SchlumbergerSema

SENTINEL™ Meter Technical Reference Guide

Release 2.0

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SENTINEL™ Meter Technical Reference Guide

C&I-SEN-0007.1-04.03
Part Number: 7002-CCC

SchlumbergerSema Energy & Utilities
313-B North Highway 11
West Union, SC 29696
Tel: (864) 638-8300
Fax: (864) 638-4950

Compliance With FCC Regulations

FCC Part 68, Class B Registration

This equipment complies with Part 68 of the FCC Rules. The label affixed to this equipment contains, among other information, the FCC Registration Number and Ringer Equivalence Number (REN) for this equipment. Upon request, you must provide this information to your telephone company.

The REN is useful to determine the quantity of devices you can connect to your telephone line and still have all of those devices ring when your telephone number is called. In most, but not all areas, the sum of the RENs of all devices connected to one line should not exceed five (5.0). To determine the number of devices your can connect to your line in your calling area—as determined by the REN—contact your local telephone company.

The following jacks must be ordered from the telephone company to interconnect this product with the public communication network: RJ31.

If your telephone equipment causes harm to the telephone network, the Telephone Company can discontinue your service temporarily. If possible, they will notify you in advance. If advance notice is not practical, you will be notified as soon as possible. You will be informed of your right to file a complaint with the FCC.

Your telephone company can make changes in its facilities, equipment, operations, or procedures that could affect the proper function of your equipment. If they do, you will be notified in advance. You will then have an opportunity to maintain uninterrupted telephone service.

If you have trouble with this equipment, please contact us at the address below for information on obtaining service or repairs. The telephone company may ask that you disconnect this equipment from the network until the problem has been corrected or until you are sure that the equipment is not malfunctioning.

This product is not field repairable; however, the maintenance section of this manual described troubleshooting steps that you can take in the even of equipment problems.This equipment can not be used on coin service lines provided by the telephone company.

Connections to party lines are subject to state tariffs. Contact your local telephone company if you plan to use this equipment on party lines.

The installation of this product does not require any connections or changes to the internal wiring of other registered terminal equipment.

FCC Part 15, Class B

This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to Part 15 of the FCC rules. These rules are designed to provide reasonable protection against harmful interference when the equipment is operated in a residential/ commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

1 Re-orient or relocate the receiving antenna.

2 Increase the separation between the equipment and the receiver.

3 Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.

4 Consult the dealer or an experienced radio/TV technician for help. This device complies with Part 15 of the FCC rules.

Operation is subject to the following two conditions: (1) The device may not cause harmful interference, and (2) this device must accept any interference received, including the interference that may cause undesired operation.

This equipment complies with the FCC RF radiation requirements for controlled environments. To maintain compliance with these requirements, the antenna and any radiating elements should be installed to ensure that a minimum separation distance of 20cm is maintained from the general population.

FCC Part 15, Subpart C

When equipped with a radio transmitter option, this equipment has been tested and found to comply with the limits for an intentional radiator, pursuant to Part 15, Subpart C of the FCC Rules. This equipment generates, uses, and can radiate radio frequency energy. If not installed and used in accordance with the instructions, it may cause interference to radio communications.

The limits are designed to provide reasonable protection against such interference in a residential situation. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause interference to radio or television reception. which can be determined by turning the equipment on and off, the user is encouraged to try to correct the interference by one of more of the following measures:

- Reorient or relocate the receiving antenna of the affected radio or television.
- Increase the separation between the equipment and the affected receiver.
- Connect the equipment and the affected receiver to power outlets on separate circuits.
- Consult the dealer or an experienced radio/TV technician for help.

Changes or modifications not expressly approved by SchlumbergerSema Inc. could void the user's authority to operate the equipment.

This equipment complies with the FCC RF radiation requirements for controlled environments. To maintain compliance with these requirements, the antenna and any radiating elements should be installed to ensure that a minimum separation distance of 20cm is maintained from the general population.

Technical Support

Contact Information

	North American Business Offices
United States	SchlumbergerSema Energy & Utilities 313-B North Highway 11 West Union, SC 29696 USA Tel: 864-638-8300 Fax: 864-638-4950
Canada	SchlumbergerSema Energy & Utilities 6700 Century Avenue, Suite 100 Mississauga, Ontario L5N 2V8 CANADA Tel: 905-812-2227 Fax: 905-812-5028
Mexico	Schlumberger Distribucion S.A. de C.V. Ejercito Nacional 425 Piso7° Col. Granada Mexico, D.F. 11520 MEXICO Tel: 52 (55) 5263 3000 / 3092 Fax: 52 (55) 5263 3193

Contacting Technical Support

Within the United States, SchlumbergerSema technical support is available by telephone, fax, or email. Whichever method you use to contact technical support, be prepared to give the following information:

- An exact description of the problem you encountered.
- A description of what happened and what you were doing when the problem occurred.
- A description of how you tried to solve the problem.

Telephone

Technical support is available Monday through Friday from 8:00 a.m. to 5:00 p.m. (EST) by calling 1-866-877-2007. If all support technicians are helping other customers, your call will be routed to the SchlumbergerSema Support voice mail system. Please leave a brief message that includes the following information:

- Your name
- Your company's name
- Your telephone number

A support technician will return your call as soon as possible within normal business hours. Technicians return all calls in the order that they are received.

Fax

If you prefer, you may fax a description of your problem any time to 1-864-638-4850. A support technician will answer you fax within 1 business day. Follow these instructions when sending a fax:

- Address the fax to "SchlumbergerSema SENTINEL Support."
- Include a brief description of the problem.
- Tell us the best time of day to contact you.

Email

If you prefer, you may email a description of your problem to:

elecsupt@slb.com

A support technician will return your email as soon as possible within normal business hours. Technicians return all emails in the order that they are received.

Factory Repair of Meters

SchlumbergerSema recommends that all repairs be performed at the factory. Certain repairs may be performed by the user; however, unauthorized repairs will void any existing warranty. All surface mounted parts must be replaced by the factory.

Repair of Meters Under Warranty

If the meter is under warranty, then SchlumbergerSema will repair the meter at no charge if the meter has failed due to components or workmanship. A return authorization number must be obtained before the equipment can be sent back to the factory. Contact your SchlumbergerSema Sales Representative for assistance.

Repair of Meters Not Under Warranty

The same procedure as above applies. SchlumbergerSema will charge for the necessary repairs based on the failure.

A purchase order will be required before any investigation will begin.

Replacement Parts

Refer to Chapter 8 for a list of available parts and SchlumbergerSema part numbers.

Service Return Address

SchlumbergerSema Inc.
Customer Repair Department
313 North Highway 11 Dock C
West Union, SC 29696

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Chapter 1 General Information

This technical reference guide explains the installation, operation, and maintenance of the SchlumbergerSema SENTINEL™ meter (hereafter referred to simply as the meter or the SENTINEL). SchlumbergerSema urges you to read the entire manual before attempting installation, tests, operations, or maintenance. Programming the SENTINEL requires SchlumbergerSema's PC-PRO+® 98 Programming Software. For more information on PC-PRO+ 98, refer to the *PC-PRO+ 98 Installation Guide*, the *PC-PRO+ 98 System Online User's Manual*, the *PC-PRO+ 98 SENTINEL Device User's Manual*, and the online help files.

How to Use This Manual

This technical reference guide contains the following information:

Chapter 1	**General Information**—Provides a general background for the operation of the SENTINEL meter. This chapter includes general, physical, and functional descriptions, as well as complete specifications.
Chapter 2	**Installation**—Describes how to install a SENTINEL meter and details the precautions that must be taken when handling the SENTINEL Meter.
Chapter 3	**Operating Instructions**—Describes how to operate the SENTINEL meter. This chapter gives the location of the controls and explains how to obtain the desired operating modes and displays. It also provides detailed information on the Demand, Time-of-Use, and Load Profile functions and their associated options, as well as R300, Modem, and I/O Communication options.
Chapter 4	**Theory of Operation**—Explains the theory of operations of the SENTINEL multimeasurement meter. This chapter can be used as an aid to Chapter 6, ***Testing, Troubleshooting, and Maintenance***.
Chapter 5	**SiteScan™ On-Site Monitoring System**—Explains how the SiteScan on-site monitoring system provides the ability to diagnose and resolve metering or tampering problems.
Chapter 6	**Testing, Troubleshooting, and Maintenance**—Explains testing, troubleshooting and maintenance of the SENTINEL meter.
Chapter 7	**Replacement Parts, Accessories, and Drawings**—Contains schematics, applicable block diagrams, cable assemblies, and lists of replacement parts.
Glossary	Contains definitions of terms used in this manual.
Index	

General Description

The SENTINEL Multimeasurement Meter is a solid-state, electronic multimeasurement, polyphase meter of exceptional accuracy. This self-contained or transformer rated meter, available in socket and A-base packaging, is designed for use at a variety of advanced singlephase and polyphase installations.

The meter requires PC-PRO+ 98, the Windows™-based programming software. PC-PRO+ 98 is both easy to use and flexible. PC-PRO+ 98 can be used to create a program whether the software is connected to the meter or not. This allows maximum flexibility to customers needing to work on programs in the shop for meters that will be installed at a future time.

Measurement Levels

The SENTINEL incorporates digital sampling technology to accurately measure active, reactive, and apparent power.

The SENTINEL meter is available in five measurement levels.

Level 0	Wh delivered
Level 1	W/Wh delivered and PF
Level 2	W/Wh delivered and PF plus *one* of the following: a. Var/Varh b. VA/VAh c. Qh d. (Canadian installations only) Var/Varh delivered and received and Qh e. (Canadian installations only) VA/VAh delivered and received and Qh
Level 3	W/Wh delivered and PF plus VA/VAh delivered, Var/Varh, Qh
Level 4	W/Wh delivered/received/net and PF plus VA/VAh delivered/ received/net, Var/Varh (Q1, Q2, Q3, Q4), Qh

There are four optional adders that may be added to any measurement level:

- Per Phase V&A (Vh, Ah, Amp Demand)
- Aggregate, A^2h, V^2h
- Bidirectional Measurement (Received and Net Quantities)
- Time-of-Use (4 + Total Rates or 7 + Total Rates)
- Load Profile (48 kilobytes of memory, 8 channels or 96 kilobytes of memory, 8 channels)

Table 1.1 shows the quantities and optional adders that are available in each measurement level.

Table 1.1 Measurement Level Quantities

Quantities	0	1	2a	2b	2c	3	4
Wh delivered	X		X	X	X	X	
W/Wh delivered		X	X	X	X	X	X
W/Wh received (* Bidirectional Adder)		*[1]	*	*	*	*	X
Net W/Wh (*Bidirectional Adder)		*	*	*	*	*	X
Var/Varh Q1			X			X	X
Var/Varh Q2							X
Var/Varh Q3							X
Var/Varh Q4			X			X	X
Var/Varh delivered (lag) (Q1 + Q2)			X			X	X
Var/Varh received (lead) (Q3 + Q4)			X			X	X
Varh net delivered (Q1 - Q4)						X	X
Varh net received (Q2 - Q3)							X
VA/VAh delivered				X		X	X
VA/VAh lagging				X		X	X
VA/VAh received (*Bidirectional Adder)				*		*	X
Qh delivered					X	X	X
PF		X	X	X	X	X	X
Event/Error Logging	X	X	X	X	X	X	X
Optional Adders (if purchased):							
• Per-phase V&A:		*	*	*	*	standard	standard
- Vh (A, B, C, average)							
- Ah (A, B, C, N)							
- Amp Demand (A, B, C)							
- A^2h (aggregate)							
- V^2h (aggregate)							
• TOU basic (4+T) or extended (7+T)		*	*	*	*	*	*
• Load Profile (48 KB or 96 KB)		*	*	*	*	*	*
• Bidirectional Measurement		*	*	*	*	*	standard

[1] The asterisks indicate that these options are not standard, but can be ordered for any measurement level.

Packaging

The SENTINEL meter is available in the following Socket and A-base packaging:

Table 1.2 SENTINEL Package Forms

Socket Package (ANSI[1])	
Self Contained (200A and 320A)	**Transformer Rated (20A)**
16S (14S, 15S, 17S)[2]	9S (8S)[2]
12S	45S (5S)[2]
2S	46S (6S)[2]
	66S (26S)[2]
A-base Package (ANSI[1])	
Self Contained (150A)	**Transformer Rated (20A)**
16A (14A, 15A, 17A)	10A (9A)
	45A (5A)
	46A (6A)
	48A (8A)

1 As specified in ANSI 12.10

2 Forms listed in parentheses have been consolidated

Meter Components

The SENTINEL meter package holds and protects the various meter components, both in service and in shipping. The mechanical package also contributes to safety by enclosing all high voltage conductors. The package has been designed to control solar gain and associated temperature rise of the meter. Finally, the package contributes to tamper resistance by hiding the location of critical meter components and shielding them from unauthorized access.

The SENTINEL is modular in that it consists of:

- A meter platform that allows the addition (inside or outside the factory) of communication or I/O modules
- Independent register and metrology components

The meter consists of the upper housing (or upper inner cover), the base assembly (with lower inner cover), and the cover.

Upper Housing

The upper housing (see Figure 1.1), consists of both the Register board and the Power Supply board.

Figure 1.1 Upper Housing

Base Assembly

The base assembly consists of a meter base (socket: Figure 1.2, A-base: Figure 1.3) with CTs, potential leads, and the lower protective housing. The base assembly will vary according to the meter form number. For various cable assemblies, a knockout is located at the six o'clock position in the socket base assembly to allow wires from an option board to exit the meter base. The A-base configuration will support cable assemblies either through the terminal block, or on the side(s) of the meter.

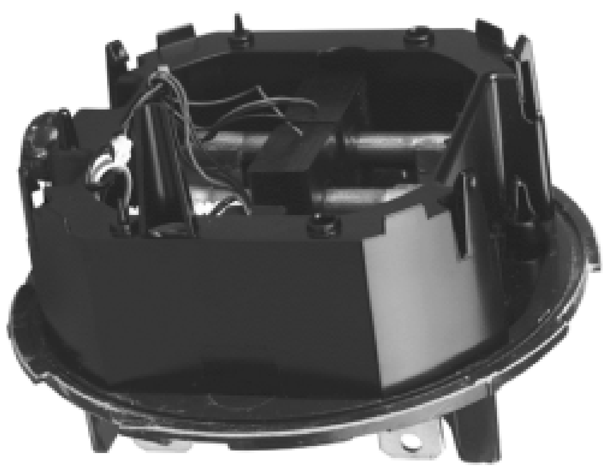


Figure 1.2 Socket Base Assembly

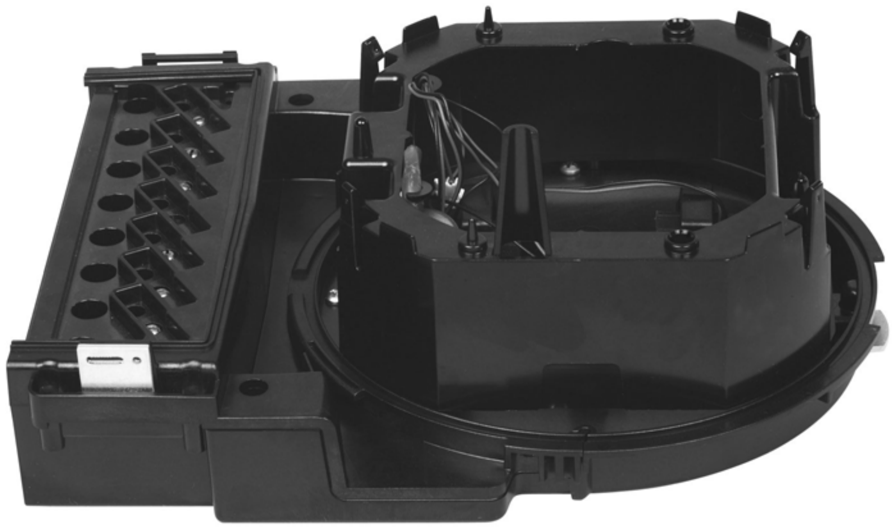


Figure 1.3 A-base Base Assembly

Covers

The SENTINEL meter is equipped with a polycarbonate cover. Cover options include:

- Demand reset (keylock available)
- Without demand reset
- Communication cable connector “factory knock-out” (6 o’clock position on cover face)

Meter Availability

The SENTINEL is available with the following communication options:

- Input/Output Pulse Modules
- R300 Series Communication Modules
- Modem Communication Module
- RS-232/RS-485 Communication Module

Each of these options is described in the following sections.

Input/Output Module (Optional)

Five input/output variations are available with the SENTINEL meter:

- Option 1 has one Form C KYZ output and one Form A low-current solid-state contact output. (See Figure 1.5 on page 1-7.)
- Option 2 has two Form C KYZ outputs and one Form A low-current solid-state contact output. (See Figure 1.6 on page 1-8.)
- Option 3 has four Form C KYZ outputs and one Form A low-current solid-state contact output. (See Figure 1.7 on page 1-8.)
- Option 4 has two Form C KYZ outputs, one Form A low-current solid-state contact output, and two Form A KY pulse inputs. (See Figure 1.8 on page 1-9.)
- Option 5 has four Form C KYZ outputs, one Form A low-current solid-state contact output, and two Form A KY pulse inputs. (See Figure 1.9 on page 1-10.)

Figure 1.4 shows a fully loaded Input/Output board.

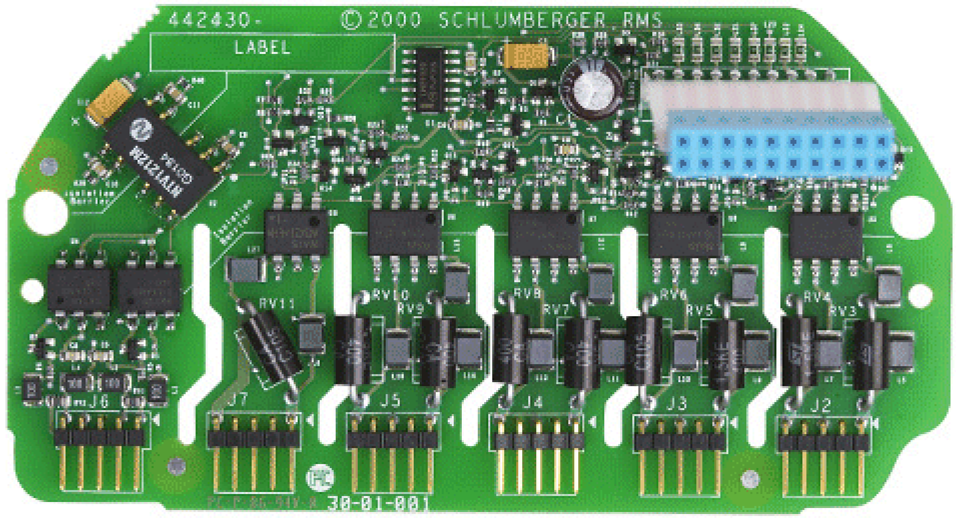


Figure 1.4 Input/Output Board

Input/Output Module Color Coding

The following diagrams illustrate the color coding for each of the I/O Module options available.

In the following diagrams, NO means Normally Open.

