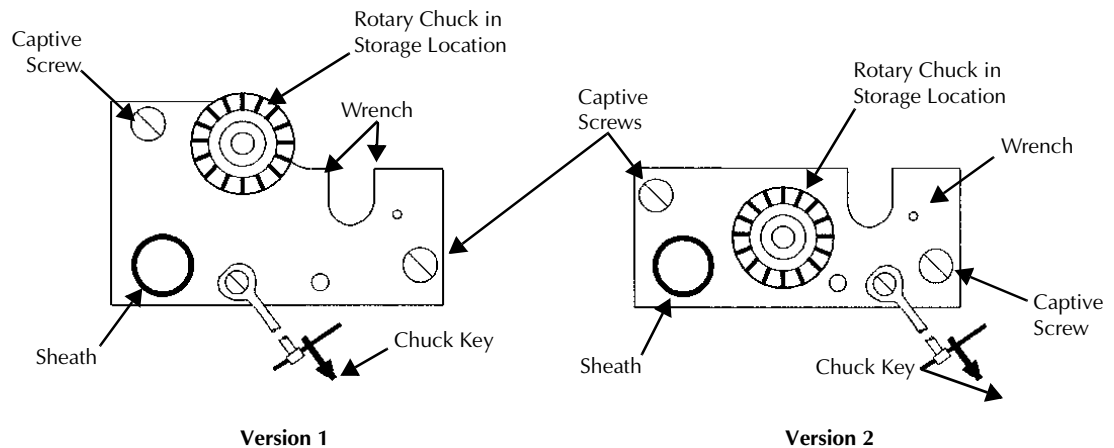
The Chuck Holder Plate is mounted in different locations, depending on whether a rotary or linear measurement is intended.



**Figure 4.4 TR3190™ (TR3160LR™) Transducer Components**

The Chuck Holder Plate is shipped in two different configurations, as shown in Figure 4.5. This plate provides five different functions:

- When mounted in the ROTARY position
  - It depresses a micro-switch that indicates to the TDR9000 that a rotary measurement is being performed.
  - It covers the gate area, which serves as a reminder that it must be moved to the LINEAR position prior to inserting the travel rod to perform a linear measurement.
- It includes a metal sheath that covers the Rotary Shaft to ensure that the threads do not come in contact with any foreign objects that could cause thread damage during storage or operation.
- It has a cutout that is used as a wrench to hold the Rotary Shaft, while the Rotary Chuck is loosened or tightened.
- It provides a storage location for the Rotary Chuck when a linear measurement is made.

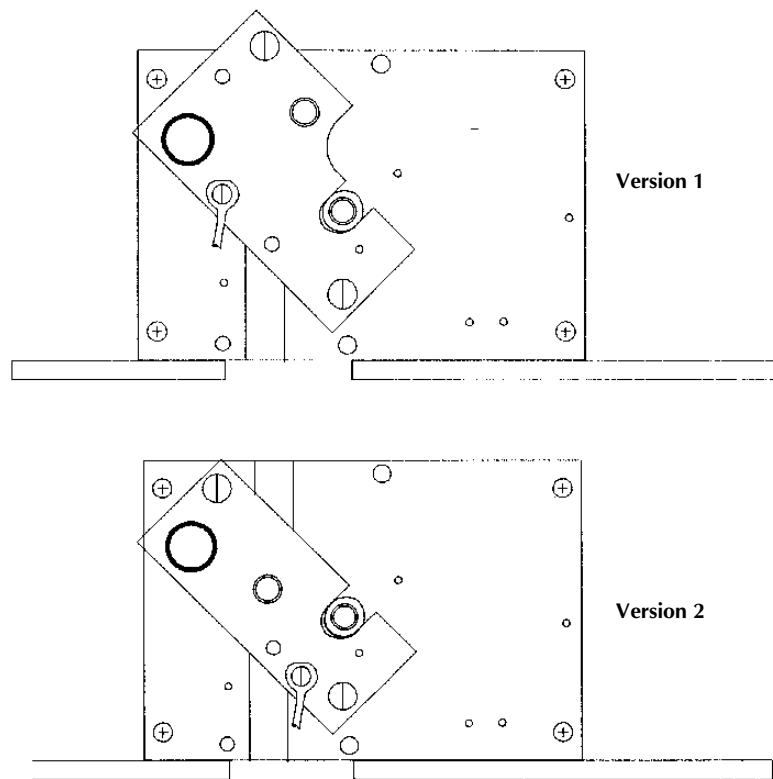


**Figure 4.5 Chuck Holder Plate Configuration**

Rotary Motion

To configure for rotary motion:

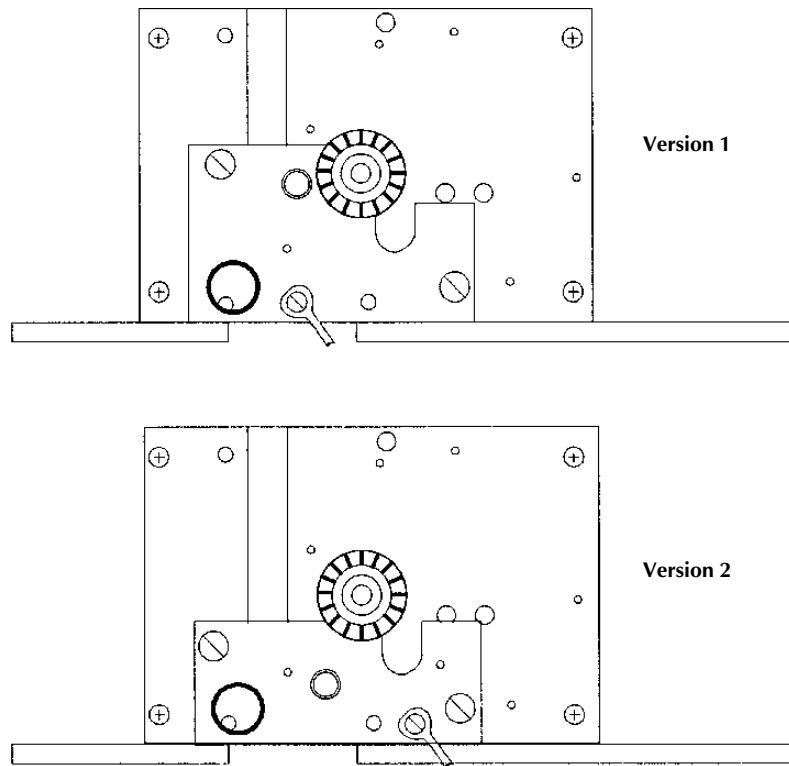
1. Remove the Rotary Chuck from its storage location on the Chuck Holder Plate by rotating it counterclockwise.  
The Chuck Key can be inserted into the Rotary Chuck for added torque.
2. Remove the Chuck Holder Plate from the Transducer by loosening the two captive screws.
3. Position the wrench portion of the Chuck Holder Plate on the Rotary Shaft (see Figure 4.6).
4. Thread the Rotary Chuck onto the Rotary Shaft and hand tighten, using the Chuck Holder Plate to keep the Rotary Shaft from moving.
5. Insert the Chuck Key into the Rotary Chuck.
6. Hold the Chuck Holder Plate against the Transducer and use a light object to tap the Chuck Key until it rotates the Rotary Chuck clockwise, tightening the Rotary Chuck on the Rotary Shaft.
7. Remove the Chuck Key from the Rotary Chuck.



**Figure 4.6 Chuck Holder Plate Mounting to Tighten Rotary Chuck**

8. Remove the Chuck Holder Plate from the Rotary Shaft and use the two captive screws to secure it in the ROTARY position on the Transducer (Figure 4.7).

Configuration is complete.



**Figure 4.7 Chuck Holder Plate mounted in ROTARY position**

Linear Motion

To configure for linear motion:

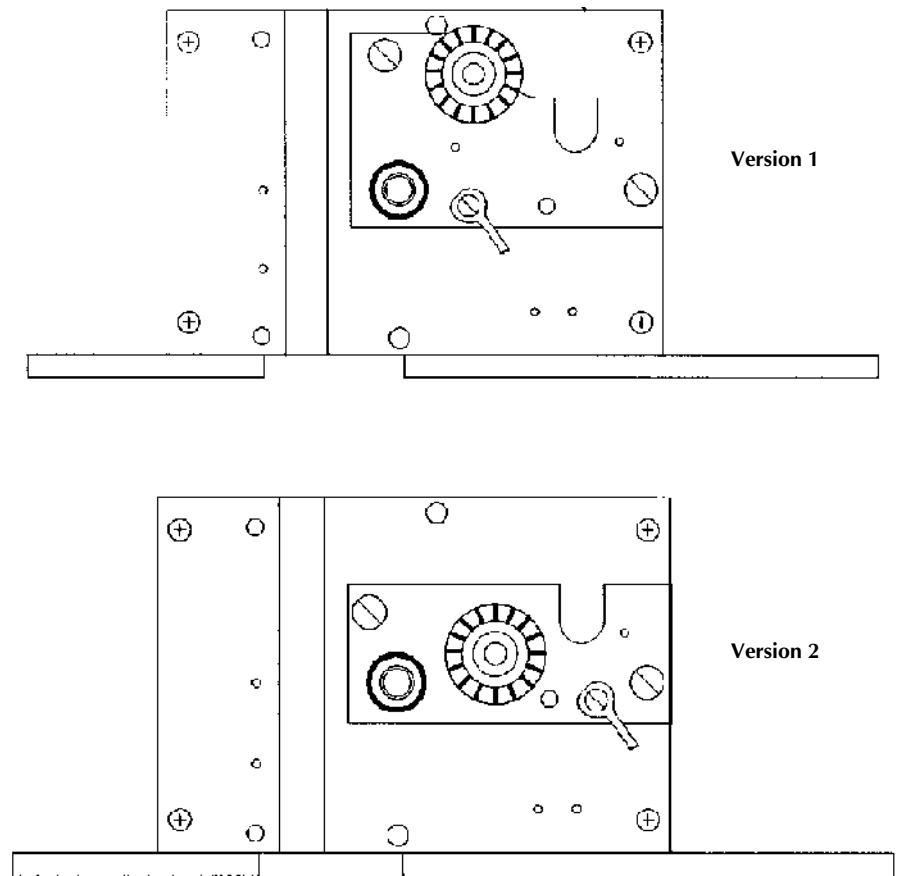
1. Remove the Chuck Holder Plate from the Transducer by loosening the two captive screws.
2. If the Rotary Chuck is:
  - Mounted to the Rotary Shaft, proceed to step 3
  - Otherwise, proceed to step 6
3. Position the wrench portion of the Chuck Holder Plate on the Rotary Shaft (see Figure 4.6 on page 4-18).
4. Rotate the Rotary Chuck counterclockwise and remove it from the Rotary Shaft.  
  
Utilize the Chuck Key, if necessary, as described in step 6 of the previous procedure.
5. Store the Rotary Chuck on the Chuck Holder Plate as shown in Figure 4.5 on page 4-17.

**NOTE**



**If the Rotary Chuck is mounted on the Rotary Shaft during a linear measurement, the added mass of the chuck can induce internal slippage to the transducer causing measurement error.**

6. Mount the Chuck Holder Plate in the LINEAR position on the Transducer (Figure 4.8) using the two captive screws to secure it.  
  
Configuration is complete.



**Figure 4.8 Chuck Holder Plate Mounted in LINEAR Position**

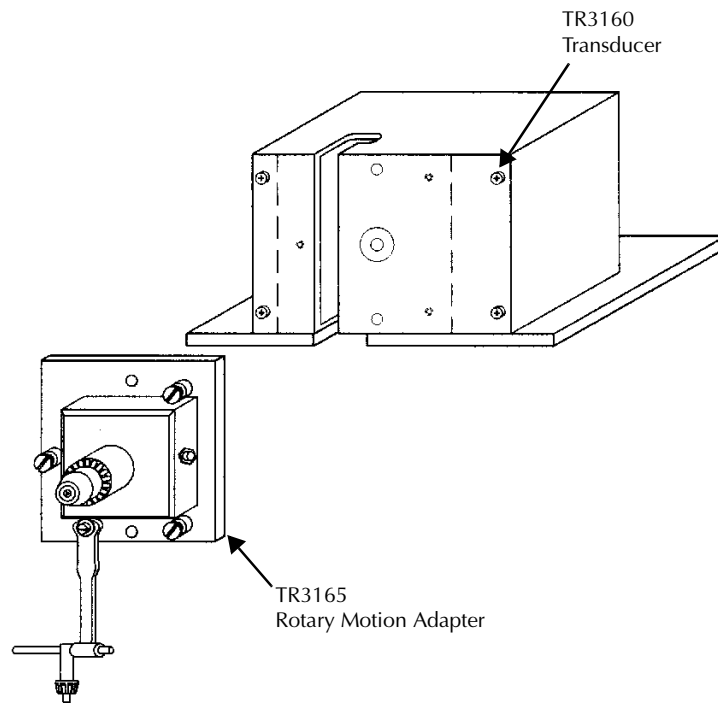
## Configuring the TR3160™

The TR3160 Motion Transducer is used to measure linear or, with the optional TR3165 Rotary Adapter, rotary motion. The setup for both is described below.

There are two configurations of the TR3160, which differ only in the design of the Rotary Adapter mechanism.

- The TR3160 model has the Rotary Adapter shown in Figure 4.9 and is configured using the following procedures.
- The TR3160LR has the Chuck Holder Plate described in "Configuring the TR3190™" on page 4-16 and is configured using TR3190 procedures.

The TR3160LR configuration is also indicated in the serial number on the side of the transducer.



**Figure 4.9 TR3160™ Transducer Components**

The Rotary Adapter, shown in Figure 4.10, provides two different functions:

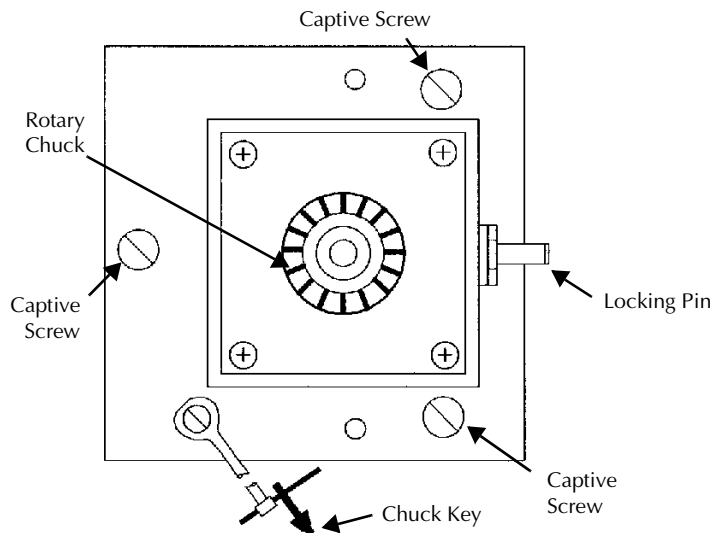
- When mounted in the ROTARY position, the adapter toggles a micro-switch that indicates to the Instrument that a rotary measurement is being performed.
- When mounted in the ROTARY position, it covers the gate area, which serves as a reminder that it must be removed prior to inserting the travel rod to perform a linear measurement.

**NOTE**

**If the Rotary Chuck requires tightening, tighten while using the locking pin to hold the Rotary Shaft in place.**

To tighten the Rotary Chuck:

1. Press on the locking pin while rotating the Rotary Chuck. The locking pin drops into a slot in the Rotary Shaft and holds the Rotary Shaft in place.
2. Insert the Chuck Key into the Rotary Chuck and tap it with a light object until the Rotary Chuck rotates clockwise.



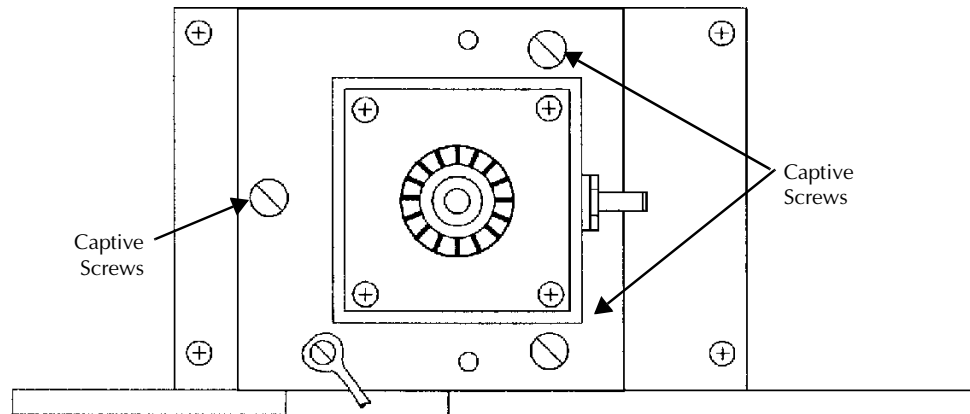
**Figure 4.10 Rotary Adapter**

Rotary Motion

To configure for rotary motion:

1. Mount the Rotary Adapter onto the transducer by inserting the hex shaft that extends from the back of the Rotary Chuck into the hexagonal opening in the face of the transducer and align the three captive screws (refer to Figure 4.11 on page 4-24).
2. Tighten the captive screws.

Configuration is complete.



**Figure 4.11 Rotary Adapter Mounted on Transducer**

Linear Motion

To configure for linear motion:

1. Remove the Rotary Adapter from the Transducer by loosening the three captive screws.
2. Store the Rotary Adapter in the Cable Bag to avoid damage.

Configuration is complete.

## Configuring the TDR9000™

With the field-side connections complete, the laptop running TRXField is connected and the Virtual Front Panel is configured.

Once the TDR9000 is powered up and a Test Plan is selected or configured, the Virtual Front Panel displays all the active channels included in that Test Plan. Channels active in the Test Plan appear on the Virtual Front Panel according to a color scheme that indicates their readiness to start (refer to "Connector Indications" on page 3-9) and acts as an aid to personnel in completing all required connections. Refer to "Basic Virtual Front Panel Functionality" on page 3-5.

Each time a test is run, different values can be configured on different modules. A general procedure for the tasks required to configure the TDR9000 Virtual Front Panel follows. After each step, a cross reference leads to the specific discussion of that topic. Once all required tasks from this general procedure are complete, the test is run.

### Configuring the TDR9000™: General Procedure

To configure the TDR9000:

1. Connect the laptop to the serial port of the TDR9000, power up the laptop and the TDR9000, and run the TRXField software.

If necessary, refer to "Connecting to the Laptop, Printer and Powering Up" on page 4-27.

The TRXField software on the laptop determines what version of the firmware is resident on the TDR9000. If the versions do not match, a dialog box appears asking for permission to download the laptop version to the TDR9000 firmware. If permission is given, the process takes approximately five minutes. A status bar appears on the laptop to monitor download progress.

The download can be cancelled by clicking **Cancel**.

#### NOTE



**If the download is cancelled or not done, the TDR9000 becomes inaccessible.**

2. Connect the TDR9000 Physical Front Panel. Refer to page 4-30

3. Import a Test Plan from TRX, by:
  - a. Using an existing Library Test Plan
  - b. Modifying a Library Test Plan to create a specific Circuit Breaker Test Plan
  - c. Using an existing Circuit Breaker Test Plan as the basis for a new test
  - d. Creating a new Test Plan, using the TRXField software default values as a basis

Refer to "Connecting the TDR9000™ Physical Front Panel" on page 4-30.

4. Configure the Virtual Front Panel.

If an item is not configurable via the Virtual Front Panel, return to the **Test Plan** tab to access it. For example, Travel Specifications for the Motion portion of the OCB/Motion module, is only configurable from the **Test Plan** tab.

For any test, the configuration process can include:

- "Configuring the OCB/Motion Module" on page 4-45
- "Configuring the EHV Module" on page 4-48
- "Configuring the Event Module" on page 4-51
- "Configuring the System Module" on page 4-54
- "Selecting a Test Type" on page 4-56

## Connecting to the Laptop, Printer and Powering Up

The laptop, where the TRXField software resides, runs the Virtual Front Panel of the TDR9000. The laptop is used to:

- Configure test values
- Select test types
- Run tests
- View and interpret Test Results
- Save Library Test Plans and Breaker Test Plans/Results for use by the TRX program
- Print Test Results

Before configuring a Test Plan, the laptop and printer (if any printing will be done) must be connected and powered up. During laptop power up, the TRXField software alerts the user about conflicts between the software version being run on the laptop and the firmware version on the Instrument. If a conflict exists, the laptop, unless cancelled by the user, downloads its version of the software to the TDR9000.

### NOTE



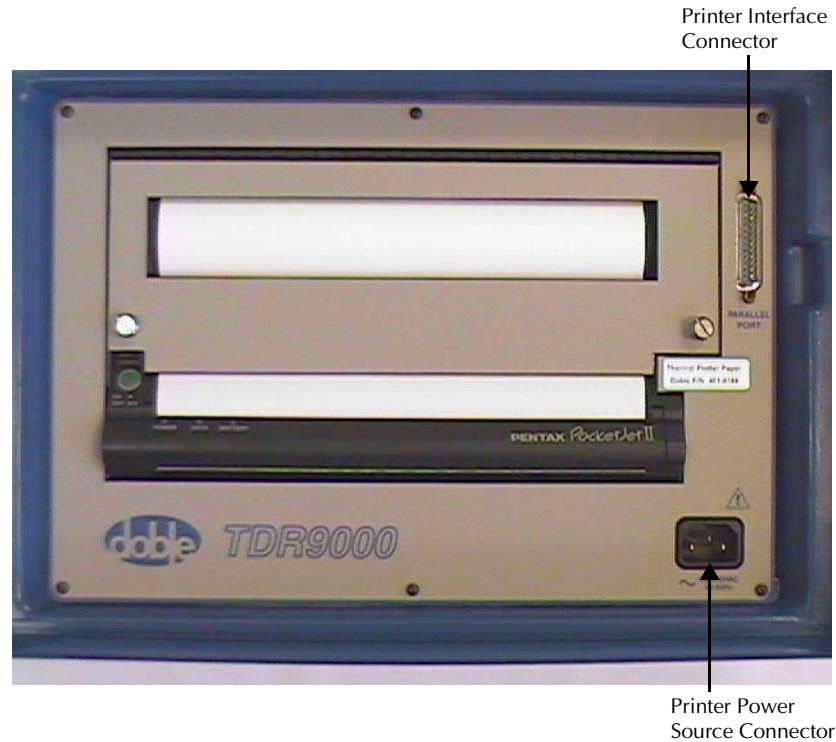
**Before using the built-in printer, the printer driver must be installed on the laptop's hard drive. This is a one-time procedure in "Loading the Printer Driver" on page C-6.**

**The power supply for the optional printer has a narrower AC input range than the TDR9000. If the available power does not meet printer specifications, use the internal battery. Refer to the printer's user manual for further information.**

To connect the laptop and printer:

1. Connect the laptop power cable.
2. Connect the RS-232 cable between an available COM port on the laptop and the PC RS-232 9-Pin D connector on the System module panel.

3. Connect the printer parallel interface cable to the interface connector and secure the catches, as shown in Figure 4.12.



**Figure 4.12 Printer Cable Installation**

4. Connect the other side of the printer parallel interface cable to the LPT1 port of the laptop.
5. Connect the power source for the printer.

There are two power sources provided with the printer:

- Rechargeable battery (Instructions for recharging the battery are given in the *Pentax® PocketJet II™ Printer User's Guide*)
  - AC adapter with a standard U.S. cable, the connection for which is shown in Figure 4.12
6. Turn the power switch **ON**.  
Wait while Windows™ boots up.

7. Double-click the **TRXField** icon shown below or select *Start/Program Files/Doble/TRX/TRXField*.



The firmware polls the Instrument to detect the modules present and the window shown in Figure 4.15 on page 4-40 appears. At this point a Test Plan can be selected or configured. Information about TDR9000 configuration can also be viewed using the TDR9000 Help.

## Connecting the TDR9000™ Physical Front Panel

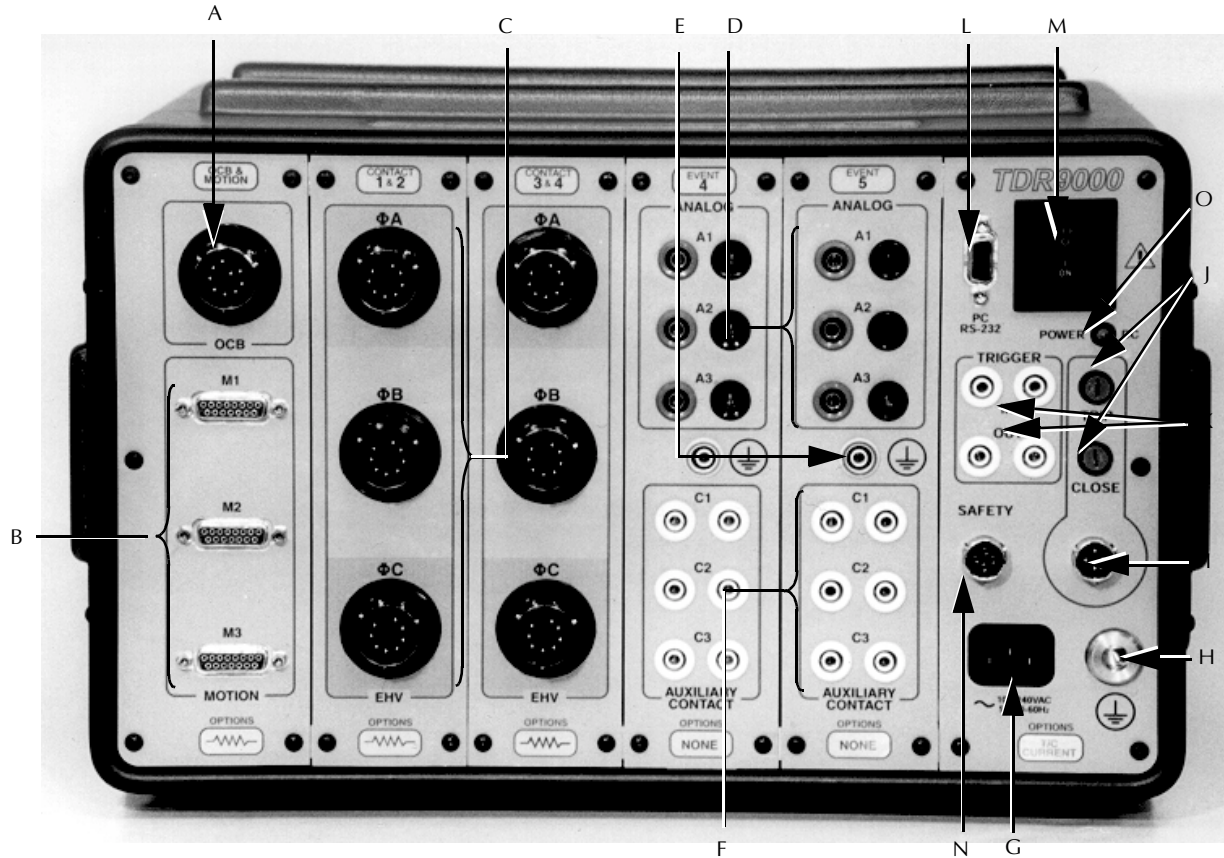
When performing connections, refer to Figure 4.13 on page 4-30.

**NOTE**



**Not all connections are required for all tests.**

**For First Trip/Close tests wiring connections, refer to "Configuring Analog/Auxiliary Channels for First Trip/Close Tests" on page 4-4.**



**Figure 4.13 TDR9000™ Physical Front Panel Connections**

For definitions of the connections, refer to Table 3.1 on page 3-3.

**WARNING**

To connect the TDR9000:

**When performing connections, always make sure that appropriate service disconnects are secured and that all safety procedures are followed. Complete the connection to the TDR9000 Physical Front Panel first. Connecting cables from a grounded instrument reduces problems associated with arcing.**

1. Remove the front protective cover and store it in a safe place for reuse.  
If the printer option is available, locate the cover/printer assembly near the laptop.
2. Plug the ground cable into the system ground receptacle and ground the other end, assuring a secure and reliable connection.  
See **H** in Figure 4.13 on page 4-30.
3. Plug the Safety Switch cable into the **SAFETY** receptacle of the System module. If using an external trigger, use the Safety Bypass flag. See **N** in Figure 4.13.
4. Ensure that the line voltage is correct (100 - 240 VAC, 50 or 60 cycles).
5. Connect the male end (pin contacts) of the Motion Transducer cable to one of the three **MOTION** connectors on the TDR9000 OCB/Motion module (or one of the six, if six channels are available).  
See **B** in Figure 4.13.
6. Connect the female end of the Motion Transducer cable (socket contacts) to the transducer.
7. Repeat steps 5 and 6 for as many transducers required.
8. Connect one side of the Breaker Control cable to the **TRIP/CLOSE** connector on the TDR9000 System module, then connect the other end of the Breaker Control cable to the circuit breaker.  
See **I** in Figure 4.13.

9. Connect the:

- a. **Trip** leads across the terminals of the manual Trip switch on the circuit breaker control panel.
- b. **Close** leads across the terminals of the manual Close switch on the circuit breaker control panel (local connection schemes may vary).

If the manual trip switch connections are inaccessible:

- connect between the +DC voltage supply of the terminal strip to the input side of the trip coil.

This configuration also serves for close coil operations. Either method, across the switch or using the coils makes the TDR9000 a series switch that applies +DC voltage to the appropriate coil for operation.

10. Taking appropriate safety precautions, use the attachment accessories provided to connect an:

- OCB Contact Monitor cable to the **OCB** connector on the TDR9000 OCB/Motion module and then to the appropriate circuit breaker bushings.

See **A** in Figure 4.13 on page 4-30. Connect alligator clip leads as labeled, A,B,C Common or 1,2,3 Common.

or

- EHV Contact Monitor cables to the **EHV** connectors on the TDR9000 EHV module and then to the appropriate circuit breaker bushings.

See **C** in Figure 4.13 on page 4-30. Connect alligator clip leads as labeled PH A, Contact 1,2, Common, etc.

## Analog and Auxiliary Setup

### Monitoring Auxiliary Channels

Setup issues for the Event module include:

- Monitoring Auxiliary Channels
- Monitoring Analog Channels: Current and Voltage

The TDR9000 Auxiliary Contact channels support inputs from external devices. Auxiliary Contacts can be wetted with voltages from 48 to 300 V peak. Configuration is performed using the **Auxiliary Contact Connector** or the **Auxiliary Contacts** dialog box of the Virtual Front Panel. Refer to "Configuring the Event Module" on page 4-51.

**NOTE**

**It is possible to factory order an Event module configured for use with 24 V station batteries.**

To connect an Auxiliary Contact:

1. Attach one end of the Doble supplied Auxiliary Contact cable to a pair of **Auxiliary Contact** channel banana jacks (**F** on Figure 4.13 on page 4-30).

**NOTE**

**The Auxiliary Contact measurement channels are not polarity sensitive.**

2. Taking appropriate safety precautions, use the attachment accessories provided to attach the other end of the cable across the device to be monitored, either directly across the device or at the terminal block.

Monitoring  
Analog  
Channels:  
Current and  
Voltage

The TDR9000 monitors both current and voltage using the Analog Channel connectors of the Event module. The Event module analog channels are used to accept:

- Voltage input (up to 300 V peak)
- Current probe input
- Current shunt input

*Voltage Monitor*

The Analog Channels accept voltage inputs up to 300 V peak. Configuration is performed using the **Analog Channel Connector** or the **Analog Channels** dialog box of the Virtual Front Panel. Refer to "Configuring the Event Module" on page 4-51.

**NOTE**

**The Analog cable is not symmetrical. The Instrument end has a shield connector; the other end does not.**

To connect a voltage input:

1. Attach the Instrument end of the Doble supplied Analog cable to a pair of Analog Channel banana jacks.

**D** on Figure 4.13 on page 4-30.

**NOTE**

**Analog measurement channels are polarity sensitive.**

2. Make sure to attach the shield (green/yellow) banana plug to the chassis ground (green/yellow) banana jack on the Event module.

Multiple shields can be stacked (see Figure 4.13 on page 4-30).

3. Taking appropriate safety precautions, use the attachment accessories provided to attach the other end of the cable across the device to be monitored, either directly across the device or at the terminal block.

Generally, voltage measurements are made from the high side of the load to the neutral rail.

*Current Probes* Current probe inputs can be configured for 20 A or 200 A. Configuration is performed using the **Analog Channel Connector** or the **Analog Channels** dialog box of the Virtual Front Panel.

Two types of probes are currently in service for use with the TDR9000:

- An older probe version with an adjustable wheel used for zeroing
- A newer self-zeroing version with a zeroing button on the probe

To maximize performance, either probe should be re-zeroed immediately before performing any critical measurements. The TDR9000 does not allow a test to run using an unzeroed probe.

#### *Adjustable Wheel Probe*

The probe must be re-zeroed whenever a new Test Plan is loaded or a channel is reactivated using the clamp-on current probe's built-in offset adjustment. When zeroing a probe, the PC running the Virtual Front Panel might not be visible, therefore, the TDR9000 Instrument creates a modulated beep which aids in properly zeroing the probe. When the probe is at zero for two seconds, it is considered to be zeroed. The Instrument emits a steady tone as confirmation.

To zero probe:

1. To connect and zero the current probe:
  - a. Taking appropriate safety precautions, plug the Instrument end of the probe cable into the desired **Analog Channel Connector**.  
  
The **Analog** channel inputs are polarity sensitive. Make sure to attach the shield (green/yellow) banana plug to the chassis ground (green/yellow) banana jack on the Event module.
  - b. Set the probe range switch to the low range (10 A or 20 A) position.  
  
Zeroing the probe with the switch on the high range may yield inaccurate results. For best results, start the process with the thumbwheel rotated all the way in one direction.
  - c. Plug the free end of the **Analog** cable into the current probe.  
  
This requires adapters that are supplied with the Analog cables.
  - d. Turn the probe ON and latch the Trigger into the ON position.

**NOTE**

**Make sure that the probe is not attached to, or placed near, current-carrying wires during the zeroing process.**

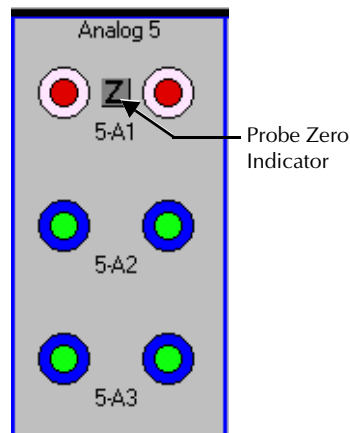
- e. Click the **Probe Zero** button on the Virtual Front Panel.

The following message displays on the Virtual Front Panel:

*Adjust probe until tone becomes constant. The process ends automatically when the probe is correctly adjusted for 2 seconds.*

- f. Slowly adjust the thumbwheel on the top of the probe until the modulated tone remains constant for two seconds.

When the probe reaches zero offset, the tone becomes steady. If zero offset is maintained for two seconds, the tone stops and the channel indicator turns green (Figure 4.14).



**Figure 4.14 Probe Zero Indicator**

- g. Repeat this procedure for any additional probes.

**NOTE**

**If no activity is detected on the channel within 30 seconds, an error message appears on the Virtual Front Panel. If the process fails, the Probe Zero button remains red and the following error message appears: *Process incomplete, Probe not zeroed.* Pressing OK removes the error message, leaving the Probe Zero button red.**

2. Leave the probe on with the trigger locked in the ON position. Place the range switch on the probe in the desired position.

**NOTE**

**Be careful not to disturb the thumbwheel.**

3. Securely clamp the probe around the wire that carries the current to be monitored.

### *Self-Zeroing Probe*

The probe must be re-zeroed whenever a new Test Plan is loaded or a channel is reactivated.

**NOTE**



**To conserve battery power, Doble's MR 20 A/200 A/ 2 V Autozero probe powers down after ten minutes. To disable this feature, when turning the probe on, press the Zero button. The green LED flashes several times to indicate the battery saver feature is disabled.**

To zero the probe:

1. Connect and zero the current probe by:
  - a. Taking appropriate safety precautions, plug the Instrument end of the probe cable into the desired **Analog Channel Connector**.

The **Analog** channel inputs are polarity sensitive. Make sure to attach the shield (green/yellow) banana plug to the chassis ground (green/yellow) banana jack on the Event module.

- b. Plug the free end of the **Analog** cable into the current probe.
  - c. Click the **Probe Zero** button on the Virtual Front Panel.

The following message displays on the Virtual Front Panel:

*Adjust probe until tone becomes constant. The process will end automatically when the probe is correctly adjusted for 2 seconds.*

- d. Turn the probe on by setting the selector switch to the desired range.

**NOTE**



**Make sure that the probe is not attached to, or placed near, current-carrying wires during the zeroing process.**

- e. Press the **Probe Zero** button on the probe.

When the probe reaches zero offset, the tone becomes steady. If zero offset is maintained for two seconds, the tone stops and the channel indicator turns green.

- f. Repeat this procedure for any additional probes.

**NOTE**

If no activity is detected on the channel within 30 seconds, an error message appears on the Virtual Front Panel. If the process fails, the Probe Zero button remains red and the following error message appears: *Process incomplete, Probe not zeroed*. Pressing OK removes the error message, leaving the Probe Zero button red.

2. Leave the probe on and securely clamp the probe around the wire that carries the current to be monitored.

*Current Shunt* Current shunt configuration is performed using the **Analog Channel Connector** or the **Analog Channels** dialog box of the Virtual Front Panel. Refer to "Analog Channels" on page 4-51.

To set up a current shunt:

1. Connect the Instrument end of the Doble supplied Analog cable to a pair of **Analog** channel banana jacks.

The **Analog Channel** inputs are polarity sensitive.

2. Make sure to attach the shield (green/yellow) banana plug to the chassis ground (green/yellow) banana jack on the Event module.

Multiple shields can be stacked (see Figure 4.13 on page 4-30).

3. Taking appropriate safety precautions, use the attachment accessories provided to attach the other end of the cable across the device to be monitored, either directly across the device or at the terminal block.

For best results, Doble recommends that the shunt be installed on the low or neutral side of the circuit through which the test current flows.

#### System Module Trigger In/Out Setup

The Trigger In and Trigger Out connections on the System module are connected as follows:

1. Attach one end of the Doble supplied Auxiliary Contact cable to a pair of **Trigger In or Trigger Out** channel banana jacks (**K** on Figure 4.13 on page 4-30).
2. Taking appropriate safety precautions, use the attachment accessories provided to attach the other end of the cable across the device to be monitored, either directly across the device or at the terminal block.

**Trigger Out performs no monitoring on the device described in step 2.**

#### NOTE



#### WARNING



**The System module Trigger In channel is the only TDR9000 channel rated to 600 V peak. When connecting this channel use appropriately rated test leads.**

## Configuring Test Plans

There are two types of Test Plans:

- Library Test Plan
- Breaker Test Plan

A Library Test Plan contains the information required to run a general test on a breaker type. This plan is flexible, in that none of the nameplate information stored in this format is specific to a particular circuit breaker. The Library Test Plan can be used repeatedly as a basis for configuring multiple tests with the same basic test configuration, and on circuit breakers of the same type.

A Breaker Test Plan is created when any circuit breaker-specific information is entered in the nameplate on the **Test Plan** tab. Once such information is entered, the title on top of the **Test Plan** tab changes from *Library Test Plan* to *Breaker Test Plan*. This occurs by entering information into *any* of the following fields:

- *Manufacturer*
- *Serial Number*
- *Location*
- *Special ID*

Both Test Plan types minimize the time required to configure tests as they store common circuit breaker testing information and test parameters.

Items that can comprise a Test Plan include:

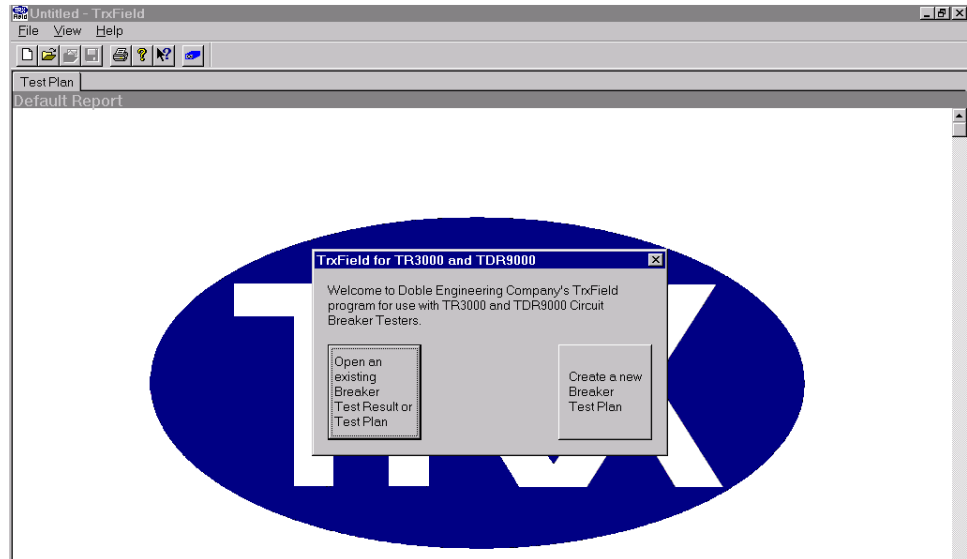
- Circuit breaker ID, such as type, serial number and manufacturer
- Range selection for Trip/Close currents
- Circuit breaker specifications and measurement zones, as specified by the manufacturer
- Units of measurement (seconds or cycles, English or Metric)
- Transfer function for motion measurements
- Channel activation
- Performance specifications

### NOTE



**The TDR9000 can be used in either the 50 or 60 Hz environment. This selection is made using the TRX Options window accessed from the TRXField View pulldown menu. For a complete description of this window, refer to page A-31.**

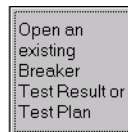
The TRXField software opens with the **TRXField for TR3000 and TDR9000** dialog box open (Figure 4.15).



**Figure 4.15 TRXField™ Test Plan Choice Window**

The **TRXField for TR3000 and TDR9000** dialog box open shown in Figure 4.15 is for choosing between manually entering a Test Plan or choosing an existing plan.

One of the following buttons is selected:

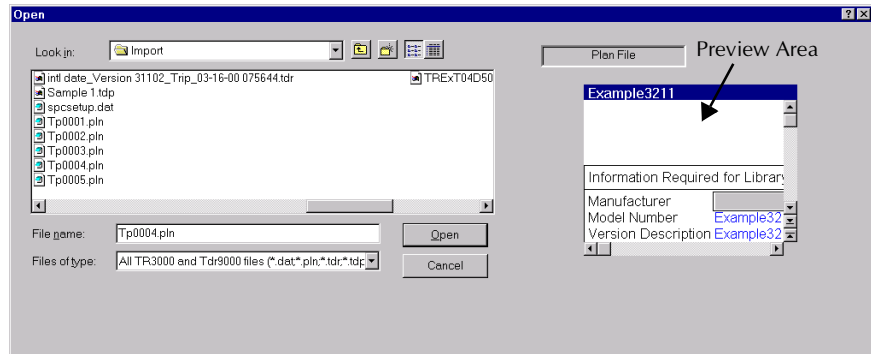


Opens the **Open** window (Figure 4.16 on page 4-41) where an existing Test Plan is selected. Each active channel is populated with its test plan-dictated value. In the field this Test Plan must be supplied via floppy disk or be resident on the hard drive.

- The Test Plan can be used as is.  
Proceed to "Running Tests" on page 4-75.

or

- The Test Plan can be modified.  
Proceed to "Setting Up a Test Plan Manually with TRXField™" on page 4-43.



**Figure 4.16** Open

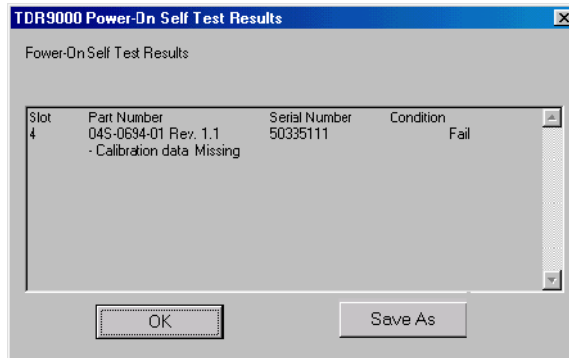
Create a new  
Breaker  
Test Plan

Creates a new, blank Test Plan once the *Model Number* field is filled in and the **TDR9000** tab becomes accessible containing the Virtual Front Panel. If this option is selected, the modules and channels detected are added to the Virtual Front Panel with default values in place. It is then necessary to configure each channel's specifications to meet test needs.

The Open window (Figure 4.16) contains a preview area for viewing and selecting Test Plans. Its scrolling horizontal and vertical positions allow the user to view the full contents of the Test Plan.

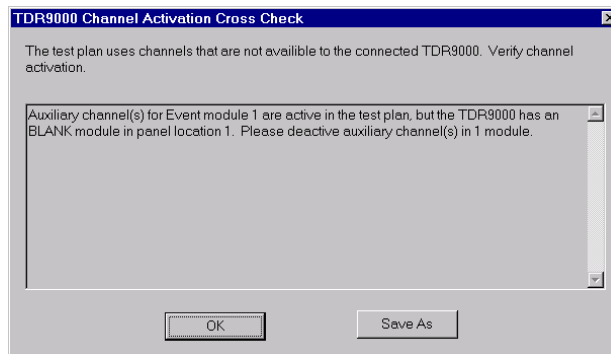
Power-Up  
Diagnostics and  
Channel Activation  
Checks

The TDR9000 performs power up diagnostics. If an error is detected, a dialog box containing diagnostic results is displayed, as shown in Figure 4.17. The results contained in this dialog box are useful for troubleshooting. If there is a problem, save the dialog box results to a text file using the Save As button for Doble Customer Service (email: customerservice@doble.com).



**Figure 4.17 Power-Up Diagnostics**

If the TRXField software detects that a channel designated for use is not supported or that a Test Plan field is configured in a way that causes conflicts with other configured items, a dialog window appears (Figure 4.18).



**Figure 4.18 Channel Activation Check**

Use the Save As button to save the results to a text file and then click **OK**.



**Using the Save As button does not solve the problem. The problem must be resolved on the Test Plan, TDR9000 tab or in the equipment test setup. If the problem is not resolved, Test Results may be affected, or the test may not be allowed.**

## Setting Up a Test Plan Manually with TRXField™

Once the choice to manually create a Test Plan is made, the **New Test Plan - TRXField** window (Figure 4.19) appears (Only the top portion of this window is shown). All the data fields required to create a Test Plan appear on this **Test Plan** editor tab. Explanations of all these fields are given in Appendix A "TRXField™ Software and Circuit Breaker Testing Theory".

Figure 4.19 is primarily meant to show the two tabs that appear at this time on TRXField: **Test Plan** and **TDR9000**.

### NOTE



**The Test Plan tab is the default tab. It is not possible to move to any other tab until the Model Number is entered.**

**Figure 4.19** TRXField™ Library Test Plan

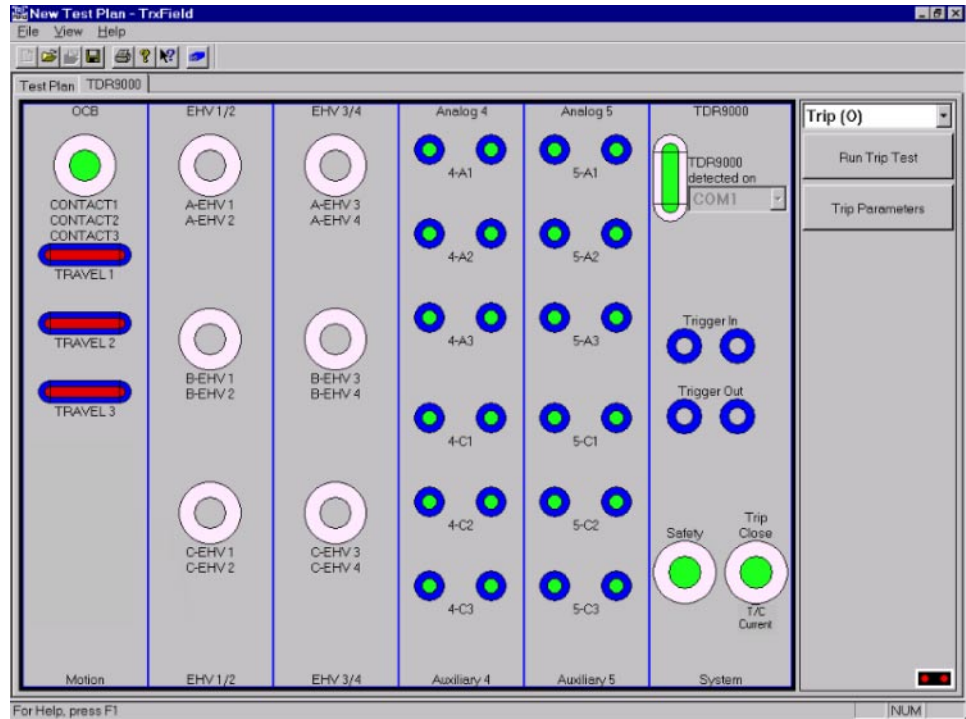
The **Test Plan** and **TDR9000** tabs are used to configure Test Plans. Since Appendix A "TRXField™ Software and Circuit Breaker Testing Theory" explains the use of the fields on the **Test Plan** tab, the discussions in this chapter focus only on the use of the **TDR9000** tab Virtual Front Panel to create or modify Test Plans. All changes implemented on the Virtual Front Panel are reflected on the **Test Plan** tab.

### NOTE



**Not all parameters available on the Test Plan tab are available on the TDR9000 tab.**

Figure 4.20 shows a Virtual Front Panel that has an OCB, three Motion channels, two EHV modules (each module has two breaks/phase and three phases), six Analog and six Auxiliary channels, Trip/Close, and Trigger options.

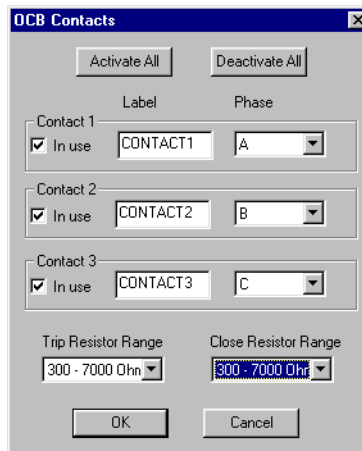


**Figure 4.20 Example Virtual Front Panel**

## Configuring the OCB/Motion Module

Figure 4.21 shows the **OCB Contacts** window. The OCB portion of this module uses one window to configure all three contacts. To access this window:

- Click the **OCB** connector or OCB label, for example, **CONTACT1**, as shown in Figure 4.20.



**Figure 4.21 OCB Contacts**

The following items are configurable:

<i>In use</i>	A checkbox that activates or deactivates the associated channel.
<i>Label</i>	A user-entered field for entering the Contact Name associated with the channel.
<i>Phase</i>	A scrollable picklist for selecting the phase associated with the channel.
<i>Trip Resistor Range</i>	A scrollable picklist for selecting the Trip Resistor configuration. If the resistor is not present, <b>None</b> should be selected.

The choices are:

- **None** (default)
- **10 - 400 Ohms**
- **300 - 7000 Ohms**

### Close Resistor Range

A scrollable picklist for selecting the Close Resistor configuration. If the resistor is not present, **None** should be selected.

The choices are:

- **None** (default)
- **10 - 400 Ohms**
- **300 - 7000 Ohms**



Activates all **In use** checkboxes.



Deactivates all **In use** checkboxes.

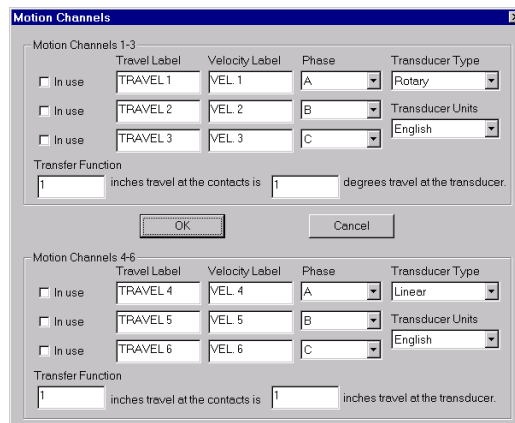
Figure 4.22 and Figure 4.23 on page 4-48 show the **Motion Channels** and **Motion Connector** windows, respectively.

The **Motion Channels** window configures items specific to individual channels, as well as items applicable to overall motion interpretation.

To access this window:

- Click the **Motion** label on the bottom of the virtual module, as shown in Figure 4.20 on page 4-44.

Figure 4.22 shows three **Motion Channels**. Since motion channels are configured in groups of three, this window displays either three channels or six channels.



**Figure 4.22 Motion Channels – Collective**

*Items that Effect Individual Motion Channels*

The following items are configurable.

<i>In use</i>	A checkbox that activates or deactivates the associated channel.
<i>Travel Label</i>	A field for entering the travel name associated with the channel.
<i>Velocity Label</i>	A field for entering the velocity name associated with the channel.
<i>Phase</i>	A scrollable picklist for selecting the phase associated with the channel.

*Items that Effect Overall Motion Channel Behavior*

The motion channels are split into two groups:

- **Motion Channels 1-3**
- **Motion Channels 4-6**

The selections described below apply to these groups.

<i>Transducer Type</i>	A picklist for choosing the transducer type: <ul style="list-style-type: none"> <li>• <b>Linear</b></li> <li>• <b>Rotary</b></li> </ul>
------------------------	---

**NOTE**

**Selecting Rotary changes the Transfer Function field to reflect degree measurement.**

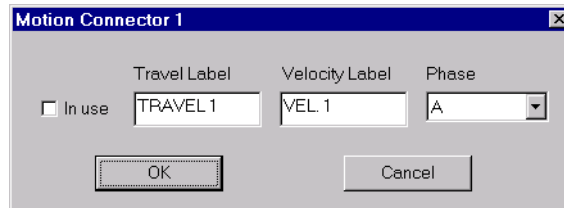
<i>Transducer Unit</i>	A picklist for choosing the transducer unit of measurement: <ul style="list-style-type: none"> <li>• <b>English</b></li> <li>• <b>Metric</b></li> <li>• <b>Degrees</b> (dictated by <i>Transducer Type</i>)</li> </ul>
<i>Transfer Function</i>	Two user-entered fields for entering the data used to translate the travel of the contacts into a useful indication of transducer travel. For an in depth explanation of this topic, refer to "Transfer Function" on page A-58.

A **Motion Connector** window is available for each configured motion channel. This window configures only items specific to an individual motion channel.

To access this window:

- Click any motion connector or motion channel label, for example, **TRAVEL1**, as shown in Figure 4.22 on page 4-46.

The window shown in Figure 4.23 appears.



**Figure 4.23 Motion Connector – Individual**

The following items are configurable:

<i>In use</i>	A checkbox that activates or deactivates the associated channel.
<i>Travel Label</i>	A field for entering the travel name associated with the channel.
<i>Velocity Label</i>	A field for entering the velocity name associated with the channel.
<i>Phase</i>	A scrollable picklist for selecting the phase associated with the channel.

Configuring the EHV Module

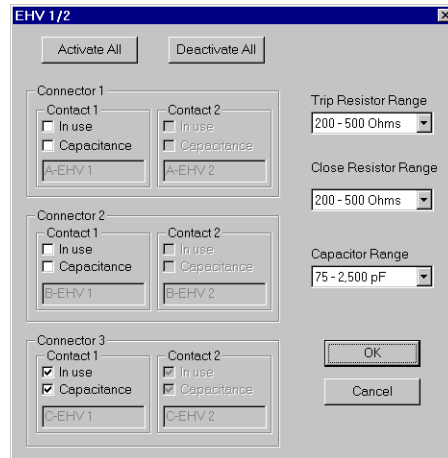
Figure 4.24 and Figure 4.25 on page 4-51 show the **EHV** and the **EHV Connector** windows, respectively.

The **EHV** window configures items specific to individual channels, as well as items applicable to overall module interpretation.

To access this window:

- Click the **EHV** label on the top or bottom of the virtual module, as shown in Figure 4.20 on page 4-44.

Figure 4.24 on page 4-49 shows three connectors with two contact measurement channels each. EHV channels are generally activated by breaker head or tank, or by module (three tanks, one each for phases A, B, and C). As additional breaker modules are added, additional EHV modules are activated. This group activation allows for easy activation of the additional channels from the virtual interface.



**Figure 4.24 EHV – Collective**

The following items are configurable.

Items that effect individual EHV channels:

*In use*

Two checkboxes per connector, one for each contact. If **Split** mode is not selected, activating the **Contact 1** checkbox implicitly activates the **Contact 2** checkbox.

Refer to “Main Contact Configuration – EHV/SPLIT Contact Channel Activation” on page A-64 for a description.

*Capacitance*

Two checkboxes per connector, one for each contact, to activate the TDR9000 for a capacitance test. If **Split** mode is not selected, activating the **Contact 1** checkbox implicitly activates the **Contact 2** checkbox.

Refer to “Main Contact Configuration – EHV/SPLIT Contact Channel Activation” on page A-64 for a description.

*Label*

Two fields, one per connector contact, where a label associated with the contact is entered. This field is not editable.

*Items that Affect  
Overall EHV  
Channel Behavior*

The values specified for the following areas apply to all EHV channels of that module. The Trip and Close resistor ranges always appear, and must be set correctly, even if the resistor value measurement option is not present.

**NOTE**



**An incorrect resistor range setting can result in an incorrect Wipe calculation. The Average Velocity values may also be incorrect if Contact Open or Contact Close was used to specify the velocity measurement zone.**

**Setting the Trip Resistor Range or Close Resistor Range on any EHV module sets the range for all EHV modules in that TDR9000.**

If there is no pre-insertion resistor in parallel with the contact, the default resistor range **None** is used. If the value of the resistor overlaps both ranges, either range can be selected.

*Trip Resistor Range* A scrollable picklist for selecting the Trip resistor configuration. If the resistor is not present, **None** should be selected. Choices include:

- **None**
- **10 - 300 Ohms**
- **200 - 500 Ohms**

*Close Resistor Range* A scrollable picklist for selecting the Close resistor configuration. If the resistor is not present, **None** should be selected. Choices include:

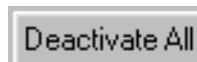
- **None**
- **10 - 300 Ohms**
- **200 - 500 Ohms**

*Capacitor Range* A scrollable picklist for selecting the Capacitor configuration. Choices include:

- **75 - 2,5000 pF**
- **300 - 10,000 pF**



Activates all ***In use*** checkboxes.

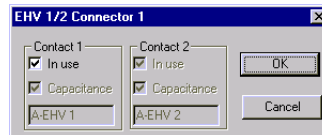


Deactivates all ***In use*** checkboxes.

Figure 4.25 shows the **EHV Connector** window. To access this window:

- Click any EHV connector or channel label (for example, **A-EHV 1**), as shown in Figure 4.20 on page 4-44.

There is an **EHV Connector** window for each configured EHV channel. This window configures only items specific to an individual EHV channel.



**Figure 4.25 EHV Connector – Individual**

The configurable items are the same as explained for individual EHV channels, above.

#### Configuring the Event Module

The Event module is comprised of six sets of virtual connectors:

- Three analog measurement connectors that are independently configured for either currents or voltages
- Three auxiliary contact connectors

#### Analog Channels

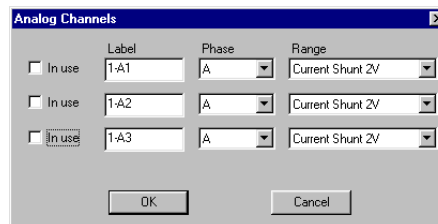
Figure 4.26 and Figure 4.27 on page 4-52 show the **Analog Channels** and the **Analog Channel Connector** windows, respectively.

The **Analog Channels** window configures all three channels using one window.

To access this window:

- Click the **Analog** label on the top of the virtual module, as shown in Figure 4.20 on page 4-44.

The window shown in Figure 4.26 appears.



**Figure 4.26 Analog Channels – Collective**

The following items are configurable:

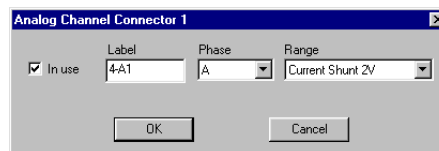
- |               |   |
|---------------|---|
| <i>In use</i> | A checkbox that activates or deactivates the associated channel.  |
| <i>Label</i>  | A field for entering the name associated with that channel.   |
| <i>Range</i>  | A scrollable picklist for selecting the voltage range, current probe range or current shunt range. The choices are: <ul style="list-style-type: none"> <li>• <b>.2 V</b></li> <li>• <b>2 V</b></li> <li>• <b>10 V</b></li> <li>• <b>300 V</b></li> <li>• <b>20 A Current Probe</b></li> <li>• <b>200 A Current Probe</b></li> <li>• <b>Current Shunt 200 mV</b></li> <li>• <b>Current Shunt 2 V</b></li> <li>• <b>Current Shunt 10 V</b></li> </ul> |
| <i>Phase</i>  | A scrollable picklist for selecting the phase associated with the channel.  |

An **Analog Channel Connector** window is available for each available analog channel.

To access this window:

- Click any Analog connector or channel label, for example, **4-A1**, as shown in Figure 4.20 on page 4-44.

The window shown in Figure 4.27 appears.



**Figure 4.27 Analog Channel Connector – Individual**

The configurable items are identical to those explained above.

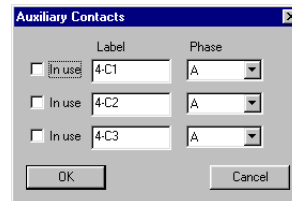
*Auxiliary Channels* Figure 4.28 and Figure 4.29 show the **Auxiliary Contacts** and the **Auxiliary Contact Connector** windows, respectively.

The **Auxiliary Contacts** window configures all three channels using one window.

To access this window:

- Click the **Auxiliary** label on the bottom of the virtual module, as shown in Figure 4.20 on page 4-44.

The window shown in Figure 4.28 appears.



**Figure 4.28 Auxiliary Channels – Collective**

The following items are configurable:

*In use* A checkbox that activates or deactivates the associated channel.

*Label* A field for entering the name associated with that channel.

*Phase* A scrollable picklist for selecting the phase associated with the channel.

An **Auxiliary Contact Connector** window is available for each available analog channel.

To access this window:

- Click any **Auxiliary** connector or channel label, for example, **4-C1**, as shown in Figure 4.20 on page 4-44.

The window shown in Figure 4.29 appears.



**Figure 4.29 Auxiliary Contact Connector – Individual**

The configurable items are identical to those in "Auxiliary Channels".

Configuring the System Module

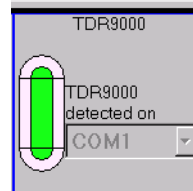
The System module is comprised of the following connections:

- Safety cable
- Serial communications port
- Trip/Close control (an option)
- System Triggers (options configured through the individual test **Parameters** window or through the appropriate trigger connector)

The configuration of each is discussed in the sections that follow.

*Serial Communications*

The communications port for the serial communications is configured using the picklist to the right of the port icon on the Virtual Front Panel, as shown in Figure 4.30.



**Figure 4.30 Com Port**

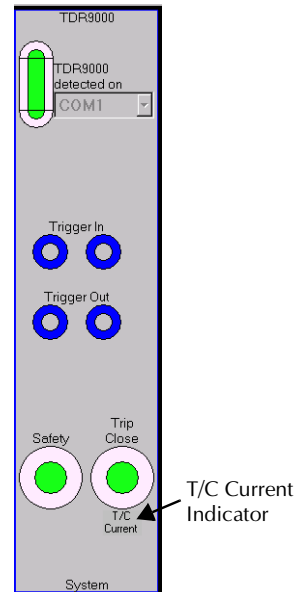
The following items are configurable:

*Port Picklist*

A scrollable picklist for selecting the communications port in use by the laptop. Choices include all available communications ports. For example:

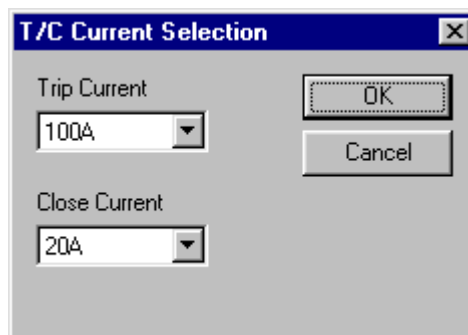
- **COM1**
- **COM2**

*Trip/Close Module* The Trip/Close module has configuration options only when the Trip/Close Current option is being used. The virtual System module appears as shown in Figure 4.31 when this option is present.



**Figure 4.31 Trip/Close with Trip/Close Current Option**

Click the virtual **Trip Close** connector shown in Figure 4.31 to access the **T/C Current Selection** window shown in Figure 4.32. This window configures the current range expected on the Trip or Close control circuit. For instance, when **100 Amps** is selected in the *Trip Current* field, the system reads the circuit's shunt voltage, and converts it into a current reading, in the range of  $\pm 100$  A.



**Figure 4.32 T/C Current Selection**

The following items are configurable:

*Trip Current* A scrollable picklist for selecting the Trip circuit range. Choices include:

- 100 A
- 20 A
- 5 A
- 2 A

*Close Current* A scrollable picklist for selecting Close circuit range. Choices include:

- 20 A
- 5 A
- 1 A
- 0.2 A

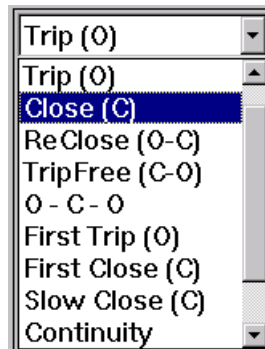
**NOTE**



**To maximize the resolution for all range selections, use the lowest practical range for the expected measurement.**

Selecting a Test Type

On the right side of the Virtual Front Panel is a scrollable picklist, as shown in Figure 4.33.



**Figure 4.33 Test Selection Picklist**

This picklist is used to select the test type. Test types include:

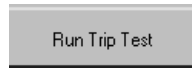
- **Trip (O)**
- **Close (C)**
- **Reclose (O-C)**
- **Trip Free (C-O)**
- **O-C-O**
- **First Trip (O)**
- **First Close (C)**
- **Slow Close (C)**
- **Continuity**
- **Capacitance**
- **Self-Diagnostics**

Once a test type (**XXX**) is selected, two operational buttons appear on the Virtual Front Panel: **Run XXX Test** and **XXX Parameters** as shown in Figure 4.34.

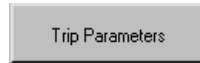


**Figure 4.34 Run Test and Parameters Buttons**

Clicking these buttons:



Displays the first window of the testing sequence. Refer to "Running Tests" on page 4-75.



Displays a window, comprised of three tabs, where the command parameters, including the triggers, for that test type are configured or reconfigured from an original Library Test Plan or Breaker Test Plan. A complete description of command parameters is given in "TDR9000™ TRXField™ Software and Test Plan Dynamics" on page A-28.

These three tabs include:

- **XXX Parameters** (XXX is the test being run) – Refer to "Parameters Tab".
- **Trigger Input** – Refer to page 4-64.
- **Trigger Output** – Refer to page 4-66.

The **Trip Parameters** window (Figure 4.37) is used to explain functionality. The Trigger Input and Trigger Output windows are the same regardless of test type. Additional parameters for the Close test are listed in Table 4.4 on page 4-61. Table 4.5 on page 4-62 lists the general command parameters from the **XXX Parameters** tab that are available by test type.

Configuring the Command Parameters

Configuring the command parameters for a test depends on the test type. The Command Parameters window can be accessed in one of two ways:

- Click the **XXX Parameters** button.

or

- Click either the **Trigger In** or **Trigger Out** System module Virtual Front Panel connectors, as shown in Figure 4.35.

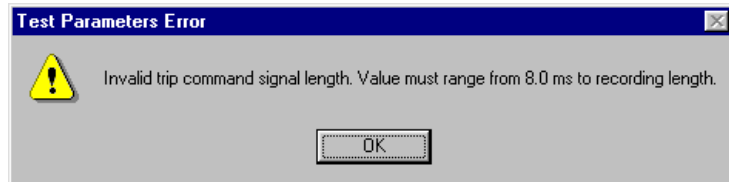


**Figure 4.35 Virtual Front Panel Trigger Connectors**

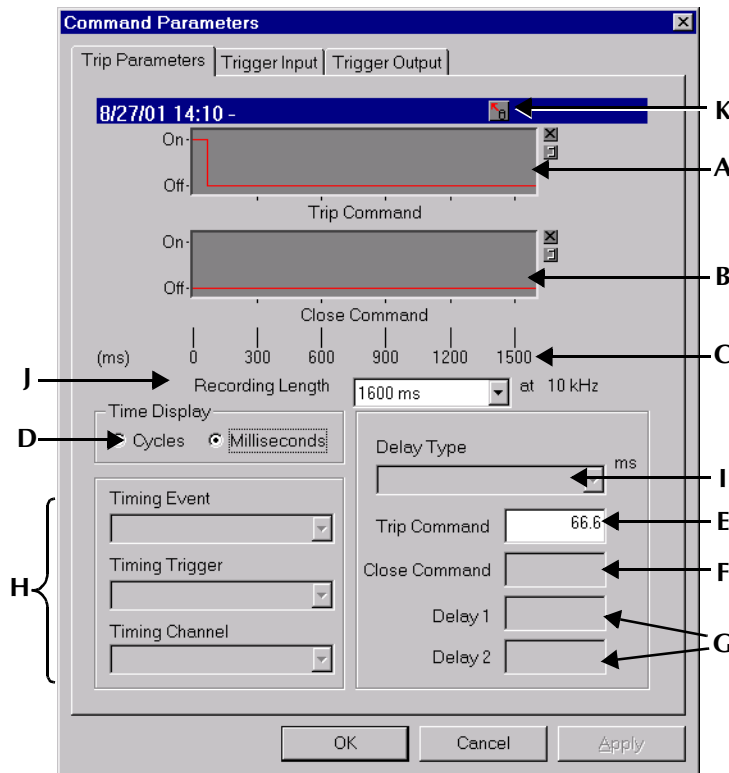
*Parameters Tab* Figure 4.37 shows the Parameters tab followed by discussions of its components.



