



**ORTMASTER ORTM-4 and ORTM-4H
RECLOSER TEST SET ACCESSORY
INSTRUCTION MANUAL**

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Software Version 20100712

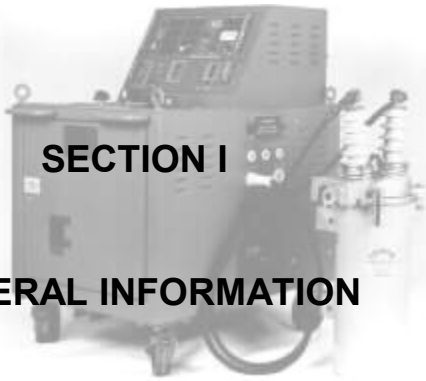
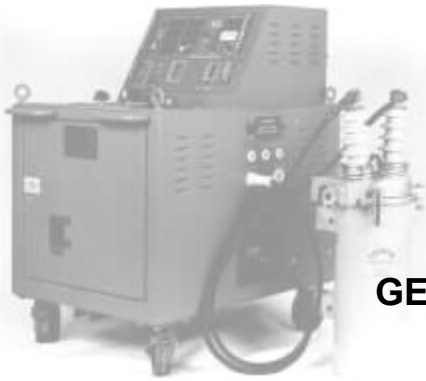
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TABLE OF CONTENTS

SECTION I	GENERAL INFORMATION	
	Introduction	I-1
	General Description	I-2
	Low Voltage Testing	I-3
	Instrumentation	I-4
	How ORTMASTER works	I-4
	Specifications	I-5
SECTION II	DETAILED DESCRIPTION	
	Theory of Operation - Hardware	II-1
	Theory of Operation - Software	II-2
SECTION III	OPERATING INSTRUCTIONS	
	Installation - Hardware	III-1
	Installation - Software	III-3
	Main Form	III-4
	Basic Software	III-5
	Waveform Viewing and Analysis	III-7
	Database and Time-current curves	III-8
	Minimum Pickup Test	III-9
	Full Sequence Test	III-12
	Time-current Curves	III-14
	Test Setup	III-15
	Software Calibration	III-16
	Electrical Testing of Devices	
	Recloser Min. Pick-up Test	III-19
	Recloser Full Sequence Test	III-20
	Vacuum Int. Type Reclosers	III-21
	Pilot-Series Type Reclosers	III-22
	Sectionalizers	III-22
	Low Voltage Circuit Breakers	III-22
	Molded Case Circuit Breakers	III-22
	Motor Overload Relays	III-22
	Other Devices	III-22
SECTION IV	SERVICE INFORMATION AND DOCUMENTATION	
	Preventive Maintenance	IV-1
	Field Calibration	IV-2
	Major Calibration	IV-3
	Troubleshooting Guide	IV-5
	Parts Lists	IV-6
	Overall Schematic	IV-7
	Warranty	IV-8



SECTION I

GENERAL INFORMATION



SECTION I

GENERAL INFORMATION

INTRODUCTION

The P S Technology **Ortmaster ORTM-4** is an electronic current monitoring accessory used in conjunction with an IBM PC compatible computer and any system for primary injection testing of oil and vacuum type reclosers and sectionalizers. It incorporates advanced circuitry and software, which provide an accurate, inexpensive and efficient means for monitoring output current and time for proper testing and calibration. Real time digital waveform recording and analysis provides true RMS (root-mean-square) reading of current, including DC offset and decay, for excellent correlation of results with manufacturers' calibration.

The **Ortmaster** interface module is designed to connect to the output of ANY recloser test set. It interfaces to a USB port of any IBM compatible computer, and a Windows program displays trip current, trip times, and reclose times for up to five recloser operations.

A precision 10 bit A/D converter reads the current flowing through the bus bar or cable connection at the bottom of the rugged steel enclosure, and stores the waveform in memory. A continuous readout of TRUE RMS current is indicated at all times, and accurate readings of time and current for each operation are displayed as they occur.

After the test, one may view and analyze the waveform of each shot, and this waveform can be saved to disk for future reference.

Software is included which uses a database of various recloser types, and can compare readings to manufacturers' data for immediate GO/NOGO verification of test results. Test results can be saved in a dBase III+ compatible database and formatted reports printed.

The **Ortmaster** has been fully tested on an EIL Model ORT-560 recloser test set, and has been proven to provide much better accuracy and consistency, especially on waveforms with moderate to severe current decay. The exclusive software controlled TRUE RMS computation always gives the correct current reading, and properly reads waveforms with DC offset and distortion. This system was designed and tested by Paul E. Schoen, now president of P S Technology. In 1980, he was awarded patent #4,307,345 for the recloser test set originally EIL model ORT-15 and later an improved ORT-560.

GENERAL DESCRIPTION

The P S Technology Ortmaster ORTM-4 is a self-contained unit consisting of:

1. A rugged steel enclosure which may be bolted to the frame of the recloser test set.
2. A high-current capacity shunt for simple connection to the output of the test set.
3. A 120 VAC line cord for connection to a source of power.
4. A USB cable for connection to computer USB port.
5. 4. Internal noise filtering and surge protection.
6. A high current shunt and protection circuitry for reliability and accuracy when measuring currents with DC components.
7. Precision low-noise amplifiers and solid-state range switching.
8. A highly accurate 10 bit analog-to-digital converter.
9. A high-speed serial interface to a standard USB port.
10. Easy-to-use real-time software for accurate current and time measurements.
11. A fused, filtered and grounded convenience outlet for connection of PC compatible computer.

LOW VOLTAGE TESTING

To appreciate how the Ortmaster works, it is important to have an understanding of the effects of low-voltage testing of reclosers. When a fault occurs on a power line protected by a recloser, typically 14.4 KV AC, the impedance of the power line circuit is also fairly high, so that fault currents are in the order of 5 to 20 times continuous rated current. A 100 ampere recloser will typically see a fault current of about 1000 amperes, which translates to an impedance of about 14 ohms.

When a recloser operates, a plunger is drawn into a coil, which causes an increase in impedance. A 100 ampere, type 4E recloser has an impedance change from 0.072 ohms to 0.227 ohms, as the plunger moves inside the coil. In the example given, at high voltage, this change in impedance has minimal effect on the current. Recloser curves assume current flow to remain constant. The impedance change at high voltage has a negligible effect on timing.

Practical test methods for reclosers are limited by reasonable available power, and safe voltage levels. The power involved in this example is 14.4 MVA, which is far beyond available power. Most recloser test sets are 10 to 50 KVA, which limits power available for testing.

The manufacturer recommends a test voltage of 138 VAC for this recloser, for a test current of 800 amps. If a solid 138 VAC is applied to the recloser, it will begin its operation at 1916 amps, which requires over 200 KVA, but will complete its operation at only 608 amps. Obviously, this will make it difficult to measure the current unless a true RMS computation of the entire pulse is utilized.

Most recloser test sets incorporate some sort of resistive compensation, which can limit the current change to about 10-20%, but even this amount of decay can affect the current metering.

INSTRUMENTATION

Several methods of current measurement are utilized by different recloser test sets. Some systems read the current near the beginning of the operation, and others track the current and read it near the end of the operation. However, the recloser operates on the true RMS value of the current over the entire length of the pulse.

For example, assume the recloser is a 100 Amp type L, with a D curve, and current decay of 20%. The expected trip time at 1000 Amps is 0.3163 seconds, but 0.4914 seconds at 800 Amps. The average current is actually about 900 Amps, with an expected trip time of 0.3807 seconds. If the 0.3807 second trip time is compared to the curve at 1000 amps, the time would appear to be about 17% slow. If your test set measures at the end of the operation, reading 800 Amps, the recloser would appear to be about 29% fast. Either reading would appear to be out of tolerance.

HOW ORTMASTER WORKS

The Ortmaster records the entire waveform of each current pulse, by taking 2400 samples per second, or about 40 samples per cycle. After each operation has completed, a true-RMS computation is performed, taking into account any distortion, decay, or DC offset, which directly affect recloser operation and timing. Extensive testing has determined that timing will closely match that which will be produced at high voltages and minimal decay under actual operating conditions.

In addition to its unequalled accuracy of current measurement, the ORTMASTER also excels in timing measurement. At 2400 samples per second, a precision of 0.417 mSec is possible.

The Ortmaster software also has a database of recloser curves and software which can provide go/nogo test results for minimum pickup and full sequence operation, for main phase trip coils as well as ground trip devices.

It also may be interfaced to optional TCC software, which provides a separate means of analyzing test results and printing reports.

SPECIFICATIONS

INPUT POWER

105-130 VAC, Single Phase, 50/60 Hz, 15 VA

OUTPUT and Interface

Standard USB-B port for control and data acquisition.
120 VAC convenience outlet for computer (1.5 A Maximum).

MEASUREMENT SYSTEM

CURRENT INPUT (50% duty cycle, 5 minutes max.):
Shunt, with 1/2"-13 hardware, 1000 Amperes

CURRENT RANGES:
0-50/100/250/500/1K/2.5K/5K/10K Amperes Full Scale

CURRENT ACCURACY (add 1% if not field calibrated):
+/- 1% Full Scale (Continuous)
+/- 2% Full Scale (Pulse)

TIMING:
Range: 0-99.999 seconds
Resolution: 0.0004 seconds
Timebase Accuracy: +/- 0.005% of reading

TIMING ACCURACY:
+/- 0.01 Seconds

DIMENSIONS AND NET WEIGHT

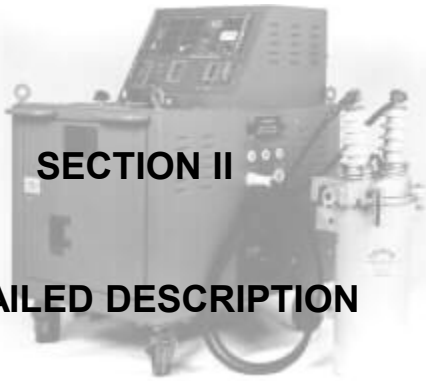
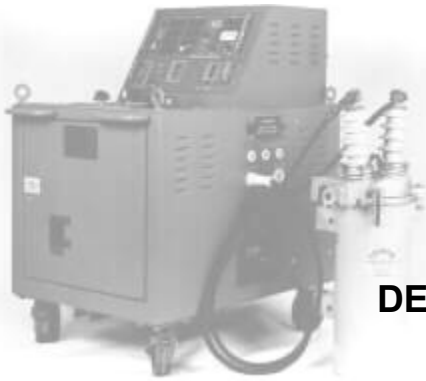
Height:	13.00 in.	(330 mm)
Width:	8.0 in.	(203 mm)
Depth:	6.0 in.	(152 mm)
Weight:	18 lb.	(8.2 kg)

HOUSING

14 gauge gray steel enclosure with neoprene gasketing.
Removable cover with captive plated screws.
External flange mounting.