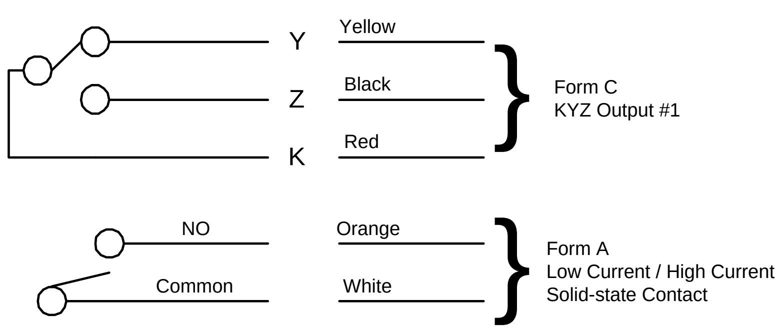


Figure 1.5 Input/Output Option 1

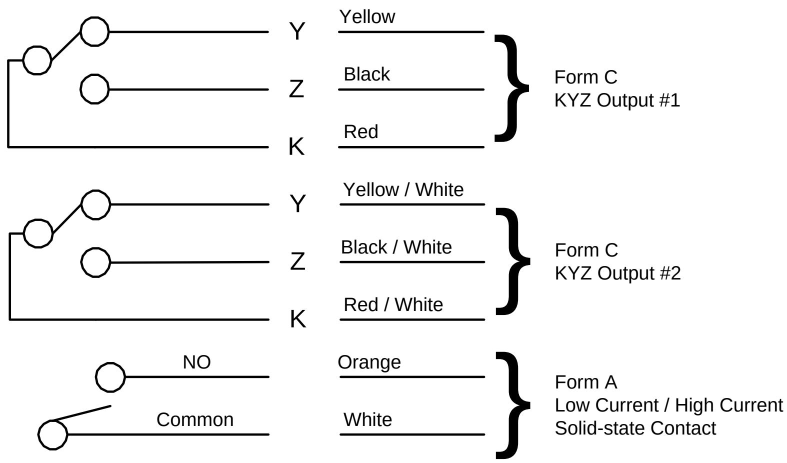


Figure 1.6 Input/Output Option 2 & Supplemental Option 1

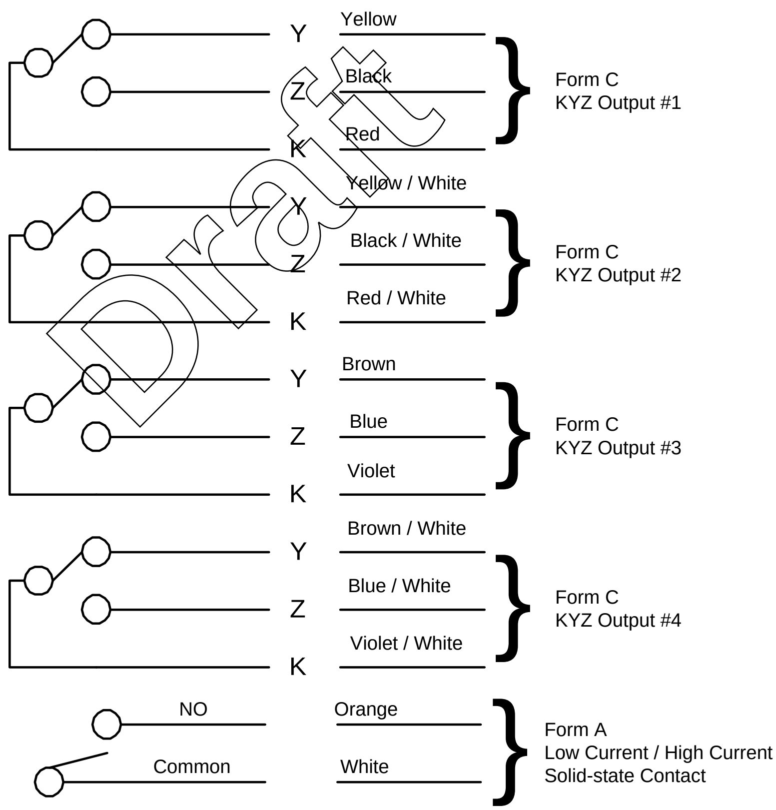


Figure 1.7 Input/Output Option 3

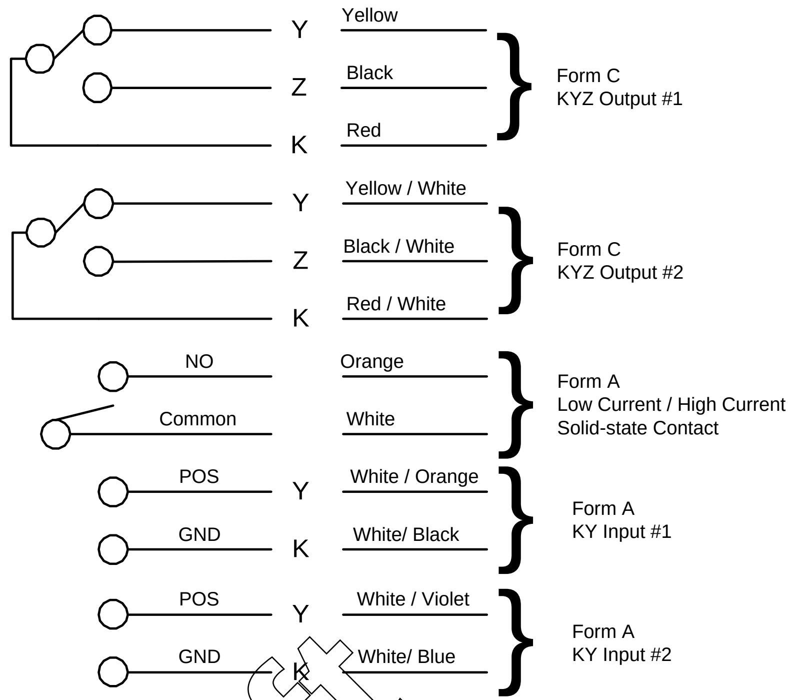


Figure 1.8 Input/Output Option 4 & Supplemental Option 2

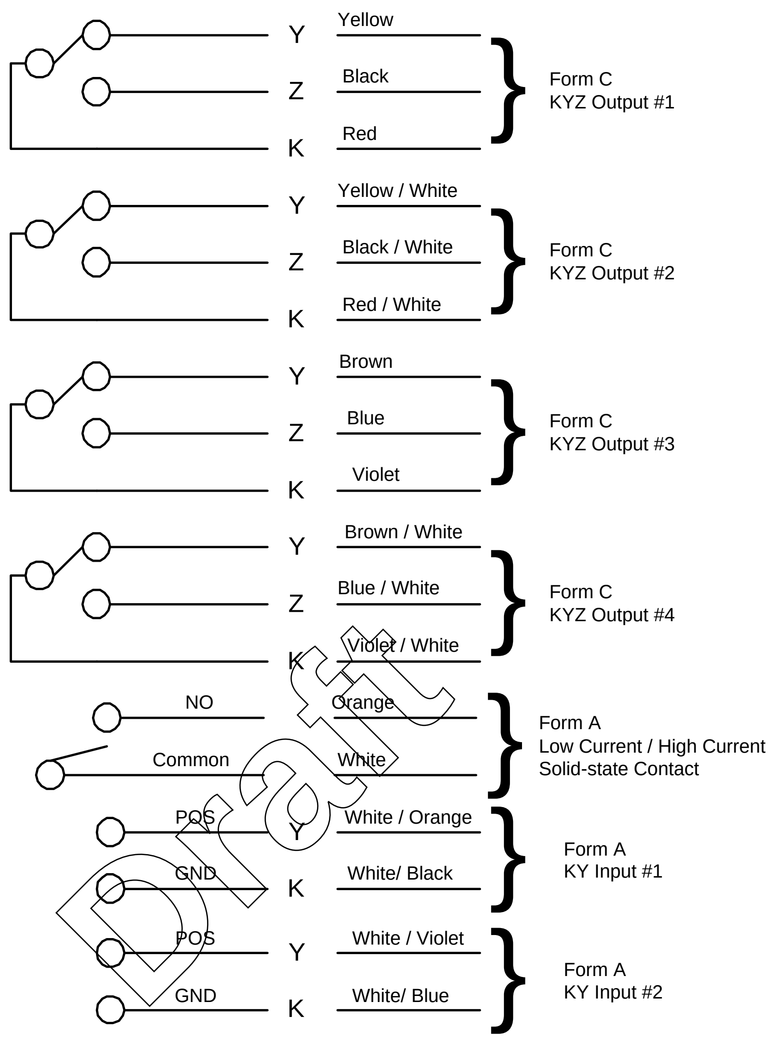


Figure 1.9 Input/Output Option 5

R300 Communication Module (Optional)

The R300 is an option board that allows energy and maximum demand values to be transmitted from the SENTINEL via 900 MHz radio frequency. The R300 features include:

- R300S: Broadcasts energy only for demand meters.
- R300SD: Broadcast any two quantities (energy and/or demand) for TOU/LP meters
- R300SD3: Broadcast any three quantities (energy and/or demand) for TOU/LP meters
- Tamper detection
- All components housed within the meter
- Contains no mercury

Two optional input/output supplemental board variations are available in conjunction with the R300 Communication Module. The variations are:

- Supplemental Option 1: Two Form C KYZ outputs and one Form A low-current solid-state contact output.
- Supplemental Option 2: Two Form C KYZ outputs, one Form A low-current solid-state contact output, and two Form A KY pulse inputs.

Figure 1.10 shows the R300 board with the Supplemental I/O board.

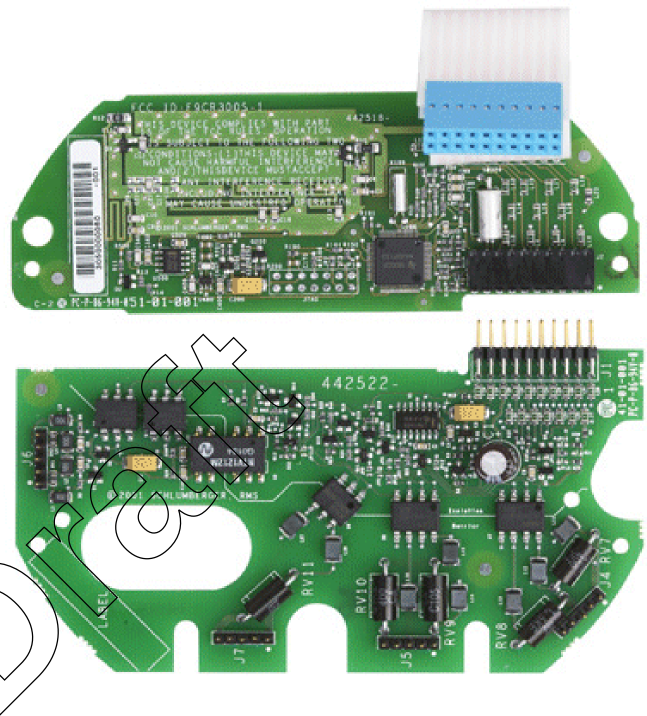


Figure 1.10 R300 Series Option Board with Supplemental I/O Board

Modem Communication Module (Optional)

The Modem Communication Module allows for remote communication at 2400 bps. The modem features include:

- Phone Line Sharing (up to 5 meters)
- Call Windows
- Answer Delays
- Phone Home on Event
- Phone Home on Schedule

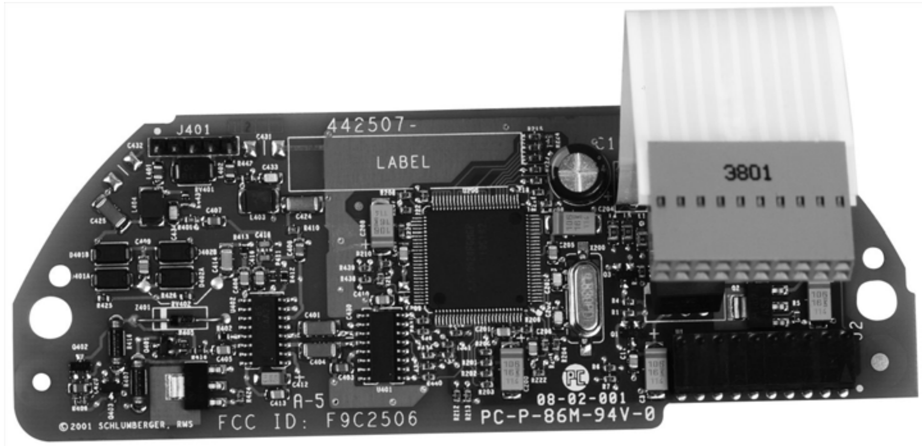


Figure 1.11 Modem Communication Module

Specifications

Electrical

Power Supply

Voltage Ranges:	60 Hz range: (Nominal)	60 Hz range: (Actual)
Single Phase	120-480 volts	96-528 volts
Three Phase	57.7-277 volts	45-332 volts

Frequency:	50 Hz or 60 Hz
Operating Range	45 Hz to 65 Hz
Load Profile/TOU Battery	
Voltage:	3.6 V nominal
Operating Range:	3.4 V - 3.8 V
Carryover:	12 years minimum
Shelf Life:	25 years minimum
Surge Suppression	IEEE C62.41 - 1980 ANSI C12.1

Programmable Outputs

Solid State KYZ & Low Current Solid-State Contacts	
Voltage	12 - 400 V DC (400 V DC maximum) 12 - 282 V AC (282 V AC maximum)
Current	100 mA DC or AC RMS
Pulse Rate	40 Hz maximum

Programmable Inputs

Pulse Inputs	12 V DC Internally Wetted

Operating Environment

Temperature Range	-40°C to +85°C (-40°F to +185°F)
Humidity	0% to 95% non-condensing
Time Base	Power line frequency or crystal oscillator (selectable)

Rated Accuracy (Typical, at ambient temperature)

1% of class to class	+/-0.2% @ unity power factor
	+/-0.4% @ 50% power factor

Time

Line Sync	Power line frequency
Crystal Sync	+/-0.003% @ 25°C; +/- 0.02% over full temperature range

Burden Data

Potential (120V - 480V) Single Phase Power Supply

Table 1.3 Single Phase Power Supply Potential (120V - 480V)

		Typical for Base Meter		Typical for Meter with R300 or Modem and/or I/O	
Voltage	**Phase**	**Watts**	**VA**	**Watts**	**VA**
120	A	1.3034	2.2814	2.3204	3.7513
	B or C	<0.001	0.001	<0.001	0.001
240	A	1.5989	3.1056	2.6441	4.9303
	B or C	<0.06	0.06	<0.06	0.06
277	A	1.6867	3.3506	2.8937	5.5201
	B or C	<0.08	0.08	<0.08	0.08
480	A	2.4413	5.1525	3.7556	7.719
	B or C	<0.24	0.24	<0.24	0.24

Potential (57.7V - 277V) Three Phase Power Supply

Table 1.4 Three Phase Power Supply Potential (57.7V - 277V)

		Typical for Meter	
Voltage	Phase	Watts	VA
57.7	A	2.3714	3.1127
277	A	2.3048	4.2541

Isolation

I/O Board Outputs 5kV for one minute

I/O Board Inputs 3kV for one minute; limited by the 12-12Vdc Switcher

Current

Current (Per Element) At Test Amps	
Meter	VA
CL 20	0.002
CL 200	0.09
CL 320	0.18

Starting Load, Creep

Maximum Starting Current	5 mA for CL 20 meter
	50 mA for CL 200 meter
	80 mA for CL 320 meter
Voltages On, No Current	Guaranteed no output pulses

Standards

ANSI C12.1 — 1995

ANSI C12.16 (Solid-state electricity meters)

ANSI C12.20

ANSI C37.90.1 — 1989 (Oscillatory and fast-transient waveforms)

ANSI C62.45 — 1987 (Ringing wave form)

Dimensions

All dimensions are in centimeters and (inches).

Meter	A	B	C	D	E
Socket base	17.65 (6.95)	16.03 (6.31)	13.87 (5.46)	15.24 (6.00)	18.54 (7.30)
A-base	24.03 (9.459)	18.48 (7.276)	14.97 (5.895)	16.35 (6.438)	NA

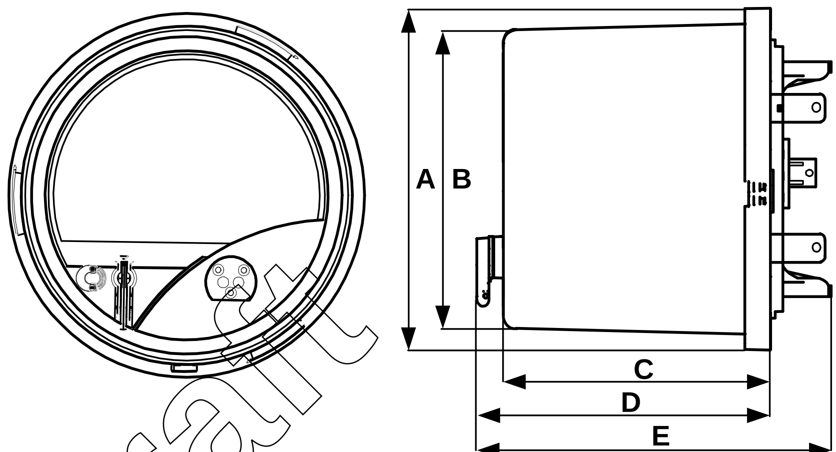


Figure 1.12 Socket-Base Meter Dimension Drawing

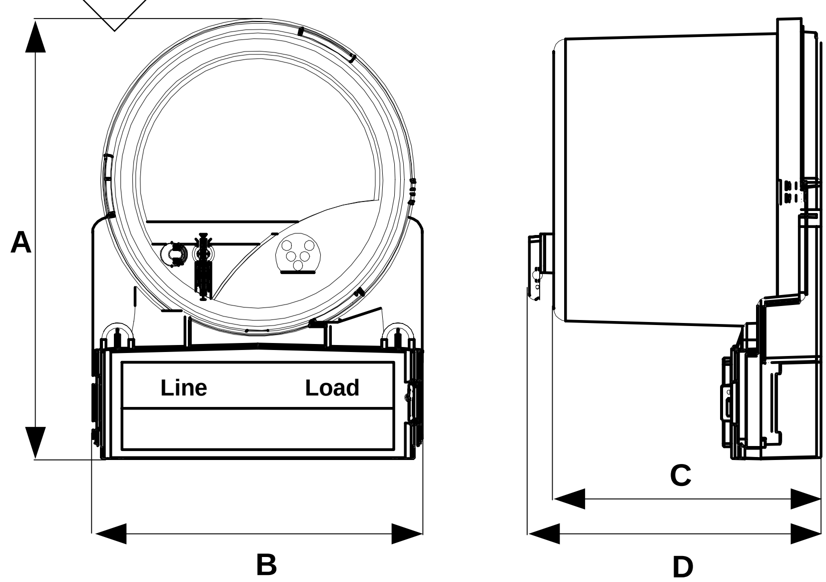


Figure 1.13 A-Base Meter Dimension Drawing

Shipping Weights

All weights are in kilograms and (pounds).

Table 1.5 Shipping Weights for the SENTINEL Meter

Meter	Net Weight	Gross Weight (Meter & Carton)	Gross Weight 4 Pack
Socket-base	1.8 kg. (4 lbs.)	3.4 kg. (7.5 lbs.)	9.2 kg. (20.2 lbs.)
A-base	2.6 kg. (5.7 lbs.)	4.2 kg. (9.3 lbs.)	12.4 kg. (27.3 lbs.)

Chapter 2 Installation

This chapter provides information and instructions to correctly store, unpack, and install the SENTINEL meter.

Storage

Inspect the meter upon receipt before storing. Store the SENTINEL meter in the original packing material. Store the meter in a clean, dry environment at temperatures between -40°C and +85°C (-40°F to +185°F). Avoid prolonged storage (more than one year) at temperatures above +70°C (+158°F).

Unpacking

As with all precision electronic instruments, the SENTINEL meter should be handled with care; however, special handling is unnecessary. The demand reset mechanism is self-secured and should be inspected for proper operation.

Preliminary Inspection

Meters Without Batteries

Upon receipt, do the following:

1 Inspect for obvious shipping damage to the cover and the meter assembly.

2 Ensure that the reset mechanism is secure and not damaged.

3 From the meter nameplate, verify that the following information is as specified on the original order:

Meter Type	Kh
Class	Test Amps
Service	Frequency
Voltage (Range)	Serial Number
Form #	Bar Code Data

Meters With Batteries (TOU and Load Profile Meters)

The SENTINEL battery is a 3.6 volt lithium battery (TADIRAN type 5276/C) with two twisted wires and a 2-pin connector as shown in Figure 2.1.