**If the combination of values entered in these fields is operationally invalid, when the OK button is clicked a Test Parameters dialog box appears describing the conflict (Figure 4.36). Action must be taken to resolve the conflict before proceeding.**



**Figure 4.36 Test Parameters Error**



**Figure 4.37 Trip Parameters**

**NOTE**



**For the Slow Close test the following parameters are available: Recording Length, Time Display, and Timing Events as listed in Table 4.4.**

The Trip parameters identified in Figure 4.37 on page 4-59 are defined as follows:

- A**                    A *Trip Command* graph that displays the Trip waveform produced by the present test parameters.
- B**                    A *Close Command* graph that displays the Close waveform produced by the present test parameters.
- C**                    A measurement scale with dimensions that toggles between cycles or msec.
- D**                    Radio buttons for displaying measurements in time or in cycles.
- E**                    A *Trip Command* field where the Trip duration is input or changed. This is then displayed in item A.
- F**                    A *Close Command* field where the Close duration is input or changed. This is then displayed in item B.
- G**                    Two delay fields, *Delay 1* and *Delay 2*, where the Trip or Close command test delays are input or changed.
- H**                    A series of fields that configure the test timing functions for Close only. These fields are activated when Close is selected as the test type. Selections made on this list activate the *Timing Event* picklist and the *Timing Trigger* and *Timing Channel* picklists as listed in Table 4.4.  
  
Timing Trigger and Timing Channel depend on the timing event selected.  
  
The *Timing Channel* picklist displays all configured channels and sets the channel where recording is performed.

**Table 4.4 Close Test Timing Functions**

<b>Timing Event Selection</b>	<b>Timing Trigger Picklist Available?</b>	<b>Timing Channel Picklist Available?</b>
Test Initiation	No	No
Close Current	Yes	No
Analog	Yes	Yes - Analog channels listed
AUX Contact	No	Yes - Auxiliary channels listed

These parameter selections are fully discussed in the *"Close Pulse (Timing)"* on page A-37.

The Delay Type picklist determines whether a Standing, Delay, or Contact 1 Make is used.

The Reclose, Trip Free and O-C-O versions of this window have a scrollable picklist, which contains the Standing, Delay, and Contact 1 test choices. Each of these choices activates the Trip, Close, and Delay 1 and 2 fields as listed in Table 4.5.

**Table 4.5 Command Parameters**

<b>Test Type</b>	<b>Command Parameters</b>
<b>Reclose (O-C)</b>	
Standing	Trip Command
Delay	Trip Command Delay 1
<b>Trip Free (C-O)</b>	
Standing	Close Command
Delay	Close Command Delay 1
Contact 1 Make	Close Command
<b>O-C-O</b>	
Standing	Trip Command Close Command Delay 2
Delay	Trip Command Close Command Delay 1 Delay 2
Contact 1 Make	Trip Command Close Command Delay 1

**J** A *Recording Length* field where a recording length is selected from a picklist. Each recording length has a sampling rate associated with it. When a length is selected, the sampling rate appears on the window next to the picklist. Table 4.6 lists the Recording Lengths and their associated sampling rates.

## NOTE



When a test with a length greater than 5 minutes is completed, the Safety Bypass Plug must be used. The TDR9000 will not commence a test without it.

**Table 4.6 Recording Lengths and Sampling Rate**

Recording Length	Sampling Rate
500 ms	10 kHz
1600 ms	10 kHz
10 s	1 kHz
30 s	500 Hz
1 min	200 Hz
5 min	50 Hz
20 min	10 Hz

**K**

A Signal Viewer functionality button that is used to restore both the Trip Command or Close Command graph once they have been closed. Right-click anywhere on the **Parameters** window to access Signal Viewer help or the Signal Viewing Properties window.

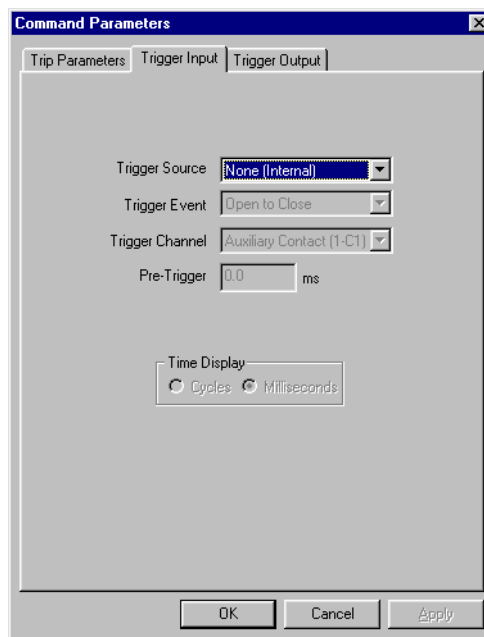
*Trigger Input Tab*

Trigger inputs can be configured for all tests, except Continuity, Self-Diag., Capacitance and Slow Close, using the **Trigger Input** tab (Figure 4.38) for the test being run. The default configuration for this tab is to have a *Trigger Source* of *None(Internal)*. It causes the external trigger inputs to be inactive and causes the TDR9000 firmware to initiate a test in response to input from the safety switch.

**NOTE**



**Selecting None(Internal) requires the use of the safety cable. Selecting either external trigger input type requires the use of the safety bypass flag.**



**Figure 4.38 Trigger Input Tab**

The following parameters are configured on the Trigger Input tab:

*Trigger Source*

This picklist is used to select either:

- **AUX Contact** trigger  
This is when the trigger comes through one of the Auxiliary contacts of the Event module. This selection does not automatically activate the auxiliary contact channel for recording. The channel must be activated via the Test Plan tab also.

or

- **Trigger In** trigger  
This is when the trigger comes in through the Trigger In connectors of the System module. This selection automatically activates the channel for recording.

*Timing Event*

This picklist is used to select the change in contact status that causes the trigger and initiates data recording. Choices available depend on the *Trigger Source* and are outlined in Table 4.7.

**Table 4.7 Trigger Input Timing Events**

Trigger Source	Timing Events Available
AUX Contact	<ul style="list-style-type: none"> <li>• Open to Close</li> <li>• Close to Open</li> <li>• Volts On to Off</li> <li>• Volts Off to On</li> </ul>
Trigger In	<ul style="list-style-type: none"> <li>• O → C or On → Off (Open to Close or Volts On to Volts Off)</li> <li>• C → O or Off → On (Close to Open or Volts Off to Volts On)</li> </ul>

*Trigger Channel*

This picklist is used to select the channel configured to accept the trigger input. It is only active when *AUX Contact* is in use for the *Trigger Source*. The number of channels available depends on the number of Event modules in the TDR9000.

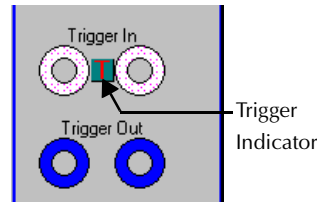
*Pre-Trigger*

This user-entered field sets the length of time, in ms or cycles, prior to a triggering event for which data is retrieved from the circular buffer. The TDR9000 is able to do this because it continually records data once the Continue button is clicked for an external trigger test. The pre-trigger time is subtracted from the total recording time; the overall recording time does not change.

*Time Display*

These two radio buttons toggle the time units between ms and cycles.

When **OK** is clicked on the **Parameters** window, the **TDR9000** tab reappears with a *T* icon displayed, as shown in Figure 4.39. This icon indicates that a trigger is configured.

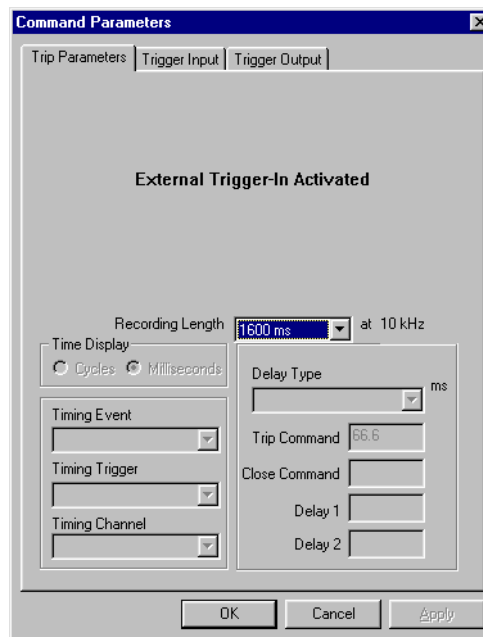


**Figure 4.39** *Trigger Indicator*

**NOTE**



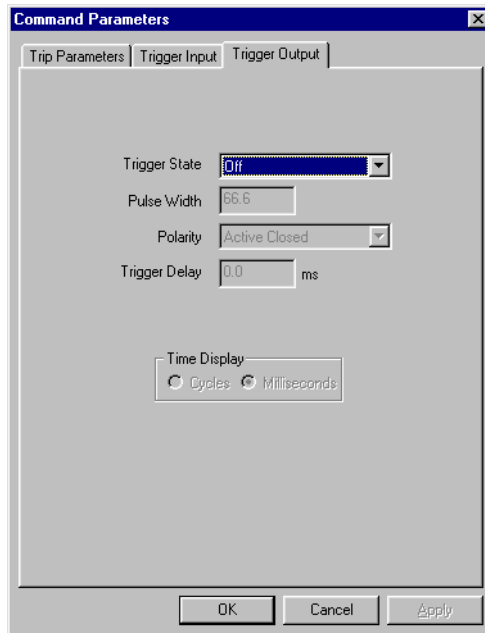
Once any external trigger is configured, all fields on the **Parameters** tab except the **Recording Length** are disabled and it appears as shown in Figure 4.40.



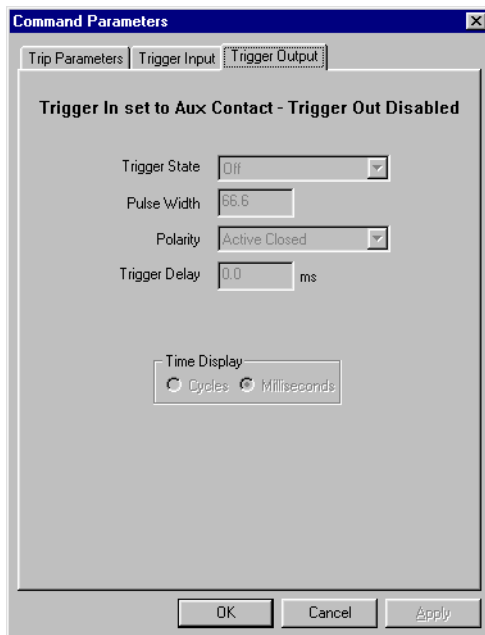
**Figure 4.40** *Trigger In Activated*

*Trigger Output Tab*

Trigger outputs may be configured for all tests, except Continuity, Self-Diag., Capacitance and Slow Close, using the **Trigger Output** tab (Figure 4.41) for the test being run. When this tab is selected, the *Trigger State* is set to **Off**, which deactivates the output triggers from the Virtual Front Panel. This also occurs when the *Trigger In* is set to *Aux Contact* (Figure 4.42).



**Figure 4.41 Trigger Output Tab**



**Figure 4.42 Trigger Output Tab: Trigger In set to Aux Contact**

The following parameters are configured on the **Trigger Output** tab:

- |                      |  |
|----------------------|--|
| <i>Trigger State</i> | This picklist toggles the trigger output On or Off and activates the other fields.   |
| <i>Pulse Width</i>   | A user-entered field that sets the pulse width of the trigger out command in ms or cycles. This is the length of time that the Trigger Output remains in the active condition. |
| <i>Polarity</i>      | <i>Active Closed</i> only.   |
| <i>Trigger Delay</i> | This user-entered field sets the length of time between the start of the test and when the trigger is set.   |

**NOTE**



**A negative time value for Trigger Delay causes the start of recording to be delayed by that time value after the inception of the Trigger Out command. A negative Trigger Delay can only be used when the Trigger Source for the Trigger Input is set to None(Internal).**

*Time Display* Two radio buttons that toggle the time units between ms and cycles.

When **OK** is clicked on the **Parameters** window, the **TDR9000** tab reappears with the *Trigger Out* channel connectors activated.

## Running Tests

This section explains the procedures involved in running tests and saving Test Results to disk. These include:

- Removing Safety Grounds
- Using the Pretest Checklist
- Running the Continuity Test
- Running Other tests
- Saving Test Results for importation to the back office server running TRX
- Disconnecting after the test is complete

## Removing Safety Grounds

Before the test can be run, ground connections must be removed from either side of the circuit breaker. Certain electrical/physical conditions, however, may dictate which safety grounds can safely be removed. Refer to the warning below.

### WARNING



**If the circuit breaker is closely connected to a transformer (there is no disconnect switch between the transformer and the circuit breaker) whose neutral is grounded, the safety grounds that remain must be the ones between the transformer and the circuit breaker.**

**If there is high voltage between one side of the circuit breaker and the closest isolating disconnect switch, the safety grounds that remain must be on the long section of the high-voltage bus.**

## Using the Pretest Checklist

Use the checklist given in Table 4.8 to ensure that the system is safely configured for testing. Once this Pretest Checklist is complete, DC power can be restored to the circuit breaker Trip and Close circuits, and AC power can be applied to the Instruments.

**Table 4.8 Pretest Checklist**

Item	✓
Circuit breaker under test is removed from service according to government and company safety rules (Not applicable to First Trip/Close tests)	
A Safety Ground cable is installed on the TDR9000	
Proper AC power is available	
One end of each phase of the circuit breaker is grounded (Not applicable to First Trip/Close tests)	
All cables are connected to the TDR9000	
Transducer Connecting Rod is coupled to the circuit breaker rod (Not applicable to First Trip/Close tests)	
Rotary Attachment is installed (optional- not applicable to First Trip/Close tests)	
All Motion Transducer cables are connected to the transducer (Not applicable to First Trip/Close tests)	
All Contact Monitor cables are connected to the circuit breaker bushings (Not applicable to First Trip/Close tests)	
All test parameters are configured via the Virtual Front Panel or Test Plan	
All the current probes are zeroed (if used)	

## Running the Continuity Test

The Continuity Test is recommended. This test confirms that all Main Contact cable clamps are properly connected. Run this test after equipment setup is complete and before any other test is run.

The Test Results shown in Figure 4.8 on page 4-70 include the channel label and a Pass/Fail indication whose text format is configured on the **TRX Options** window (see page A-31).

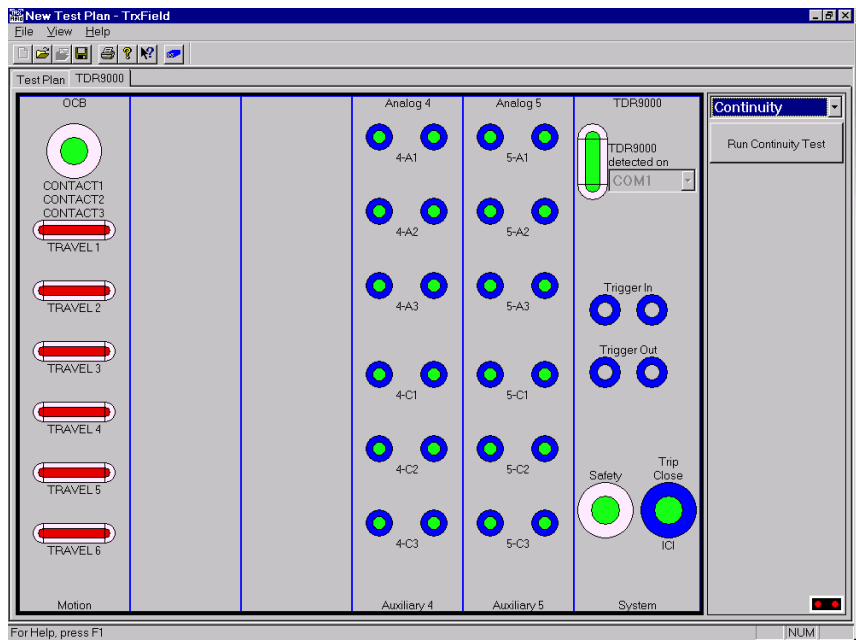
### Note



**This test *MUST* be performed with the circuit breaker closed.**

To perform a Continuity test:

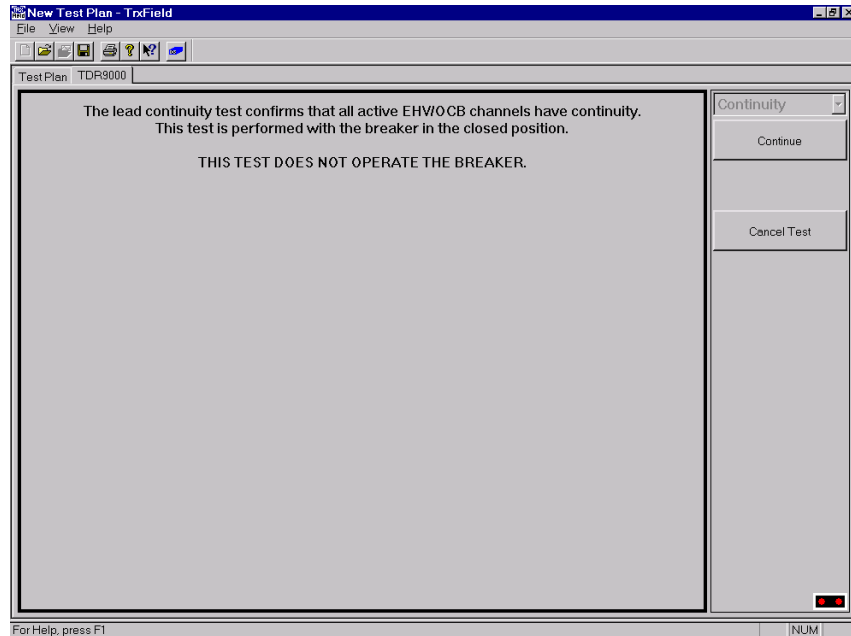
1. Select **Continuity** from the picklist of the right side of the Virtual Front Panel, as shown in Figure 4.43.



**Figure 4.43 Continuity Test Selection**

2. Click **Run Continuity Test**.

The **Run Continuity Test** window appears (Figure 4.44).

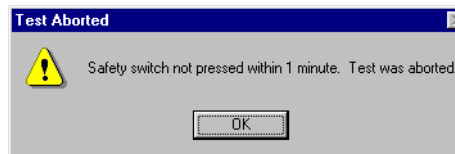


**Figure 4.44 Run Continuity Test**

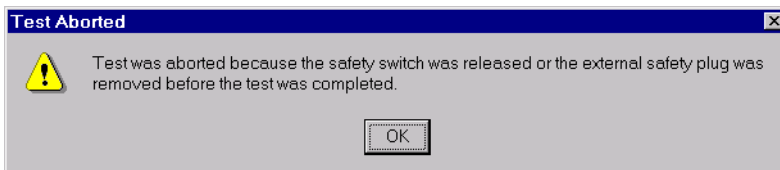
3. Click **Continue**.

Once the test data is loaded, an alarm sounds from the TDR9000.

4. Press the button on the Safety Switch cable until the alarm ceases.
  - If the Safety Switch is not pressed within 60 seconds, the test is aborted and the window shown in Figure 4.45 appears.
  - If the Safety Switch is released before the alarm ceases, the test is aborted and the window shown in Figure 4.46 appears.

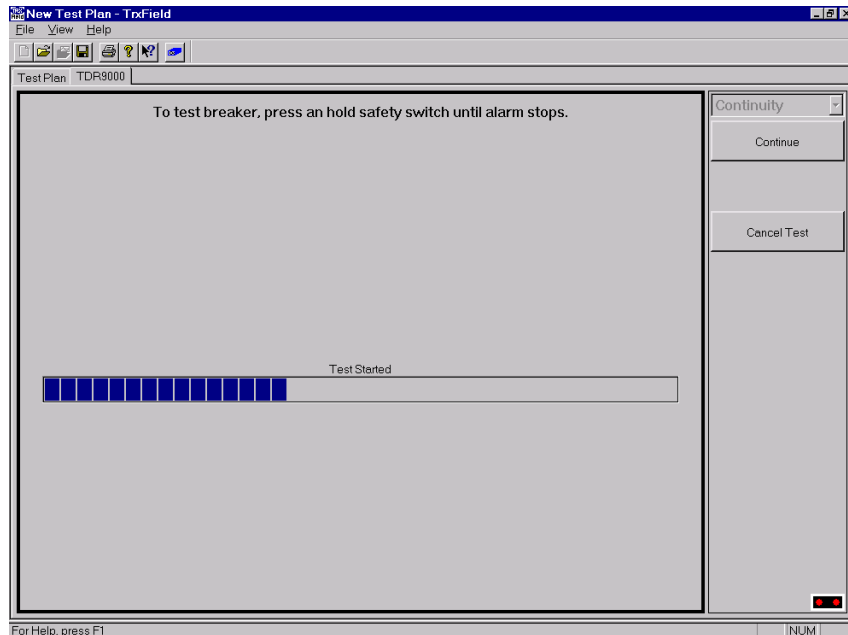


**Figure 4.45 Test Abort Message – Switch Release**



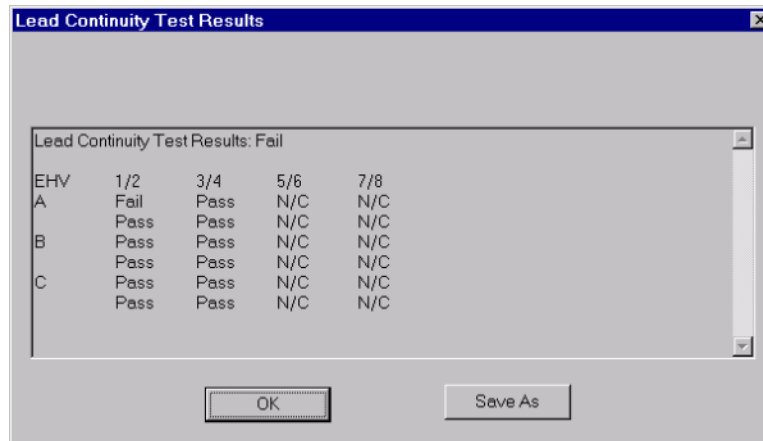
**Figure 4.46 Test Abort Message – Switch Not Operated**

The window shown in Figure 4.47 appears as the data is collected.



**Figure 4.47 Continuity Test Execution**

When the test is successfully completed, the **Continuity Test Results** window appears (Figure 4.48). The active channels are listed, along with a Pass/Fail designation.



**Figure 4.48 Continuity Test Results**

If the Continuity Test fails, check all test connections starting with the circuit breaker connections and then the TDR9000 Physical Front Panel connections.

## Running Tests

With the TDR9000 properly connected to the test environment and the Virtual Front Panel configured with the proper channels and values, a first test can be run.

### Running a First Trip/Close Test: Special Considerations

Special considerations include:

1. Run the First Trip test.

The TDR9000 records the test results after the circuit breaker is tripped externally.

2. Run the First Close test, after making the following changes in the preparations described above:

- Change the Analog Channel label in the Test Plan from Trip Coil to Close Coil.
- Move the current probe measuring the Trip relay coil current to measure the Close relay coil current.
- Change the Auxiliary Contact label in the Test Plan from 52CS/T to 52CS/C.
- Move the Aux Contact channel cables on the circuit breaker from across the 52CS/T contacts to across the 52CS/C contacts.

This serves as the trigger source for the First Close operation.

3. Repeat both the Trip and Close tests, alternating the connections and labels as described in step 2, for comparison of the First Trip/Close tests to subsequent tests.

To reduce time re-labeling of the Analog and Auxiliary Contact channels when alternating between First Trip and First Close, the channels being used to measure First Trip/Close relay coil current and Trigger source contact state can be given a more generic label, such as T/C Coil for the Analog channel and 52CS/T-C for the Auxiliary Contact channel.

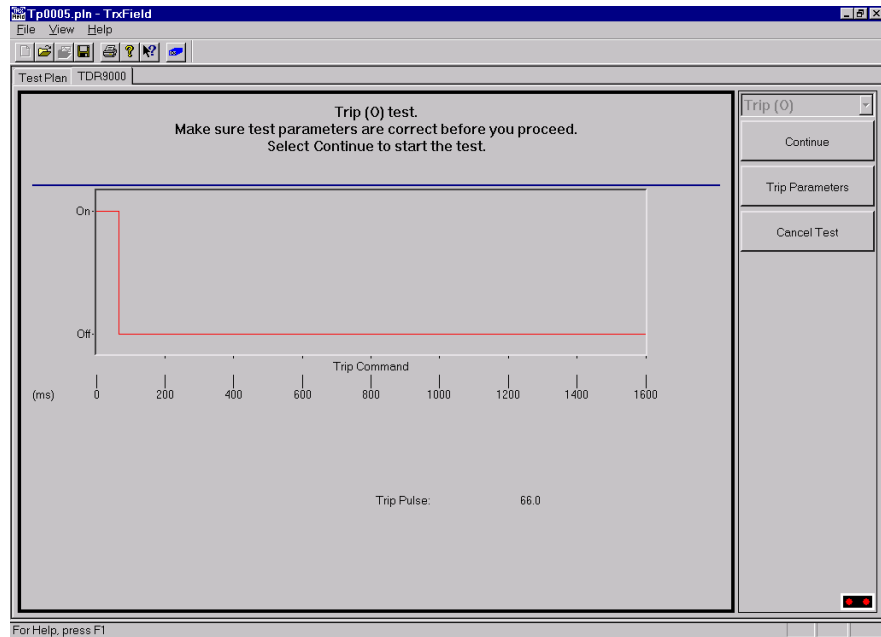
To run the test:

1. Select a test type from the picklist on the upper right corner of the window.
2. Click **Run XXX Test** where **XXX** designates the type of test.

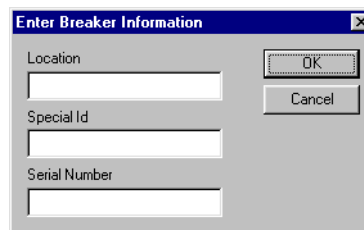
The Virtual Front Panel then appears as shown in Figure 4.49. This window displays the values of the configured command parameters and allows for confirmation by the operator.



**If the fields shown in Figure 4.50 have not been correctly filled in on the Test Plan, the Enter Breaker Information window appears. This window contains the fields constituting the minimal information required to identify a specific breaker in the field. If Special ID is not used, enter *NONE*.**



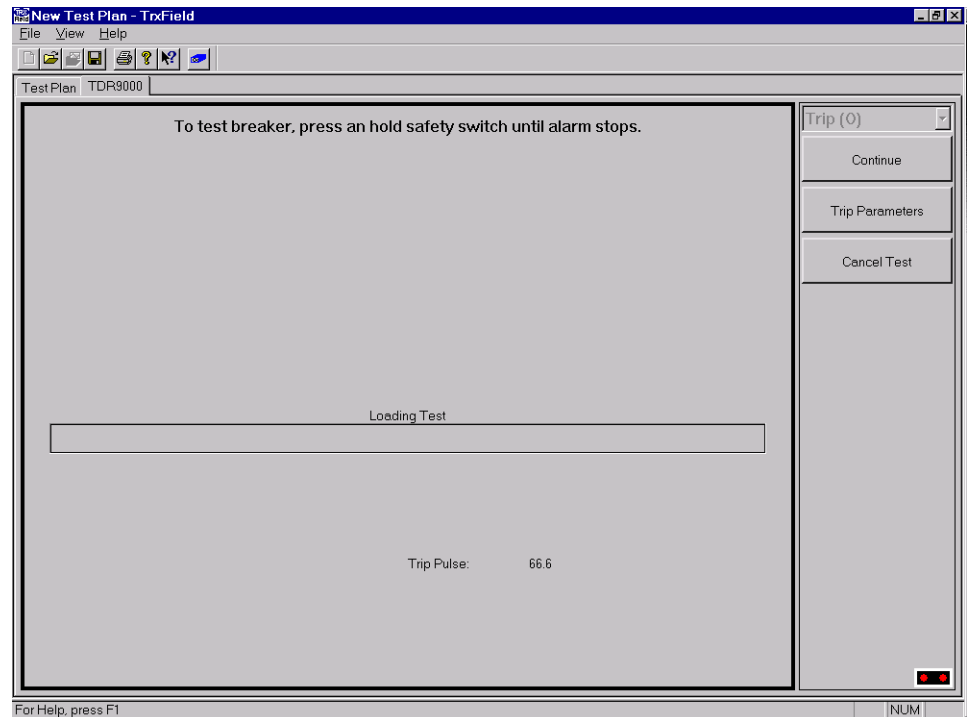
**Figure 4.49 Enable Safety Switch**



**Figure 4.50 Enter Breaker Information**

3. Click **Continue**.

A status bar appears on the window (Figure 4.51) as the test data is loaded.



**Figure 4.51 Loading Test**

Once the test data is loaded, an alarm sounds from the TDR9000.

**NOTE**



**For externally triggered tests, perform the action to activate the trigger and skip step 4.**

4. Press the button on the Safety Switch cable until the alarm ceases.

**WARNING**



**This is the last warning before circuit breaker operation, so make sure all safety issues are in compliance.**

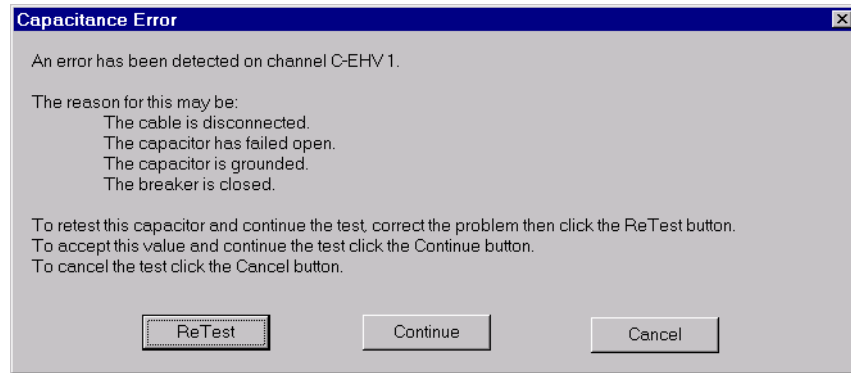
**NOTE**



**For a Capacitance test, making sure all safety issues comply is a lengthy process. The Loading Test status bar cycles a minimum of six times and a maximum of eight times.**

### Capacitance Test Errors

During a Capacitance test, a Capacitance Error dialog box may appear (Figure 4.52).



**Figure 4.52 Capacitance Testing Error**

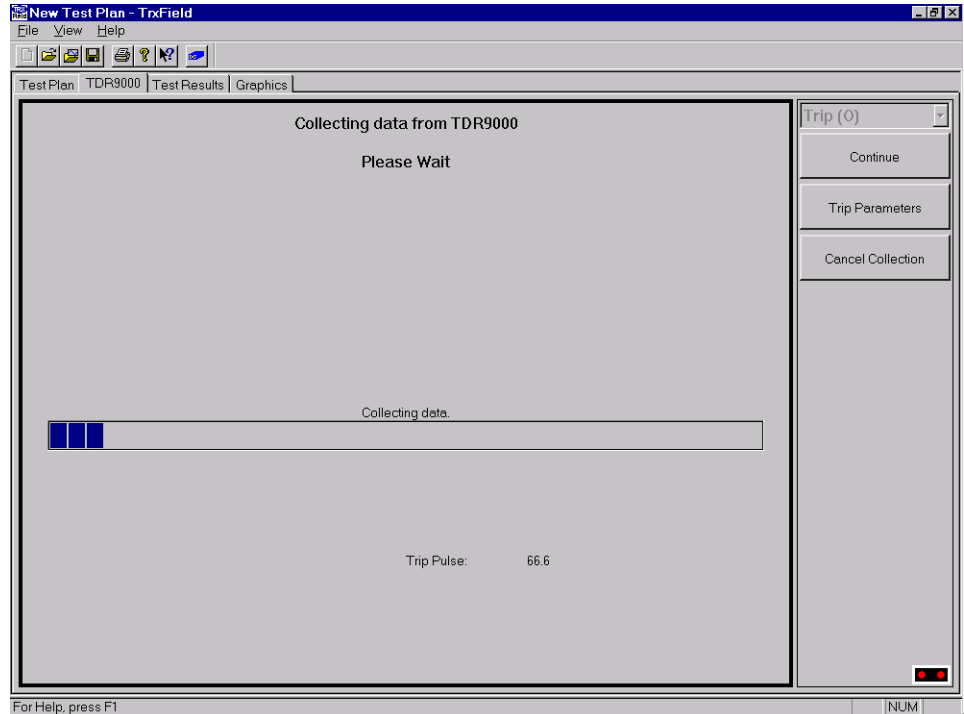
If this occurs, click one of the buttons:

- **ReTest** to start the test over after fixing the problem.
- **Continue** to accept a potentially incorrect value and move to testing the next contact

or

- **Cancel** to abort the test

A status bar appears on the screen showing the progress of the data collection process (Figure 4.53).



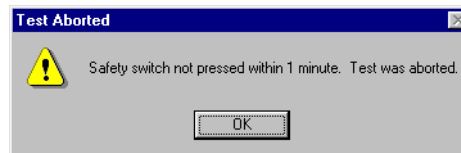
**Figure 4.53 Data Collection Status**

**NOTE**



Data collection times vary depending on the types and number of channels in use. This process can take several minutes.

- If the Safety Switch is not pressed within 60 seconds, the test is aborted and the window shown in Figure 4.54 appears.
- If the Safety Switch is released before the alarm ceases, the test is aborted and the window shown in Figure 4.55 appears.



**Figure 4.54 Test Abort Message – Switch Release**



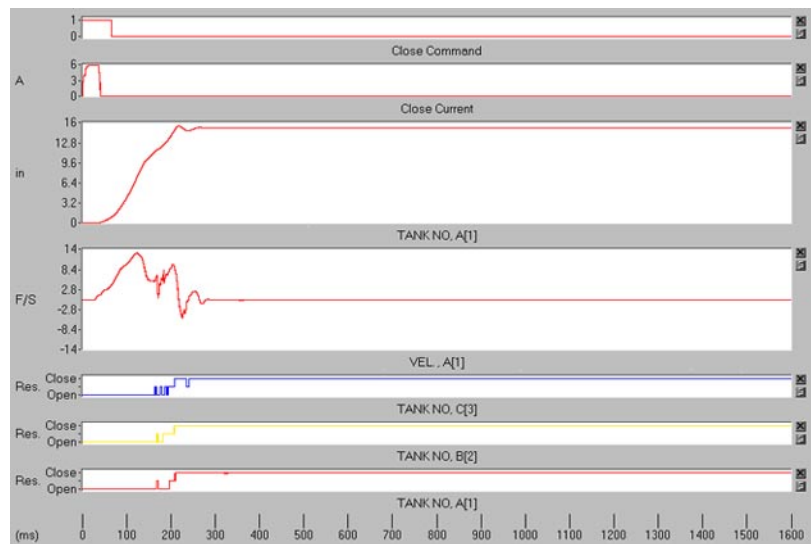
**Figure 4.55 Test Abort Message – Switch Not Operated**

Once data collection is complete, the TRXField software presents the information by switching to the **Graphics** tab. Figure 4.56 shows a sample graphical result.

**NOTE**



**Capacitance Test results do not include graphical results.**



**Figure 4.56 Graphics Tab with Results**

Tabulated test results are also available. Refer to *“Interpreting Test Results”* on page A-97 for an explanation of these.

## Working with Test Results

TRXField is designed to allow viewing of a Test Result file in both tabulated and graphical format, as well as viewing of the associated Test Plan. This can be done with one Test Result at a time or Test Results of a similar type can be overlaid and viewed together for comparison in the graphical format.

To work with the Test Results:

If a test has just been run, the Test Results appear as shown in Figure 4.56. Once a test is run the Overlay Graphics File menu item becomes active. The available tabs appear as in Figure 4.57.



**Figure 4.57 Navigation Tabs After a Test**

There are several options for working with Test Results. They can be manipulated using either:

- Signal Viewer
- Edit Specs. Tab
- Tabulation

### NOTE

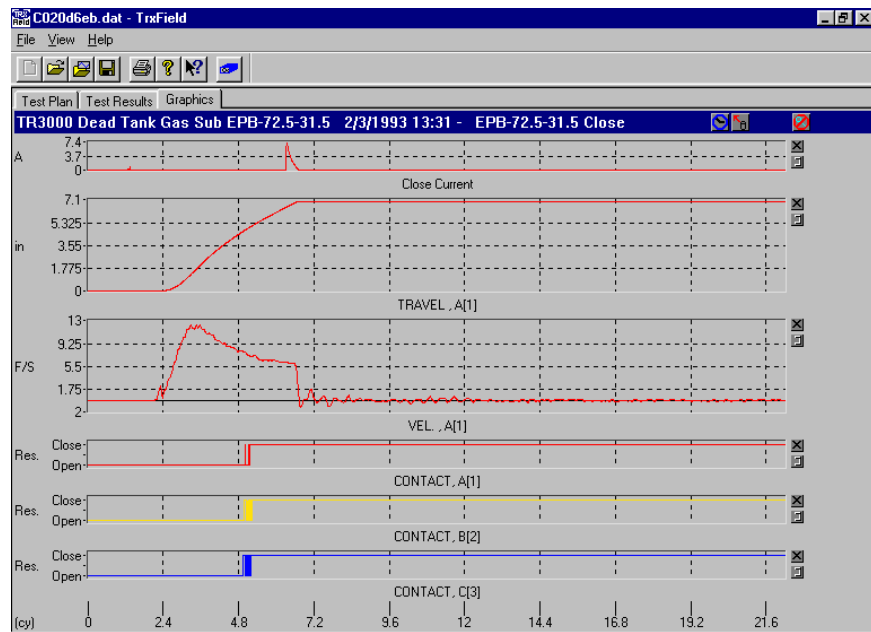


**This discussion deals with physically manipulating Test Results. Refer to "Interpreting Test Results" on page A-97 for details on interpreting the meaning of Test Results.**

## Signal Viewer

The Graphics tab of the TDR9000 works as part of another Doble Engineering program called Signal Viewer. For the most part, this program remains indistinguishable to the user as it relates to TDR9000 operation. As graphical results are used and manipulated, however, the Signal Viewer program is in use and the display properties of this program are accessible for configuration.

When viewing test results, they appear in graphical form (Figure 4.58) on the **Graphics** tab or in tabulated form on the **Tabulation** tab. The graphics can be zoomed, overlaid, and re-ordered. Cursors are used to mark key points of a channel and determine their value and time of occurrence. The Time and Channel values only appear when a cursor is active.



**Figure 4.58 Graphical Display of Test Results**

## Tabulation Tab

The Tabulation tab (Figure 4.59) is used to check measured values against the manufacturer's recommended limits. If the manufacturer's limits for the various measured parameters were entered in the Test Plan, TRXField compares the measured vs. manufacturer's limit and passes or fails each parameter. If no limits were entered into the Test Plan, no comparison can be made, but the measured values still appear.

This tab is useful when a user's time or skill level does not permit a detailed examination of a graphical display.

Main Contact Closing Time Measured From Test Initiation						
Specifications		Test results	Travel	Velocity	Compare	
Maximum	6.00 cy	CONTACT1 5.00 cy	4.768 in.	7.71 f/s	Pass	
Minimum	0.00	CONTACT2 4.99	4.758	7.92	Pass	
		CONTACT3 4.96	4.700	7.92	Pass	

Delta Main Contact Closing Time Within the Breaker			
Specifications		Test results	Compare
Maximum	0.20 cy	Breaker 0.04 cy	Pass

**Figure 4.59 Tabulation Tab (Partial View)**

## Graphics Tab

The Graphics tab, using the **Overlay** function, gives a detailed comparison between new Test Results and previous Test Results, as well as between the results of different circuit breakers of identical types and rating. Other tab features include **Zoom** and **Re-order**. The two cursors are used to determine channel values at precise moments in time, for example, to determine the time elapsed between two selected points, or the distance between two selected points. TRXField shows the difference between the primary (green) and secondary (red) cursor values by subtracting green from red, and then showing the difference in yellow.

*Displaying Time and Channel Values on the Graphs Tab*

Time and channel values appear only when a cursor is active, as described in "Cursors" on page 4-90. When a cursor is active, time appears in the lower left corner. The channel values appears to the right of each channel.

- Red channel values represent the point marked by the red cursor.
- Green channel values represent the point marked by the green cursor.

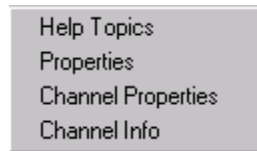
To display time and channel values:

1. Move the cursor to determine the value of the channel at different points in time. If both cursors are active, the difference between the two is also displayed in yellow.

When channels are overlaid, only time values appear.

2. Right-click a set of overlaid curves to obtain its values.

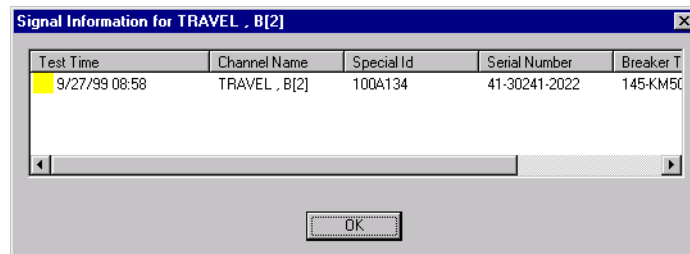
The menu shown in Figure 4.60 appears.



**Figure 4.60 Properties Window**

3. Select **Channel Info**.

The **Signal Information** window shown in Figure 4.61 appears.



**Figure 4.61 Signal Information Window**

4. Note the information needed to select the Test Result desired for further viewing.
5. Open a Test Result using the **Open** icon or the **File/Open** command. View it alone to see values for each channel when cursors are activated.

<i>Contact Timing Values</i>	In graphical mode, the following values appear for a Main Contact channel in a column on the right side of the <b>Data</b> window:
<b>O</b>	Indicates the contact was open at the time selected.
<b>C</b>	Indicates the contact was closed at the time selected.
<b>R</b>	Indicates the contact was in Resistor state at the time selected.
<b>O-R-C</b>	Indicates the contact was in a state of change at the time shown, and the selected sample time contained instances of the circuit breaker in the Open, Resistor, and Closed states.
<b>R-C</b>	Indicates the contact was in a state of change at the time shown, and the selected sample time contained instances of the circuit breaker in the Resistor and Closed states.
<b>O-R</b>	Indicates the contact was in a state of change at the time indicated, and the selected sample time contained instances of the circuit breaker in the Open and Resistor states

**NOTE**

**The compound states described for R and O-R-C may be the result of contact bounce during circuit breaker operation.**

<i>Trip and Close Current Values</i>	All trip and close current values appear as positive.
<i>Auxiliary Contact and Analog Values</i>	The following auxiliary and analog contact values appear:
<b>C</b>	Indicates the contact was closed at the time selected.
<b>OD</b>	Indicates the contact was open dry at the time selected.
<b>OW</b>	Indicates the contact was open wet at the time selected.
	All Current and Voltage values are positive.

*Time  
(Milliseconds  
or Cycles)* Time can be displayed in msec or cycles, regardless of the units selected in the original Test Plan.

To change the time format:

- Click the **mSec/Cycles** button for the Graphics tab.
- or
- Select the units under **Tools/TRX Options** before displaying the Test Results. All subsequent windows appear with the selected units.

Adjusting  
Displayed Test  
Results

Test Results can be zoomed vertically and horizontally, overlaid and re-ordered.

*Zoom*

To select and enlarge a portion of the channels:

1. Display the channels.
2. Ensure that the cursors are turned off.  
If they are on, click the **Cursor Delete** button.
3. Click the upper left corner of the channel area to be enlarged and hold the left mouse button.
4. Drag the mouse down to the bottom right corner of the channel area to be enlarged, and release the mouse button.

The area selected can include one or more channels.

- **Zoom** repeatedly to continue adjusting the displayed area.
- To **Unzoom**, click the **Unzoom** icon in the upper right area of the channel viewing area.

Channels return to their original display form.

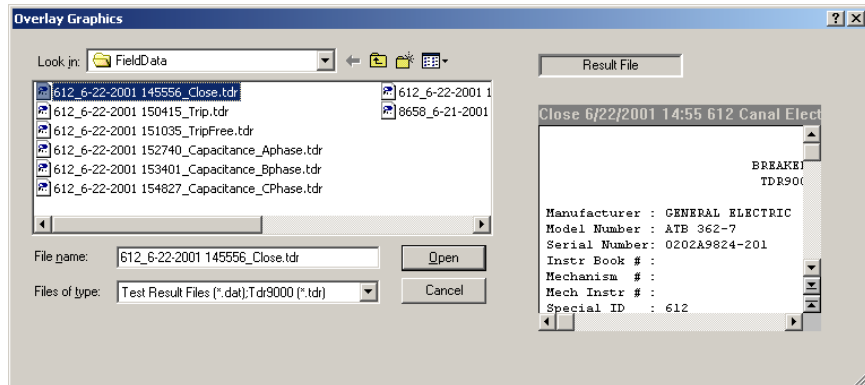
- To re-order the channels so that they can be zoomed together, or to overlay the channels before zooming, see the sections "Overlay" on page 4-87 and "Re-order Displayed Channels" on page 4-89.

*Overlay* Like tests from different circuit breakers can be overlaid using the **Tabulation** tab.

To overlay Test Results:

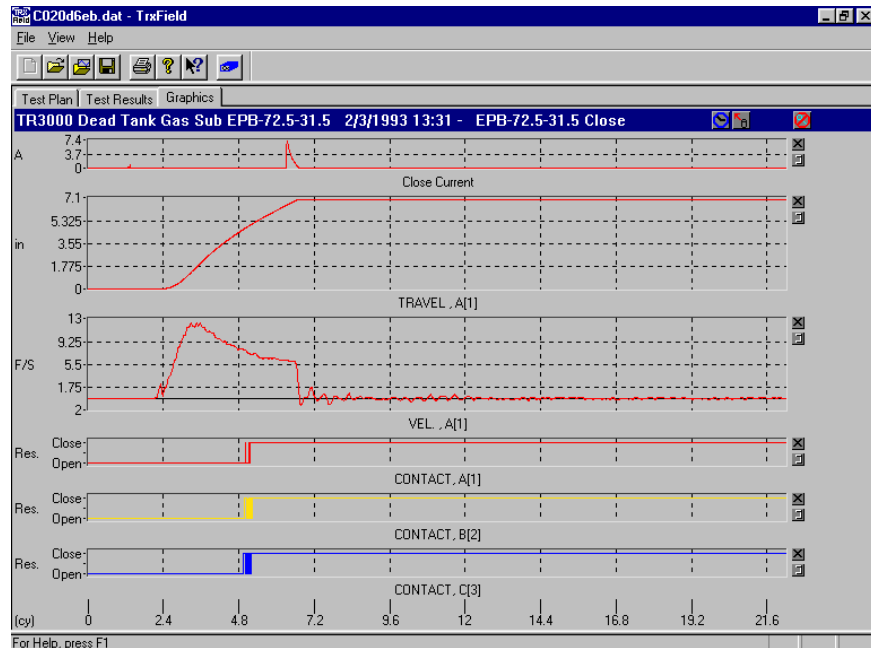
1. Select Overlay Graphics from the File menu.

The Overlay Graphics file selection window appears (Figure 4.62).



**Figure 4.62 Overlay Graphics File Selection**

2. Navigate to the desired folder and select a Test Result file and click **Open**.  
Test Result files have a *.tdr* extension.
3. Click the **Overlay Graphics** tab to view the overlay (Figure 4.63).  
Additional overlays can be added.



**Figure 4.63 Test Results with an Overlay**

The original Test Result is available for viewing alone in graphical format or in tabulated format, however, overlaid Test Results can only be viewed graphically by using the **Overlay Graphics** tab.

It is also possible to further overlay displayed signals (for example, the travel signals from different phases, if multiple transducers were used).

To do so:

1. Right-click either the **Graphics** or **Overlay Graphics** tab to access to the **Properties** window.

If the *Automatically Overlay Signals With The Same Name* box:

- Is checked, channels with the same name, such as all Main Contact channels, are automatically overlaid.
  - Is not checked, all overlays must be performed manually.
2. Point to the **Drag and Drop** icon to the right of a signal.
  3. Click and hold the mouse button.
  4. Move the mouse until it is over the target channel and the **Overlay** icon appears.
  5. Release the mouse button.

The two channels are now overlaid in the same channel frame. TRXField automatically selects different colors for each ("Channel Viewing Properties" on page 4-92).

6. To overlay more channels, Repeat steps 1 through 5.
  - When moving a channel:
    - If the **Re-order** icon appears, the user is re-ordering, not overlaying, the channels.
    - If the **Overlay** icon is displayed, channels are overlaid.
  - To restore all Test Results, select the **Reload Original** button.

*Re-order  
Displayed  
Channels*

Test Results can contain many channels. To remove unwanted channels:

- Click the **X** next to channels.  
This deletes the channels from the display only, not from the Test Results. Moving the channels up or down on the screen can make it easier to compare them.

To change the order in which the channels appear:

1. Use the **Open** icon or select **File/Open** to open a Test Result.
2. Click the **Drag and Drop** icon next to the channel to be moved.
3. Drag the mouse to the new location for that channel.

The **Re-order** appears.

4. Release the mouse button.

**NOTE**



**If the Overlay icon appears and the mouse button is released by mistake, the channel is overlaid, rather than re-ordered.**

To restore the entire Test Result:

- Click the **Reload Original** button.

*Cursors*

TRXField has a primary (green) and a secondary (red) cursor, or vertical marker, which is used to determine either the value of a channel or the time elapsed at one or more chosen points.

The time appears in the bottom right corner of the data screen. The channel values appear to the right of each channel.

Facts about cursors include:

- Precisely positioning the cursors determines the time and distance values for a channel which can then be compared to the manufacturer's specifications.
- If the primary cursor (green) appears, the time and values are displayed in green.
- If both the primary and secondary cursors appear, the times and channel values at each cursor point appear. These values appear in their respective colors (green and red), with the delta value for time in yellow, along the right side of the **Data** window.

To activate the cursors:

1. Activate the primary (green) cursor first.  
Position the mouse at or near the point of interest on the channel.
2. Click the mouse and the green cursor appears, along with the cursor **Delete** button (green).
3. Reposition the cursor by clicking the mouse repeatedly.

4. Use the keyboard to make precision moves (Table 4.9).  
Each 1600 mSec channel consists of 16,000 samples.

**Table 4.9 Keyboard Selections for Precision Cursor Movement**

Key	Cursor Direction
Left arrow	Moves 0.1 mSec (1 sample) left.
Right arrow	Moves 0.1mSec right.
Up arrow	Moves 1 mSec (10 samples) left.
Down arrow	Moves 1 mSec right.
Page Up	Moves 10 mSec (100 samples) left.
Page Down	Moves 10 mSec to the right.
Home	Moves to the first displayed mSec.
End	Moves to the last displayed mSec.

Once the primary cursor is active, the secondary cursor can also be activated.

5. Position the mouse at or near the second point of interest on the channel.
6. Right-click and the red cursor appears.  
The **Cursor Delete** button changes to red, indicating the secondary (red) cursor is now active.
7. Reposition this cursor by clicking the right mouse button repeatedly.
8. Precision moves can be made using the keyboard as described in step 4.

The keyboard acts on the active cursor only. The **Cursor Delete** button indicates whether the active cursor is the primary (green) or secondary (red). Click the mouse, or press **Ctrl-P** to activate the green cursor, and right-click or press **Ctrl-S** to activate the red cursor.

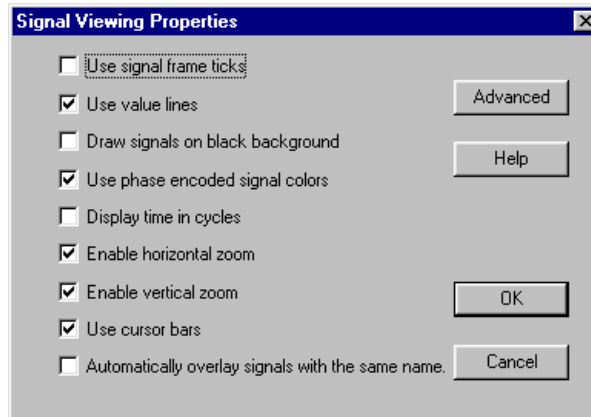
Clicking on the **Cursor Delete** button deletes the cursors.

*Channel Viewing Properties*

To change the way channels are viewed:

1. Display a graphical Test Result.
2. Right-click in the **Data** window before activating any cursors.
3. From the resulting menu, choose *Properties*.

The **Signal Viewing Properties** window appears (Figure 4.64).



**Figure 4.64** *Signal Viewing Properties*

The following checkboxes can be selected:

**Use signal frame ticks**

Adds a tiny vertical tick under each vertical value line outside the signal frame.

**Use value lines**

Adds vertical and horizontal value lines to the channel frames.

**Draw signals on black background**

Makes the channel frame background black (de-selecting makes it gray).

When printing, the background is always white and is not affected by this command.

**Use phase encoded signal colors**

Enables the automatic encoding of phases in the display, as shown in Table 4.10.

If more than four Test Results are displayed, this feature automatically turns off. The result is that all channels from a given circuit breaker become the same color. It is assumed that with five or more circuit breakers, a comparison of channels among different circuit breakers is more necessary than a comparison of different channels associated with the same circuit breaker.

**Table 4.10 Phase Encoded Signal Colors**

Test Result In Frame	Phase	Color
First	Phase A	Red
	Phase B	Yellow
	Phase C	Blue
Second	Phase A	Purple Bright
	Phase B	Green
	Phase C	Bright Light Blue
Third	Phase A	Brown
	Phase B	Olive Green
	Phase C	Purple Medium Dark
Fourth	Phase A	Black
	Phase B	Green Flat
	Phase C	Blue Flat

**Automatically overlay signals with the same name**

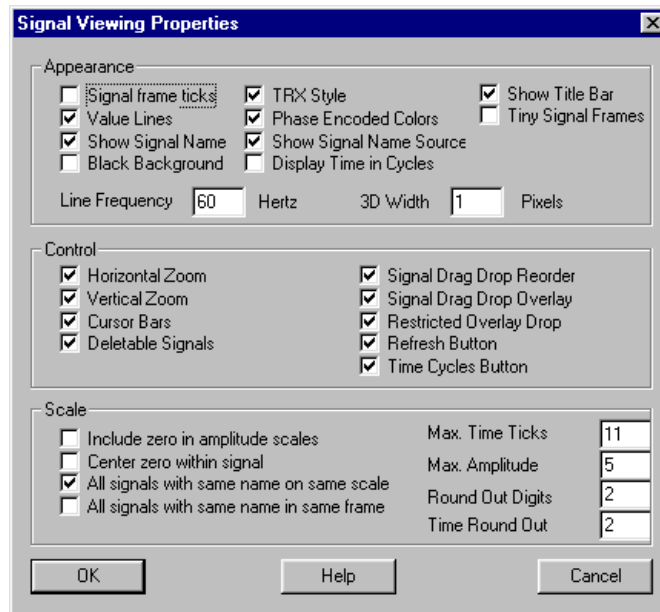
Overlays similar channels automatically.

*Channel Viewing  
Advanced  
Properties*

To access advanced channel viewing properties:

- Click the **Advanced** button.

The **Signal Viewing Properties Advanced** window shown in Figure 4.65 appears.



**Figure 4.65** *Signal Viewing Properties Advanced Window*

**NOTE**



**Doble recommends that these defaults remain unchanged.**

Using the Edit Specs. Tab

The Edit Specs. tab appears once the test is run. This tab contains all the fields that were configured for the test. Some fields can be edited. The effects of changing the parameters can then be viewed on the Graphics and Test results tabs. This is merely an analysis tool, as the original Test Results file and the original Test Plan configuration remain intact.

## Saving Test Results/Test Plans

Once a test is complete:

- Save the Test Results, which includes a portion of the Test Plan or
- Save the Test Plan as either:
  - Library Test Plan
  - Specific Circuit Breaker Test Plan

If circuit breaker specific information, such as *Serial #*, *Special ID* or *Location*, is included, the file is automatically saved as a Circuit Breaker Test Plan.

Both types of files fit onto a floppy disk and should be loaded into the TRX software database in the home office for storage, for further use, or in the case of Test Results, for comparison against previous tests.

### Test Results

#### NOTE



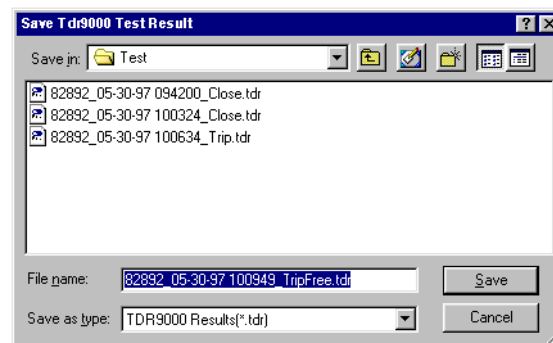
To save Test Results from the **Graphics** or **Tabulation** tab:

**When saving a Capacitance test the filename structure is:**  
**[Special Id][Date][Time]capacitance.TDR**

1. Click **Save** on the **File** menu.

If a test has been run and the **Tabulation** or **Graphics** tab is selected, the data is saved as a Test Result File.

The **Save TDR9000 Test Result** window appears, as shown in Figure 4.66.

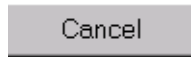


**Figure 4.66 Save TDR9000™ Test Result**

2. Navigate to the desired folder and click:



To save the Test Results.



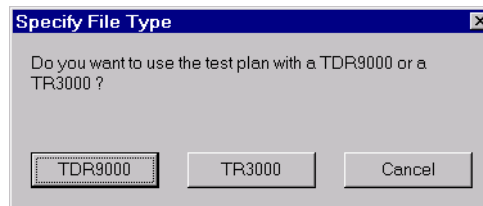
To return to step 1 and select another directory.

## Test Plan

To save Test Results from the **Test Plan** or **TDR9000** tab:

1. Click **Save** on the **File** menu.

The **Specify File Type** window appears as shown in Figure 4.67.



**Figure 4.67 Specify File Type Window**

2. Select the type of save to perform:

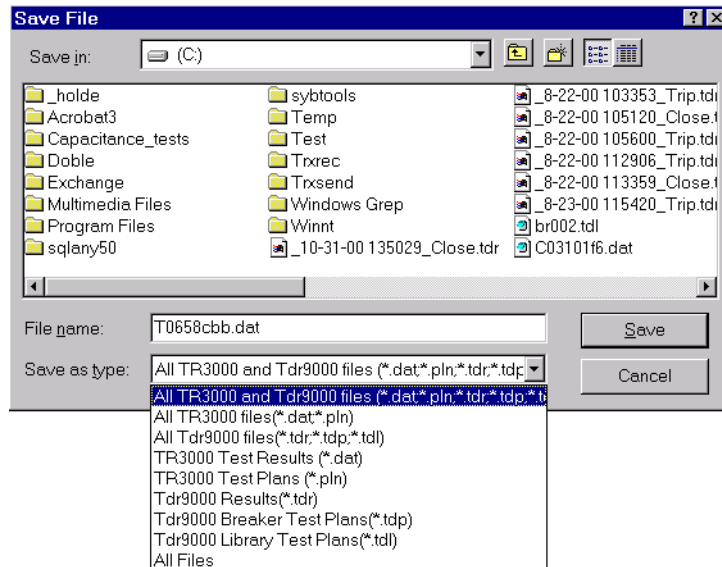
- Click the TDR9000 button.

The window shown in Figure 4.66 appears. Follow the procedure for saving Test Results, starting at step 2 of "Test Results" above.

or

- Click the TR3000 button.

The window shown in Figure 4.68 appears.



**Figure 4.68 Save File**

3. Enter a file name and click **Save**.

**NOTE**



**It is possible to use a file type other than the default .dat, however, doing so restricts later use of the file and makes locating the file more difficult.**

**Closing Without Saving**

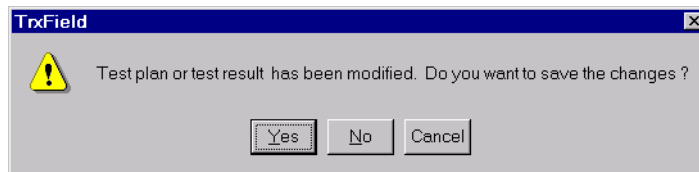
If the Close icon on the upper right of the TRXField window is clicked before a save is completed, the following sequence of events occur:

A dialog box appears asking whether to save the Test Results or Test Plan, as shown in Figure 4.69.

**NOTE**

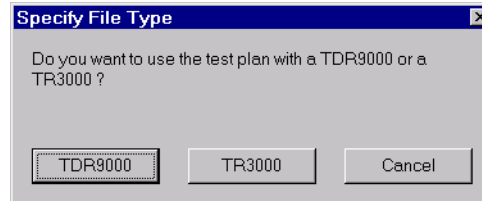


**If no changes are made to the Test Plan, even if a test is run, this dialog box does not appear. The software immediately proceeds to Figure 4.70.**



**Figure 4.69 Saving a Test Plan**

1. Click **Yes** and the **Specify File Type** window appears as shown in Figure 4.70.

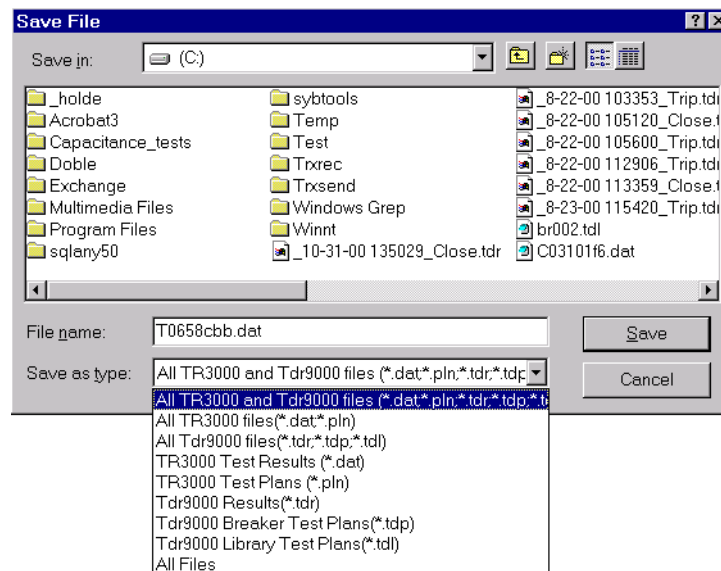


**Figure 4.70 Specify File Type Window**

2. Select the type of save to perform:
  - Click the TDR9000 button.  
The window shown in Figure 4.66 on page 4-95 appears. Follow the procedure for saving Test Results, starting at step 2 of "Test Results" on page 4-95.

or

- Click the TR3000 button.  
The window shown in Figure 4.71 appears.



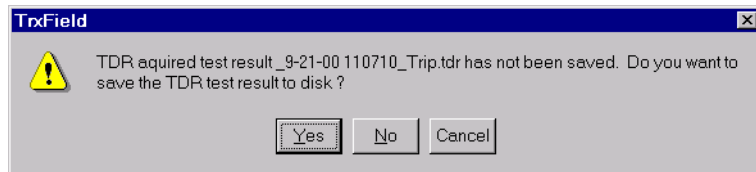
**Figure 4.71 Save File**

**NOTE**

3. Enter a file name and click **Save**.

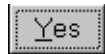
**It is possible to use a file type other than the default.dat, however, doing so restricts later use of the file and makes locating the file more difficult.**

At this time, if the Close icon on the **Choose Test Plan or Result Destination** window is clicked the dialog box shown in Figure 4.72 appears.

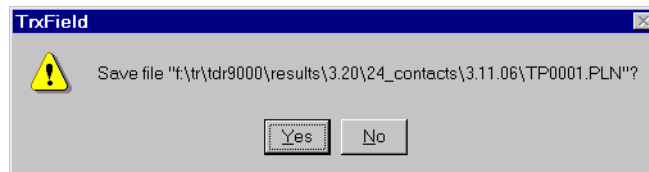


**Figure 4.72 Final Save Warning I**

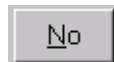
4. Select one of the following buttons:



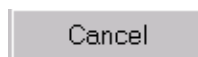
To save the Test Plan by clicking **Yes** on the dialog box shown in Figure 4.73.



**Figure 4.73 Final Save Warning II**



To exit without saving the Test Plan.



To return to step 1 and select another directory.

## Printing Test Results

Test Results can be printed before or after saving the Test Results.

- If the **Test Plan** or **TDR9000** tab is selected when printing, the contents of the **Test Plan** tab prints.
- If the **Tabulation** tab is selected when printing, the contents of the **Tabulation** tab prints.
- If the **Graphics** tab is selected when printing, the contents of the **Graphics** tab prints.

To print Test Results before a save is performed:

1. Click the tab containing the type of results for printing.
2. Click the Print icon shown below.



The Test Results are sent to the Windows default printer.

To print the Test Results of an existing test, open the desired plan using the instructions given in "Connecting the TDR9000™ Physical Front Panel" on page 4-30 and then print using the procedure above. This requires that the open Test Plan be saved or closed without being saved.

## Disconnecting After the Test

1. Turn the power switch to OFF.
2. Replace all safety grounds that were removed to perform tests.

### WARNING



**All safety grounds must be replaced before proceeding.**

**When performing connections, always make sure that appropriate service disconnects are secured and that all safety procedures are followed. Disconnect the cables from the circuit breaker first.**

3. Remove the Contact Monitor cables from the circuit breaker.  
Do not pull the cables. Remove the cables at the connection.
4. Unplug the following cables from the Instrument:
  - a. Contact Monitor
  - b. Motion Transducer
  - c. Breaker Control

5. Unplug the AC power cord from the power receptacle.
6. Unplug the AC power cord from the Instrument.
7. Remove the Safety Switch cable from the **SAFETY** receptacle on the Instrument.
8. Remove safety grounds from the circuit breaker.
9. Unlock and remove the tags from the isolating disconnects.
10. Remove the ground cable from the connection to the ground grid.
11. Restore the circuit breaker to service.

Disconnecting After  
a First Trip/Close  
Test

To disconnect after a First Trip/Close test:

1. Turn the power switch to OFF.

**NOTE**



**Disconnect the cables from the circuit breaker end first.**

2. Disconnect the Doble current probe from the CT secondary phases.
3. Disconnect Doble current probes from the selected relay coil circuits.
4. Disconnect the Analog cable across the DC supply switch.
5. Disconnect the Auxiliary Contact cables from the selected contacts.
6. Disconnect:
  - Trigger In cables across the 52CS/T contacts.
 or
  - Auxiliary Contact cables across the 52CS/T contacts.
7. Unplug the Breaker Control cable from the Instrument.
8. Unplug the AC power cord from the power receptacle.
9. Unplug the AC power cord from the Instrument.
10. Remove the Safety Switch cable from the **SAFETY** receptacle on the Instrument.
11. Disconnect the TDR9000 ground connection to circuit breaker ground.
12. Remove the ground cable from the connection to the ground grid.



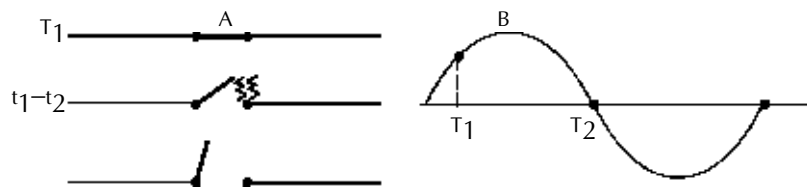
# Appendix A. TRXField™ Software and Circuit Breaker Testing Theory

This appendix discusses several topics useful in understanding circuit breaker testing. These include:

- Basic Circuit Breaker Interruption Principles
- Understanding Contact Measurement
- TDR9000 TRXField Software and Test Plan Dynamics
- Interpreting Test Results

## Basic Circuit Breaker Interruption Principles

When a switch carrying AC current opens, an arc forms. This arc strikes as the last metal-to-metal contact breaks, as shown in A of Figure A.1.



**Figure A.1 Arc Principles**

The arc is a conductor. As the contact in motion moves away from the stationary contact, the arc stretches. This stretching and cooling enables the arc to quench at a point where the current is zero,  $t_2$ , B in Figure A.1, subsequent to contact parting. In a sixty cycle sine wave, the voltage and current cross zero twice each cycle. At these zero crossings the arc extinguishes. It remains extinguished if the dielectric strength of the medium between the contacts is greater than the dielectric strength necessary to withstand the voltage across the contacts.

If the dielectric strength across the contacts is insufficient to withstand this voltage, a restrike occurs and the arc is re-established. At the next zero crossing the arc again extinguishes and this process continues until the dielectric strength becomes sufficient to withstand voltage across the contacts.