STANDARD ACCESSORIES

USB cable ass'y, 6 ft (1.8 m)	1 pc.
Removable line cord, 6-8 ft (1.8-2.4 m)	1 pc.
Operation Manual on CD	1 pc.
Software CD	1 pc.



SECTION II

DETAILED DESCRIPTION



SECTION II

DETAILED DESCRIPTION

Theory of Operation - Hardware

The 120 VAC input power for the **Ortmaster** enters the unit through a standard three wire grounding type line cord with an IEC connector. A two ampere fuse provides short circuit protection. A rocker switch allows AC power to be switched on or off as desired. An internal line filter provides immunity from high frequency noise on the AC line. This filtered and fused AC power is available for use by a computer through a convenience outlet.

The internal circuit board has a linear power supply consisting of a transformer, bridge rectifier, filter capacitors, and standard three-terminal regulators, for outputs of 5 VDC at 0.25 A, and +/- 15 VDC at 0.1 A. A solid-state LED lamp provides external indication of 5 volt power.

The recloser test current passes through a shunt, rated at 100 mV at 1000 amperes (700 amps true continuous). The output millivolt signal is directly proportional to input current, and accurately reproduces the current waveform even when large DC components or distortion are present. It will also work on test systems using DC (although not usually recommended by recloser manufacturers).

A precision instrumentation amplifier provides common mode rejection and gain as required. Another operational amplifier, in conjunction with a precision voltage divider and an analog multiplexer, provides an additional programmable gain of 1, 2, 5, 10, 20, 50, 100, or 200, for corresponding full-scale input currents of 10,000 to 50 Amperes. The amplified voltage is fed to the input of a 10 bit analog-to-digital converter in a microcontroller (PIC). A sinusoidal input equal to full scale of any range is processed to have a peak value of about 50% of the input range of the A/D converter.

The range is selected by setting the appropriate I/O outputs of the PIC, which represent a three bit address for the eight ranges.

Data acquisition is accomplished by means of the A/D converter in the PIC. Its internal circuitry samples and holds the voltage appearing at its input, and performs a conversion 2400 times a second, determined by a divider for the system clock, which runs at 14.7456 MHz. The conversion completes in approximately 100 microseconds. When the conversion is complete, the 10 bit result of the conversion is available to be read. The data is transmitted by means of an onboard USART, or serial port, in the form of two characters for each sample. The baud rate is 57.6 k. The actual connection to the PC is by means of a USB port, which appears as a serial port on the PC, and is converted to standard RS232 by a USB-Serial Bridge. Direct connection using a serial port is also possible.

Verification of the serial port and hardware is accomplished by sending a special test character to the Ortmaster, which responds with a specific string of characters. Other special characters turn sampling on and off, change range, and allow access to

calibration information stored in the PIC program flash memory.

Theory of Operation - Software

When loaded and run, the Ortmaster software first reads a setup file, Ortmaster.osf. The complete list of parameters in this file are as follows:

NAME	TYPICAL VALUE	RANGE OF VALUES
===== Range:	===== 4	===== 0 to 7
Max ON Time:	5.0	0.1 TO 55 Seconds
Max OFF Time:	5.0	0.1 TO 55 Seconds
Data File:	Ortmaster.odf	Any Valid File Name
Source:	COM1	Any valid COM port, or USB
Normal Max Ops:	4	1 TO 5
Test Mode:	0	0=NORM, 1=MINPU
ShuntAmps:	1000	10 to 20,000
ShuntMillivolts:	100.0	10.0 to 1000

If desired, this file may be modified by an ASCII text editor, or by a software program, before ORTRUN is executed. The optional TCC software modifies this file, particularly the range and maximum times, to match the recloser to be tested. All values are checked for validity, and adjusted if necessary.

Several command line parameters are accepted by the Ortmaster program. A "/M" sets up the program for Minimum Pickup mode, as described below, and "/N" is for normal mode. It will also accept a file name, which will be used as a waveform file, and will set up the program in simulator mode, even if the hardware is connected. A new format for the file includes the test type, and the Ortmaster is configured accordingly.

If the Ortmaster hardware is connected, the program will attempt to communicate with it using the specified COM port. If this fails, it will attempt to find the correct port, but will alert the operator first, in case a device is connected which could have problems if sent an unexpected character. If the hardware is not located, the program will revert to Demo mode, and will allow the user to select an appropriate waveform file.

If the hardware test is OK, the software will send a special character and receive the calibration information stored in the PIC program memory. This includes its serial number, which will be displayed in the main window. If all is OK, the program will start sampling, and the Continuous Current readout will show residual noise current less than 1% of the range value. Sampling may be stopped and restarted at any time by clicking on the red STOP button, which then turns green and reads START.

Once the software is "ARMED", it samples the input at a standard rate of exactly 2400 times per second. This sample rate provides 40 samples per cycle at 60 Hz, and is sufficient to provide accurate measurement of the current waveform and reasonable harmonics. The results of each A/D conversion are stored in a queue several samples deep, which provides a pretrigger function. Detection of current flow is determined when A/D readings exceed a preset threshold. Each such reading increments an "on counter",

while readings below threshold decrement it. When the "on counter" exceeds a preset "on delay", current is determined to be flowing, and subsequent A/D readings are stored in the appropriate waveform buffer. During this phase, a timer is incremented at the sample rate, which indicates trip time. When the current drops below this threshold for a period of time equal to the "off delay", a "current off" condition is determined, and the software reverts to timing the reclose interval and waiting for the next pulse of current.

The continuous current is updated at about 5 times per second. This calculation is based on true RMS. The value is determined using a window of 0.05 to 0.50 seconds, consisting of the most recent data.

In Minimum Pickup mode, the maximum continuous current sample is displayed, time-out is disabled, and only one trip and reclose operation is indicated. There is also an additional display of Min PU, which is determined when current has reached a peak and then begins to drop. A circular Analog Meter display is provided for easier viewing.

After the "current on" phase, when the recloser is open, the trip current is calculated for the entire series of readings, using a true RMS calculation. This process involves squaring each sample, adding it to the total, dividing by the number of samples, and taking the square root of the result. The reading is adjusted to take into account the ON and OFF delay.

If any on time or off time exceeds the maximum on or off time, a time-out error message will be displayed, and the user may retry the test by clicking the RESET button.

Percentage drop-off, or decay, is calculated by the ratio of the true RMS value of the entire waveform to the RMS value of the maximum full half-cycle. Thus, a ratio of 0.8 would be a decay of 20%.

Upon exit from the program, data is saved in a file, as named in the setup file Ortmaster.osf, and normally Ortmaster.odf. The format of this ASCII file is as follows:

TRIP CURR 1:	0.00
TRIP TIME 1:	0.0000
RECL TIME 1:	0.0000
TRIP CURR 2:	0.00
TRIP TIME 2:	0.0000
RECL TIME 2:	0.0000
TRIP CURR 3:	0.00
TRIP TIME 3:	0.0000
RECL TIME 3:	0.0000
TRIP CURR 4:	0.00
TRIP TIME 4:	0.0000
RECL TIME 4:	0.0000
TRIP CURR 5:	0.00
TRIP TIME 5:	0.0000
RECL TIME 5:	0.0000

Decay readings are the ratio of last cycle to first cycle

DECAY 1:	1.000
DECAY 2:	1.000
DECAY 3:	1.000
DECAY 4:	1.000
DECAY 5:	1.000

The maximum average reading indicates minimum pickup:

MAX AVERAGE:	0.00
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These values may then be stored in a spreadsheet, database, or used by an external program such as TCC.



SECTION III

OPERATING INSTRUCTIONS



SECTION III OPERATING INSTRUCTIONS

INSTALLATION - Hardware

The **Ortmaster** is very simple to install on any recloser test set. It was designed for use with the EIL model ORT-15 or ORT-560, but should be adaptable to any comparable unit.

Requirements for installing the Ortmaster are as follows:

- (1) A reliable source of 120 VAC power with a properly grounded outlet.
- (2) A short length of flexible cable, preferably #4-0, terminated with 3/8" lugs (ORTM-1) or 1/2" lugs (ORTM-2).
- (3) An IBM compatible computer, preferably a Pentium class 500 MHz or better, with a full speed USB port, running Windows 98 or higher. (Windows XP recommended).
- (4) A standard A male to B male USB cable.

If permanent installation of the ORTMASTER is desired, it should be mounted to the chassis of the recloser test set, close to the output connections. For temporary hook-up, the ORTMASTER may be placed on its back on the floor, taking care to protect the line cord, switch, fuse holder, and indicator lamp from damage, and assuring that the current-carrying bus connections will not contact anything.

The enclosure **MUST BE SOLIDLY GROUNDED** to the test set chassis. If not permanently bolted on, connect a flexible lead of least #2 AWG from an enclosure mounting hole **WITH PAINT REMOVED** to a solid ground point on the test set. This will ensure sufficient ground current capacity in case an energized test lead should contact the case.

The flexible cable should be solidly connected between the output COMMON of the recloser test set, and one side of the ORTMASTER shunt. It should be routed so that it follows a short and direct path that does not significantly cross over the enclosure. **ACCURACY MAY BE ADVERSELY AFFECTED** if output cables lay on or wrap around the ORTMASTER. The common cable should be heavy enough to allow maximum current flow required with minimal heating and voltage drop.