Note: Early production batteries used red and black wires to the connector; current production batteries use red and white wires.

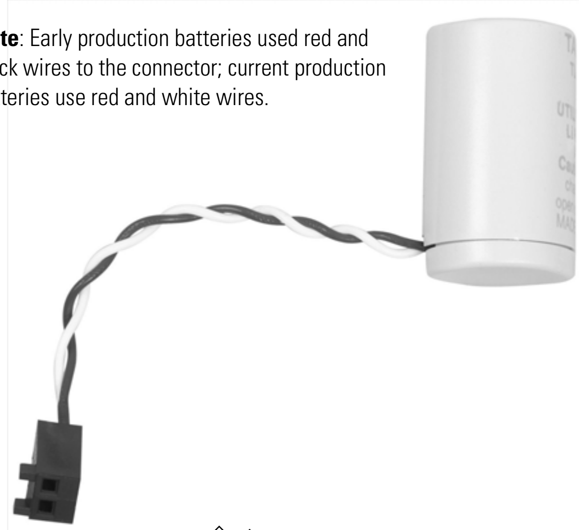


Figure 2.1 SENTINEL Battery

The SENTINEL battery is very similar to the VECTRON® battery in appearance. However, the two batteries are significantly different. You should only use SENTINEL batteries in SENTINEL meters. To be certain you are using a SENTINEL battery, verify the part number before installing the battery. The approved battery is the TADIRAN TL-5276/C. For more information, see the battery specifications on page 1-12.

The battery is packaged with the meter. To preserve the capacity of the battery, the battery may not be connected to the circuit board. Upon receipt of the meter, take the following steps:

1 Follow the steps for a meter without batteries.

2 Inspect for obvious shipping damage to the battery.

3 Use a standard voltmeter to measure battery voltage. Place a 100 kilo-ohm, 1/4 watt resistor in series with the battery, as shown in Figure 2.2, by inserting the resistor leads into the two-pin connector.

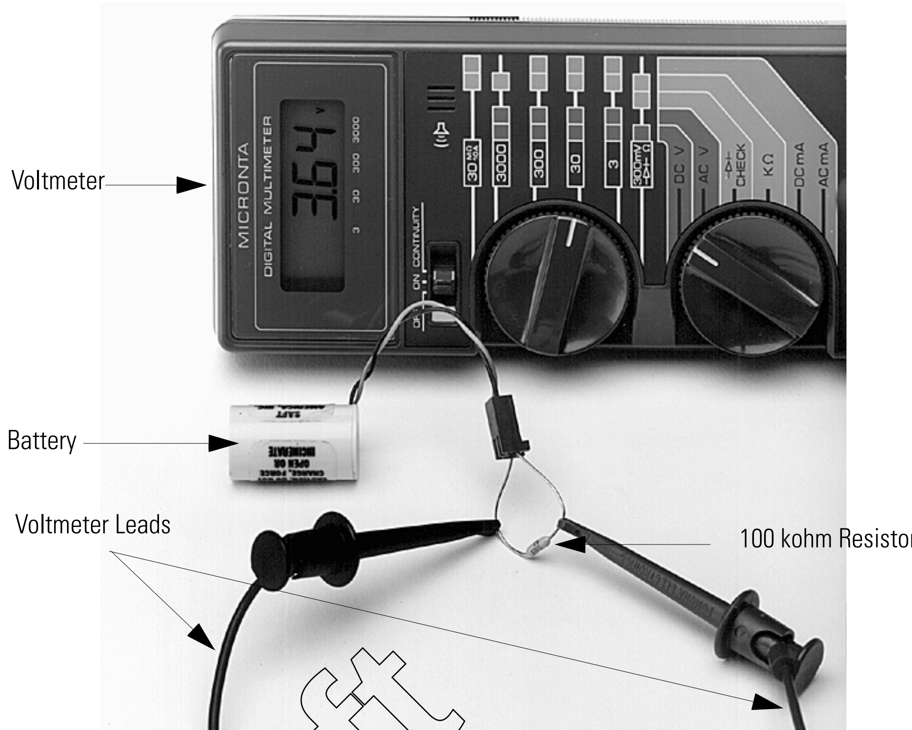


Figure 2.2 Testing Battery with Voltmeter

Place the voltmeter probes in parallel with the 100 kilo-ohm resistor. The measured voltage should be between 3.45 and 3.75 volts. If the voltage is below 3.45 volts, replace the battery.

Ensure that the voltmeter probes do not short the battery terminals and that the voltmeter is set to the proper voltage range. The product you have purchased contains a battery which is recyclable. At the end of its useful life, under various state and local laws, it may be illegal to dispose of this battery into the municipal waste stream. Check with your local area solid waste officials for details about recycling options or proper disposal.

Site Selection

The SENTINEL meter is designed and manufactured for use in either indoor or outdoor environments with temperature ranges between -40°C and +85°C (-40°F to +185°F).

Installation

Terminal arrangement diagrams for applicable form numbers are shown in Chapter 5. Refer to these diagrams for proper meter connections.

Socket-Mount Meters

In the socket-mount SENTINEL meter, the current and potential terminals extend as blades, or bayonets, from the back of the meter. Connection is made by plugging the meter into a socket where the bayonets engage main terminal jaws that have been connected to the service lines. Electrical connection is provided by the heavy spring pressure of the socket jaws on the meter bayonets. In some heavy-duty sockets, clamping pressure provided by a handle or wrench ensures proper connection. Figure 2.3 shows a socket-mount meter.

Figure 2.3 Socket Mount Meter

Cover

To install the cover, turn it clockwise until it is properly seated. Be sure the locking tabs on the cover are engaged with the base, and the optical port or aperture and demand reset are properly aligned with their corresponding accessories on the register faceplate. If the cover is not correctly aligned, a demand reset or communications with the meter via the optical port or aperture will not be possible.

Do not power up the meter without the upper and lower housing properly secured in place. Line-level voltages are present inside the housings. Failure to follow this procedure could result in serious personal injury or death.

Battery (TOU and Load Profile Versions)

For initial installation, the battery may be installed with the meter power on or off. Replacement of a battery may be done with the meter power on or off. Make sure that the upper housing is secured to the lower housing (base assembly) prior to applying power to the meter.

1. Remove the connector housing located at the six o’clock position on the front of the meter faceplate (upper housing).
2. Install the two-pin battery connector into the connector housing as shown in Figure 2.4, making sure that the battery connector is flush with the connector housing.

3 Plug the connector housing with the installed battery connector back into the front of the meter faceplate (upper housing), and then snap the battery into the side support of the meter as shown in Figure 2.5.

Figure 2.4 Connecting the Battery

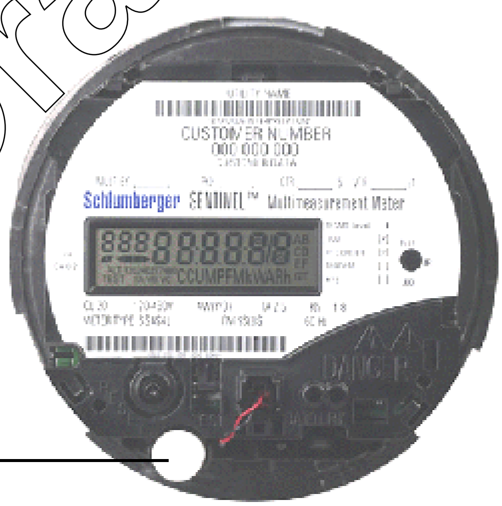


Figure 2.5 Battery Installed

Programming

The battery should be connected, if applicable, and the meter must be powered up prior to programming. The meter can be programmed through the cover using the optical port. The communication baud rate for the optical port is 9600.

Refer to the *PC-PRO+ 98 SENTINEL Device User's Manual* for detailed instructions for programming the SENTINEL meter.

Notes:

Chapter 3 Operating Instructions

This chapter describes the basic operation of the SENTINEL meter. It also explains how to configure the SENTINEL while providing detailed information on energy and demand multi14measurement functions, as well as TOU, load profile, KYZ, and communications board options.

Controls and Indicators

All controls and indicators are shown in Figure 3.1.

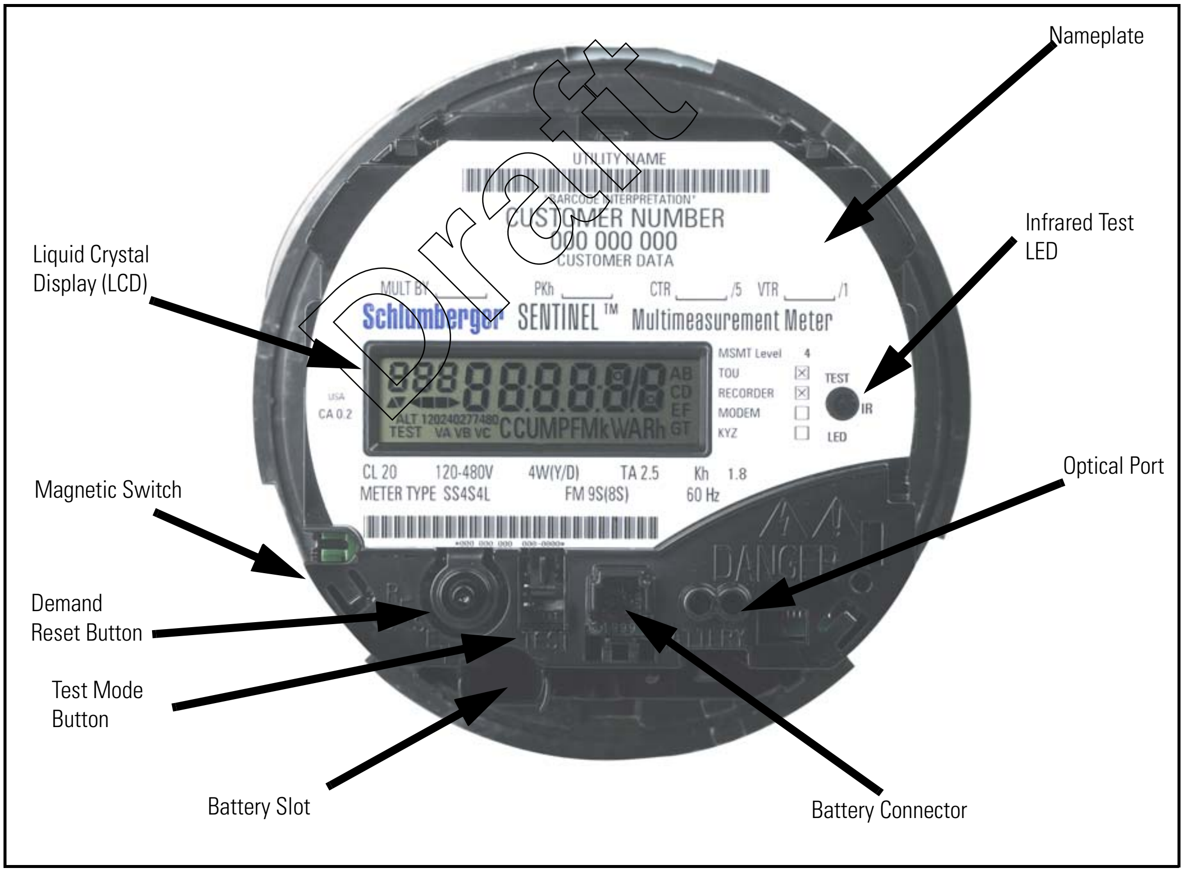


Figure 3.1 Controls and Indicators of the SENTINEL Meter

Demand Reset Button

The demand reset button is located at the 7 o'clock position on the meter face. The demand reset mechanism is used to initiate a demand reset. The demand reset cover mechanism can be physically locked with a meter seal. The reset mechanism can also be disabled by the meter programming software.

There are two methods of triggering a demand reset. When the demand reset button is pressed, a demand reset is immediately performed. A demand reset can also be done using the system programming software communicating directly with the meter.

The following actions occur with a demand reset:

- 888 888888 is displayed on the LCD.
- The demand registers are processed and reset.
- The Demand Reset Count is incremented.
- A self read "snapshot" occurs.

The meter can be programmed with a demand reset lockout time. This is the minimum time required to pass between demand resets configurable from 0 to 255 minutes. If a demand reset is attempted before this amount of time elapses since the last demand reset, the meter will not reset demands. This lockout time does not apply to software initiated demand resets.

If the demand reset button has been programmed to be disabled, the meter will not perform a demand reset when the button is pushed.

Infrared Test LED

One infrared LED is located at the 3 o'clock position of the meter nameplate. The LED can be configured to pulse based on any of the following energy quantities:

- Wh delivered, received
- Varh delivered, received, Q1, Q2, Q3, Q4
- VAh delivered, received (arithmetic or vectorial)

The Kh value, or energy per pulse, is also programmable for each selected quantity.

A different LED configuration is allowed for each of the following display modes: Normal, Alternate, Test, and Test Alternate. This test LED configuration redefines both the energy register programmed and respective pulse weights.

While in Toolbox Display Mode, the LED pulses the Normal Mode energy selection.

Liquid Crystal Display (LCD)

The SENTINEL meter features a versatile 9-character LCD display. The LCD with all segments lit is shown in Figure 3.2. There are several static indicators available on the LCD as described in Table 3.1.

Figure 3.2 SENTINEL LCD

Table 3.1 Static Indicators

Indicator	Description
◄■■►	Load Emulator (-> for positive, <- for negative)
888 888888	Nine digits (7 segments each) for display of alphanumeric information
VA, VB, VC	Indicators for phase voltages being present
▲▼	Reactive Load Indicator: No arrow for unity PF ▲ for positive [delivered] (lag) ▼ for negative [received] (lead)
120 240 277 480	Nominal Voltage Indicator (one value appears at a time)
EOI	End of Interval (Registers - Dmd)
Scr Loc	Scroll Lock (indicates temporary scroll lock of a display item)
SEL nor, SEL Alt, SEL tooL	Selection of Normal, Alternate, or Toolbox display sequence
nor diSP	Entry into Normal Mode.
TEST	Entry into Test Mode.
ALT TEST	Entry into Test Alternate Mode.

The indicators shown in Table 3.1 actually display in a digital readout font; some characters may display as upper case.

Magnetic Switch

The magnetic switch allows for manual switching between display modes as well as scroll lock of display items. To activate the magnetic switch, hold the magnet to the location shown in Figure 3.3 (magnet icon embedded in cover).

Figure 3.3 Activating the Magnetic Switch

Optical Port

The optical port is mounted on the meter cover. The optical port is a communication interface from the meter to a PC. Interface to a PC is accomplished through a DC TAP, AC powered, or port powered communication cable, which plugs into the optical port on one end and the PC's serial port on the other end. Communication through the optical port is at 9600 bps.

Test Mode Button

The Test Mode button is located in the lower center of the meter nameplate under the meter cover. Pressing the button activates Test Mode. Pressing the button a second time activates Test Alternate Mode, enabling the user to test a different energy quantity with the IR LED. Pressing the button a third time will exit Test Mode and activate the Normal display.

If the TEST button has been programmed to be disabled, the meter will not enter Test Mode when the button is pressed.

Application of Power and Power-up

To energize electronics, apply 120-480V (50/60 Hz) between A-phase and Neutral.

Do not power up the meter if the upper and lower housing are not properly secured. Line-level voltages are present inside the housings. Failure to follow this procedure could result in serious personal injury or death.

Power Down Procedures

To de-energize all electronics, remove power from the meter.

A power outage is recognized any time the line voltage drops 20 percent below the lowest nominal point of the voltage range. With a standard singlephase power supply, a power outage occurs when line voltage drops below 96 volts; with a polyphase power supply, a power outage occurs when line voltage drops below 45 volts. When a power outage is recognized, the SENTINEL meter saves all billing values to nonvolatile memory.

Demand Meter

Restoration of AC power energizes the electronics and causes the meter to perform self diagnostic check procedures. The meter then retrieves all billing data from non-volatile memory, begins measuring energy, and starts the process of calculating any demand values.

TOU/Load Profile Meters

During normal operation some data is stored in volatile (RAM) memory. When a TOU or Load Profile meter recognizes a power outage according to specifications, it begins battery carry-over operation. All program and billing data will be transferred to nonvolatile (EEPROM) memory. All circuits except the timekeeping circuit and battery-backed RAM are de-energized. The timekeeping circuitry powered by the lithium battery maintains real time during an outage.

Upon the return of AC power, the register undergoes a procedure similar to the initial power-up. The meter performs self-diagnostic checks, data is retrieved from non-volatile memory, and normal operation is resumed. The number of minutes of power outage maintained while the meter was in carry-over operation, is added to the Time on Battery register. Since the demand interval is synchronized to the top of the hour, the first demand interval after a power outage may be shorter than the programmed interval value.

Cold Load Pickup

Normally, when power is restored to the meter after an outage, a new demand interval is started and demand calculations begin immediately. The meter can be configured to recognize a demand delay or cold load pickup (CLPU) time. If a CLPU is configured in the meter, the meter will delay demand calculations for the configured amount of time—0 to 255 minutes. For example, if a CLPU time of five minutes is programmed into the meter, a power outage will cause the meter to wait five minutes after power restoration before resuming demand calculations.

Defining CLPU as zero will cause demand calculations to restart immediately after any recognized power outage.

Interval Make-up

Interval Make-up applies only to Load Profile meters.

Before the end of power-up processing, meter components that store interval data make up any intervals that may have been missed during the outage, to maintain the normal progression of interval end times. Intervals inserted, if warranted, for makeup are inserted with zero data and an outage status, if the length of the outage was greater than a programmable length. If the length of the outage was not greater than the programmed length, the interval does not contain an outage status.

Operating Modes

The SENTINEL meter has two operating modes: Normal Mode and Test Mode.

In the Normal Mode of operation, there are three display mode options: Normal Display Mode, Alternate Display Mode, and Toolbox Display Mode.

In the Test Mode of operation, there are two display mode options: Test Display Mode and Test Alternate Display Mode. See "Display Modes" on page 3-7 for more information on display modes.

When the meter is placed in Test Mode, it ceases all normal billing functions. The TEST switch can be used to control the operating mode of the SENTINEL meter.

Normal Mode

This is the standard mode of operation and the mode in which the meter automatically starts when energized. Selected quantities are measured and processed in billing registers. During this mode of operation, billing registers are saved in non-volatile memory during power outages.

Test Mode

The meter can be placed into Test Mode either by pressing the TEST button or through software communications. Manual use of the TEST button can be disabled via PC-PRO+ 98 software.

If the TEST button has been programmed to be disabled, the meter will not enter Test Mode when the button is pressed.

While in Test Mode, the “TEST” annunciator is displayed on the LCD. When the Test Mode is activated, all billing registers and certain non-billing registers are preserved in non-volatile memory until Test Mode is exited.

To exit Test Mode, press the TEST button. The meter will change display mode to Test Alternate. Press the TEST button again. The LCD will display “nor diSP” signifying the exit of Test Mode and entry into Normal Mode operation. The meter keeps a running total of the number of times Test Mode is entered.

Mode Timeout

If the meter is left in Test Mode, the meter will automatically exit after a user-configurable Mode Timeout. See the PC-PRO+ 98 online help for more information on configuring the Mode Timeout. This action prevents someone from accidentally leaving a meter in Test Mode and thus losing billing data.

Display Modes

The SENTINEL meter has five display modes as shown in Table 3.2: Normal, Alternate, Test, Test Alternate, and Toolbox. Each display mode has a separate list of items (quantities) it can display. The aggregate of items associated with a display mode is called a display list. Test and Test Alternate modes employ the same display list. All SENTINEL meters can display a maximum of 32 Normal, 32 Alternate, and 16 Test Items. The display items and sequence of display, along with any desired annunciators or ID code number, are selected during program setup, a feature of the PC-PRO+ 98 programming software.