## Interruption in Air

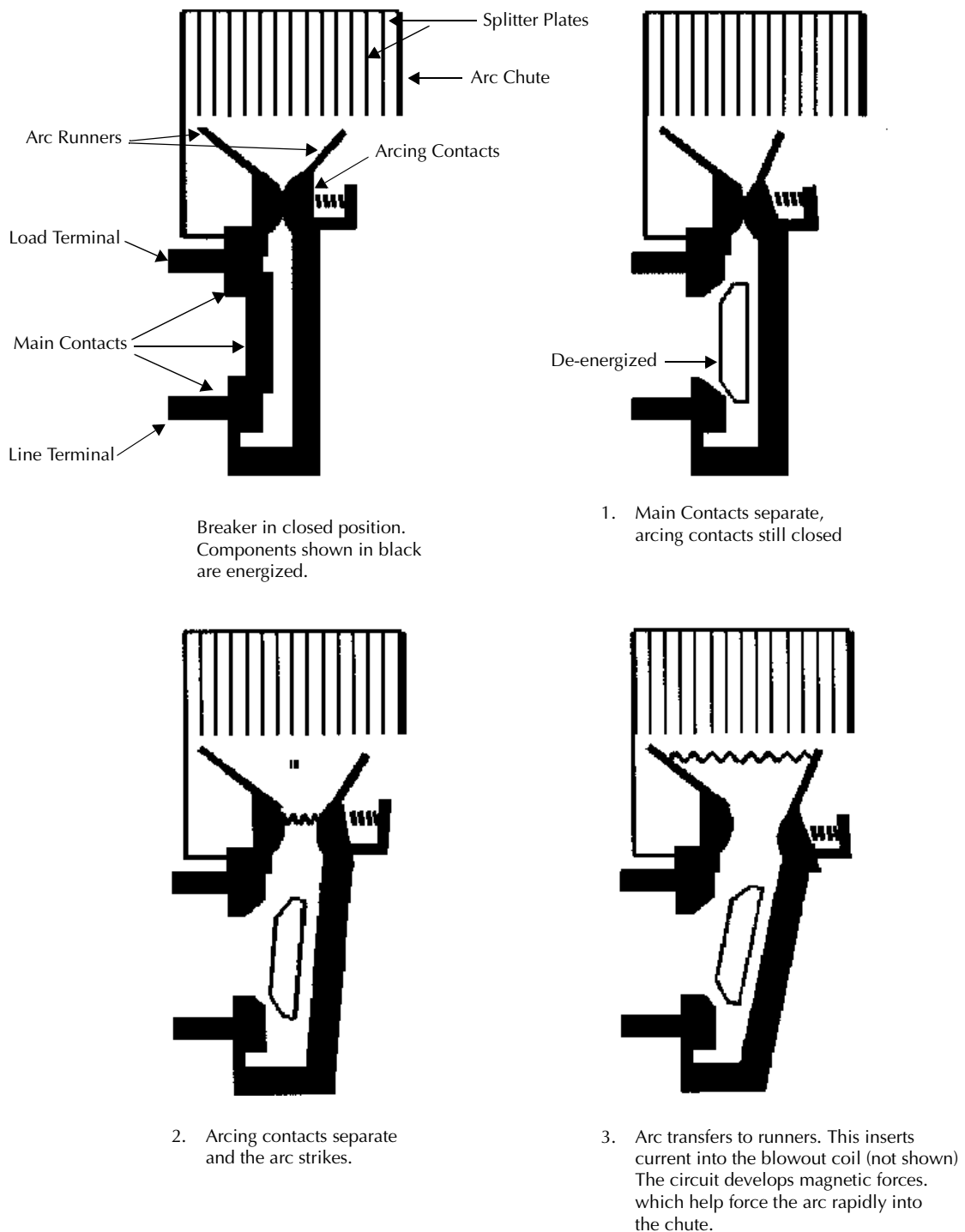
The following discussions explain circuit breaker interruption in air, including:

- Air-Magnetic Circuit Breakers
- Air-Blast Circuit Breakers

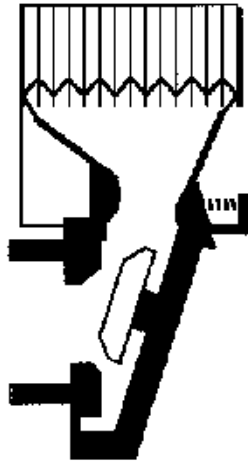
### Air-Magnetic Circuit Breakers

Figure A.2 and Figure A.3 on page A-4 explain the process that occurs for current interruption in an Air-Magnetic Circuit Breaker.

The distinctive feature of Air-Magnetic Circuit Breakers is the use of a magnetic field to lengthen the arc and force it into a labyrinth of insulating plates where it is stretched, dispersed and cooled by the interleaved arc plates.



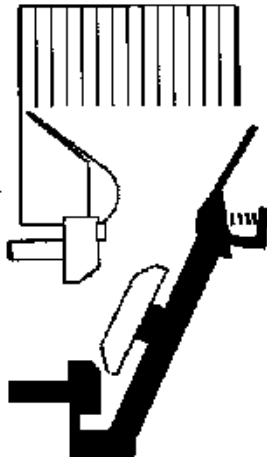
**Figure A.2 Air-Magnetic Breaker Operation**



5. Arc transfers to splitters to form a number of short series arcs.



6. Small arcs are attached into loops. This cools the arc and increases resistance to a point where, at an early current zero, the arc is quenched.



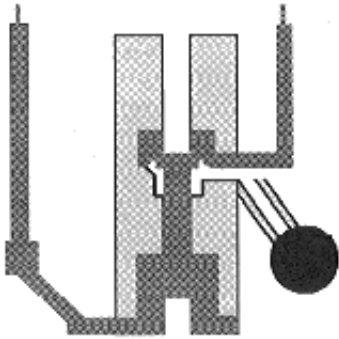
7. Current is interrupted. Visible break.

**Figure A.3 Air-Magnetic Breaker Operation (Continued)**

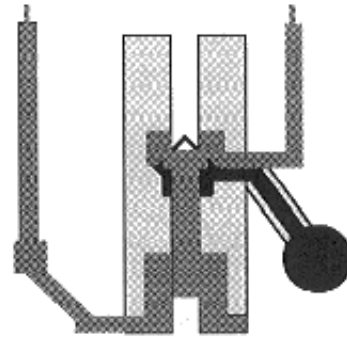
## Air-Blast Circuit Breakers

Figure A.4 and Figure A.5 on page A-6 explain the process that occurs for current interruption in an Air-Blast Circuit Breaker.

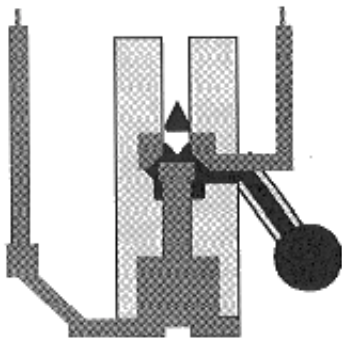
This technique is used in the circuit breakers rated up to 46 kV.



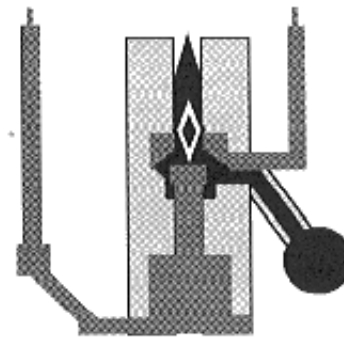
1. Cross section of a circuit breaker showing the path of current when the circuit breaker is in the closed position.



2. The trip coil is energized and releases a pilot air valve which allows the air to flow from the breaker tank. This air flows to the contact chamber and displaces the interrupting contacts.

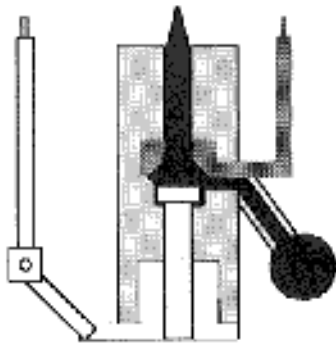


3. Air blast continues to force air past the interrupting contacts as the arc is initiated.

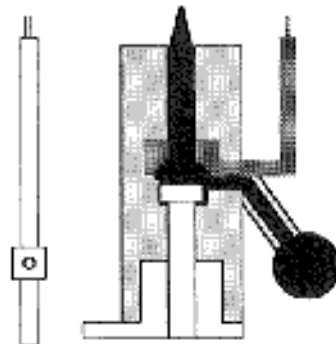


4. When the air travels and streams alongside the arc, the arc is enveloped and the arc products are directed to a cooling chamber.

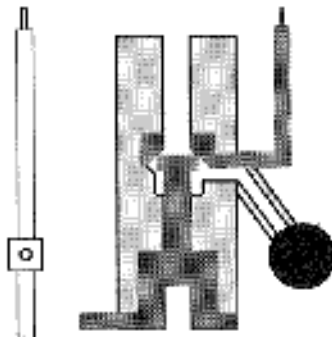
**Figure A.4 Air-Blast Circuit Breaker Operation**



5. As the air blast continues, the energy of the arc is absorbed by further cooling and the dielectric strength is increased.



6. The arc is extinguished at the end of 1/2 cycle. After a time delay, the isolating contacts open.

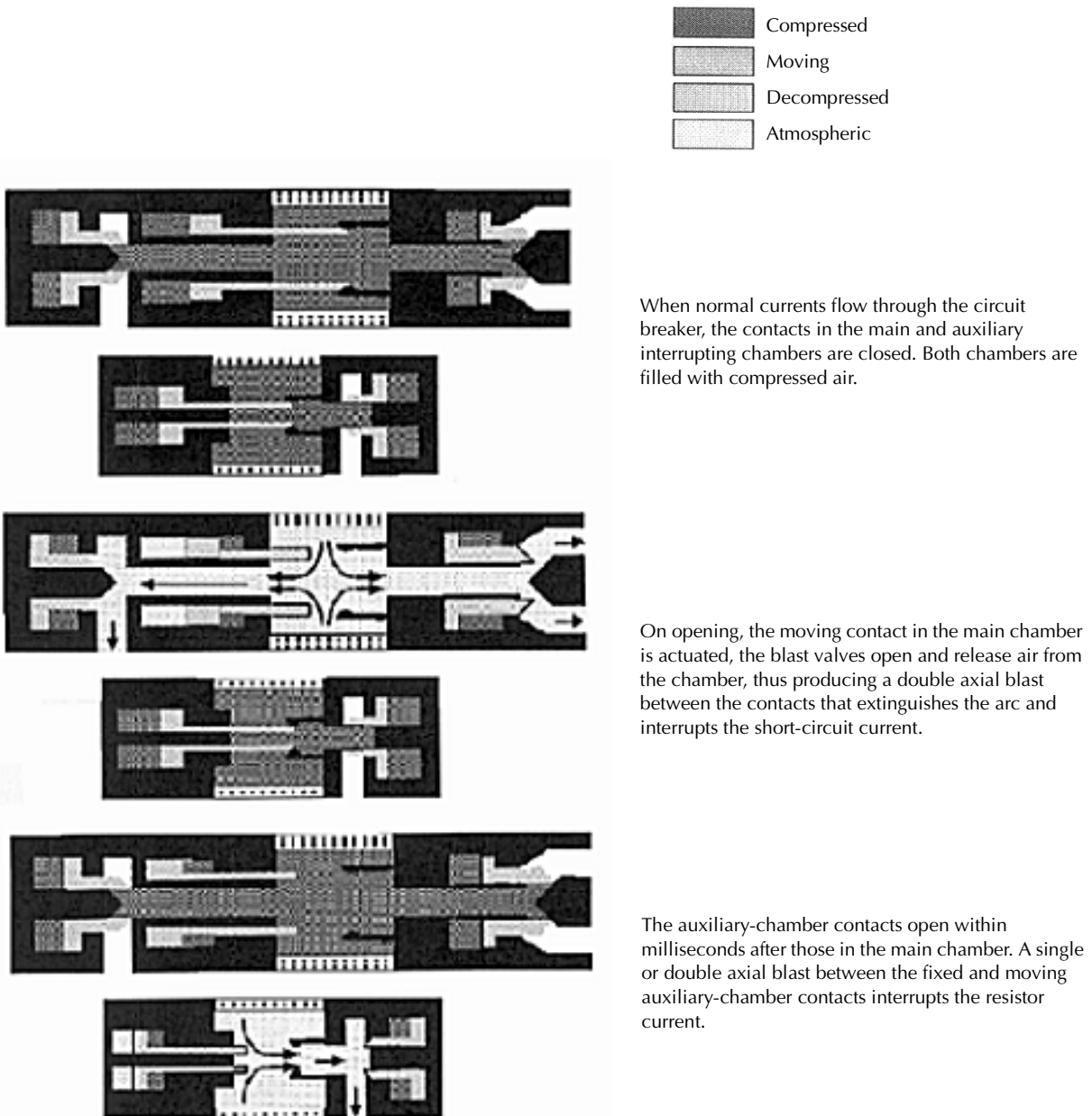


7. When the isolating contacts are open, the air valve shuts off the air blast supply and the interrupting contacts reset through spring pressure.

**Figure A.5 Air-Blast Circuit Breakers Operation (Continued)**

Air-Blast Circuit  
Breakers –  
General

This technique is used in circuit breakers rated up to 36 kV; however, the basic principle illustrated in Figure A.6 (under normal conditions current carrying conductors are surrounded by compressed air) is used in circuit breakers rated up to 765 kV.



When normal currents flow through the circuit breaker, the contacts in the main and auxiliary interrupting chambers are closed. Both chambers are filled with compressed air.

On opening, the moving contact in the main chamber is actuated, the blast valves open and release air from the chamber, thus producing a double axial blast between the contacts that extinguishes the arc and interrupts the short-circuit current.

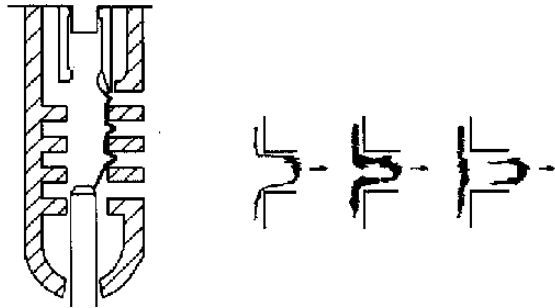
The auxiliary-chamber contacts open within milliseconds after those in the main chamber. A single or double axial blast between the fixed and moving auxiliary-chamber contacts interrupts the resistor current.

**Figure A.6 Air Blast Circuit Breaker – General Operation**  
(Courtesy of GEC Alstom T&D Inc.)

## Interruption in Oil

The heart of the circuit breaker is the arc control device. This device brings about a condition, at the earliest instance when the current is zero after contact separation, where the path of the resulting arc *loses its memory* concerning its conducting state.

Figure A.7 shows the crossblast interrupter method, where the arc is drawn in front of a series of lateral vents. The heat of the arc vaporizes the oil, and the gases formed (mainly hydrogen) increase in pressure and force the arc to bow into the vents. Before the arc can escape from the vents, it short circuits itself at the entry point to the vents.



**Figure A.7** *Circuit Breaker Interruption in Oil*

This process continues throughout the arcing period at intervals of the order of tens of microseconds, though these time intervals are not constant because the relevant events both inside and outside the arc control device are changing continuously.

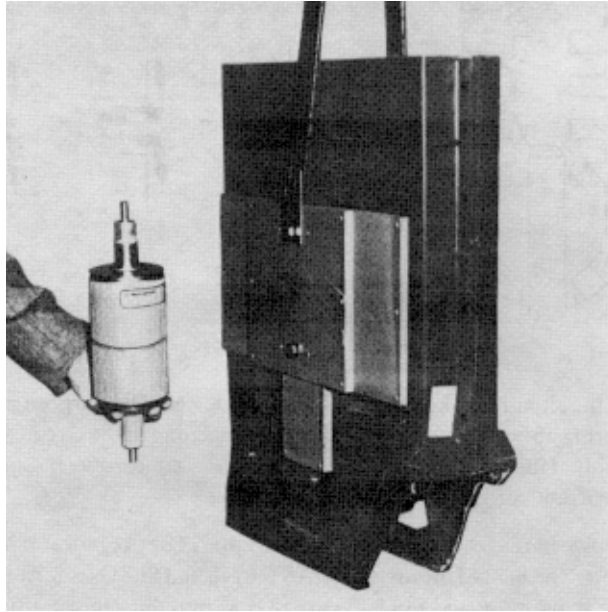
Ultimately, when the pressure inside the arc control device becomes sufficiently high, and the length of the arc is also sufficiently extended at a power frequency of current zero, the arc is extinguished.

The arc always burns inside a bubble of gas, and this bubble extends and expands through the vents to the outside of the arc control device. The hot gases emerging from the vents are initially still ionized and it is essential to ensure by correct vent design that no breakdowns occur between the vents external to the arc control device. This is particularly important for EHV interrupters where multiple series vent arrangements are invariably used.

Oil circuit breakers are used up to 345 kV.

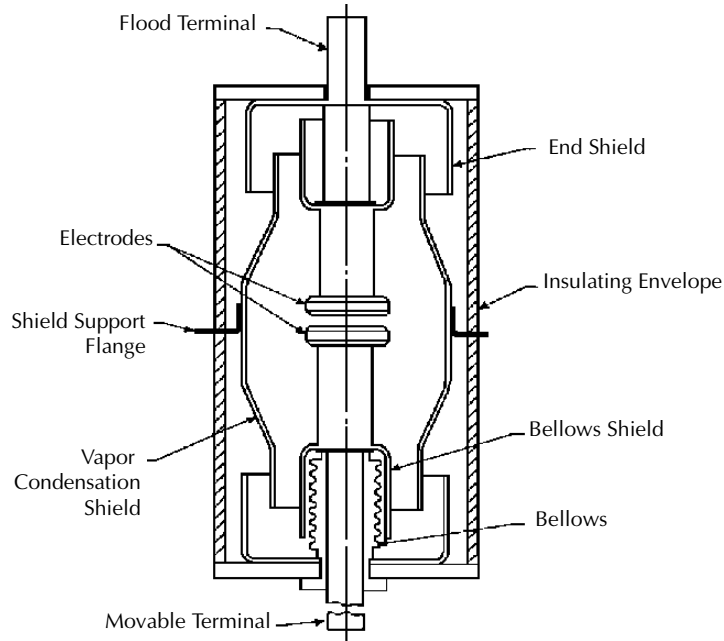
## Interruption in Vacuum

Figure A.8 gives a size comparison between a Westinghouse 10-cm-diameter vacuum interrupter rated 500 MVA (15 kV / 22 kA) and the arc chute of a Westinghouse Air Circuit Breaker of comparable rating. (Reprinted from Reference 2. Permission granted by Marcel Dekker, Inc.)



***Figure A.8 Size Comparison Westinghouse 10-cm-Diameter Vacuum Interrupter/Arc Chute of a Westinghouse Air Circuit Breaker***

Figure A.9 gives a general vacuum interrupter operational scheme. (Reprinted from Reference 2. Permission granted by Marcel Dekker, Inc.)



**Figure A.9 Vacuum Interrupter Schematic**

The ambient gas pressure within the evacuated envelope is  $10^{-6}$  torr. Under normal circuit conditions the interrupter is closed and contacts butt together.

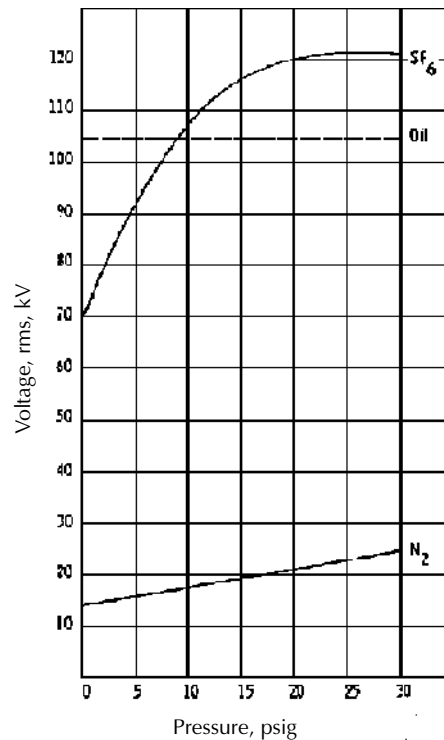
Arcing is established within the interrupter by withdrawing the movable contact from the stationary contact. This arc burns in the metal vapor evaporated from local hot spots on the contact surfaces. The metal vapor continually leaves the intercontact region and recondenses on the contact surfaces and the surrounding metal vapor condensation shield.

The shield is usually isolated from both contacts and serves to protect the glass or ceramic envelope from vapor deposition. When the current waveform crosses zero, vapor production ceases and the original vacuum condition is rapidly approached with the contacts in the open position. The circuit voltage is withstood internally by the intercontact gap and externally by the insulating envelope.

Vacuum interrupters are currently applied in 5 through 72.5 kV circuit breakers.

## Interruption in SF<sub>6</sub>

One of the most important electrical characteristics of SF<sub>6</sub> (sulfur hexafluoride) is its dielectric strength. Figure A.10 shows a graph demonstrating the dielectric strength of SF<sub>6</sub> and N<sub>2</sub>. (Reprinted from Reference 2. Permission granted by Marcel Dekker, Inc.)



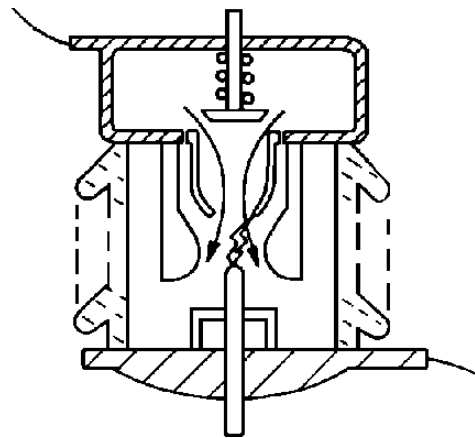
**Figure A.10 60 Hz Dielectric Strength of SF<sub>6</sub> vs. N<sub>2</sub>**

At any given pressure the dielectric strength of SF<sub>6</sub> is generally three to five times that of air.

The remainder of this discussion gives the specific information on how Double-Pressure, Puffer Type, and Self-Extinguishing SF<sub>6</sub> circuit breakers operate.

Double-Pressure  
SF<sub>6</sub> Circuit Breakers

Figure A.11 shows the structure of a Double-Pressure SF<sub>6</sub> Circuit Breaker (Reprinted from Reference 2. Permission granted by Marcel Dekker, Inc.).

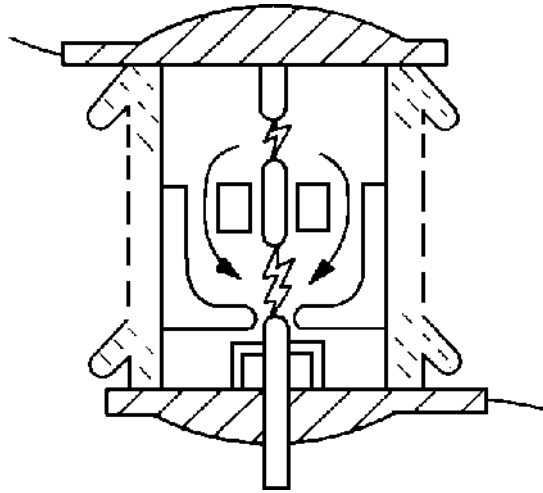


**Figure A.11 Double-Pressure SF<sub>6</sub> Circuit Breaker Operation**

This is the early design of SF<sub>6</sub> Circuit breakers. Its operation is similar in principle to that of Air-Blast Circuit Breakers: It is comprised of mainly a high-pressure metal reservoir, where most of the SF<sub>6</sub> is kept, and an interrupter compartment containing the circuit breaker contacts, surrounded by SF<sub>6</sub> at lower pressure. For the current breaking operation, the circuit breaker contacts part while the high-pressure gas is released from its reservoir to the interrupter compartment, where it blows out the arc. After the current interruption, the gas is pumped back to its reservoir.

## Self-Extinguishing SF<sub>6</sub> Circuit Breakers

Figure A.12 shows the structure of a Self-Extinguishing SF<sub>6</sub> Circuit Breaker. (Reprinted from Reference 2. Permission granted by Marcel Dekker, Inc.)

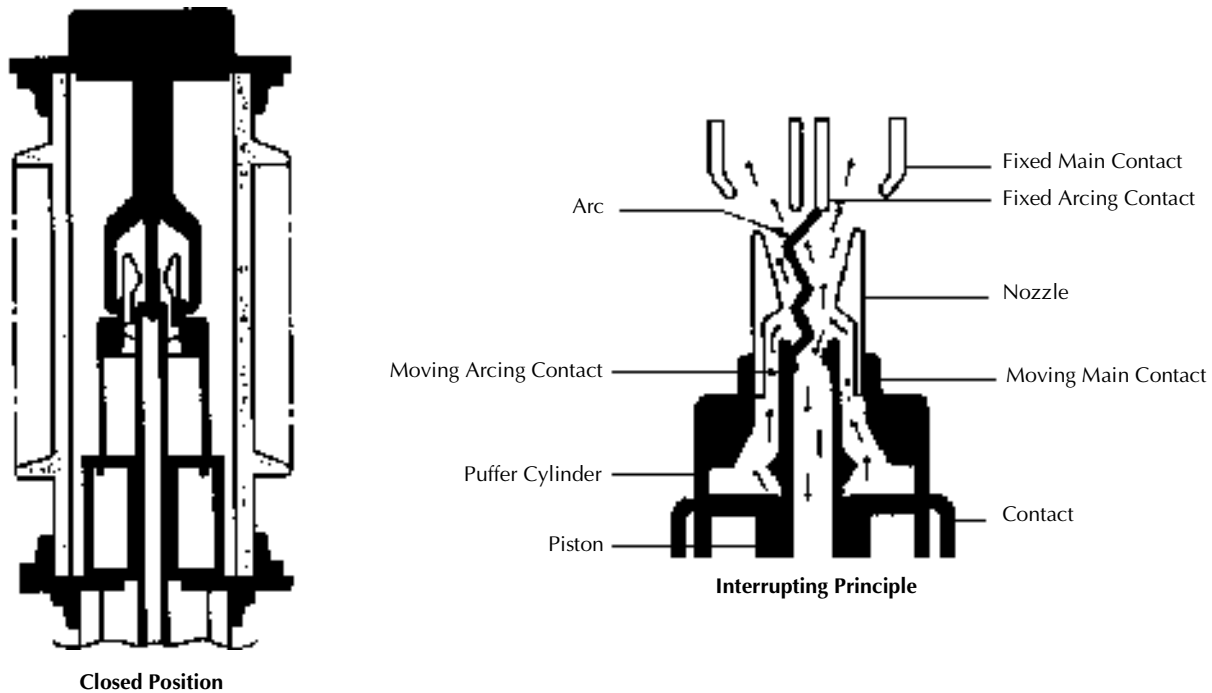


**Figure A.12 Self-Extinguishing SF<sub>6</sub> Circuit Breaker Operation**

The interrupting chamber is divided into two main compartments; one is the arc compartment. Both have the same gas pressure, about 5 atm, while the circuit breaker is closed. When the circuit breaker is being opened, the contacts separate and an arc is drawn between them. The heat generated by the arc heats the gas in the arc compartment and rapidly increases its pressure. The gas blasts from the arc compartment to the other compartment. This rapid expansion cools the arc column and extinguishes it at a current zero point. A third compartment (not shown) is incorporated to augment the gas pressure while interrupting smaller currents. Using this arrangement, the arcing time is independent of the current magnitude; and the currents are interrupted at their natural zero.

Puffer-Type SF<sub>6</sub> Circuit Breakers

Figure A.13 shows the structure of a Puffer-Type SF<sub>6</sub> Circuit Breaker (courtesy of Mitsubishi Electric). These circuit breakers are sometimes called *single-pressure* or *impulse-type* circuit breakers. Circuit breakers of this type are applied in 765 kV range.

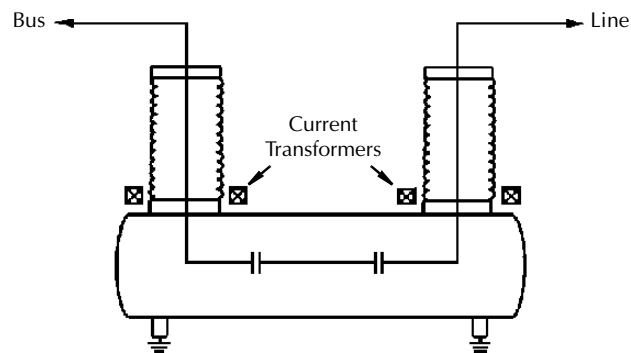


**Figure A.13 Puffer Type SF<sub>6</sub> Circuit Breaker Operation**

The SF<sub>6</sub> gas in the cylinder is compressed by the downward movement of the cylinder and is forced into the nozzle area where the arc is drawn between the stationary arc contact and the moving arc contact. The nozzle concentrates the gas flow to the area of the arc, resulting in very effective arc extinction.

## Live Tank vs. Dead Tank

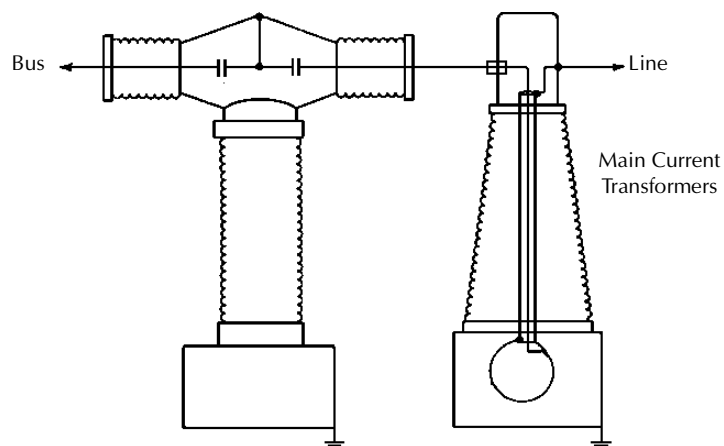
In the dead-tank design, shown in Figure A.14, the interrupting elements are enclosed in a grounded metal tank and the line and bus conductors enter the interrupting chamber through entrance bushings.



**Figure A.14 Dead-Tank Circuit Breaker Schematic**

In the live-tank design, as shown in Figure A.15, the circuit breaker interrupters are mounted in a container at line potential and are insulated from ground potential using porcelain insulating columns. The major advantage of the live tank is its lower cost, especially at a higher voltage rating.

A major disadvantage is that it requires externally mounted current transformers, which are more expensive and require more substation space than bushing current transformers.

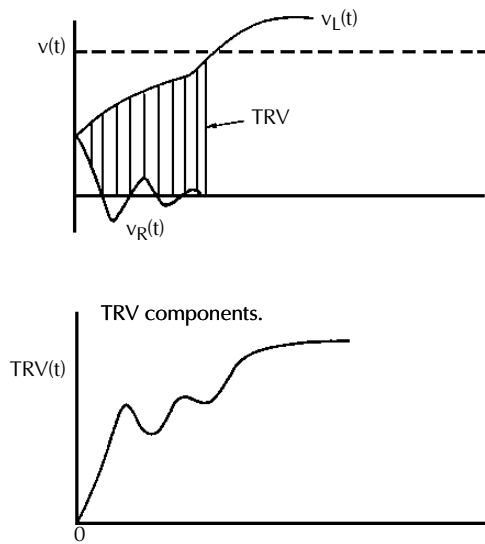
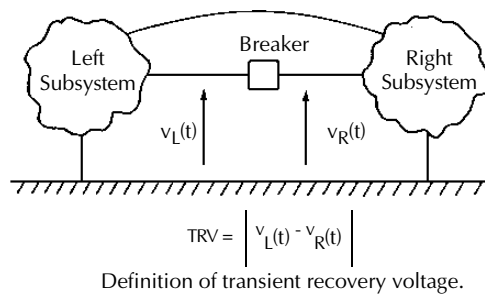


**Figure A.15 Live-Tank Circuit Breaker Schematic**

## Transient Recovery Voltage

Figure A.16 shows the Transient Recovery Voltage scheme. (Reprinted from Reference 2. Permission granted by Marcel Dekker, Inc.)

When the current through the circuit breaker is interrupted, the entire system adjusts to its new operating state. The voltage transients produced separately by the left subsystem,  $V_L(t)$ , and the right subsystem,  $V_R(t)$ , stress the recently conducting arc plasma. The transient recovery voltage (TRV) is defined as the difference between the voltage on the left and right sides of the circuit breaker.

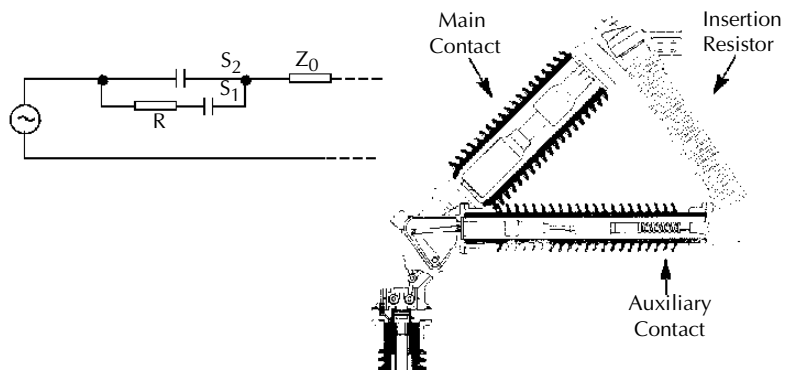


**Figure A.16 Transient Recovery Voltage Scheme**

When the basic interrupter of the circuit breaker does not meet the interruption requirements, auxiliary devices, including an insertion resistor, shunt capacitor or open-gap grading capacitor, are used to modify the TRV.

## Insertion Resistor

Figure A.17 shows how an insertion resistor is used to modify the TRV (courtesy of ABB Power T&D Company, Inc.).



**Figure A.17 Transient Recovery Voltage: Insertion Resistor Operation**

Many circuit breakers, especially those used in transmission circuits, employ resistors for operation. They were originally used during opening operations and still, if present, provide a useful function at these times.

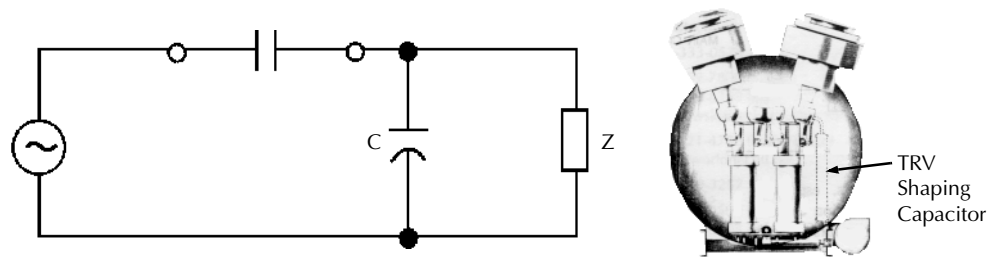
Such resistors serve one of two functions: In a multibreak circuit breaker they are used to help to distribute the transient recovery voltage more uniformly across the several breaks. They can also be used to reduce the severity of the transient recovery voltage at the time of interruption by introducing damping into the oscillation. When the fault current has been switched by  $S_2$ , a remaining current flows through  $R$ . This must be interrupted subsequently by opening the auxiliary interrupter  $S_1$ .

The primary use of the resistors in modern circuit breakers is to reduce voltage transients on closing. If the source is stiff, a high percentage of the source voltage is impressed across the line at the time the circuit breaker closes to energize a transmission line. If the line is open at the far end, or terminated in a load such as an unloaded transformer which has a high surge impedance, the wave essentially doubles at the far end. Such high switching surges put severe stress on components at that location, and led to the introduction of transmission circuit breakers with closing resistors that are pre-inserted at the time of line energization. Switch  $S_1$  is closed first; the voltage across it is shared by  $R$ . The voltage impressed on the line is reduced by the factor  $Z_0R+Z_0$  and all the waves generated as a consequence are correspondingly reduced. The switch,  $S_2$ , is closed a short time later, after the surges on the line have subsided.

Shunt Capacitor

Figure A.18 shows how a shunt capacitor is used to modify the TRV (Courtesy of ABB Power T&D Company, Inc.).

A shunt capacitor is connected across the phase-to-ground voltage. This has no effect on the magnitude of the recovery voltage but does affect the initial rate of rise of the transient voltage.



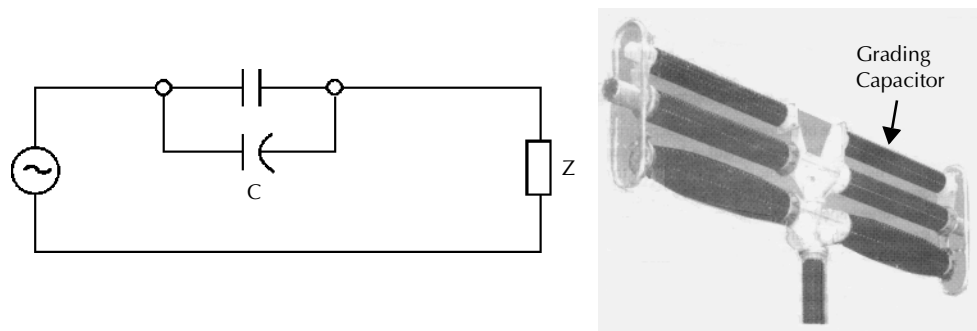
**Figure A.18 Transient Recovery Voltage: Shunt Resistor Operation**

Open-Gap Grading Capacitor

Figure A.19 shows how an open-gap grading capacitor is used to modify the TRV (courtesy of Mitsubishi Electric).

A capacitor is applied across the open contacts of a circuit breaker. Most multibreak circuit breakers use grading capacitors across the contacts to obtain the proper voltage division for interruption and surge voltage control.

The grading capacitor acts the same as a shunt capacitor in affecting the initial rate of the transient voltage.



**Figure A.19 Transient Recovery Voltage: Open-Gap Grading Capacitor Operation**

## Gang Operation vs. Independent Pole Operation

Gang operation is a term used for a circuit breaker mechanism that operates all three poles together.

As the voltage level increases, the separation between the phases also increases in order to maintain the necessary distance for dielectric strength. It is very difficult using gang operation to maintain contact synchronism. The length and the mass of the interconnecting rod also becomes a problem. Therefore, multiple single pole operators are used in most circuit breakers above 345 kV.

When a high voltage circuit breaker consisting of three single pole operators is used (Independent Pole Operation), it is necessary to employ a phase disagreement circuit to eliminate the possibility of having one or more phases closed while one or more phases are open.

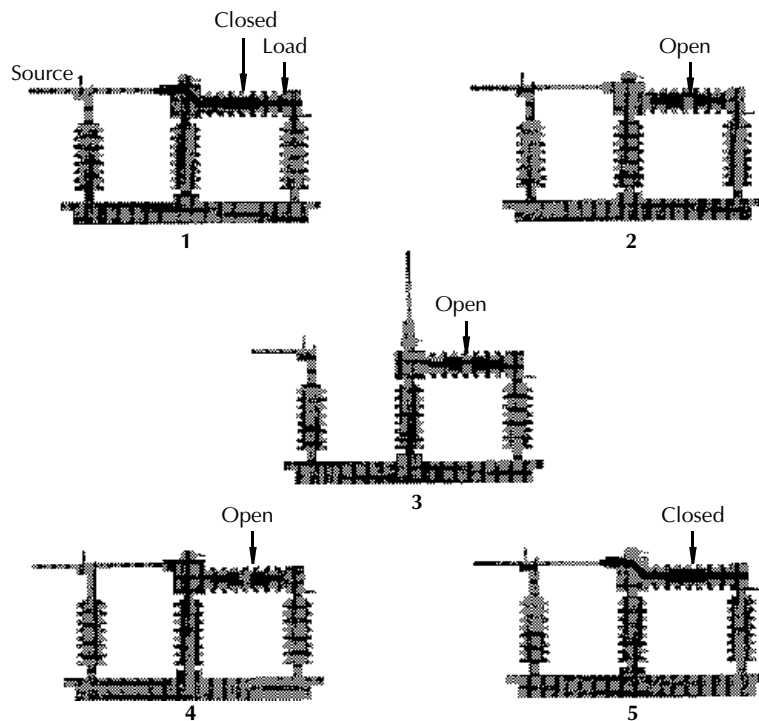
Single phase tripping and reclosing for single phase-to-ground faults may be used in a circuit breaker with Independent Pole Operation. Power can be transmitted in the two unfaulted phases, while the third phase interrupts the fault and then recloses to restore the circuit. If the reclosing is not successful, the other two phases must be opened. This scheme may aid in maintaining system synchronism and stability in addition to maintaining power flow.

## Circuit Switchers and High-Current Generator Breakers with Isolating Contacts

A circuit switcher is an outdoor switching device which incorporates an interrupter and knife blade. This combines the functions of a circuit breaker and a disconnect switch. Although more limited in application than a circuit breaker due to, for example, lower interrupting ratings, they are an economical solution when higher ratings are not required.

Circuit switchers employ SF<sub>6</sub>, vacuum, or other types of interrupters to break a circuit, and either the interrupter or the knife blade to make the contact. Models with more than one gap can utilize voltage-grading resistors. The interrupter/knife blade combination is mounted on a disconnect switch structure, while the center insulators of each phase are linked mechanically with an interphase pipe that simultaneously rotates them in the same way as a disconnect switch. The sequence of operation varies with the type of circuit switcher.

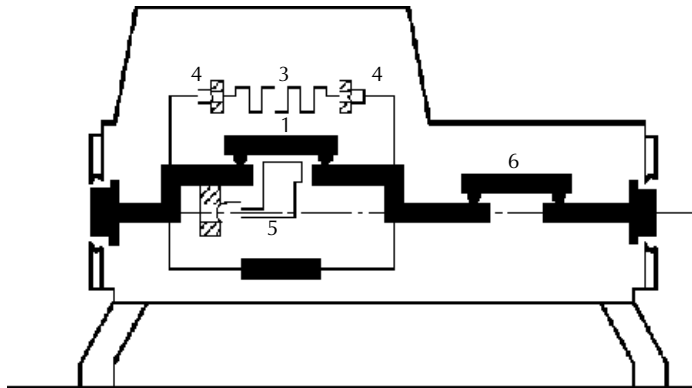
Figure A.20 presents an example where the interrupter does the circuit breaking and the knife blade does the circuit making.



**Figure A.20** *Circuit Switcher Operations*

Both the blade and the interrupter are closed, carrying current. When activated, the interrupter opens, breaking the current, while the blade is still closed. The blade then opens for full visual confirmation of circuit isolation. On closing, the blade is rotated closed, while the interrupter is still open. The final closing of the blade activates the mechanism, closing the interrupter.

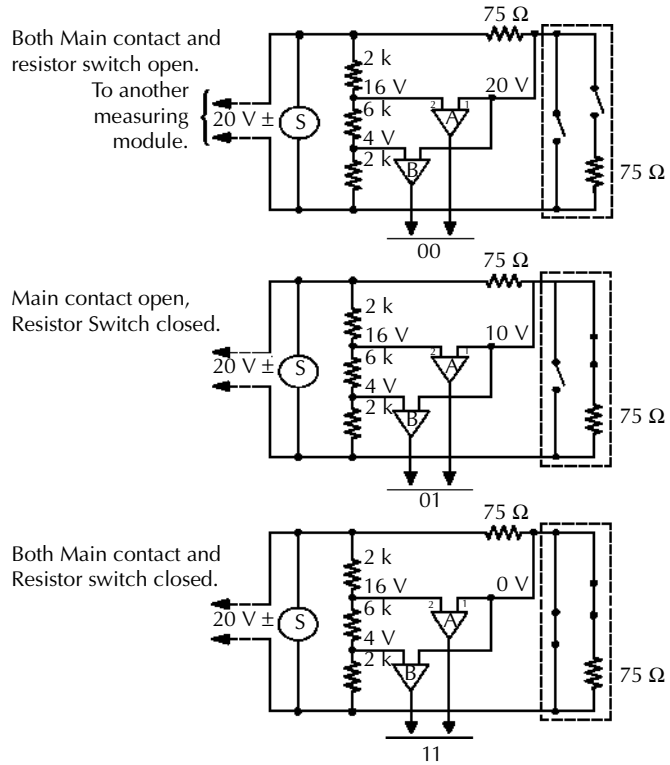
Some circuit breakers have isolators (#6, Figure A.21) in conjunction with their main interrupting contacts (#1, Figure A.21) as well as arcing contacts (#2, Figure A.21) and auxiliary arcing chambers. The BBC DR 36 is such a circuit breaker. Because the main, arcing and resistor chamber contacts all have distinct timing characteristics, it is necessary to use a timing device which allows for several different sets of contact timing specifications.



**Figure A.21** *Circuit Breaker with Isolating Contacts*

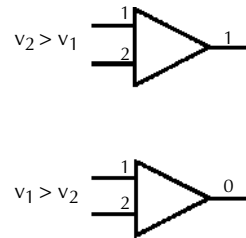
## Understanding Contact Measurement

Figure A.22 displays a typical circuit used to monitor contact status.



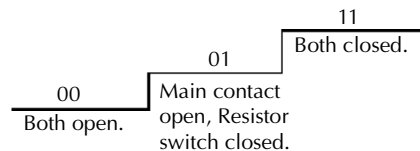
**Figure A.22 Contact Monitoring**

The source voltage (20V) is applied across the voltage divider comprised of the contact assembly and the internal resistor (75 Ohm). This voltage divider determines the contact voltage signal, which depends on the status of the contact assembly. The contact voltage signal is compared with a scaled replica of the source voltage. The output of the comparator depends on the relationship between inputs, as shown on Figure A.23.



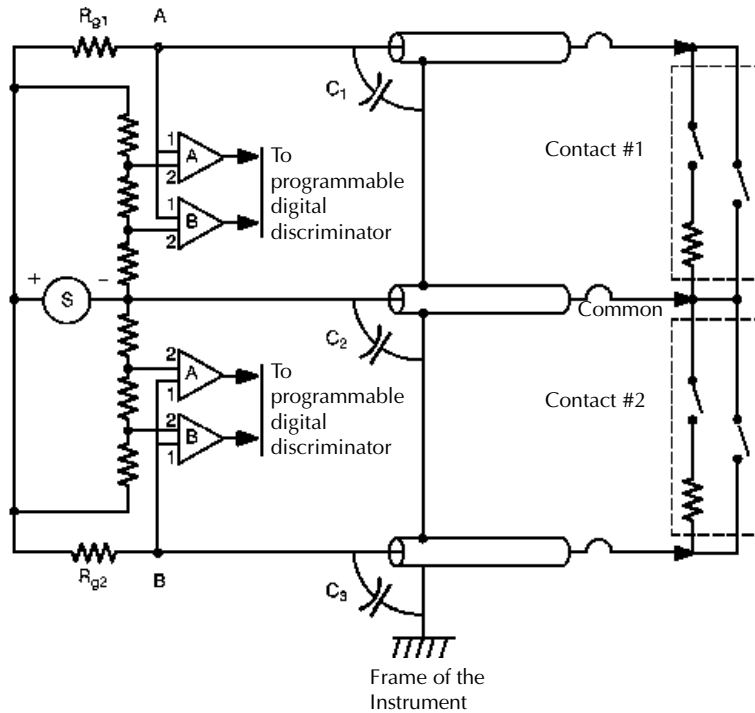
**Figure A.23 Voltage Comparator Output**

Figure A.24 shows how changing the contact assembly status (both open, Main Contact open-resistor switch closed, both closed) changes the contact voltage signal applied to the input 1 of the comparators, which results in different combinations of the outputs. These different combinations of output signals are further interpreted to assign a corresponding status to the contact assembly.



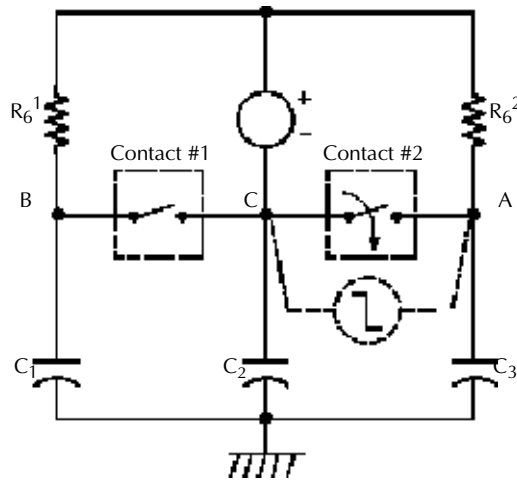
**Figure A.24 Effect of Contact Assembly Status on Output Voltage**

Due to the physical geometry of a multiple module Live Tank Circuit Breaker, there is a stray capacitance-to-ground present in each Circuit Breaker head. Additional capacitance is added by the measurement cables attached to the circuit breaker. Figure A.25 shows  $C_1$ ,  $C_2$ ,  $C_3$  as the total capacitances-to-ground present during the measurement. These typically are 4000 to 8000 pF.



**Figure A.25** Capacitance-to-Ground for a Circuit Breaker

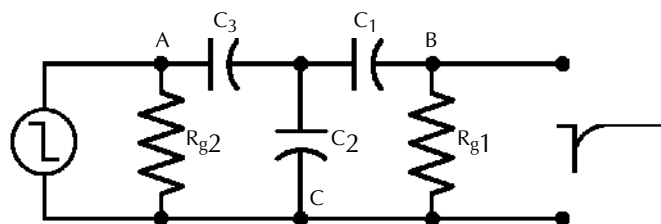
Figure A.26 shows what happens when the diagram is simplified and analyzed at the moment when contact #2 closes and contact #1 is still open.



**Figure A.26 Capacitance-to-Ground:  
Contact #2 Closed, Contact #1 Open**

When contact #2 closes, the potential at point A goes from  $+V_s$  to zero. Consequently, to simplify the analysis, replace the closing of contact #2 with a voltage source, which represents a step-down function.

Excluding the Instrument power supply (S) from the circuit, since it has no effect on the transient process, and redrawing the diagram, it appears as shown in Figure A.27.



**Figure A.27 Capacitance-to-Ground:  
Contact #2 Closed, Contact #1 Open (Simplified)**

When contact #2 is still open (step-down voltage is not applied to point A), all capacitors are charged according to the circuit parameters ( $C_2$  in series with  $C_1//C_3$  – see Figure A.26 on page A-25). As soon as the step-down voltage is applied, the capacitors discharge ( $C_1$  in series, with  $C_2//C_3$ ) and due to the current through  $R_{g1}$ , the voltage at point B drops. When the discharge process is completed, and the capacitors are charged according to the new circuit condition, the potential at point B returns (no current through  $R_{g1}$ ).

The voltage at point B is monitored by the comparators that follow the open-to-close transition of contact #1. The temporary voltage drop can be misinterpreted as a change in the state of contact #1. This phenomenon results in *cross-talk* between the contact operation measurement channels. The cross-talk occurs within the module and between all the modules in a phase. It produces erroneous contact state transition information.

Although it is desirable to distinguish between real contact activity and cross coupled signals with 2  $\mu$ s resolution, this is neither a practical nor realistic task because fast contact bounces and cross-talk appear as identical events. The cross-talk is dealt with by using a Digital Discriminator.

The Digital Discriminator is a digital filter circuit located on each channel of the Main Contact Board. The device is located downstream of the comparator circuit, and qualifies the data before it is stored in memory. The Digital Discriminator operates upon any type of contact activity, and qualifies both Main Contacts and resistor switch data.

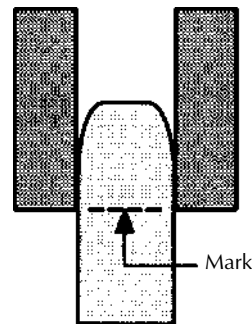
The filter time can range from 4 to 100  $\mu$ s and is set by the Test Plan in 2  $\mu$ s increments.

The Digital Discriminator circuit is triggered when a bounce is first detected, and sets up a *window* in time equal to the Filter Time. Bounces with durations equal to or greater than the Digital Filter Time are passed through and stored in memory as valid contact data, while bounces with durations less than the Filter Time are rejected and not recorded. The TDR9000 does, however, flag these events so they are not used when calculating the resistor value.

## Contact Penetration, Insertion, and Wipe

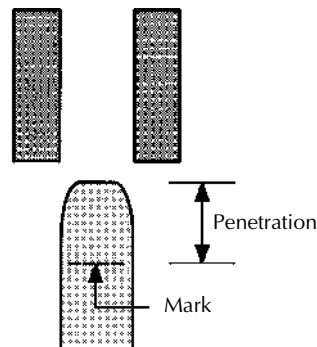
The main distinction between the contact penetration, sometimes referred to as contact insertion, and the contact wipe is that the first is obtained through mechanical measurement and the second through electrical measurement.

The value of contact penetration is obtained as follows: with the circuit breaker closed, a mark is made on the moving contact as shown in Figure A.28.



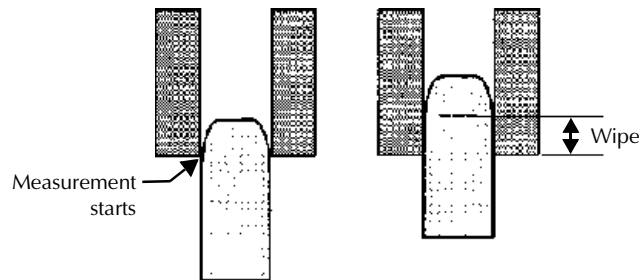
**Figure A.28 Contact Penetration Value Preparation**

With the circuit breaker open, the distance between the mark and the top of the moving contact is measured as shown in Figure A.29. This distance is the value of contact penetration or contact insertion.



**Figure A.29 Contact Penetration Measurement**

During the measurement of contact wipe, the measurement starts when the moving contact makes an electrical contact with the stationary contact and ends when the moving contact stops (Figure A.30).



**Figure A.30 Contact Penetration Measurement Endpoints**

Figure A.29 on page A-27 and Figure A.30 show that due to the chamfer on the moving contact, the mechanical and electrical measurements may yield different results.

Before the manufacturer's specification is used, it is important to know how this value is obtained. If the only specification available is the result of mechanical measurement, the benchmark for future trending analysis should be obtained using the TDR9000.

## TDR9000™ TRXField™ Software and Test Plan Dynamics

The main body of this guide explained the procedures for operating the TDR9000, including the mechanics for creating or using existing Test Plans. This section describes the effect that changing Test Plan fields has on running a test. It does so by relating individual Test Plan items to the physical components they affect in the field.

## TRX™/TRXField™ and the Circuit Breaker Test Plan

The TRX software, comprised of TRX and TRXField, facilitates the creation of Circuit Breaker Test Plans, analysis of test data, and storage of Circuit Breaker test data. The TDR9000 operates using only the TRXField portion of the software. The Test Plan can be created using either of these programs and is the key to simplifying circuit breaker testing. By creating a Test Plan, the time-consuming work of entering repetitive circuit breaker ID information and test parameters is eliminated. Once this data has been entered, it is saved in the Test Plan on a floppy diskette for reuse later.

## General Test Plan Functionality

The two areas of functionality used to configure the TRXField Test Plan are the:

- TRXField menu bar
- Right-click menu

## TRXField™ Menu Bar

The TRXField menu bar is shown in Figure A.31.



**Figure A.31 TRXField™ Menu Bar**

The menu items include:

### File

- New Test Plan  
A blank Library test Plan appears.
- Open  
An Open window appears from which existing Test Plans or Test Results are opened. Refer to "Tab Navigation" on page 3-5 for more information.
- Save  
A Specify File Type dialog box appears and a TDR9000 file or TR3000 file is created. Refer to "Saving Test Results/Test Plans" on page 4-95 for more information.
- Overlay Graphics  
A dialog box appears where the Graphics tabs for Test Result files of similar type can be overlaid. This item is only active when a Test Result file is open. Refer to the TRX User's Guide for more information.
- Print  
Refer to "Printing Test Results" on page 4-100 for more information.
- Exit

## View

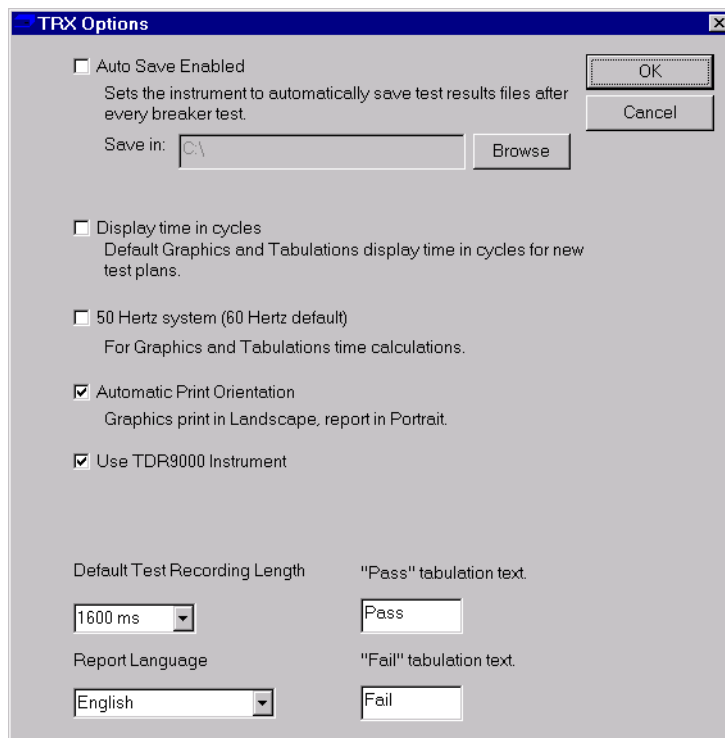
- Toolbar
- Status Bar
- TRX Options

The TRX Options window appears (Figure A.32). Its options include:

- *Autosave Enabled*  
For a TDR9000, causes the computer running TRXField to automatically save the Test Results to the last directory accessed.
- *Display Time in Cycles*  
Displays time in cycles by default rather than in milliseconds. This can be changed temporarily when viewing results.
- *50 Hz System*  
Calculates Test Results based on 50 Hz instead of 60 Hz (default).
- *Automatic Print Orientation*  
Automatically prints graphics in landscape format; Test Plans and Tabulated format Test Results are printed in portrait format.
- *Default Test Recording Length*  
Sets the user-preferred length for recording. This also implicitly sets the sampling rate. This is the default and can be change elsewhere in the program for individual instances.
- *Report Language*  
Sets the default language for use on the Tabulation tab. This also dictates what language is used for printing. This is the default and can be change elsewhere in the program for individual instances.
- *Pass/Fail tabulation text*  
Enables the use of words other than *Pass* and *Fail* to rate Test Results. If these fields are blank, then they are also blank in the *compare* fields when viewing Test Results in the Tabulated format.

1. Access the TRX Options window by:

- Selecting TRX Options from the **View** menu.
- or
- Clicking the **Options** button.



*Figure A.32 TRX™ Options*

2. Modify the settings as needed and click **OK**.

**Help**

- Help Topics
- About TRXField

Right-Click Menu

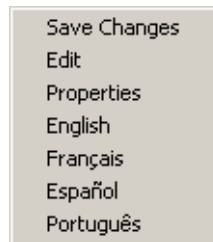
The right-click menu contains functionality dictated by whether a Test Plan or a Test Result is in use. For a Library Test Plan (Figure A.33), use the Right-Click Menu to:

- Open the Test Plan parameters for editing
- Open the Properties window
- Select the language in which the Test Plan appears

**NOTE**



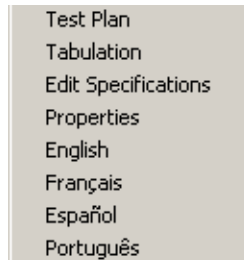
**Portuguese is under development. Save Changes is available once the Test Plan is modified.**



**Figure A.33 Right-Click Menu: Test Plan**

For a Test Result (Figure A.34), use the Right-Click Menu to:

- Move between Test Result tabs
- Open the Test Plan parameters for editing
- Open the Properties window
- Select the language in which the Test Plan appears



**Figure A.34 Right-Click Menu: Test Result**

## Test Plan Items

The discussions that follow explain each Test Plan item and its effect on the system.

### Nameplate Parameters

Figure A.35 shows the Nameplate portion of the Test Plan. There are two areas:

- Required Information
- Optional Information

In the Required Information area, only the Model Number is required.

**NOTE**



**Doble recommends that all the Required parameters be entered.**

Required Information	
Information Required for Library Plans	Information Required for Breaker Plans
Manufacturer Alstom	Location
Model Number 0STGB-250A	Special Id
Version Description	Serial Number
Optional Information	
Inst. Book Number	Operator
Mech. Number	Circuit
Mech. Book Number	User 1 :
Operation Counter	User 2 :

**Figure A.35 Nameplate Parameters**

### Required Information

Manufacturer	This is selected from a pulldown list.
Model Number	This is selected from a pulldown list.
Version Description	A user-entered field.
Location	This is selected from a pulldown list and is a combination of the <i>Manufacturer</i> and <i>Model Number</i> fields.

**NOTE**



**The location, model number and manufacturer lists are contained in the *Location.tab*, *ModelNumber.tab*, and *Man\_Name.tab* files in *c:\Program Files\Doble\TRXField* directory and they can be edited using any text editor.**

Special ID	User-entered fields.
Serial Number	

Optional Information

Inst. Book Number  
 Mech. Number  
 Mech Book Number  
 Operation Counter  
 Operator  
 Circuit  
 User 1 and User 2

User-specified fields, for entering additional breaker information.

Command Parameters

Figure A.36 shows the Command Parameters.

Trip Current Range	100.0 A	Close Current Range	20.0 A	Timing Measurement:	Seconds
Trip Parameters		Trip-Free Parameters		O-C-O Parameters	
Trip Pulse	66.6 ms	Close Pulse	133.3 ms	O-C-O	Standing
		Trip Free	Standing	Trip Pulse	66.6 ms
				Close Pulse	133.3 ms
				Delay Length	113.3 ms
Close Parameters		Reclose Parameters		Trigger Input Parameters	
Close Pulse	133.3 ms	Trip Pulse	66.6 ms	Trigger Source	None (Internal)
Timing Event	Test Initiation	Reclose	Standing		
Trigger Output Parameters		Main Contact Digital Discriminator		Test Duration Parameters	
Trigger State:	Off	Digital Discriminator:	Auto	Recording Length:	1600 ms
				Sample Rate:	10 kHz

**Figure A.36 Command Parameters**

## Device Timing Parameters

These parameters apply to the tests overall. Restrictions are discussed individually.

## Delay Length:

Delay Length and Delay 1 Length/Delay 2 Length

Delay Length is the length of time after the inception of running a test before the test condition, for example a trip pulse, is implemented.

Delay 1 Length sets the time for a first test condition to be implemented.

Delay 2 Length sets the time, for those tests where it is applicable, such as an O-C-O test, for a second test condition to be applied.

Each of these choices activate the Trip, Close, and Delay 1 and 2 fields as listed in Table A.1.

**Table A.1 Delay Command Parameters**

Test Type	Command Parameters
<b>Reclose (O-C)</b>	
Standing	Trip Command
Delay	Trip Command Delay 1 (Close Command)
<b>Trip Free (C-O)</b>	
Standing	Close Command
Delay	Close Command Delay 1 (Trip Command)
Contact 1 Make	Close Command
<b>O-C-O</b>	
Standing	Trip Command Close Command Delay 2 (Trip Command)

**Table A.1 Delay Command Parameters (Continued)**

Test Type	Command Parameters
Delay	Trip Command Close Command Delay 1 (Close Command) Delay 2 (Trip Command)
Contact 1 Make	Trip Command Close Command Delay 1 (Close Command)

Timing Measurement

Either seconds or cycles can be selected for the time base.

Timing Frequency

Either 50 or 60 cycles can be selected as a base for the second/cycles conversion.

**NOTE**



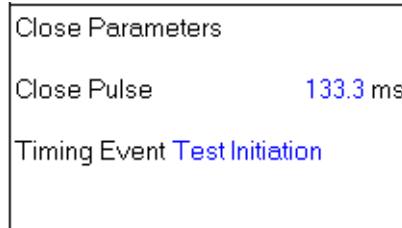
**The Timing Frequency is set on the TDR9000 Virtual Front Panel or from the TRX Options window opened from the TRXField View menu.**

Trip/Close Range Selection Currents	<p>The following ranges are available:</p> <ul style="list-style-type: none"><li>• Trip Current Range: 0-2; 0-5; 0-20; 0-100 A</li><li>• Close Current Range: 0-0.2; 0-1; 0-5; 0-20 A</li></ul>
Trip Pulse (Timing)	<p>The trip pulse is adjustable in 1/10 ms increments. Select a pulse length that is long enough to allow the <i>X</i> relay to drop out and de-energize the coil.</p> <p>The trip pulse is:</p> <ul style="list-style-type: none"><li>• 66.6 ms at 60 Hz</li><li>• 80 ms at 50 Hz</li></ul> <p>Select a trip pulse length that is long enough to allow the <i>A</i> switch to de-energize the trip coil.</p>
Close Pulse (Timing)	<p>The close pulse is adjustable in 1/10 ms increments. Select a close pulse length that is long enough to allow the <i>X</i> relay to drop out and de-energize the close coil.</p> <p>Main Contact timing tabulation can be initiated from the following timing event selections:</p> <ul style="list-style-type: none"><li>• Test Initiation (T0)</li><li>• Close Current</li><li>• Analog</li><li>• AUX Contact</li></ul>

**NOTE**

**Changing the Close Timing Event only affects the tabulated test results for a Close test.**

*Test Initiation* Timing a Close test from test initiation is achieved using the Close Pulse and Timing Event parameters (Figure A.37).



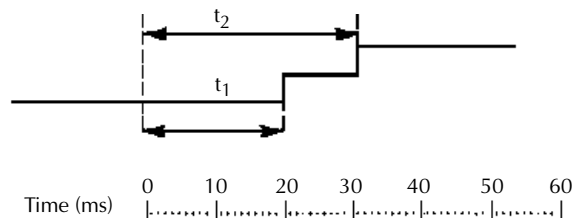
**Figure A.37 Close Parameters**

The default values for the Close Pulse are:

- 133.3 ms for 60 Hz
- 160 ms for 50 Hz

Figure A.38 shows how timing works for test initiation. The times,  $t_1$  and  $t_2$ , indicate the following:

- $t_2$  The time required to close the Main Contact. The close time is measured from the test initiation.
- $t_1$  The time required to close the resistor switch. The close time is measured from the test initiation (if the T0 option is selected in Resistor Switch Timing Specification, see "Resistor Switch Timing – Close" on page A-77).



**Figure A.38 Close Time**

*Close Current Magnitude* Timing a close test based on close current magnitude is achieved through a combination of the Close Pulse, Timing Event and Timing Trigger parameters (Figure A.39).

Close Parameters	
Close Pulse	133.3 ms.
Timing Event	Close Current
Timing Trigger	30% Full Scale

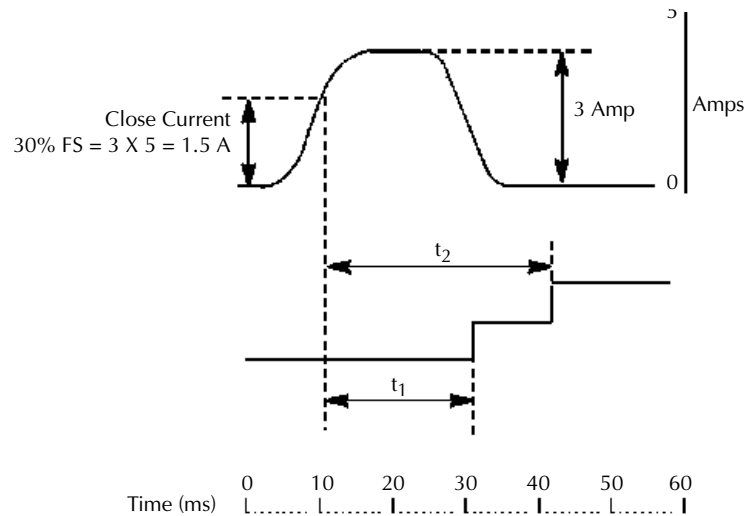
**Figure A.39 Set Magnitude of Close Current**

The timing trigger value is set as a percentage of full scale current (of the range selected) and is adjustable in 10% increments.

The selection made calculates the timing of the Main Contact ( $t_2$ ) and resistor switch ( $t_1$ ) (Figure A.40 on page A-40) after the close current reaches 30% of the selected full scale for the close current range if the T0 option is selected in "Resistor Switch Timing – Close" on page A-77.

It is important to select the current range ("Current Selection Probe/Shunt" on page A-68) and percentage of the full scale so that the value selected in Timing Trigger is less than the maximum value of the close current.

If, in the example shown in Figure A.40, the range selected was 20 A instead of 5 A, then 30% FS = 0.3 X 20 = 6 A, which is a value that close current never reaches. Consequently, the Instrument will not record any time in the tabulations.