THE COMMON CONNECTION MUST BE AT OR NEAR GROUND POTENTIAL. If it is not, erroneous readings or damage to the ORTMASTER may occur. This ground connection is normally made inside the test set. If it is not, a separate connection from COMMON to the chassis **MUST BE SUPPLIED**.

BEFORE ATTEMPTING TO USE THE ORTMASTER, adequate internal grounding **MUST** be verified as follows:

- (1) Connect a recloser (preferably rated 100 Amps or greater) to the test set as recommended by the manufacturer.
- (2) Connect an AC voltmeter from the output COMMON connection to the frame of the test set (which **MUST** be grounded).

(3) Initiate the output of the test set and apply rated current to the recloser.

(4) While current is flowing, read the AC voltmeter. A reading of 0.1 VAC or less (at 100 amps) indicates adequate internal grounding.

(5) If more than 0.1 VAC is detected, a ground connection must be supplied before connecting the ORTMASTER. Wire size should be based on input current rating of the test set - #6 AWG or heavier is recommended. This connection should be made directly from the test set COMMON to the frame, with a low impedance path back to earth ground.

(6) When this ground connection has been made, repeat the test described above. If excessive voltage is still present, carefully check for proper internal ground connections, or insulation breakdown of output transformer.

The computer should be set up for maximum convenience for the test technician, and for optimum connection of the USB cable. This cable should be routed away from any current-carrying conductors, and should be as short as practical. It should also be protected from physical damage, and placed so that the operator or other personnel will not trip over it. The computer power cord should be plugged into the convenience outlet on the **Ortmaster**, or into the same duplex outlet.

The cable connectors should be firmly inserted into the corresponding receptacles on the **Ortmaster** and the computer. USB connectors are rated for only several hundred insertion and removal cycles before degradation occurs and replacement becomes necessary. If frequent reconnection is necessary, it would be advisable to procure a short extension cable to be attached to the computer or the **Ortmaster**, and disconnect the cable only at this point. When contacts become unreliable, just those cables may be replaced at minimal cost.

The **Ortmaster** is normally configured to connect to a USB port of the computer. If other USB devices must be connected, the ORTM-4H includes a USB hub for a single device. If more devices need to be connected, a powered hub should be used. Although hubs do not normally interfere with data transfer, it may be best to use a USB port directly from the computer for the **Ortmaster**.

INSTALLATION - Software

To install the software on the computer, basic knowledge of Windows is assumed. A special installation disk may be supplied with an autorun install program, especially as part of the **TCC** program, but a manual installation may be performed as follows:

Boot up the computer with Windows 98 or greater, and insert the Ortmaster floppy disk or CD. The setup program will run, and it will create a folder named **Ortmaster** in Program Files. The following files, among others, will be copied to the computer:

Ortmaster.exe
Ortmaster.osf
Ortmaster.ocf
Ortmaster.chm
OrtmasterNorm.owf
OrtmasterMPU.owf

The **Ortmaster.ocf** calibration file is designed to be READ ONLY. This serves to protect the unique calibration data that has been supplied with your hardware. The values supplied on the disk are for demo mode, but they will be updated from the hardware when it is queried by the software at startup.

The setup program makes a desktop shortcut to the Ortmaster program.

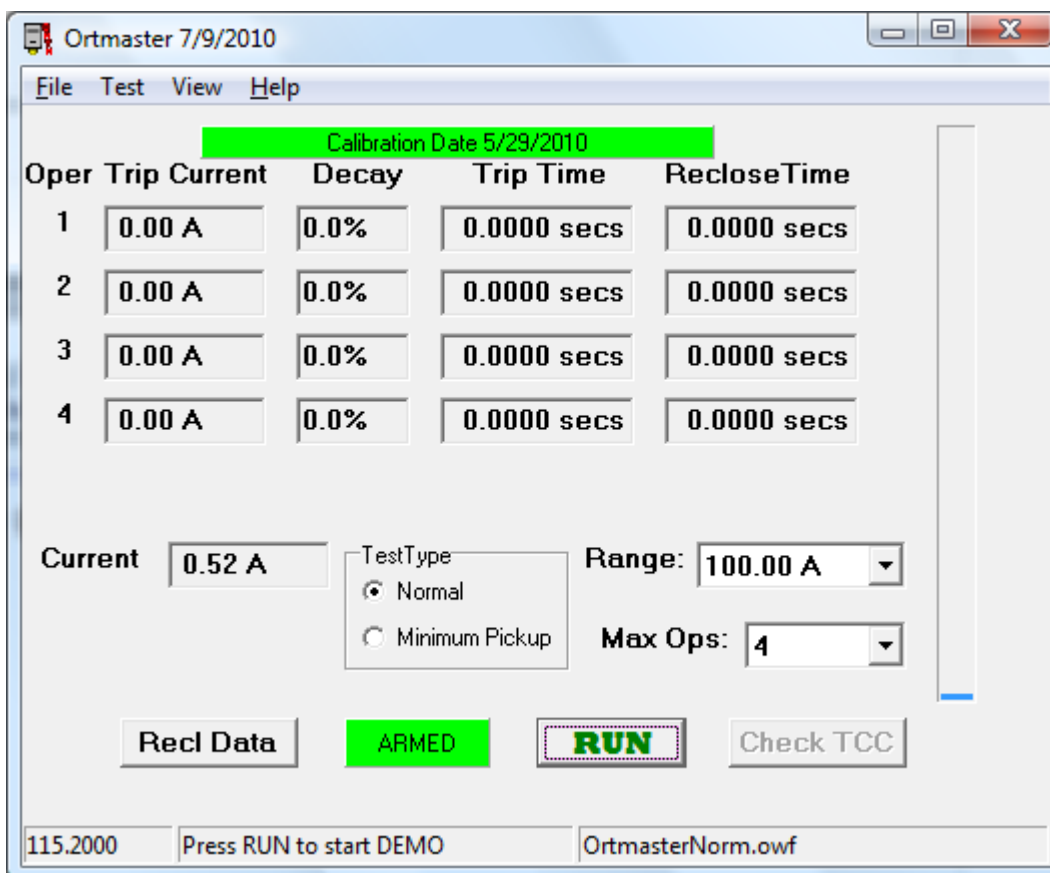
If everything has been installed as described above, plug in the ORTMASTER, and plug the computer into the auxiliary outlet. Connect the **Ortmaster** to a USB port. You will need to install the USB drivers, which will be on the distribution media.

Turn the POWER switch ON, verify that the POWER light glows, and test the system with the software by clicking on the executable file in Explorer, or the desktop icon. In this mode, run without command line parameters, a splash screen will appear. Click on the screen, and the main form for the Ortmaster will appear. If the hardware is properly connected and operational, a prompt may appear saying checking hardware. The status bar at the bottom of the screen should read the serial number of the Ortmaster, and the COM port to which it is connected. The OUTPUT CURRENT value should read a minimal value less than 1% of the RANGE, and the message at the bottom of the window should read:

ARMED -- INITIATE FULL CYCLE TEST

If there is a problem with the hardware, or it does not exist, a different window box will appear, stating that the hardware was not found, and prompting selection of a waveform file to be used for DEMO mode. Normal mode may be run by selecting **OrtmasterNorm.owf**, and Minimum Pickup mode by selecting **OrtmasterMPU.owf**. Other waveform files may be also be selected.

Figure 1: Ortmaster Screen Displays



OPERATING INSTRUCTIONS - Basic Software

The **Ortmaster** software may be run in stand-alone mode by simply clicking on it in Explorer. If the software does not detect the presence of the **Ortmaster** hardware, it enters a DEMO mode, in which it reads a waveform file, which is "played back" by the software to simulate an actual recloser. The name of the waveform file for normal demo purposes is **OrtmasterNorm.owf**, but any valid file name may be entered. DEMO mode may also be invoked by using a valid waveform file name as a command line parameter. This can be done by double clicking on a waveform file such as "**OrtmasterNorm.owf**"

The normal main window for **Ortmaster** consists of a header bar which indicates the software version, a status bar which indicates the unit serial number, or waveform file used in DEMO mode, a message area which indicates program status and other information, and a grid of test information. This information includes operation number (from 1 to 5), trip current, decay percentage, trip time, and reclose time for each operation. There is also a display of continuous current and RANGE. A linear vertical bargraph is included to the right of the display, indicating continuous current as a percentage of full-scale reading.

The message area normally will indicate "ARMED - INITIATE FULL CYCLE TEST", denoting that the software is ready to read and process information from the **Ortmaster** hardware. In MINIMUM PICKUP MODE, which may be selected from the Test Mode control, this message will read "ARMED - INITIATE MIN PICKUP TEST". The continuous current display will normally indicate a small current, typically 1/4% to 1% FS, which represents internal noise in the circuitry, but will not significantly affect accuracy. In DEMO mode, this reading is made to fluctuate to more closely simulate actual appearance. You may select a range from the drop down combo box control. The corresponding precision of measurement is indicated by the number of decimal places on the current displays.

When the test begins, either by applying current to the **Ortmaster**, or by clicking the **START** button in DEMO mode, the message area will read "Test In Progress", and the RANGE no longer may be adjusted manually. The **START** button will now read STOP, and it may be clicked to abort the test. When the test is over, this button will read "RESET".

If the current exceeds the limitations of the A/D converter, the current readings will indicate "OVER", and the test will be aborted. In this case, click on **RESET** to clear the data, reset the range to an appropriate value, and restart the test.