Table 3.2 Modes Table

Operating Mode	Display Mode	Metrological LED Quantity
Normal	Normal (32 items user-selectable) Alternate Toolbox	Normal Mode LED Selection
Test	Test Test/Alternate	

The following types of displayable items are available for the user-defined display lists:

- Energy registers
- Demand registers
- Instantaneous registers
- Self Read
- SnapShot registers
- Informational items (non-billing items)

Numerical values may be displayed in various formats depending on configuration. For example, kilo units, mega units, fixed decimal point, floating decimal point, and leading zeros can all be configured.

The user may program the behavior that the meter should exhibit for every specific error condition. The possible actions in order of increasing severity are ignore the error (do not display the error code), scroll the error code (an error is automatically displayed after each display item), or lock the error, showing only the error code (do not display anything else).

Table 3.3 through Table 3.6 show, in alphabetical order, items programmable for display in the modes indicated. Detailed information about display items is also provided in the *PC-PRO+ 98 SENTINEL Device User's Manual*.

Energy Data

Table 3.3 Energy Data Display Items

Display Item	Display Mode			
	Normal	Alternate	Test	Toolbox
Wh (delivered, received, net)	X	X	X	
Varh (delivered [lag], received [lead], net delivered, net received, Q1-Q4)	X	X	X	
VAh (delivered, received)	X	X	X	
VAh lag (vectorial)	X	X	X	
Qh	X	X	X	
Vh (Phase A, Phase B, Phase C, Average)	X	X		
Ah (Phase A, Phase B, Phase C, Neutral)	X	X		
V^2h Aggregate	X	X		
A^2h Aggregate	X	X		

Demand Data

Table 3.4 Demand Data Display Items

Display Item	Display Mode			
	Normal	Alternate	Test	Toolbox
W Delivered (Max, Present, Previous, Projected, Cumulative, Continuous Cumulative)	X	X	X	
W Received (Max, Present, Previous, Projected, Cumulative, Continuous Cumulative)	X	X	X	
W Net (Max)	X	X	X	
Var Q1-Q4 (Max, Present, Previous, Projected, Cumulative, Continuous Cumulative)	X	X	X	
Var Delivered [lag: Q1+Q2] (Max, Present, Previous, Projected, Cumulative, Continuous Cumulative)	X	X	X	

Table 3.4 Demand Data Display Items

Display Item	Display Mode			
	Normal	Alternate	Test	Toolbox
Var Net Delivered [Q1+Q4] (Max, Present, Previous, Projected, Cumulative, Continuous Cumulative)	X	X	X	
Var Received [lead: Q3+Q4] (Max, Present, Previous, Projected, Cumulative, Continuous Cumulative)	X	X	X	
Var Net Received [Q2+Q3] (Max, Present, Previous, Projected, Cumulative, Continuous Cumulative)	X	X	X	
VA Delivered [arithmetic or vectorial] (Max, Present, Previous, Projected, Cumulative, Continuous Cumulative)	X	X	X	
VA Received [arithmetic or vectorial] (Max, Present, Previous, Projected, Cumulative, Continuous Cumulative)	X	X	X	
VA Lag (Max, Present, Previous, Projected, Cumulative, Continuous Cumulative)	X	X	X	
Max A (per phase: A, B, C)	X	X		
PF Average	X	X		
Min P.F.	X	X		
Coincident Demands (up to 4)	X	X		

Instantaneous Data

Table 3.5 Instantaneous Data Display Items

Display Item	Display Mode			
	Normal	Alternate	Test	Toolbox
Instantaneous W	X	X	X	
Instantaneous Var	X	X	X	
Instantaneous VA	X	X	X	
Instantaneous Volts (A, B, C)	X	X		X
Instantaneous Amps (A, B, & C)	X	X		X
Instantaneous Amps (N)	X	X		
Instantaneous P.F.	X	X		
Instantaneous Frequency (Hz)	X	X		
Instantaneous Current Phase Angles (A, B, C)				X
Instantaneous Voltage Phase Angles (A, B, C)				X

Information Data

Table 3.6 Information Data Display Items

Display Item	Display Mode			
	Normal	Alternate	Test	Toolbox
Calibration Date & Calibration Time	X	X		
Cold Load Pickup Outage Time	X	X		
Current Transformer Ratio	X	X		
Current Date & Current Time	X	X		
Days Since Demand Reset	X	X		
Demand Reset Count	X	X		
Demand Threshold 1-4	X	X		
Diagnostic Counters 1-5				X
Display On Time	X	X		
Firmware Revision #	X	X		
Last Outage Date & Last Outage Time	X	X		
Last Program Date & Last Program Time	X	X		
Last Reset Date & Last Reset Time	X	X		
Last Test Date & Last Test Time	X	X		
Load Research ID	X	X		
Last Season Self Read Registers	X	X		
Meter ID & Meter ID 2	X	X		
Minutes on Battery	X	X		
Normal Kh & Normal Kh #2 (Alternate Kh)	X	X		
Number of Subintervals	X	X		
Number of Test Subintervals			X	
Optical Port Last Interrogate Date & Optical Port Last Interrogate Time	X	X		
Outage Count	X	X		
Program Count	X	X		
Program ID	X	X		
Register Fullscale	X	X		
Register Multiplier	X	X		
Segment Test	X	X	X	
Self Read 1-4 Registers	X	X		
Service Type	X	X		
Snapshot #1 (@Last Reset) Registers & Snapshot #2 (@2nd Last Reset) Registers	X	X		
Software Revision Number	X	X		
Subinterval Length	X	X		
Test Kh & Test Kh #2 (Test Alternate Kh)			X	
Test Subinterval Length			X	
Time Remaining in Demand Subinterval	X	X	X	

Table 3.6 Information Data Display Items

Display Item	Display Mode			
	Normal	Alternate	Test	Toolbox
Time Remaining in Test Mode			X	
TOU Expiration Date	X	X		
TOU Schedule ID	X	X		
Mode Timeout	X	X	X	
Transformer Ratio	X	X		
User Data 1-3	X	X	X	
Voltage Transformer Ratio	X	X		
Option Board Fields 1 - 3	X	X		

Changing Display Modes

The magnetic switch allows for manual switching between display modes as well as scroll lock of display items.

The switch is located near the front of the meter face in the 8 o'clock position.

When a magnet is held to the switch for one second, "Scr Loc" appears on the LCD indicating that Scroll Lock can be enabled if the magnet is removed at that moment. When a magnet is held to the switch for four seconds, the display mode can be changed (^{SEL}nor, ^{SEL}ALt, ^{SEL}tooL) by removing the magnet when the desired mode appears on the display.

When the magnetic switch is activated for one second and removed, the "Scr Loc" message appears on the LCD and the display locks on the current display item. Whatever value is displayed on the locked screen will continue to be updated every second. The user may scroll to the next display item by again momentarily activating the magnetic switch.

Mode Timeout

When the display is put into display modes other than Normal display (Alternate, Toolbox, Scroll Lock, Test, or Test Alternate display modes), the meter will return to normal operation after a programmable Mode Timeout expires. The Mode Timeout can be configured from 1 to 255 minutes using the meter programming software.

Normal Display Mode

The Normal Display Mode is the default display when the meter is energized and when the meter is in Normal Operating Mode. When Mode Timeout occurs from any other display mode, the display returns to Normal Display Mode.

The Normal Display Mode list is user-defined and allows for 32 display items.

Alternate Display Mode

The Alternate Display Mode is functionally identical to the Normal Mode. The meter itself still operates under normal measurement, but the display sequence can be programmed to show a different set of displayable items from those in the Normal Display Mode. Like in the Normal Display Mode, a maximum of 32 displayable items can be viewed in the Alternate Display Mode.

While in Alternate Display Mode, the letters “ALT” appear on the LCD to designate activation of the Alternate Display Mode. Upon completion of the Mode Timeout period, the meter automatically returns to the Normal Display Mode.

Toolbox Display Mode

Toolbox Display Mode is identical to Normal Mode except that the list of displayable items is a fixed list dependent on the service type.

You can enter the Toolbox Mode from either Normal or Alternate Mode. While in Toolbox Mode, a flashing “TEST” appears on the left side of the display.

Once activated, the Toolbox Mode scrolls through the list of per phase items and diagnostic counters. See Table 3.7, Toolbox Mode Display List, for an example of a 3-element SENTINEL meter. For a more detailed discussion about the Toolbox Mode Display List, refer to Chapter 5, "Communications".

Table 3.7 Toolbox Mode Display List

Description	Display		
Phase A voltage angle	PhA	0.0°	U
Phase A voltage	PhA	xxx.x	U
Phase A current angle	PhA	xxx.x°	A
Phase A current	PhA	xxx.x	A
Phase B voltage angle	PhB	xxx.x°	U
Phase B voltage	PhB	xxx.x	U
Phase B current angle	PhB	xxx.x°	A
Phase B current	PhB	xxx.x	A
Phase C voltage angle	PhC	xxx.x°	U
Phase C voltage	PhC	xxx.x	U
Phase C current angle	PhC	xxx.x°	A
Phase C current	PhC	xxx.x	A
# of Diagnostic 1 errors	d1	xxx	
# of Diagnostic 2 errors	d2	xxx	
# of Diagnostic 3 errors	d3	xxx	
# of Diagnostic 4 errors	d4	xxx	
# of Diagnostic 5 errors	d5	xxx	

All “PhA”, “PhB”, “PhC” quantities are displayed with a fixed decimal and no leading zeros. The Load Emulator is not displayed while the diagnostic counters are displayed. The diagnostic counters are displayed with leading zeros (000-255).

The per phase Volt and Amp readings are Root-Mean-Square (RMS) values which are updated every second. The voltage and current angles are updated every five seconds. The direction of the load emulator is the same as the direction of energy flow for the phase being displayed. If any quantity is undefined due to the meter’s form, the per phase information for that quantity will be displayed as zeros.

If the magnitude of the current for that phase is too low, the current magnitude and angle for a particular phase (A, B, or C) are displayed as zeros.

The SiteScan diagnostic counters represent the number of times each diagnostic error occurred since the last time the counters were reset. (For detailed information about the SiteScan Diagnostic Checks, refer to Chapter 5, "Communications".)

The diagnostic counters range from 0 to 255 and can only be reset to zero through the PC-PRO+ 98 programming software.

Upon completion of the Mode Timeout period, the meter automatically returns to the Normal Display Mode.

Test Display Mode

The Test Mode can be accessed from either the Normal, Alternate, or Toolbox Mode by removing the meter cover and pressing the Test button.

To activate this mode with a programming device, refer to the appropriate software user's manual.

The Test Mode annunciator, "TEST" shown in Figure 3.2, is displayed while the SENTINEL meter is in Test Mode.

Activating Test Mode causes all billing data to be transferred to nonvolatile memory. Upon entry of Test Mode, if any of the present interval's calculated demand values are higher than the stored maximum demand values, the new values are stored as maximum demands. All Test Mode program parameters are then retrieved from nonvolatile memory for use in Test Mode. The parameters are demand test interval length, number of subintervals, and test Kh. Each is independent from those specified for Normal Mode. Activating the demand reset while in Test Mode initializes the demand test interval. (This interval is not synchronized to the top of the hour.)

To exit Test Mode and place the register in Normal Mode, perform one of the following:

- Press and then release the manual Test Mode button twice.
- Wait for selected Test Mode time-out to occur; if the meter is inadvertently left in Test Mode, it will return to Normal Mode at the completion of Mode Timeout.
- Removal of power for a brief period will force Test Mode to end.

Values calculated in Test Mode are not added to previous billing values or stored for retrieval. After exiting Test Mode, all billing data previously transferred to nonvolatile memory is retrieved, an end-of-interval (EOI) is initiated, and a new demand interval begins.

Any time-related activities, such as TOU rate changes or Daylight Savings Time (DST) changes that occur while the meter is in Test Mode, are performed upon exiting Test Mode.

Test Alternate Display Mode

Test Alternate Mode is functionally identical to Test Mode. To enter Test Alternate Mode, press the Test switch twice. The meter will return to Normal Mode at the completion of Mode Timeout.

Diagnostic Displays

The user may program the behavior that the meter should exhibit for every specific error condition. The possible actions in order of increasing severity are ignore the error (do not display the error code); scroll its error code (an error code is automatically displayed after each display item); or lock the display, showing only the error code (do not display anything else).

Registers

There are five register types in the SENTINEL: energy, demand, instantaneous, self read (or snapshot), and Information.

Energy Registers

The SENTINEL can measure numerous energy quantities (Table 3.8) from which the user can configure any eight to be registered.

Table 3.8 SENTINEL Energy Quantities

Measured Quantity Type	Phases	Directions
Watthours	aggregate	delivered received
Varhours	aggregate	delivered received net delivered net received per quadrant
VA-hours (vectorial or arithmetic [RMS])	aggregate	delivered received lagging
Volt-hours (Vh)	phase A phase B phase C average	
Amp-hours (Ah)	phase A phase B phase C neutral	
V^2h	aggregate	
A^2h	aggregate	
Q-hours	aggregate	delivered

Demand Registers

Demands can be calculated from any of the 8 selected energy quantities. The user can configure up to 10 demand registers. The SENTINEL can compute three types of demand: Block Demand, Rolling Demand, or Thermal Demand.

Table 3.9 SENTINEL Demand Quantities

Measured Quantity Type	Demand Registers	Phases	Directions
Watthours	Block, Rolling, Thermal	aggregate	delivered received
Varhours	Block, Rolling, Thermal	aggregate	delivered received per quadrant
VA-hours (vectorial or arithmetic [RMS])	Block, Rolling, Thermal	aggregate	delivered received lagging
Volt-hours (Vh)	no	phase A phase B phase C average	
Amp-hours (Ah)	Block	phase A phase B phase C neutral	
V^2h	no	aggregate	
A^2h	no	aggregate	
Q-hours	no	aggregate	delivered

Instantaneous Registers

The SENTINEL is capable of displaying Primary or Secondary Instantaneous registers, with the following exceptions: Frequency, P.F., and Phase Angles. The user can configure the CT and VT multipliers (transformer ratios) using PC-PRO+ 98 Programming Software.

Table 3.10 Instantaneous Registers

Quantity	Directions (Types) [Range]	Phases
W	Signed (+) Delivered or (-) Received	Aggregate
Var	Signed (+) Delivered or (-) Received	Aggregate
VA (Vectorial or Arithmetic)	None	Aggregate
V	None	A, B, C
A	None	A, B, C, N
PF	None	Average
Frequency	None	A
Phase Angles	Va = 0°	Vb, Vc, Ia, Ib, Ic

Self Read and Snapshot Registers

There are up to seven self-read registers available in the SENTINEL meter, depending on the particular version. All meters have two snapshot registers that store self read data triggered by a demand reset. Snapshot 1 is taken at the most recent demand reset. Snapshot 2 is the next most recent set of self read data at demand reset. Meters with time keeping functionality have an additional four self-read registers used for scheduled self-reads, and one Last Season self read register triggered at a season change in TOU meters.

Information Registers

The SENTINEL also stores a significant amount of informational data. These nonregistered values are listed in Table 3.11.

Table 3.11 Information Registers

Calibration Date	Last Program Date	Program ID
Calibration Time	Last Program Time	Register Fullscale
Cold Load Pick-Up	Last Reset Date	Register Multiplier
CT Ratio	Last Reset Time	Segment Test
Current Date	Last Test Date	Service Type
Current Day of Week	Last Test Time	Software Revision Number
Current Time	Load Research ID	Subinterval Length
Days Since Demand Reset	Meter ID	Test Kh
Demand Reset Count	Meter ID2	Test Kh #2 (Test Alternate Kh)
Demand Reset Lockout Time	Minutes on Battery	Test Subinterval Length
Demand Thresholds 1-4	Normal Kh	Time Remaining in Demand Subinterval
Diagnostic Counters 1-5	Normal Kh #2 (Alternate Kh)	Time Remaining in Test Mode
Display On Time	Number of Subintervals	Transformer Ratio
Firmware Revision Number	Number of Test Subintervals	User Data 1
Last Interrogation Date	Optical Port	User Data 2
Last Interrogation Time	Option Board Field 1,2,3	User Data 3
Last Outage Date	Outage Count	VT Ratio
Last Outage Time	Program Count	

Interrogation and Programming

Interrogation

The meter can be interrogated via the ANSI C12.18 optical port at a rate of 9600 bps using PSEM (ANSI C12.18-1996) protocol.

Programming

The software for programming this meter (PC-PRO+ 98/PC-PRO+ 98 Advanced) is a 32-bit Windows 98/NT/2000 application. User-definable security codes in both the programming software and the meter prevent unauthorized access to the meter.

Programming and/or interrogation of the meter can be accomplished through the optical port using a laptop PC and an optical probe.

Time-of-Use (TOU)

The Time-of-Use (TOU) functionality is designed for use in billing applications where multiple rates (bins) are required for energy and demand.

The TOU option can be added to measurement levels 1-4 of the SENTINEL meter. The TOU option is available in two levels:

- Basic TOU: 4 Rates + Total
- Extended TOU: 7 Rates + Total

TOU Schedules

Schedule information is programmed using the PC-PRO+ 98 Programming software.

When using the TOU functions of the meter, energy and demand registrations are segmented into time blocks during the day. Each time block is assigned one of four (or one of seven) rate periods. In addition to these four (or seven) rate periods, a total rate is always available.

Calendar Schedule

The calendar schedule contains all daily and yearly information needed for the meter to measure and register data in real time. The schedule contains daily patterns, seasons, and holidays with programmable day types, and rates and outputs. For information concerning the entry of these parameters into the PC-PRO+ 98 software package, consult the *PC-PRO+ 98 System Manual*.

Rates

Four (or seven) independent rates are available for TOU registration. These are designated A, B, C, and D (or A, B, C, D, E, F, and G). Only one of these rates can be active at a time. The Total register, designated Rate **T**, is always active, regardless of the active rate period.

The SENTINEL TOU rates are applied to all energy and demand registers that have been selected for measurement. Therefore, all energy and demand registers are segmented as per the TOU schedule and available in each rate period, in addition to the Total rate.

Daily Patterns

Up to four daily patterns are available. Each pattern defines the times during the day that rate period A, B, C, or D (or A, B, C, D, E, F, or G) begins and ends. Up to 24 rate period changes may be specified for each daily pattern.

Day Types

There are four day types: Weekday, Saturday, Sunday, and Holiday. Each day of the week is assigned to one of the four day types. Each day type is assigned one of the four daily patterns when each season is defined. Any of the daily patterns can be used in any combination with the day types.

Seasonal Schedules

A season is a period of weeks during the year when a particular rate is in effect. The year can be divided into a maximum of eight seasons. The day types with associated daily patterns can be defined differently for each season. Up to eight season change dates are specified for each year in the calendar schedule. If multiple seasons are not used, the TOU schedule contains one year-round season.

Season changes occur at midnight of the season change date (where midnight corresponds to 00:00 hours) or can be designated through programming to occur at the first demand reset following the season change date.

TOU Registers

The SENTINEL meter can measure up to eight energies and ten demands. When the meter is configured for a TOU calendar, all energies and demands that are selected for measurement also have the configured TOU rates applied to them, with the exception of previous, projected, and instantaneous registers. The TOU energy and demand registers are available for display as well. Cumulative and Continuous Cumulative registers are not TOU functions of the SENTINEL meter.

Current Season Registers

All energy and demand registers selected are considered current season registers. If a single rate schedule is applicable year-round, then only current season registers are used.

Last Season Registers

Last season registers are available when two or more seasons are used during the year. For every current season register (with the exception of Cumulative and Continuous Cumulative registers), there is a last season register for the same quantity. Last season registers are designated “LS” in the programming software. Last season registers can be selected for display in Normal and Alternate Display Lists.