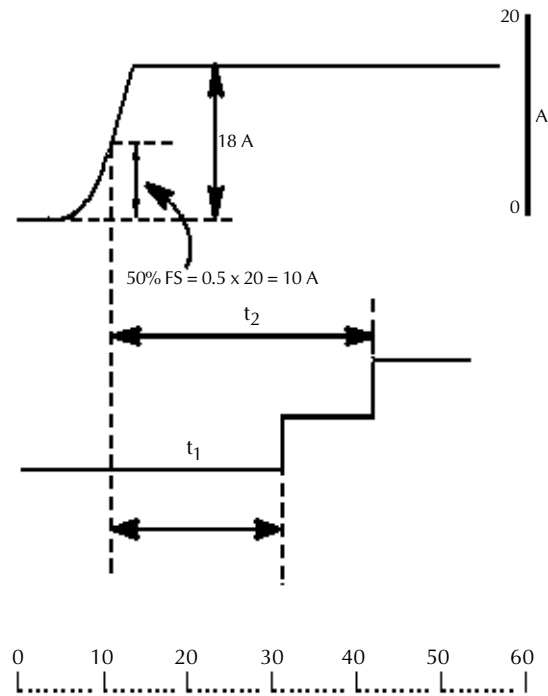
**Figure A.40 Close Timing from Close Current Measurement**

*Analog: Current/Voltage Magnitude* Timing a close test based on current/voltage magnitude for a particular channel is achieved through the combination of the Close Pulse, Timing Event, Timing Trigger, Timing Channel parameters (Figure A.41).

Close Parameters	
Close Pulse	133.3 ms
Timing Event	Analog
Timing Trigger	50% Full Scale
Timing Channel	5-A1

**Figure A.41 Set Magnitude of Analog Measurement**

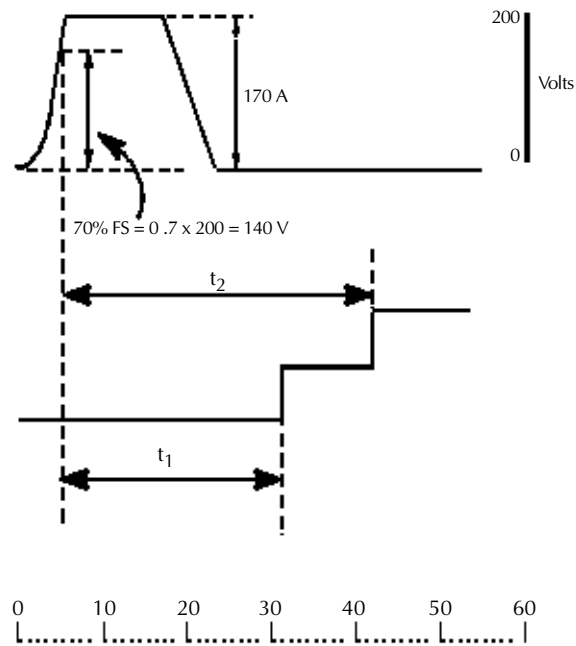
The selection made calculates the timing of the Main Contact ( $t_2$ ) and resistor switch ( $t_1$ ), after the measurement by the designated channel reaches 50% of the full scale current selected for that channel (Figure A.42) if the T0 option is selected in "Resistor Switch Timing – Close" on page A-77. The measurements in Figure A.42 were calculated using an external current probe with a selected range of 20 A.



**Figure A.42 Close Timing from Current Measurement**

If external shunt is used, let us say  $5 \text{ V} = 100 \text{ A}$ , then the timing starts when the shunt output reaches  $2.5 \text{ V}$  which corresponds to  $50 \text{ A}$ .

Figure A.43 shows an example for voltage, where the selection made calculates the timing of the Main Contact ( $t_2$ ) and resistor switch ( $t_1$ ), after the voltage controlled by the designated channel reaches 70% of the full scale selected for that channel, if the T0 option is selected in "Resistor Switch Timing – Close" on page A-77.



**Figure A.43 Close Timing from Voltage Measurement**

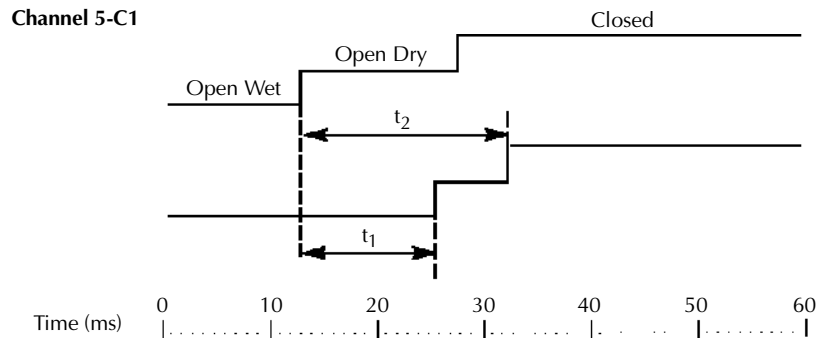
*AUX Contact Transition*

Timing a Close test based on the transition of a contact for a particular channel is achieved through the combination of the Close Pulse, Timing Event and Timing Channel parameters (Figure A.44).

Close Parameters	
Close Pulse	133.3 ms.
Timing Event	Aux Contact
Timing Channel	5-C1

**Figure A.44 Set Contact Channel**

The selection made calculates the timing of the Main Contact ( $t_2$ ) and resistor switch ( $t_1$ ) (Figure A.45), after the first transition of the auxiliary contact, measured by channel 5-C1 in the TDR9000, if the T0 option is selected in "Resistor Switch Timing – Close" on page A-77.



**Figure A.45 Transition of Contact**

#### Trip Free Parameters (C-O)

The close pulse and the delay length are adjustable in 1/10 ms increments. 1/2 Cycle

The following options are available for the trip initiation command:

- Standing
- Delay
- Contact 1 Make

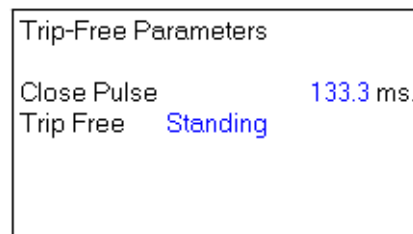
#### *Standing*

The trip pulse is applied 8.33 ms (1/2 cycle) for 60 Hz (10 ms for 50 Hz) after the close pulse and continues for the duration of the test (Figure A.46).

#### NOTE



**If the 1/2 cycle delay must be eliminated, the Trip-Free test with delay option set to 0.0 ms should be used.**

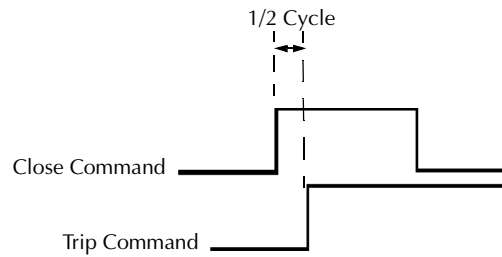


**Figure A.46 Trip Free Standing**

The default Close Pulse value is:

- 60 Hz - 133.3 ms
- 50 Hz - 160 ms

Figure A.47 shows how the Standing Trip command is delayed.



**Figure A.47 Trip-Free Standing Operation**

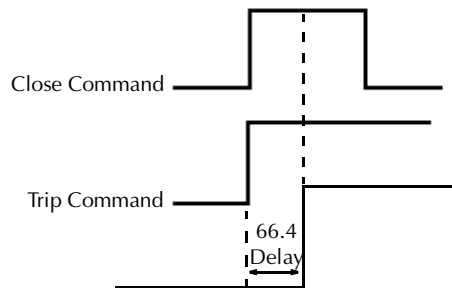
*Delay* The trip pulse is applied after the specified time delay (0.0 to 1600 ms), and continues for the duration of the test (Figure A.48).

Trip-Free Parameters	
Close Pulse	133.3 ms.
Trip Free Delay	
Delay Length	8.3 ms.

**Figure A.48 Trip-Free Delay**

The delay length default value is 8.3 ms.

Figure A.49 shows how the Trip command is delayed.



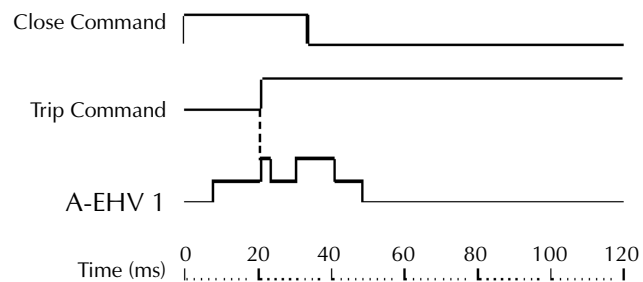
**Figure A.49 Trip-Free Delay Operation**

**Contact 1 Make** The trip pulse is applied when contact monitoring channel #1 (which is usually connected to contact #1 in Phase A) senses that the Main Contact is closed. The Trip pulse continues for the duration of the test (Figure A.50).

Trip-Free Parameters	
Close Pulse	133.3 ms.
Trip Free	Make 1 Contact

**Figure A.50 Trip-Free Contact 1 Make**

Figure A.51 shows how the Trip is started when Contact 1 makes a first pulse touch.



**Figure A.51 Trip-Free Contact 1 Make Operation**

#### Reclose Parameters (O-C)

The pulse and delay length are adjustable in 1/10 ms increments.

The following options are available for the close initiation command:

- Standing
- Delay

The close pulse default values are:

- 60 Hz - 66.6 ms
- 50 Hz - 80 ms

*Standing* The close pulse is applied 8.33 ms (1/2 cycle) for 60 Hz (10 ms for 50 Hz) after the trip pulse and continues for the remainder of the test (Figure A.52).

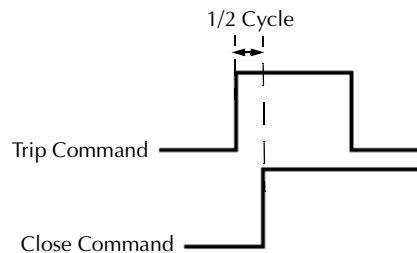


**If the 1/2 cycle delay must be eliminated, the reclose test with the delay option set to 0.0 ms should be used.**

Reclose Parameters		
Trip Pulse		66.6 ms.
Reclose	Standing	

**Figure A.52 Reclose Standing**

Figure A.53 shows how the Standing Close command is delayed.



**Figure A.53 Reclose Standing Operation**

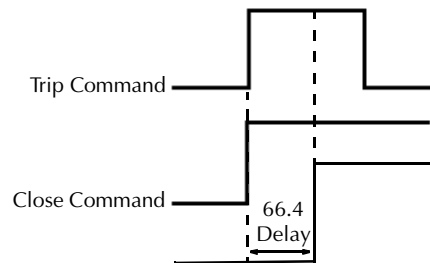
*Delay* The close pulse is applied after the specified delay time (0.0 to 1600 ms) and continues for the duration of the test (Figure A.54).

Reclose Parameters		
Trip Pulse		66.6 ms.
Reclose	Delay	
Delay Length		8.3 ms.

**Figure A.54 Reclose Delay**

The delay length default value is 8.3 ms.

Figure A.55 shows how the Reclose Delay works.



**Figure A.55 Reclose Delay Operation**

### O-C-O

To run an O-C-O test, the time period between the end of the first trip and the initiation of the second trip must be equal to or greater than 55 ms. The 55 ms requirement is based on the pickup and dropout time of the TR3000's relay, which allows the SCR inside the Instrument to initiate the command pulse. To maintain plan compatibility, these limits are maintained for the TDR9000.

The following options are available for the close command initiation:

- Standing
- Delay
- Contact 1 Make

#### *Standing*

A trip command of a specified duration (8.0 to 1600 ms) is applied to the circuit breaker at time zero (Figure A.56). A close command of a specified duration (8.0 to 1600 ms) is applied 1/2 cycle (8.3 ms for 60 Hz and 10 ms for 50 Hz) after the initiation of the trip command. The second trip command is applied to the circuit breaker delayed by a specified time interval (Delay) after the initiation of the close command and is left on for the remainder of the test.

O-C-O Parameters	
O-C-O	Standing
Trip Pulse	66.6 ms.
Close Pulse	133.3 ms.
Delay Length	113.3 ms.

**Figure A.56 O-C-O Standing**

The delay value is calculated as follows:

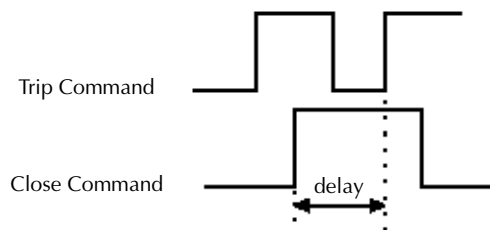
For 60 Hz                      Delay  $\geq 55 \text{ ms} + (\text{Trip pulse} - 8.3 \text{ ms})$

For 50 Hz                      Delay  $\geq 55 \text{ ms} + (\text{Trip pulse} - 10 \text{ ms})$

The default values are:

	<b>60 Hz</b>	<b>50 Hz</b>
Trip Pulse	66.6 ms	80 ms
Close Pulse	133.3 ms	160 ms
Delay	$55 \text{ ms} + (66.6 \text{ ms} - 8.3 \text{ ms}) = 113.3 \text{ ms}$	$55 \text{ ms} + (80 \text{ ms} - 10 \text{ ms}) = 125 \text{ ms}$

Figure A.57 shows how the O-C-O with a Standing Delay works.



**Figure A.57 O-C-O Delay Operation**

*Delay* A trip command of a specified duration is applied to the circuit breaker at time zero (Figure A.58). A close command of a specified duration is applied to the circuit breaker delayed by a specified time interval (Delay 1 Length) after the initiation of the trip command. The second trip command is applied to the circuit breaker that is delayed by a specified time interval (Delay 2 Length) after the initiation of the close command, and is left on for the remainder of the test.

O-C-O Parameters	
O-C-O	Delay
Trip Pulse	66.6 ms.
Close Pulse	133.3 ms.
Delay 1 Length	55.0 ms.
Delay 2 Length	66.6 ms.

**Figure A.58 Reclose Trip Delay**

The Instrument does not impose any special restrictions on Delay 1 Length, however, the following formula is useful:

$$\text{Delay 1 Length} \leq 55 \text{ ms} + \text{Trip Pulse}$$

The default value is:

$$55 \text{ ms}$$

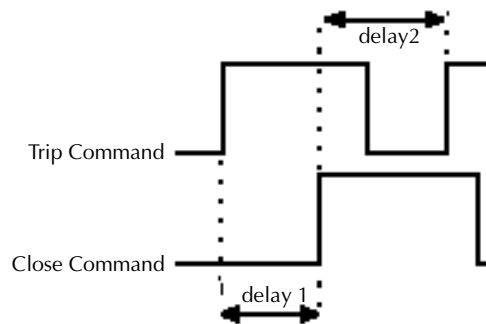
The Delay 2 Length can be calculated as follows:

$$\text{Delay 2 Length} \geq 55 \text{ ms} + (\text{Trip pulse} - \text{Delay 1 Length})$$

The default value is:

$$\text{Delay 2 Length} = 55 \text{ ms} + (66.6 \text{ ms} - 55 \text{ ms}) = 66.6 \text{ ms}$$

Figure A.59 shows how the O-C-O Delay works.



**Figure A.59 Reclose Trip Delay Operation**

*Contact 1 Make* A trip command of a specified duration is applied to the circuit breaker at time zero (Figure A.60). A close command of a specified duration is applied to the circuit breaker delayed by a specified time (delay) after the initiation of the trip command. The second trip command is initiated when electrical closure is first detected on the Main Contact channel #1 (usually connected to contact #1 in Phase A) and is left on for the duration of the test.

O-C-O Parameters	
O-C-O	Make 1 Contact
Trip Pulse	66.6 ms.
Close Pulse	133.3 ms.
Delay Length	121.6 ms.

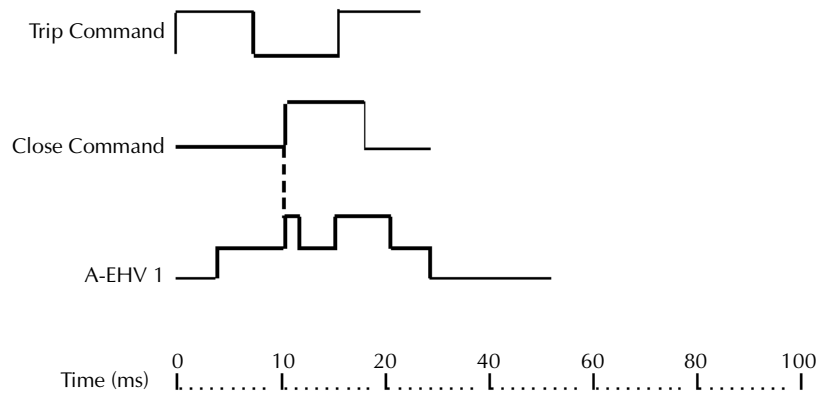
**Figure A.60 O-C-O Contact 1 Make**

The delay can be calculated as follows:

$$\text{Delay} \geq \text{Trip Pulse} + 55 \text{ ms}$$

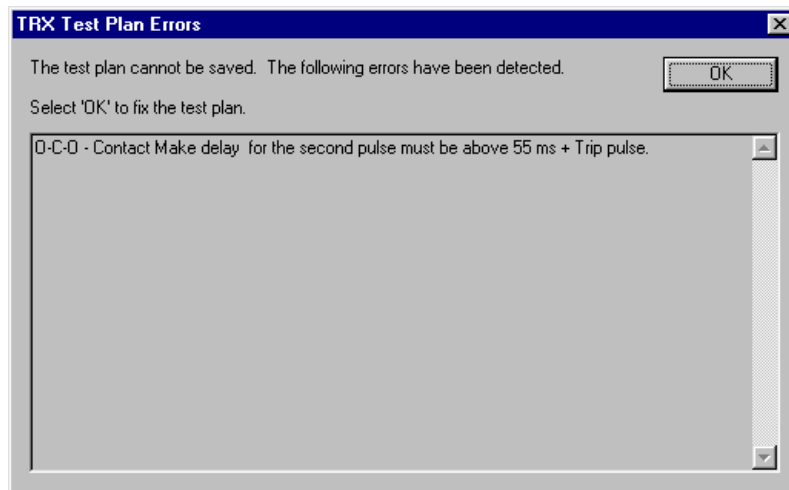
The delay default value is  $66.6 \text{ ms} + 55 \text{ ms} = 121.6 \text{ ms}$

Figure A.61 shows how the O-C-O Delay works.



**Figure A.61 O-C-O Contact 1 Make Operation**

If the delays for any of the options described are selected improperly, a message similar to Figure A.62 appears.



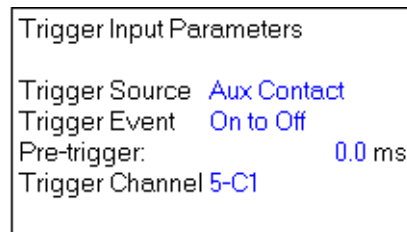
**Figure A.62 O-C-O Setup Error**

## Trigger Input Parameters

This feature enables the user to operate a circuit breaker using an external trigger, such as a command from a remote control room, instead of the Run Test button.

There are three Trigger Source conditions:

- |                 |   |
|-----------------|---|
| None (Internal) | Test recording is triggered internally, and accepts no external trigger inputs. The Instrument controls the circuit breaker using the Trip/Close module.  |
| AUX Contact     | An input that comes in through an Auxiliary Contact triggers the test and is assigned to be recorded on a designated channel of the Event module (Figure A.63). The Trip/Close module is not used for this test. The trigger can be one of four types: <ul style="list-style-type: none"> <li>• Open to Close</li> <li>• Close to Open</li> <li>• Volts On to Volts Off</li> <li>• Volts Off to Volts On</li> </ul> |



**Figure A.63** AUX Contact Trigger Parameters

### NOTE



**The AUX Contact Trigger In channel is designed to work in a substation using station battery voltages of 48 VDC or higher. Voltages less than 48 VDC may not meet the threshold requirements of the Volts On state.**

After selecting the type of trigger, the TDR9000 channel being used to monitor this trigger must be specified. Fifteen channels are available (optionally) on the TDR9000: 1 through 5, C1 through C3. To record the timing of the channel receiving the trigger, activate this chosen channel (see "Auxiliary Contacts Channel Activation" on page A-67).

"Pre-Triggering Data Collection" on page A-53 describes the pre-trigger data functionality available for this test.

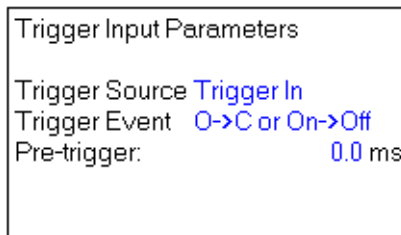
Trigger In

A System Trigger In (Figure A.64) functions somewhat differently than an AUX Contact Trigger In. An input that comes in through the External Trigger connection of the System module and is conditioned by a delay time, starts the TDR9000 test.

Although the System module Trigger In channel is a tri-state channel like the Aux Contact channel, it is not a measurement channel. For each of the two settings, it detects the state change, but only the fact that a trigger event has occurred is sent to the firmware.

Trigger In detects two different sets of Either/Or conditions.

- Open to Closed or On to Off  
Use this setting to detect a transition either from Open to Close or Volts On to Volts Off.
- Closed to Open or Off to On  
Use this setting to detect a transition either from Close to Open or Volts Off to Volts On.



**Figure A.64 TDR9000™ System Trigger In Parameters**

**NOTE**



**Only the Trigger In channel on the System module is rated for 600 V peak operation.**

The System Trigger In channel cannot be in the active state when the test is started. The active state is the second state of the trigger event transition. In an Open to Close transition, closed is the active state. Therefore, if *Open to Close* or *On to Off* is selected, and Continue is clicked while the Trigger In channel is connected across a closed switch, the test is aborted because the trigger input is already in the active state.

**NOTE**

**The System Trigger In channel is designed to work in a substation using station battery voltages of 48 VDC or higher. Voltages less than 48 VDC may not meet the threshold requirements of the Volts On state.**

When any external trigger is used, the internal command parameters (whether default values or values set by the operator), are effectively disabled, since the command to operate originates externally.

Testing using an external trigger gives the user a way to check that the remote command of the circuit breaker works. "Pre-Triggering Data Collection" describes the pre-trigger data functionality available for external trigger tests.

**NOTE**

**For a test tabulation of an external test to be meaningful, the T0 (trigger event) and the circuit breaker activation must coincide.**

Pre-Triggering  
Data Collection

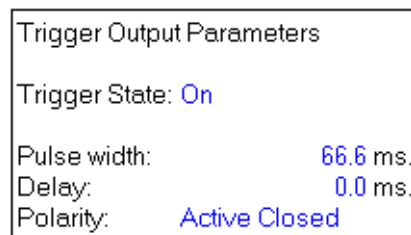
This is available for both the AUX Contact and Trigger In test. It is the length of time, in ms or cycles, prior to a triggering event for which data is retrieved. This pre-trigger data is useful for recording events that occur prior to the trigger event. *Zero to 500 ms of pre-trigger time is available.*

Trigger Output  
Parameters

Trigger Output enables the user to operate a circuit breaker using an input generated by the TDR9000, as connected through the Trigger Out connectors of the System module. The pulse width can be set, along with a trigger delay. The Trigger Output parameters pertain to only one thing: the TDR9000 Trigger Out channel (on the System module). The Trigger Output is essentially a solid state switch output (dry contact), that can be used to control an accessory or trigger another TDR9000. The Trigger can operate in circuits up to 300 V peak, 0.5 A maximum.

There are two Trigger State conditions:

- Off This disables the Trigger Output feature.
- On This enables the Trigger Output and activates the fields shown in Figure A.65.



**Figure A.65 Trigger Output Parameters**

Pulse Width	The length of signal transmission in ms sent to the circuit breaker that determines the length of time that the Trigger Output remains in the active condition.
Trigger Delay	<p>The length of time between the inception of the test and when the trigger is set.</p> <p>This defines the timing relationship between the trigger input and the trigger output. The Trigger Out channel can be used in conjunction with internal triggering, when controlling the test initiation with the Trip/Close control, or with an external System trigger input. Trigger Out cannot be used with Event Triggers, like Aux. Contact Trigger input.</p> <p>When used with:</p> <ul style="list-style-type: none"><li>• Internal triggering (Trip/Close control), the delay can be either positive or negative.<ul style="list-style-type: none"><li>• A positive delay causes the Trigger Out channel to transition to the active state after the test/recording has begun (delayed by Trigger Delay value).</li><li>• A negative delay causes the Trigger Out channel to transition to the active state immediately after the safety switch is activated, with the Trip/Close commands and recording delayed by the Trigger Delay value.</li></ul></li><li>• External triggering, only positive delay values are valid. The Trigger Out channel transitions to the active state after the external trigger in event occurs, which is delayed by the Trigger Delay value.</li></ul>
Polarity	Active Closed state only.

Digital  
Discriminator

For more information on the Digital Discriminator, see "Understanding Contact Measurement" on page A-22.

Test Duration  
Parameters

The Instrument supports a recording length field where a recording length is selected from a picklist. Each recording length has a sampling rate associated with it. When a length is selected, the sampling rate appears below it. Table A.2 lists the Recording Lengths and their associated sampling rate.

**Table A.2 Recording Lengths and Sampling Rate**

Recording Length	Sampling Rate
500 ms	10 kHz
1600 ms	10 kHz
10 s	1 kHz
30 s	500 Hz
1 min	200 Hz
5 min	50 Hz
20 min	10 Hz (Analog only)

The user-preferred recording length can be set using the TRX Options window.

NOTE



**The Test Duration parameter is not available for the Capacitance test.**

Motion Channel Parameters

Figure A.66 shows the Motion Channel Activation parameters available for each channel.

Motion Channel Activation

Enable only the motion channels which have Linear/Rotary Transducers connected. The channel label on this screen can be edited and phase A to B or C can be selected.

Motion Channel 1-3 Activation				
Motion Channel 1	Off	TRAVEL 1	A	VEL 1
Motion Channel 2	Off	TRAVEL 2	B	VEL 2
Motion Channel 3	Off	TRAVEL 3	C	VEL 3
Transducer Type		Transfer Function		
Linear	English	1.000 in. at contacts is	1.000 in. at transducer	

Motion Channel 4-6 Activation				
Motion Channel 4	Off	TRAVEL 4	A	VEL 4
Motion Channel 5	Off	TRAVEL 5	B	VEL 5
Motion Channel 6	Off	TRAVEL 6	C	VEL 6
Transducer Type		Transfer Function		
Linear	English	1.000 in. at contacts is	1.000 in. at transducer	

**Figure A.66 Motion Channel Parameters**

**Transducer Type**      Either Linear or Rotary motion can be selected. Measurement units can be English, Metric or Degrees (only available for Rotary motion).

There is a limit switch in the transducer that alerts the Instrument if the rotary adapter is mounted on the transducer. If a rotary adapter is mounted, but not selected in the Test Plan or Virtual Front Panel, the TDR9000 does not execute the test and an error message appears.

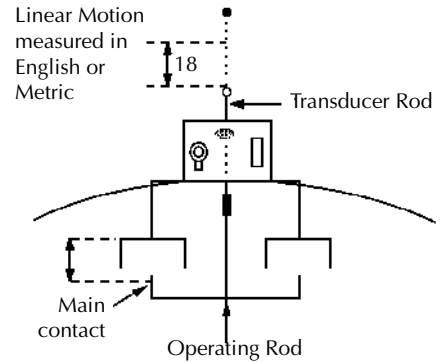
Figure A.67 and Figure A.68 show the relationships between the Test Plan and the transducer linear and rotary motion characteristics.

Motion Channel 1-3 Activation				
Motion Channel 1	On	TRAVEL 1	A	VEL 1
Motion Channel 2	On	TRAVEL 2	B	VEL 2
Motion Channel 3	On	TRAVEL 3	C	VEL 3

Transducer Type		Transfer Function		
Linear	English	1.000 in. at contacts is	1.000 in. at transducer	
	Metric			

Motion Channel 4-6 Activation

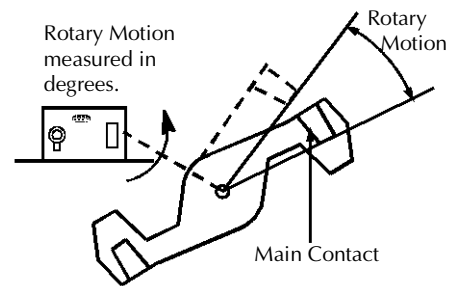


**Figure A.67 Linear Motion Measured in English or Metric**

Motion Channel 1-3 Activation				
Motion Channel 1	On	TRAVEL 1	A	VEL 1
Motion Channel 2	On	TRAVEL 2	B	VEL 2
Motion Channel 3	On	TRAVEL 3	C	VEL 3

Transducer Type		Transfer Function		
Rotary	Degrees	1.0 deg. at contacts is	1.0 deg. at transducer	



**Figure A.68 Rotary Motion Measured in Degrees**

If the measurement units are changed after specifications have been entered, the Instrument automatically recalculates the specifications and enters information using the new measurement unit.

Transfer Function

In most Bulk Oil Circuit Breakers, the transducer connecting rod is connected to the moving contact assembly through the operating rod. Thus, the contact movement and the transducer connecting rod movement are essentially identical.

Advances in circuit breaker design have resulted in many new types of circuit breakers. In many of these circuit breakers, it is not possible to attach a transducer connecting rod to a part of the circuit breaker mechanism whose movement is identical to the movement of the Main Contacts. However, it should be possible to connect it to a mechanism whose motion (secondary motion) has a relationship to the Main Contacts. This relationship or *Transfer Function*, when applied to the secondary motion, allows the Instrument to see Main Contact motion (primary motion).

The Transfer Function is where numbers relating the transducer connecting rod travel to the Main Contact travel are entered, when they are not the same. The Transfer Function acts on the following quantities: Total Travel, Overtravel, Rebound, Contact Wipe, and Velocity, to produce measurements for the Main Contacts that can be compared to circuit breaker specifications.

Figure A.69 shows an example of linear to linear Transfer Function.

Motion Channel 1-3 Activation				
Motion Channel 1	On	TRAVEL 1	A	VEL 1
Motion Channel 2	On	TRAVEL 2	B	VEL 2
Motion Channel 3	On	TRAVEL 3	C	VEL 3

Transducer Type		Transfer Function		
Linear	English	6.000 in. at contacts is	3.000 in. at transducer	

**Figure A.69 Transfer Function**

In this example, the Instrument has to multiply all travel data by 2 to come up with measurements related to the Main Contacts.

Keep in mind that the value of the Transfer Function affects the resolution of the measurement.

**Example:** If the transducer connecting rod moves 10", these 10" are measured with the resolution 0.00125" (according to the transducer specification).

**NOTE**



**Resolution is the smallest change in the characteristic being measured which can unambiguously be detected in a measurement process.**

The Transfer Function is shown in Figure A.70.

Motion Channel 1-3 Activation				
Motion Channel 1	On	TRAVEL 1	A	VEL 1
Motion Channel 2	On	TRAVEL 2	B	VEL 2
Motion Channel 3	On	TRAVEL 3	C	VEL 3

Transducer Type		Transfer Function	
Linear	English	3.000 in. at contacts is	1.000 in. at transducer

**Figure A.70 Transfer Function Resolution**

If the Main Contacts have moved 30", that means that for every 0.00125" movement of the Transducer connecting rod, the Main Contacts would move 0.00375". Consequently, when the Transfer Function 3:1 is used, the resolution becomes  $0.00125 \times 3 = 0.00375$ ".

Practical considerations limit the value of the Transfer Function values. The Instrument checks to ensure that linear-to-linear Transfer Function is less than or equal to 50:1.

Figure A.71 shows an example of the rotary-to-linear Transfer Function.

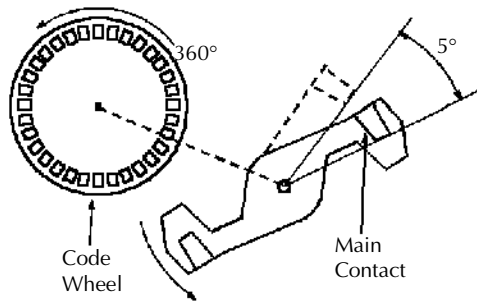
Motion Channel 1-3 Activation				
Motion Channel 1	On	TRAVEL 1	A	VEL 1
Motion Channel 2	On	TRAVEL 2	B	VEL 2
Motion Channel 3	On	TRAVEL 3	C	VEL 3

Transducer Type		Transfer Function	
Rotary	English	1.00 in. at contacts is	50.00 deg. at transducer

**Figure A.71 Rotary-To-Linear Transfer Function**

The rotary to linear Transfer Function is used when the manufacturer provides specification for the linear motion of the contacts, however, the mechanism accessible for the transducer connection is involved in a rotary motion (Figure A.72). The rotary to linear Transfer Function is also checked for the entry of a ratio that is too large.



**Figure A.72 Transducer Wheel**

The default value for a rotary to linear Transfer Function using English transducer units is 1.00 in/50.00 deg.

The following is an explanation for the chosen default value.

The transducer wheel has a circumference of 5". Consequently, if the Main Contact travel is such that the transducer wheel makes a full turn (360 deg.), the rod pressing against the wheel would have moved 5".

If the transducer rod movement is the result of the wheel movement of 1 deg., the transducer rod traveled:

$$1 \text{ deg.}/360 \text{ deg.} \times 5" = 0.01389"$$

If the default Transfer Function value is 1"/1 deg., which seems logical, the Transfer Function ratio is:

$$1"/0.01389" = 72, \text{ which is above the 50 that the Instrument uses as a limit.}$$

To bring the Transfer Function ratio into the more practical (and allowable by the Instrument) range, the Instrument defaults to the 1"/50 deg., which results in the following ratio:

$$50 \text{ deg.}/360 \text{ deg.} \times 5" = 0.694", \quad 1"/0.694" = 1.44$$

When The rotary to linear Transfer Function is used with Metric transducer units, the default value is 1 cm/1 deg., which results in a ratio below the limit imposed by the Instrument.

$$5'' = 2.54 \times 5 = 12.7\text{cm}$$

$$1 \text{ deg./}360 \text{ deg.} \times 12.7 \text{ cm} = 0.0353 \text{ cm}$$

$$1 \text{ cm/}0.0353 \text{ cm} = 28.35$$

The following example underlines the importance of the transducer resolution when the rotary to linear Transfer Function is used.

**Example:** In the SFA Circuit Breaker, when the Main Contacts travel 8.05", the rotation at the rotary input of the transducer is 35.5 deg (Figure A.73).

Motion Channel 4-6 Activation				
Motion Channel 4	Off	TRAVEL 4	A	VEL 4
Motion Channel 5	Off	TRAVEL 5	B	VEL 5
Motion Channel 6	Off	TRAVEL 6	C	VEL 6

Transducer Type		Transfer Function		
Rotary	English	8.05 in. at contacts is	35.50 deg. at transducer	

**Figure A.73 Rotary-To-Linear Transfer Function**

This corresponds to a linear travel at the transducer end of:

$$35.5 \text{ deg./}360 \text{ deg.} \times 5'' = 0.493''.$$

This results in a primary motion (Circuit Breaker Main Contacts) to secondary motion (transducer) ratio of:

$$8.05''/0.493'' = 16.32.$$

In primary terms the resolution of the measurement becomes:

$$0.00125'' \times 16.32 = 0.0204''.$$

This resolution is sufficient for SFA published tolerances (for example, wipe  $1.06 \pm 0.06$ ), however, transducer resolutions worse than 0.00125, that are used with a Transfer Function, should be considered questionable in applications such as these.

Dead Tank/OCB

The section discusses the Dead Tank/OCB Main Contact parameters (Figure A.74) available for a circuit breaker.

OCB Contact Channel Activation

These parameters activate the OCB Main Contact channels and change the label and/or phase designation for the circuit breaker contacts being monitored.

*OCB Resistor Ranges*

Trip/Close

For circuit breakers with insertion resistors, set a resistor value range in the Test Plan for the program to pick up the resistor level, for the time during which the resistor is in the circuit during circuit breaker operation, and for correct wipe measurement.

If there is no resistor in parallel with the contact, set the resistor range to *NONE*. If the value of the resistor overlaps both ranges, either can be selected.



**An incorrect resistor range setting can result in an incorrect Wipe calculation. The Average Velocity values can also be incorrect if Contact Open or Contact Close was used to specify the velocity measurement zone.**

Dead Tank / OCB Channel Activation			
OCB Channel 1	On	CONTACT1	A
OCB Channel 2	Off	CONTACT2	B
OCB Channel 3	On	CONTACT3	C
OCB Resistor Ranges	Trip: 300 - 7000 Ohms		Close: 300 - 7000 Ohms

**Figure A.74 Dead Tank/OCB – Parameters**

Table A.3 lists the voltages used when testing the Main Contacts.

**Table A.3 Voltages Used When Testing the Main Contacts**

ITEM TESTED	RANGE SELECTION	TEST VOLTAGE
Resistor, OCB	10 – 400 Ohms	7.5 V
Resistor, OCB	300 – 7,000 Ohms	48 V
All without resistors	None	15 V

If the command current range selected is too small for the actual current applied, the current recorded in the masthead reads *\*Over\**. The current on the graphical output appears clipped. The performance of the test is not affected (Figure A.75).

BREAKER PERFORMANCE REPORT	
TDR9000 Version: RE 2.24	
Manufacturer : ELECTRO SWITCH	Location : DOBLE
Model Number : A	Circuit : TEST
Serial Number : 001	Operator : MFT
Instr Book # : NONE	Operation Counter : 999
Mechanism # : TOMBOX	USER FIELD 2 : ANY DATA 2
Mech Instr # : NONE	Test Plan Name : DOBLE
ID Number : NONE	
USER FIELD : ANY DATA 1	
Test Type : TRIP	
Test was performed on 12/19/99 at 10:40:01, with digital filter time 32 mS.	
Motion Channels 1-3 Transfer Function	
1.00 in. Travel at the contacts is 45.00 deg. Travel at the transducer.	
Resistor range selected 200-500 Ohms	
Resistor times tabulated if a 200 mS resistor rate is detected.	
Command Parameters	Trip Pulse 66.6 ms.
Command Currents	Trip Current 6.35 A pk.

**Figure A.75 Breaker Performance Report Header**

Live Tank/EHV

Figure A.76 shows the Live Tank/EHV parameters available for a circuit breaker.

Live Tank / EHV Channel Activation

Main Contact Configuration: [EHV](#)

Module	EHV 1	EHV 2	EHV 3	EHV 4	EHV 5
Channel	1 / 2	3 / 4	5 / 6	7 / 8	9 / 10
Phase A	On	Off	Off	Off	Off
Phase B	On	Off	Off	Off	Off
Phase C	On	Off	Off	Off	Off
EHV Resistor Ranges		Trip: 200 - 500 Ohms		Close: 200 - 500 Ohms	

**Figure A.76 Live Tank/EHV – Parameters**

Main Contact Configuration – EHV/SPLIT Contact Channel Activation

The EHV screen activates the EHV contact channels for circuit breaker contact monitoring. A selection can be made between EHV and SPLIT contact configuration. EHV channels are activated by pairs.

**NOTE**



**The SPLIT screen allows singular channel activation. This is used when testing a Live Tank Circuit Breaker with an odd number of breaks per phase.**

*EHV Resistor Ranges*

Trip/Close

For circuit breakers with insertion resistors, set a resistor value range in the Test Plan for the program to pick up the resistor level, for the time during which the resistor is in the circuit during circuit breaker operation, and for correct wipe measurement.

If there is no resistor in parallel with the contact, set the resistor range to *NONE*. If the value of the resistor overlaps both ranges, either can be selected.

**NOTE**



**An incorrect Resistor range setting can result in an incorrect Wipe calculation. The Average Velocity values can also be incorrect if Contact Open or Contact Close was used to specify the velocity measurement zone.**

Table A.4 lists the test voltages used when testing Main Contacts.

**Table A.4 Voltages Used When Testing Main Contacts**

ITEM TESTED	RANGE SELECTION	TEST VOLTAGE
Resistor, EHV	10 – 300 Ohms	7.5 V
Resistor, EHV	200 – 500 Ohms	15 V
All without resistors	None	15 V

If the command current range selected is too small for the actual current applied, the current recorded in the masthead reads *\*Over\**. The current on the graphical output appears clipped. The performance of the test is not affected (Figure A.77).

BREAKER PERFORMANCE REPORT	
TDR9000 Version: RE 2.24	
Manufacturer : ELECTRO SWITCH	Location : DOBLE
Model Number : A	Circuit : TEST
Serial Number : 001	Operator : MFT
Instr Book # : NONE	Operation Counter : 999
Mechanism # : TOMBOX	USER FIELD 2 : ANY DATA 2
Mech Instr # : NONE	Test Plan Name : DOBLE
ID Number : NONE	
USER FIELD : ANY DATA 1	
Test Type : TRIP	
Test was performed on 12/19/99 at 10:40:01, with digital filter time 32 mS.	
Motion Channels 1-3 Transfer Function	
1.00 in. Travel at the contacts is 45.00 deg. Travel at the transducer.	
Resistor range selected 200-500 Ohms	
Resistor times tabulated if a 200 mS resistor rate is detected.	
Command Parameters	Trip Pulse 66.6 ms.
Command Currents	Trip Current 6.35 A pk.

**Figure A.77 Breaker Performance Report Header**

Capacitance Channel Parameters

The TDR9000 can measure the capacitance of grading capacitors that are connected across the main contact of a circuit breaker in the range of 75 to 10,000 pF.

The test measures capacitance between each of the two EHV leads and the common lead for each phase and each module. The test result is presented as a pass/fail rating based on whether each measurement is within the Test Plan limits.

Figure A.78 shows the parameters available for the Capacitance channels.

Module	EHV 1	EHV 2	EHV 3	EHV 4	EHV 5
Channel	1 / 2	3 / 4	5 / 6	7 / 8	9 / 10
Phase A	Off	Off	Off	Off	Off
Phase B	Off	Off	Off	Off	Off
Phase C	Off	Off	Off	Off	Off
Cap. Range: 75 - 2500 pF	Capacitance Min. ***** pF		Capacitance Max. ***** pF		

**Figure A.78 Capacitance Channel Activation**

Parameters include:

- Phase This activates/deactivates on a phase-by-phase and module-by-module basis.
- Cap. Range A scrollable picklist for selecting the Capacitor configuration. Choices include:
  - 75 - 2,5000 pF
  - 300 - 10,000 pF
- Capacitance Min. A user-entered field for entering the minimum expected capacitance.
- Capacitance Max. A user-entered field for entering the maximum expected capacitance.

Auxiliary Contact Channel Parameters

Figure A.79 shows the parameters and specifications available for Auxiliary Contact Channels.

Auxiliary Contact Channel Activation

Module	Event 1	Event 2	Event 3	Event 4	Event 5
State	Off	Off	Off	Off	Off
Label	1-C1	2-C1	3-C1	4-C1	5-C1
Phase	A	A	A	A	A
State	Off	Off	Off	Off	Off
Label	1-C2	2-C2	3-C2	4-C2	5-C2
Phase	A	A	A	A	A
State	Off	Off	Off	Off	Off
Label	1-C3	2-C3	3-C3	4-C3	5-C3
Phase	A	A	A	A	A

**Figure A.79 Auxiliary Contact Channel – Parameters and Specifications**

Auxiliary Contacts Channel Activation

This portion of the Test Plan activates and labels the contact channels for auxiliary contacts being monitored.

Analog Channel Parameters

Figure A.80 shows the Analog Channel parameters and specifications available for Circuit Breaker Main Contacts.

Analog Channel Activation

Module	Event 1	Event 2	Event 3	Event 4	Event 5
State	Off	Off	Off	Off	Off
Label	1-A1	2-A1	3-A1	4-A1	5-A1
Phase	A	A	A	A	A
Type	Shunt	Shunt	Shunt	Shunt	Shunt
Range	1.0 Volts	1.0 Volts	1.0 Volts	1.0 Volts	1.0 Volts
State	Off	Off	Off	Off	Off
Label	1-A2	2-A2	3-A2	4-A2	5-A2
Phase	A	A	A	A	A
Type	Shunt	Shunt	Shunt	Shunt	Shunt
Range	1.0 Volts	1.0 Volts	1.0 Volts	1.0 Volts	1.0 Volts
State	Off	Off	Off	Off	Off
Label	1-A3	2-A3	3-A3	4-A3	5-A3
Phase	A	A	A	A	A
Type	Shunt	Shunt	Shunt	Shunt	Shunt
Range	1.0 Volts	1.0 Volts	1.0 Volts	1.0 Volts	1.0 Volts

**Figure A.80 Analog Channel – Parameters and Specifications**

Analog Channel Activation This screen allows the user to activate and label the contact channels for any analog contacts the user plans to monitor.

Voltage Range Selection The following voltages are available:

- .2 V peak
- 2 V peak
- 10 V peak
- 100 V peak
- 200 V peak
- 300 V peak
- 500 V peak (Not supported by the TDR9000)

Current Selection Probe/Shunt The selection can be made between probe and shunt. Table A.5 lists the selections available.

**Table A.5 Probe/Shunt Current Selections**

Probe	Shunt
Low (20A peak)	.2 V peak
High (200A peak)	1 V peak
	2 V peak
	2.5 V peak
	5V peak
	10 V peak

It is important to select appropriate matching current ranges on the TDR9000 and on the probe itself. The recommended probes are:

- Autozero probe (Doble P/N 401-0055) clip-on, Hall effect probe, with current ranges 20 A and 200 A.  
This probe provides 2 V output on both ranges, when current is at maximum.
- Fluke Y8-100 clip-on, Hall effect probe, with current ranges 20 A and 200 A.  
This probe provides 2 V output on both ranges, when current is at maximum.

- F. W. Bell CG-100A clip-on, Hall effect probe, with current ranges of 10 A and 100 A.

This probe provides 1 V output on both ranges, when current is at maximum. It is also capable of 100% overload, bringing output to 2 V.

The Instrument has two current ranges to use with the probe:

- Low – 20 A
- High – 200 A

The following example shows how inappropriately selected current ranges can give misleading test results. Trip current was measured using the TDR9000, an external 1 V/10 A shunt and a F. W. Bell CG-100A clip-on probe with 10 A and 100 A ranges.

*Example #1 (Figure A.81)*

Ranges selected: Probe - 10 A, TDR9000 - Low (20 A)

Current Monitoring Trip Operation  $I_{shunt} .631 \times 10 = 6.31 \text{ A}$

BREAKER PERFORMANCE REPORT	
TDR9000 Version: RE 2.24	
Manufacturer : ELECTRO SWITCH	Location : DOBLE
Model Number : A	Circuit : TEST
Serial Number : 001	Operator : MFT
Instr Book # : NONE	Operation Counter : 999
Mechanism # : TOMBOX	USER FIELD 2 : ANY DATA 2
Mech Instr # : NONE	Test Plan Name : DOBLE
ID Number : NONE	
USER FIELD : ANY DATA 1	
Test Type : TRIP	
Test was performed on 12/19/99 at 10:40:01, with digital filter time 32 mS.	
Motion Channels 1-3 Transfer Function	
1.00 in. Travel at the contacts is 45.00 deg. Travel at the transducer.	
Resistor range selected 200-500 Ohms	
Resistor times tabulated if a 200 mS resistor rate is detected.	
Command Parameters Trip Pulse 66.6 ms.	
Command Currents Trip Current 6.35 A pk.	

Test Results	Range
I1 0.631 V pk	Shunt 1 V
I2 6.12 A pk	Probe Low

**Figure A.81 Current Monitoring Trip Operation**

6.12 A through the probe produces the following outputs:

- 10 A corresponds to 1 V
- 6.12 A corresponds to  $V_{out}$
- $V_{out} = 6.12/10 = 0.612$  V

This voltage is interpreted by the TDR9000 on the 20 A scale as:

- 2 V corresponds to 20 A
- 0.612 V corresponds to  $I_2$
- $I_2 = 0.612 \times 20/2 = 6.12$  A

Contact Timing Parameters

Figure A.82 shows the Contact Timing parameters and specifications available for Circuit Breaker Main Contacts.

Contact Timing Specifications					
	Minimum	Maximum	Module	Phase	Breaker
Main Open	ms.	ms.	ms.	ms.	ms.
Main Close	ms.	ms.	ms.	ms.	ms.
Main Reclose	ms.	ms.	ms.	ms.	ms.
Trip-Free Dwell Time:		min. ms.	max. ms.		
Reclose Dead Time:		min. ms.	max. ms.		

**Figure A.82 Main Contact Timing: – Open Parameters and Specifications**

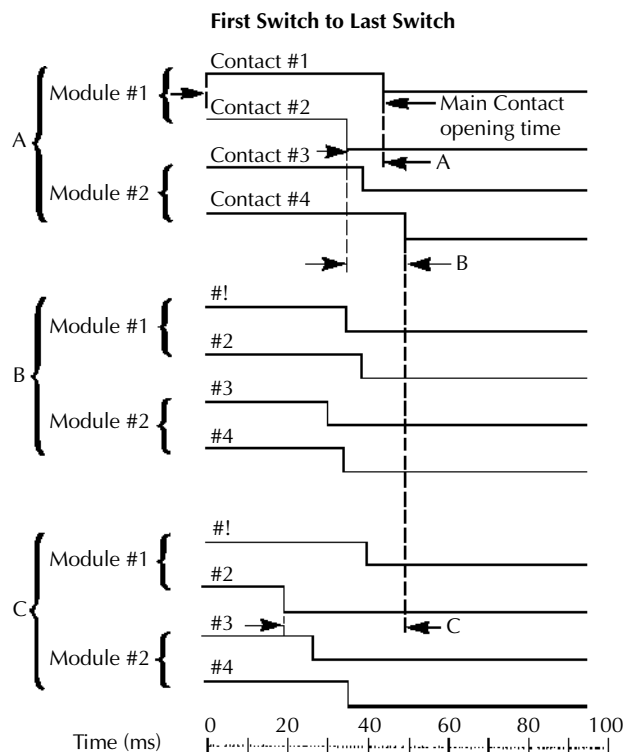
Main Contact  
Timing – Open

Parameters include:

- Minimum            The minimum time for the Main Contacts to part.
- Maximum           The maximum time for the Main Contacts to part.

Figure A.83 shows how contact timing occurs on a module-by-module level.

- Module (A)**            The maximum allowable difference in time between the opening of the two Main Contacts in any module.
- Phase (B)**            The maximum allowable difference in time between the opening of any two Main Contacts in a phase.
- Breaker (C)**           The maximum allowable difference in time between the opening of any two Main Contacts in a circuit breaker.



**Figure A.83 Main Contact Timing – Open Breaker**

Main Contact  
Timing – Close

Parameters include:

Minimum            The minimum time for the Main Contacts to make.

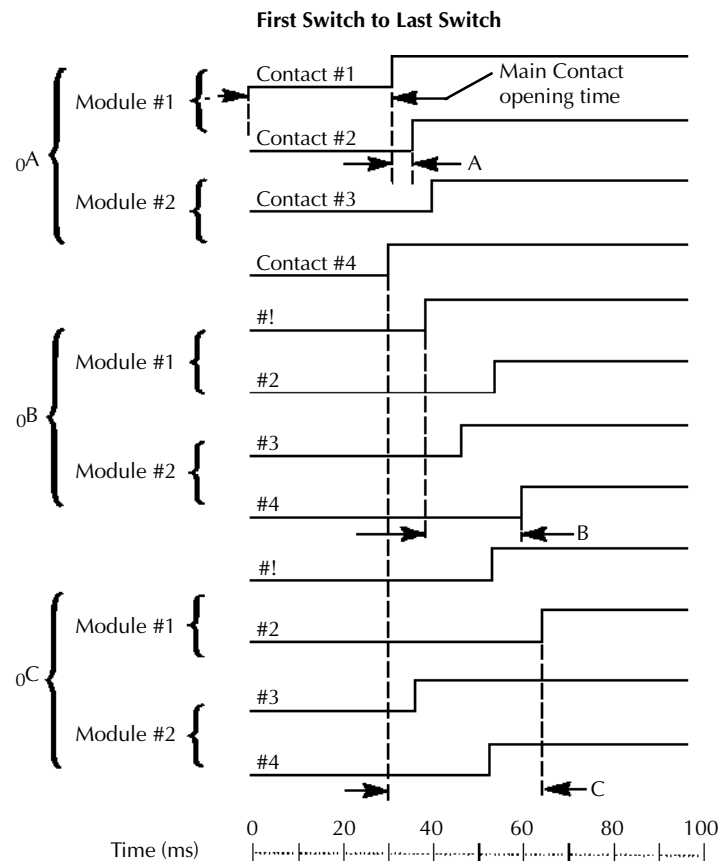
Maximum           The maximum time for the Main Contacts to make.

Figure A.84 shows how contact timing occurs on a module-by-module level.

**Module (A)**            The maximum allowable difference in time between the closing of the two Main Contacts in any module.

**Phase (B)**            The maximum allowable difference in time between the closing of any two Main Contacts in a phase.

**Breaker (C)**            The maximum allowable difference in time between the closing of any two Main Contacts in a circuit breaker.



**Figure A.84 Main Contact Timing – Close Breaker**

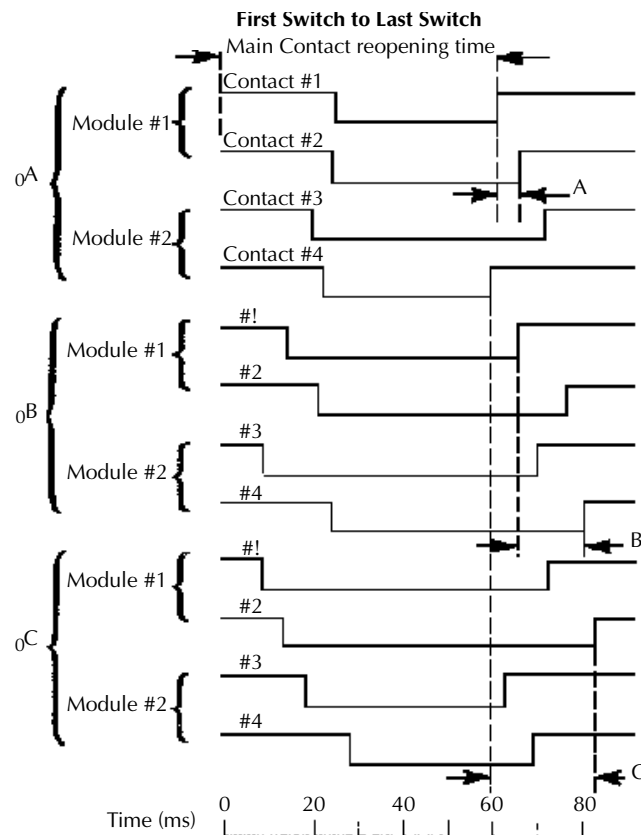
Main Contact  
Timing – Reclose

Parameters include:

- Minimum            The minimum time from trip initiation to Main Contact make
- Maximum           The maximum time from trip initiation to Main Contact make.

Figure A.85 shows how contact timing occurs on a module-by-module level.

- Module (A)**            The maximum allowable difference in time between the Trip initiation and the closing of the two Main Contacts in any module.
- Phase (B)**            The maximum allowable difference in time between the Trip initiation and the closing of any two Main Contacts in any phase.
- Breaker (C)**           The maximum allowable difference in time between the Trip initiation and the closing of any two Main Contacts in a circuit breaker.



**Figure A.85 Main Contact Timing – Reclose**

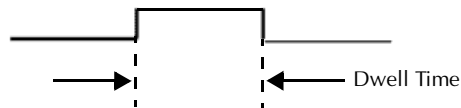
Main Contact  
Timing: Trip-Free  
Dwell – Reclose  
Dead

Trip-Free Dwell parameters include:

Trip-Free Dwell min The minimum time the Main Contacts may be CLOSED during a Trip-Free test.

Trip-Free Dwell max The maximum time the Main Contacts may be CLOSED during a Trip-Free test.

Figure A.86 shows the Trip-Free Dwell Time.



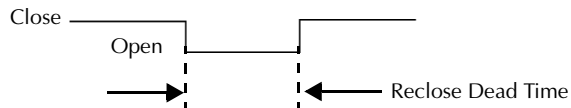
**Figure A.86 Trip-Free Dwell Time**

Reclose-Dead Time parameters include:

Reclose Dead min The minimum time the Main Contacts are OPEN during a Reclose test.

Reclose Dead max The maximum time the Main Contacts are OPEN during a Reclose test.

Figure A.87 shows the Reclose Dead Time.



**Figure A.87 Reclose Dead Time**

Resistor Contact  
Timing Parameters

Figure A.88 shows the Resistor Contact Timing parameters and specifications available for the circuit breaker resistor contacts.

Resistor Contact Timing Specifications

	Minimum	Maximum	Module	Phase	Breaker
Res. Open	ms.	ms.	ms.	ms.	ms.
Res. Close	ms.	ms.	ms.	ms.	ms.
Insertion Resistor Open:	min.	Ohms	max.	Ohms	
Insertion Resistor Close:	min.	Ohms	max.	Ohms	
Resistor Relative to: Main			Resistor Tabulation Qualifier: 200 us		

**Figure A.88 Resistor Contact Timing – Parameters and Specifications**

Resistor Switch  
Timing – Open

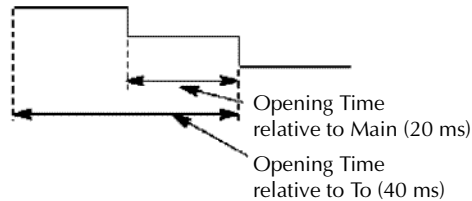
The selection can be made, using the Resistor Relative To parameter, between MAIN and T0 (Test Initiation). This enables the timing of Resistor Switches relative to the opening of the Main Contacts or test initiation, respectively.

Parameters include:

Minimum                      The minimum time for the Resistor Switch Contacts to part.

Maximum                      The maximum time for the Resistor Switch Contacts to part.

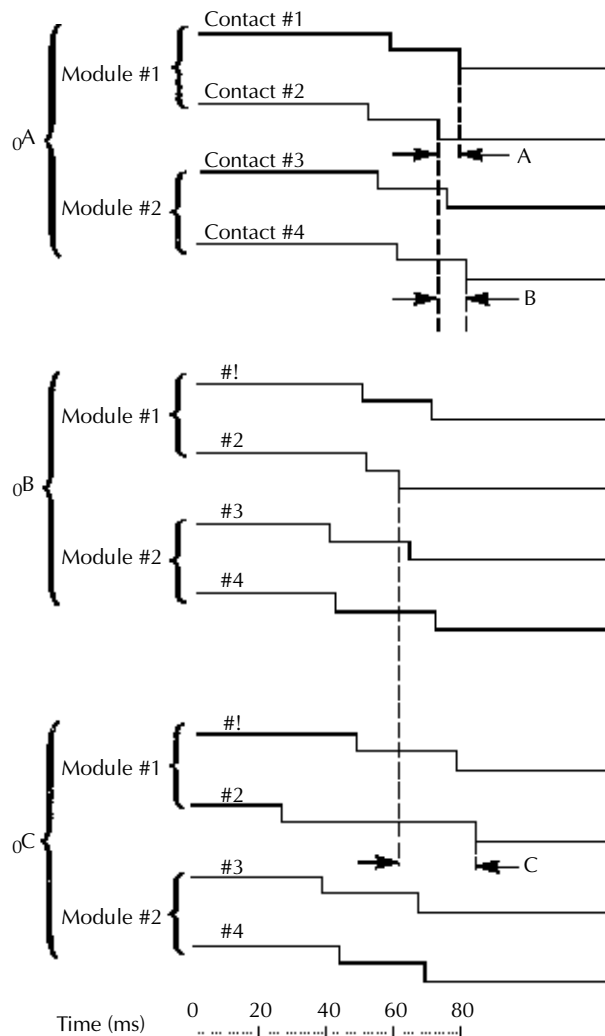
Figure A.89 shows timing relative to MAIN an T0.



**Figure A.89 Opening Time – Resistor Switch**

Figure A.90 shows how contact timing occurs on a module-by-module level.

- Module (A)** The maximum allowable difference in time between the opening of the two resistor switches in any module.
- Phase (B)** The maximum allowable difference in time between the opening of the two resistor switches in a phase.
- Breaker (C)** The maximum allowable difference in time between the opening of the two resistor switches in a circuit breaker.



**Figure A.90 Resistor Switch – Opening**

## Resistor Switch Timing – Close

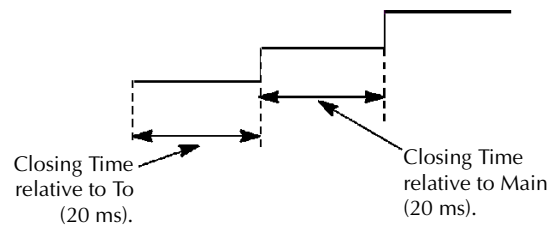
The selection can be made between MAIN and T0 (Test Initiation). This enables the timing of Resistor Switches relative to the closing of the Main Contacts or test initiation.

Parameters include:

Minimum                    The minimum time for the Resistor Switches to make.

Maximum                    The maximum time for the Resistor Switches to make.

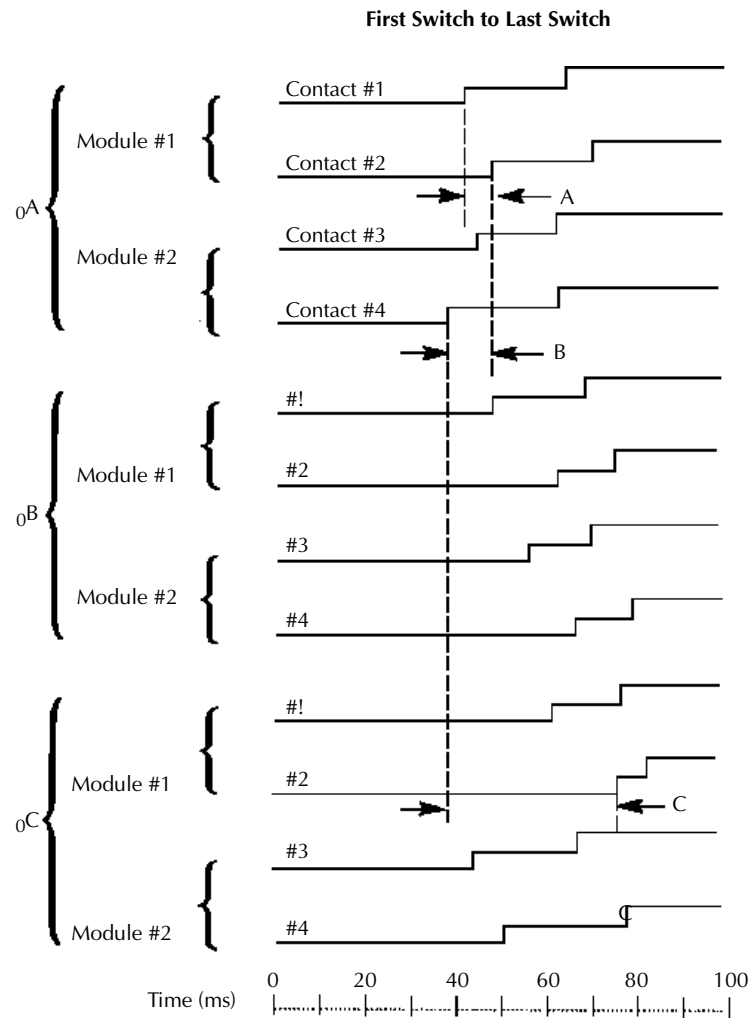
Figure A.91 shows timing relative to MAIN and T0.



**Figure A.91 Closing Time – Resistor Switches**

Figure A.92 shows how contact timing occurs on a module-by-module level.

- Module (A)** The maximum allowable difference in time between the closing of the two resistor switches in any module.
- Phase (B)** The maximum allowable difference in time between the closing of the two resistor switches in a phase.
- Breaker (C)** The maximum allowable difference in time between the closing of the two resistor switches in a circuit breaker.



**Figure A.92 Resistor Switch – Closed**

Insertion Resistor  
Value – Open  
and Close

Parameters include:

- |                    |   |
|--------------------|---|
| Open Resistor min  | The minimum allowable value for the Opening Resistor in Ohms. |
| Open Resistor max  | The maximum allowable value for the Opening Resistor in Ohms. |
| Close Resistor min | The minimum allowable value for the Closing Resistor in Ohms. |
| Close Resistor max | The maximum allowable value for the Closing Resistor in Ohms. |

The TDR9000 measures resistance values from **10 Ω** to **7500 Ω**.

Res Tab Qualifier

For tabulation, the Resistor Tabulation Qualifier sets the minimum amount of time a resistor level (resistor switch closed and Main Contact open) must be present for the *first touch* to be considered the beginning of the resistor level. The options are 200 ms, 100 ms, and bounce. If 200 ms or 100 ms are selected, the resistor level must be present during the entire period specified (200 ms or 100 ms) without any transitions or bounces for the *first touch* to be acceptable.

**NOTE**



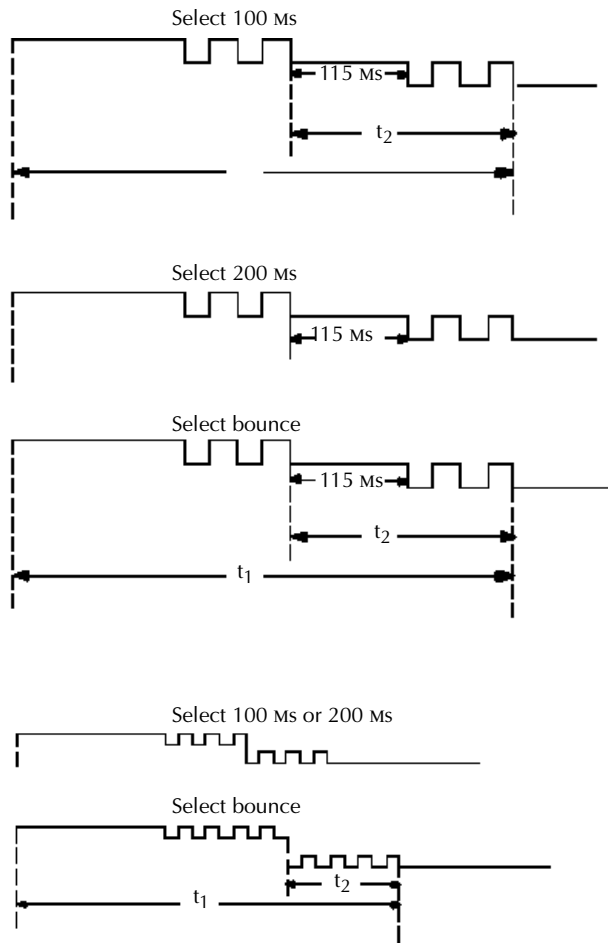
**First touch is considered first strike for a close test and last break for an open test.**

Different values of resistor tabulation qualifiers are needed to accommodate the characteristics of different circuit breakers. If the characteristic of a circuit breaker is such that the resistor switch tends to bounce extensively during operation, and the bouncing results in no resistor switch *touching* long enough to match the qualifier setting, then the resistor switch is not *seen* by the test set, and the operating time of the resistor switch is not tabulated. In such a case, the qualifier time can be reduced from the default value of 200 ms to 100 ms to *catch* the resistor switch (despite its bouncing) and obtain a tabulated value. This is acceptable if the bouncing is a normal part of this particular circuit breaker's operation. If it is an abnormal phenomenon, however, reducing the qualifier time to make the switch visible is self-defeating since the tabulated value has no real meaning.

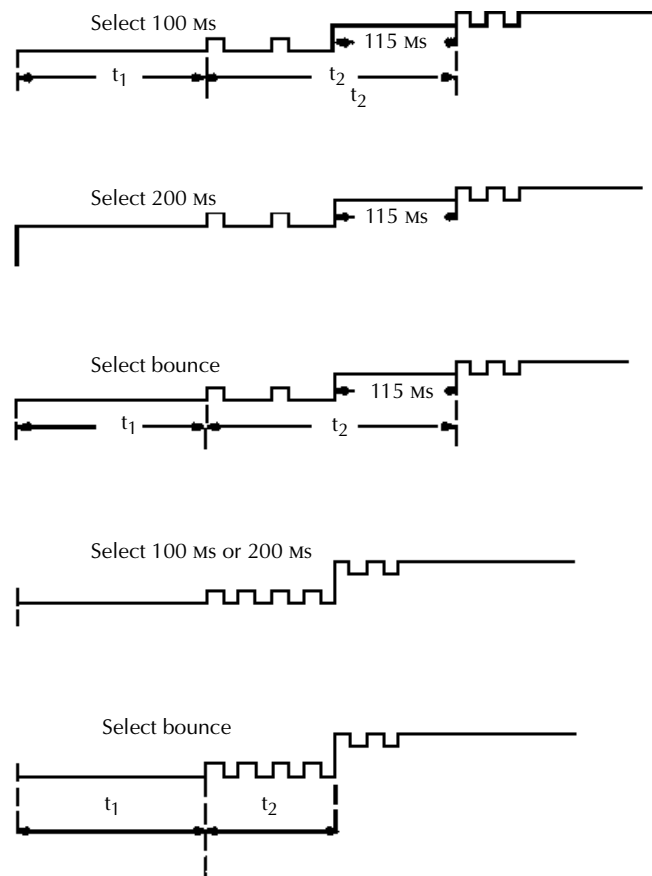
For purposes of determining a trend in a circuit breaker, and for comparison among similar circuit breakers, use the largest time setting which consistently yields a tabulated value for the resistor switch timing.

If *bounce* is selected and the first touch is at the resistor level, then the first touch is used for the resistor switch tabulation, without the necessity of having a resistor level present for any minimum amount of time. The default value is 200 ms.

Figure A.93 and Figure A.94 give examples that clarify the matter.



**Figure A.93 Resistor Tabulation Qualifier Operation – Open Test**



**Figure A.94 Resistor Tabulation Qualifier Operation – Close Test**

**NOTE**



The Test Initiation option tabulates Resistor Switch timing from the beginning of the test ( $t = 0$ ).

The Main option tabulates resistor switch timing relative to the closing (first strike) or opening (last break) of the Main Contact.