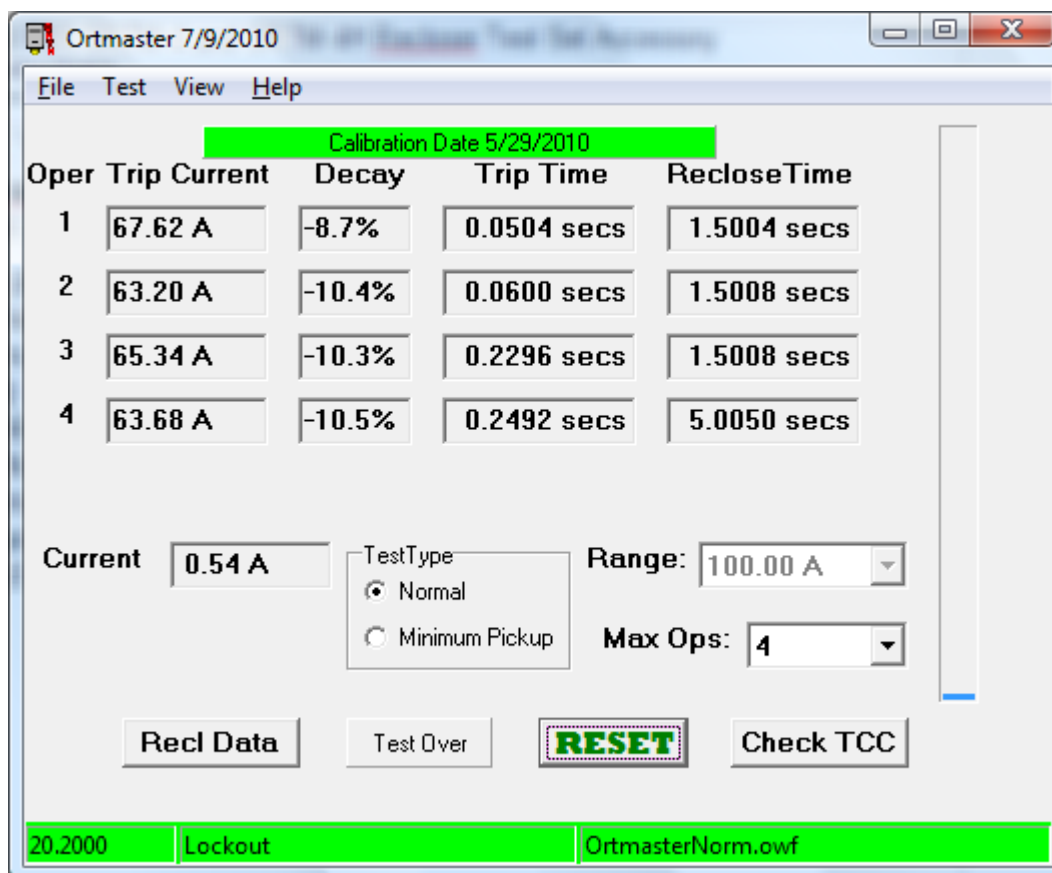
In FULL CYCLE MODE, the display will normally indicate the progress of the test as the recloser sequences through its operations. When lockout occurs, the reclose time after the last shot will advance until it exceeds the MAX OFF TIME programmed in the SETUP file, or if the operator clicks on the **STOP** button. In either case, the software will assume the test to be complete, and will indicate this in the status bar: "**Lockout**". If the maximum ON time is exceeded, the test will stop, but the display will read "**Timeout**".

When the test is complete, you may choose to **CHECK TCC** or **RESET**. You may also choose to save test results to a file by choosing the menu item **File | Save Data**.

Before or after testing, on-screen help may be accessed by pressing F1 selecting

Help from the menu. There is a standard helpfile, but also a choice that will display the contents of the **Ortmaster Operation Guide.txt** file. This file may be edited so that the user may add specific test procedures or other information for ready reference.

The minimum pickup test is set up by selecting Min Pickup. To perform the minimum pickup test, set up the recloser test set for minimum compensation, and initiate the unit with a current well below the expected minimum pickup level. Slowly raise the applied voltage, and observe the linear bargraph. The message box should read "Maximum average: nnn.nn A", When the bargraph begins to go down while the test set output is raised, stop the test. If the message box reads "Maximum average: 100.00 A", this indicates a minimum pickup value of 100 amperes. It is important to raise the current slowly. It is advised to repeat this test several times to obtain correct and consistent readings. The maximum average current is saved in the data file.



OPERATING INSTRUCTIONS - Waveform Viewing and Analysis

After test results have been computed and displayed, the operator can view and analyze the waveforms of each operation of the recloser, by selecting **View | Waveform** in the menu. The waveform screen will appear with a view of the first 1 second of the test. A series of buttons at the bottom of the screen allow several functions to be performed, as follows:

- EXPAND** Stretches the waveform to show what is between the cursors
- CONTRACT** Contracts the waveform by a factor of 2, to see a longer time

The mouse may be left-clicked on a part of the waveform to set the green cursor at that time point, and a right-click will similarly set the red cursor.

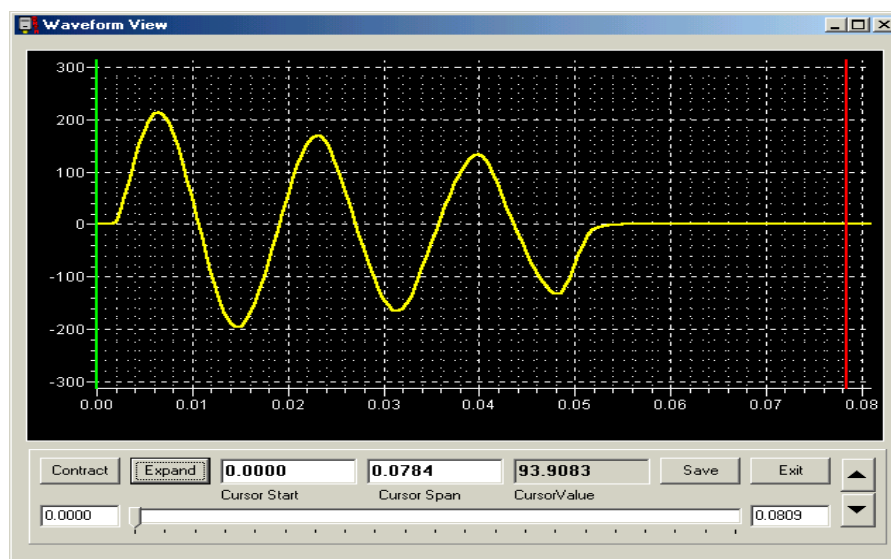
A slider control may be used to position the waveform as desired, and edit boxes are provided to manually enter start and end times for the display.

The **UP** and **DOWN** arrows may be clicked to expand or contract the waveform display vertically.

The top of the display indicates the time between the green and red cursors, and the true RMS value represented by that portion of the waveform.

The waveform display may be used to determine if a suspected erroneous reading may have been caused by noise, excessive decay, distortion, or DC offset. You may save the displayed waveform by clicking the **SAVE** button. To end waveform viewing, click **EXIT**. All operations, and reclose intervals, are saved in the waveform file. To "play back" the waveform file, run the program in simulator (**DEMO**) mode, using the name of the desired waveform file, or select **File | Open** in the main menu. To obtain the same results, the range must be set as it was when saved.

Figure 2: Waveform Display



Database and TCC Analysis:

Here is a step-by-step example of how to use the database and time-current curve analysis features of the program. From the main window, click on Recl Data:

The screenshot shows the 'Recloser Data' window with the following fields and values:

- Recloser Information:**
 - Tech ID: PES
 - Recl ID: RECL012
 - Cust ID: PST
 - Recl Type: 3H
 - Recl Time: 1.00
- Recloser Settings:**
 - Phase Trip: (empty)
 - Coil Size: 15
 - Phase MPU Current: 30.000
 - Fast Ops: 2 (Curve A)
 - Slow Ops: 1 (Curve B)
- Phase Fast Curve / Phase Slow Curve:**
 - Min Pickup: 30.000
 - Ref Current: 15.000
 - Max Time @ 2X: 0.500
 - Max Time @ 2.5X: 0.279
 - Max Time @ 3X: 0.177
 - Max Time @ 4X: 0.110
 - Max Time @ 5X: 0.083
 - Max Time @ 6X: 0.068
 - Max Time @ 7X: 0.059
 - Max Time @ 8X: 0.052
 - Max Time @ 10X: 0.044
 - Max Time @ 15X: 0.035
 - Tol Min: 100
 - Tol Max: 0
- Test Settings:**
 - Test Type: 4X
 - Phase: A

Buttons: Save Settings, Save, View Curves, Run Test.

This form is used to manipulate the databases which contain information about reclosers and test results.

First, select a TechID or enter a new code. For a technician not in the database, a prompt appears where you enter the full name.

Next, select or enter a new CustID. Similarly, for a customer not in the database, a prompt appears where you enter the full name.

Now, select or enter a ReclID. This is usually the serial number. If a recloser ID is not in

the database, there is a prompt asking if you wish to add this new recloser. An existing recloser will update fields with the stored information for that ID.

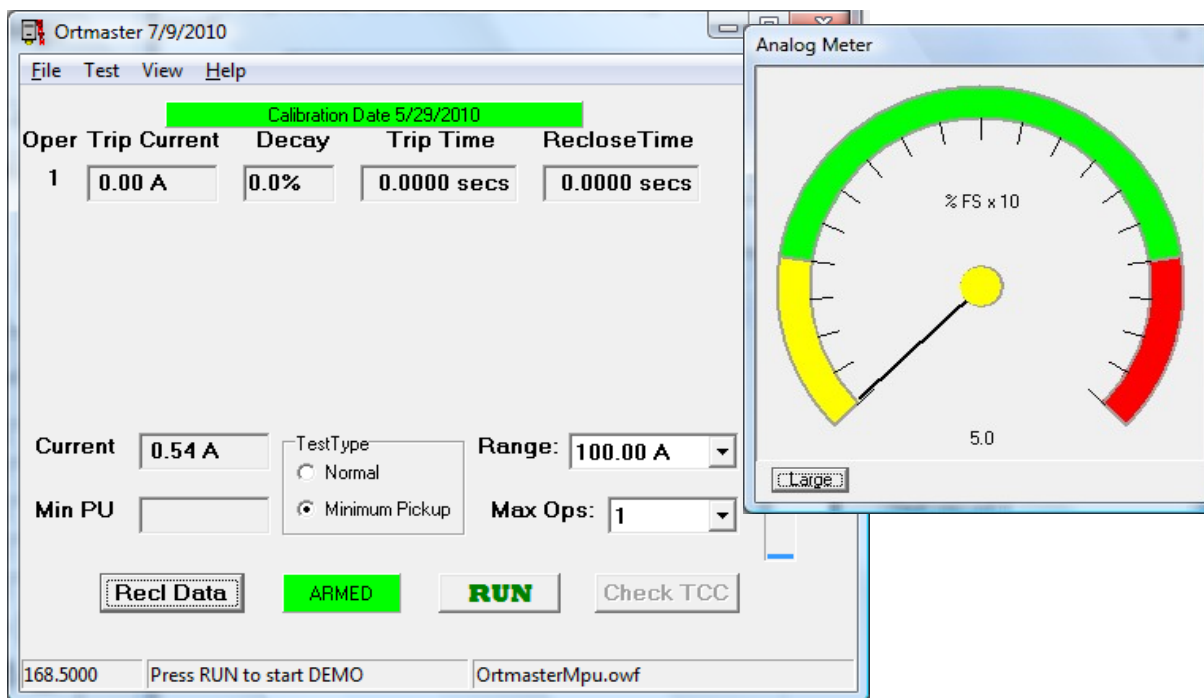
If necessary, select the recloser type and then the coil size from the available options. Finally select the number of fast operations and number of slow operations as well as the slow (delayed) curve. For a three-phase recloser with ground trip, there is a second page for the Gnd Trip CT ratio and operation sequence, including slow curve.