TOU Operation

This section describes TOU operation specific to the meter display. Several TOU indicators are available on the liquid crystal display (LCD).

Rate Annunciators and Active Rate Indicators

Rate annunciators are available with each demand and energy register. An A, B, C, or D (Basic TOU) or an A, B, C, D, E, F, or G (Extended TOU) will appear on the far right side of the LCD (see Figure 3.2 on page 3-3) to indicate the rate period for each quantity being displayed. The rate annunciator that will be displayed for the Total Rate is **T**.

If the rate annunciator is flashing while a demand or energy value is displayed, the annunciator indicates that it is the current rate in effect. This gives a quick indication that the register is programmed with the correct TOU schedule and that it is currently storing the correct time.

Season Change

At the end of a specified season, all last season registers are updated with current season register data. The meter can be programmed to activate an automatic demand reset at season change. A season change occurs at midnight at the end of the programmed season change date or at the first demand reset following the season change date, depending on how the meter has been programmed. Some utilities program the season change to occur at the first demand reset following the season change date to make season changes concurrent with the meter reading cycles.

The following events take place when an automatic demand reset occurs at a season change:

1 The current season energy registers are copied directly to the last season energy registers.
2 The current season maximum demand registers are copied directly to the last season maximum demand registers, and **T** rate is added to the cumulative demand register.
3 After the demand reset, the maximum demand registers are reset to zero, and the **T** rate cumulative demand register is copied to the last season cumulative demand register.

If there is no demand reset at season change, all current season registers are directly copied to last season registers at season change, but no current season registers are zeroed.

Battery Carryover

When the meter recognizes a power outage, it begins battery carryover operations. All billing data is transferred to nonvolatile memory at this time, and all circuits, except the timekeeping circuit, are de-energized. Load Profile data is transferred to non-volatile memory only if there is a full block of data (128 intervals). The timekeeping circuitry, powered by the lithium battery, keeps time while the meter is in battery carryover mode.

Upon restoration of AC power, all self-diagnostics are completed, and all data is retrieved from nonvolatile memory. The real time is retrieved from the real time clock. The elapsed time of the outage is also added to the stored value for the time spend on battery.

Load Profile

Load Profile (mass memory) data is stored in blocks (records) of 128 intervals. The profile interval length is the same for all channels and is independent of the interval length for demand quantities. Each interval of load profile data is identified by date and time. Each interval contains status bits indicating the occurrence of outages, Test Mode, and other significant events or errors. Refer to the PC-PRO+ 98 online help for a list of Load Profile Status Codes. Register readings are also stored for each channel for data validation.

The Load Profile functionality is designed for use in billing and load research applications where multi-channel high resolution data is needed. The load profile option can be added to measurement levels 1-4 of the SENTINEL meter. Load profile does not require Time-of-Use to operate.

Load Profile Specifications

Capacity

The load profile option is available in two sizes: 48 kBytes or 96 kBytes of memory. The amount of memory actually used for load profile recording is programmable in 1 kByte increments (1-48 or 1-96). In both load profile options, there are up to 8 channels available for interval load profile data.

Bit Resolution

The load profile operates with 16-bit data resolution. Equivalent pulse count resolution is as follows:

Bits	Pulse Counts
16	65,535
15[1]	32,767

[1] When a Net quantity (i.e., Net Wh) is chosen as a load profile channel, all load profile channels have 15-bit data resolution.

Interval Lengths

The load profile records data on a block interval basis. The interval length is programmable for 1, 2, 3, 4, 5, 6, 10, 12, 15, 20, 30, or 60 minutes. The interval length is the same for all channels and is independent of the interval length for demand quantities.

Power Outage

The SENTINEL meter flags an interval when a power outage exceeds a specified number of seconds. The range for power outage length is programmable from 0 to 255 seconds and must not exceed the programmed interval length.

Channel Configuration

The SENTINEL meter can be programmed to have one to eight channels of interval load profile data. Each channel corresponds to an energy register selected during the programming process. In order to load profile an energy, the energy must first be selected as a quantity to be measured.

Selection of channel configuration and pulse constants is accomplished through the programming software. Each data channel is programmed to record load profile data from user-selected register. The energy registers allowed for load profile are listed in Table 3.3 on page 3-8.

Pulse Constants

For each load profile channel, the pulse constant is programmable from 0.025 to 10 unithours per pulse in 0.025 increments. As with the KYZ pulse output constants, the load profile pulse constants apply to secondary readings only.

Example: Calculation of pulse weight from kWh

A SENTINEL meter, 3-element, 120 Volts, CL20 is programmed to record kWh in load profile with 15 minute intervals.

First, calculate the maximum watthour accumulation during 15 minute intervals:

$$Wh_{max} = (120V) \times (20A) \times (3\ \text{phases}) \times (0.25\ \text{hours})$$

$$Wh_{max} = 1,800\ \text{watthours}$$

The maximum number of pulses is 65,535; therefore, the smallest pulse weight (PW) that can be used is:

$$PW_{min} = \frac{1800\ \text{Wh}}{65,535} = 0.0275$$

Since the pulse weight value must be a multiple of 0.025 in the SENTINEL, therefore 0.05 Wh could be programmed as the pulse weight (Ke) for the kWh channel in load profile in this example.

Data Storage

The SENTINEL meter uses non-volatile flash memory to record load profile data. Data is stored in load profile memory at the end of each interval. Each channel has 16 bits written to load profile memory. For example, consider 8 channels of load profile. At the end of an interval, a 16-bit number is written into load profile memory for channel 1; a 16-bit number for channel 2 follows immediately; and so on, up to the last 16-bit number for channel 8, which follows immediately.

The process continues for each interval until 128 intervals (one block or record) have been recorded. In addition to the profile data, each interval contains eight types of status bits written into each data interval.

1 **Partial Interval**—The status bit is set for a partial interval due to a time adjust, power outage, or beginning interval.

2 **Long Interval**—The status bit is set for a long interval due to a time adjust backwards.

3 **Skipped Interval**—The status bit is set for a skipped interval due to either a power outage, Test Mode, or time adjusted forward during the interval.

4 **Test Mode**—The status bit is set for Test Mode due to the meter being in test mode during the interval.

5 **DST**—The status bit is set for DST due to DST being in effect during the interval.

6 **Power Outage**—The status bit is set for each interval during which a power outage occurs (greater than the minimum time programmed in software).

7 **Time adjust forward**—The status bit is set for time adjust forward during the interval.

8 **Time adjust backward**—The status bit is set for time adjust backward during the interval.

Refer to the PC-PRO+ 98 Online Help for a list of Load Profile Status Codes.

In addition to the interval profile data and the interval status data, each block contains a time tag specifying the month, day, hour, and second of the end of the data block.

Recording Duration

The following equation can be used to determine the recording duration of the load profile:

Recording Duration (days) = (M x I x 1024) / (1,440 x [(2 x C + 2) + ((6 x C + 4) / 128)])

M = Memory size in kilobytes

C = Number of channels

I = Interval Length in minutes

Table 3.12 shows the recording duration for 48 kilobytes (KB) load profile memory size; Table 3.13 shows the recording duration for 96 KB load profile memory size.

Table 3.12 Recording Duration (in days) for 48 KB of Load Profile Memory

Recording Duration (48 KB)	INTERVAL LENGTH (Minutes)											
Number of Channels	**1**	**2**	**3**	**4**	**5**	**6**	**10**	**12**	**15**	**20**	**30**	**60**
1	8	17	25	33	42	50	84	100	126	167	251	502
2	6	11	17	22	28	33	56	67	84	111	167	334
3	4	8	13	17	21	25	42	50	63	84	125	251
4	3	7	10	13	17	20	33	40	50	67	100	200
5	3	6	8	11	14	17	28	33	42	56	83	167
6	2	5	7	10	12	14	24	29	36	48	72	143
7	2	4	6	8	10	13	21	25	31	42	63	125
8	2	4	6	7	9	11	19	22	28	37	56	111

Table 3.13 Recording Duration (in days) for 96 KB of Load Profile Memory

Recording Duration (96 KB)	INTERVAL LENGTH (Minutes)											
Number of Channels	**1**	**2**	**3**	**4**	**5**	**6**	**10**	**12**	**15**	**20**	**30**	**60**
1	17	33	50	67	84	100	167	201	251	335	502	1004
2	11	22	33	45	56	67	111	134	167	223	334	669
3	8	17	25	33	42	50	84	100	125	167	251	501
4	7	13	20	27	33	40	67	80	100	134	200	401
5	6	11	17	22	28	33	56	67	83	111	167	334
6	5	10	14	19	24	29	48	57	72	95	143	286
7	4	8	13	17	21	25	42	50	63	83	125	250
8	4	7	11	15	19	22	37	45	56	74	111	223

Event Log

The SENTINEL meter has an Event Log that allows for the recording of historical events that have taken place in the meter. The events that can be logged must be configured via the PC-PRO+98 programming software.

In order to have date and time associated with an event, Time-of-Use or Load Profile is required. A Demand-only SENTINEL meter allows for event log recording, however the date and time will not be retained in the event of a power outage.

The SENTINEL Event Log is circular in nature, allowing for the capture of the most recent events in the meter at all times. The SENTINEL is capable of retaining a minimum of 188 events and a maximum of 412 events prior to wrapping, depending upon the size of the events that are captured in the Event Log.

Each event log record includes an event description, a time and date stamp, and additional information on certain events.

The Event Log is written to non-volatile memory periodically. In the event of a power outage, the four most recent events are maintained along with the events already stored in memory.

The contents of the event log can be viewed using the meter programming software. Refer to the *PC-PRO+98 SENTINEL Device User's Manual* for information on viewing the SENTINEL Event Log.

The following events may be configured for recording in the SENTINEL Event Log:

- **Clear Billing Data**—billing data has been cleared upon initialization of the meter, or as a secondary activity by authorized personnel
- **Configuration Error**—meter configuration was not successful
- **Demand Reset**—a demand reset occurred
- **Demand Threshold Exceeded**—a demand exceeded a configured demand threshold
- **Demand Threshold Restored**—a demand restored below a demand threshold after exceeding it
- **Diagnostic 1 On**—diagnostic 1 condition occurred
- **Diagnostic 1 Off**—diagnostic 1 condition went away
- **Diagnostic 2 On**—diagnostic 2 condition occurred
- **Diagnostic 2 Off**—diagnostic 2 condition went away
- **Diagnostic 3 On**—diagnostic 3 condition occurred
- **Diagnostic 3 Off**—diagnostic 3 condition went away
- **Diagnostic 4 On**—diagnostic 4 condition occurred
- **Diagnostic 4 Off**—diagnostic 4 condition went away
- **Diagnostic 5 On**—diagnostic 5 condition occurred
- **Diagnostic 5 Off**—diagnostic 5 condition went away
- **DST Time Change**—DST adjustment forward or backward has occurred
- **Event Log Cleared**—Event Log was cleared by programming software
- **Full Scale Overflow**—see page 7-12: Non-fatal Error 6 for description
- **Input High**—(I/O) a KY input switched from low to high
- **Input Low**—(I/O) a KY input switched from high to low
- **Option Board Event**—R300 or modem board is active
- **Load Profile Error**—see page 7-11: Non-fatal Error 5 for description
- **Logon Successful**—a user or option board logged on successfully to the meter
- **Loss of Phase**—see page 7-11: Non-fatal Error 2 for description
- **Loss of Phase Restored**—phase voltage was restored
- **Low Battery**—see page 7-11: Non-fatal Error 1 for description
- **Meter Reprogrammed**—meter was initialized or reconfigured
- **Power Outage**—power was lost
- **Power Restored**—power was restored
- **Register Self Read**—self read occurred
- **Reverse Power Flow**—see page 7-11: Non-fatal Error 4 for description

- **Reverse Power Flow Restored**—delivered power flow resumed after reverse flow occurred
- **Season Change**—TOU season change occurred
- **Security Fail**—logon with security code failed
- **Security Pass**—logon with security code succeeded
- **Test Mode Entered**—Test Mode or Alternate Test Mode was entered
- **Test Mode Exited**—Test Mode or Alternate Test Mode was exited
- **Time Changed**—a time adjustment forward or backward occurred
- **TOU Schedule Error**—see page 7-11: Non-fatal Error 3 for description

Security Codes

The meter security codes provide protection for meter register and load profile data. Four levels of security are inherent in the SENTINEL meter. Table 3.14 describes the level of access to the meter provided by each device security code. Once security codes are programmed and stored in the meter, users are required to logon to the meter with an appropriate password. The user may choose not to use security codes in the meter's program.

Table 3.14 SENTINEL Security Code Levels

Level	Access Level	Description
Primary/Firmware Download	Read/Write access and firmware download	Access to the meter is unrestricted. All read/ write functions are available including all programming options, the ability to download new firmware to the meter, and upgrade or downgrade MeterKey features. New security codes can be programmed into the meter using the level of access provided by this security code.
Limited Reconfigure	Read/Limited Write access	Provides read and limited write access including the ability to reset demand, change the time in the device, and reconfigure the device. You cannot clear billing data, change display modes, or change security codes.
Secondary	Read-only access plus Demand Reset and Reset Time	Read-only access is provided as well as the ability to reset demand and change the time.
Tertiary	Read-only access	Access to the meter is limited to reading information from the meter. No operation that writes information to the meter is available. This code can be used by other applications that contact the meter.
Previous Security Code	Read-only access	This code is not programmed into the meter; it allows a user to log on to the device for read-only access.

Implementing Security Codes

When a customer file is created, security codes are entered by the software (PC-PRO+ 98) operator. Each security code may be from 1 to 20 characters long. For example, the primary code is selected to be ABC and the secondary code is to be 123. When the software first attempts to communicate with a meter that has just been delivered from the factory, the meter has only null security codes. The software downloads and unlocks the meter with these null security codes. When the meter is initialized, the software downloads security codes ABC and 123 to the meter.

When unlocking a meter with security codes, the software downloads the primary code that is in the PC-PRO+ 98 Device Security Codes dialog— in this case ABC. If this code matches the meter primary code, the operator can read and/or program the meter. If it does not match the primary, but matches the secondary, 123, the operator can only read data from the meter.

For example:

Three PCs are set up to interrogate SENTINEL meters. One PC is designated as the Master PC. The Master PC programs SENTINEL meters for installation and interrogates meters in the field. In this example, the Master PC programs a meter with a primary security code of SEN1 and a secondary security code of 222. The Master PC can then read data from and reprogram the meter. The remaining two PCs are configured so that the same customers are in each database, but each PC-PRO+ 98 software is configured with a security code that matches the meter's secondary security code only. In this case, the two additional PCs have been given security code 222. When the two PCs interrogate the meter, the security code they download provides them with secondary security code privileges only.

To set up a meter so that the Master PC can perform all meter functions, but any other PC has limited access, program the meter through the Master PC with a primary security code, but leave the secondary security code blank. Any PC other than the Master PC will connect to the meter using a blank security code and thereby gain secondary access only.

Clearing Security Codes—Customer Default Mode

To clear the existing security codes in the meter, return the meter to the Customer Default Mode. See "Firmware Upgrades" on page 3-27.

If security codes are cleared from the meter in this manner, the PC will have no record of a security code change. The PC will go through the following attempts to gain access to the meter:

- If the **Options | Default Values | Device Security Codes | Override Security Code** menu option ***IS NOT*** checked, PC-PRO+ 98 will:
    - a Use the security code in the device **Primary** field.
    - b Use the security code in the device **Previous Security Code** field.
    - c Use all nulls.
- If the **Options | Default Values | Device Security Codes | Override Security Code** menu option ***IS*** checked, PC-PRO+ 98 will:
    - a Use the security code entered in the **Security Code** field on the logon screen.
    - b Use the security code in the device **Previous Security Code** field.
    - c Use all nulls.

Firmware Upgrades

PC-PRO+ 98 5.1 and higher supports upgrading firmware for SENTINEL meters. When the firmware is upgraded, all billing data in the meter is erased. After a meter's firmware is upgraded, you must reinitialize the meter.

In order to upgrade firmware on a SENTINEL meter, you must first install the SENTINEL firmware on your computer. PC-PRO+ 98 can then be used to communicate with a meter and download the firmware to the meter. Refer to the *PC-PRO+ 98 SENTINEL Device User's Manual* for specific instructions.

After you have installed the SENTINEL firmware on your computer, if you attempt to initialize a SENTINEL meter that has a different version of firmware, a message is displayed stating that the firmware in the meter is different and asks if you want to change the meter firmware.

This feature is not available for meters that have been initialized (sealed) for Canadian installations. If a Canadian meter has not been sealed, the firmware can be upgraded.

Installing SENTINEL Firmware on the PC

You must install the SENTINEL firmware on your computer to make it available to PC-PRO+ 98. You can obtain firmware upgrades through your SchlumbergerSema Sales Representative. You can install only one version of SENTINEL firmware on a computer.

For more information, refer to your PC-PRO+ 98 online help files and other documentation.

Notes:

Chapter 4 Theory of Operation

This chapter explains the operating theory of the SENTINEL multimeasurement electronic meter. The first two subsections describe the main circuit boards of the meter and the associated functions. Subsequent sections describe the measurement and calibration techniques and the packaging architecture.

Meter Platform

The meter platform consists of sensors, metrology, and registers as depicted in the SENTINEL block diagram shown in Figure 4.1.

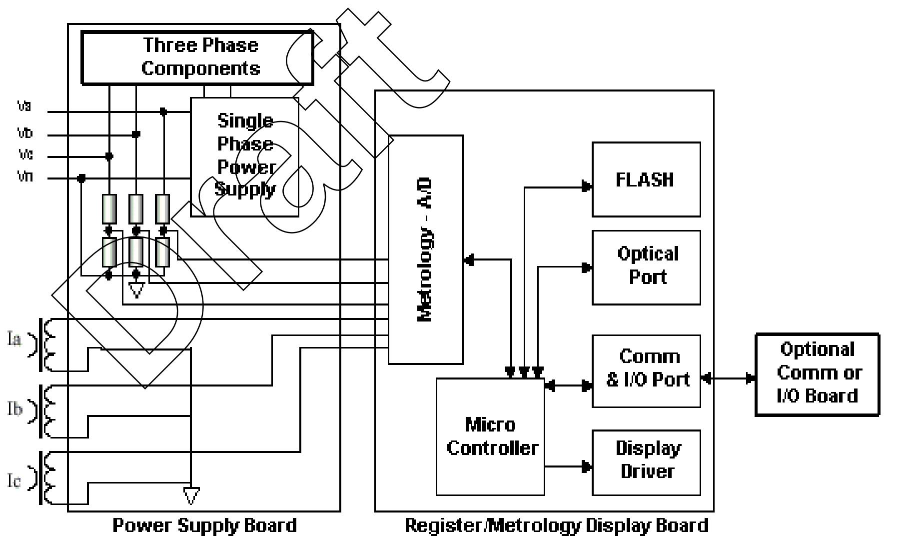


Figure 4.1 SENTINEL Meter Block Diagram

The sensors are current transformers and resistive voltage dividers as used in the SchlumbergerSema VECTRON® meter. As a result of using non-isolated voltage sensors, the internal ground plane of the meter is connected to the meter's neutral, which in some services is at line potential.

The metrology is Cosmos-Poly-Complex (CPC), consisting of a six-channel delta-sigma converter and a digital signal processor.

There are three serial data ports for connection to the optical port, the metrology, and for future connection to a communication or I/O module (optionally installed).

Meter Architecture

The electronic portion of the SENTINEL meter consists of a main circuit board connected with a ribbon cable to a power supply circuit board. These circuit boards are housed in a single module called the upper housing.

SENTINEL meters configured with any of the numerous output options contain an additional circuit board which is installed between the upper housing assembly and the lower housing. Connection between the option board and the main board is achieved through a single ribbon connector. The resulting package is a compact and aesthetically appealing configuration for all applications.