For further information, refer to "Resistor Switch Timing – Open" on page A-75 and "Resistor Switch Timing – Close" on page A-77.

Travel Parameters

Figure A.95 shows the Travel parameters and specifications available for a circuit breaker.

Travel Specifications	Channels 1-3			Channels 4-6		
	Expected	Plus	Minus	Expected	Plus	Minus
Total Travel	in.	in.	in.	in.	in.	in.
Overtavel Open	in.	in.	in.	in.	in.	in.
Overtavel Close	in.	in.	in.	in.	in.	in.
Rebound Open	in.	in.	in.	in.	in.	in.
Rebound Close	in.	in.	in.	in.	in.	in.
Contact Wipe	in.	in.	in.	in.	in.	in.

**Figure A.95 Travel – Parameters and Specifications**

Total Travel,  
Contact Wipe

Parameters include:

Total Travel

This is the total Circuit Breaker Main Contact travel during close or open operations. Negative tolerance for total travel must never be greater than the specified total travel.

This is the Transducer Connecting Rod or Rotary Adapter travel, if the Transducer Connecting Rod or Rotary Adapter and Main Contact travel are identical (Transfer Function is 1).

Contact Wipe (Close) This is the distance the Transducer Connecting Rod or Rotary Adapter moves from the first Main Contact make to the fully closed position of the circuit breaker.

The Main Contact used to calculate wipe is determined by the phase selected on the Motion Channel Parameters (Refer to "Motion Channel Parameters" on page A-56).

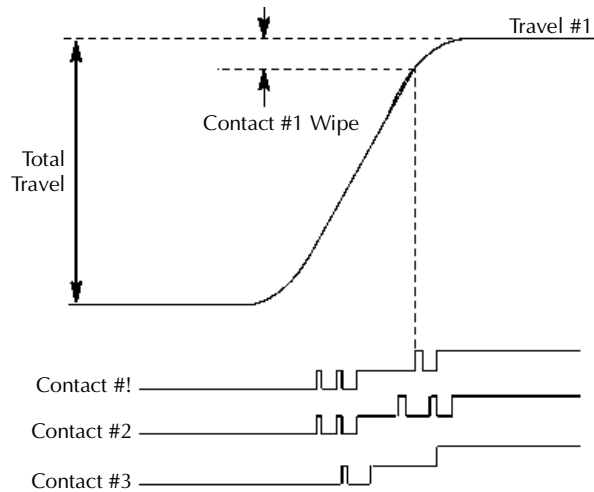
Negative tolerance for contact wipe must never be greater than the specified contact wipe.

For Oil Circuit Breakers, the Instrument determines wipe for each Motion Channel that is activated and has a transducer connected to it.

Example:

To measure Contact Wipe on the contact labeled phase A (Figure A.96):

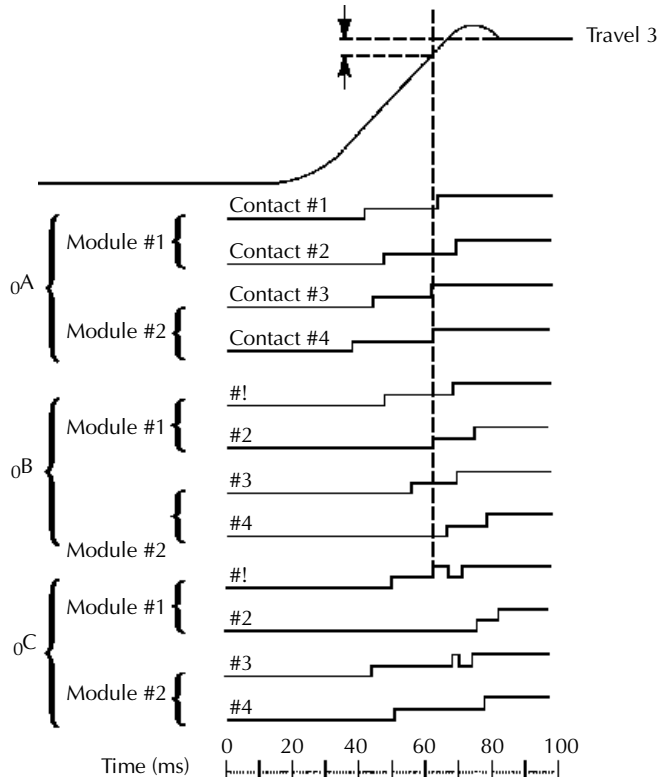
- Mount the transducer on the phase A tank.
- Connect the Transducer Cable to the first channel on the Motion/OCB module.
- Activate Motion Channel 1 on the Test Plan tab and label it A.
- Connect Contact Monitor Cable 1 to phase A.
- Set the Expected, Plus and Minus specifications in the Contact Wipe parameter portion of the Travel Specifications on the Test Plan tab.



**Figure A.96 Contact Wipe Measurement**

For an EHV Circuit Breaker (module type), the Instrument determines wipe for activated Contact 1 of the phase that has a corresponding activated Motion Channel and a Transducer connected to it. Phase A always corresponds to Motion Channel 1, Phase B to Motion Channel 2, Phase C to Motion Channel 3.

Figure A.97 shows timing for Total Travel and Contact Wipe.



**Figure A.97 Total Travel and Contact Wipe Operation**

Overtravel,  
Rebound – Open

Parameters include:

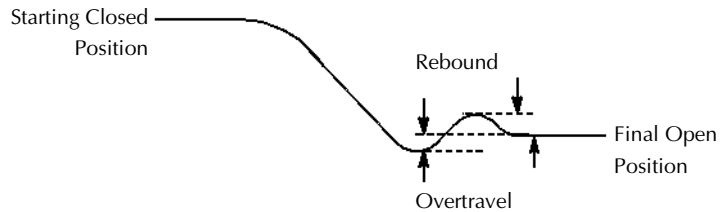
Overtravel

This is the distance between the maximum temporary displacement of the Circuit Breaker Main Contacts beyond the final open position. Negative tolerance for overtravel must never be greater than the specified overtravel.

Rebound

This is the distance between the maximum temporary displacement of the Circuit Breaker Main Contacts which is short of the final open position. Negative tolerance for rebound must never be greater than the specified rebound.

Figure A.98 shows how overtravel and rebound operate during a circuit breaker opening operation.



**Figure A.98 Overtravel/Rebound Open**

Overtravel,  
Rebound – Close

Parameters include:

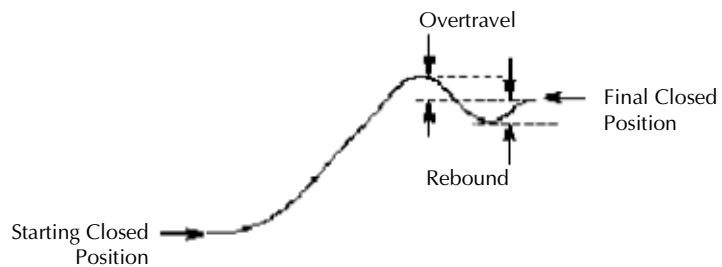
Overtravel

The distance between the maximum temporary displacement of the Circuit Breaker Main Contact beyond the final closed position. Negative tolerance for overtravel must never be greater than the specified overtravel.

Rebound

The distance between the maximum temporary displacement of the Circuit Breaker Main Contacts, which is short of the final closed position. Negative tolerance for rebound must never be greater than the specified rebound.

Figure A.99 shows how overtravel and rebound operates for a circuit breaker closing operation.



**Figure A.99 Overtravel/Rebound Closed**

Average Velocity Parameters

Figure A.100 shows the Average Velocity parameters and specifications available during a circuit breaker.

Average Velocity Specifications Channels 1-3

	Zone Definition	From	To	Minimum	Maximum
Velocity Open	Distance, Distance	***** deg	***** deg	***** d/s	***** d/s
Zone 1 Close	Distance, Distance	***** deg	***** deg	***** d/s	***** d/s
Velocity Open	Distance, Distance	***** deg	***** deg	***** d/s	***** d/s
Zone 2 Close	Distance, Distance	***** deg	***** deg	***** d/s	***** d/s

Average Velocity Specifications Channels 4-6

	Zone Definition	From	To	Minimum	Maximum
Velocity Open	Distance, Distance	***** in	***** in	***** ft/s	***** ft/s
Zone 1 Close	Distance, Distance	***** in	***** in	***** ft/s	***** ft/s
Velocity Open	Distance, Distance	***** in	***** in	***** ft/s	***** ft/s
Zone 2 Close	Distance, Distance	***** in	***** in	***** ft/s	***** ft/s

**Figure A.100 Average Velocity – Parameters and Specifications**

Average Velocity – Open

The velocity zone must be entered before the test for the velocity in that zone to be calculated by the Instrument.

There are five methods of specifying the zone for Average Velocity measurements during open test.

- Distance – Distance
- Distance – Time
- Time – Time
- Contact Open – Time
- Contact Open – Distance

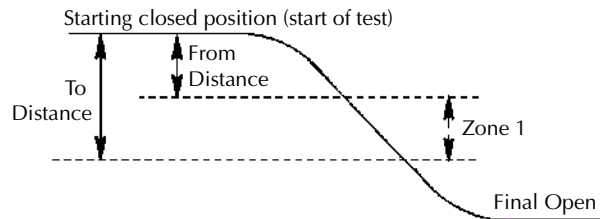
These serve as the Open and Close conditions that define each zone. These same parameters apply to Velocity Open Zone 2.

*Velocity Open  
Zone 1 and 2*

*Velocity Open Zone 1*

Velocity Open Zone 1 is comprised of the Open and Close parameters listed above. Zone 2 is similar to Zone 1 but is totally independent of Zone 1 (Figure A.108).

**Distance – Distance** The Circuit Breaker Average Velocity is calculated between the two distances specified. Distances are relative to the starting closed position (0.000 in/mm) of the circuit breaker (Figure A.101).



**Figure A.101 Contact Open Distance – Distance**

The end distance (*TO*) must be greater than the start distance (*FROM*).

**NOTE**



**When selecting values for calculating Average Velocity, avoid choosing beginning or ending distances of 0.000 in/mm. Since the circuit breaker remains in those positions for a relatively long period of time, incorrect Average Velocities are calculated.**

**Distance – Time**

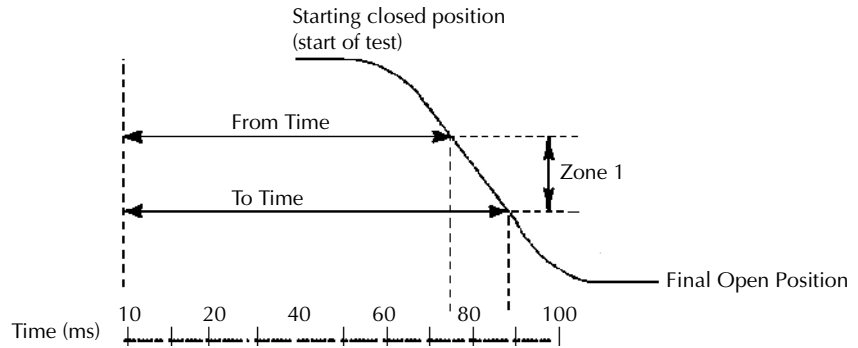
The Circuit Breaker Average Velocity is calculated between the distance specified and a time after the circuit breaker mechanism passes the specified point. Distance is relative to the starting closed position (0.000 in/mm) of the circuit breaker (Figure A.102).



**Figure A.102 Contact Open Distance – Time**

Time – Time

The Circuit Breaker Average Velocity is calculated between the two times specified (Figure A.103). In Figure A.103, the end time (*T<sub>O</sub>*) must be greater than the start time (*FROM*).

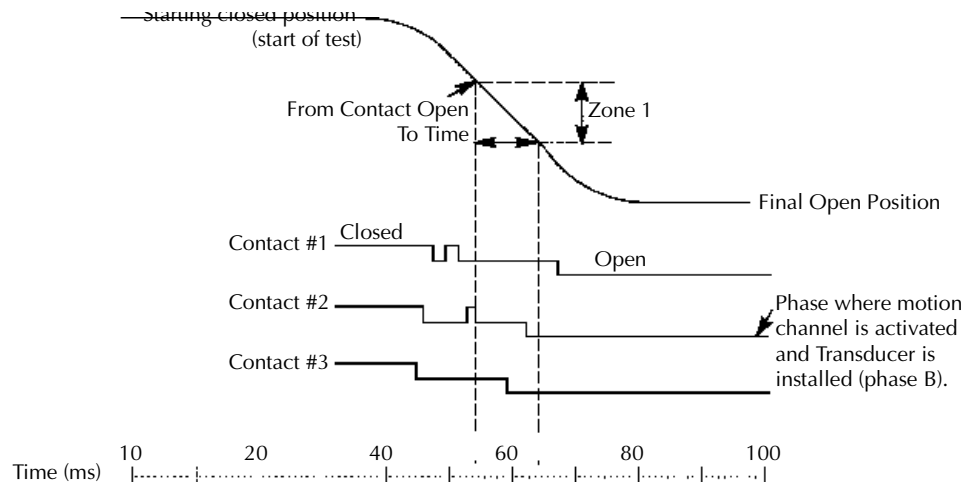


**Figure A.103 Contact Open Time – Time**

Contact Open – Time

The Circuit Breaker Average Velocity is calculated for the period between when the Main Contacts part and the specified time after that moment.

For an Oil Circuit Breaker (Figure A.104), if only one transducer is used, the Instrument uses the Main Contact data for the phase where the motion channel is activated.

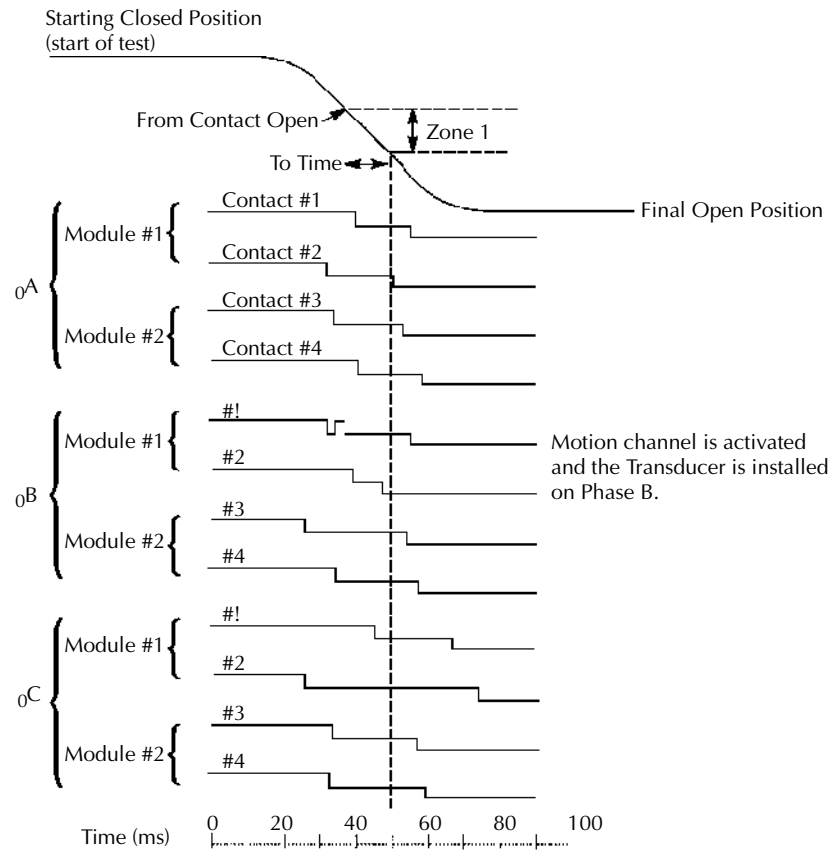


**Figure A.104 Contact Open – Time Oil Circuit Breaker**

## NOTE



For the EHV Circuit Breaker (Figure A.105), the Instrument uses the data for Main Contact 1 from the phase where the motion channel is activated to calculate the average velocity.

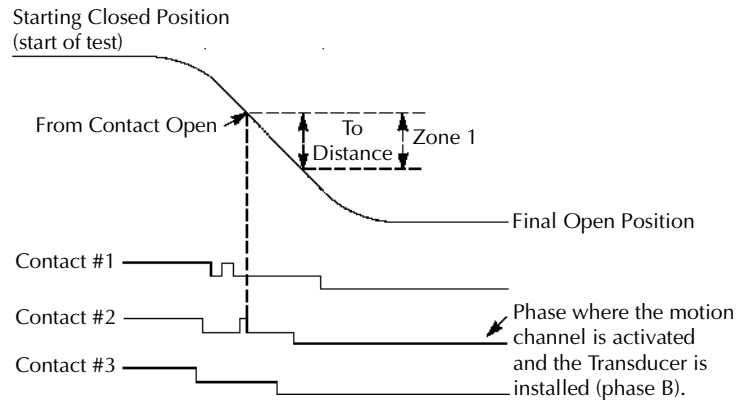


**Figure A.105 Contact Open – Time EHV Breaker**

### Contact Open – Distance

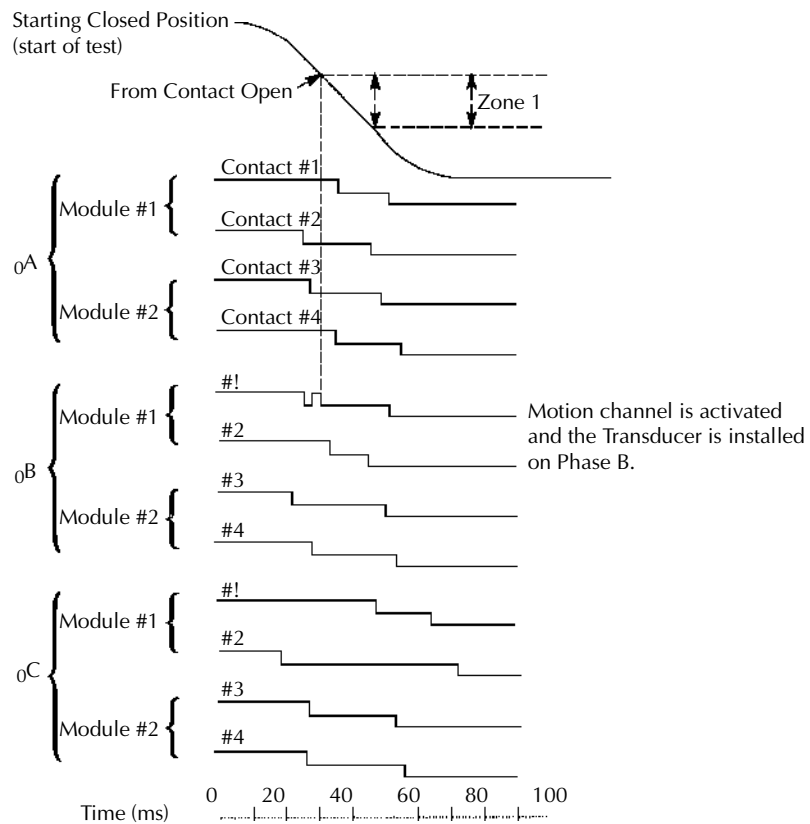
The Circuit Breaker's Average Velocity is calculated for the interval between when the Main Contacts part and the point in time that corresponds to the specified distance.

Figure A.106 on page A-90 shows the operation of this zone type for a circuit breaker.



**Figure A.106 Contact Open – Distance Oil Circuit Breaker**

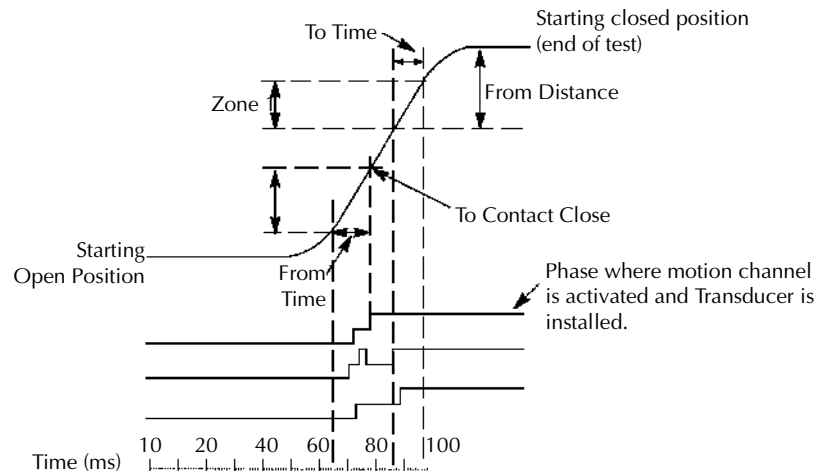
Figure A.107 shows the operation of this zone type for an EHV Circuit Breaker.



**Figure A.107 Contact Open – Distance EHV Circuit Breaker**

### Velocity Open Zone 2

Zone 2 is totally independent of Zone 1 (Figure A.108).



**Figure A.108 Contact Open Velocity Open Zone 2**

#### Average Velocity – Close

The velocity zone must be entered before the test for the velocity in that zone to be calculated by the Instrument.

There are five methods of specifying the zone for Average Velocity measurements during a close test.

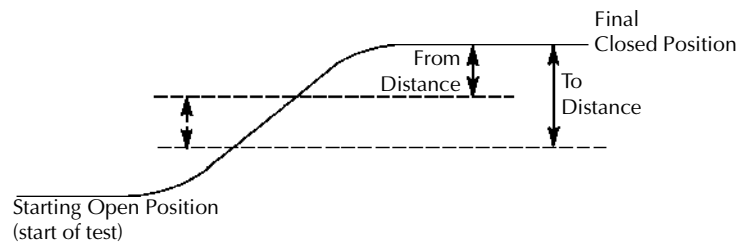
- Distance – Distance
- Distance – Time
- Time – Time
- Time – Contact Close
- Distance – Contact Close

These serve as the Open and Close conditions that define each zone. These same parameters apply to Velocity Open Zone 2.

*Velocity Open  
Zone 1 and 2*

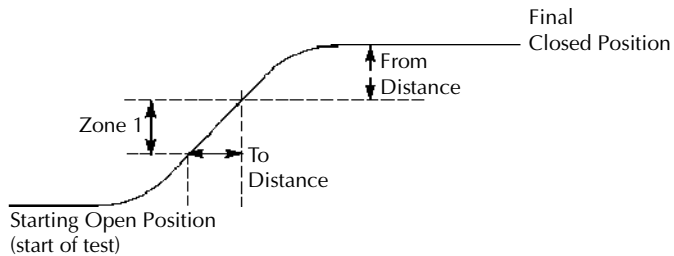
Velocity Open Zone 1 is comprised of Open and Close parameters listed above. Zone 2 is similar to Zone 1 and is totally independent of Zone 1 (Figure A.108 on page A-91).

Distance – Distance The Circuit Breaker Average Velocity is calculated between the two distances specified. Distances are relative to the final closed position (0.000 in/mm) of the circuit breaker (Figure A.116 on page A-97). In Figure A.109, the end distance (*TO*) must be less than the start distance (*FROM*).



**Figure A.109 Contact Close Distance – Distance**

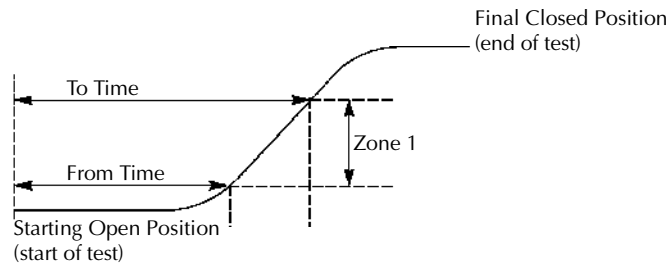
Distance – Time The Circuit Breaker Average Velocity is calculated between the distance specified and a time after the circuit breaker mechanism passes the first specified point. Distance is relative to the final closed position (0.000 in/mm) of the circuit breaker (Figure A.110).



**Figure A.110 Contact Closed Distance – Time**

Time – Time

The Circuit Breaker Average Velocity is calculated between the two times specified (Figure A.111). In Figure A.111, the end time (*TO*) must be greater than the start time (*FROM*).

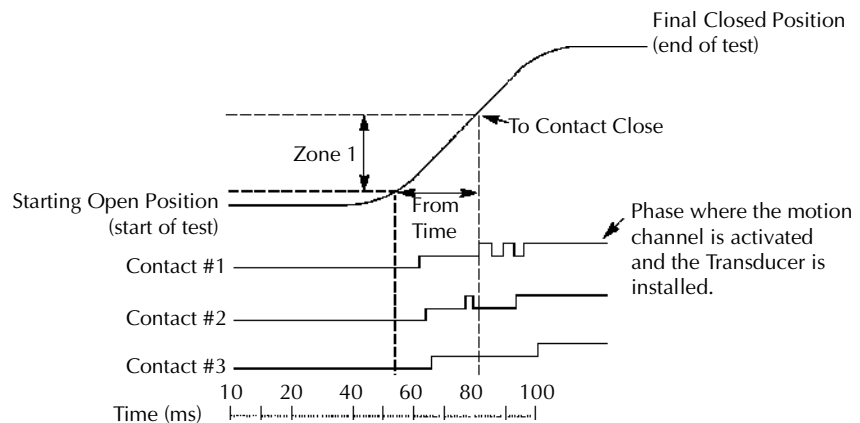


**Figure A.111 Contact Closed Time – Time**

Time – Contact Close

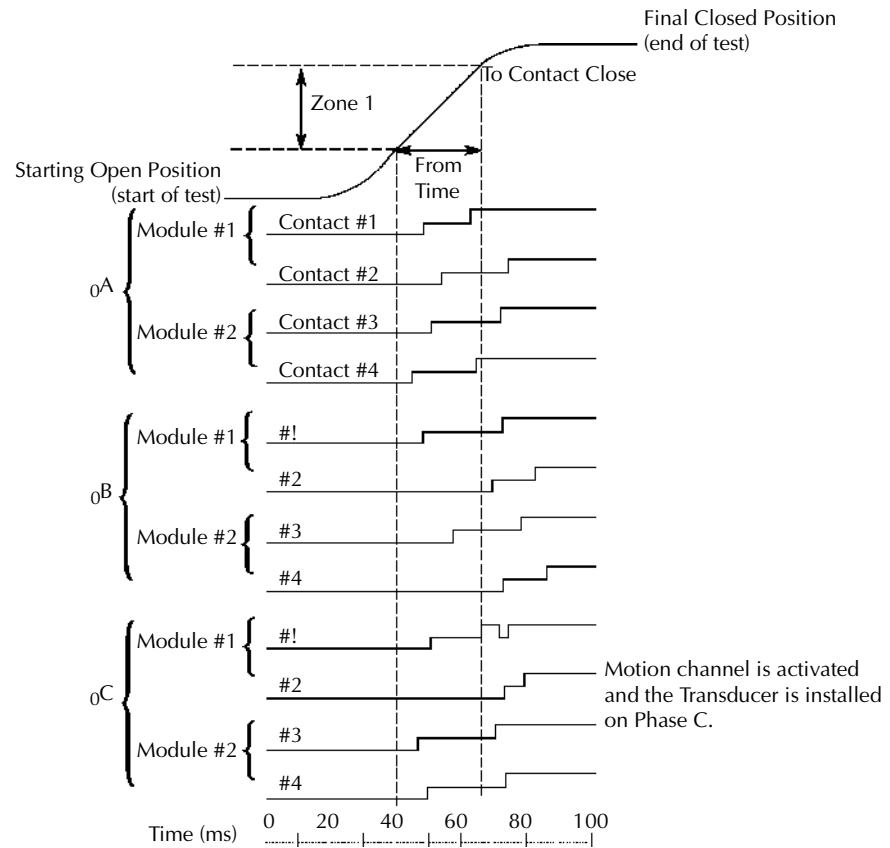
The Circuit Breaker Average Velocity is calculated for the period between the moment when the Main Contacts make and the time specified before the make (Figure A.112).

For the Oil Circuit Breaker, if only one transducer is used, the Instrument uses the Main Contact data for the phase of the active motion channel.



**Figure A.112 Contact Closed Time – Contact Close Circuit Breaker**

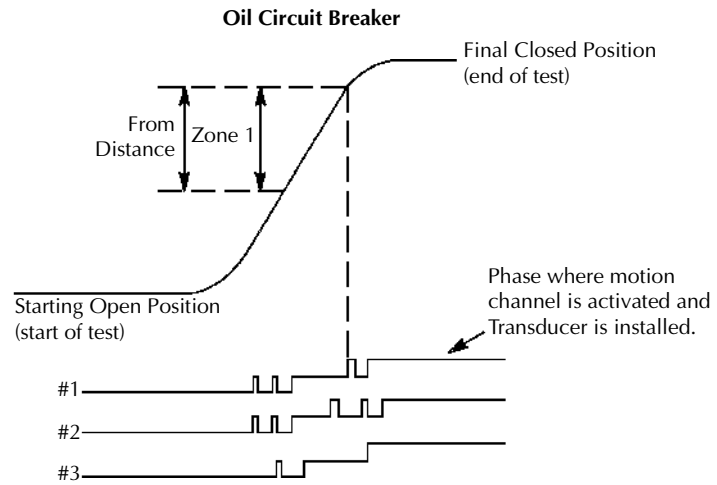
For the EHV Circuit Breaker, the Instrument uses the data for Main Contact 1 from the phase of the active motion channel (Figure A.113).



**Figure A.113 Contact Closed Time – Contact Close EHV Circuit Breaker**

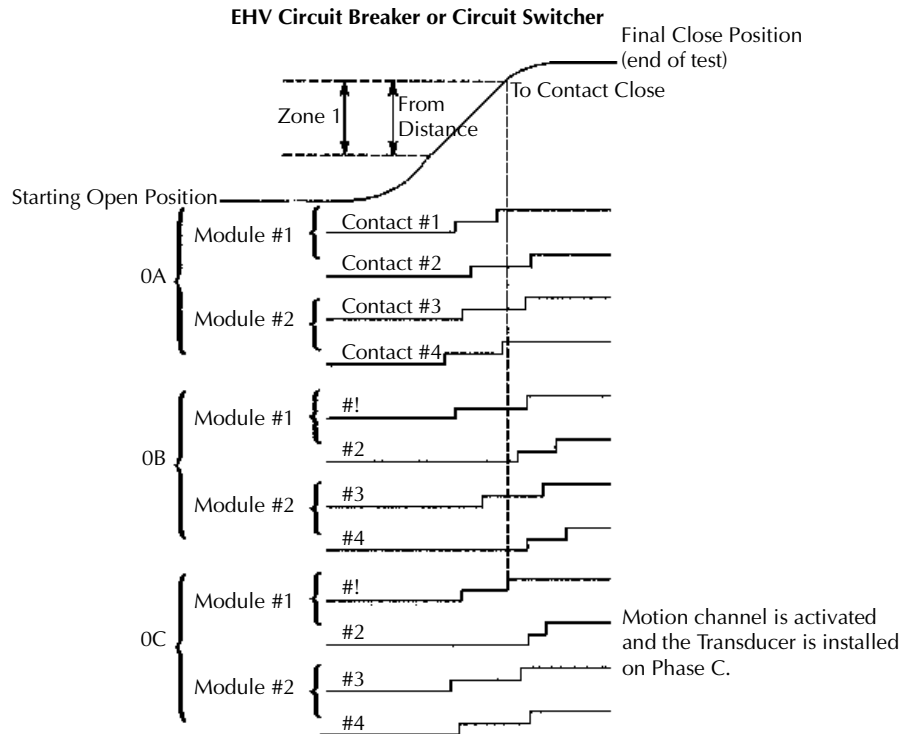
## Distance – Contact Close

The Circuit Breaker Average Velocity is calculated for the period between the moment when the Main Contacts make and the time specified before the make (Figure A.114).



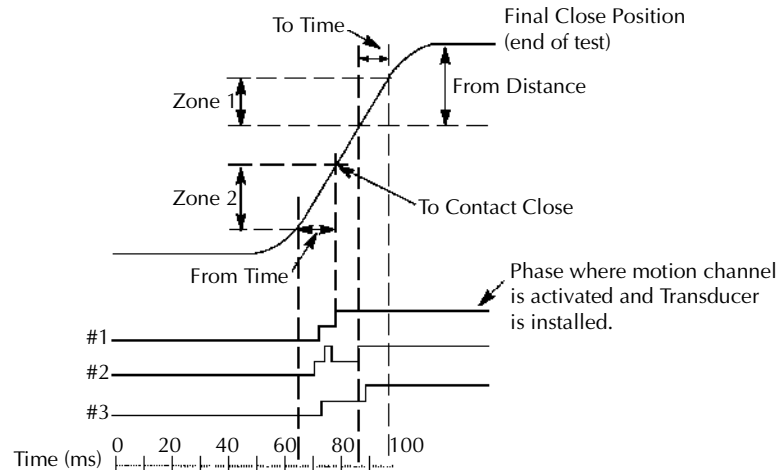
**Figure A.114 Contact Closed Time – Contact Close Oil Circuit Breaker**

For the EHV Circuit Breaker, the Instrument uses the data for Main Contact 1 from the phase of the active motion channel (Figure A.115).



**Figure A.115 Contact Closed Time – Contact Close EHV Circuit Breaker**

Zone 2 is similar to Zone 1 and is totally independent from Zone 1 (Figure A.116).



**Figure A.116 Zone 2 Closed**

## Interpreting Test Results

The TDR9000 tests parameters and compares them with circuit breaker specifications. Each tabular printout provides a pass or fail determination for each measurement corresponding to a limit that was set in the Test Plan.

This section shows both Breaker Performance Reports and their associated graphical results.

Important topics are represented by letters defined in text that match letters called out in specific figures. Refer to the pages referenced for lengthier discussions of these topics.

## Trip Test Tabulation

Live Tank and Dead Tank trip Test Results follow, with explanations of the origination of important results.

### Live Tank Breaker

This discussion covers the characteristics for a Live Tank Circuit Breaker test, whose report is shown in Figure A.117.

**A** See "Digital Discriminator" on page A-55 for details about this setting.

**B** See "Res Tab Qualifier" on page A-79 for details about this setting.

```

                                BREAKER PERFORMANCE REPORT
                                TDR9000 Version: RE 2.23

Manufacturer : ABB                      Location: Tall Top Sub
Model Number : ELF SP7-2                Circuit : C182
Serial Number: 100315-02                Operator: JHG-TCT
Instr Book # :
Mechanism # : AHMA-8
Mech Instr # :
Special ID  : C182                      Operation Counter : 304
:
Test Type   : TRIP                      Test Plan Name   :

Test was performed on 10/21/99 at 13:11:44, with digital filter time 32 µs. ← A

                                Motion Channels 1-3 Transfer Function
                                8.000 in. Travel at the contacts is 3.082 in. Travel at the transducer.

Resistor range selected 200-500 Ohms
Resistor times tabulated if a 200 µs. resistor state is detected
Insertion resistor duration times tabulated ← B

Command Parameters      Trip Pulse      40.0 mS.
Command Currents       Trip Current   8.63 A pk.
```

**Figure A.117 Live Tank Breaker Report Header**

Mechanical  
Motion

All the mechanical motion characteristics shown in Figure A.118 and Figure A.119 on page A-100 are for the Main Contacts. These are the same for the Main Contacts and the operating rod only when the Transfer Function is 1:1 ("Transfer Function" on page A-58).

MECHANICAL MOTION CHANNELS 1-3				
TRIP OPERATION				
Specifications		Test results		Compare
Average velocity in Open zone 1				
Maximum	32.80 Ft/Sec	VEL. 1	35.40 Ft/Sec	Fail
Minimum	28.80	VEL. 2	37.16	Fail
Zone 1	2.170 in. to 12.0 mS	VEL. 3	36.27	Fail
Average velocity in Open zone 2				
Maximum	32.80 Ft/Sec	VEL. 1	33.28 Ft/Sec	Fail
Minimum	28.80	VEL. 2	37.98	Fail
Zone 2	2.170 in. to 3.170 in.	VEL. 3	33.57	Fail
Total Travel				
Expected	8.000 inches	TRAVEL 1	7.703 inches	Fail
Tolerance +	0.070	TRAVEL 2	8.034	Pass
-	0.130	TRAVEL 3	7.852	Fail

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**Figure A.118 Mechanical Motion Channels 1-3 Trip Operation Section (Continued)**

Expected	***** inches	TRAVEL 1	0.000 inches	
Tolerance +	*****	TRAVEL 2	0.003	
-	*****	TRAVEL 3	0.000	
Rebound				
Expected	***** inches	TRAVEL 1	0.003 inches	
Tolerance +	*****	TRAVEL 2	0.003	
-	*****	TRAVEL 3	0.003	

**Figure A.119 Mechanical Motion Channels 1-3 Trip Operation Section**

Contact Timing Main Contact timing parameters and specifications are shown in Figure A.120 and Figure A.121, and the graphical results are shown in Figure A.122 on page A-102 and Figure A.123 on page A-103.

**C** The difference in time between the opening of the two Main Contacts in the module (Figure A.120).

EHV CONTACT TIMING  
TRIP OPERATION

Main Contact Opening Time Measured From Test Initiation									Specs:	
									Maximum	19.0
									Minimum	15.0
Phase A			Phase B			Phase C				
Contact	Time (mS)	Compare	Contact	Time (mS)	Compare	Contact	Time (mS)	Compare		
A-EHV 1	17.0	Pass	B-EHV 1	17.0	Pass	C-EHV 1	16.8	Pass		
A-EHV 2	16.9	Pass	B-EHV 2	16.8	Pass	C-EHV 2	16.8	Pass		

C {

Delta Main Contact Opening Time Within a Module									Specs:	
									Maximum	0.5
Phase A			Phase B			Phase C				
Contact	Time (mS)	Compare	Contact	Time (mS)	Compare	Contact	Time (mS)	Compare		
A-EHV 1			B-EHV 1			C-EHV 1				
A-EHV 2	0.1	Pass	B-EHV 2	0.2	Pass	C-EHV 2	0.0	Pass		

Delta Main Contact Opening Time Within a Phase									Specs:	
									Maximum	2.0
Phase A			Phase B			Phase C				
Contact	Time (mS)	Compare	Contact	Time (mS)	Compare	Contact	Time (mS)	Compare		
Phase A	0.1	Pass	Phase B	0.2	Pass	Phase C	0.0	Pass		

Delta Main Contact Opening Time Within the Breaker									
Maximum	2.0 mS		Breaker	0.2 mS		Pass			

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**Figure A.120 Motion Characteristics for Main Contacts**

E

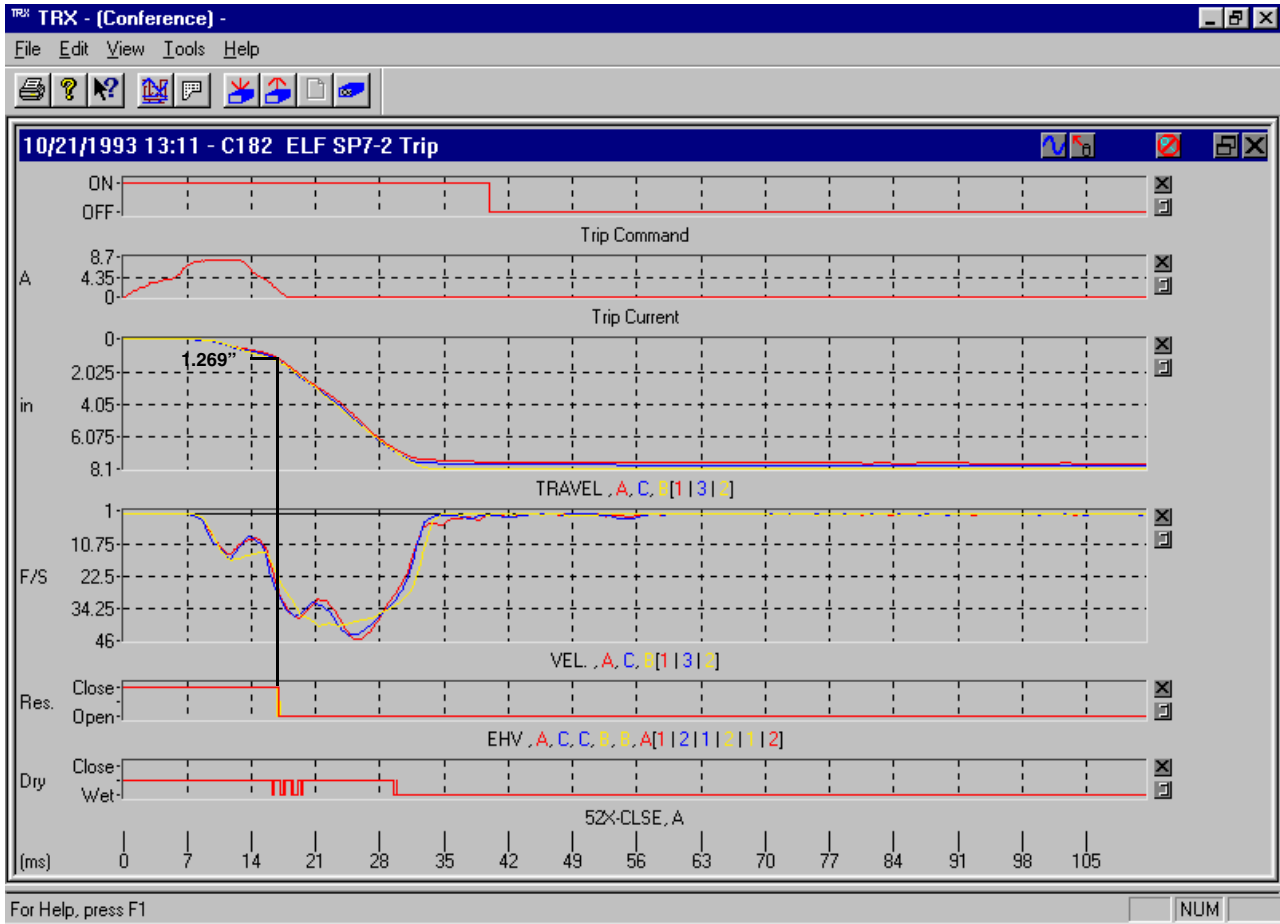
D

Main Contact Opening Time Vs Mechanical Motion									
Phase A			Phase B			Phase C			
Contact	Travel (in.)	Vel. (f/s)	Contact	Travel (in.)	Vel. (f/s)	Contact	Travel (in.)	Vel. (f/s)	
A-EHV 1	1.269	30.28	B-EHV 1	1.437	24.60	C-EHV 1	1.330	29.47	
A-EHV 2	1.233	29.47	B-EHV 2	1.379	23.25	C-EHV 2	1.330	29.47	

**Figure A.121 Motion Characteristics for Main Contacts (Continued)**

D

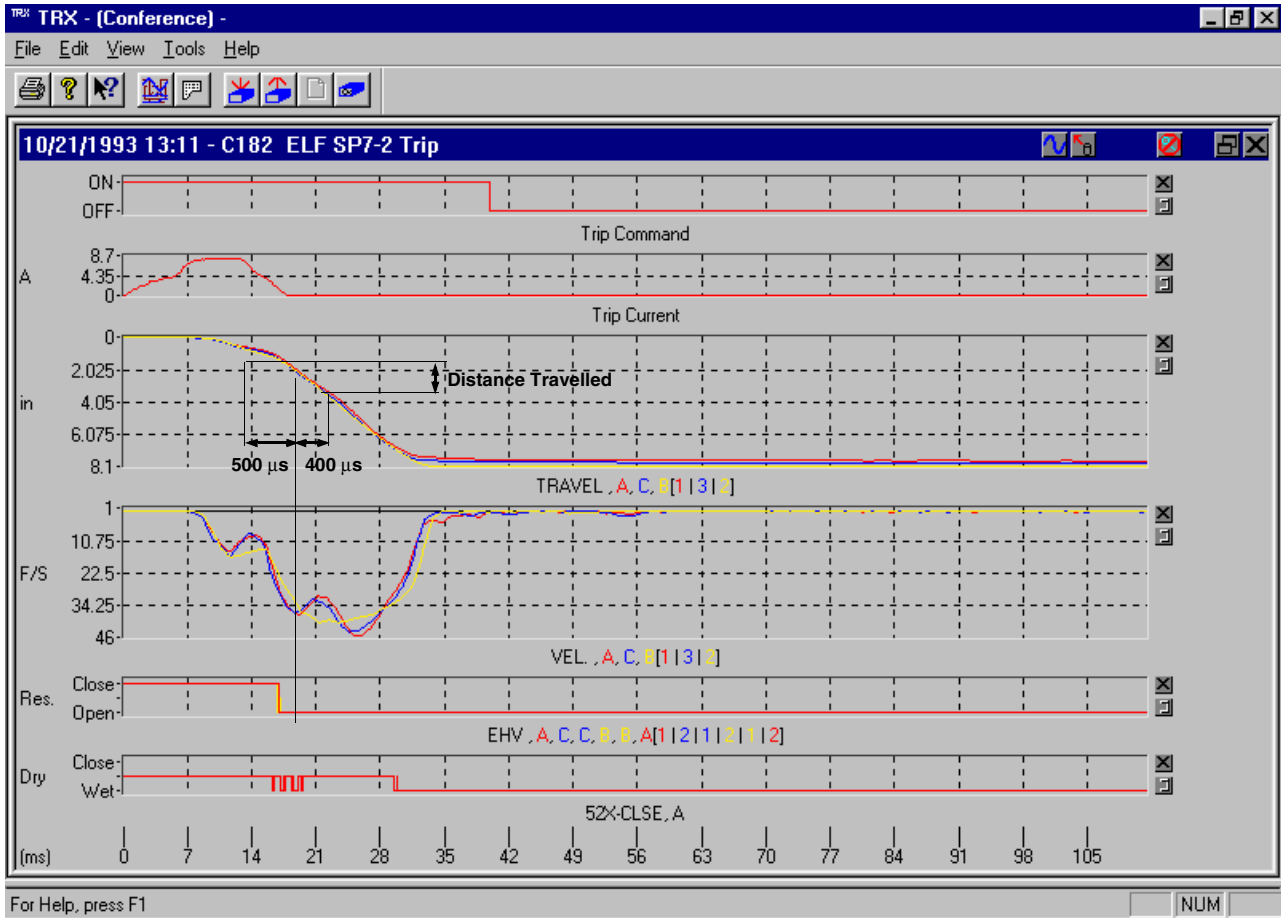
This is the distance that the Main Contacts travel from the close position baseline to the point where they part (last break) (Figure A.122).



**Figure A.122 Main Contact Travel: Closed to Part**

E

This is the Average Velocity measured during the period from 500 ms before and 400 ms after Main Contacts part (Figure A.123).



**Figure A.123 Main Contact Average Velocity**

Resistor Switching

Figure A.124 and Figure A.125 show the parameters and specifications for the opening of the resistor switches.

**A** This is the difference in time between the opening of the two Resistor Switches in the module ("Resistor Contact Timing Parameters" on page A-75).

Insertion Resistor Duration Time									Specs: Maximum ***** Minimum *****
Phase A			Phase B			Phase C			
Contact	Time (mS)	Compare	Contact	Time (mS)	Compare	Contact	Time (mS)	Compare	
A-EHV 1	0.0		B-EHV 1			C-EHV 1			
A-EHV 2			B-EHV 2			C-EHV 2			
A-EHV 3			B-EHV 3			C-EHV 3			
A-EHV 4			B-EHV 4			C-EHV 4			

Resistor Switch Opening Time Measured From Test Initiation									Specs: Maximum ***** Minimum *****
Phase A			Phase B			Phase C			
Contact	Time (mS)	Compare	Contact	Time (mS)	Compare	Contact	Time (mS)	Compare	
A-EHV 1	64.2		B-EHV 1			C-EHV 1			
A-EHV 2			B-EHV 2			C-EHV 2			
A-EHV 3			B-EHV 3			C-EHV 3			
A-EHV 4			B-EHV 4			C-EHV 4			

**A** {

Delta Resistor Switch Opening Time Within a Module									Specs: Maximum *****
Phase A			Phase B			Phase C			
Contact	Time (mS)	Compare	Contact	Time (mS)	Compare	Contact	Time (mS)	Compare	
A-EHV 1			B-EHV 1			C-EHV 1			
A-EHV 2			B-EHV 2			C-EHV 2			
A-EHV 3			B-EHV 3			C-EHV 3			
A-EHV 4			B-EHV 4			C-EHV 4			

Delta Resistor Switch Opening Time Within a Phase									Specs: Maximum *****

**Figure A.124 Resistor Switches Opening Time**

Contact	Time (mS)	Compare	Contact	Time (mS)	Compare	Contact	Time (mS)	Compare
Phase A	0.0		Phase B			Phase C		

Delta Resistor Switch Opening Time Within the Breaker		
Maximum	***** mS	Breaker 0.0 mS

**B**

Resistor Switch Opening Time Vs Mechanical Motion								
Phase A			Phase B			Phase C		
Contact	Travel (deg)	Vel. (d/s)	Contact	Travel (deg)	Vel. (d/s)	Contact	Travel (deg)	Vel. (d/s)
A-EHV 1	20.6	899	B-EHV 1	*****	*****	C-EHV 1	*****	*****
A-EHV 2	*****	*****	B-EHV 2	*****	*****	C-EHV 2	*****	*****
A-EHV 3	*****	*****	B-EHV 3	*****	*****	C-EHV 3	*****	*****
A-EHV 4	*****	*****	B-EHV 4	*****	*****	C-EHV 4	*****	*****

**C**

Resistor Value									Specs:
									Maximum *****
									Minimum *****
Phase A			Phase B			Phase C			
Contact	Ohms	Compare	Contact	Ohms	Compare	Contact	Ohms	Compare	
A-EHV 1			B-EHV 1			C-EHV 1			
A-EHV 2			B-EHV 2			C-EHV 2			
A-EHV 3			B-EHV 3			C-EHV 3			
A-EHV 4			B-EHV 4			C-EHV 4			

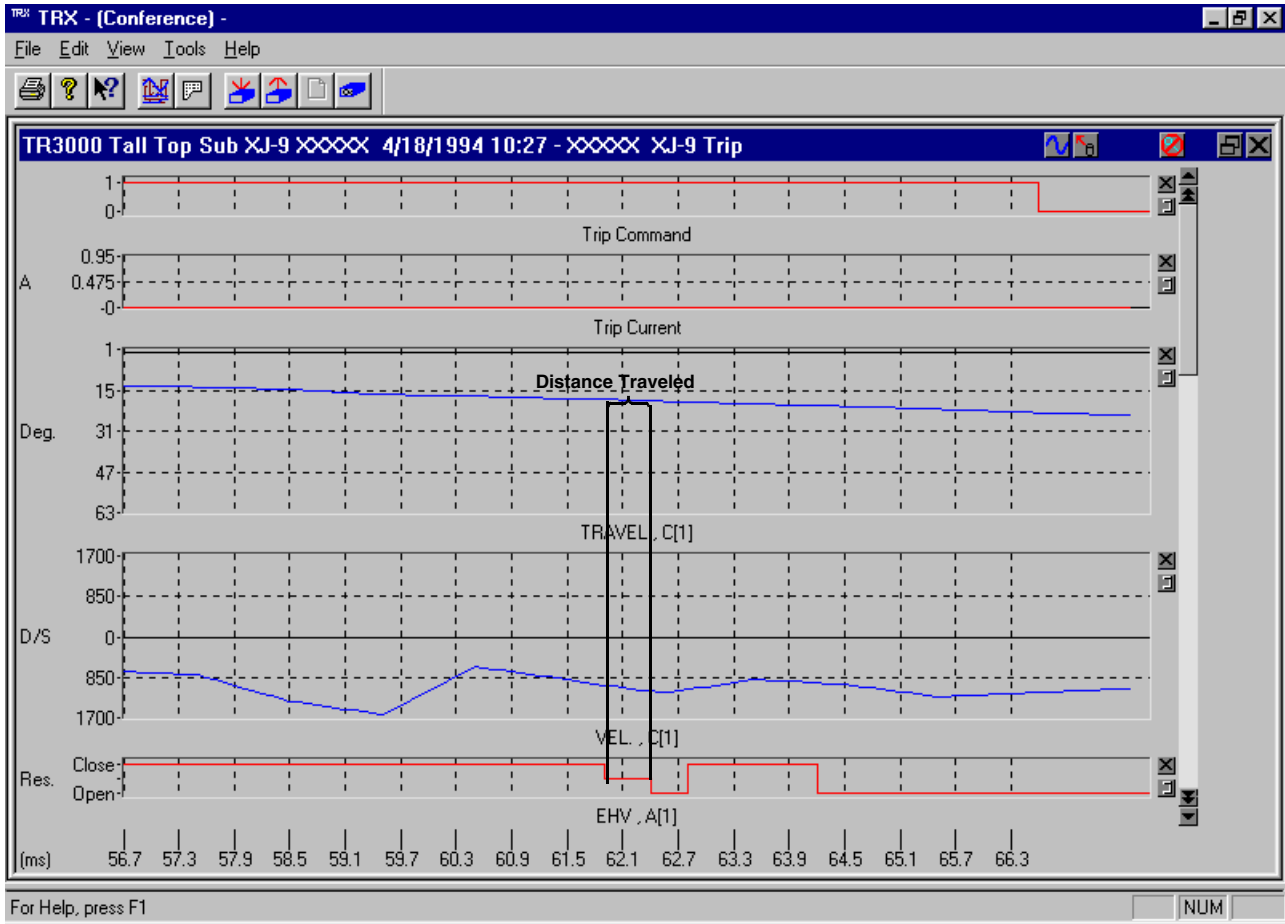
CONTACT MONITORING  
TRIP OPERATION

Test results		
	C1	mS

**Figure A.125 Resistor Switches Opening Time (Continued)**

**B**

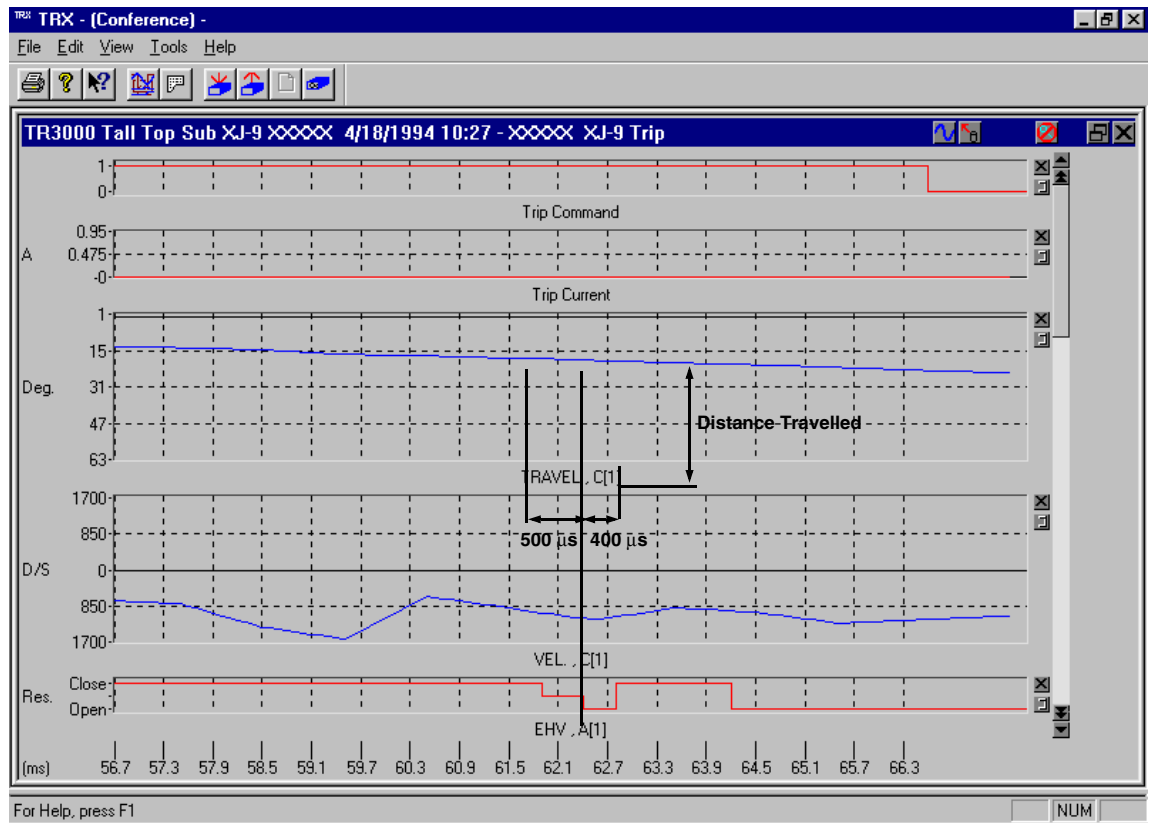
This is the distance the Resistor Switches travel from the close position baseline to the point where they part (last break) (Figure A.126).



**Figure A.126 Resistor Switch Travel: Closed to Part**

C

This is the Average Velocity measured during the period from 500 ms before and 400 ms after the Resistor Switches part (Figure A.127).



**Figure A.127 Resistor Switch Average Velocity**

Voltage and Current Monitoring

Figure A.128 shows the parameters and specifications for voltage and current monitoring.

- A** These are the peak values for each voltage and current waveform monitored during circuit breaker operation that are tabulated.
- B** This is the time of the first transition (of the auxiliary contact being monitored) measured from the initiation of the test.

VOLTAGE MONITORING TRIP OPERATION		
Test results	Range	
E1 165.9 V pk	30-300 Volts	

A

CURRENT MONITORING TRIP OPERATION		
Test results	Range	
I1 8.643 V pk	Shunt 1 V	

B

CONTACT MONITORING TRIP OPERATION		
Test results		
C1 10.6 mS		
C2 17.0		

**Figure A.128 Voltage and Current Monitoring**

Dead Tank Circuit Breaker

Figure A.129 and Figure A.130 on page A-110 show the report for a Dead Tank Trip Test.

```

                                BREAKER PERFORMANCE REPORT
                                TDR9000 Version: RE 2.24

Manufacturer : SPRECHER SCHUH           Location: Dead Tank Gas Sub
Model Number : HG 309                  Circuit : TRAF0 2
Serial Number: 2132452-03              Operator:
Instr Book # :
Mechanism # :
Mech Instr # :
Special ID  : AAAAA                    Operation Counter :
                                :
Test Type   : TRIP                      Test Plan Name   :

Test was performed on 01/20/99 at 11:08:33, with digital filter time 30 µs.

                                Motion Channels 1-3 Transfer Function
                                1.000 cm. Travel at the contacts is 1.000 cm. Travel at the transducer.

Resistor range selected 300-7K Ohms
Resistor times tabulated if a 200 µs. resistor state is detected
Insertion resistor duration times tabulated

Command Parameters      Trip Pulse      66.6 mS.
Command Currents       Trip Current   3.14 A pk.
    
```

MECHANICAL MOTION CHANNELS 1-3  
TRIP OPERATION

Specifications	Test results	Compare
Total Travel		
Expected ***** centimeters	TRAVEL 1 14.767 centimeters	
Tolerance + *****	TRAVEL 2	
- *****	TRAVEL 3	
Overtravel		
Expected ***** centimeters	TRAVEL 1 0.013 centimeters	
Tolerance + *****	TRAVEL 2	
- *****	TRAVEL 3	
Rebound		
Expected ***** centimeters	TRAVEL 1 0.032 centimeters	
Tolerance + *****	TRAVEL 2	
- *****	TRAVEL 3	

**Figure A.129 Dead Tank Breaker Trip Tabular Report**

Main Contact Opening Time Measured From Test Initiation				
Specifications	Test results	Travel	Velocity	Compare
Maximum ***** mS	PHASE 0 24.0 mS	4.299 cm.	5.207 m/s	
Minimum *****	PHASE 4 24.3	4.455	5.239	
	PHASE 8 24.0	4.299	5.207	

Delta Main Contact Opening Time Within the Breaker		
Specifications	Test results	Compare
Maximum ***** mS	Breaker 0.3 mS	

**Figure A.130 Dead Tank Breaker Trip Tabular Report (Continued)**

## Close Test Tabulation

This discussion presents results for a Close test, with explanations of the origination of important results. The Breaker Report is shown in Figure A.131.

- A** The auxiliary switch monitored by the AUX contact triggers the timing of the Main Contacts, which happens to be 15.3 ms after test initiation (Figure A.133 on page A-113). This is useful when timing specifications are based on close coil energization rather than test initiation.

```

                                BREAKER PERFORMANCE REPORT
                                TDR9000 Version: RE 2.24

Manufacturer : ABB                      Location: Tall Top Sub
Model Number : ELF SP7-2                Circuit : C182
Serial Number: 100315-02                Operator: JHG-TCT
Instr Book # :
Mechanism # : AHMA-8
Mech Instr # :
Special ID  : C182                      Operation Counter : 304
:                                                :

Test Type   : CLOSE                     Test Plan Name   :

Test was performed on 10/21/99 at 14:21:50, with digital filter time 32 µs.

                                Motion Channels 1-3 Transfer Function
0.000 in. Travel at the contacts is 3.082 in. Travel at the transducer.

                                Motion Channels 4-6 Transfer Function
1.000 in. Travel at the contacts is 1.000 in. Travel at the transducer.

Resistor range selected 200-500 Ohms
Resistor times tabulated if a 200 µs. resistor state is detected
Insertion resistor duration times tabulated

A → Test Initiation to 3400 Contact Channel 1 = 15.3mS

Command Parameters   Close Pulse   133.3 mS.
Command Currents     Close Current  0.78 A pk.
    
```

MECHANICAL MOTION CHANNELS 1-3  
CLOSE OPERATION

Specifications		Test results		Compare
Average velocity in Close zone 1				
Maximum	15.00 Ft/Sec	VEL. 1	11.59 Ft/Sec	Fail
Minimum	12.00	VEL. 2	13.68	Pass
Zone 1	2.170 in. to 10.0 mS	VEL. 3	11.72	Fail
Average velocity in Close zone 2				
Maximum	15.00 Ft/Sec	VEL. 1	18.18 Ft/Sec	Fail
Minimum	12.00	VEL. 2	18.93	Fail
Zone 2	3.170 in. to 2.170 in.	VEL. 3	18.69	Fail
Total Travel				

**Figure A.131 Dead Tank Breaker Close Tabular Report**

**Main Contact**

Main Contact parameters and specifications are shown in Figure A.132 and Figure A.133. Graphical results are shown in and Figure A.134 on page A-114 and Figure A.135 on page A-115.

- *****	TRAVEL 6	0.054	
Rebound			
Expected ***** inches	TRAVEL 4	0.004 inches	
Tolerance + *****	TRAVEL 5	0.004	
- *****	TRAVEL 6	0.010	
Contact Wipe			
Expected ***** inches	TRAVEL 4	1.603 inches	
Tolerance + *****	TRAVEL 5	1.684	
- *****	TRAVEL 6	1.591	

EHV CONTACT TIMING  
CLOSE OPERATION

Main Contact Closing Time Measured From 3400 Cont. CH 1								Specs: Maximum 60.0 Minimum 50.0	
Phase A			Phase B			Phase C			
Contact	Time (mS)	Compare	Contact	Time (mS)	Compare	Contact	Time (mS)	Compare	
A-EHV 1	54.4	Pass	B-EHV 1	52.9	Pass	C-EHV 1	54.0	Pass	
A-EHV 2	54.6	Pass	B-EHV 2	53.1	Pass	C-EHV 2	54.0	Pass	

**B** {

Delta Main Contact Closing Time Within a Module								Specs: Maximum 0.5	
Phase A			Phase B			Phase C			
Contact	Time (mS)	Compare	Contact	Time (mS)	Compare	Contact	Time (mS)	Compare	
A-EHV 1			B-EHV 1			C-EHV 1			
A-EHV 2	0.2	Pass	B-EHV 2	0.2	Pass	C-EHV 2	0.0	Pass	

Delta Main Contact Closing Time Within a Phase								Specs: Maximum 2.0	
Phase A			Phase B			Phase C			
Contact	Time (mS)	Compare	Contact	Time (mS)	Compare	Contact	Time (mS)	Compare	
Phase A	0.2	Pass	Phase B	0.2	Pass	Phase C	0.0	Pass	

**Figure A.132 Delta (Difference) in Main Contacts Travel Time**

**B** The delta (difference) in time between the closing of the two Main Contacts in the module (Figure A.133). Refer to "Main Contact Timing – Close" on page A-72.

Maximum	2.0 mS	Breaker	1.5 mS	Pass
---------	--------	---------	--------	------

Main Contact Closing Time Vs Mechanical Motion Channels 1-3								
Phase A			Phase B			Phase C		
Contact	Travel (in.)	Vel. (f/s)	Contact	Travel (in.)	Vel. (f/s)	Contact	Travel (in.)	Vel. (f/s)
A-EHV 1	6.022	12.98	B-EHV 1	6.181	15.68	C-EHV 1	6.152	14.33
A-EHV 2	6.055	12.71	B-EHV 2	6.220	15.41	C-EHV 2	6.152	14.33

Main Contact Closing Time Vs Mechanical Motion Channels 4-6								
Phase A			Phase B			Phase C		
Contact	Travel (in.)	Vel. (f/s)	Contact	Travel (in.)	Vel. (f/s)	Contact	Travel (in.)	Vel. (f/s)
A-EHV 1	6.281	12.29	B-EHV 1	6.199	12.40	C-EHV 1	6.289	12.40
A-EHV 2	6.311	11.88	B-EHV 2	6.229	12.40	C-EHV 2	6.289	12.40

**C**  
**D**

Insertion Resistor Duration Time									Specs:	
Phase A			Phase B			Phase C			Maximum	9.0
Contact	Time (mS)	Compare	Contact	Time (mS)	Compare	Contact	Time (mS)	Compare	Minimum	5.0
A-EHV 1	8.1	Pass	B-EHV 1	7.1	Pass	C-EHV 1	7.0	Pass		
A-EHV 2	8.2	Pass	B-EHV 2	7.1	Pass	C-EHV 2	7.3	Pass		

Resistor Switch Closing Time Measured From 3400 Cont. CH 1									Specs:	
Phase A			Phase B			Phase C			Maximum	*****
Contact	Time (mS)	Compare	Contact	Time (mS)	Compare	Contact	Time (mS)	Compare	Minimum	*****
A-EHV 1	46.3		B-EHV 1	45.8		C-EHV 1	47.0			
A-EHV 2	46.4		B-EHV 2	46.0		C-EHV 2	46.7			

Delta Resistor Switch Closing Time Within a Module									Specs:	
									Maximum	2.0

Close 10/21/1993 14:21 C182 Tall Top Sub ABB ELF SP7-2

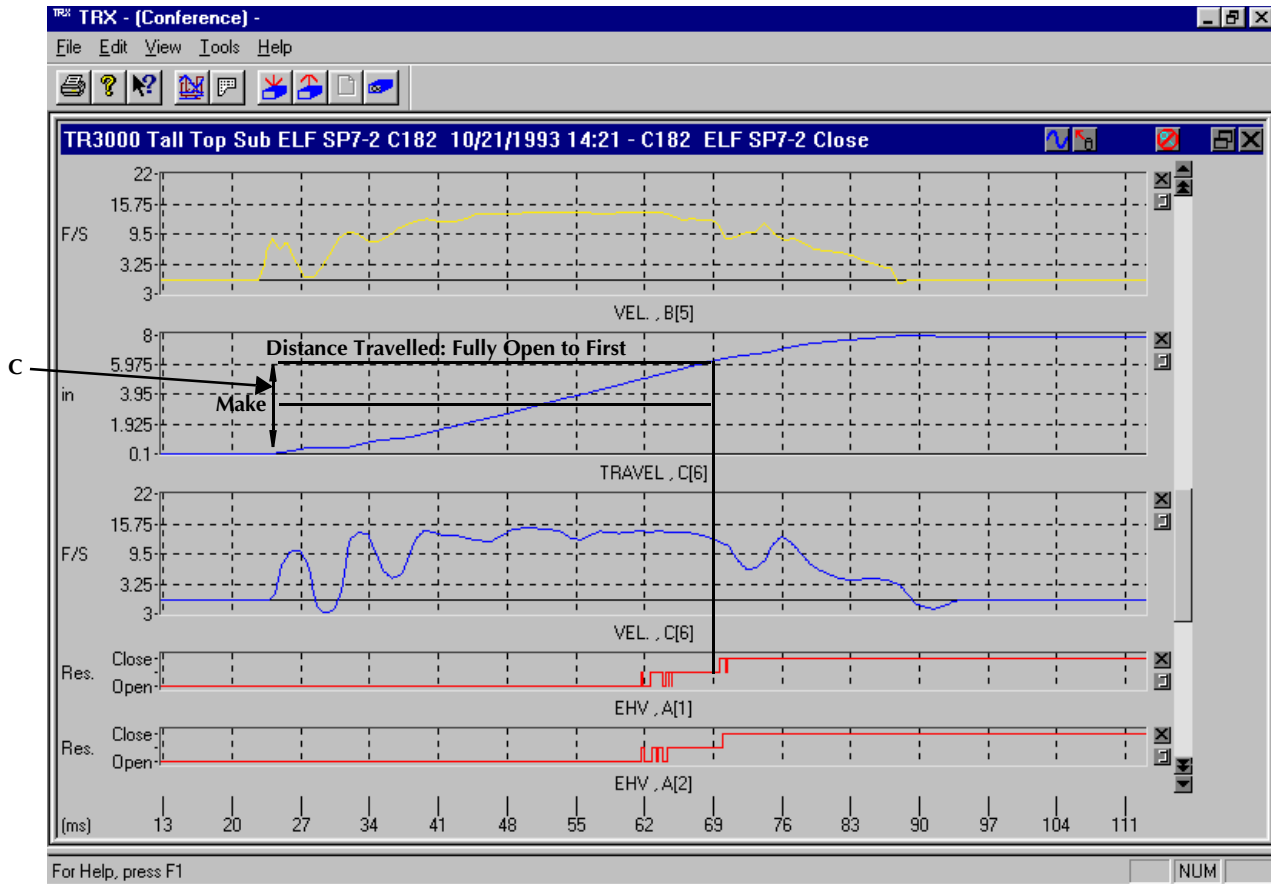
Page 4 of 6

**Figure A.133 Delta (Difference) in Main Contacts Travel Time (Continued)**



C

This is the distance the Main Contacts travel from the fully open position to the first make (Figure A.134).