Once all information has been entered, click on the “**Save Settings**” button.

Now the recloser is ready to be tested. In the Test Settings group at the bottom of the form, select the phase to be tested as well as the type of test to be performed. The phases may be A, B, C, or G (for Gnd Trip), and the types of tests are MPU (Minimum Pickup), and multiples from 2x to 10x, based on coil size or CT ratio.

Minimum Pickup Test

Normally, MPU test is done first. Once everything is set up for this test, click the “**Run Test**” button. After confirming the details of the test, the main form will appear with the range preset for the amount of current expected, and also a round analog meter will appear for easier observation of current:



To run the test, apply current to the recloser with minimum compensation, and slowly increase the output of the test set until the current reaches a peak and starts to drop. This is the minimum pickup current, and it should be displayed on the main form.

When this has been done, click the **Check TCC** button:

	TEST	MIN	MAX	Optimum	Result
Trip Current 1	37.90 A				
Trip Time 1	1.8721 secs				
RecTime 1	0.5358 secs				
Trip Current 2	0.00 A				
Trip Time 2	0.0000 secs				
RecTime 2	0.0000 secs				
Trip Current 3	0.00 A				
Trip Time 3	0.0000 secs				
RecTime 3	0.0000 secs				
Trip Current 4	0.00 A				
Trip Time 4	0.0000 secs				
RecTime 4	0.0000 secs				
Min Pickup	52.78 A	45.00	55.00	50.00	OK

Results: MPU OK

Op Counter: 198 <Enter Comments>

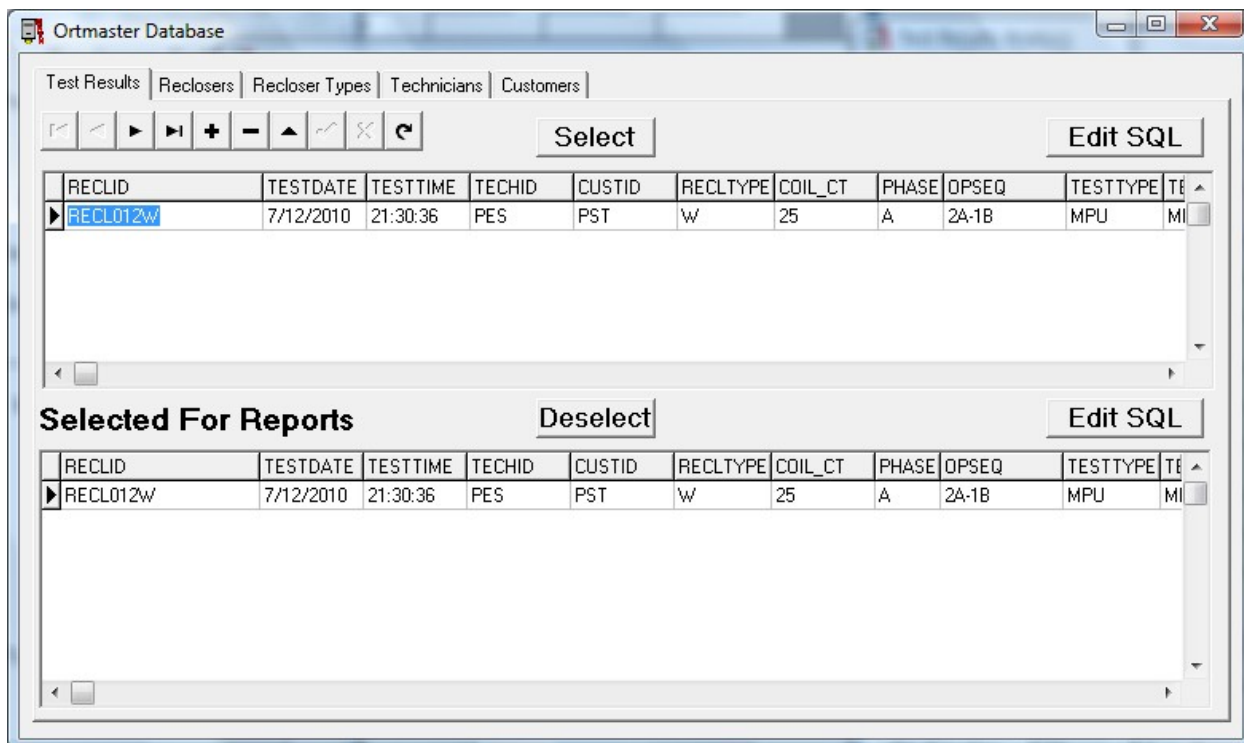
Close Keyboard Input Analyze Save Results View Results Report

This form shows the test result, along with the minimum, maximum, and optimum values for minimum pickup. The results field shows the results as determined by the software, which in this case may be MPU OK, MPU LOW, or MPU HIGH. There is also a field where you may enter the reading of the operations counter, and a field for comments.

On the right side is a column where test results are indicated by means of a green “OK” rectangle or red “HIGH” or “LOW” rectangles.

If you wish to save these results, click the **Save Results** button. A dialog box will appear asking if you wish to include these results in the report. Click **yes** or **no** as desired.

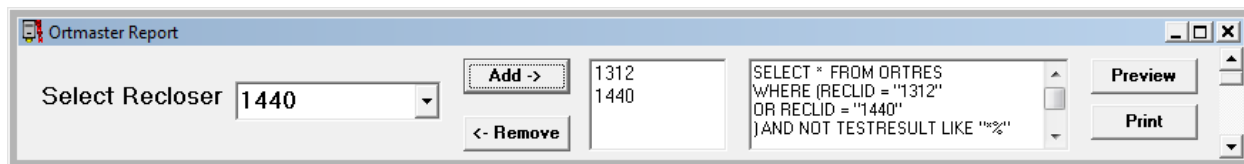
If you want to see the test results for this recloser, click the View Results button:



This form shows all test results for the recloser with the Recloser ID selected in the Recloser Data form before the test. This is a general purpose spreadsheet display which allows complete access to the entire database. There are also pages for individual reclosers by ID, Recloser Types, Technicians, and Customers. The top list includes all tests, while the bottom list contains only those that will be printed in the report. You can click **Select** or **Deselect** on any test result to include or exclude a result from the report.

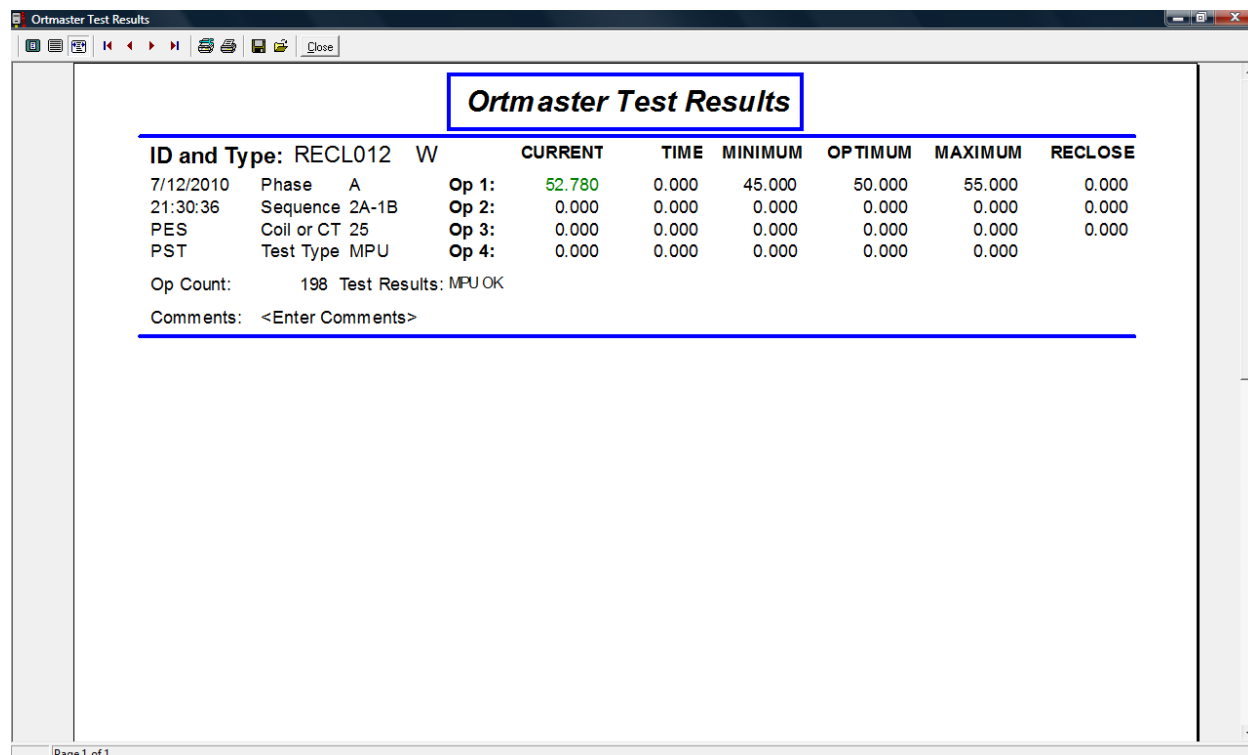
The **Edit SQL** button is an advanced feature which allows more complex selection criteria for the results displayed. If you understand Structured Query Language you may try this feature. If you have problems, just delete the entire block of text to return to the default selection.