Main Board

The main board contains all of the low voltage circuitry for the meter. It is a surface mount four-layer design utilizing all solid-state general purpose integrated circuits. This design provides excellent transient noise immunity and enhanced reliability. The circuitry on the main board can be described in five sections: register, metrology, display, communication ports, and switches as shown in Figure 4.2.

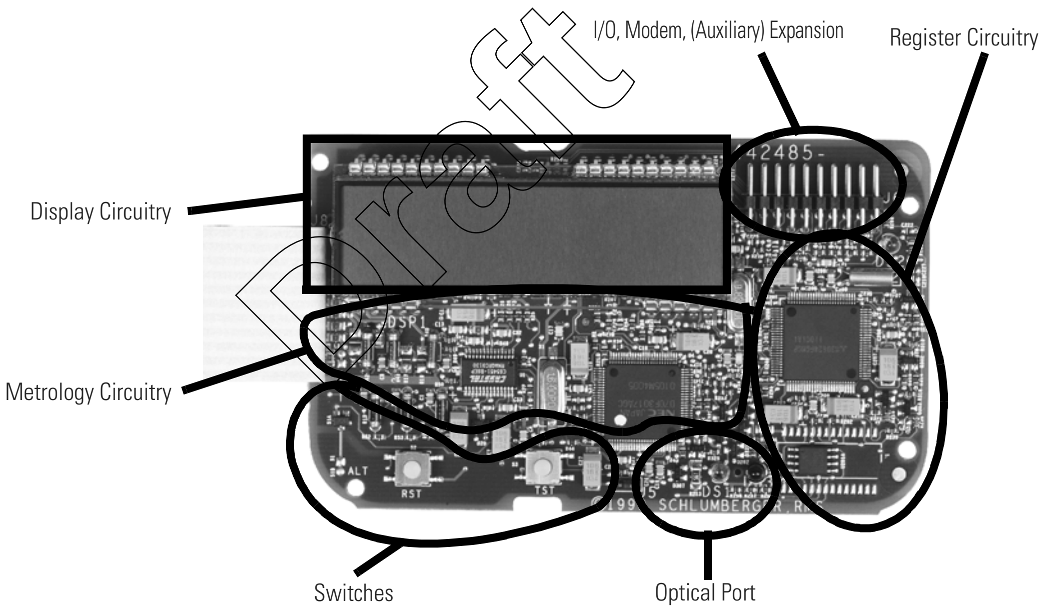


Figure 4.2 Main Circuit Board

Register

The register performs the primary functions of the meter including energy, demand, time-of-use, and load profile. It is comprised of a microprocessor connected to a non-volatile memory. The microprocessor includes on-chip flash memory where the firmware resides. This memory is non-volatile, but is re-writable to allow firmware upgrades in the shop or field. The microprocessor performs all the control, calculation, communication and data storage functions associated with the register function.

The microprocessor is connected to an off-chip non-volatile memory. This device stores all the measurement data including load profile and event/history logs.

In TOU/Load Profile versions of the meter, the power to the register microprocessor is battery backed. This allows the microprocessor to directly perform the real-time clock function (keeping accurate time and date through outages). The battery does not back the power to any other component on the board. For demand-only functionality, the battery is not needed.

Metrology

The metrology performs the direct sampling of the voltage and current waveforms and the raw processing of these samples to compute all the energy quantities. It is comprised of a dedicated microprocessor and six analog-to-digital (A/D) converters. Low level signals proportional to the service voltages and currents are connected to the analog inputs of the A/D converters. These converters, which are contained in one package, simultaneously sample the signals and send the digital result to the microprocessor 1,953 times per second. The microprocessor takes these samples, applies precision calibration corrections and computes all the fundamental quantities required for the specific meter configuration.

Every second, the register processor requests data from the metrology processor. The metrology processor does not store any data at power-down.

Display

The display circuitry is contained on the main board shown in Figure 4.2 and is mounted in the upper housing so that the LCD is exposed through a window in the housing. The LCD is driven by an application-specific driver that keeps the information on the display clearly visible across the widest possible temperature range.

When power is first switched on, a hardware controlled reset signal is activated and the LCD is initialized with a “TEST” indicator in the lower left corner. This signifies that the meter is powering up and running diagnostics. The meter will then test the voltage on the line and verify that there is enough voltage present at the inputs to the meter so that normal operation can begin.

The display can be programmed for a segment test where all of the digits and annunciators are turned on. This allows ongoing verification of the integrity of the LCD and its driver. Unless programmed otherwise, new meters will only display this segment test. Temperature compensation circuitry is provided to maintain proper display contrast through wide ambient temperature changes. If extremely low temperature is expected, the programmable display on-time may need to be increased so that the LCD will have time to respond to different displays.

Communication Ports

The main board supports communication to the register processor through two ports: optical and auxiliary.

The optical port is comprised of an optical transmitter / receiver pair that are mounted on the main board so that they are communicable through the ANSI optical port on the front of the meter. Through this port, the meter can be configured, firmware can be upgraded, and all the meter's data can be read.

The auxiliary port is a UART (Universal Asynchronous Receiver and Transmitter) made available on three pins (GND, TX, RX) on the option board connector. This port is capable of 9600 Baud communication of all the meter data. This port will be utilized by a third party communication module when installed “under the cover”.

Switches and LED

There are three special purpose switches in the SENTINEL: Demand Reset, Magnetic, and Test. The microprocessor monitors each switch position continuously. If a change of state is detected, the appropriate control function is executed.

The function of each switch is described in the following sections.

Demand Reset Switch

When this switch is activated, the demand values are updated to include the current demand interval, a 'snap-shot' of the registers is stored, the peak demand values are added to the cumulative values, and the demand registers are cleared. The demand reset counter is incremented by one. A new demand interval is started. If the meter is battery backed, then the new interval will remain synchronized to the clock. If there is no battery, then the new interval will be synchronized to the demand reset.

Magnetic Switch

The function of the magnetic switch is twofold; it controls the display mode of the meter and scroll locks the display.

The scroll lock may be activated with the trigger of the magnetic switch. “ScrLoc” will be displayed on the LCD. The scroll lock “freezes” the display on its current quantity. This quantity is then updated once per second.

If the magnet is placed near the magnet icon on the front of the meter and quickly removed, the meter will display “ScrLoc”. The display can then be advanced to the next list item by passing the magnet by the icon on the meter. This applies to all display modes.

The magnetic switch also allows toggling between Normal, Alternate, and Toolbox display lists. To accomplish this, the magnet is held in place by the icon on the front cover for four seconds. The display will then scroll between “SEL nor”, “SEL ALt” and “SEL tooL”. If the magnet is removed while “SEL nor” is displayed on the LCD, then the Normal display list will begin. In the same way, if the magnet is removed while “SEL ALt” is displayed, then the Alternate display list will begin. And likewise, “SEL tooL” for the Toolbox display list. To return to Normal display Mode, activate the magnetic switch again, wait for “SEL nor” to be displayed on the LCD, and then remove the magnet.

The Normal and Alternate display lists are fully configurable. The Toolbox display list is fixed and provides useful service-specific information including per phase RMS voltage and RMS current values and their angles relative to phase A voltage. This information can be used to verify that the service is properly wired.

Test Mode Switch

In order to activate the Test switch, the cover must be removed. When the Test switch is pressed, the meter enters Test Mode and “tESt” appears on the LCD. When it is pressed a second time, the meter enters Test Alt Mode and “Alt tESt” appears on the LCD. When it is pressed a third time, the meter returns to Normal mode. Both Test Mode and Test Alt Mode have the same programmable display list. They only differ on the quantity that is pulsed by the LED.

While in Test Mode and Test Alt Mode, the magnetic switch may be used to scroll lock, but it will not change the display mode.

Test LED

The SENTINEL meter has an LED dedicated to generating pulses in proportion to selected energy quantities. The meter allows configuration of different quantities on the LED for each display mode: Normal, Alternate, Test and Test Alternate. This allows successive testing of multiple energy quantities without reconfiguring the meter. In Toolbox Mode, the LED pulses represent the same quantity as in Normal Mode.

Data Storage

Data storage is accomplished using non-volatile memory. The data storage function saves billing values during power outages, maintains the programming and calibration values, and stores the load profile data The advantage of using non-volatile memory technology is that the device does not have to be battery backed. This allows the SENTINEL meter to run longer on a battery than many other products.

Power Supply Board

The power supply board provides the +3 VDC for all analog and digital circuits within the SENTINEL meter. Additionally, it contains a capacitor that provides the energy necessary to store billing information in non-volatile memory upon an outage. Although they are not related to the power supply, resistor dividers for sensing the service voltages are located on the power supply board to keep all of the high voltage signals away from the register board circuitry.

A four-layer board has been designed for the power supply circuit. This board, working together with the electronic components, provides excellent power line surge, transient, and noise immunity.

The SENTINEL is available with a singlephase power supply that powers the meter from the A-phase service voltage, or a polyphase power supply that powers the meter from any phase service voltage.

The circuitry on the power supply board can be described in three sections: switching power supply, surge protection, and EMI filtering as shown in Figure 4.3 on page 4-6.

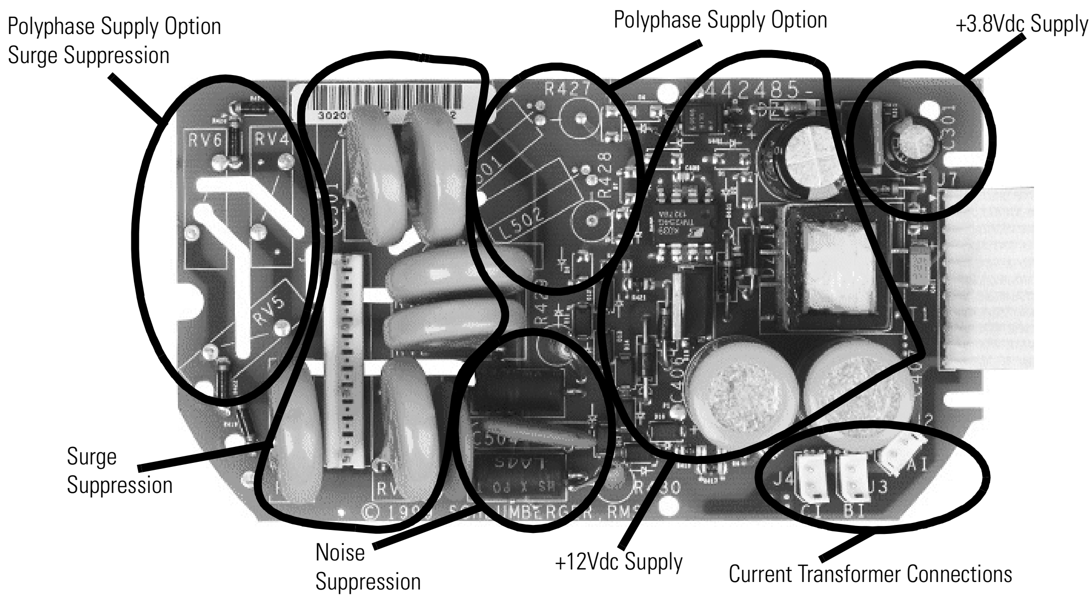


Figure 4.3 Power Supply Board

Switching Power Supply

The SENTINEL meter is not line isolated. The circuit board ground is electrically linked to the external meter neutral connection. The internal meter ground could be as much as 480V above earth ground in certain metering installations.

The switching power supply is a classic isolated flyback topology supply. This topology provides high power conversion efficiency and is optimal for wide-ranging input voltages. The immediate output of the switching supply is 12[Vdc]. The 12[Vdc] is linearly regulated to 3[Vdc] for the meter electronics.

A large capacitor on the 12[Vdc] output stores the energy needed to write billing data to non-volatile memory upon an outage.

Surge Protection

Surge protection for the electronics in the SENTINEL meter is provided by Metal Oxide Varistors (MOVs). MOVs are clamping devices that allow voltage up to a limit, and then increasingly conduct current to prevent the voltage from exceeding the limit. The MOVs on the power supply board are connected directly across the voltage inputs to the meter. Although this approach requires very large MOVs, it prevents high voltages from appearing on or near the electronic boards giving the SENTINEL superior performance when exposed to extremely high-voltage surges.

EMI Filtering

The EMI filtering prevents high frequency noise from the meter's power and digital circuits from radiating out onto the power lines. Resistors, inductors, and capacitors work together to provide the needed filtering.

Measurement Techniques

The SENTINEL uses voltage dividers to sense voltage and current transformers to sense current. Use of this type of voltage circuit requires that the ground for electronics be connected to line neutral. These sensors produce low-level signals that are exactly proportional to the service voltage and current. These low level signals are sampled simultaneously by 6 analog-to-digital converters packaged in a single device. The voltage and current waveforms from each meter phase are sampled 1953 times per second.

Special techniques employed in the digital sampling process ensure that the sample measurements track the waveform shape exactly, even when the normal 50/60 Hz sine wave becomes distorted. These techniques make the SENTINEL meter much more accurate than standard induction meters under high harmonic conditions because high frequency waveform components do not go undetected.

A dedicated microprocessor analyzes the rapid succession of voltage and current samples and computes instantaneous values and energy quantities. Because processing is done at the sample rate, the meter can determine both active and reactive power.

Another processor accumulates the desired active energy, reactive energy, demand, Time-of-Use (TOU), and load profile quantities. In addition, this processor maintains an LCD and real-time clock.

A current mode flyback switching power supply supports the SENTINEL meter's circuitry. The power supply provides +3 VDC for analog and digital circuit operation. SENTINEL meter functions are implemented in a combination of hardware and firmware. The operation of some of these functions depends on parameters that are programmed within the meter using PC-PRO+ 98.

Calibration

Factory calibration corrects for normal part-to-part variations for each component that impacts metrological accuracy. Although these components vary in initial value, they have been chosen by design to be stable over time and temperature. Field verification of the metrological accuracy can be done many ways, but field calibration is not required.

Factory calibration of the SENTINEL meter is accomplished by corrective digital signal processing. During the manufacturing process, precision instrumentation is used to compute correction coefficients for each phase under a variety of load and power factor conditions. At the end of the calibration, the correction coefficients are written into a protected non-volatile memory that can never be erased. The meter is then immediately verified for accuracy with the calibration coefficients applied.

Sampling

The six analog-to-digital converters sample each phase voltage and current signal every 512 µs (independent of the line frequency) and send the digital values immediately to the microprocessor. This amounts to approximately 32 samples per cycle at 60[Hz]. Each time a new set of digital samples are received by the microprocessor, it calculates all of the selected metrological quantities.

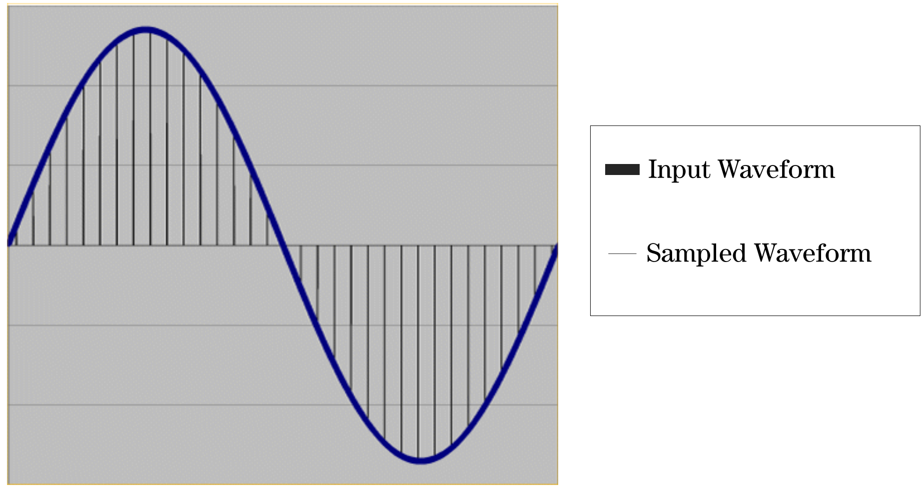


Figure 4.4 Input & Sampled Waveforms

At this sampling rate, harmonics to the 15th can be directly calculated. The high rate and simultaneous nature of the sampling enables the SENTINEL meter to measure energy quantities accurately under high harmonic distortion conditions.

The sampling continues uninterrupted as long as the meter is powered up. All other processing is done in the background between samples. From the continuous train of digital samples on each of the six channels, current, voltage, active energy, reactive energy, and apparent energy quantities are computed.

Voltage and Current Measurement

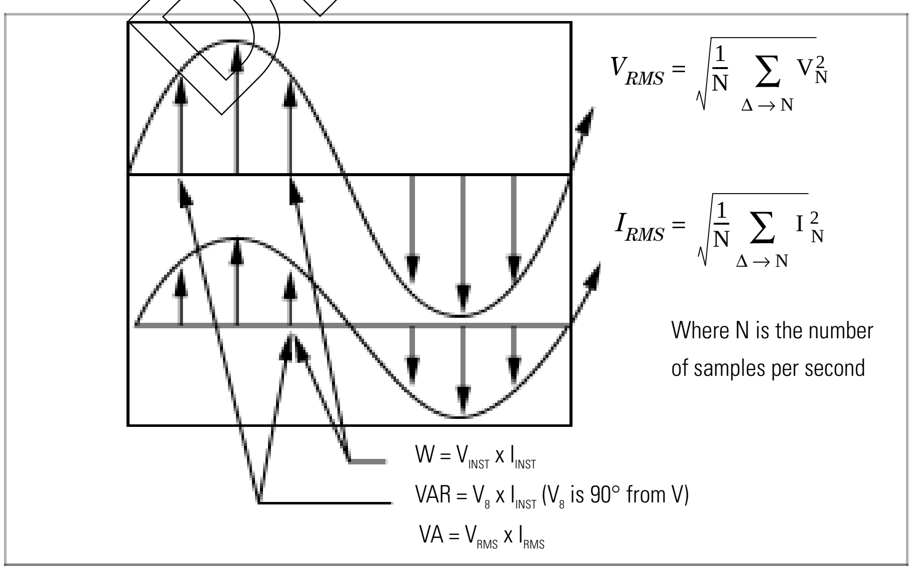


Figure 4.5 Accumulator

Watthour (Wh) Measurement

Watthours are measured by multiplying the instantaneous value of the voltage on each phase times the instantaneous value of the current on the same phase (Figure 4.5).

The resulting values are added to the Wh accumulator. After the completion of two cycles, the registers are compared to a threshold. This threshold represents 0.025 watthours. The value in the accumulator is then divided by this threshold, and the registers are updated accordingly. This means that under bidirectional measurement, if the consumption changes from delivered to received within one second, the meter will respond correctly to the change and accumulate in both the delivered and received registers. The SENTINEL meter can be programmed to register watthours either in the delivered quadrants only, or under bidirectional measurement, in the delivered and received quadrants. When only delivered watthours are measured, any negative watthour value is ignored. This has the same effect as a detent mechanism on an induction watthour meter.

When delivered and received watthours are measured, there will be one register for each quantity available—Wh delivered and Wh received, as well as one combined register—Wh net.

VARhour (Varh) Measurement

The Varhour Measurement is much like that of the Watthour measurement. The voltage sample buffer is created when the meter powers up. This buffer is up to 12 samples deep. The SENTINEL multiplies the current sample by a previous voltage sample. Since the sampling is not synchronized to the line frequency, as the frequency changes, the number of samples that the SENTINEL must shift is different. The meter also needs to correct for the phase difference between 90 degrees and the actual amount of phase error that is generated by the buffered samples. The SENTINEL metrology places the reactive energy into one of four quadrant registers based on the result of the accumulator after two cycles have been completed. These accumulators can also be configured as required to provide the various varh options such as varh delivered (Q1+Q2), varh received (Q3+Q4), varh net delivered (Q1-Q4), and varh net received (Q2-Q3).