**Figure A.134 Main Contacts Time: Fully Open to First Make**

D

This is the Average Velocity measured during the period from 500 ms before and 400 ms after Main Contacts make (Figure A.135).

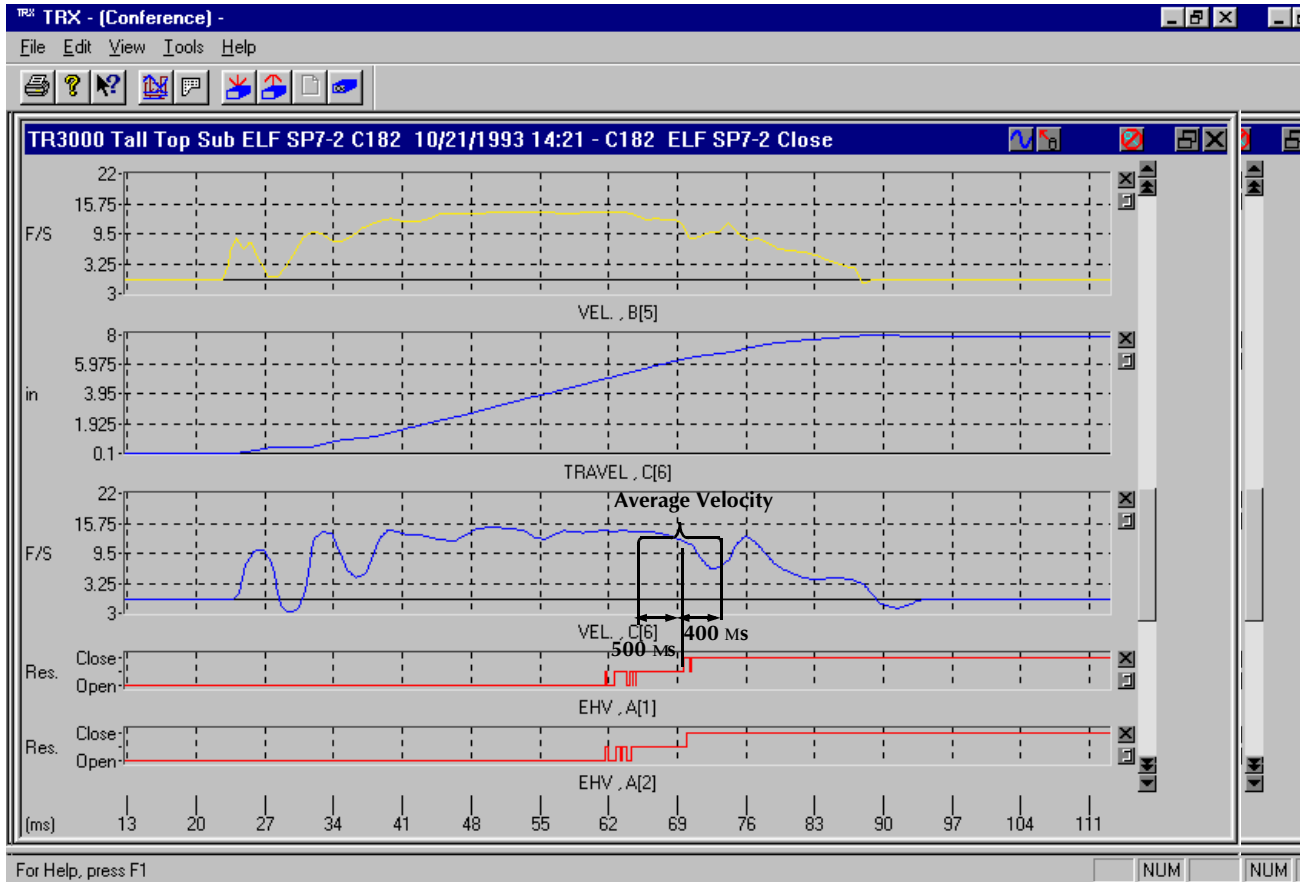


Figure A.135 Average Velocity for Main Contacts Close

Resistor Timing

Resistor Timing parameters and specifications are shown in Figure A.136, Figure A.137, and Figure A.138 on page A-118. Graphical results are shown in Figure A.139 on page A-118 and Figure A.140 on page A-119.

**A** This is the difference in time between the closing of the two Resistor Switches in the module (Figure A.138 on page A-118). Refer to "Resistor Switch Timing – Close" on page A-77

Insertion Resistor Duration Time									Specs:	
									Maximum	9.0
									Minimum	5.0
Phase A			Phase B			Phase C				
Contact	Time (mS)	Compare	Contact	Time (mS)	Compare	Contact	Time (mS)	Compare		
A-EHV 1	8.1	Pass	B-EHV 1	7.1	Pass	C-EHV 1	7.0	Pass		
A-EHV 2	8.2	Pass	B-EHV 2	7.1	Pass	C-EHV 2	7.3	Pass		

Resistor Switch Closing Time Measured From 3400 Cont. CH 1									Specs:	
									Maximum	*****
									Minimum	*****
Phase A			Phase B			Phase C				
Contact	Time (mS)	Compare	Contact	Time (mS)	Compare	Contact	Time (mS)	Compare		
A-EHV 1	46.3		B-EHV 1	45.8		C-EHV 1	47.0			
A-EHV 2	46.4		B-EHV 2	46.0		C-EHV 2	46.7			

Delta Resistor Switch Closing Time Within a Module									Specs:	
									Maximum	2.0

**Figure A.136 Delta Time for Resistor Switches in a Module**



**A** →

Phase A			Phase B			Phase C		
Contact	Time (mS)	Compare	Contact	Time (mS)	Compare	Contact	Time (mS)	Compare
A-EHV 1	0.1	Pass	B-EHV 1	0.2	Pass	C-EHV 1	0.3	Pass
A-EHV 2			B-EHV 2			C-EHV 2		

Delta Resistor Switch Closing Time Within a Phase								Specs:	
								Maximum	2.0
Phase A			Phase B			Phase C			
Contact	Time (mS)	Compare	Contact	Time (mS)	Compare	Contact	Time (mS)	Compare	
Phase A	0.1	Pass	Phase B	0.2	Pass	Phase C	0.3	Pass	

Delta Resistor Switch Closing Time Within the Breaker			
Maximum	2.0 mS	Breaker	1.2 mS
			Pass

Resistor Switch Closing Time Vs Mechanical Motion Channels 1-3								
Phase A			Phase B			Phase C		
Contact	Travel (in.)	Vel. (f/s)	Contact	Travel (in.)	Vel. (f/s)	Contact	Travel (in.)	Vel. (f/s)
A-EHV 1	4.439	20.28	B-EHV 1	4.640	20.01	C-EHV 1	4.708	19.47
A-EHV 2	4.461	20.01	B-EHV 2	4.689	19.74	C-EHV 2	4.637	19.47

**B** →      **C** →

Resistor Switch Closing Time Vs Mechanical Motion Channels 4-6								
Phase A			Phase B			Phase C		
Contact	Travel (in.)	Vel. (f/s)	Contact	Travel (in.)	Vel. (f/s)	Contact	Travel (in.)	Vel. (f/s)
A-EHV 1	5.019	13.75	B-EHV 1	5.059	14.17	C-EHV 1	5.125	14.27
A-EHV 2	5.035	13.85	B-EHV 2	5.093	14.17	C-EHV 2	5.074	14.27

Resistor Value	Specs:
	Maximum 250
	Minimum 225

Close 10/21/1993 14:21 C182 Tall Top Sub ABB ELF SP7-2

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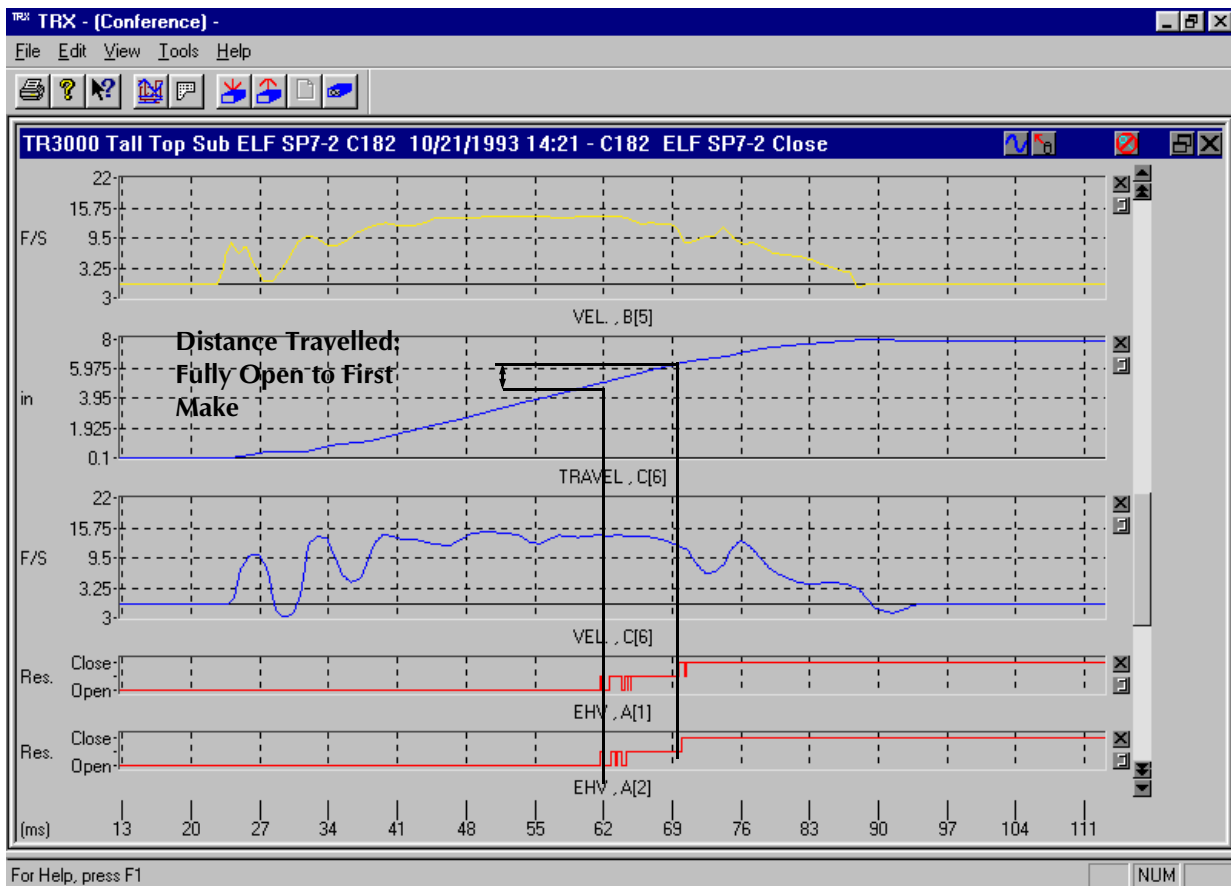
**Figure A.137 Delta Time for Resistor Switches in a Module (Continued)**

Contact	Ohms	Compare	Contact	Ohms	Compare	Contact	Ohms	Compare
A-EHV 1	238	Pass	B-EHV 1	236	Pass	C-EHV 1	233	Pass
A-EHV 2	236	Pass	B-EHV 2	234	Pass	C-EHV 2	245	Pass

**Figure A.138 Delta Time for Resistor Switches in a Module**

**B**

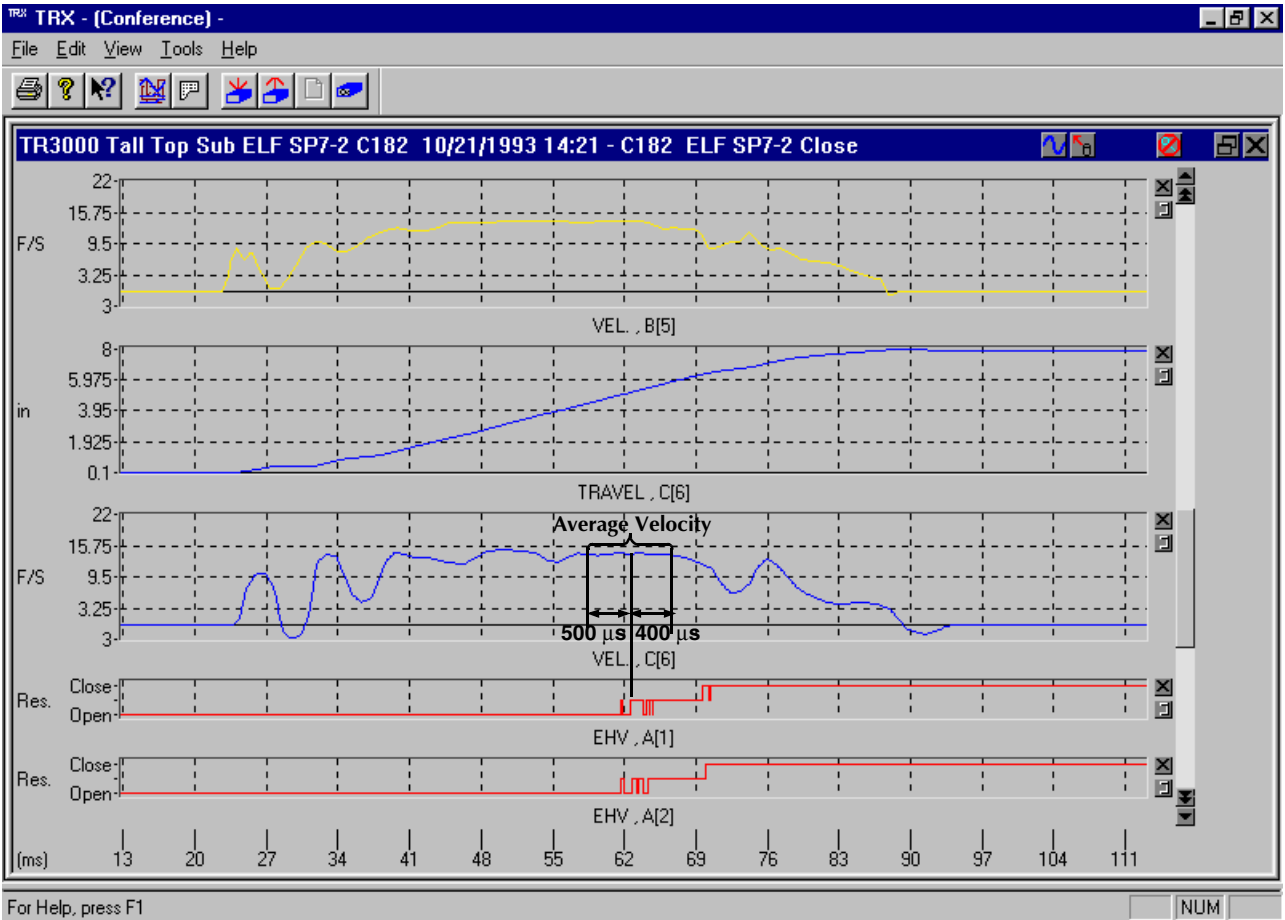
This is the distance the Resistor Switches travel from the fully open position to the first make (Figure A.139).



**Figure A.139 Resistor Switches Time: Fully Open to First Make**

C

This is the Average Velocity measured during the period from 500 ms before and 400 ms after the Resistor Switches make (Figure A.140).



**Figure A.140 Average Velocity for Resistor Switches**

## Trip-Free Test Tabulation

This section discusses the characteristics of Trip-Free test results. Figure A.141 shows a Trip-Free Breaker Test Report.

Refer to "Trip Free Parameters (C-O)" on page A-43 for more information on these parameters.

**A** Delay 1 Length is shown in Figure A.145 on page A-123.

Delay 1 is:

- 8.3 ms if Standing option is used
- Time selected in Trip Parameters, if the Delay option is used.
- Time from close command initiation to contact 1 make if the Contact Make option is used.

```

                                BREAKER PERFORMANCE REPORT
                                TDR9000 Version: RE 2.24

Manufacturer : ME                      Location: Big Tank Sub
Model Number : CG-38                  Circuit : 227
Serial Number: 26791                 Operator: NK
Instr Book # :
Mechanism # : OA-3
Mech Instr # :
Special ID  : 227                      Operation Counter :
                                         :

Test Type   : TRIP-FREE                Test Plan Name   :

Test was performed on 06/11/98 at 10:44:51, with digital filter time 30 µs.

                                Motion Channels 1-3 Transfer Function
                                1.000 in. Travel at the contacts is 1.000 in. Travel at the transducer.

Resistor range selected None

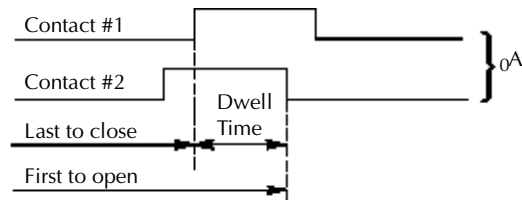
Command Parameters  Trip Pulse  1467.0 mS.   Close Pulse  150.0 mS.
                   A → Delay 1  133.0 mS.   (Delay)
Command Currents   Trip Current 9.47 A pk.   Close Current 5.65 A pk.
    
```

**Figure A.141 Dead Tank Breaker Trip Free Tabular Test Report Header**

## Dwell Time

The callouts (**B** and **C**) in Figure A.144 on page A-122 show the parameters and specifications that effect Dwell times for a breaker.

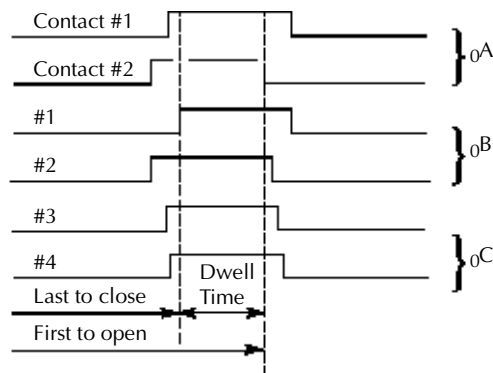
- B** This is the time when all Main Contacts within a phase are closed during trip-free operation (Figure A.142).



**Figure A.142 Trip-Free Test Operation for a Phase (Live Tank Breaker)**

Within the phase, the Dwell time (Figure A.144 on page A-122) is measured as the difference between the time required for the first Main Contact to open and the last Main Contact to close.

- C** This is the time when all Main Contacts within the circuit breaker are closed during trip-free operation (Figure A.143).



**Figure A.143 Trip-Free Test Operation Within a Breaker (Live Tank Breaker)**

OCB CONTACT TIMING  
TRIP-FREE OPERATION

Trip-Free Dwell Time Within a Phase				
	Specifications		Test results	Compare
<b>B</b> ↘	Maximum 88.0 mS		Phase A 33.7 mS	Pass
	Minimum 17.0		Phase B 34.0	Pass
			Phase C 32.5	Pass
Trip-Free Dwell Time Within the Breaker				
	Specifications		Test results	Compare
<b>C</b> ↘			Breaker 34.0 mS	Pass

Main Contact Closing Time Measured From Test Initiation						
	Specifications		Test results	Travel	Velocity	Compare
Maximum	333.0 mS	CONTACT1	130.1 mS	11.570 in.	13.23 f/s	Fail
Minimum	217.0	CONTACT2	129.9	11.538	12.50	Fail
		CONTACT3	130.5	11.639	13.23	Fail

Delta Main Contact Closing Time Within the Breaker				
	Specifications		Test results	Compare

Trip-Free 6/11/1998 10:44 227 Big Tank Sub ME CG-38

Page 1 of 2

**Figure A.144 Dwell Times within a Circuit Breaker**

**D**

Average Velocities (Figure A.145) as specified for the trip operation are tabulated here. The close position baseline cannot be clearly defined during trip-free operation. Consequently, if close position baseline is used to specify the Average Velocity Zone in trip operation (for example, if the zone is defined by distance-distance or distance-time), this velocity is not tabulated for trip-free operation.

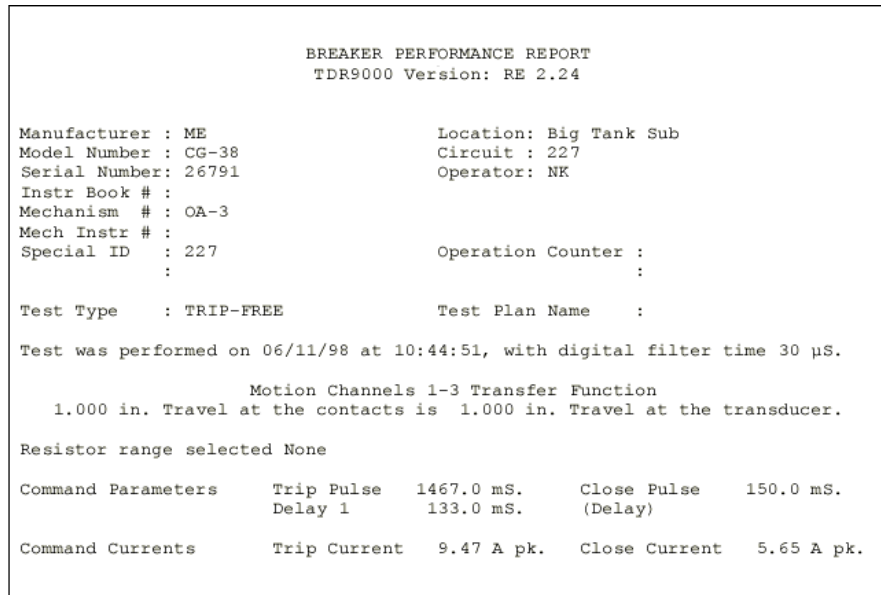
MECHANICAL MOTION CHANNELS 1-3  
TRIP OPERATION

Specifications	Test results	Compare
Average velocity in Open zone 2		
Maximum 15.50 Ft/Sec Minimum 12.60 Zone 2 Open to 6.250 in.	VEL. 2 14.42 Ft/Sec	Pass
Average velocity in Close zone 2		
Maximum 17.00 Ft/Sec Minimum 15.00 Zone 2 6.250 in. to Close	VEL. 2 15.86 Ft/Sec	Pass

**Figure A.145 Trip-Free Test Mechanical Motion – Average Velocities**

## Reclose Test Tabulation

This section discusses the characteristics of the Reclose test results. Figure A.146 shows the top portion of the Breaker test report for a Reclose test. Refer to "Reclose Parameters (O-C)" on page A-45 for more information on these parameters.

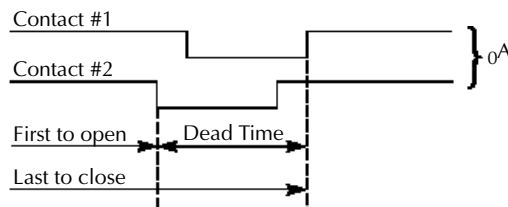


**Figure A.146 Dead Tank Breaker Reclose Test Report – Header**

**A**

### Dead Time

This is the time when at least one Main Contact within a phase is open during the reclose operation (Figure A.147).



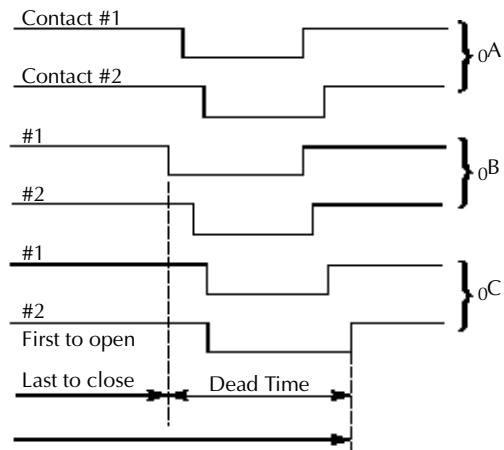
**Figure A.147 Reclose Dead Time within a Phase**

Within the phase, the Dead time is calculated as the difference between the time required for the last Main Contact to close and the first Main Contact to open.

**B**

### Dead Time with a Circuit Breaker

This is the time when at least one Main Contact within the circuit breaker is open during the reclose operation (Figure A.148).



**Figure A.148 Reclose Operation within a Circuit Breaker**

- C Main Contact Opening Time measured from Test Initiation**  
This is the time from test initiation to Main Contact make (Figure A.149).
- D Main Contact Reclosing Time measured from Test Initiation**  
This is the time required for the last contact to close (measured from test initiation).
- E Delta Main Contact Reclosing Time within the Breaker**  
This is the allowable difference in time for reclose of all Main Contacts within the breaker.

OCB CONTACT TIMING  
RECLOSE OPERATION

Reclose Dead Time Within a Phase						
	Specifications	Test results	Compare			
Maximum	333.0 mS	Phase A 315.6 mS	Pass			
Minimum	250.0	Phase B 315.7	Pass			
		Phase C 316.6	Pass			

Reclose Dead Time Within the Breaker						
	Specifications	Test results	Compare			
		Breaker 315.4 mS	Pass			

Main Contact Opening Time Measured From Test Initiation						
	Specifications	Test results	Travel	Velocity	Compare	
Maximum	50.0 mS	CONTACT1 20.1 mS	0.799 in.	10.42 f/s	Pass	
Minimum	0.0	CONTACT2 20.3	0.824	10.42	Pass	
		CONTACT3 19.7	0.750	10.00	Pass	

Main Contact Reclosing Time Measured From Test Initiation						
	Specifications	Test results	Travel	Velocity	Compare	
Maximum	333.0 mS	CONTACT1 335.7 mS	0.735 in.	11.67 f/s	Fail	
Minimum	217.0	CONTACT2 336.0	0.689	12.81	Fail	
		CONTACT3 336.3	0.637	13.75	Fail	

Delta Main Contact Reclosing Time Within the Breaker						
	Specifications	Test results	Compare			
Maximum	4.0 mS	Breaker 0.6 mS	Pass			

**Figure A.149 Reclose Contact Timing Parameters And Specifications**

- F** Average Velocity measured in the Zone specified for a trip test (Figure A.150).
- G** Average Velocity measured in the Zone specified for a close test (Figure A.150).

	Specifications	Test results	Compare	
<b>F</b>	Average velocity in Open zone 1			
	Maximum	15.50 Ft/Sec	Ft/Sec	
	Minimum	12.60	VEL. 2 13.66	Pass
	Zone 1	0.250 in. to 6.500 in.		
<b>G</b>	Average velocity in Open zone 2			
	Maximum	15.50 Ft/Sec	Ft/Sec	
	Minimum	12.60	VEL. 2 14.58	Pass
	Zone 2	Open to 6.250 in.		
<b>F</b>	Average velocity in Close zone 1			
	Maximum	17.00 Ft/Sec	Ft/Sec	
	Minimum	15.00	VEL. 2 *****	
	Zone 1	6.500 in. to 0.250 in.		
<b>G</b>	Average velocity in Close zone 2			
	Maximum	17.00 Ft/Sec	Ft/Sec	
	Minimum	15.00	VEL. 2 16.97	Pass
	Zone 2	6.250 in. to Close		

**Figure A.150 Average Velocity Characteristics for a Reclose Test**

## O-C-O Test Parameters

This section discusses the characteristics of the O-C-O test results. Figure A.151 shows the top portion of the Breaker test report for an O-C-O test. Refer to "O-C-O" on page A-47 for more information on these parameters.

```

                                BREAKER PERFORMANCE REPORT
                                TDR9000 Version: RE 0.00

Manufacturer : GE                      Location: Westborough
Model Number : FK 121 43000 4          Circuit :
Serial Number: 0202A9405-701          Operator:
Instr Book # :
Mechanism # : TP CREATED 8/9/99
Mech Instr # : BY PHIL PROUT
Special ID  : Westborough              Operation Counter :
                                         :

Test Type   : O-C-O                    Test Plan Name   :

Test was performed on 10/14/1999 at 12:28:49.

                                Motion Channels 1-3 Transfer Function
                                1.000 in. Travel at the contacts is 1.000 in. Travel at the transducer.

Resistor range selected 300-7K Ohms
Resistor times tabulated if a 200 µS. resistor state is detected
Insertion resistor duration times tabulated

Command Parameters      Trip Pulse      66.6 mS.      Close Pulse      133.3 mS.
                        Delay 1          8.3 mS.       Delay 2          113.3 mS.

Command Currents       Trip Current ***** A pk.   Close Current ***** A pk.
```

**Figure A.151 Breaker Test Report for an O-C-O Test**

# Appendix B. Troubleshooting and Parts Replacement

This appendix covers troubleshooting for the TDR9000 and related parts replacement procedures.

## Troubleshooting

The topics that follow discuss these troubleshooting-related areas:

- Running and interpreting the results of the Self-Diagnostics test
- Analyzing the system for specific problems
- Troubleshooting tools designed to pinpoint problems based on symptoms, including:
  - Troubleshooting flowcharts
  - A Problem/Solution table
  - A drawing, from the top view, of the circuit boards that comprise the system
- Interpreting TDR9000 LEDs

## Self-Diagnostics Test

The Self-Diagnostics test is comprised of the two different automated test sequences defined below. For both tests, all external stimuli are physically disconnected from the inputs using relays that switch simulated test signals into each of the sensor channels.

*Global Self Test* This test always runs and if it detects no failures, completes the Self-Diagnostics cycle. It sources test signals to the Physical Front Panel. Isolation of the Physical Front Panel is achieved by breaking the input circuit just inside the front panel connector.

*Local Self Test*

This test only runs if the Global Self-Test detects a failure. It localizes the failure by sourcing test signals to the sensing cards. Isolation of the sensing cards is achieved by breaking the circuit just as the signal enters the backplane card. The backplane cards are responsible for providing the interface between the system processor and the front panel modules.

The combination of these two tests allow the controller software to isolate functional failures to the circuit board/module level. The Self-Diagnostics test simulates a circuit breaker test without activating the Trip or Close output signals. During this test, hardware circuitry provides test signals that are tailored to functionally test each type of input channel associated with the TDR9000 system. Channels of the same type are provided with identical signals.

**NOTE**



**The Trip/Close Current board is physically located in the Trip/Close module; however, its functionality is implemented through the System module of the Physical Front panel. For the Trip/Close Current module, if the Self-Diagnostic fails only during the Global phase, it reports the failure as being related to the System module and reports the internal circuit board responsible for this module's operation.**

**NOTE**

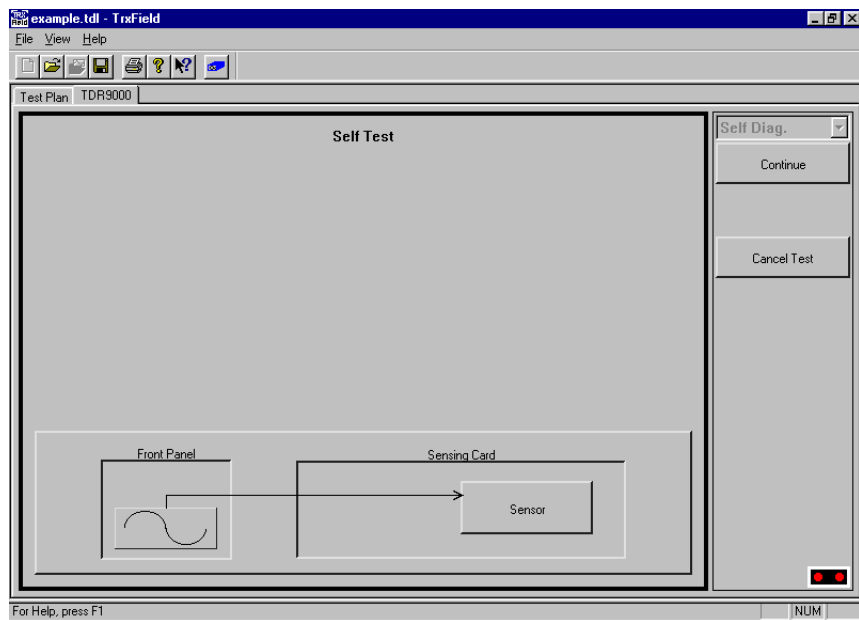
To run the Self-Diagnostics test:

**This test can be run with cables connected to the Instrument.**

1. Click *Self-Diag.* from the test picklist on the upper right corner of the **TDR9000** tab.

The **Run Self-Diag. Test** button appears on the **TDR9000** tab.

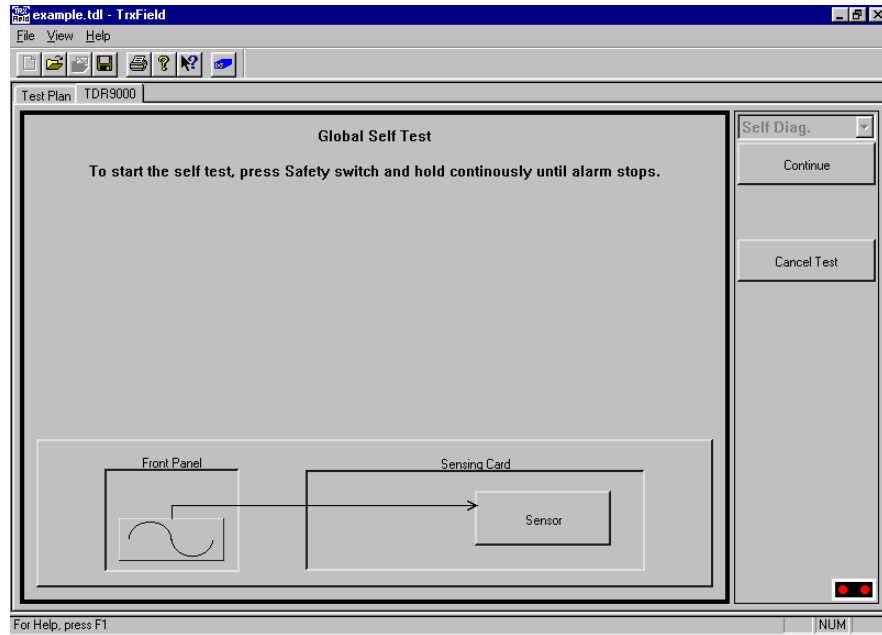
2. Click **Run Self-Diag. Test**.
3. The **Self Test** window appears, as shown in Figure B.1.



**Figure B.1 Self-Diag Test**

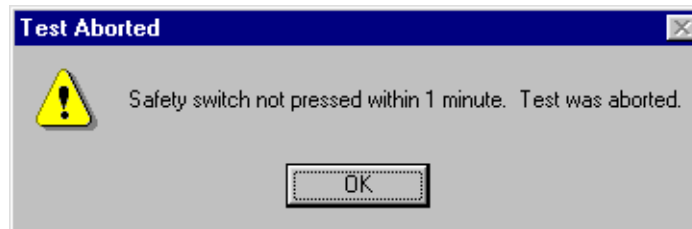
4. Click **Continue**.

The TDR9000 controller configures the Instrument to run a test that uses the signal generators in the Physical Front Panel modules. The system is armed and the window prompts for the Safety Switch to be pressed, as shown in Figure B.2.



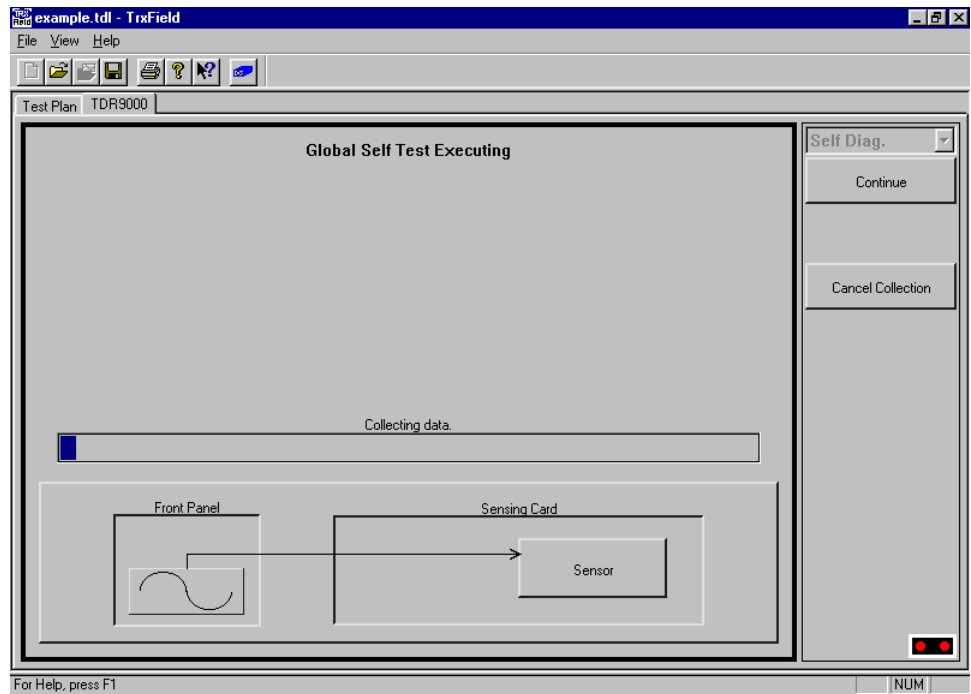
**Figure B.2 Safety Switch Operation**

5. Press the Safety Switch and hold until the alarm ceases.  
If the safety switch is not pressed:
  - Within 60 seconds, the test is abortedor
  - Until the alarm ceases, the test is aborted and the window shown in Figure B.3 appears



**Figure B.3 Test Abort Message**

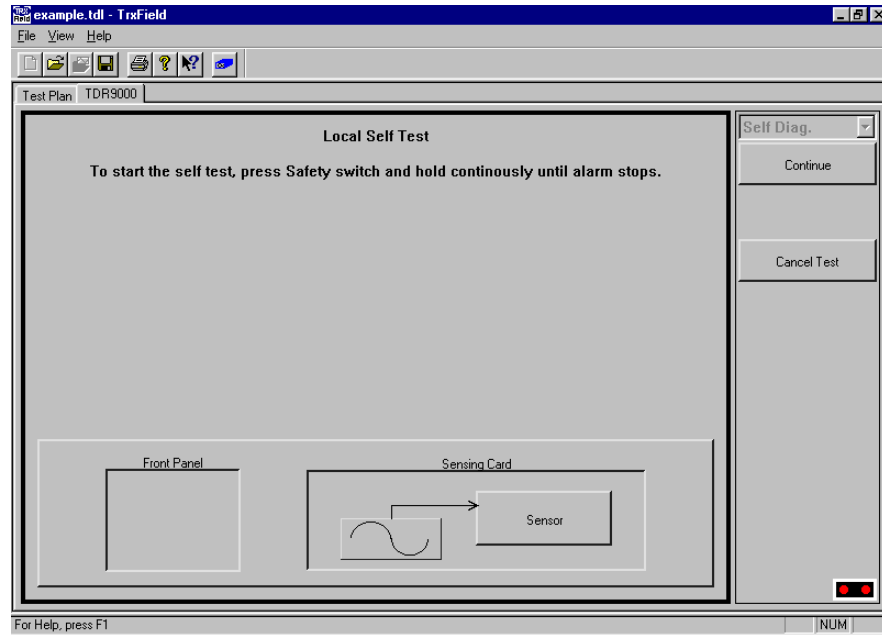
Once the test begins, the window appears as shown in Figure B.4. The first test run is the *Global Self Test*. A status bar appears as the TDR9000 collects data about the validity of source signals on the Physical Front Panel. This test requires several minutes to complete and can take longer for fully populated units.



**Figure B.4 Global Self Test**

A status bar appears as results are calculated.

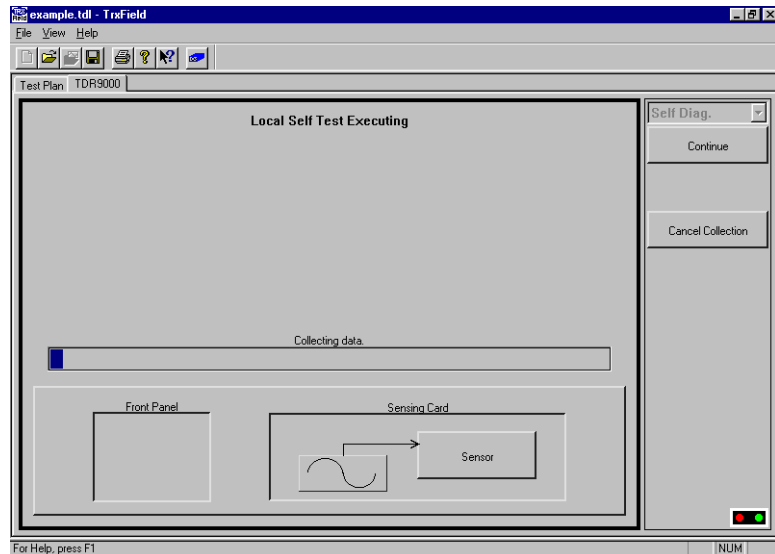
If no failures are detected, the test ends with the *Global Self Test* complete. If a failure is detected, the software moves on to the *Local Self Test* (Figure B.5). An alarm sounds and, as with the *Global Self Test*, the Safety Switch must be pressed within 60 seconds.



**Figure B.5 Local Self Test**

**6.** Press the Safety Switch until the alarm ceases.

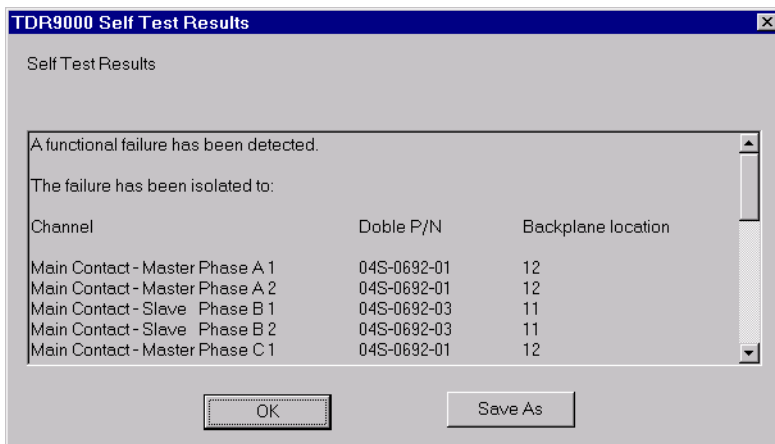
Once this second part of the test begins, the window appears as shown in Figure B.6. A status bar appears as the TDR9000 collects data about the validity of source signals sent through the sensing cards, the cards responsible for signal processing for all test types during normal operation. This test requires several minutes to complete, and is longer for fully populated Instruments.



**Figure B.6 Local Self Test Executing**

A status bar appears as results are calculated.

If a failure is found, a window appears containing the slot or location of the failed circuit board or module, a part for the circuit board or module and a notation as to the type of failure (Figure B.7).



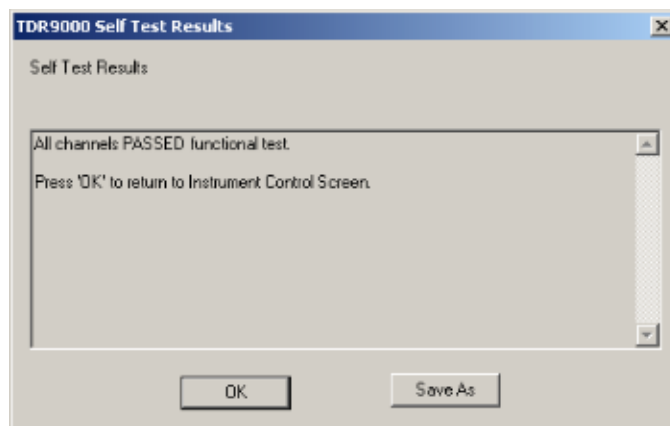
**Figure B.7 Self-Test Failure**

information on this window is helpful to Doble personnel in troubleshooting. Data gathered includes:

- Motion Transducer receiver results
- Contact timing and resistor timing measurement
- Analog and Auxiliary contact status

There is no way to directly print this data; however, it can be saved using the Save button and saving the results presented to a .txt file.

If no failures are found, the **TDR9000 Self Test Results** window appears, as shown in Figure B.8.



**Figure B.8 TDR9000™ Self Test Results**

## Backplane Board Registration Errors

It is possible that a backplane board (VME Bus, slots 1 through 12) in the TDR9000 can fail in such a way that the board is not recognized by the Instrument. If this happens, there is no failure indication at power up, nor will the Self-Diagnostics test report a failure. All built-in tests require that the relevant backplane board be recognized in the first place.

This condition can be detected in two ways:

- Observe the Virtual Front Panel, and compare it to the Physical Front Panel of the TDR9000. If there is a front panel module (or modules) on the Instrument that is not being represented on the VFP, one or more of the backplane boards associated with that module may not be registered. This can be a result of damaged connectors or poor seating of the board in the backplane; or, the board's electronics may have a problem.
- Use the diagram shown in Figure B.12 on page B-16 to determine which board is causing the problem. A backplane board that is not registered will not display a green LED indication. Before replacing the board, check the integrity of the connectors, and if the connectors appear to be OK, try reseating the board.

### NOTE



**It is possible that failure in a Physical Front Panel module may cause the same symptom as in the first bullet. If the LEDs on the associated backplane boards appear OK (green), then the Physical Front Panel module is suspect.**

## Cable-In Bits Failure

This failure occurred in several early units because the cable-in sense bit inputs on the EHV module front panel connectors were not sufficiently protected against extreme high levels of Electro-Static Discharge (ESD). The damaged units had been used in EHV transmission yards, where ESD is most severe.

The most common symptom was that one or more cable-in bits failed in an *active* condition, giving the false indication that an EHV cable (or cables) was connected when it was not. This did not prevent the Instrument from being used to perform EHV testing. It did prevent the Instrument from being used for OCB testing, because there is a crosscheck in the firmware that does not allow a test to be run when the Instrument thinks that both OCB and EHV cables are connected. Damaged cable-in bit circuitry is not detected as part of the Self-Diagnostics test, and will most likely to be detected while attempting to perform an OCB test. It can also be detected by observing that the Virtual Front Panel indicates *channel ready* status on EHV connectors that have no cable attached.

## Troubleshooting Flow Chart

The flow charts shown in Figure B.9 on page B-11 and Figure B.10 on page B-12 assist in troubleshooting TDR9000 operations. They start from TDR9000 trouble indications, LEDs, non-operation, etc., and proceed through to pinpointing the origin of the trouble down to the circuit board level.

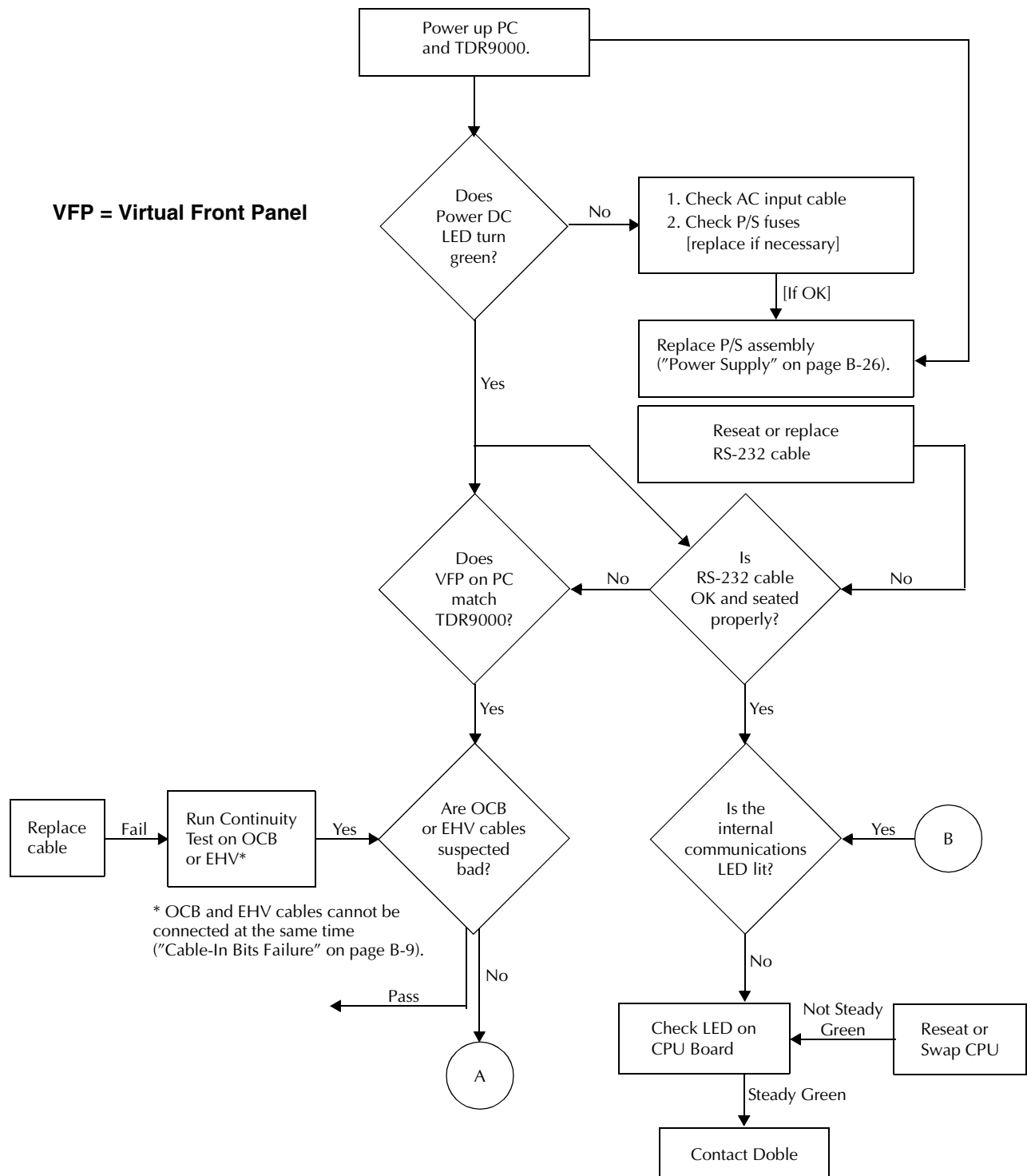
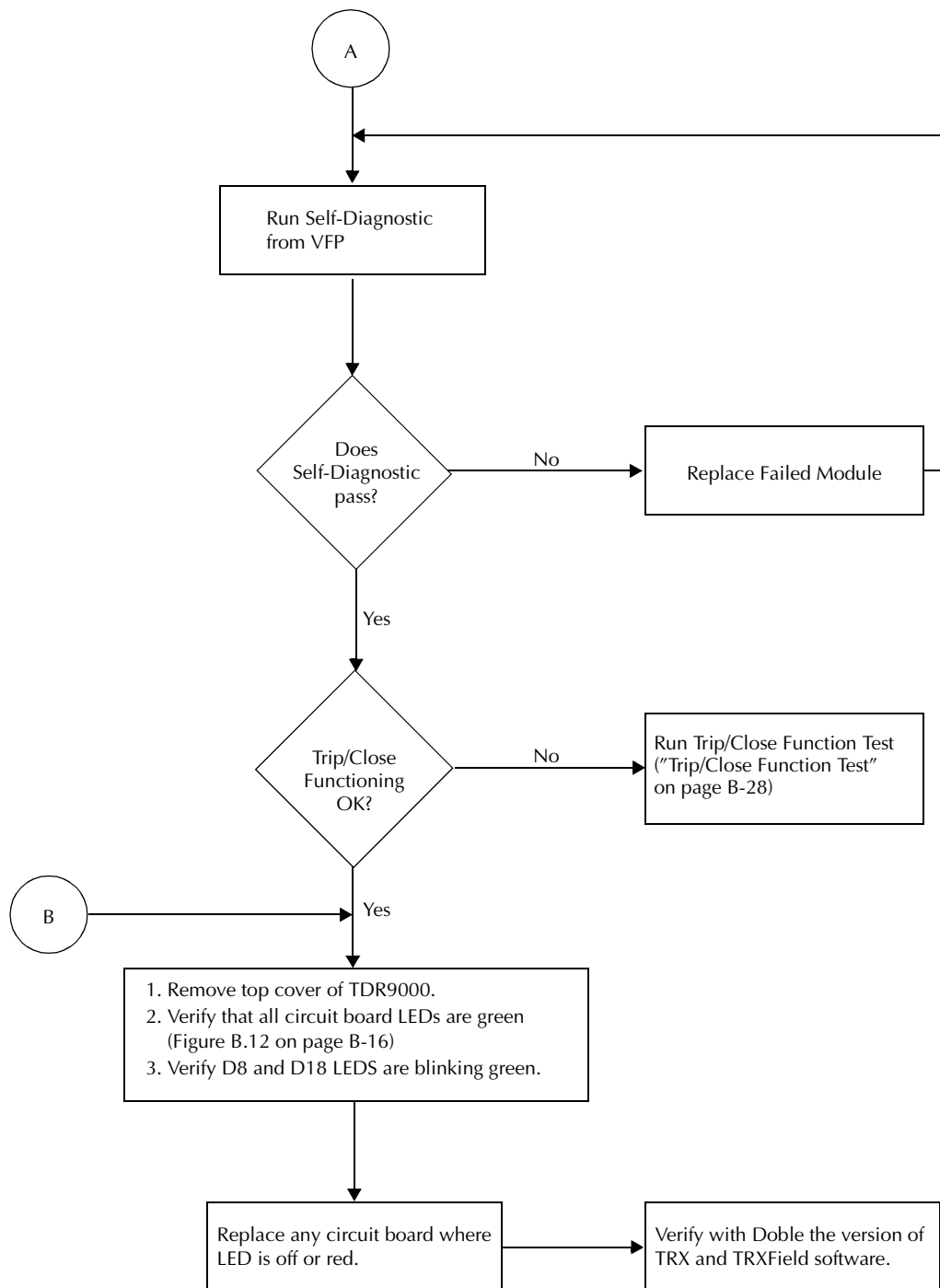


Figure B.9 Troubleshooting Flow Chart I



**Figure B.10 Troubleshooting Flow Chart II**

## Application and Troubleshooting Problems and Solutions

Table B.1 lists some additional problems and associated solutions.

**Table B.1 Application and Troubleshooting Problems and Solutions**

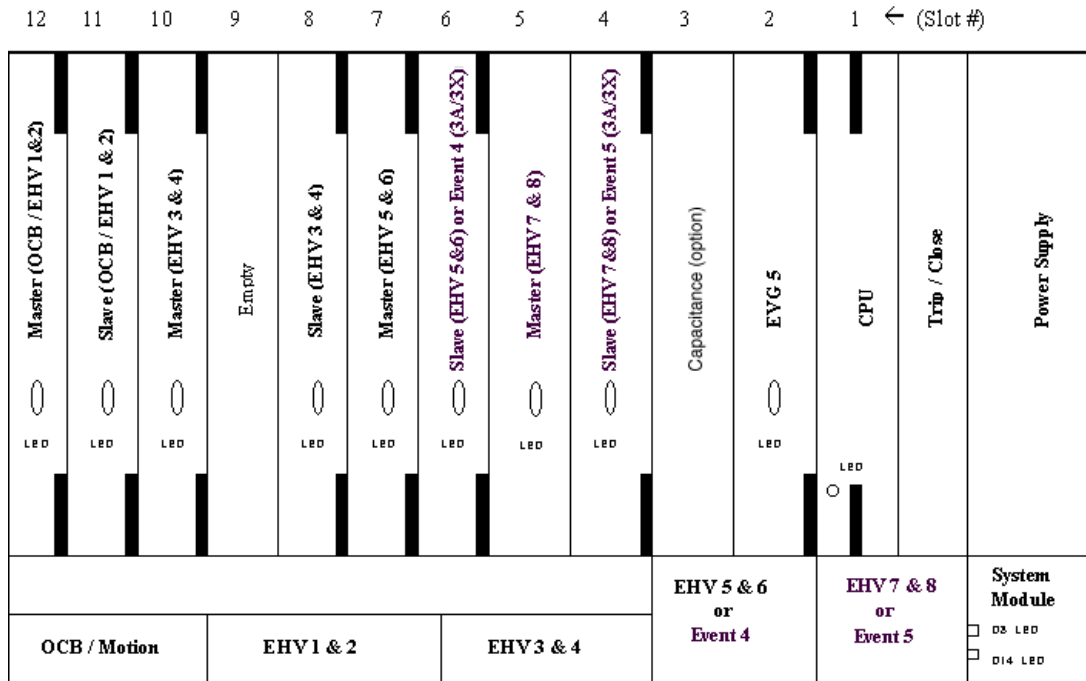
Problem Indication	Solutions
Unrecognizable data displayed on the screen or plotted	Check: <ul style="list-style-type: none"> <li>• Mounting of Motion Transducer</li> <li>• Line frequency settings</li> <li>• Connections to the breaker contacts or control circuits</li> </ul>
Instrument dropped or physically damaged	Return to Doble for repair
Spilled liquid penetrates the Instrument case	Return to Doble for repair
A test is run, breaker functions properly, but no Main Contact data is collected, or data for a contacts is missing	Run Continuity Test ("Running the Continuity Test" on page 4-71)
Breaker does not operate  A test is run but the breaker does not respond	Check the: <ul style="list-style-type: none"> <li>• Width setting of the command signal pulse. If the command pulse is too short, the breaker may not respond.</li> <li>• Control cable. Verify cable configuration requirements for the test.</li> <li>• Condition of the Trip/Close fuses using an Ohmmeter (refer to "Connecting the TDR9000™ Physical Front Panel" on page 4-30). Only 3 A, 250 V, Slo-Blo types should be used.</li> <li>• Refer to "Trip/Close Function Test" on page B-28.</li> </ul>

**Table B.1 Application and Troubleshooting Problems and Solutions (Continued)**

<b>Problem Indication</b>	<b>Solutions</b>
Printer doesn't work	Check that: <ul style="list-style-type: none"><li>• Power is ON</li><li>• Printer is not jammed</li><li>• Refer to Pentax documentation provided with the Instrument</li></ul>
Connections on Virtual Front Panel appear gray	Check the: <ul style="list-style-type: none"><li>• Connection between the laptop and the Instrument</li><li>• Com port configuration on laptop</li><li>• Internal LEDs</li></ul>

## TDR9000™ Top View

Figure B.11 and Figure B.12 on page B-16 show a generalized internal top view drawing of the TDR9000.



**Figure B.11 Top View of TDR9000™ with Top Removed (OCB/Motion Module Installed)**

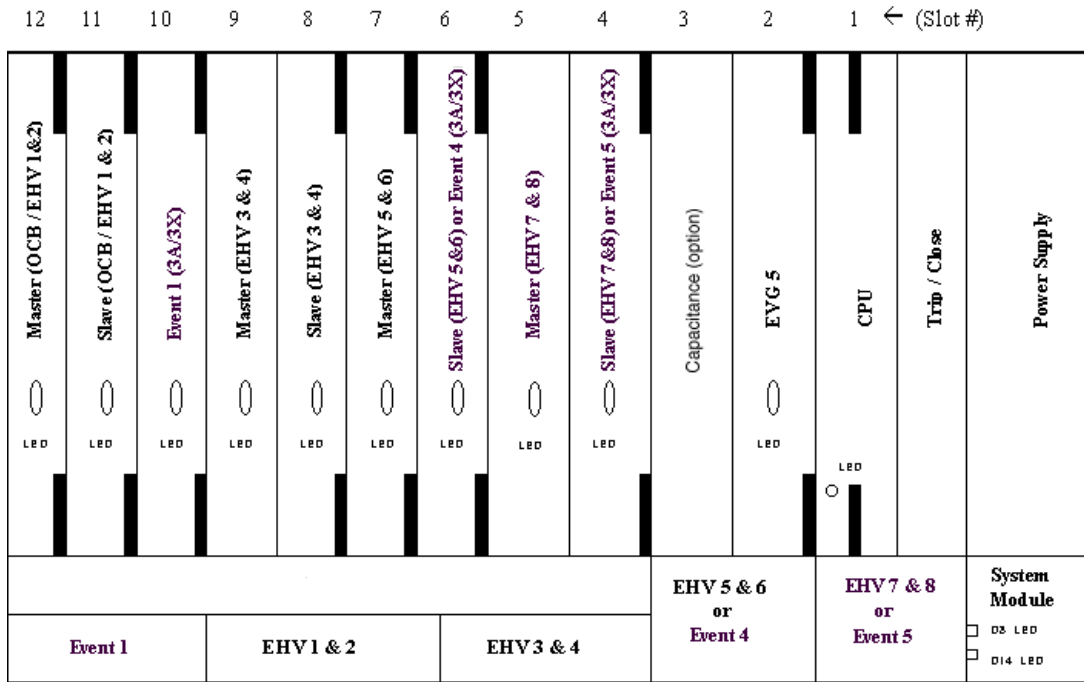


Figure B.12 Top View of TDR9000™ with Top Removed (Event 1 Module Installed)

## LED Indicators

Internally, each circuit board type, excluding the Power Supply circuit board and the Trip/Close module, has an LED which is visible through the oval cut into the top of the circuit board housing (Figure B.11 on page B-15). These LEDs indicate circuit board operation as follows:

- All circuit board LEDs change from Off to Green, or from Off to Bi-color to Green during the startup sequence.
- After the startup sequence, all LEDs shown in Figure B.11 should be Green, indicating that the set is operating correctly. The D8 and D14 LEDs (Figure B.13) blink green only during communications with the PC, otherwise they are off.



**Figure B.13 D8 and D14 LEDs**

- With the exception of D8 and D14, if any LED shown in Figure B.11 on page B-15 is Off or Red after the startup sequence, that circuit board has experienced a startup problem.
- After the startup sequence, the communications loopback LED should illuminate. This LED is viewed by looking through the handle/vent opening (nearest the System module) on an angle from the back of the Instrument to the front. There are three LEDs visible. The loopback LED is on the bottom. If the LED:
  - Illuminates after instrument startup completes, serial communications are working up to the front panel connector.
  - Does not illuminate, check the CPU, the internal W6 ribbon cable, and the System module communications circuits.

Externally, the Instrument comes equipped with an LED on the System module Physical Front Panel that indicates proper operation of the power supply, as shown in Figure B.14.



**Figure B.14 DC Power Supply LED**

If this LED is not lit when power is applied, use the Troubleshooting flow charts shown in Figure B.9 on page B-11 and Figure B.10 on page B-12 to resolve the problem.

## Replacement Procedures

This section discusses the replacement procedures for the TDR9000. These procedures include:

- Internal circuit boards
- Physical Front Panel Modules
- Power Supply Circuit Board Fuses
- Power Supply Module

### WARNING



**Turn power OFF and disconnect from line power before reaching into the Instrument.**

## Internal Circuit Boards

The on-site repair philosophy is to replace only complete printed circuit boards or other subassemblies. None of the solid-state printed circuit boards need user calibration or adjustment.

Remove or insert printed circuit assemblies carefully to avoid damage to their mating connectors and make sure that replacement circuit boards are placed in the same locations from which damaged circuit boards were removed. Circuit boards are shipped with a label identifying the type of board. Individual slots are marked with labels, as well.

### NOTE



**Wear ESD wrist straps when working with circuit boards.**

To replace a circuit board:

1. Turn the power OFF.
2. Disconnect all external cables from the Instrument, except the Instrument ground cable.

3. Unscrew the two flat head screws that hold the two top rubber feet, as shown in Figure B.15.



**Figure B.15 Screws that Hold Top Rubber Feet**

4. Remove the top cover from the Instrument by lifting it up at the back and sliding it backwards.
5. Disconnect any circuit board ribbon cables required to perform the replacement.

Table B.2 lists the ribbon cables that need to be disconnected by circuit board type.

**Table B.2 Required Cable Disconnects by Circuit Board**

Circuit Board Type Replaced	Cables for Disconnection
EVG	Disconnect the W4 and W3 from the EVG using the ejectors
CPU	Disconnect the W6 from this circuit board using the two common screws and disconnect the W4 and W3 from the EVG using the ejectors
Trip/Close	Disconnect the W4 and the W3 ribbon cables from the EVG circuit board and the W6 cable from the CPU board

6. Unscrew the captive screws on the circuit board.
7. Unlock and lift the circuit board ejectors and pull the circuit board up and out. Alternately lifting up on the front and rear ejectors eases circuit board removal.
8. Slide the replacement board into the card guides, align the connectors on the replacement board with the connectors on the backplane and carefully push down on the card ejectors to seat the circuit board.
9. Ensure the replacement board is fully seated by pressing down on the center of the card bracket.
10. Tighten the captive screws on the circuit board.
11. Reconnect any circuit board ribbon cables.
12. Plug the TDR9000 in and power up the unit.
13. Check to make sure the LED associated with the replacement circuit board is on and green. The power up process takes about 1 minute before the LED lights.  
If LED is not green, refer to the Troubleshooting Flow Charts starting on page B-11.
14. Replace the top cover and reinstall the two rubber feet.

**NOTE**

**All circuit boards and modules that are removed must be protected from further damage by placing them into the protective packaging that came with the replacement part.**

Table B.3 lists the replaceable internal boards and their part numbers.

**Table B.3 Replaceable Internal Board Part Numbers**

Circuit Board	Part Number
EVG	04S-0691-01
CPU	04D-0603-04
Event (3A/3X)	04S-0694-01
Trip/Close Module	03D-1372-01 (with Trip/Close Current) 03D-1372-02 (without Trip/Close Current)
Main Contact Master	04S-0692-01 (with resistance) 04S-0692-02 (without resistance)
Main Contact Slave	04S-0692-03 (with resistance) 04S-0692-04 (without resistance)
Capacitance Measurement Board	04S-0695-01

## Physical Front Panel Modules

The following Front Panel modules can be replaced in the field:

- OCB/Motion
- EHV
- Event

These replacement procedures are geared to replacing only Front Panel modules that have failed in existing configurations. Reconfiguration of the TDR9000, changing the type of module located in any position, must be done by Doble personnel.

**NOTE**



**The System Front Panel module is not replaceable in the field. If troubleshooting analysis indicates a problem or failure is related to this module, contact Doble Customer Service. Also, it is necessary to remove the module in Location 2 before removing a module in Location 1.**

To replace a Front Panel module:

1. Turn the TDR9000 power off and unplug.
2. Remove the four hex head screws in the corners of the module using a 5/64" driver.

**NOTE**

**Modules in Location 1 have five screws.**

3. Pull the module straight forward and out by:
  - Grabbing a circular connector on an OCB/Motion or EHV module. Rock the module side-to-side while extracting.
  - Inserting two banana clip leads into two connectors on the module face of an Event module and gently pull, while rocking the module side-to-side.
4. Align the connector on the replacement module with the connector on the backplane and carefully seat the module.
5. Replace the hex head screws.

**NOTE**

**The screws located on the outer edge of the System module and the module in Location 1 are longer.**

6. Plug the TDR9000 in and power up the unit.
7. Check to make sure the Physical Front Panel and the Virtual Front Panel match. If they don't, refer to the Troubleshooting Flow Charts starting on page B-11.
8. Replace the top cover and reinstall the two rubber feet.

Table B.4 lists the replaceable modules and their part numbers.

**Table B.4 Replaceable Physical Front Panel Module Part Numbers**

Module	Part Number
EHV	03D-1381-01
Event (3A/3X)	03D-1383-01
OCB/Motion (3 Motion)	03D-1382-01
OCB/Motion (6 Motion)	03D-1382-02
OCB only	03D-1382-05
3 Motion only	03D-1382-03
6 Motion only	03D-1382-04

## Power Supply Fuses

The Instrument comes equipped with an LED on the System module Physical Front Panel that indicates proper operation of the power supply, as shown in Figure B.16.

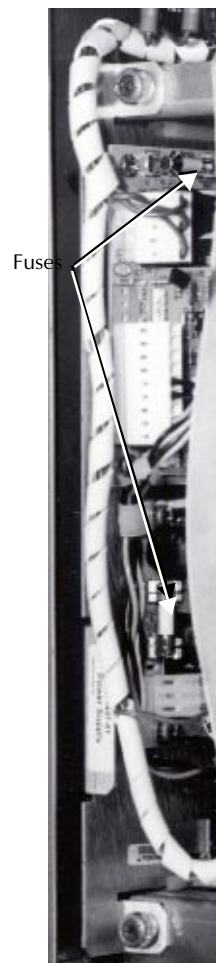


**Figure B.16 DC Power Supply LED**

If this LED is not lit when the power is applied, then one of the two power supply fuses is blown, the power supply is bad, the internal temperature of the Instrument is too high, or the monitoring circuit is bad.

To access the power supply module and examine the fuses:

1. Turn the TDR9000 power off and unplug.
2. Unscrew the two flat head screws that hold the two top rubber feet, as shown in Figure B.15 on page B-20.
3. Measure the resistance across the fuse using a multimeter. The fuses are shown in Figure B.17.