For reports, click on the Reports button:



Here you can select any number of reclosers for a printed report. Click “Add” to include it in the report. To remove it, select the ID and click “Remove”. If all reclosers are removed, the report will include all test results in the database. See the SQL statement for details.

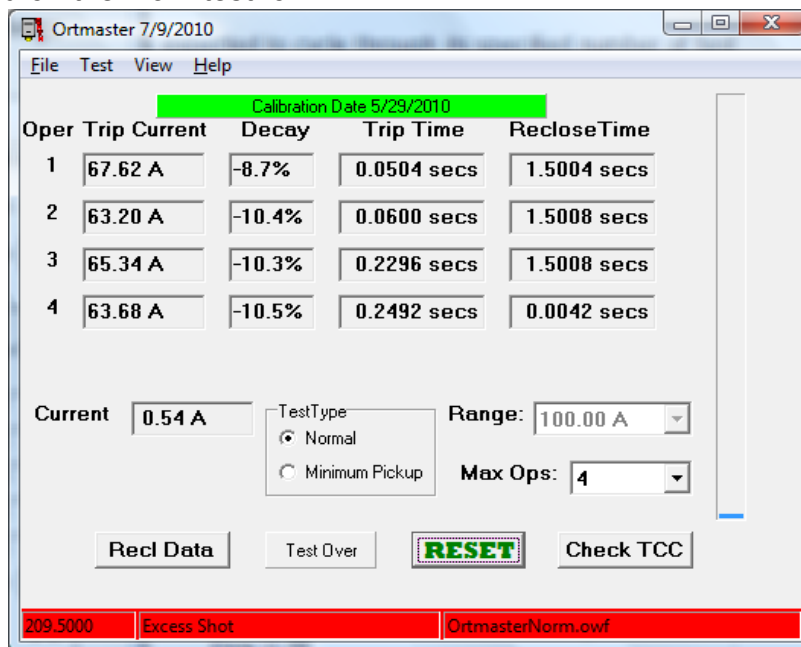
To see what the report will look like, click on **Preview**:



This report may be several pages long. In this case, the Minimum Pickup test on Phase A is shown. The current is shown in green, indicating that the test passed.

Full Sequence Test:

This is a test where the recloser is expected to cycle through its specified number of fast and slow operations and then lock out. In this case, the recloser had an extra shot, which is indicated on the main test form:



In this case, when you click on Check TCC, this is the result form:

	TEST	MIN	MAX	Optimum	Result
Trip Current 1	67.62 A	60.00	90.00	75.00	OK
Trip Time 1	0.0504 secs	0.0000	0.1077	N/A	OK
RecTime 1	1.5004 secs	1.350	1.650	1.500	OK
Trip Current 2	63.20 A	60.00	90.00	75.00	OK
Trip Time 2	0.0600 secs	0.0000	0.1150	N/A	OK
RecTime 2	1.5008 secs	1.350	1.650	1.500	OK
Trip Current 3	65.34 A	60.00	90.00	75.00	OK
Trip Time 3	0.2296 secs	2.6277	4.5707	3.3241	LOW
RecTime 3	1.5008 secs	1.350	1.650	1.500	N/A
Trip Current 4	63.68 A	60.00	90.00	75.00	N/A
Trip Time 4	0.2492 secs	2.7977	5.0550	3.5446	N/A
RecTime 4	0.0042 secs	1.350	1.650	1.500	N/A
Min Pickup					
Results:	Op 3 TripTimeLow,ExcessOp.				
Op Counter:		<Enter Comments>			

Buttons: Close, Keyboard Input, Analyze, Save Results, View Results, Report

Note that the first two fast operations were OK, but the third, slow operation was much lower than expected, and a fourth operation occurred. In this case it was actually a different type of recloser with a 2A-2C sequence, as well as a smaller coil size which showed the expected faster delay trip times.

Normally such a test would not be saved, but it can.

Another feature of this dialog is the **Keyboard Input** button. Normally the test results cannot be edited. But it is possible to do so by clicking this button. After making changes, click the **Analyze** button, and results will be recalculated.

You can even change the recloser information, such as coil size or type, and then re-analyze the results with the updated parameters.

It's also possible to access the database from the main form menu by selecting **View | Database**. And similarly, the reports may be accessed by selecting **File | Report**.

Here is a sample of a more complete report:

The screenshot shows the 'Ortmaster Test Results' window. The main content area displays a report titled 'Ortmaster Test Results' with the following data:

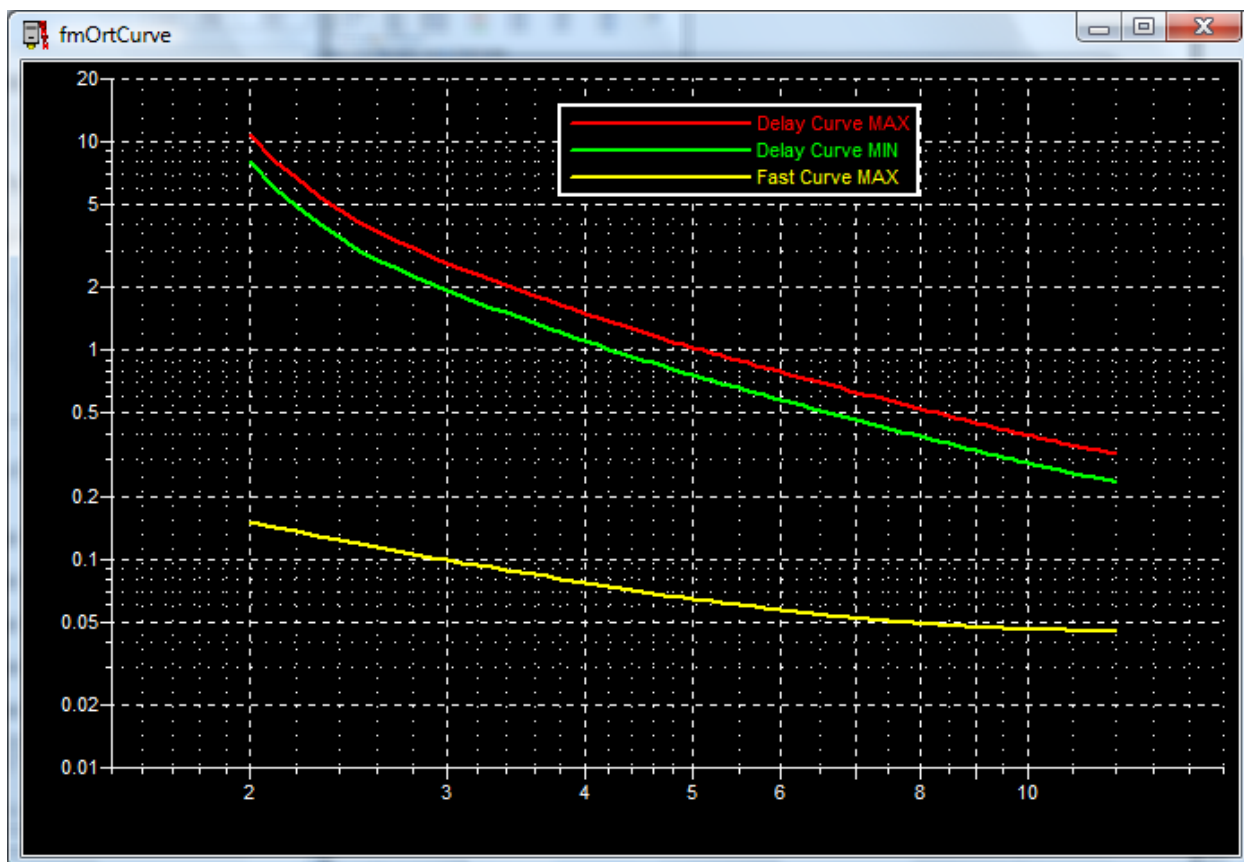
ID and Type:	108S 4H	CURRENT	TIME	MINIMUM	OPTIMUM	MAXIMUM	RECLOSE
4/13/2010 Phase A	Op 1:	125.210	0.000	125.000	140.000	154.000	0.000
15:46:53 Sequence DA-2B	Op 2:	0.000	0.000	0.000	0.000	0.000	0.000
S2 Coil or CT 70	Op 3:	0.000	0.000	0.000	0.000	0.000	0.000
Nedax Test Type MPU	Op 4:	0.000	0.000	0.000	0.000	0.000	0.000
Op Count: 0 Test Results: OK							
Comments: <Enter Comments>							

The report continues with several more test entries, each with similar data points. At the bottom of the window, it shows 'Date/Time: 7/12/2010 10:20:33 PM', 'Ortmaster Test Results', and 'Page: 1'.

Recloser Curves

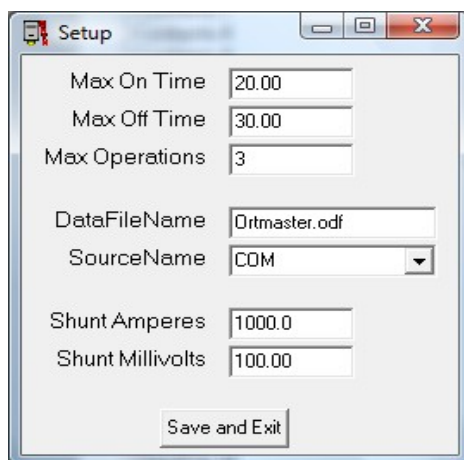
The recloser curve data is stored in a special file named **Ortmaster.rcf**. This consists of the optimum trip times at various multiples of reference current from 2x to 15x. In the Recloser Data form there are several pages of curve data displayed in the center. These values are normally read-only, but it is possible to edit them by double-clicking the curve letter, and then clicking **Save**. However, this may invalidate the test results. It is possible to create a new set of curves for a recloser type not included in the database, but this is also an advanced feature.