Volt-amperehour (VAh) Measurement

The SENTINEL meter measures either Vectorial or RMS volt-amperes using arithmetic phase summation. The arithmetic method of measurement ensures that the resulting VAh value contains as much of the harmonic information as possible.

Volt-ampere values are calculated by multiplying the RMS voltage value times the coincident RMS current value (see Figure 4.5).

The voltage and current values from each phase are squared and then stored in their respective accumulators. At the end of one second, each accumulator contains the sums of the square of the voltages or currents for each phase. The contents of these accumulators are passed to the consumption routine where they are averaged (divided by the sample count) and the square root is taken, yielding the RMS voltage and RMS current for each phase.

Every second the RMS voltage and the RMS current for each phase are multiplied together to establish a VA-second value for each phase. These values are scaled and corrected.

The total Vahour value is calculated by adding the VA-second quantities for each phase and dividing the total by 3600. This value is added to the appropriate register. If the harmonics on the Voltage waveform differ from the harmonics on the Current waveform, then the harmonic energies will fall out of the Watthour and Varhour calculation, and thus the VA Vectorial measurement, but they will not fall out of the VA Arithmetic measurement.

The VA Vectorial and VA Arithmetic measurements will also differ when there is imbalanced power. Imbalanced power is generated when the phases of the service are not in balance with one another.

Qhour (Qh) Measurement

The SENTINEL meter calculates Qh from watthour and varhour values according to the following general formula:

$$Qh = \frac{Wh + \sqrt{3}Varh}{2}$$

The Qh measurement parallels the inherent characteristics of the electromechanical Qh meter.

Power Factor (PF) Calculations

The SENTINEL meter calculates four power factor quantities:

- **Instantaneous Power Factor**—This is the division of the Instantaneous kW value by the Instantaneous kVA value. It is calculated upon request.
- **Previous Interval Power Factor**—This is the division of the previous demand interval kW value by the previous demand interval kVA value. It is calculated at the end of each demand interval.
- **Minimum Power Factor**—This is the lowest previous demand interval power factor value calculated since last demand reset. This value is reset to 1.00 at a demand reset.
- **Average Power Factor**—When the demand reset is executed, the total kWh and total kVAh values at that time are stored in nonvolatile memory. When the average power factor value is displayed, these previously stored kWh and kVAh values are subtracted from the kWh and kVAh totals at the last end-of-interval (EOI). The differential kWh is divided by the differential kVAh, yielding the average power factor since the last demand reset.

Demand Calculations

To calculate demand, the selected quantities are accumulated over a programmable time period (1 - 60 minutes) depending on the programmed demand interval length. At the end of the interval, the accumulated values are stored in separate demand storage registers and the accumulating registers are cleared. Incremental values for the next demand interval are then accumulated.

The maximum demand in a billing period is determined by comparing the demand values for the most recently completed interval to the respective readings presently stored in the peak demand registers. If the previous demand is greater than the value in the corresponding peak demand register, the lower value (the maximum demand recorded so far) is replaced. If the previous demand is less than the value in the corresponding peak demand register, the maximum demand value remains unchanged. This update process is carried out when a demand interval is completed, when a power outage occurs, or when Test Mode is initiated.

The SENTINEL meter demand calculations are performed using one of three possible methods: block, rolling, or thermal emulation. The demand method is selected when the register is programmed.

Block Interval Demand Calculation

Block Demand calculations are based on user-defined interval lengths. The demand is the total energy accumulated during the interval divided by the length of the interval. At each end of interval (EOI), demand calculations are made and "EOI" can be displayed on the LCD.

For block interval, demand calculations are made at the end of each completed demand interval. This method is similar to the way mechanical demand meters operate. As load is applied to the demand register, an indicating pointer and maximum demand indicator are driven upscale. At the end of each interval, the indicating demand pointer is returned to the zero position, and the maximum demand pointer retains its highest or maximum position.

Rolling/Sliding Demand Interval Calculation

A selected number of subintervals make up the demand interval. At the end of each subinterval, new demand calculations occur based on the last full demand interval and "EOI" can be displayed on the LCD.

The following quantities can be selected for rolling demand: W d, W r, W net, Var Q1-Q4, VA d (arithmetic or vectorial), and VA lagging.

Block interval demand calculation is subject to peak splitting, whereby it is possible for an electricity consumer to manipulate the load for limited periods within the demand interval. The registered demand reading will be less than the actual maximum demand of the load.

To counter this situation, the concept of rolling demand was introduced. Rolling demand is calculated as follows:

1 For illustration purposes, assume a 15 minute billing demand interval with three five-minute subintervals has been selected. Then, at any given moment, the meter has three complete sets of five minute information available for demand calculations.

2 At the end of the present five minute subinterval, the information on the oldest five minute subinterval is discarded, and demand calculations are performed on the three newest sets of subintervals. In this manner, the SENTINEL meter with the rolling demand option updates the demand calculations every five minutes.

3 If the billing demand interval is 30 minutes with five minute subintervals, then six sets of five-minute information or updates will be used for calculating previous demand.

Thermal Emulation

The SENTINEL meter will emulate the response of a thermal demand meter for kW and kVA. This type of demand calculation is approximated exponentially. The meter will record 90% of a change in load in 15 minutes, 99% in 30 minutes, and 99.9% in 45 minutes. The four characteristics of a thermal demand meter that the SENTINEL meter will emulate are:

- Arithmetic phase summation
- Continuous rolling average demand
- Response calibrated to RMS values
- No End-of-Interval (EOI)

The following quantities can be selected for thermal demand: W d, W r, W net, Var Q1-Q4, VA d (arithmetic or vectorial), and VA lagging.

The demand registers are processed according to the demand type defined in the meter program. Most demand values are reset at a demand reset, but some provide other functionality. The types of demand values available are described in the following sections.

The thermal demand option has only one demand interval available. This interval length (response time) is 15 minutes. When you enter into Test Mode, this interval length is fixed at 1 minute.

Cumulative Demand Values

Cumulative demand is the summation of previous maximum demands after each demand reset. When a demand reset occurs, the maximum demand values are added to the existing corresponding cumulative demand values, and the sums are saved as the new cumulative demands. These values will not increase until the next demand reset. This feature not only protects the user from false or erroneous readings, but also provides the customer with extra security against tampering. Cumulative demand may be used for block, rolling and thermal demand types.

Continuous Cumulative Demand Values

Continuous cumulative demand is the sum of the maximum demand and the cumulative demand at any point in time. At the end of each demand interval, if a new maximum demand is reached, continuous cumulative demand will also be adjusted to reflect this new maximum demand value. A demand reset will clear the maximum demand value but will not affect the continuous cumulative demand. Continuous cumulative demand may be used for block, rolling and thermal demand types.

Present Demand

Present demand is the value that would be used if an EOI were to occur when the data is being viewed. It is calculated by dividing the accumulated energy in the current interval by the time of a full interval. For block demands, present demand starts at zero for each interval and ramps up to the demand value at the EOI. For rolling demands, the energy from the oldest subinterval is discarded and the present demand is calculated using the energy in the remaining subintervals and the energy in the current subinterval. At the beginning of a new subinterval, it drops by the demand of the oldest subinterval and ramps up to the demand value at the next EOI.

Present demand is not affected by a demand reset.

Previous Demand

Previous demand is the demand from the most recently completed demand interval. When a demand interval ends, the present demand is transferred to the previous demand. When using rolling demand, this quantity is updated after each subinterval. For thermal demand types, the previous demand value is equal to the present demand.

Projected Demand

Projected demand is an estimate of the demand the meter will have accumulated by the end of the current interval. This value is calculated by dividing the accumulated energy by the amount of time accumulated in the interval. Projected demand is calculated upon request. Projected demand is available for block and rolling demand only.

Peak Demand (Maximum Demand)

Peak demand is the largest demand value that has occurred during any demand interval since the last demand reset. At the end of a demand interval, the present demand is compared with the current maximum demand register. If the present demand is greater, it is transferred to the maximum demand. The maximum demand is reset to zero on a demand reset. The date and time of the maximum demand are also recorded. Maximum demand is used for block, rolling, and thermal demand types.

Multiple Peaks (1-5)

The SENTINEL can measure the top five maximum demands for the quantities selected. The quantities include W d, W r, W net, Var d, Var r, Var Q1-Q4, VA d, VA r, and VA lagging.

Minimum PF

Minimum PF is the lowest PF value that has occurred during any demand interval since the last demand reset. At the end of a demand interval, the “present” PF is compared with the current minimum PF. If the present PF is less, it is transferred to the minimum PF. The minimum PF is reset to one (1) on a demand reset.

Demand Thresholds

Table 4.1 describes parameters that define the configuration of demand thresholds. A threshold is a value against which a meter quantity is compared. If the quantity is beyond the threshold, an alarm is generated.

Table 4.1 Parameters, Threshold Alarms

Parameter	Description
Quantity	Selects the demand register to which this threshold will apply.
Threshold Value	Sets the limit for this threshold event to be activated. • The valid range for Power factor (PF) is 0.0 - 1.0 • The valid range for %THD is 0.00 - 99.99 (in 0.01 increments) • The valid range for all others is 1.0 - 500.000

Notes:

Chapter 5 Communications

This chapter describes the communication architecture of the SENTINEL meter.

The SENTINEL meter has one option board slot. Although there is only one slot, in some cases, the option board slot can contain more than one physical board.

The SENTINEL meter supports several different communication options. These include a modem, R300 Series boards, RS-232/RS-485 boards, a Multifunction Meter Module, and an Inputs/Output board. These options are described in the following sections of this chapter.

Modem Board

An optional 300/1200/2400 baud sensing internal modem provides telephone communication for data retrieval and programming of the SENTINEL meter. The SENTINEL modem will support the CCITT V.22bis 2400 telephone communication standard for initiating and receiving telephone calls.

Call Windows

Call windows are time ranges that determine when the meter will answer the phone or place calls to the master station. Different answer delays are available for inside and outside of call windows. The PC-PRO+ 98 programming software is used to define call windows.

There are two programmable windows per day type, and there are four day types: Weekdays, Saturdays, Sundays, and Holidays.

The windows, which can overlap, have an open and close time with a one minute resolution and a maximum length of 24 hours. If a window is set to 24 hours (Start Time = 00:00 and Stop Time = 23:59), the call window is open all day. If the open and close time is set to zero (0) for both windows, the calling window for that day is always closed. If a call is in progress while a window closes, the call will be completed.

Answer Delays

There are separate answer delays available for inside and outside the call window. The value for either time delay can be 1 to 255 seconds. One ring is approximately 4 to 6 seconds.

An unprogrammed meter is shipped from the factory with a preset answer delay of 35 seconds (6-9 rings). Once the meter is programmed, the preset answer delay will be reset to the programmed value.

Dialing Features

The SENTINEL meter supports the following dialing features:

- **Phone Numbers**—The SENTINEL meter can dial up to four phone numbers, each of which can contain up to 50 digits including dial modifiers.
- **Blind Dialing**—If blind dialing is enabled in the software, the SENTINEL meter will dial the specified number even if there is no dial tone.
- **Wait Time**—If blind dialing is not enabled in the software, the modem can be programmed to wait until a dial tone is present before dialing.

Phone Home on Event

The meter can be programmed to call a host (master station) when an event occurs. If the master station is set up to receive calls and interrogate meters, incoming calls will be logged to alert the operator that a certain condition exists. The host must interrogate the meter for the reason it is calling and clear the event. The meter will not automatically volunteer this information. If the meter is programmed to call outside of its windows, it will wait a random time (from 6 to 255 seconds) and then place a call to the master station after an event has taken place. When the meter has a call window, the meter will wait until the window is open to make the second attempt. The meter will only attempt to make a call outside a call window if this option is enabled in the programming software. If the phone home attempts are not successful, the meter will use the retry strategy specified in Call On Schedule on page 5-2. The meter can be configured to phone home on the events listed in Table 5.1.

Meters that are set up as subordinates in a phone-line sharing configuration cannot initiate phone calls.

Table 5.1 SENTINEL Phone Home Events

Alternate Mode Entry [1]	Fatal Error 1 - 5
Demand Threshold 1 - 4 Exceeded	Demand Threshold 1- 4 Restored
Demand Reset	SiteScan Diagnostic Error 1 - 5
Low Battery Error (Non-Fatal Error #1)	Meter Reconfigured
Loss of Phase Error (Non-Fatal Error #2)	Power Restored
TOU Schedule Error (Non-Fatal Error #3)	Season Change
Reverse Power Flow Error (Non-Fatal Error #4)	Security Failed
Clock, TOU Error (Non-Fatal Error #5)	
Full Scale Overflow (Non-Fatal Error #6)	

[1] Placing the meter in Alternate Mode via the magnetic switch may be selected to initiate a phone home without the need for laptop/PC communications.

Call On Schedule

The SENTINEL can be configured for the modem to have an initial call home strategy. The user has two choices:

- Call *N* minutes after initialization.
- Call on a specific day and hour.

Phone Line Sharing

PC-PRO+ 98 5.1 and higher supports communication with SENTINEL meters that are networked in a phone line sharing configuration. The Phone Line Sharing feature can connect up to five auto-answer meters, one master and four subordinate meters, to a single analog telephone line for remote interrogation. To facilitate phone-line sharing, each SENTINEL modem can be configured as a master meter or as a subordinate meter. Upon receiving a phone call, only a master will respond with the required handshake signal. All other SENTINEL meters will be in “listen only” mode until the proper command addresses a corresponding subordinate meter and the master meter releases the line. At this point, the next SENTINEL meter will come on line.

A subordinate unit cannot be configured to call on schedule or phone home on event. If you program the master and subordinate units via the modem, SchlumbergerSema requires that the subordinates be programmed first.

When call windows are used, all windows must be identical for master and subordinate meters. When using the master station to call meters in a phone-line sharing situation, the master station should wait several minutes after the call window opens so that all meters have time to set up. Blind dialing is not recommended when using phone line sharing. The phone line sharing option can be disabled. If you program the master and subordinate units via the modem, SchlumbergerSema requires that the subordinates be programmed first. If the master is configured first and the carrier is lost while configuring the subordinates, the subordinates will require a direct connect communication resulting in a visit to each meter site.

For more information, refer to your PC-PRO+ 98 online help files and other documentation.

Recommended Modems

SchlumbergerSema has tested several manufacturer’s modems and recommends using any of the following:

1. US Robotics Sportster 56K
2. Hayes Accura 56K
3. Hayes Accura 14.4
4. Practical Peripherals PM144MT
5. Intel 144/144e
6. Hayes 1200 Smartmodem
7. Lucent Technologies Softmodem AMR
8. IBM Data/Fax
9. Xircom PCMCIA Cardbus Ethernet 10/100+ Modem 56K
10. Zoom USB 56K External

The key features of the modem board are:

- Phone line sharing
- Call windows
- Answer delays
- Phone home on event

- Off-hook detection
- Five input/output board options:
  - One Form C KYZ output and one Form A low-current, solid-state contact output
  - Two Form C KYZ outputs and one Form A low-current, solid-state contact output
  - Four Form C KYZ outputs and one Form A low-current, solid-state contact output
  - Two Form C KYZ outputs, one Form A low-current, solid-state contact output, and two Form A KY pulse inputs
  - Four Form C KYZ outputs, one Form A low-current, solid-state contact output, and two Form A KY pulse inputs

The modem communication board is available for both socket-base and A-base configurations.

R300 Series Board

The optional R300 Series communication boards continuously transmits data using a radio frequency (RF) signal which can be read by handheld or vehicle receivers. Table 5.2 describes these boards.

Table 5.2 R300 Series Communication Boards

Board	Description
R300S	One energy quantity.
R300D	Two energy or demand quantities.
R300SD3	Three energy or demand quantities.

Using the PC-PRO+ 98 programming software, you can:

- Configure the quantity(s) to be transmitted.
- Enable TOU and select the TOU rate to be transmitted.
- Select the type of registers to be transmitted.
- Select the number of digits for the data to be transmitted as well as the number of decimal place digits for the data.
- Select whether transmission shall be stopped based on SiteScan diagnostic or non-fatal/displayable error occurrences.

TOU Schedules do not have to be configured for R300 Series use.

RS-232/RS-485 Boards

The optional SENTINEL RS-232/RS-485 board provides additional methods for data retrieval and programming. The RS-232 standard and/or the RS-485 standard allows point-to-point and multi-drop communication. The board also provides the ability to use other communication equipment for data retrieval and programming.

The RS-232/RS-485 board adds up to two serial communication ports to the SENTINEL meter. Each of these ports can be configured through PC-PRO+ 98 for either RS-232 or RS-485 communication. A user can program the option board as two RS-232 ports, two RS-485 ports, or one of each. The ability to program either serial port as either RS-232 or RS-485 allows the customer to buy only one board, thereby maximizing the customer's flexibility while having a positive impact on inventory.

Each port can also be programmed for different protocols. The PSEM and QDIP protocols are supported by the RS-232 /RS-485 communication board.

This board provides simultaneous bi-directional communication. The meter can communicate through the optical port, both serial ports, and all inputs/outputs at the same time.

Depending on the input/output option the user selects, a variety of external connectors can be ordered with the RS-232/RS-485 board. These connectors include DB-9, DB-25, and Viking connectors.

The key features of the RS-232/RS-485 board are:

- One or two serial communication ports added to the SENTINEL meter using PSEM C12.18 protocol
- Ports are configured for RS-232 or RS-485 through PC-PRO+ 98 software
- Allows other communication equipment to be connected to the SENTINEL meter
- Each port is addressable
- Five input/output board options:
    - One Form C KYZ output and one Form A low-current, solid-state contact output
    - Two Form C KYZ outputs and one Form A low-current, solid-state contact output
    - Four Form C KYZ outputs and one Form A low-current, solid-state contact output
    - Two Form C KYZ outputs, one Form A low-current, solid-state contact output, and two Form A KY pulse inputs
    - Four Form C KYZ outputs, one Form A low-current, solid-state contact output, and two Form A KY pulse inputs

The RS-232/RS-485 communication board is available for both socket-base and A-base configurations.

Multifunction Meter Module

The SENTINEL Multifunction Meter Module (MFMM) is a RF module that allows the SENTINEL meter to interface with the Fixed RF Network. The MFMM is installed into the option board slot in the meter and is connected to the meter via the option board interface. The MFMM uses a Direct Sequence Spread Spectrum (DSSS) transmitter that operates in the unlicensed Industrial, Scientific and Medical (ISM) 900 MHz RF band. The MFMM acts as a transmitter only and does not receive any communications from the RF network. The MFMM provides increased third channel message capability to provide increased network access to the SENTINEL advanced metering data.

In addition to the standard SENTINEL information, a meter with a MFMM will show the LAN ID(s) on the nameplate.

The MFMM communicates with the SENTINEL meter via the option board interface as the master control device. When an End-Of-Interval (EOI) condition is detected, the MFMM interfaces with the meter and retrieves advanced metering data from the meter registers. The MFMM then formats the data and schedules the data for transmission to the network. The meter status, meter diagnostic, MFMM status, Direct Register Read (DRR) and analog Revenue Integrity Service (RIS) data is also transmitted.

The MFMM can be programmed with three separate LAN IDs, thereby making the network host believe it is receiving data from three separate transmitters. This allows the MFMM to transmit the SENTINEL's advanced metering data to the network.

The SENTINEL MFMM hardware consists of the digital circuit, the power supply circuit, and the RF circuit. The system also contains a tuned dipole antenna on the printed circuit board that acts as the faceplate of the meter when the MFMM is installed.

Optional Inputs/Outputs

The SENTINEL meter allows for optional inputs and outputs on an option board mounted between the upper and lower housing. Five versions of input/output boards are available. However, these are not available for meters with an R300 Series communications board or modem.