**Figure B.17 Power Supply Assembly Fuses**

If the meter registers:

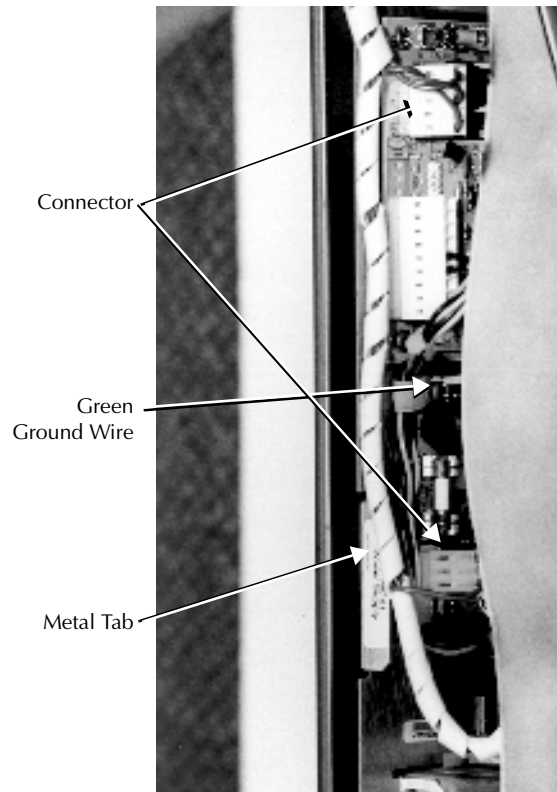
- More than 800 kOhms, the fuse is blown, proceed to step 4.
  - Less than 800 kOhms, the fuse is not blown, replace the Power Supply circuit board assembly. Refer to "Power Supply" on page B-26.
4. Pull the blown fuse out and insert a new fuse.  
Replacement fuses are 5 x 20mm and 250 VAC. The:
    - 5V supply fuse is 3.15A, Littlefuse #216 3.15 or equivalent
    - 24V supply fuse is 4A, Littlefuse #216 004 or equivalent
  5. Plug the unit in and power up the TDR9000.
  6. Check the LED on the System module Physical Front Panel.  
If LED is not green, refer to the Troubleshooting Flow Charts starting on page B-11.
  7. Replace the top cover and reinstall the two rubber feet.

## Power Supply

If the Physical Front Panel LED does not illuminate and the fuses located on the Power Supply circuit board are not blown, the DC power supply is suspect and should be replaced. The power supply is called out in Figure B.11 on page B-15.

To replace the power supply:

1. Turn the TDR9000 power off and unplug.
2. Remove the top cover, as shown in Figure B.15 on page B-20.
3. Unscrew the captive fasteners on the circuit board.
4. Disconnect the two connectors and the green ground connector indicated in Figure B.18.

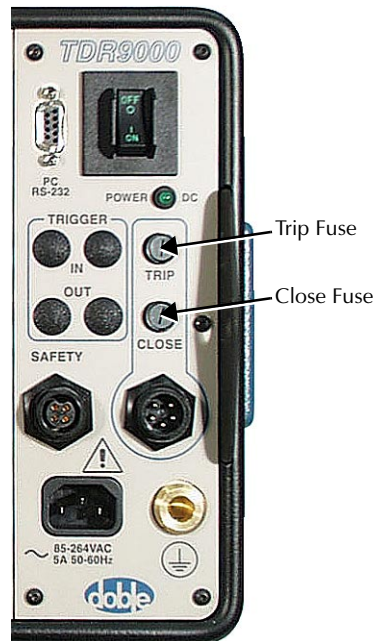


**Figure B.18 Power Supply Circuit Board Connectors**

5. Pull up gently on the metal tab (Figure B.18) to remove the assembly.
6. Insert the replacement assembly into the guides and gently push it into position.
7. Replace the cables disconnected in step 4.
8. Plug the unit in and power up the TDR9000.
9. Check the LED on the System module Physical Front Panel.  
If LED is not green, refer to the Troubleshooting Flow Charts starting on page B-11.
10. Replace the top cover and reinstall the two rubber feet.

## Trip/Close Fuses

Fuses for the Trip and Close coil currents are located on the TDR9000 Physical Front Panel, as shown in Figure B.19. The status of a Trip/Close fuse is determined using the procedure for testing the Trip/Close function given in "Trip/Close Function Test" below.



**Figure B.19 Trip/Close Fuses**

### Trip/Close Function Test

The TDR9000 Trip/Close module is monitored during every test. If there is an internal electronics problem, a run-time error is reported. These run-time tests cannot test the cables, fuses, or the final high current stage of the module.

**NOTE**



**Before running this test, run the Continuity test on the EHV or OCB cables.**

If a test is run and no errors are reported, and the circuit breaker does not operate, this procedure isolates the cause of the failure to the Trip/Close fuses or to the Breaker Control cable responsible for the Trip/Close function or the Trip/Close module, unless the circuit breaker is defective. Fuses can be checked by inspection. The cable can be checked with a meter, but this is difficult if the pinout pattern is not known. This makes the following procedure the quickest troubleshooting solution:

1. Connect the alligator clips of the Breaker (Trip/Close) Control cable across the test clamps of an activated OCB or EHV cable.

**WARNING**

**All the cables used for this test should be detached from the breaker while performing this procedure.**

*Example*

Connect a Trip clip to a contact clamp, connect a Close clip to another contact clamp, and connect the remaining Trip/Close clips to the common clamp.

2. Run a test sequence that exercises both controls (e.g., Trip Free, Reclose, O-C-O).
3. Check for activity on both contact channels.
  - If only one control is misbehaving, the test can be done using only one contact channel and the suspect T/C clip pair. Run a simple test (e.g., Trip, Close).
  - If both the Trip and Close control pulses are seen on the contact channels graphs, the TDR9000 is OK. The problem is outside the Instrument.
  - If one or both of the patterns is missing, check the fuses with a meter.
    - If the fuses are OK, then the cable is suspect.
    - If the fuses and cables are OK, then replace the Trip/Close module. Refer to "Internal Circuit Boards" on page B-19.
    - Otherwise, replace the bad fuse. Refer to "Replacing Trip/Close Fuses".

Replacing  
Trip/Close Fuses

To replace fuses:

1. Turn the power OFF.
2. Remove and replace the defective fuse using a flat head screwdriver.

**WARNING**

**Always use a bus type 3 A, 250V Slo-Blo (Doble Part # 384-0002). Use of any fuse other than the designated type can result in damage to the TDR9000.**

3. Restore system connections.
4. Turn the power ON.

## Cable Verification and Replacement

To verify that the Contact Measurement cables are in proper working condition, run a Continuity Test. It is useful to run the Continuity test with only the suspect cable connected.

TDR9000 interconnection cables are listed in Table B.5. If a system failure occurs, and if the failure is traced to a particular cable, ensure that the cable is properly seated and connected, before replacing the cable.

To verify cables:

1. Disconnect all connections to the circuit breaker.
2. Disconnect all but the suspect cable from the TDR9000 Physical Front Panel.

The connector on the Virtual Front panel for the cable being tested should be green, indicating the channel is ready.

3. Clip the circuit breaker contact clamps together.
4. Run the Continuity test. Refer to "Running the Continuity Test" on page 4-71.
5. Repeat step 1 through 4 for all cables until the test fails.

Contact Doble Customer Service to order replacement cables.

### NOTE



**If no particular cable is suspect, running the Continuity Test with all cables connected will still produce useful results, since all cables are independent. For this to work, only cable clamps from the same cable should contact each other.**

**OCB and EHV cables cannot be connected at the same time.**

**Other cable lengths and extensions are available. Please contact Doble Customer Service.**

**Table B.5 Cable Replacement List**

<b>Part Number</b>	<b>Description</b>
02C-0019-01	Chassis Ground cable (30 feet)
071-0021-01	External Cable kit
02B-0050-10	Safety Switch cable (25 feet)
181-0095	Power cord (USA standard)
401-0168	RS-232 cable (25 feet)
05B-0620-01	OCB cable (60 feet, standard)
020-0127-01 through 04	EHV cable set (Specify module number)
05B-0621	EHV cable, individual (specify module number and phase)
05B-0634-01 through 03	Analog channel cable (specify red, yellow or blue)
05B-0635-01 through 03	Auxiliary channel cable (specify red, yellow or blue)
02B-0013-06	Trip/Close Control cable
05C-0648-01	Safety Plug w/Flag (used for External Trigger test)
181-0107	Motion Transducer cable (40 feet)
03C-1397-01	Battery Clips (black)
03C-1398-01	Battery Clips (red)

## Customer Service

Before calling or sending an e-mail to Customer Service for assistance, please take the following preliminary service steps:

1. Repeat all the pertinent procedures in this chapter.
2. Check all cable connections.
3. Review the problems and solutions given in Table B.1 on page B-13.
4. Try the test on another Instrument, if available.
5. Compare system requirements to your test setup and Instrument configuration.
6. Run the Self-Diagnostics program ("Self-Diagnostics Test" on page B-1) and have the results ready for Customer Service.

If possible, have the Instrument setup near a telephone to facilitate telephone assistance. Call Doble Engineering Customer Service at (617) 926-4900 or e-mail: [customerservice@doble.com](mailto:customerservice@doble.com).

Please have the following available when calling or e-mailing Customer Service:

- Date of purchase
- Instrument serial numbers, hardware configuration and software revision
- Results of the Self-Diagnostics test
- Exact description of the problem, including error messages, and the sequence of events before it appeared
- List of solutions that have been tried
- Electronics tool kit and digital multimeter, in case Customer Service suggests that a circuit board or subassembly be removed

Write down the Customer Service Representative's name and any instructions. If you call back, it is more efficient to talk to the same person.

## Safe Packing of the TDR9000™

If troubleshooting and the completion of Doble requested parts replacements fails to resolve a system problem, the TDR9000 may need to be sent back to Doble for servicing. It is recommended that the original packing material be kept for reuse. Before transporting, contact Doble Engineering Customer Service at 617-926-4900 or FAX 617-926-0528, for return instructions.

Before packing:

1. Disconnect and remove all external cables.
2. Attach the front cover.

If the original packing material is not available, pack the Instrument for shipment as normal for fragile, electronic equipment. Alternatively, triple wall shipping containers can be ordered from Customer Service for a nominal charge (Doble Part # 903-0044). The Instrument may be packed using either of the following methods:

- 2-wall minimum corrugated cardboard box with a minimum 2 inch thick poly foam padding.
- Wood crate with minimum of 2 inch thick poly foam padding all around.

### NOTE



**Doble Engineering is not responsible for shipping damage. Carefully protect each Instrument from shipping and handling hazards. Ensure protective covers are securely in place.**

**Instruments must be sent to Doble freight pre-paid, unless other arrangements have been authorized in advance by Doble Customer Service.**

**Before returning the Instrument to Doble Engineering, contact Customer Service to obtain a *Repair Work Order (RWO)* number. The RWO number must be attached to the Instrument, as it is used to track the Instrument during shipping to Doble and back to the customer.**

**Instruction manuals, cables, and transducer connecting rods should not be returned with an Instrument, unless recommended by Doble Customer Service.**



# Appendix C. Software Field Upgrades

This appendix gives the procedures for upgrading TDR9000 software in the field, including:

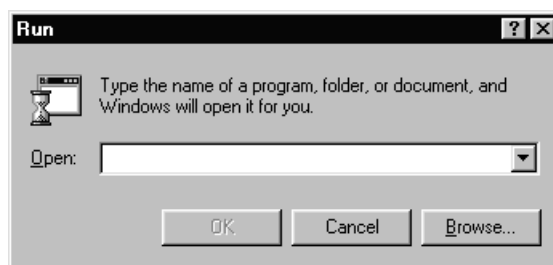
- Installing new software
- Updating firmware
- Updating the Pentax printer drivers

## Updating Software

To upgrade the TRXField software:

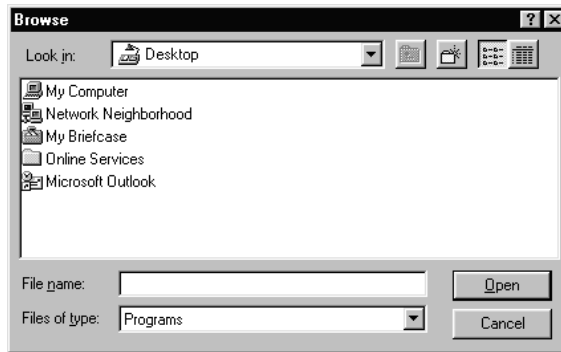
1. Insert the TRXField CD-ROM into the correct drive.
2. Proceed to:
  - Step 11, if autorun is working.
  - Step 3, if autorun is not working.
3. Select *run* from the taskbar **start menu**.

The **Run** window appears as shown in Figure C.1.



**Figure C.1 Run**

4. Click **Browse** and the **Browse** window appears, as shown in Figure C.2 on page C-2.



**Figure C.2 Browse**

5. Double-click *My Computer* and then double-click the CD-ROM drive.

The contents of the drive appear in the **Browse** window.

6. Browse to the *Disk1* folder.
7. Click *setup.exe*.
8. Click **Open**.

The **Run** window reappears with the directory path added, as shown in Figure C.3.



**Figure C.3 Run with Directory Path**

9. Click **OK**.

Install Shield™ software automatically runs and the **Welcome to Installation of TRXField** window appears.

10. Click **Next**.

11. The **Choose Destination Location** window appears, as shown in Figure C.4.



**Figure C.4 Choose Destination Location**

The default directory for the TRXField software installation is *C:\Program Files\Doble\TRX*.

This should not be changed.

12. Click **Next**.

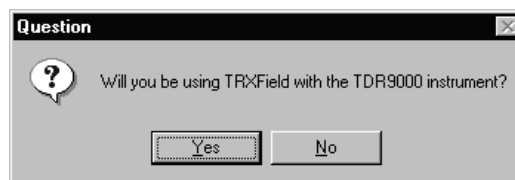
A status bar appears as the TRXField files are copied to the hard drive.

A dialog box appears, as shown in Figure C.5. If **No** is selected, the **TDR9000** tab does not appear and the system will not have the ability to configure or run tests.

**NOTE**



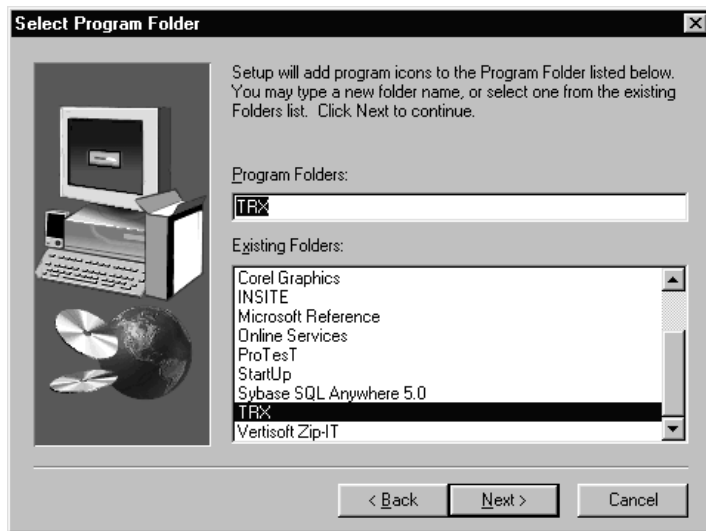
**This option can be changed after installation.**



**Figure C.5 TRXField™ Choice**

13. Click **Yes**.

The **Select Program Folder** window appears, as shown in Figure C.6.



**Figure C.6** *Select Program Folder*

These settings should not be changed, as they overwrite any existing TRX folder.

**14.** Click **Next**.

The **Choose Desktop Preference** window appears.

**15.** Click:

- **Yes** to add a **TRXField** icon to the desktop.
- **No** to proceed to the next window without adding the icon.

The **Setup Complete** window appears.

**16.** Click **Finish**.

TRXField installation is complete.

## Updating TDR9000™ Firmware

**NOTE**

**The power management functions on certain laptops can interfere with communications between the laptop and the TDR9000 during the loading process. If this occurs, disable the power management software.**

The CPU board is equipped with a re-writeable non-volatile memory *Flash ROM* to which revised firmware is loaded automatically using a flash loader program. When the laptop running the TRXField program detects the TDR9000, the TRXField software confirms the firmware version the TDR9000 is running. If these versions are not identical, a dialog box appears, requesting permission to download the laptop version of the software to the TDR9000. If permission is:

- Given, the download requires approximately five minutes to complete
- Not given, the TDR9000 is disabled for the remainder of the TRXField session

**NOTE**

**This process occurs regardless of whether the laptop contains a higher or lower software version. The progress bar can be viewed by entering a Model Number and selecting the TDR9000 tab.**

**Firmware versions are matched to software versions.**

## Power Failure During Firmware Load

To guard against loss of power during loading, make sure that the laptop and the TDR9000 have reliable power source. If the power source is interrupted during the loading process, the firmware installation could be incomplete or corrupted, and the process must be repeated.

If the loading process is interrupted by computer or power failure:

1. Turn the Instrument and the laptop OFF.
2. Turn the laptop and the Instrument ON.

The loading process repeats.

## Loading the Printer Driver

In order to print, the Pentax PocketJet II printer requires a driver be resident on the laptop running the TRXField program. A driver diskette accompanies the TDR9000 unit, including a driver for Windows 95/98 and one for Windows NT. This driver needs only to be loaded once.

Once the driver is loaded, refer to "Printer Settings" on page C-18 to explain the procedure for tailoring the printer settings to those recommended by Doble Engineering.

## Windows 95/98™

To load the Windows 95/98 driver:

1. Turn on the laptop.  
Wait for Windows to fully boot up.
2. Insert the diskette provided into the laptop's floppy drive.
3. Click *Printers* from the *Settings* menu on the Windows *Start* menu bar.

The **Printers** window appears, as shown in Figure C.7.



**Figure C.7 Printers**

4. Double-click *Add Printer*.

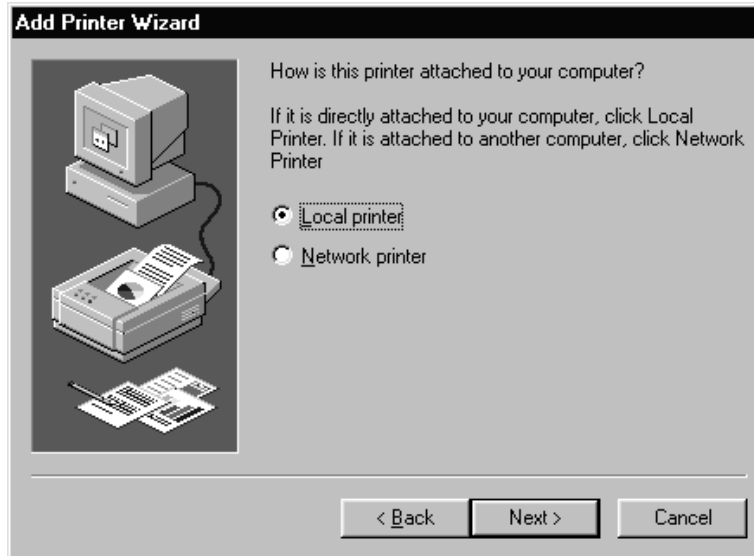
The **Add Printer Wizard** window appears, as shown in Figure C.8.



*Figure C.8 Add Printer Wizard*

5. Click **Next**.

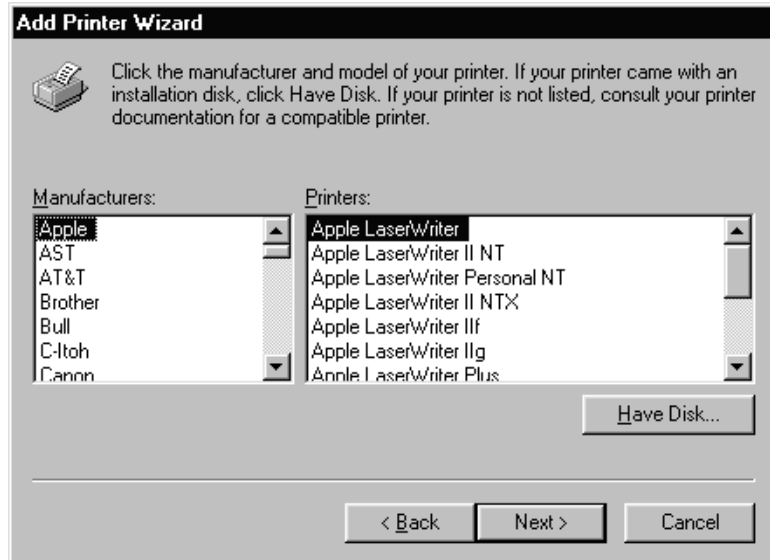
A second **Add Printer Wizard** window appears, as shown in Figure C.9.



**Figure C.9 Add Printer Wizard II**

6. Click the *Local Printer* radio button.  
Click **Next**.

A third **Add Printer Wizard** window appears, as shown in Figure C.10.



*Figure C.10 Add Printer Wizard III*

7. Click **Have Disk...**

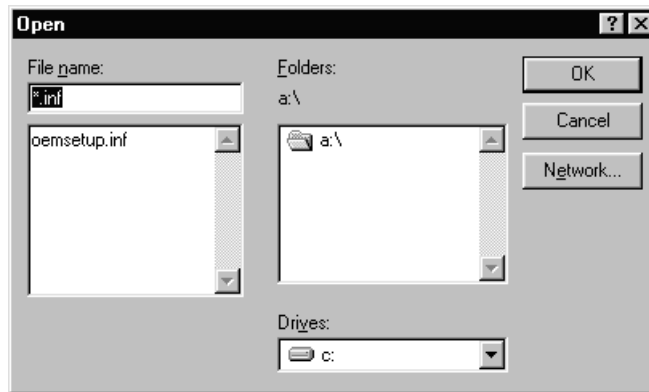
The **Install From Disk** window appears, as shown in Figure C.11.



*Figure C.11 Install From Disk*

8. Click **Browse**.

The **Open** window appears, as shown in Figure C.12.



**Figure C.12 Open**

9. Select the A:\ drive from the *Drives* picklist.

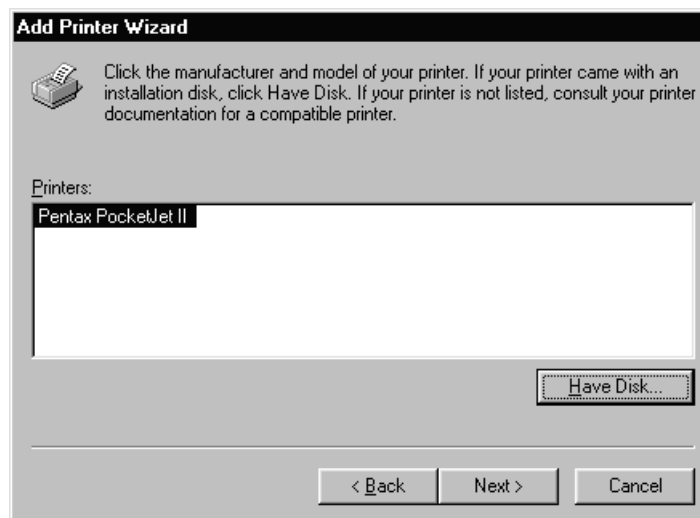
10. Click **OK** and *OEMSETUP.INF* is added to the *File Name* field.

11. Click **OK**.

The **Install From Disk** window reappears.

12. Click **OK**.

The **Add Printer Wizard** window shown in Figure C.13 appears with *Pentax PocketJet II* added to the *Printers* list.



**Figure C.13 Add Printer Wizard IV**

**13. Click Next.**

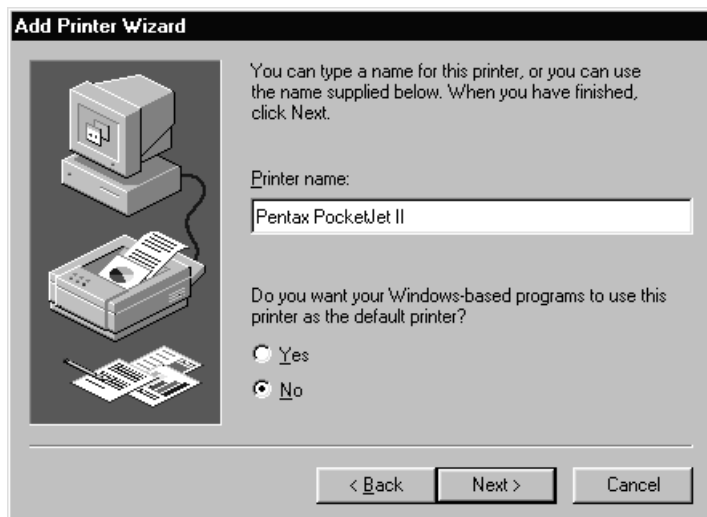
A fifth **Add Printer Wizard** window appears, as shown in Figure C.14.



**Figure C.14 Add Printer Wizard V**

**14. Ensure that LPT1 is selected and click Next.**

A sixth **Add Printer Wizard** window appears, as shown in Figure C.15.



**Figure C.15 Add Printer Wizard VI**

15. Enter *Pentax PocketJet II* in the *Printer Name* field and click **Next**.
16. Click **Finish** on the **Add Printer Wizard** window that appears. This prints a test page once installation is complete.

**NOTE**



**A Version Conflict window may appear similar to the one in Figure C.16. It is recommended that the newer version of a file be kept by clicking Yes.**



**Figure C.16 Version Conflict**

A status bar appears as the files are copied.

## Windows NT™

To load the Windows NT driver:

1. Turn on the laptop.  
Wait for Windows to fully boot up.
2. Insert the diskette provided into the laptop's floppy drive.

3. Click *Printers* from the **Settings** menu on the Windows **Start** menu bar.

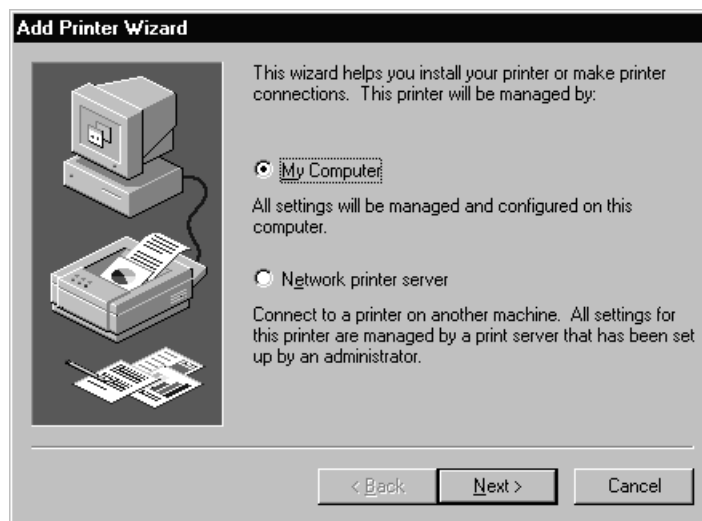
The **Printers** window appears, as shown in Figure C.17.



**Figure C.17 Printers**

4. Double-click **Add Printer**.

The **Add Printer Wizard** window appears, as shown in Figure C.18.



**Figure C.18 Add Printer Wizard**

5. Ensure that the *My Computer* radio button is selected.

Click **Next**.

A second **Add Printer Wizard** window appears, as shown in Figure C.19.

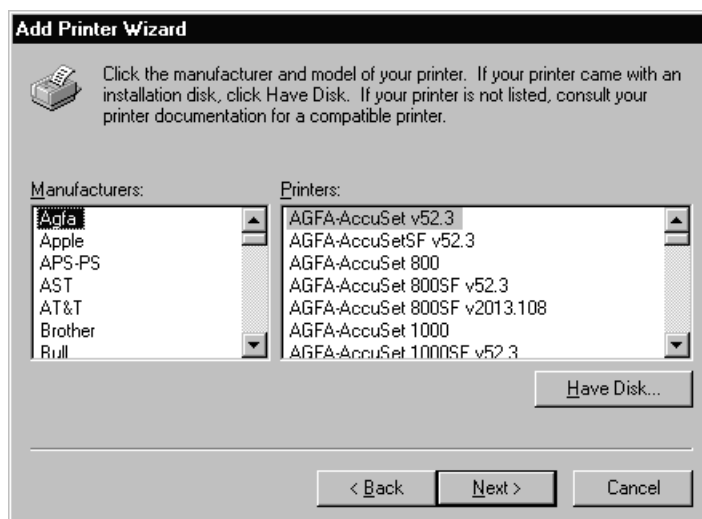


**Figure C.19 Add Printer Wizard II**

6. Click the *LPT1* checkbox.

Click **Next**.

A third **Add Printer Wizard** window appears, as shown in Figure C.20.



**Figure C.20 Add Printer Wizard III**

7. Click **Have Disk...**

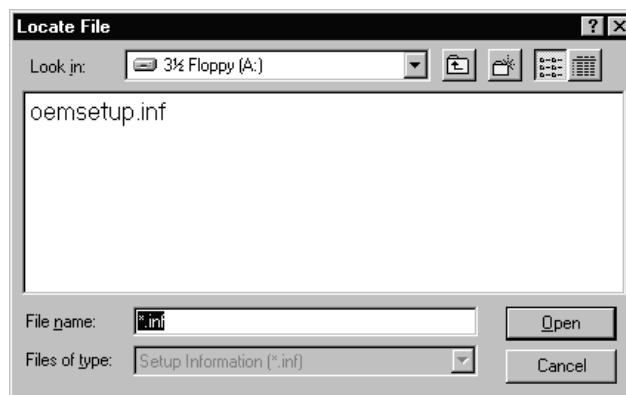
The **Install From Disk** window appears, as shown in Figure C.21.



*Figure C.21 Install From Disk*

8. Click **Browse**.

The **Locate File** window appears, as shown in Figure C.22.



*Figure C.22 Locate File*

9. Select the **A:\** drive from the drives picklist.

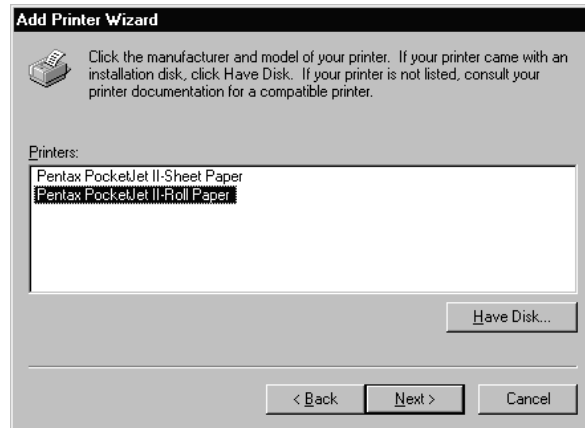
10. Click **OEMSETUP.INF** from the files listed.

11. Click **OK**.

The **Install From Disk** window reappears.

12. Click **OK**.

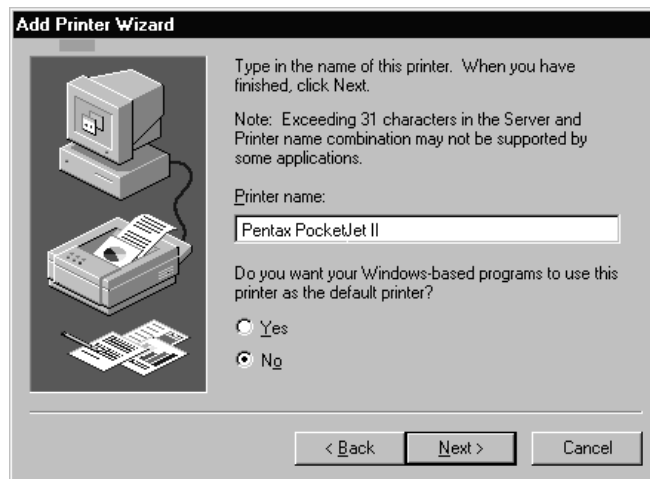
A fourth **Add Printer Wizard** window, shown in Figure C.23, appears with two versions of the Pentax PocketJet II driver added to the *Printers* list.



**Figure C.23 Add Printer Wizard IV**

13. Click *Pentax PocketJet II - Roll Paper* and then click **Next**.

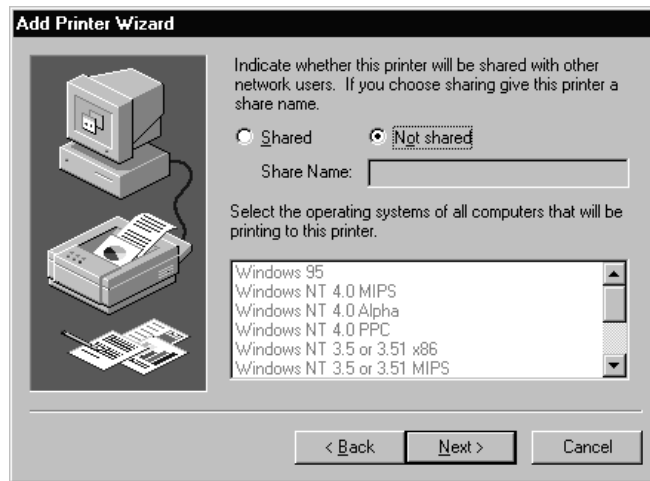
A fifth **Add Printer Wizard** window appears, as shown in Figure C.24.



**Figure C.24 Add Printer Wizard V**

14. Enter the printer name and click **Next**.

A sixth **Add Printer Wizard** window appears, as shown in Figure C.25.



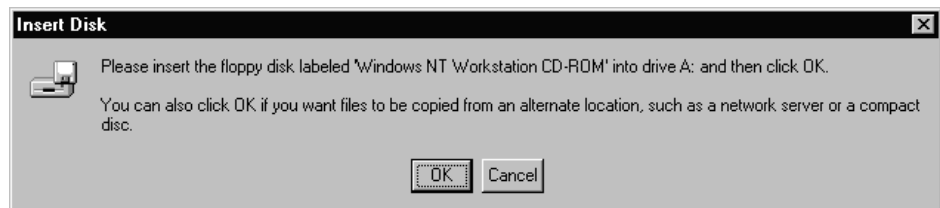
**Figure C.25 Add Printer Wizard VI**

15. Ensure that the *Not Shared* radio button is selected and click **Next**.

**NOTE**



A dialog box may appear, as shown in Figure C.26. If this occurs, insert the CD-ROM and follow all instructions.



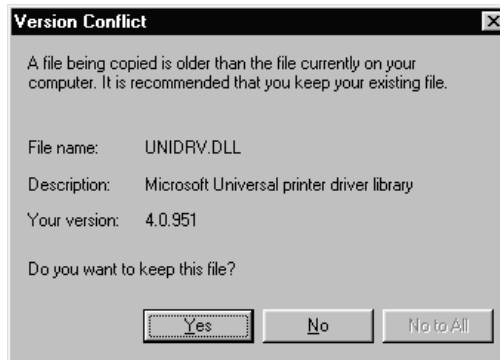
**Figure C.26 Windows NT™**

16. Click **Finish** on the next **Add Printer Wizard** window that appears. This prints a test page once installation is complete.

**NOTE**



A **Version Conflict** window may appear similar to the one in Figure C.27. It is recommended that the newer version of a file be kept by clicking **Yes**.



**Figure C.27** *Version Conflict*

A status bar appears as the files are copied.

## Printer Settings

The procedure that follows explains how to make the Doble recommended modifications to the Pentax PocketJet II printer settings.

To modify the printer settings:

1. Click *Printers* from the *Settings* menu on the Windows *Start* menu bar.

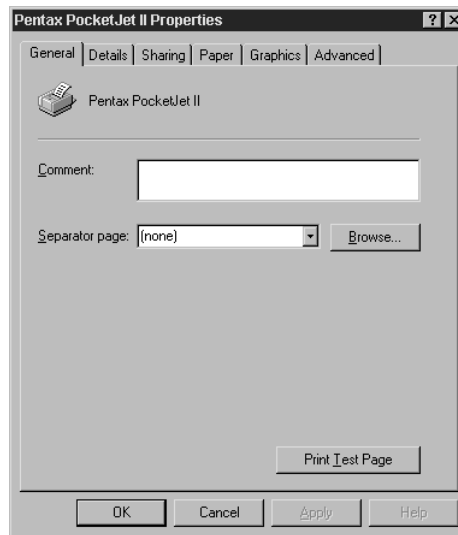
The **Printers** window appears, as shown in Figure C.28.



**Figure C.28** *Printers Window*

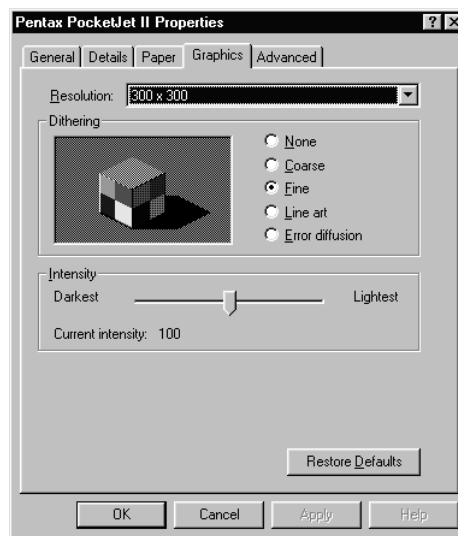
2. Right-click the **Pentax PocketJet II** icon.

The **Pentax PocketJet II Properties** window appears, as shown in Figure C.29.



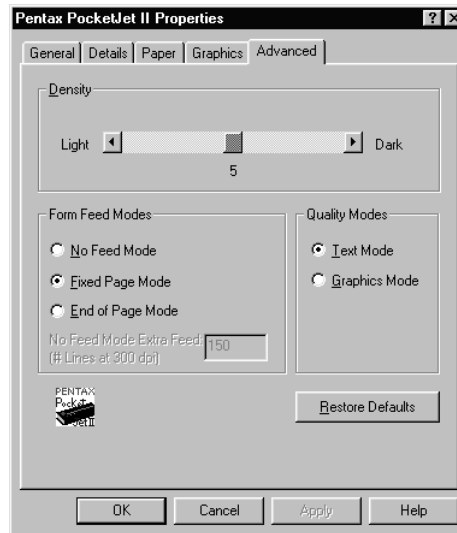
*Figure C.29 Pentax® PocketJet II™ Properties*

3. Click the **Graphics** tab and the window appears as shown in Figure C.30.



*Figure C.30 Pentax® PocketJet II™ Properties – Graphics*

4. Click the *Line Art* radio button.
5. Click the **Advanced** tab and the window appears as shown in Figure C.31.



**Figure C.31 Pentax® PocketJet II™ Properties - Advanced**

6. Click the *No Feed Mode* radio button.
7. Enter *200* in the *No Feed Mode Extra Feed (# of lines at 300 dpi)* field.
8. Reset the *Density* to *7*.
9. Click **OK** and close the **Printers** window.

# Appendix D. Concepts of Operation

The TDR9000 is a multi-purpose data recorder outfitted with different signal sources and receiver channels depending on the type of circuit breaker under test. Five Physical Front Panel modules can be populated into numerous configurations of measurement channels. A sixth module, the System module, is configured to control the circuit breaker under test, or initiate recording based on an external trigger input.

## Channel Types

There are currently six channel types supported by the TDR9000:

- Main and contact Pre-Insertion resistor switch timing
- Pre-Insertion resistor value
- Motion (using a transducer) channels
- Auxiliary contact channels
- Analog channels
- Capacitance channels

Each channel type, except Capacitance, has a different front end. However, all channels are collected and forwarded to the controller for processing in the same manner. Data processing creates measurements that are compared to specifications (circuit breaker vendor limits or learned results shared between utilities) resulting in Pass/Fail decisions.

## Main Contact Timing

Contact timing is achieved by providing a voltage source (isolated in pairs for EHV) to the contacts and comparing the voltage across the contacts to references internal to the TDR9000. A voltage below the lower threshold (on the order of 5% of the source voltage) is logged as a Close state. A voltage above the higher threshold (on the order of 95% of the source voltage) is logged as an Open state. The state is sampled at 10 kHz and stored in a circular buffer for transfer to the computer.

A hardware discriminator qualifies state transitions to eliminate noise and cable capacitance that might be perceived as switch bounce. The discrimination time is set to 60  $\mu$ sec and is sampled at 2 MHz.

## Pre-Insertion Resistor Timing

Resistor Switch timing is measured much the same as Main Contact timing. When the measured voltage falls between the lower threshold and the higher threshold, the channel is determined to be in the *resistance* state.

## Pre-Insertion Resistor Ohmic Value

The pre-insertion resistor measurement circuit employs the same voltage source and source resistor as the contact timing circuits. The voltage across the contacts is monitored by a voltage to frequency converter whose output is optically coupled to a digital counting circuit. Knowing the source voltage, source resistance and voltage across the pre-insertion resistor contacts allows the actual pre-insertion resistance to be calculated. The output of the digital counting circuit is updated every 800  $\mu$ sec (1.25 kHz).

## Motion Channels

Motion channels accept inputs from Doble motion transducers. The transducers output two quadrature signals generated from optical sensors which switch on and off based on a *picket fence* of lines passing between the sensors and a light source. Each transition is equal to a movement of 0.0125" (0.09° for rotary motion) imposed on the transducer. The transitions are counted and sampled at 10 kHz. The direction of movement is identified by which quadrature signals leads and which lags at any moment in time. The distance curve is generated by providing a running sum of the transitions vs. time, using the initial position as zero. The velocity curve is generated by taking the change in distance vs. time.

## Auxiliary Contact Channels

The Auxiliary Contact channels measure and display the timing of three different states: Open-Wet, Open-Dry, and Closed. An isolated wetting voltage is provided for each channel that is not externally wetted to allow for the differentiation of open vs. closed and to clean any oxide buildup on the contacts. Both the open/close decision and the wet/dry decision are made based on the voltage across the channel inputs. The states are sampled at 10 kHz.

## Analog Channels

The analog channels are general purpose voltage recordings. The inputs are isolated from each other and sampled by a 12-bit serial A/D converter. The A/D converter clock is 80 kHz. Eight consecutive samples are averaged and sampled by the system at 10 kHz.

## Capacitance Channels

The Capacitance Measurement test is used to measure EHV grading capacitors. These capacitors are located in parallel with the main contacts and can be measured through the EHV modules/cables when the contacts are open. The test consists of measuring capacitance, in the range of 75 to 10,000 pF, between each of the two EHV leads and the common lead for each phase and each module. The test measurement accuracy is in the range of  $\pm 5\%$ . Since the circuit breaker is not operated during the test, no waveform is sent through the system.

## Circuit Breaker Control

The system can be configured with a Trip/Close module capable of activating the control coils of the circuit breaker under test. The command signals are capable of switching 100 A of current on the Trip channel and 20 A of current on the Close channel. These levels can be sustained for tens of milliseconds, with lower current values sustainable for tenths of seconds. Each channel is protected with a slow-blow fuse.

The Trip and Close command signals are programmed into timers, configured via user inputs, when the operator initiates a test. Before a Trip or Close command leaves the Instrument, each command signal is interrupted by a relay that has three control mechanisms:

- When the test is initiated, the firmware outputs a logic enable signal to the relay control circuitry.
- Once the safety switch is pressed, voltage is supplied to one side of the relay coil.
- The firmware detects the safety switch closure and outputs a signal, which completes the relay coil circuit allowing the command signals out to the breaker.

## System Operation

The system is composed of two functional components, the Instrument and the controller software, TRXField, running on a laptop. The following describes the interaction between the two components.

### System Startup and Pre-Test Configuration

On power up, the Instrument runs a short self-test to identify all cards and modules that are present. Once contacted by the controller, the Instrument transfers its configuration to the controller and it is displayed as a Virtual Front Panel on the computer's screen.

The channels of interest can be activated from the Virtual Front Panel or via a Test Plan created with the TRX or TRXField products. The type of test to perform is selected from a pull down menu on the Virtual Front Panel.

### Test Execution

The controller downloads a list of channels to activate, range settings for the appropriate channels, and the signal on which to trigger the recording. Appropriate action by the operator (including the pressing of the Safety Switch) turns on all of the test voltages and starts the sampling of all the activated channels. Samples are stored in a circular buffer. When the predefined trigger signal is detected, the samples are transferred from the circular buffer to a permanent buffer pending the end of the test, at which point the information is transferred to the controller.

### Data Transfer

The amount of data transferred to the controller is proportional to the number and type of channels activated. A Main Contact measurement could be made up of a channel of timing and a channel of pre-insertion resistance value measurement. Each Analog Channel and/or Auxiliary Contact channel is a single channel. The internal Trip and Close coil current channels are individual channels.

Data is compressed and transferred to the controller at 38.4 kbps. The different channel types compress to varying degrees depending on content: timing channels compress very well; analog channels do not.

## Results Processing

TRXField receives the test data and decompresses it. Calculations are performed on a channel by channel basis resulting in switching times, maximum values, and average values during specific times. The results of these calculations are then compared to specifications either received as part of a Test Plan or entered manually by the user prior to the test. A Pass/Fail comparison is performed and the results are reported on all channels with specifications.

Results are made available in both tabular and graphical formats. Numerous utilities such as zooming, overlaying, and on screen measurements are made available as part of the graphics package.

## Self-Test

The Instrument has a Self-Diagnostics test, comprised of two individual tests, which functionally test the operation of all measurement channels. No Trip or Close command signals are output from the Instrument during the Self-Diagnostic test.

Once the test is initiated from the Virtual Front Panel, the first test, the Global Self-Test begins. Each measurement channel is disconnected from the external connector via relays. This allows the entire Self-Diagnostics test to run without disconnecting the Instrument test setup. Simulated signals are injected just inside the Physical Front Panel and sampled as if a standard test was under way. The results are interpreted by the TRXField software and compared to expected results. If all channels are functioning properly, the test ends. If a functional failure is detected, the second test begins, the Local Self-Test, which continues testing with the measurement channels disconnected between the Physical Front Panel modules and the measurement cards in the card cage. Again, test signals are injected and the results interpreted. Logic is applied to the two Test Results and the failed card or module is identified and displayed.



# Appendix E. Maintenance

This appendix covers the following maintenance areas:

- TDR9000 Rules for Safe Operation
- Maintenance

## TDR9000™ Rules for Safe Operation

**WARNING**



**Safe operation of the system requires adherence to the following guidelines:**

- *Always* install the Safety Ground cables when using the system in the field.
- Use the correct electrical line voltage to avoid an electrical short circuit, overheating and shocks. If in doubt, check the electrical rating label attached to each unit.
- Do not, for any reason, cut or remove the grounding prong from the power cord.
- Turn power OFF and disconnect from line power before reaching into the Instrument.
- Never insert metal objects, such as screwdrivers or paper clips, inside the Instrument while power is ON.
- Unplug the Instrument if it is not to be used for an extended period of time, or before cleaning.
- If the Instrument is dropped, have it checked by a qualified service technician before placing it back in service. Dropping the Instrument can disturb the insulation system.
- Do not place the Instrument in excessively warm or humid locations.

## Maintenance

The topics that follow discuss the following maintenance related areas:

- Cleaning the TDR9000
- Replacing the printer's paper supply

## Cleaning

Normal care and cleaning of the Instrument is comprised of the following areas:

### Instrument Covers and Panels

Sponge with a mild soap solution. *DO NOT* use household cleaners containing chlorinated or abrasive compounds. *DO NOT* spray liquids directly onto the Instrument.

### Printer

For care and maintenance of the built-in printer, refer to its service manual.

#### NOTE



**Do not use flammable liquids, such as gasoline or lighter fluid, for cleaning electrodes, electrical components or moving parts. Disconnect the Instrument's power cord and all other external cables before cleaning or removing the Instrument cover.**

## Changing Printer Paper

The built-in Pentax printer uses the following replacement paper types:

- Cut sheet thermal paper – letter, legal or A4 sizes
- Rolls of thermal paper – Approximately 100 ft. (Doble P/N 401-0169)

To replace the paper roll:

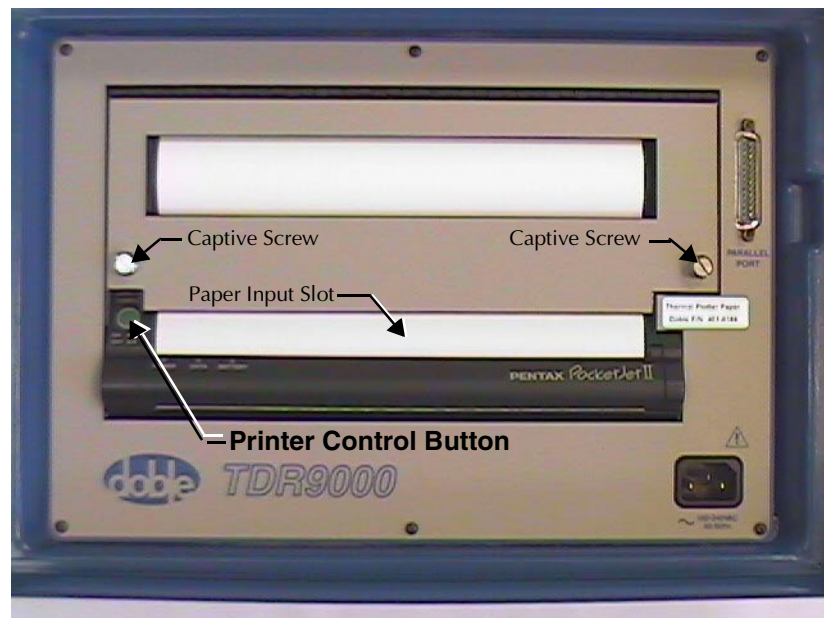
1. Loosen the two captive screws securing the printer cover and pull the cover up (Figure E.1).
2. Pull back the pin on the right side of the paper roll to loosen the roll.
3. Rotate the roll clockwise to remove it from the paper roll assembly.
4. Remove the empty roll.
5. Insert a new roll, unroll the first six inches and tear an even edge.
6. Align the bottom edge of the paper roll parallel with the paper input slot (Figure E.1).

7. Insert the paper under the paper roller until the roller pulls it into the starting position, then let go.
8. Press the printer control button until, as shown in Figure E.1, until the paper feeds through fully aligned (6" -12").
9. Close the printer cover and tighten the two captive screws.

If the paper is skewed after the printer pulls it into the starting position, the situation can be corrected as follows:

- If the printer does not print immediately, open the release cover as far back as it goes. Pull the paper out, reinsert it and close the cover.
- If the printer does start to print, wait for the page to be printed and then reprint that page if necessary.

The paper can be pulled out of the printer in either direction.



**Figure E.1 Printer Paper Installation**

**NOTE**



For complete instructions on the operation of the Pentax printer, refer to its user's manual, which is included with the TDR9000.



# Appendix F. Glossary

## Slow Close

A manual operation that consists of the operating mechanism, usually by a hydraulic jack, to measure contact insertion. Contact insertion being the point of travel at initial contact make to the final resting place of the contacts in the fully closed position.

## First Trip or First Close

When a circuit breaker is not operated for a long period of time, whether in service or out, the lubrication for mechanical components may suffer changes its viscosity resulting in a loss of lubricating ability. This may cause an in-service breaker to be slow in tripping or an out of service breaker to be slow in closing.

By connecting the TDR9000 to the in-service breaker, phase currents, trip and close coil currents, DC battery supply and auxiliary contacts can be monitored as the recording is started by an external signal. This provides data that indicates if the circuit breaker operated properly when prompted. If not, data analysis indicates the problem so that appropriate maintenance can be applied. This is useful, as often times the breaker operates properly on a second trip operation (out-of-service), as the lubricant has been exercised.

## Capacitor

The TDR9000 T9330 Capacitance Measurement option allows the testing of grading capacitors to determine their picofarad value.

Refer to "Open-Gap Grading Capacitor" on page A-18 for an explanation of their function.



# Appendix G. Error Messages

This appendix lists the error messages for the TDR9000. Throughout this appendix, the % character indicates a variable supplied to the message.

## Test Plan and Hardware Conflict Errors

Table G.1 lists channel activation cross check error messages that occur when a TDR9000 is not connected. These indicate Test Plans that cannot be used with any TDR9000. The error message appears when the Test Plan is opened, an edit is performed, and the **TDR9000** tab is selected.

**Table G.1 Test Plan and Instrument Configuration Conflicts – TDR9000™ Unconnected**

<b>Error Message</b>	<b>Solution</b>
<i>The fifth module of EHV has been activated. The TDR9000 does not support 5 EHV modules. The module 5 EHV channels will be ignored by the TDR9000.</i>	N/A
<i>Both EHV and Analog/Auxiliary channels are active on slot %d.</i>	Check <b>Test Plan</b> and <b>TDR9000</b> tab for configuration conflicts.

Table G.2 on page G-2 lists channel activation cross check error messages that occur when there is a TDR9000 connected, which indicate the Test Plan cannot be used with the specific TDR9000 connected. The error message appears when the Test Plan is opened, an edit is performed, and the test is run.

The problem is addressed by deactivating the appropriate channels on the TDR9000 Virtual Front Panel or the **Test Plan** tab.

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**Table G.2 Test Plan and Instrument Configuration Conflicts –  
TDR9000™ Connected**

<b>Error Message</b>
<i>Motion channels are active in the test plan, but the TDR9000 does not have a motion module. Please deactivate all motion channels.</i>
<i>OCB channels are active in the test plan, but the TDR9000 does not have a OCB module. Please deactivate all OCB channels.</i>
<i>Channels for EHV module %d are active in the test plan, but the TDR9000 does not have required EHV module. Please deactivate all channels on EHV module %d.</i>
<i>Motion channel %d is active in the test plan, but the TDR9000 does not have the 6 channel motion module required. Please deactivate motion channel %d.</i>
<i>More than %d analog channels are active in the test plan, but the TDR9000 does not have a fourth event module. Please deactivate all analog channels on the fourth event module.</i>
<i>Analog channels are active in the test plan, but the TDR9000 does not have any event modules. Please deactivate all analog channels.</i>
<i>More than %d auxiliary contact channels are active in the test plan, but the TDR9000 does not have a fourth event module. Please deactivate all auxiliary channels on the fourth event module.</i>
<i>Auxiliary contact channels are active in the test plan, but the TDR9000 does not have any event modules. Please deactivate all auxiliary channels.</i>
<i>There are EHV capacitance channels active, but the TDR9000 does not have the capacitor measurement option. Activated capacitor channels will be ignored.</i>

## Run Test Conflicts

Table G.3 lists the messages that appear once the **Run Test** button is clicked.

**Table G.3 Run Test Conflicts**

<b>Error Message</b>
<i>No channels have been activated. Please activate appropriate channels.</i>
<i>The loaded test plan uses channels that are not available to the connected TDR9000. Verify channel activation.</i>
<i>Both OCB and EHV channels have been activated. The TDR9000 cannot use both EHV and OCB at the same time. Please deactivate the inappropriate channels and retry.</i>
<i>Both OCB and EHV channels have cables plugged in. The TDR9000 cannot use both EHV and OCB at the same time. Please unplug inappropriate cables and retry.</i>
Refer to "Disconnecting After the Test" on page 4-100 for instructions on how to disconnect a cable.
<i>There must be a safety switch connected in order to control the circuit breaker under test.</i>
<i>Analog channel %d is set to a current probe range, but the current probe has not been zeroed. Proceed to current probe zeroing.</i>
Zero probe using instructions given in "Current Probes" on page 4-34.
<i>EHV channel %d has been activated, but there is no cable plugged in. Verify channel activation and connect appropriate cables.</i>
Refer to "Setup and Operation" on page 4-1 before proceeding.
<i>OCB channels have been activated, but there is no cable plugged in. Verify channel activation and connect appropriate cables.</i>
Refer to "Setup and Operation" on page 4-1 before proceeding.
<i>Motion channel %d has been activated, but there is no cable plugged in. Plug in appropriate cable into active channel.</i>
Refer to "Setup and Operation" on page 4-1 before proceeding.
<i>There must be either an external trigger plug or a safety switch connected in order to run an externally triggered test.</i>

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**Table G.3 Run Test Conflicts (Continued)**

<b>Error Message</b>
<i>There must be a safety switch connected in order to control the breaker under test. Remove the external trigger plug and connect the safety switch.</i> Refer to "Setup and Operation" on page 4-1 before proceeding.
<i>Test calls for a linear travel transducer on motion channel %d, but a rotary transducer is connected. Change transducer type to rotary on the motion module.</i>
<i>Test calls for a rotary travel transducer on motion channel %d, but a linear transducer is connected. Change transducer type to linear on the motion module.</i>
<i>Duplicate labels are on motion channels %d and %d. Please change one of the labels (%s), so that all motion labels are unique.</i>
<i>Duplicate labels are on velocity channels %d and %d. Please change one of the labels (%s), so that all velocity labels are unique.</i>
<i>Duplicate labels are on OCB channels %d and %d. Please change one of the labels (%s), so that all OCB labels are unique.</i>
<i>Duplicate labels are on auxiliary channels %d and %d. Please change one of the labels (%s), so that all auxiliary labels are unique.</i>
<i>Duplicate labels are on analog channels %d and %d. Please change one of the labels (%s), so that all analog labels are unique.</i>
<i>EHV channels are set to OCB mode. The TDR9000 does not support OCB mode for the EHV connectors. Please set an available mode for the EHV connectors.</i>

## Continue Test Conflicts

Table G.4 lists the message that appears once the test has begun to run, but encountered an error. In this instance, once the conflict is resolved, the test can continue.

**Table G.4 Continue Test Conflicts**

<b>Error Message</b>
<i>There must be an external trigger plug connected in order to run an externally triggered test. Remove the safety switch and insert the external trigger plug.</i>

## Test Exceptions

Table G.5 lists the message that appears once the test has begun to run, but encountered an error. In these instances, the test is aborted.

**Table G.5 Test Exceptions**

<b>Error Message</b>	<b>Solution</b>
<i>There must be a safety switch connected in order to control the circuit breaker under test.</i>	Connect a safety switch and rerun test.
<i>Test was aborted because the safety switch was released before the test was completed.</i>	Run test again, pressing safety switch until tones ceases.
<i>Test aborted by host.</i>	
<i>General Data Acquisition System error during test run.</i>	Run Self-Diagnostics (see "Self-Diagnostics Test" on page B-1).
<i>Safety switch not pressed within 2 minutes. Test was aborted.</i>	Run test again, pressing safety switch until tones ceases.
<i>Trip overload during test run.</i>	See "Test Exceptions Procedure" on page G-7.
<i>Close overload during test run.</i>	See "Test Exceptions Procedure" on page G-7.

**Table G.5 Test Exceptions (Continued)**

<b>Error Message</b>	<b>Solution</b>
<i>Signal error on trip output during test run. This indicates a problem with the trip/close module.</i>	See "Test Exceptions Procedure".
<i>Signal error on close output during test run. This indicates a problem with the trip/close module.</i>	See "Test Exceptions Procedure".
<i>Power supply failure during test run.</i>	<i>Run Self-Diagnostics (see "Self-Diagnostics Test" on page B-1).</i>
<i>Trigger overload during test run.</i>	See "Test Exceptions Procedure".
<i>Trip module relay closed before power applied during test run. This indicates a problem with the trip/close module.</i>	See "Test Exceptions Procedure".
<i>Close module relay closed before power applied during test run. This indicates a problem with the trip/close module.</i>	See "Test Exceptions Procedure".
<i>Trip module relay opened after power applied during test run. This indicates a problem with the trip/close module.</i>	See "Test Exceptions Procedure".
<i>Close module relay opened after power applied during test run. This indicates a problem with the trip/close module.</i>	See "Test Exceptions Procedure".

**Table G.5 Test Exceptions (Continued)**

<b>Error Message</b>	<b>Solution</b>
<i>There must be an external trigger plug connected in order to run an externally triggered test. Remove the safety switch and insert the external trigger plug.</i>	N/A
<i>There must be a safety switch connected in order to control the breaker under test. Remove the external trigger plug and connect the safety switch.</i>	N/A
<i>Safety switch already pressed before start of test.</i>	Run test again, pressing safety switch only when tone is heard.
<i>Trigger input already in active state.</i>	Change the trigger setting or add another trigger.

## Test Exceptions Procedure

Use the following steps to resolve the error messages indicated in Table G.5.

1. Ensure that the equipment under test does not exceed TDR9000 operating limits.
2. Perform the Trip/Close test given in "Trip/Close Function Test" on page C-13.
3. Call customer service.

## Test Parameter Conflicts

Table G.6 lists error messages related to test parameters. Errors in these parameters are resolved on the TDR9000 Parameters window.

**Table G.6 Test Parameters**

<b>Error Message</b>
<i>Invalid trip command signal length. Value must range from 8.0 to 1600.0 ms.</i>
<i>Invalid close command signal length. Value must range from 8.0 to 1600.0 ms.</i>
<i>Invalid delay 1 length entered. Value must range from 8.0 to 600.0 ms.</i>
<i>Invalid delay 2 length entered. Value must range from 8.0 to 600.0 ms.</i>
<i>The combination of delay 1 length and delay 2 length cannot be greater than 1600.0 ms.</i>
<i>The combination of close pulse and delay 1 length cannot be greater than 1600.0 ms.</i>

Table G.7 lists error messages related to configuring the Motion module.

**Table G.7 Motion Module**

<b>Error Message</b>	<b>Solution</b>
<i>Invalid measurement units for selected transducer type.</i>	Modify <i>Transducer Type</i> or <i>Transducer Units</i> fields on <b>Test Plan</b> tab.

Table G.8 lists miscellaneous error messages.

**Table G.8 Miscellaneous**

<b>Error Message</b>	<b>Solution</b>
<i>Location, Special Id, and Serial Number must be filled in to continue running the breaker test.</i>	Enter the required information in the <b>Enter Breaker Information</b> window that appears when the test is run.

# Appendix H. TDR9000<sup>TM</sup> Circuit Breaker Test System Specifications

This appendix details specifications for the TDR9000 and its operations in the following areas:

- OCB/Motion module
- EHV module
- Event module
- System module
- Physical
- Environmental

## OCB/Motion

Table H.1 lists the characteristics of the OCB/Motion module.

**Table H.1 OCB/Motion Module**

Characteristic	Description
<i>OCB</i>	
Main Contact Channels	3 channels with 1 break per phase
Contact Sense Voltage for Main Contact Timing	48/15/7.5 VDC (Modified by pre-insertion resistor value)
Contact Sense Voltage for Resistor Switch Timing	48/15/7.5 VDC (Modified by pre-insertion resistor value)
Close and Open Timing Resolution	100 microseconds
Close and Open Timing Accuracy	± 100 microseconds
Minimum Contact Bounce Measurement	60 microseconds
Pre-Insertion Resistor Value Range	10 - 400 Ohms or 300 - 7000 Ohms

**Table H.1 OCB/Motion Module (Continued)**

<b>Characteristic</b>	<b>Description</b>
Resistor Value Measurement Accuracy	± 10%
<i>Motion Transducers</i>	
<i>Linear Transducer</i>	
Range	0.0 - 40.0"
Resolution	0.00125"
Accuracy	± 0.1% of measured value ± 0.1" max error
Display Resolution	0.002"
Velocity	50 ft/sec max
Acceleration	1200g for 50 μsec max
<i>Rotary Transducer</i>	
Range	0 - 2880°
Resolution	0.09°
Display Resolution	0.1°
Accuracy	± 0.1% of measured value ± 0.1° max error
Velocity	120 rev/sec max
Acceleration	30 x 10 <sup>6</sup> deg/sec <sup>2</sup> max

## EHV Module

Table H.2 lists the characteristics of the EHV module.

**Table H.2 EHV Module**

<b>Characteristic</b>	<b>Description</b>
Main Contact Channels	6 channels with 2 breaks per phase
Contact Sense Voltage for Main Contact Timing	15/7.5 VDC (Modified by pre-insertion resistor value)
Contact Sense Voltage for Resistor Switch Timing	15/7.5 VDC (Modified by pre-insertion resistor value)
Close and Open Timing Resolution	100 microseconds
Close and Open Timing Accuracy	± 100 microseconds
Minimum Contact Bounce Measurement	60 microseconds
Pre-Insertion Resistor Value Range	10 - 300 Ohms or 200 - 500 Ohms
Resistor Value Measurement Accuracy	± 10%
Capacitance Measurement Range and Accuracy	75 to 10,000 pF in the range of ± 5%

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## Event Module

Table H.3 lists the characteristics of the Event module.

**Table H.3 Event Module**

<b>Characteristic</b>	<b>Description</b>
<i>Analog Channels</i>	
Number of Channels	3 per module
Sampling Frequency	10 kHz
Voltage Measurement Range	$\pm 300$ DC/AC peak
Analog Signal Bandwidth	DC to 5 kHz
Amplitude Accuracy	$\pm 0.5\%$ of full scale, $\pm 0.5\%$ of reading ( $\pm 0.5\%$ of full scale, $\pm 1.5\%$ of reading for the $\pm 300$ V range)
Current Ranges	0 - 20 A, 0 - 200 A (Probe)
Isolation Voltage to Ground	300 V
<i>Auxiliary Contact Channels</i>	
Number of Auxiliary Contact Channels	3
Sense	Open Wet/Open Dry/Close
Wetting Voltage	28 VDC
Voltage Input	0 - 300 VDC

## System Module

The System module is comprised of several components whose specifications are given in the following tables.

Table H.4 lists the characteristics of the Trip/Close module.

**Table H.4 Trip/Close Module**

Characteristic	Description	
	Trip	Close
Peak Voltage	300 VDC	
Maximum Current Non-Repetitive	100 ADC, pulse	20 ADC, pulse
Maximum Turn On/Off Time	10 $\mu$ sec.	

Table H.5 list the characteristics of the Trigger In function.

**Table H.5 Trigger In**

Characteristic	Description
Sense	Open Wet, Open Dry, Close
Wetting Voltage	28 VDC
Voltage Input	0 - 600 VDC

Table H.6 list the signal characteristics of the System module.

**Table H.6 System Module Signal Characteristics**

<b>Characteristic</b>	<b>Description</b>
<i>Trip/Close Command</i>	
Pulse Width	8.0 to 1600 msec. / 0.5 to 96 cycles
Resolution	0.1 msec / 0.1 cycle
Trip Command Current Range	2/5/20/100 A
Close Command Current Range	0.2/1/5/20 A
<i>Delay</i>	
Duration	0 - 1600 msec/ 0 - 96 cycles
Resolution	0.1 msec / 0.1 cycle
<i>Recording Length</i>	
Circuit Breaker	1.6 seconds

## Physical Specifications

Table H.7 lists TDR9000 physical specifications.

**Table H.7 TDR9000™ Physical**

<b>Characteristic</b>	<b>Description</b>
Enclosure	High impact, molded, flame retardant ABS. Meets National Safe Transit Association testing specification No. 1A for immunity to severe shock and vibration.
Dimensions	10.0" H x 16.0" W x 15.5" D (25.4cm x 40.6cm x 39.4cm)
Maximum Weight	30 lbs.(13.6 kg) - includes cover, printer and maximum configuration
Supply Voltage	100 - 240 VAC 50/60 Hz
Electrostatic Discharge Immunity	Meets IEC 1000-4-2 Level 4 (formerly IEC 801-2)
Surge Withstand Capability	Meets ANSI C37.90 1989 ESD

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## Environmental Specifications

Table H.8 lists TDR9000 environmental specifications.

**Table H.8 TDR9000™ Environmental**

<b>Characteristic</b>	<b>Description</b>
Storage Temperature Range	-25° C to +70° C
Operating Temperature Range	0° C to +50° C
Storage Humidity	95%, non-condensing

# Appendix I. Application Notes

This appendix contains the application notes relevant to operating the TDR9000 and the TR3190.

These include:

- AN2: TR3190 Digital, Linear/Rotary Motion Transducer
- AN3: TR3190 Mechanical Interfaces and Other Transducers
- AN4: TDR9000 Contact Dynamics Resistor Measurement
- AN6: Velocity Measurements
- AN7: Monitoring Closing Coil Current with the TDR90000 Current Shunt in the Close Circuit
- AN8: Simultaneous Energization of Two Sets of Trip Coils in a Single Circuit Breaker
- AN9: Use of the Auxiliary Wet/Dry Contact Monitor
- AN10: Contact Sensing and Test Lead Connections
- AN11: Sampling Rates
- AN13: Safety Grounds, Close Connected Transformers and the Use of the TDR9000 OCB/Dead Tank Contact Monitors

## AN2: TR3190™ Digital, Linear/Rotary Motion Transducer

The TR3190 transducer is used to measure the position and velocity of the operating mechanism of a circuit breaker.

This transducer consists of a reference disk of known diameter, which is directly coupled to an optical shaft encoder. When the breaker operates, it displaces a rod, whose motion is transmitted through a high pressure friction drive to the circumference of the reference disk. The angular displacement of the disk is proportional to the linear travel of the rod, and is encoded by the optical shaft encoder.

With the addition of the rotary adapter, the rotary motion of a shaft in a circuit breaker can be coupled to the transducer and a measurement of angular displacement and angular velocity is obtainable.

The optical encoder translates the rotation of a shaft into interruptions of a light beam. The light source, a light emitting diode, is collimated by a molded lens into a parallel beam of light. The light beam is interrupted by a code wheel comprised of a metal disk with equally positioned apertures around its periphery.

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A matching set of apertures are located in a fixed plate. The light beam is transmitted only when the apertures are aligned, which produces a light pulse for each aperture. A molded lens beneath the base plate collects the modulated light and directs it to a detector.

There are two identical channels. Each channel consists of two photodiodes, an amplifier, a comparator, and output buffers. The apertures for the two photodiodes are positioned so that a light period on one detector corresponds to a dark period on the other. The photodiode signals are amplified and fed to the comparator whose output changes state when the difference of the two currents changes sign. The second channel has a similar configuration, but the location of its aperture pair provides an output which is in quadrature to the first channel (phase difference of 90 degrees). The direction of rotation is determined by observing which of the two channels is the leading wave form. The number of pulses encodes the angular displacement of the disk. This pulse train is converted to a number which is stored in memory at a regular interval. This interval produces a time reference which is used to plot displacement per unit time, or instantaneous velocity. The motion plot is produced by plotting the sum of the displacement data vs. time. The delta displacement for each sample interval represents the total displacement which has occurred during the sample interval. Therefore, this data can be translated directly into velocity, which is then plotted for each time interval.