However, it is possible to view the recloser curves by clicking the View Curves button:



The x-axis is the multiple of current, and the y-axis is time in seconds. The yellow line is the A curve, representing maximum fast trip time. The green and red lines show the range of allowed trip time for the delay curve. This feature is mostly used as a “reality check” to see if the curve points entered are reasonable. Any roughness in the curves usually indicates an error in the curve data.

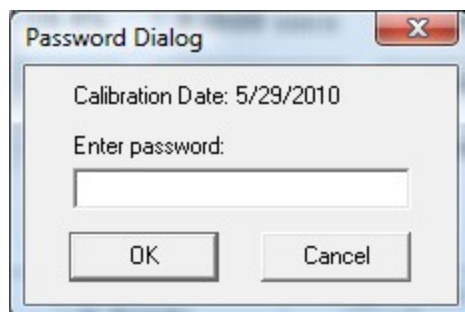
Test Setup:



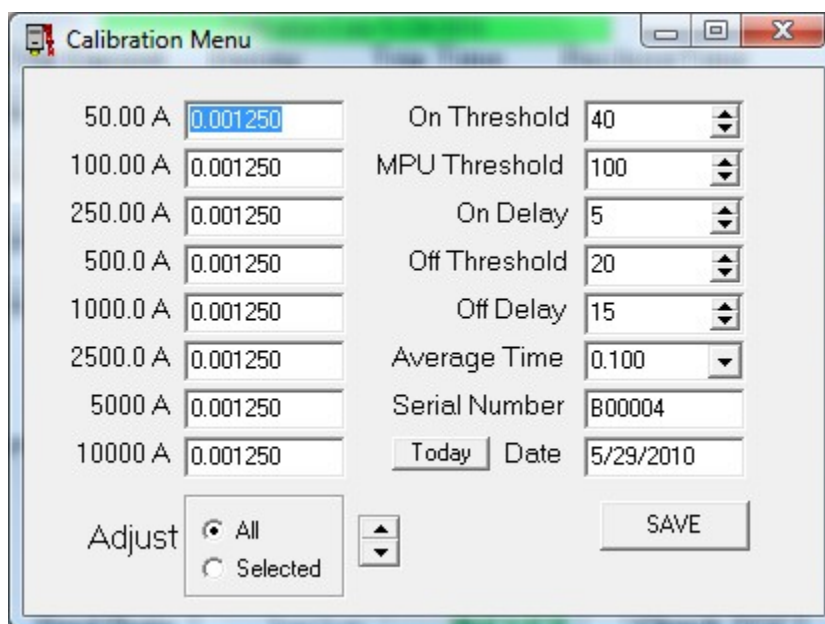
This dialog is shown by selecting the menu **Test | Setup**. Here the Max On and Max Off times may be set. The SourceName should be set to COM for the serial USB version, or USB for the Custom USB Device version (ORTM-4C or ORTM-4HC). Do not change the Shunt Amperes or Shunt Millivolts unless you have a special version.

OPERATING INSTRUCTIONS - Software Calibration

Calibration may be performed by selecting **File | Calibrate**.



You will be prompted to enter a four digit access code. Upon successful entry, the calibration menu will be displayed.



There are eight calibration factors, each of which should be nearly equal. Typical values are **0.001200** to **0.001500**. Also selectable are On Threshold, MPU Threshold, On Delay, Off Threshold, Off Delay, Average Time, Serial Number, and Date. Detailed explanations are as follows:

The **Calibration Factors** are essentially values that are multiplied by the true RMS value from the A/D converter, which may vary in the range of +/- 2048 maximum, or 1448 RMS for a sine wave. The integral overrange detector causes a range change when values greater than about 2000 are detected, so an RMS value of 1414 is the practical maximum. The actual reading in amperes is multiplied by the range factor. In order to allow for higher peak values caused by DC offset and current drop-off with minimal compensation, the normal steady-state current for a nominal range value is about 50% of its maximum. Thus, a nominal calibration value would be 1/800, or 0.001250.

To perform calibration on a given range, read a current pulse of about 50% to 80% of full scale with a pulse-reading standard instrument connected. Calculate the ratio of the true current reading to the displayed reading, and multiply this value by the calibration factor. The result is the new calibration factor.

The **ON Threshold ADC Counts** value is the initial threshold required to sense that current is flowing. Since the nominal peak value is about 1000 counts for full-scale, a threshold of 2% to 4% of that value (20-40) is generally appropriate. If the value is too low, noise may cause false triggering, and residual DC at the end of fast shots may cause erroneously long times and low current readings. If the value is too high, sensing of current turn-on may be delayed, especially when current is much less than the full-scale range value, or when turn-on occurs just prior to a zero crossing.

The **MPU Threshold** is a higher value to avoid starting the test at too low a value.

The **ON Delay** is the number of successive readings above the threshold value, to indicate current is flowing. Once current flow has been detected, the **Off Delay** is used as the number of successive readings below the **Off Threshold** to indicate current flow has stopped. The nominal sampling rate of 2400 per second corresponds to about 40 samples per cycle. It is generally recommended to use a value corresponding to about 1/8 to 1/4 cycle. If there is much noise in the waveform, a longer delay may be necessary. The ON Delay does not directly affect timing or calibration, since the same value is used before starting and stopping the ON timer, and the RMS pulse algorithm compensates by shifting the starting point of its calculation by this value. However, it may affect the discrimination between noise and significant data for distorted or noisy waveforms.

Average Time is the time, in seconds, used to compute the continuous current reading, which is displayed in digital format and on the vertical linear bargraph as well as the semicircular analog meter. The corresponding number of samples, based on A/D conversion rate, is also displayed.

Serial Number is an eight character number uniquely assigned to the ORTMASTER hardware. When calibrating or using the unit, verify that this number matches that on the ORTMASTER box.

The **Date** is the date of calibration. There is a button which sets this to the current date (Today). If the present date is within 30 days of the one year due date, the Cal Date indicator on the main form will appear in yellow, and red if overdue.

A spin control is provided which can increment or decrement individual cal factors or all at once. The desired cal factor must be selected by clicking it before using the control. The cal factors may also be edited directly.

ELECTRICAL TESTS OF RECLOSERS

Since this unit was designed for use with the EIL ORT-15 and ORT-560 recloser test sets, the following general test procedures refer to controls and connections appearing on that unit. Other test sets which may be used with the ORTMASTER may differ, but general principles will still apply.

In most cases, select the output tap with a current rating most nearly matching the name plate rating of the recloser under test. For minimum pickup, set the resistance switch to minimum (15) and use the coarse and fine output controls. For actual operation at 2X to 6X rating, set the coarse and fine controls near maximum and adjust the resistance switch for appropriate desired current.

Before testing any recloser, make sure that the test set is properly grounded, and determine that all access covers and doors on the test set are closed and secured. If possible, turn OFF source of main input power before connecting leads. Determine that the test set main power switch is in the OFF position. Connect the input power leads to the test set input power receptacles, making sure that these connections are secure. Connect the test set input leads to the input power source, and turn power source ON. Make sure that output controls are set to their minimum positions, and turn test set ON.

Minimum Pick-Up Test

Note - minimum pick-up current should be approximately twice the continuous rating of the recloser operating coil.

1. Connect the recloser under test between the ORTMASTER common terminal and the proper test set output tap.
2. Close the recloser contacts; the control handle on the recloser should be in a horizontal position.
3. Set the resistance compensation to minimum (position 15 on the ORT-560).
4. Run the software and select **Minimum Pickup Test**. The semicircular analog meter should appear. Click "Large" if desired.
5. Set RANGE to about 2-4 times recloser rating.
6. Initiate output on the test set.
7. Slowly rotate the output control clockwise. The continuous output current should register on the display and the vertical linear bargraph, as well as the semicircular analog meter.
8. Watch the continuous current reading, most easily observed on the vertical linear bargraph or analog meter. If the current is still increasing at full clockwise rotation of the output control, return the output control to its full counterclockwise position, depress the output switch knob and rotate clockwise to position 2, reset software, reinitiate, and continue.
9. Continue to increase the output of the test set until the current begins to decrease. This happens because the recloser plunger is being pulled into its operating coil, and the increasing impedance causes a decrease in current. The displayed value should be the maximum current sensed during this test. Click "Check TCC" to analyze and save this as minimum pick-up of the recloser under test.
10. Turn the test set off. Return all controls to their pretest positions.

Full Cycle Test (Timing and Number of Trips to Lock-Out)

1. Select existing or enter new recloser ID for recloser to be tested.
2. Connect the recloser under test between the ORTMASTER common terminal and the proper test set output tap, generally corresponding to recloser rating.
3. Close the recloser contacts; the control handle on the recloser should be in a horizontal position.
4. Set resistance compensation to a nominal value (position 7 on ORT-560).
5. Adjust the coarse output switch to maximum (position 9 on ORT-560).
6. Adjust the output control to midpoint.
7. Run the Ortmaster software. Message should indicate "ARMED - INITIATE FULL CYCLE TEST".
8. Select RANGE to just above test current desired (typically 3 to 10 times rating).
9. Set up the test set for MOMENTARY output initiation.
10. Initiate a brief pulse of output on the test set. The recloser may perform its first operation.
11. Should the reading be higher than the desired test current, increase the resistance compensation (a lower numbered position on the ORT-560). Should the reading be lower than the desired test current, decrease the resistance compensation (a higher numbered position on the ORT-560).
12. Use the coarse and fine output controls, and brief current pulses, to make the final adjustment to the test current. Coarse control (tap switch) should be in upper range (at least position 7 on the ORT-560).
13. Set up test set for MAINTAINED output initiation, if desired.
14. Wait several minutes for the recloser to settle (3 to 5 minutes).
15. Initiate the test set. The recloser should function through its normal sequence of instantaneous and time delay operations to lock-out. Deinitiate the output when lock-out or abnormal operation are detected.
16. The computer screen should display trip current and trip and reclose times for each operation.
17. Click "Check TCC" to analyze test results according to curves. Save and print reports as desired.
18. Turn the test set off. Disconnect the recloser from the test set and return all controls and switches to their pre-test positions.