There are a number of different ways the TR3190 Motion Transducer can be interfaced with a breaker. For applications where part of the accessible breaker mechanism exhibits linear motion, the following method may be employed:

The transducer is designed to couple to a 1/4" Mild Steel connecting rod, which must be  $0.250" \pm 0.010"$  and free from nicks or burrs. Select a point on the breaker mechanism, as close to the contacts as possible, that exhibits linear motion in one plane. The top of the lift rod on most Dead Tank oil breakers is provided with a #10 x 24 threaded hole for this application. This threaded hole is typically accessible through a small hole located under the cap for the stop adjustment on the center tank. If this attachment point is not provided, it is still possible to attach a rod to other points on the breaker. For instance, it is often possible to access the lift rod in the cabinet of the breaker. A collar could be fabricated which attaches around the lift rod, and provides a place to attach the 1/4" connecting rod. The transducer connecting rod will accommodate  $15^\circ$  of angular displacement. This displacement must be in a plane parallel with the

front surface of the transducer. The degree of freedom can be ascertained by placing the rod in the transducer, closing the latch, and then moving the rod back and forth. Observe the motion of the pressure rollers. By using this feature, it is possible to attach the transducer to a point which moves in more than one plane as the breaker operates. In many breaker mechanisms, there are bell cranks which transmit the motion of the prime mover to the contacts. Using a suitable flexible coupling for attaching the connecting rod to a bell crank provides a good representation of contact motion.

Once the attachment point for the connecting rod has been determined, the next step is to provide a suitable mount for the transducer. This mount should be rigid and hold the transducer perpendicular to the line of motion of the connecting rod. In many oil breakers, the cap which covers the access hole is a pipe cap, approximately 2" in diameter. Determine the pipe size of the cap. Obtain a pipe coupling, short pipe nipple, and a floor flange to assemble a simple but reliable/rugged circuit breaker mounting adapter. The pipe coupling -short nipple -floor flange assembly is screwed on in place of the cap. After this adapter is screwed on to the breaker, the connecting rod is then installed, and the transducer is clamped to the floor flange with C-clamps. If this approach is not possible, other fasteners on the breaker can be used, or suitable fixtures can be fabricated which clamp to the structure of the breaker. Remember that the data generated by the transducer is distorted by any motion of the mounting setup during circuit breaker operation.

There are several features of the transducer which are used to alleviate difficult mounting problems. The base plate of the transducer is detached by removing the four flat head screws visible on the bottom of the device. Other mounting plates can be fabricated to meet special needs, or the transducer can be used without the mounting plate. There are threaded holes on the bottom and front surface of the transducer which are used to secure the transducer to special mounting fixtures. When using this method take care to ensure the screws that are used are of correct length; screws that are longer than necessary may damage the internal mechanism of the transducer. The transducer can be mounted with either its top or bottom facing the breaker. Avoid applying clamping forces to the housing of the transducer, as it is possible to distort the housing and cause loss of accuracy.

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The rotary motion adapter is used to interface to circuit breakers in which the mechanism moves in a rotary manner, or to couple to a part of a breaker mechanism which moves in an arc. In the case of a breaker which exhibits rotary motion, observe the mechanism and identify the shaft to be monitored. The rotary motion adapter of the transducer must be attached to the end of this shaft. The adapter is provided with a drill chuck which accommodates up to a 3/8" diameter shaft. The shaft in the breaker can be provided with a threaded hole for a suitable adapter. If this is not the case, an adapter with a 3/8" extension for the chuck collar can be fabricated. This collar slips over the end of the shaft and is retained by a set screw. If this is not possible, the chuck is removed from the rotary motion adapter and other fixtures are installed in its place.

The transducer supports itself on the end of the rotary motion shaft, however, a means of preventing rotation of the transducer during circuit breaker operation must be provided. To do this, a length of 2" x 2" angle is clamped to the transducer and to a suitable part of the circuit breaker structure. Care should be used to minimize the free motion in this setup, as it causes errors in the recorded data. The base plate of the transducer is removed to provide more clearance. When this is done, the angle stock is screwed to the transducer using the base plate mounting holes.

A sensing switch on the transducer determines if a rotary adapter is in use before the test begins. The software then checks to ensure that the Breaker Test Plan Motion Channels are properly configured. The actual units in use for the test results are dictated by the entries into the Breaker Test Plan.

If a breaker has no location where there is a rotating shaft, or no point where a linear motion can be monitored, there could be a location where there is a component which moves through an arc. In this case, a small rod (approximately 1/4") is attached to the breaker mechanism with a swivel joint and to a similar length crank arm mounted in the chuck of the Rotary adapter. In this way the rotation of this shaft is translated and measured.

Some points to consider when designing mounting fixtures for the transducer:

- The fixture should be as rigid as possible, as any motion between the fixture and the breaker appears as an error in the results. This is particularly noticeable if the fixture shakes when the breaker strikes the stop at the end of its travel. This creates the appearance of faulty damping when none exists.
- Be careful in the design of fixtures and devices applied to the moving parts of the breaker mechanism to ensure no interference occurs when the breaker operates.
- Large forces are generated when a breaker is operated; do not stand in line with the motion of the connecting rod or allow loose parts near the transducer.

## Specifications

The TR3190 Motion Transducer is designed for interfacing to circuit breakers measuring the motion and velocity of the operating mechanism, and particularly the movement of the contacts. Table I.1 lists its specifications.

### NOTE



In Table I.1, “g” refers to gravities.

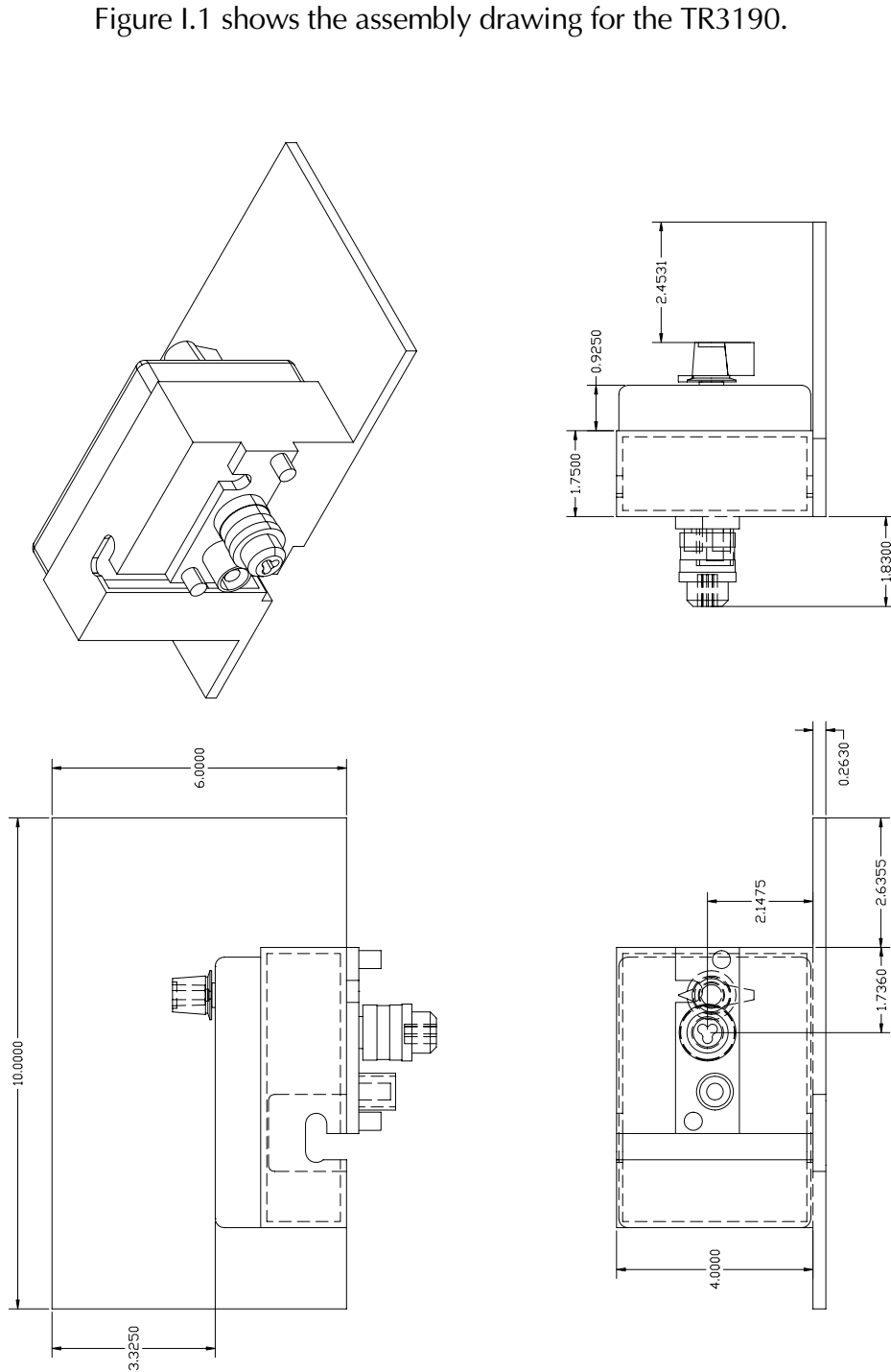
**Table I.1 TR3190™ Specifications**

Specification		Values
Range of measurement	Linear motion	0.0" - 40.0"
	Rotary motion	0.00° - 2880°
Velocity	Linear motion	50.0 ft./sec (maximum)
	Rotary motion	120 rev/sec (maximum) 43200°/sec (maximum)
Acceleration	Linear	100g 400g for 50 μsec
	Rotary	125,000 Rad./sec <sup>2</sup> 7.162 x 10 <sup>6</sup> °/sec <sup>2</sup>

**Table I.1 TR3190™ Specifications (Continued)**

Specification		Values
Displacement	Accuracy	± 0.1% of measured value or ± 0.1" (whichever is smaller) ± 0.1% of measured value or ± 0.1° (whichever is smaller)
	Resolution/Linear	0.002"
	Resolution/Angular	0.1°
Environmental	Temperature/Storage	– 55 °C to 70 °C
	Temperature/Operating	– 40 °C to 50 °C
	Acceleration and Vibration/Transporting	ASTM D 999-75 (repetitive shock test)
	Acceleration and Vibration/Operating	Vibration 2 g, sinusoidal; 5 to 500 Hz Shock 20 g
	Humidity	95% noncondensing atmosphere
	Contaminates/Transformer Oil	Accuracy is unaffected by oil adhering to the connecting rod
	Contaminates/Soil	Accuracy is unaffected by dirt adhering to the connecting rod
Mechanical	Dimensions	Transducer App. 4.0" x 6.0" x 4.0" See Doble drawing # 76D-0195
	Mounting	Clamping plate 6.0" x 10.0" See Doble drawing # 2FC-1905
	Breaker Interface/Linear	Standard Doble 1/4" Connecting rod: maximum stroke length: 40"
	Breaker Interface/Rotary Adapter	Equipped with 3/8" x 18" threaded shaft, with Jacobs Chuck; other shaft adapters may be fabricated for mounting to the threaded shaft, as required
	Interface to TR3100	Doble P/N 181-0107 (50' cable)

TR3190 Rotary Motion



**Figure I.1 TR3190™ Linear Motion with Rotary Chuck Attached**

Also available is the TR3170 Transducer (Figure I.2), a scaled-down version of the TR3190 Transducer, which is designed for linear use only.

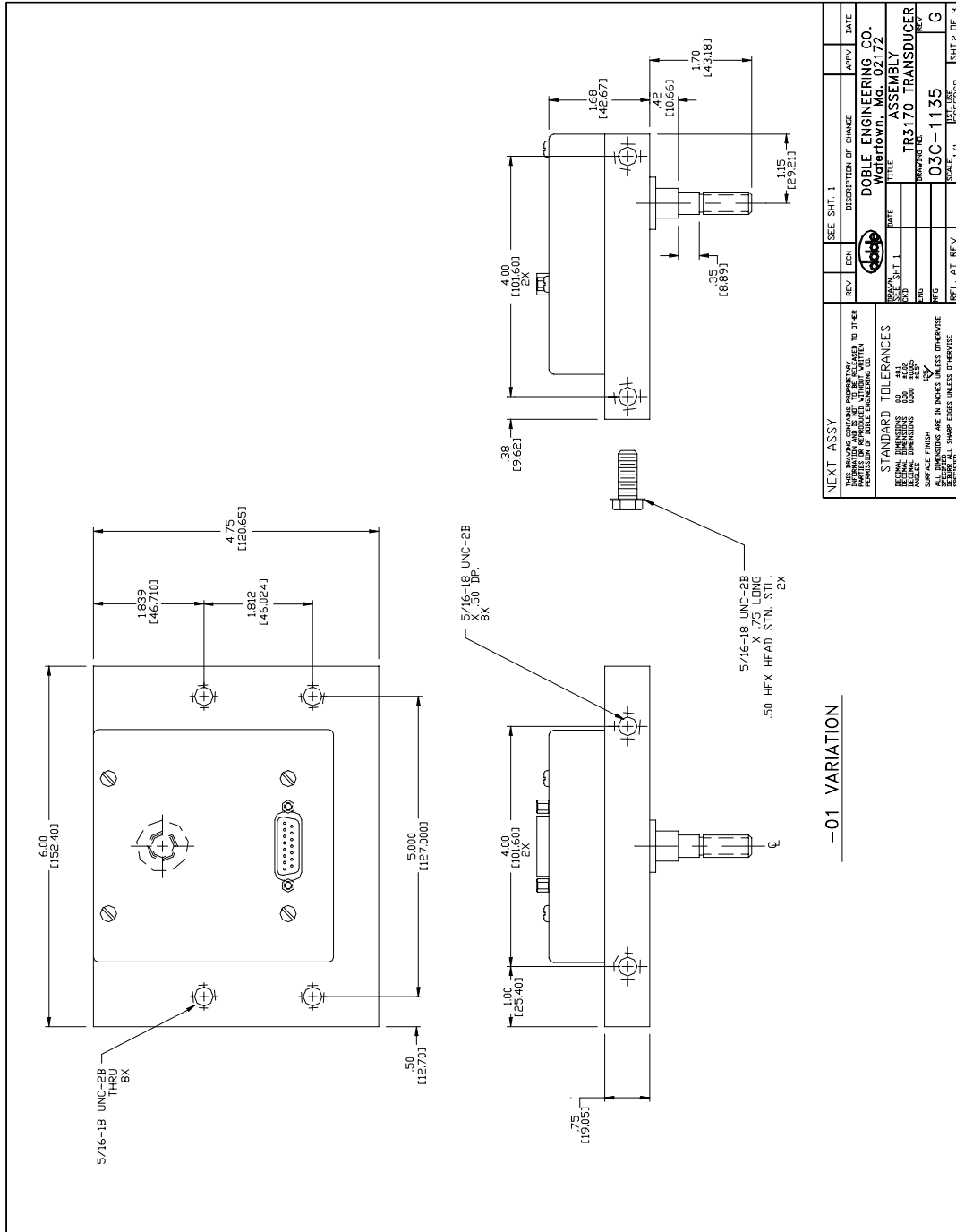


Figure I.2 TR3170™ Linear Transducer

## AN3: TR3190™ Mechanical Interfaces and Other Transducers

Measuring the mechanical displacement and velocity of circuit breaker mechanisms vs. time and contact operation is an important analytical method.

Many utilities use simple, mechanical *Tom Edison Toys* which only measure mechanical displacement vs. time as their primary breaker timing tool. Many years of TR1 and TR2 experience have taught us much about mechanical measurements using the MY transducer, including how to successfully interface the transducer to breaker mechanisms. Although it is straightforward, it is not quite so simple as it appears. High acceleration requires interfaces and transducers with low mass, so as not to affect the measurements. High shock loads at the limits of travel require rugged interfaces so they don't fall apart, or impart false movement due to their mechanical instability. High resolution and accuracy are required; none of these characteristics are commercially available, so the TR3190 was born.

"AN2: TR3190™ Digital, Linear/Rotary Motion Transducer" on page I-1 describes the design of the TR3190 Digital, Rotary/Linear Transducer in detail and provides insight into the design of adapters/interfaces. It is Doble's policy to develop both rotary and linear motion mechanical interfaces for the TR3190.

Over the years the client users of TR1/TR2 have also developed interfaces and documented many of them. The SFA interface has been developed because the OEM slide wire adapters supplied by Westinghouse to provide electrical measurements of motion are no longer available.

### NOTE



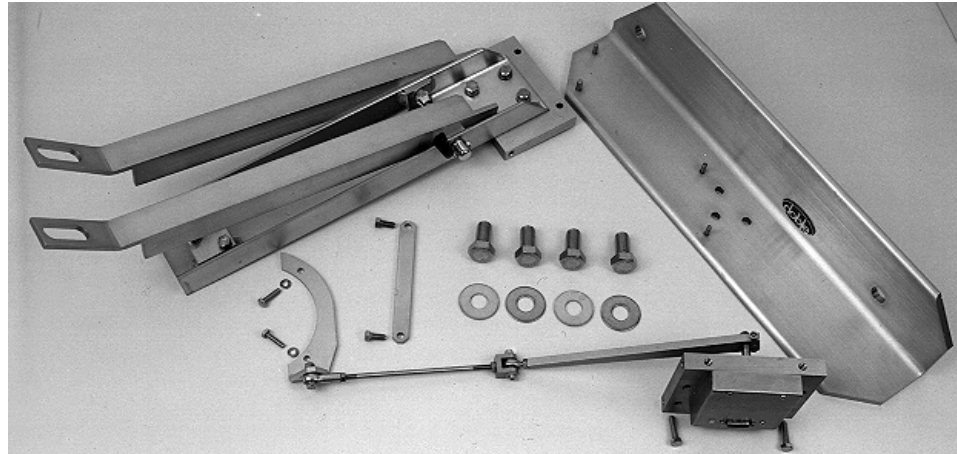
**The T3 Input Expander was an auxiliary instrument designed to interface between Westinghouse SFA slide wires and TR2/PR2, and to interface to additional MV Transducers for measuring a total of three mechanisms, simultaneously.**

Photographs of the interface connected to an SFA breaker module, a sketch of the interface form part of this design, will be provided on request.

Other additions include the TR3170 Rotary Transducer and the TR3171 AHMA-4/8 Transducer. The TR3171 Transducer is used on any circuit breaker that uses the AB AHMA-4/8 operator. This includes ABB Type PA circuit breakers, certain ELF circuit breakers and PM circuit breakers where the voltage class is 345 kV and above.

## Adapters and Transducers

Figure I.3 shows the SFA Adapter, with the motion lever arms mounted on the TR3170 Transducer, and the hardware supplied with the SFA Adapter.



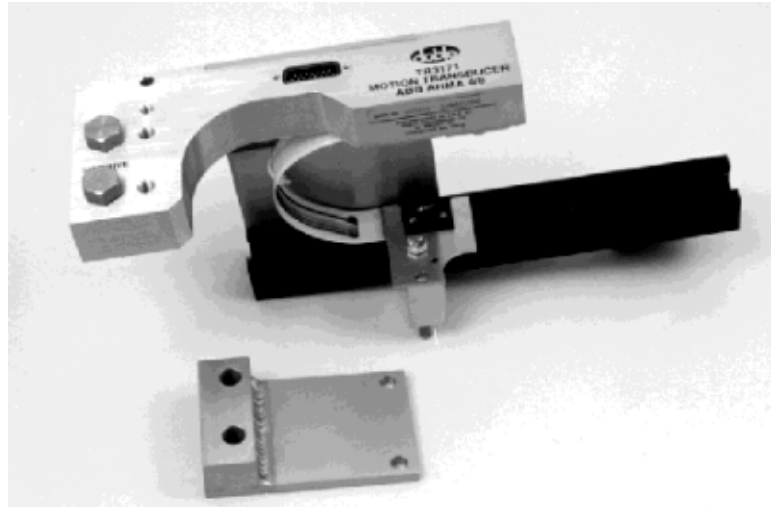
**Figure I.3 Westinghouse SFA SF6 Gas Circuit Breaker**

Figure I.4 shows the Doble ABB AHMA 4/8 Transducer for use with the ABB SF6 Gas circuit breakers using the AHMA 4 or AHMA 8 operating mechanism. This is shown with the drive fork and the gauge block stored on the transducer using the same bolts used during testing.



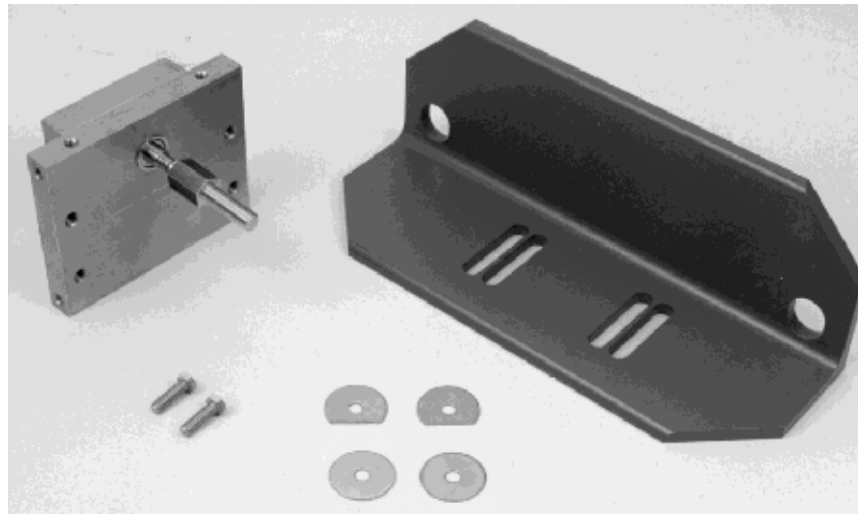
**Figure I.4 ABB PA, ELF, and PM (345 kV and above) SF6 Gas Circuit Breakers**

Figure I.5 shows the Doble ABB AHMA 4/8 Transducer for use with ABB SF6 Gas circuit breakers using the AHMA 4 or AHMA 8 operating mechanism. It is shown with the drive fork engaging the optical encoder assembly and the gauge block in front of the transducer. The gauge block is used to insure the coupler block is in the same plane as the surface to which the transducer is attached.



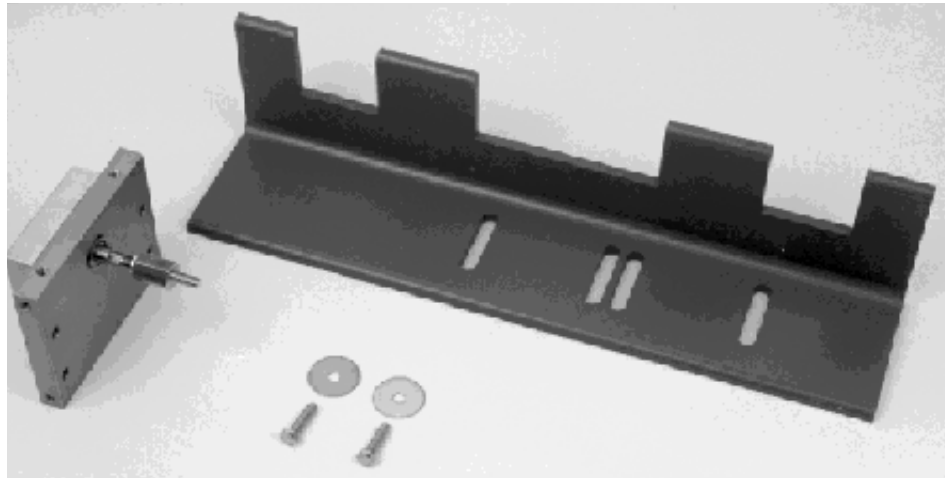
**Figure I.5 ABB PA, ELF, and PM (345 kV and above)  
SF6 Gas Circuit Breakers**

Figure I.6 shows an adapter/transducer combination that measures travel at the base of the insulator column. A hex adapter (3/8" - 24 to 12 mm) is mounted on the TR3170 rotary transducer and is attached to the rotating element of the phase. The disc that drives the semaphore remains with the rotary element. The transducer support plate is then attached to the transducer using 5/16" bolts. The transducer or transducer support plate assembly is then bolted to the aluminum casing at the base of the insulator using 8 mm x 25 mm bolts in the tapped holes used for screwing the cover on.



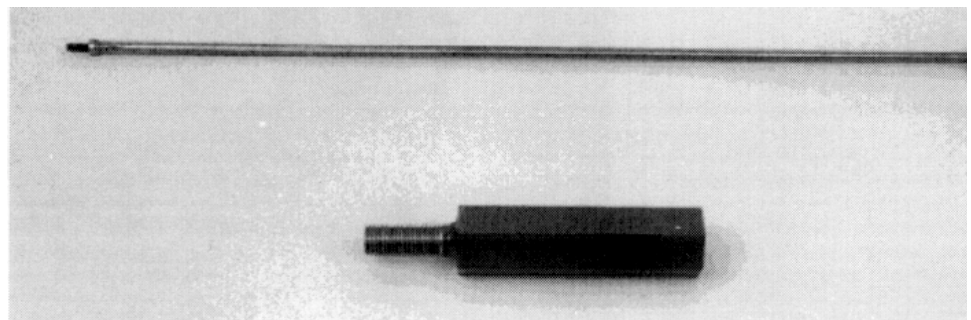
**Figure I.6 ABB HPL SF6 Gas Circuit Breaker – Insulator Column**

Figure I.7 shows a adapter/transducer combination that measures travel at the chain sprocket in the mechanism cabinet. A hex adapter (3/8" - 24 to 8mm) is mounted on the TR3170 rotary transducer and is attached to the rotating element in the cabinet. The transducer hex adapter is attached to the rotating mechanism and then to the support plate. The support plate is clamped to the structural plate in the cabinet using C-clamps.



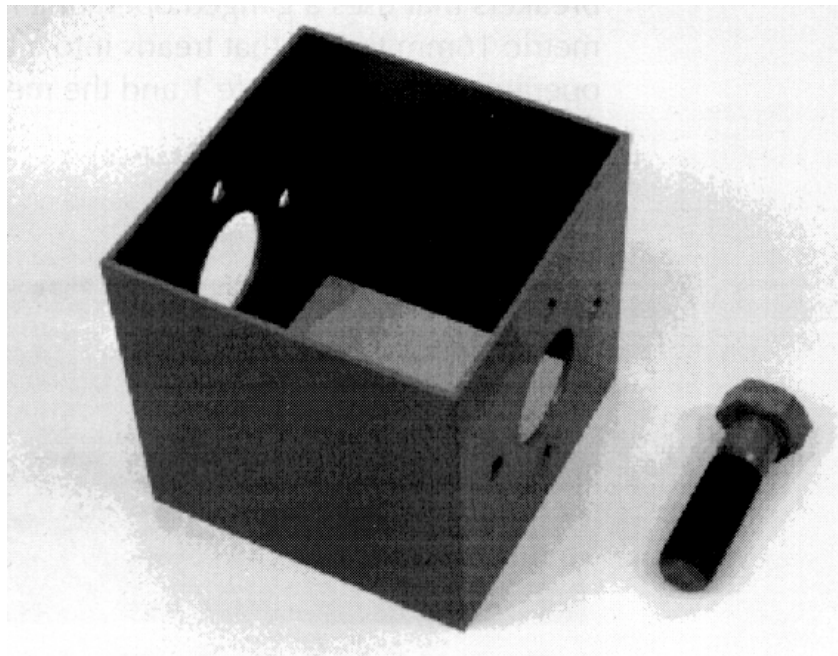
**Figure I.7 ABB HPL SF6 Gas Circuit Breaker – Chain Sprocket**

Figure I.8 shows an adapter for use with the HVB SF6 Gas circuit breakers that uses a ganged operating mechanism. The adapter has a metric 16mm thread that threads into a tapped hole on the horizontal operator adjacent to pole 1 and the mechanism cabinet. This is shown with a 24" travel rod.



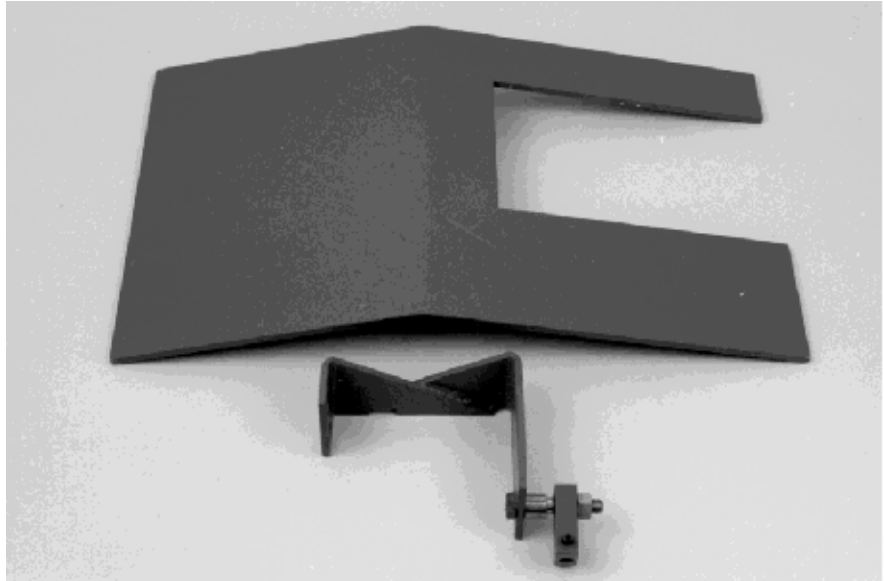
**Figure I.8 HVB SF6 Gas Circuit Breakers with Ganged Operating Mechanisms**

Figure I.9 shows an adapter for use with HVB SF6 Gas circuit breakers that uses an individual mechanism for each pole. A plate is removed from each pole, the large metric bolt is threaded into the moving element, and the spacer is attached to the point from which the plate was removed using existing hardware. The travel rod is inserted through the large holes in the spacer and is threaded into a tapped hole in the top of the large metric bolt. The transducer is then centered on the travel rod and clamped to the spacer.

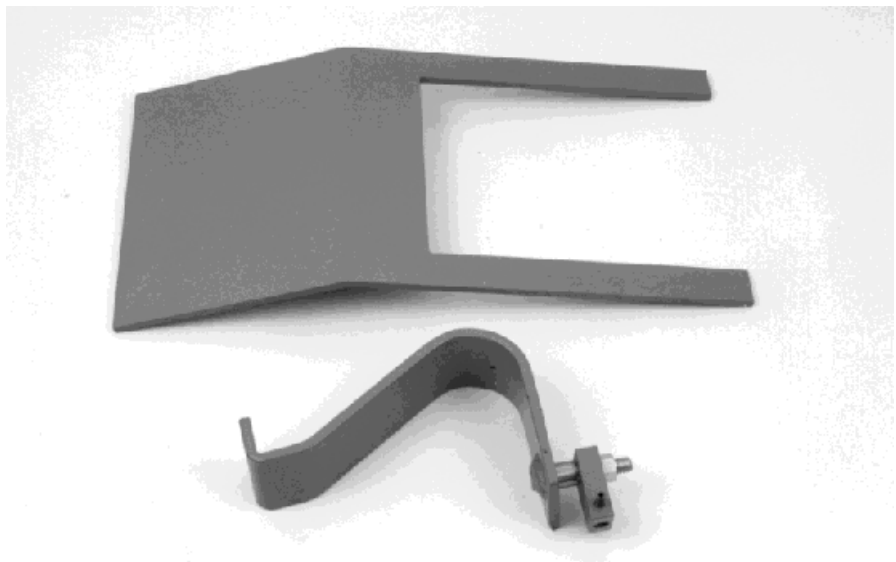


***Figure I.9 HVB SF6 Gas Circuit Breakers with Independent Pole Operating Mechanisms (IPO)***

Figure I.10 on page I-15 shows an adapter that mounts on the moving contact assembly using existing hardware. The plate is clamped to the top of the circuit breaker with the forked arms extending beyond the bushing. The transducer is clamped to the support plate. The plate is bent at the proper angle to ensure the travel rod does not touch the transducer case during circuit breaker operation. Figure I.11 shows this adapter for the 2000 Amp and above range.

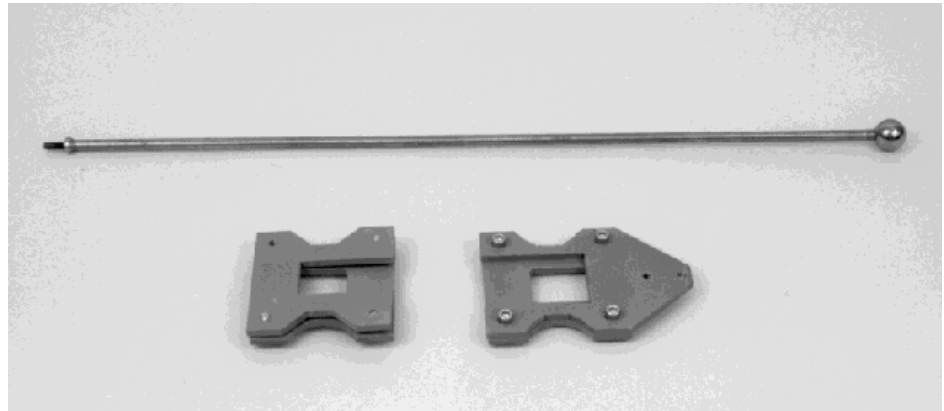


***Figure I.10 General Electric Metalclad Air Magnetic Circuit Breakers  
(600 and 1200)***



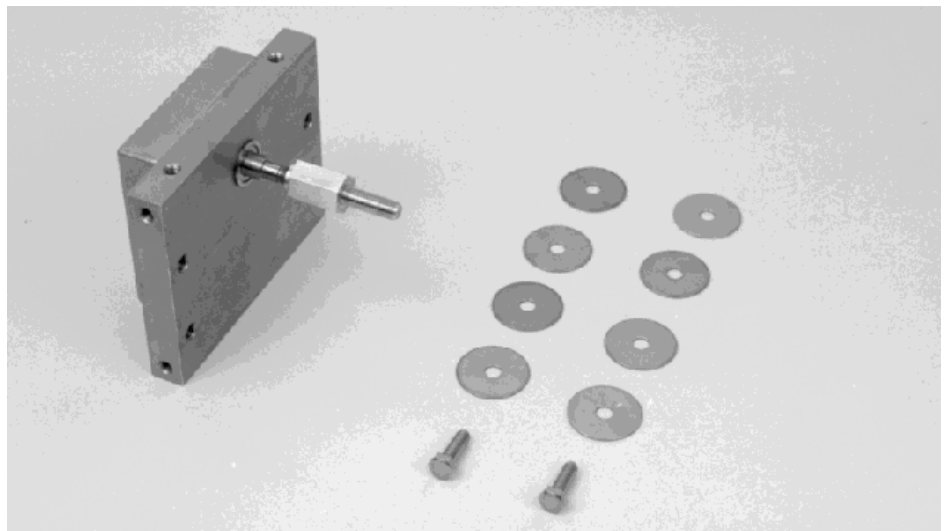
***Figure I.11 General Electric Metalclad Air Magnetic Circuit Breakers  
(2000 A and above)***

Figure I.12 shows the adapter for the VBI with the ML-18 operator (left) and the VBI with the ML-17 operator (right). These adapters mount on the vacuum bottle erosion ring and allow travel measurements to be made on the circuit breaker contacts.



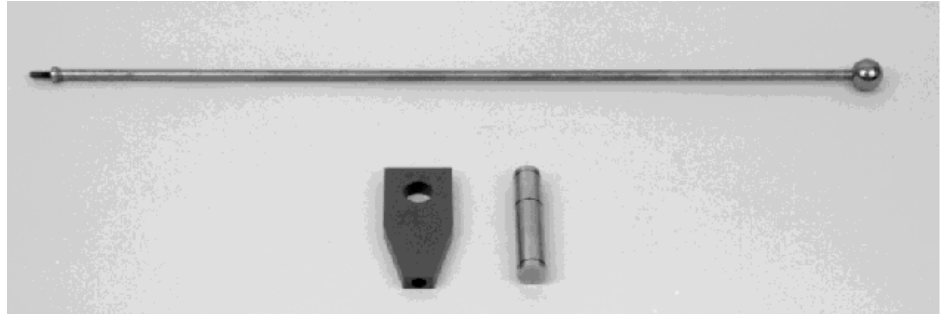
**Figure I.12 General Electric Metalclad VBI Vacuum Circuit Breaker**

Figure I.13 shows an adapter/transducer combination that measures travel at the bellcrank assembly where operating rod travel perpendicular to contact travel is changed to travel parallel to interrupter travel. A hex adapter (3/8" - 24 to 10 mm) is mounted on the TR3170 rotary transducer and is attached to the rotating element of the phase. The transducer is then secured to the cast aluminum casing that surrounds the moving elements with 5/16" bolts and several 5/16" fender washers.



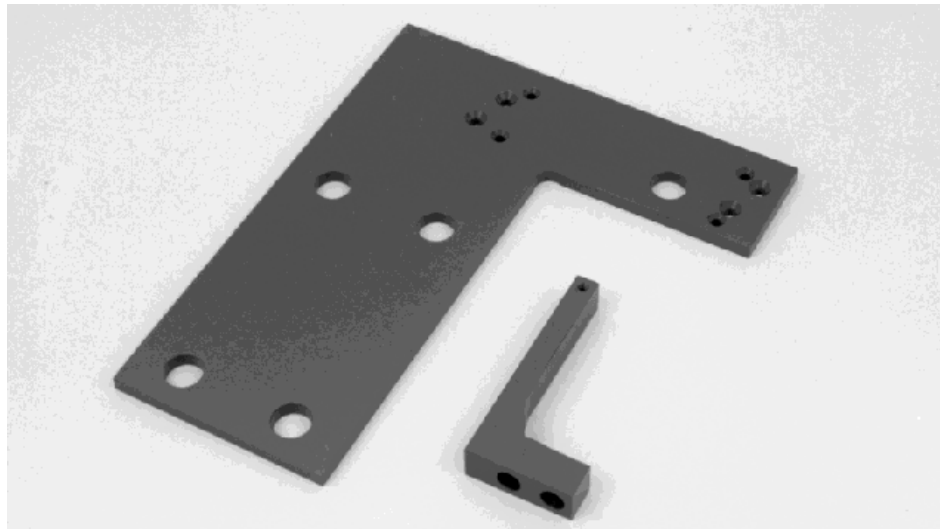
**Figure I.13 GEC Alsthom HGF Series SF6 Gas Circuit Breakers**

Figure I.14 shows the extended pin that replaces the normal drive pin. A tab slips over the pin extension and the transducer rod is threaded into a tapped hole in the tab. The transducer is clamped to the mechanism cabinet.



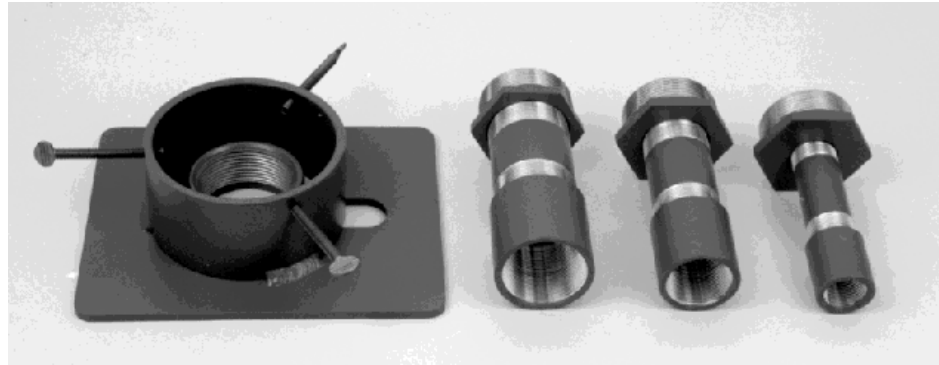
**Figure I.14 Mitsubishi Electric Power Products 100 SFMT SF6 Gas Circuit Breakers**

Figure I.15 shows the large L shaped plate that replaces the standard bottom plate on the TR3160 Transducer using the hardware that secures the standard base plate to the transducer body. The small L shaped bracket is attached to the moving element of the circuit breaker mechanism using metric cap screws. A shortened transducer rod completes the installation.



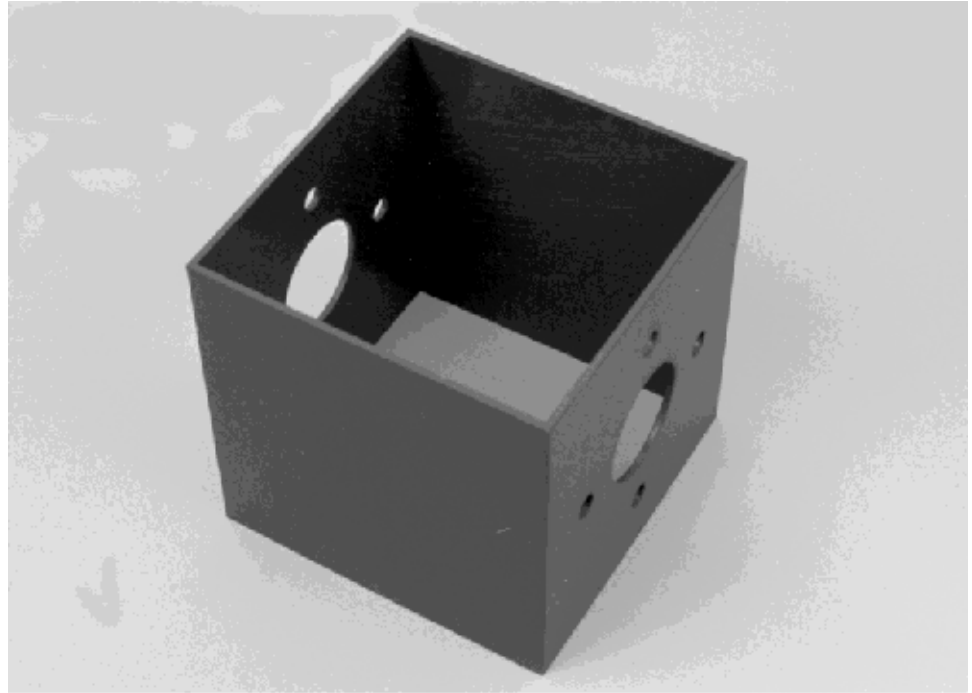
**Figure I.15 Mitsubishi Electric Power Products SFMT SF6 Gas Circuit Breakers**

Figure I.16 shows a general purpose adapter, with reducers and spacers, to allow mounting of various size circuit breaker fittings. The reducers and spacers consist of a close nipple, a coupler, and a reducer.



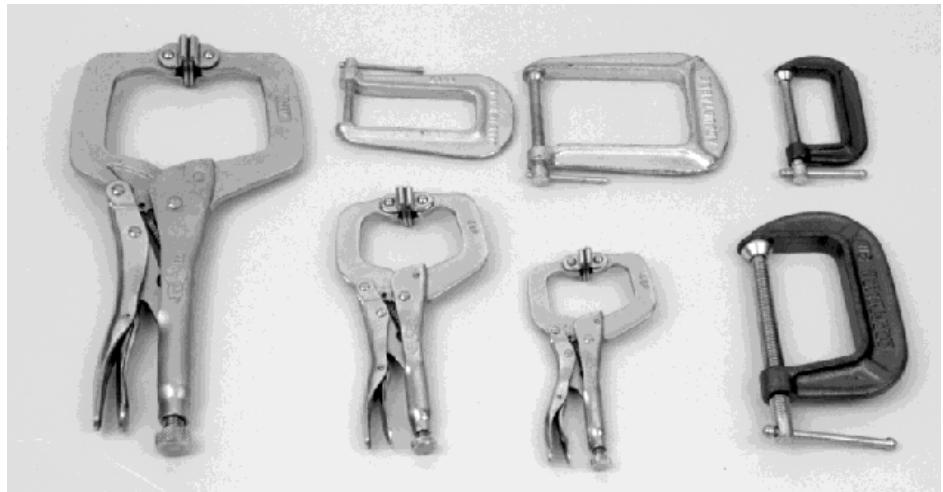
**Figure I.16 General Purpose Adapter**

Figure I.17 shows a general purpose spacer that is used where it is difficult or impossible to mount the transducer directly to the circuit breaker. The spacer is bolted to the circuit breaker using existing bolt holes and the TR3160 Transducer is clamped to the other end of the spacer using C-clamps. A hole through two ends of the spacer is provided for the transducer rod.



**Figure I.17 General Purpose Spacer**

Figure I.18 shows various clamps used to temporarily secure the transducer to a fixture.



**Figure I.18 Various Transducer Clamps**

## Universal Adapter

Measurement of circuit breaker motion can be done by transferring one physical value to another suitable for us by an electronic instrument. This universal adapter for the transducer transfers the rotary or linear motion of circuit breaker part in motion into digital impulses.

To connect the adapter to the moving part of circuit breaker:

**NOTE**



**For some circuit breakers it is very difficult to find a place with the same motion characteristics as main contact in motion. This is particularly true for Live Tank Circuit Breakers.**

**One of possible positions is rotating shaft of the operating mechanism or the shaft at the phase housing. Using the rotary motion at the shaft and the linear motion at circuit breaker main contact, a transition formula can be included in the Breaker Test Plan.**

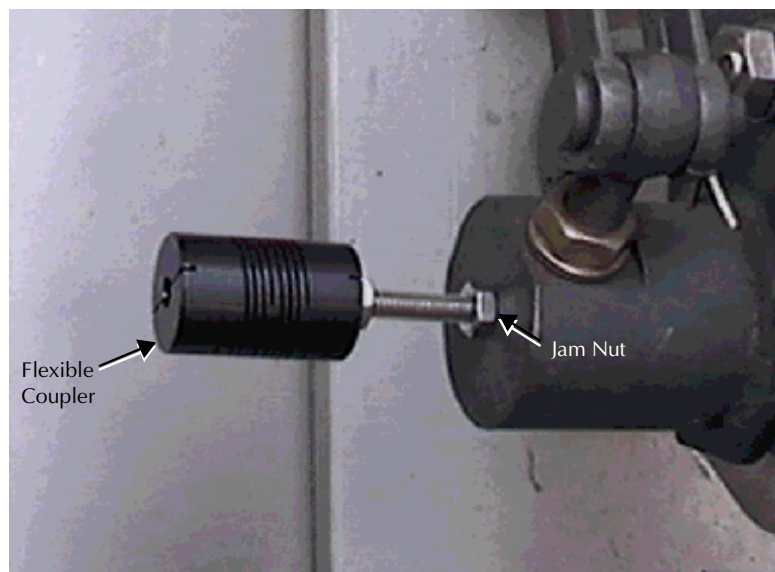
1. Attach the adapter with a C clamp to the fixed circuit breaker or the mechanism part close to the moving shaft.
2. Adjust the moving bars so they can be moved.
3. Connect a threaded shaft 1/4-24 to the rotating circuit breaker shaft.

**NOTE**



**If there is no threaded hole in the shaft – drill and tap a 1/4-24 hole. If there is threaded hole with different thread, make an adapter that accepts the threaded bar.**

4. Tighten with a jam nut, as shown in Figure I.19.



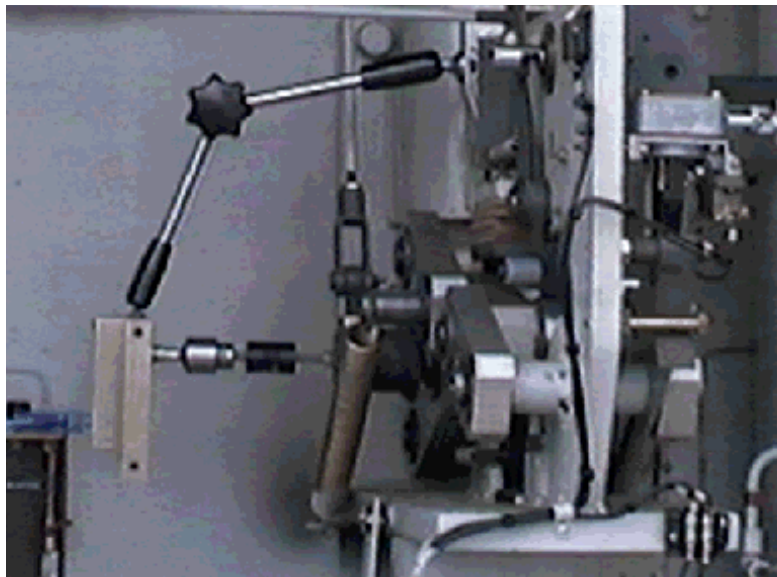
**Figure I.19 Flexible Coupler/Jam Nut**

5. Connect a flexible coupling between the threaded bar and the rotary transducer. This coupling allows axial misalignment and transfers rotary motion.
6. Connect the threaded bar with the flexible coupling and chuck at the rotary transducer and tighten the two set screws.

The transducer with the flexible connector and the circuit breaker's shaft should be in line.

7. Tighten the moving bars.

The completed installation is shown in Figure I.20.



***Figure I.20 Universal Adapter: Finished Installation***

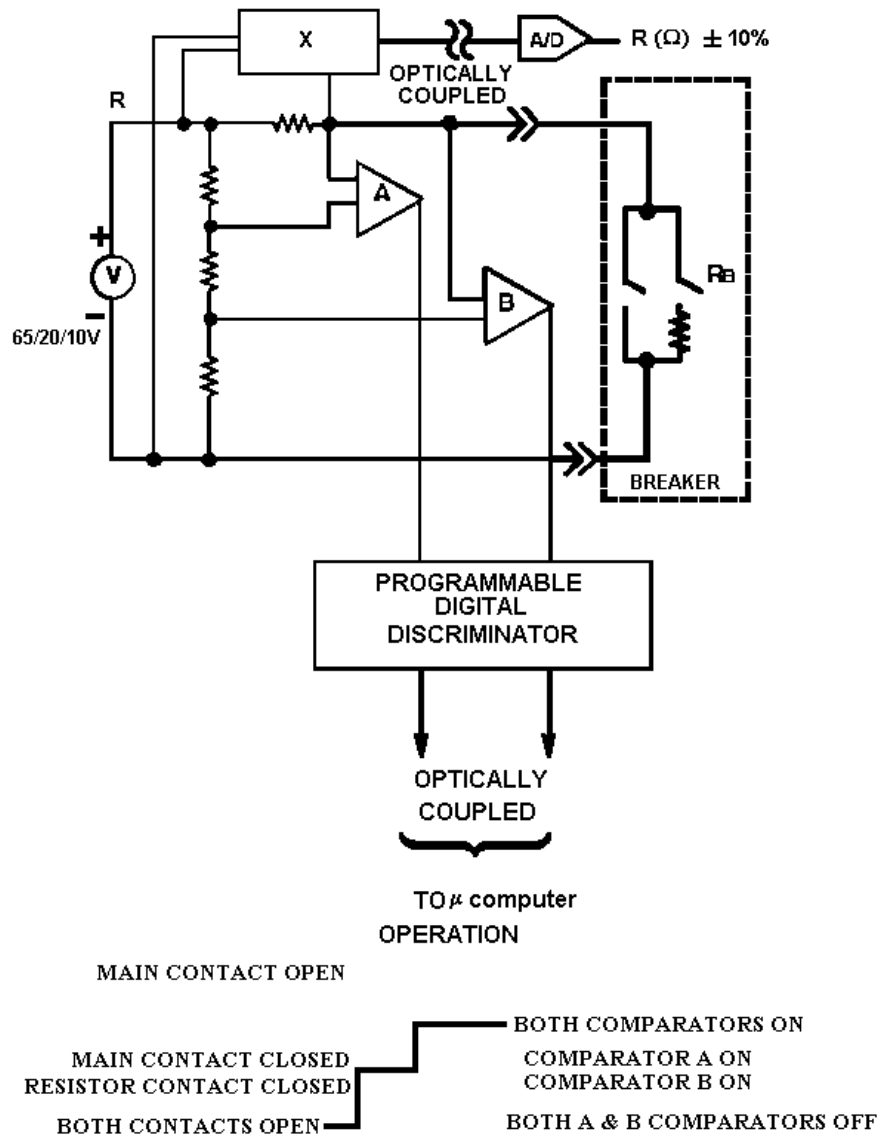
Table I.2 lists specifications for the universal adapter.

**Table I.2 Specifications: Universal Adapter**

Specification	Values
Closing	At normal pressure, the time from energizing of the pilot valve coil to contact touch is 7.0 to 7.25 cycles (117 to 121 ms)
Opening Contact Velocity	The average contact velocity measured between 1" and 2½" from the full closed position is 26 to 30 f/s.
Opening Time	<ul style="list-style-type: none"> <li>• Control voltage at the nominal value</li> <li>• The time from energizing the trip coils to main contact part is 1.30 cycles or less (2 ms)</li> <li>• Contact travel at .5 of a cycle after contact part is a minimum of 3.4" from the fully closed position</li> <li>• The contact travel at .9 of a cycle after contact part is less than 5.3" from the fully closed position</li> </ul>
Close to Open Operation	On a close to open operation the auxiliary switch will energize the trip coil at contact touch ± .15 cycle (2.5 ms)
Synchronizing Time	<ul style="list-style-type: none"> <li>• Maximum spread of the three poles on closing .25 cycles (4 ms)</li> <li>• Maximum spread of the three poles on opening contact part .15 cycles (2.5 ms)</li> </ul>
Crossarm rotation	<ul style="list-style-type: none"> <li>• Angular travel of Crossarm is 35.5°</li> <li>• Crossarm length is 12.75"</li> <li>• Travel measured with Westinghouse adapter is 7.899" (arc length). Travel measured with Doble adapters and transducers according to drawing 03D-1025</li> <li>• Crossarm rotation 35.5°, adapter lever rotates 46°</li> <li>• Angular travel ratio is <math>46/35.5 = 1.296</math>. 30% difference</li> </ul>

## AN4: TDR9000™ Contact and Resistor Measurement Dynamics

Figure I.21 shows a schematic for the TDR9000 contact and resistor measurement.



**Figure I.21 Contact and Resistor Measurement**

Figure I.22 explains contact and resistor timing.

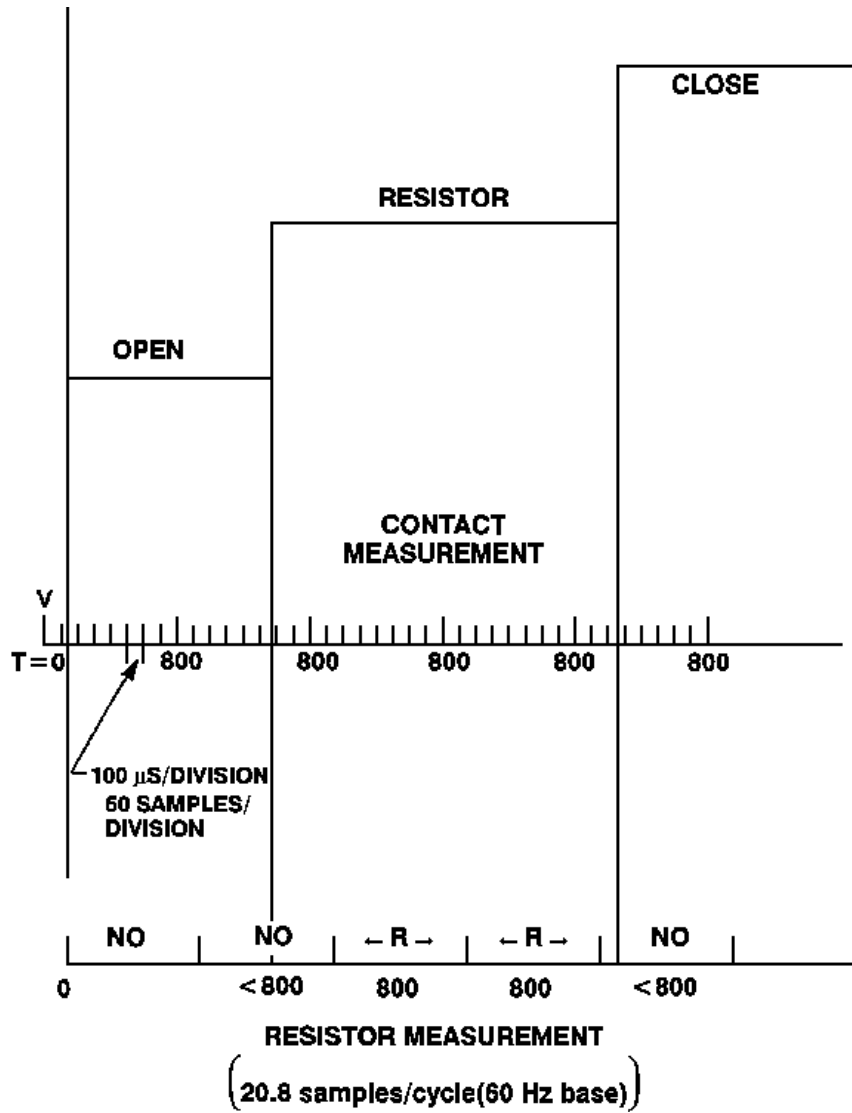


Figure I.22 Contact and Resistor Time Diagram

## AN6: Velocity Measurements

There are four types of velocity measurements made by the TDR9000 during Trip and Close operations. These measurements are tabulated in the Breaker Performance Report and displayed on the graphic trace of circuit breaker operation.

The Average Velocity for Zone 1 and Zone 2 during a Close or Open is calculated as follows:

There are five ways to specify the method for determining the zone in which the average velocity is to be calculated:

- Distance – Distance
- Distance – Time
- Time – Time
- Main Contact Operation – Time (Time before Contact Close and Main Contact Close or Main Contact Open and time after Main Contact Open)
- Main Contact Operation – Distance (Distance before Contact Close and Main Contact Close or Main Contact Open and a Distance after Main Contact part)

For each zone in which a travel velocity is desired, the beginning and ending points of the zone are specified. The reference for all distance measurements is the fully closed position of the circuit breaker, and the displacement value for the fully closed position is zero. When the transducer rod passes the selected beginning point the time is recorded. All subsequent movement of the transducer rod is summed until the transducer reaches the selected end point whose time is also recorded. The sum of these incremental travel distances is the distance the circuit breaker travels and the difference between the two times is the time it took to travel the distance. The distance traveled divided by the time required yields the Average Velocity for the respective zone. This value is printed in the tabulation under Mechanical Motion.

The value for the velocity that is tabulated under OCB or EHV Contact Timing is calculated as follows:

The time and the position of the transducer rod when the contact first makes or breaks is tagged. The position of the transducer rod 500  $\mu$ sec before contact operation and the position of the transducer rod 400  $\mu$ sec after contact operation is also tagged. The turn of the incremental movements of the transducer rod divided by the time (1000  $\mu$ sec) yields the Average Velocity at first contact make or break.

The velocity trace displayed on the graphic output is the printout of the Average Velocity calculated as follows:

The position of the transducer rod at each 100  $\mu$ sec interval from the test initiation is recorded. From this data and the 100  $\mu$ sec time period, the individual Average Velocities are calculated. These Average Velocity points are then printed in the graphical output. The scale for the velocity is printed at the end of the graph.

The velocity that is tabulated is the highest Average Velocity calculated over the 100  $\mu$ sec intervals.

All velocity measurements are directly proportional to either linear or rotary movement of the circuit breaker. If the circuit breaker contact travel is not equal to the transducer rod travel, the Transfer Function provides the correction factor necessary for these measurements. These two values are entered by the user from data provided by the circuit breaker manufacturer and or the user; the default ratio is 1.00 to 1.00.

Displacement values near the beginning or end of travel should be avoided.

During a Trip test the circuit breaker remains closed for several milliseconds after the Trip signal is applied. If zero displacement is selected as the beginning of the zone, the TDR9000 starts timing at test inception and the several milliseconds that the breaker remains fully closed prior to circuit breaker movement are included in the time used for the calculation of Average Velocity for the specified zone.

For Close tests, zero is also the fully closed position of the circuit breaker. If zero is chosen as the end point and the circuit breaker mechanism continues to move for the majority of the Close test, due to the dampener, the time used for the Average Velocity will again be excessively long.

## AN7: Monitoring Closing Coil Current with the TDR9000™ Current Shunt in the Close Circuit

### NOTE



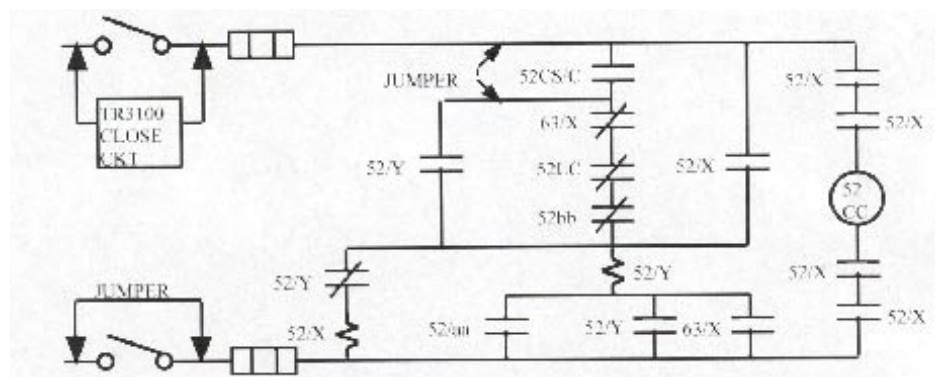
The TDR9000 system uses one set of control leads to control the operation of the circuit breaker and to monitor the Trip or Close current.

**The TDR9000 close current measurement can handle a maximum of 20 A.**

Previous test sets used a relay to initiate the Trip or Close operation. Since the pickup time of the initial relay varies from test to test, a method to mark the time of test initiation was necessary. A second set of leads (sense channel) provided this function and enabled timing from that reference point on the trace. Since the TDR9000 uses its solid-state control circuitry to initiate operational tests, this sense circuit is not necessary. The Trip and Close circuits of the TDR9000 incorporate optional shunts that enable the instrument to monitor and measure Trip and Close currents.

Since most Close tests are initiated with the Close leads bridging a closing contact on a control switch or a push button, the current monitored is the current that is present in the X relay circuit rather than the Closing Coil circuit.

The current in the Close coil circuit can be monitored and measured if a few temporary clip-to-clip jumpers are added (Figure I.23).



**Figure I.23 Jumper Placement**

Open the close circuit knife blades and add the two clip-to-clip jumpers as shown in Figure I.23 on page I-27. With the connection of the Close initiate leads as shown, and the two additional clip-to-clip jumpers, the test set now monitors and measures the current that flows in the closing circuit without disabling any fusing or anti-pump protection.

The Close pulse length should be lengthened from the default value of 133.3 ms to approximately 300 ms to allow the close coil current to be interrupted by the X relay contacts. This is done in the Command Parameter portion of the Breaker Test Plan. If the same circuit is employed for Trip-free, Reclose, or O-C-O tests, then their close pulses should be lengthened accordingly.

The time from Close coil energization to Main Contact closure is determined using the graphical results. The time from test initiation (X relay energization) to Main Contact operation is tabulated and given in the Test Results Report.

## **AN8: Simultaneous Energization of Two Sets of Trip Coils in a Single Circuit Breaker**

Many modern high voltage circuit breakers have two sets of trip coils that may have independent sources of power. To energize both sets of trip coils simultaneously from their respective power sources, without electrically tying the battery banks together, proceed as follows:

1. Connect the pair of trip leads to energize Trip Coil #1 and connect the pair of close leads to energize Trip Coil #2. On the Breaker Test Plan, Command Parameters, Trip-Free Parameters, select a Trip-Free Delay of 0.0 msec.
2. Close the circuit breaker. When the Trip-Free test is initiated, both the Trip and the Close circuits are energized simultaneously.
3. The Trip current for Trip Coil #1 is displayed as Trip Current on the Breaker Performance Report and on the graphical results. Likewise, the Trip Current for Trip Coil #2 is displayed as Close Current on the Breaker Performance Report and on the graphical results.

If the circuit breaker opens, it has passed the test.

### **NOTE**



**The Close Circuit current maximum range is 20 A.**

## AN9: Use of the Auxiliary Wet/Dry Contact Monitor

The Auxiliary Wet/Dry Contact Monitor is used to obtain the times from Close Coil energization to Resistor Switch and Main Contact Closing. The Close Parameters has a Timing Event entry in addition to the Close Pulse duration entry. One of the following channels can be used for the T=O time: the Close circuit current as measured by the current shunt in the TDR9000, a Wet/Dry Contact channel, or a current or voltage channel. The current and voltage channels have an adjustable trigger level that is settable in 10% increments. These increments are a percentage of the selected full scale of the channel. This enables the user to measure the time between the energization of the closing coil and the desired event.

The Instrument monitors three states – Dry Contact Closed, Dry Contact Open, Wet Contact Open. To use this feature, connect the two leads from the Contact Monitoring channel across the circuit breaker's closing coil (observing lead polarity). Select *Analog* as the timing event and enter the channel number in the *Timing Channel*.

Prior to closing coil energization the Instrument considers the closing coil as a Dry Contact Open. When the closing coil is energized, the Instrument considers it a Wet Contact Open.

Using this procedure, the times obtained are compared to the specifications for closing time that were entered in the Breaker Test Plan.

## AN10: Contact Sensing and Test Lead Connections

EHV Main Contact sensing circuitry of the TDR9000 applies a low DC voltage across the common lead at each contact lead. The actual voltage is dependent upon the Resistor Range selected. The EHV Contact Module applies 15 VDC when the 200 Ohm to 500 Ohm range is used and 7.5 VDC when the 100 Ohm to 300 Ohm range is used.

OCB Main Contact sensing circuitry in the TDR9000 applies 20 or 65 Volts DC across the common lead and the three contact leads. The Dead Tank/OCB Contact Module applies 48 VDC when the 300 Ohm to 7,000 Ohm range is used and 15 VDC when the 10 Ohm to 400 Ohm range is used.

The low sensing voltages are used to minimize the amount of cross talk and still maintain an adequate signal to noise ratio in areas where there may be up to 10 mA of interfering noise.

These low sense voltages make good connections a necessity. All places to which the Contact Cables are to be attached must be free of paint or corrosion. Wire brushing the point of connection is advisable. Connections to a hinge pin or similar device must be avoided. The crocodile clip grip should not be loose or wobbly. The weight of the suspended cables must not be supported by the crocodile clips; the contact cable should be draped around a fixed object which supports the weight of the cable.

On circuit breakers that have a very violent mechanical operation, a clamp type connection may be warranted. The crocodile clip is bolted to a metal tab at the cables' end and can be removed to facilitate adding another type of connector to the cables' end.

Table I.3 lists the voltages used for EHV and OCB channels for the TDR9000.

**Table I.3 TDR9000™ Contact Sensing Voltages**

		Low $\Omega$	High $\Omega$	None
TDR9000	EHV	7.5V	15V	15V
	OCB	15V	48V	15V

## AN11: Sampling Rates

The basic concept for digital sampling is that the sampling rate should be faster than the event that being captured. This sample rate captures the event. However, if there is a need to determine the actual length of the event, within 10%, then the sampling rate must be an order of magnitude faster than the event. To detect and determine the length of bounces of 1 msec, with an accuracy of 10%, a sampling rate of 10 kHz (a sample every 100  $\mu$ sec) is necessary.

Sampling rates are a prime consideration in the resolution of motion and velocity. Slower sample rates affect measurements that involve a contact event and motion subsequent to that contact event. Measurement of Contact Wipe can be affected by slow sample rates.

Instantaneous velocity measurements from digital travel transducers are also affected by the sample rate.

Travel and velocity measurements on the new vacuum circuit breakers which have very short travel and high velocities are adversely affected by the slower sampling rates.

In a circuit breaker that has a velocity of 20 ft/sec in the arcing zone, the following calculations are appropriate:

- $20 \text{ ft/sec} \times 12 \text{ in/ft} = 240 \text{ in/sec}$
- or 24 thousandths of an inch every 100  $\mu\text{sec}$ .

For a sampling rate of 10 kHz (one sample every 100  $\mu\text{Sec}$ ) and a Main Contact closing just after the sample period, the Main Contacts travel 0.024" before the next sample period begins.

If the sample rate is 5 kHz (one sample every 200  $\mu\text{Sec}$ ) with a Main Contact closing just after the sample period, the Main Contacts travel 0.048" before the next sample period begins.

If the specified Contact Wipe is 0.5", then an error of 0.048" approaches a 10% error. Although Contact Closure is an asynchronous event with respect to the instruments sample period, higher sampling rates minimize these errors.

## **AN13: Safety Grounds, Close Connected Transformers, and the Use of the TDR9000™ OCB/Dead Tank Contact Monitors**

The power supplies used for the Doble TDR9000 Contact Monitors do not have a ground reference. However, since this is the source of voltage, it is necessary that the common lead of the Contact Monitor cable be connected to the side of the breaker that has the circuit breaker bushings tied together and has the safety ground.

When testing a circuit breaker that is close connected, there is no disconnect switch between the circuit breaker and the transformer, to the Y winding of a transformer whose neutral is grounded or to an Autotransformer. Therefore, the safety ground must be placed between the transformer and the circuit breaker.

In substations where one circuit breaker disconnect switch is adjacent to the circuit breaker to be tested and the other disconnect is physically separated from the circuit breaker, place the safety ground on the poles of the circuit breaker that is farthest from the disconnect switch.



# Index

## A

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