Vacuum Interrupting Type Reclosers

In general, vacuum interrupting type reclosers may be tested in exactly the same manner as oil interrupting reclosers. However, the type of contact used in vacuum interrupting reclosers may exhibit contact bounce. If such bouncing lasts longer than about one cycle, it may be interpreted as a very fast close and reclose interval. This will be indicated on the display as an abnormally fast reclose interval (less than .05 seconds) and an equally fast close interval. If this occurs, the test should be repeated until a normal set of readings is obtained. If normal readings cannot be obtained, it may indicate faulty contacts or other internal problems, which should be corrected. It may also be possible to obtain better results by increasing or decreasing the RANGE. There are also calibration values (such as on delay), which may be adjusted for better results.

Pilot Series Type Reclosers

Pilot series or electronically controlled type reclosers may be tested in a manner similar to hydraulic reclosers, except that lower tap settings may be used because of the low internal impedance of these devices. All AC and DC power sources for relay operation and control function must remain connected; only the main power lines to the recloser terminals must be de-energized and removed. Units with standard high-voltage reclosing coils must be reclosed manually after each shot, but test voltage from the test set should be turned off before attempting to operate the reclosing handle. A remote initiate switch may be used in this case. The "INITIATE" switch may then be used to produce the second, third, or fourth shots. It is important that the manual reclosing operation be performed as quickly as possible, at least within ten seconds, so that a normal sequence of fast and delayed operations will occur. If the unit is equipped with the low-voltage reclosing option, this may be connected to suitable power, and valid reclosing times as displayed on the screen may be recorded. For three phase reclosers, it is important to check each phase individually. Due to the physical size, configuration, and location of three-phase reclosers, it may be necessary to fabricate longer extension leads to reach from the test set to the recloser terminals. If this is done, it is important that proper precautions be taken to ensure low resistance connections, sufficient size of conductor, and secure, insulated connections to avoid possible contact to ground or operator.

Sectionalizers

Sectionalizers may be tested by applying fault current pulses manually, by means of the "INITIATE" switch in "MOMENTARY" mode, with various on and off times to simulate action of a recloser. For example, a sectionalizer used with a four-shot recloser is normally set to open during the third reclose interval, thus preventing the fourth shot. When a series of fault-current pulses is applied to the sectionalizer, using the test set, it should be observed that the sectionalizer locks out during the third reclose interval, and when the "INITIATE" button is pressed for the fourth shot, the test voltage will be applied but no current should flow. At this time the output should be de-energized, and the

current readings for each shot should be recorded. The sectionalizer should then be reset, allowed to stabilize, and the test repeated at several current values. It is recommended that tests be performed at rated current to ensure that the sectionalizer does not operate at normal current levels, but only under fault conditions above pick-up.

Low Voltage Power Circuit Breakers

These devices may be tested using a recloser test set or other high current source with the ORTMASTER. Normally, only the first operation would be observed, but the breaker could be reset and retested up to five times without exiting from the software. For more details refer to the test procedures in the manuals for breaker test sets such as the EIL BTS-1000, BTS-500, BTS-300, BTS200 or BTS-100.

Molded Case Circuit Breakers

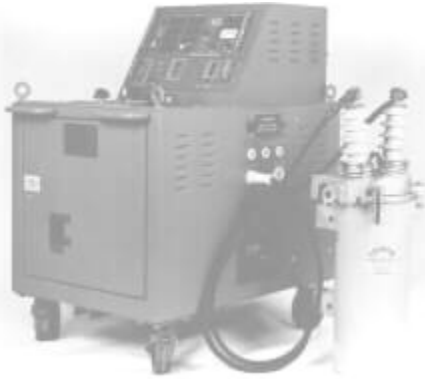
See "Low Voltage Power Circuit Breakers" above.

Motor Overload Relays

See "Low Voltage Power Circuit Breakers" above. Since these devices are typically "shunt trip", they do not stop current flow when they operate. It may be possible to modify a recloser test set or other high-current test source to de-initiate when the contacts open, so that timing measurement is possible.

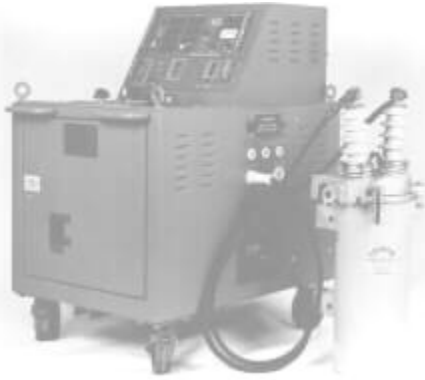
Other Devices

The ability of the ORTMASTER to measure high currents with excellent accuracy allows it to be used in conjunction with a high-current source for testing and calibrating other devices, particularly shunts, CT's and high-current AC meters.



SECTION IV

SERVICE INFORMATION AND DOCUMENTATION



SECTION IV

SERVICE INFORMATION AND DOCUMENTATION

PREVENTIVE MAINTENANCE

Periodically, the following maintenance should be performed to ensure proper operation.

1. Unplug the ORTMASTER from the 120 VAC supply.
2. Disconnect the USB cable to the computer.
3. Remove high current leads from the shunt connection.
4. Remove the ORTMASTER from the chassis of the test set (optional).
5. Thoroughly clean the enclosure and shunt.
6. Check all hardware for tightness. If loose, it may be necessary to remove the cover.
7. Check the millivolt signal connections on the shunt.
8. Inspect the surface and fins of the shunt and clean if necessary. If signs of overheating are present, shunt may need to be recalibrated or replaced.
9. Clean and inspect the USB connector and cable.
10. Re-install and perform basic operational tests to determine proper operation.

FIELD CALIBRATION:

Field calibration is recommended at minimum on a yearly basis, or whenever inaccuracy is suspected. Refer to illustration for calibration hook-ups. A standard current transformer or shunt of 500 ampere capacity and companion true RMS digital meter are recommended as the calibration references. Use the following procedures.

1. Connect the standard meter and shunt or CT to a 500 Amp or greater output tap.
2. Turn on the test set and ORTMASTER. Allow 20 minutes warm-up.
3. Run the ORTRUN software and set to 50 Ampere range.
4. Continuous current should read less than 0.50 Amperes. If greater, internal offset adjustment is required. (See major calibration)
5. Set ORTMASTER range to 500 Amperes.
6. Initiate and set the unit output to 400 amperes as read on the ORTRUN display.
7. The standard ammeter should read 400 +/- 5.0 amps.
8. Spot checks should be performed on ranges most often used

MAJOR CALIBRATION:

Major calibration is recommended if field calibration indicates inaccuracy, or on a yearly basis. Refer to illustration for calibration hook-ups. A multi-tapped current transformer, shunts of 100 ampere and 1000 Ampere capacity, a true RMS digital meter, and a waveform analyzer, are recommended as the calibration references. Use the following procedures.

1. Apply power to the ORTMASTER, turn ON, and allow 20 minutes warm up.
2. Run Ortmaster software, and set RANGE to 50 Amperes.
3. Open cover. Connect a digital multimeter from analog ground (TP11) to U3 pin 7 (TP4).
4. Using R17, adjust voltage to 0.00 +/- 0.5 mVDC. Remove multimeter.
5. Change range to 10 kA. Adjust R22 for minimum reading. Should be no more than 25 Amperes (0.25% FS).
6. Change range to 50 A. Adjust R17 slightly for minimum offset. Should be no more than 0.5 A (1% FS).
7. Try all ranges. Offset should be no more than 1% FS on any range. Adjust R17 or R22 slightly if necessary.
8. Close cover.
9. Connect ORTMASTER to test set output or current source.
10. Connect 100 Ampere shunt and true RMS voltmeter in series with output.
11. Apply 40.0 Amperes as read on ORTMASTER display. Read actual current on standard.
12. Divide standard reading by 50. This is the error ratio.
13. Access the calibration menu by selecting **File | Calibrate**, and enter access code.
14. Select 50 A calibration factor. Multiply by error ratio and enter.
15. Return to normal screen. Reading should be almost exact.
16. Check for linearity at 20, 40, and 60 amperes.
17. Increase current until OVERRANGE is detected. Record this value. Should be between 75 and 125 amperes.
18. Adjust cal factors using continuous current at 80% FS for 100, 250, and 500 A ranges, changing shunt as required.
19. For ranges over 500 Amperes, set cal factors same as for 500 A.
20. Set range to 1000. Initiate one or more pulses of about 800 Amps, and about 0.1 seconds long.
21. Use View | Waveform to observe waveform and set cursors to compare value to that displayed on main form.

22. Repeat pulse tests for 2.5 K, 5.0 K, and 10.0 K ranges.
23. Record the values of all calibration factors in calibration report.

TROUBLE-SHOOTING GUIDE:

If the unit is suspected to be malfunctioning, refer to the following guide for testing the unit and isolating the problem. Some minor repairs can be made in the field. Otherwise, call the factory for assistance.

Software does not recognize hardware - Enters DEMO mode

1. ORTMASTER not plugged in or turned ON, or blown fuse in ORTMASTER.
2. Loose or broken connection in USB cable.
3. Defective USB port in computer.
4. Hardware lockup. Remove cables, reboot computer, and reconnect.

Inaccurate Readings

1. Range too high or too low: Readings should be about 50% to 80% of full scale.
2. Noise spikes in signal. Check with WAVEFORM view. Try rerouting USB cable, check grounds, relocate recloser.
3. Excessive DC offset or decay: Increase resistive compensation; change output tap.

Loss of communication:

1. Bad USB cable. Check resistance from connector "A" to connector "B". Should be less than 1.0 ohms.
2. Poor or missing ground connection.

PARTS LIST:

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

Description	Vendor	Part Number
Enclosure	Wiegmann	B-1086SC
Line Cord, 8ft, #18-3, SJT	Qualtec	312010-01
Fuse, 2 Amp	Bussman	MDL-2
Lamp, Indicator, LED, 5VDC	Dialight	559-0202-003
Line Filter Ass'y, 2A	Corcom	2EDL1S
PC Board Assembly	P S Technology	PC-ORTM-4H
Shunt, 1000A, 100 mV	EMPRO	MLC-1000-100

OVERALL SCHEMATIC:

WARRANTY

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