Option 1:	One Form C KYZ output and one Form A KY low-current, solid-state contact output. (1 KYZ, 1KY)
Option 2:	Two Form C KYZ outputs and one Form A KY low-current, solid-state contact output. (2 KYZ, 1 KY)
Option 3:	Two Form C KYZ outputs, one Form A KY low-current, solid-state contact output, and two Form A KY pulse inputs. (2 KYZ, 1 KY, 2 KY inputs)
Option 4:	Four Form C KYZ outputs and one Form A KY low-current, solid-state contact output. (4 KYZ, 1 KY)
Option 5:	Four Form C KYZ outputs and one Form A KY low-current, solid-state contact output, and two Form A KY pulse inputs.(4 KYZ, 1 KY, 2 KY inputs)

Supplemental Inputs and Outputs

The SENTINEL meter can include supplemental inputs and outputs in conjunction with the other communication options (modem, R300 Series). There are two supplemental I/O options available.

Supplemental Option 1 Two Form C KYZ outputs and one Form A low-current, solid-state contact output.

Supplemental Option 2 Two Form C KYZ outputs, one Form A low-current, solid-state contact output, and two Form A KY pulse inputs.

Each output can be programmed as one of the output types listed in Table 5.3.

Table 5.3 KYZ/KY Output Programming

Output Type	Description
Energy Quantities	KYZ pulse output constants apply to secondary readings only. **Note**: A watthour pulse constant of 1.8 corresponds to 1.8 watthours per pulse. Assign the secondary unit hour per pulse constants to each KYZ output. To achieve the allowable maximum resolution, the following formulas apply: Pulse Weight (Ke) = Energy /Pulse $Ke = \frac{V \times I(\text{No. of Phases})}{(3600\ \text{sec/hr})/(15\ \text{pulses/sec})}$ where: V and I are the nominal voltage and current for the service Maximum pulse rate for 60 Hz is 15 pulses/second Maximum pulse rate for 50 Hz is 12 pulses/second Energy Pulse Widths can be programmed for 0, 10, or 20 milliseconds.
Demand Reset	The contact closes when a demand reset is performed. The contact is closed from 10 milliseconds up to 5 seconds, in increments of 10 milliseconds. This time is programmed as Pulse Width.
End-of-Interval (EOI)	The contact closes at the end of each interval/subinterval.The contact is closed from 10 milliseconds up to 5 seconds, in increments of 10 milliseconds. This time is programmed as Pulse Width.
Rate Change	The contact closes when the meter detects a TOU rate change. The contact is closed from 10 milliseconds up to 5 seconds, in increments of 10 milliseconds. This time is programmed as Pulse Width.
Season Change	The contact closes when the meter detects a TOU season change. The contact is closed from 10 milliseconds up to 5 seconds, in increments of 10 milliseconds. This time is programmed as Pulse Width.
Demand Threshold Exceed 1- 4	The contact closes when the programmed demand threshold value is reached. The contact remains closed until the demand value drops below the programmed value and the end of the demand interval / subinterval is reached. Four Threshold values can be programmed.The contact is closed from 10 milliseconds up to 5 seconds, in increments of 10 milliseconds. This time is programmed as Pulse Width.

Table 5.3 KYZ/KY Output Programming

Output Type	Description
Diagnostic 1 On	The contact is closed when the meter detects a SiteScan Diagnostic 1 which is Polarity, Cross-Phase and Energy Flow.The contact is closed from 10 milliseconds up to 5 seconds, in increments of 10 milliseconds. This time is programmed as Pulse Width.
Diagnostic 2 On	The contact is closed when the meter detects a SiteScan Diagnostic 2 which is Phase Deviation.The contact is closed from 10 milliseconds up to 5 seconds, in increments of 10 milliseconds. This time is programmed as Pulse Width.
Diagnostic 3 On	The contact is closed when the meter detects a SiteScan Diagnostic 3 which is Inactive Phase Current.The contact is closed from 10 milliseconds up to 5 seconds, in increments of 10 milliseconds. This time is programmed as Pulse Width.
Diagnostic 4 On	The contact is closed when the meter detects a SiteScan Diagnostic 4 which is Phase Angle Displacement.The contact is closed from 10 milliseconds up to 5 seconds, in increments of 10 milliseconds. This time is programmed as Pulse Width.
Diagnostic 5 On	The contact is closed when the meter detects a SiteScan Diagnostic 5 which is Current Waveform Distortion Detection.The contact is closed from 10 milliseconds up to 5 seconds, in increments of 10 milliseconds. This time is programmed as Pulse Width.
Customer Alert 1 - 7	The contact is closed when the corresponding TOU rate created in Calendar Editor is active. The contact remains closed until the TOU rate is no longer active.
Independent Output 1 - 4	The contact closes when the corresponding independent Output created in Calendar Editor is active. The contact remains closed until the Output is no longer active.

The KY inputs can be programmed as any of the following:

Input Type	Description
None	The KY input is not used.
Count Accumulator	The input pulses to the meter are converted to energy or accumulating quantities based the Ke provided. Demand may be calculated based on this quantity.
Log Pulse Input	The input pulses are logged as an event. They are triggered by either “On to Off” or “Off to On”.

Refer to Input/Output Module Color Coding on page 1-7 for Input/Output wiring color diagrams.

Output Configuration

Using the PC-PRO+ 98 programming software, you can:

- Select the quantity and the event that will trigger the output.
- Select the Ke value, or energy per pulse, for each digital pulse quantity.
- Select the width (duration) in milliseconds of the pulse.
- Disable outputs whenever the meter is placed in Test Mode.

To toggle pulses, set the pulse width to zero (0).

Input Configuration

Using the PC-PRO+ 98 programming software, you can:

- Select the action to occur when each input is triggered.
- Select the pulse action that will trigger the input.
- Define the pulse weight for each input quantity (if the desired action is to accumulate a count).
- Enter a quantity description.

Output Cables

A standard output cable, which extends through the base of the meter as a set of bare leads is provided whenever an I/O option board is supplied. Other connectors such as Viking, DB-9, and DB-25 connectors are also available.

Notes:

Chapter 6 SiteScan™ On-Site Monitoring System

The SiteScan on-site monitoring system consists of the following features:

- Meter self-diagnostic checks
- Toolbox Mode with its on-site and/or on-line display
- SiteScan system and installation diagnostic checks
- Diagnostic output alarms

Using the SchlumbergerSema PC-PRO+ 98 Programming software package you can customize the SiteScan System for each individual metering site. The use of the SiteScan on-site monitoring system will greatly enhance the ability to diagnose and resolve site-specific metering or tampering problems.

SiteScan Meter Self-Diagnostic Checks

The SENTINEL meter performs self-diagnostic checks to confirm proper meter operation. The following is a list of possible errors and associated error codes:

Error	Error Type	Error Code
Flash Error	Fatal Error	FAt Error1
RAM Error	Fatal Error	FAt Error2
Data Flash Error	Fatal Error	FAt Error3
CPC/Metrology Error	Fatal Error	FAt Error4
Power Down Error	Fatal Error	FAt Error5
Low Battery Error	Non-Fatal Error	ERR 1-----
Loss of Phase Voltage Error	Non-Fatal Error	ERR -2----
TOU Schedule Error	Non-Fatal Error	ERR --3---
Reverse Power Flow Error	Non-Fatal Error	ERR ---4--
Load Profile Error	Non-Fatal Error	ERR ----5-
Fullscale Exceeded	Non-Fatal Error	ERR -----6
Diagnostics 1	Diagnostic	diA 1
Diagnostics 2	Diagnostic	diA 2
Diagnostics 3	Diagnostic	diA 3
Diagnostics 4	Diagnostic	diA 4
Diagnostics 5	Diagnostic	diA 5

A fatal error indicates an internal meter problem, which ceases all meter functions except communications. These errors cause the display to lock on the error code until the meter is re-initialized. The non-fatal errors can indicate either a meter problem such as low battery error or a site problem such as the loss of phase voltage error. The non-fatal self-diagnostic checks can be independently enabled or disabled through the PC-PRO+ 98 software.

For a more detailed discussion of each fatal and non-fatal error, refer to Chapter 7.

SiteScan Toolbox Mode

SiteScan Toolbox Mode displays all the metering information used by the meter for individual phase measurements and system and installation diagnostic checks. This information helps the user verify that the meter is installed and operating correctly. The per-phase RMS voltage and current readings along with both voltage and current angle readings let the user check the meter's site phase sequencing performance. The diagnostic counters alert the user to the frequency of a metering installation or tampering problem. The combination of a diagnostic error and the information in the Toolbox Mode display will greatly enhance the ability to diagnose and resolve metering or tampering issues.

In Chapter 3, access to the Toolbox Mode display list through the use of a magnet and magnetic switch was discussed. The PC-PRO+ 98 software lets the user retrieve the same Toolbox information on an instantaneous basis with a graphical vector diagram.

To best understand the values on the Toolbox display, one should graphically plot this information. Before starting to manually plot the Toolbox data, two basic definitions must be understood about the SiteScan system.

Definition 1: The per-phase information displayed in the Toolbox Mode is referenced to the internal voltage and current sensors of the meter. The meter will designate each phase by the elements. Table 6.1 defines each element.

Table 6.1 Phase Notation in Display

Element Used in Meter	Defined Phase	Phase Notation in Toolbox Display
Left-hand Element	Phase A	PhA
Center Element	Phase B	PhB
Right-hand Element	Phase C	PhC

Figure 6.1 shows how the wiring of each element determines the phase notation used by the meter.

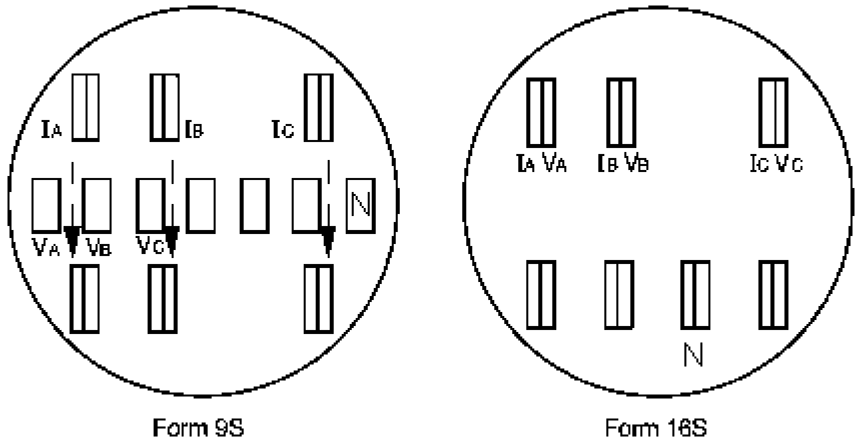


Figure 6.1 Toolbox Phase Notation for Form 9S and 16S SENTINEL Meters

Definition 2: The SiteScan system uses the A phase voltage as a reference point. Therefore, the Toolbox Mode display of the A phase voltage angle will always be 0.0°V.

The SENTINEL meter is still determining this angle and will still detect a problem if the A phase voltage angle is incorrect.

After the meter sets the A phase voltage direction to 0.0 degrees, the meter calculates all the other voltage and current angles relative to the A phase voltage. This allows the user to easily plot the vector information, not only to determine problems, but also to determine the phase sequencing of the site.

Figure 6.2 provides an example of the plot for Toolbox Mode information. No matter how the phasor information is plotted, whether the user plots the same as shown in Figure 6.2 or in the opposite direction with 90° at the 12 o'clock position, the Toolbox Mode will still provide an accurate representation of the site.

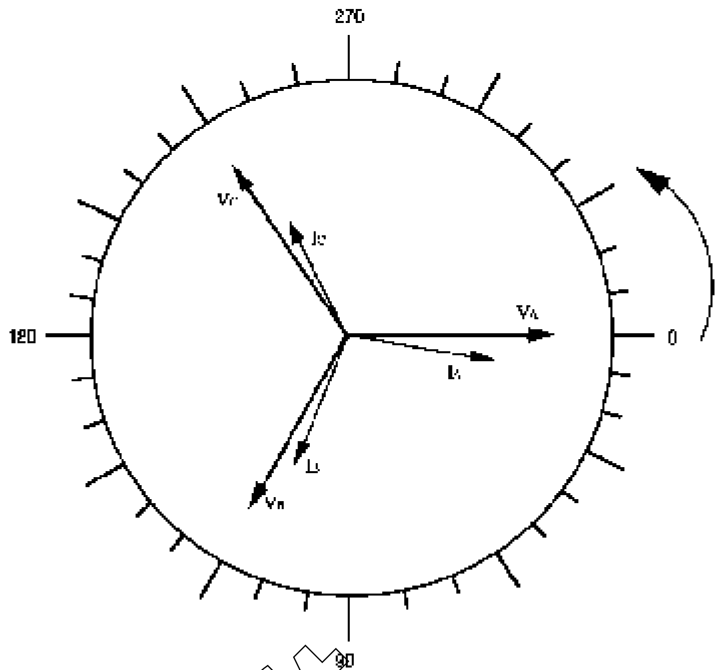


Figure 6.2 Plot of Toolbox Display Mode

In this example, the plot is going in the clockwise direction. Therefore, the phasors will be rotating in the counterclockwise direction. By using this information, the phase sequencing of the meter site can be determined. In the case shown, the A phase voltage is seen first. The next voltage phasor is B phase and last is C phase voltage, indicating ABC rotation. For CBA rotation, A phase voltage at zero will be seen first, but the user would see C phase voltage next followed by B phase.

The following is an example of the data available in the Toolbox Mode. This example is for a Form 9S meter wired for a 4-Wire Wye system:

	Phase A Display (Left Element)	Phase B Display (Center Element)	Phase C Display (Right Element)
Voltage Phase Angles	PhA 0.0° V	PhB 120.5° V	PhC 240.3° V
Phase Voltage	PhA 120.2 V	PhB 115.5 V	PhC 119.3 V
Current Phase Angles	PhA 9.0° A	PhB 117.8° A	PhC 246.0° A
Phase Current	PhA 6.8 A	PhB 10.2 A	PhC 9.8 A
Diagnostic Counters[1]	d1 000 d2 000 d3 000 d4 000 d5A 000 d5B 000 d5C 000 d5T 000		

1 The diagnostic counters are incremented each time a diagnostic error occurs.

If the magnitude of a phase voltage or current is zero or too low to measure accurately, a dashed line (—) will appear in the value location. The corresponding angle will also indicate dashed lines. Accurate measurement is considered to be 0.5% of class rating for the current:

- CL 20 = 10 mA
- CL 200 = 1 Amp
- CL 320 = 1.6 Amps

By following the definitions of the SiteScan system and the information on the Toolbox display, the above example can be graphically plotted into the phasor diagram shown in Figure 6.2.

By simply viewing the phasor diagram, several facts about the site become clear:

- There are no wiring problems currently at the site.
- Both A and C phase currents lag while B phase current leads its voltage.
- The site is wired with ABC phase rotation.

By graphically plotting the Toolbox Mode display information, many metering site problems are easily diagnosed. Problems such as cross-phasing of voltage or current circuits, incorrect polarity of voltage or current circuits, and reverse energy flow of one or more phases can be found quickly. The load emulator scrolling in the direction of energy flow for each phase will also aid in checking for reverse energy flow. Other problems, such as loss of phase voltage, incorrect voltage transformer ratio, current diversion, or a shorted current transformer circuit, can be determined through the Toolbox Mode.

While some of these problems may occur at the time of meter installation, others may happen at any time after the meter is installed. Since it is impossible to continuously watch the Toolbox Mode information, the SiteScan on-site monitoring system has been designed to continuously monitor the site. The occurrence of any diagnostic condition can be logged, as well as display error codes on the LCD.

SiteScan System and Installation Diagnostic Checks

The SiteScan on-site monitoring system has the ability to continuously monitor the site for metering installation or tampering problems through the system and installation diagnostic checks. The following software programmable diagnostic checks are available:

SiteScan Diagnostic #1	Polarity, Cross-Phase & Energy Flow Check
SiteScan Diagnostic #2	Phase Voltage Deviation Check
SiteScan Diagnostic #3	Inactive Phase Current Check
SiteScan Diagnostic #4	Phase Angle Displacement Check
SiteScan Diagnostic #5	Current Waveform Distortion Check

It is very important to note that the meter will continue to operate normally while any of the diagnostic errors are being displayed. The system and installation diagnostic checks will only report that there may be a problem with the meter or site. They have no effect on metering or on any operations performed by the SENTINEL meter.

If enabled, all the diagnostic checks will continually check for errors every five seconds. The SENTINEL meter will not check for diagnostic errors under any of the following conditions:

- When singlephase series conditions occur (Test Bench)
- When the meter is in Test Mode
- When the diagnostic(s) have been disabled by the programming software

The system reports diagnostic errors in several ways. If a diagnostic check is enabled and an error occurs, the system will always increment the corresponding diagnostic counter by one. The range for all diagnostic counters is from 0 to 255. When the counter reaches 255, it remains there until it is reset by the user. The diagnostic checks will continue to function and report any errors even after the diagnostic counter has reached 255. The PC-PRO+ 98 programming software can be used to reset the counters. Refer to the PC-PRO+ 98 documentation for instructions on how to reset the counters.

The system can also be programmed to report diagnostic errors directly to the meter display. If a diagnostic check has failed, the meter will display a diagnostic message similar to the one shown in Figure 6.3.

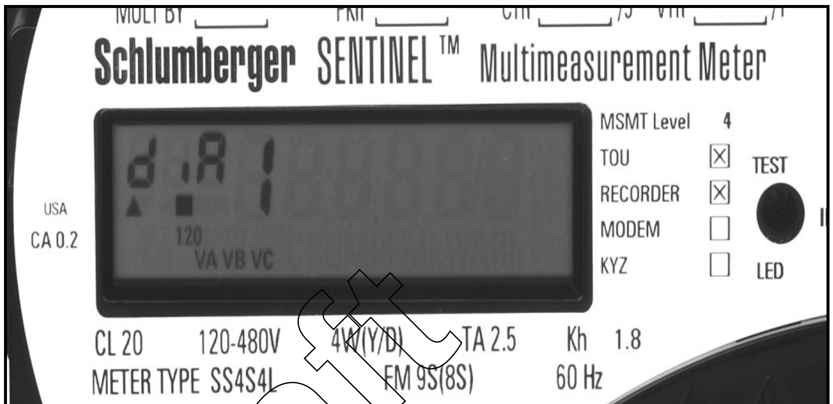


Figure 6.3 Example of Diagnostic #1 Error Display

If more than one diagnostic error condition exists, the diagnostic with the lowest number will take precedence for display. Diagnostic errors will not be shown if any fatal or non-fatal errors are displayed.

Each of the diagnostic checks can be independently programmed with one of the following display options:

Lock	The diagnostic error is locked on the display. Activating the magnetic switch for more than 4 seconds to select Normal, Alternate, or Toolbox display mode will cause the meter to scroll through that list and then lock again on the error.
Scroll	The diagnostic error will be displayed during the “Off Time” between display items. When an error occurs, the meter will display the error during the next “Off Time” of the current display mode (Normal, Alternate, or Toolbox) the meter is in.
Ignore	The diagnostic error will not be displayed on the meter. However, the diagnostic error will still increment the diagnostic counter. This option can be used to determine the frequency of an error without reporting it on the display of the SENTINEL meter.
Disable	The diagnostic error will not be displayed on the meter display or increment the diagnostic counter.

The meter will check for all enabled diagnostic errors every five seconds. If three consecutive checks fail, the meter will flag the error. Therefore the meter takes approximately 15 seconds before an error is flagged. A diagnostic error may take longer to display on the meter depending on the display option chosen. Once the condition causing the error is corrected, the meter must pass two consecutive checks before the diagnostic error is cleared from the display.

The form of the meter determines which of the service types is available for the meter. Diagrams showing possible meter forms, their associated service types, and unity PF SiteScan phasor diagrams are given in Figure 6.4 through Figure 6.22. For a complete selection of meter forms, refer to the *Site Analysis Guide for VECTRON® and SENTINEL™ Meters*.

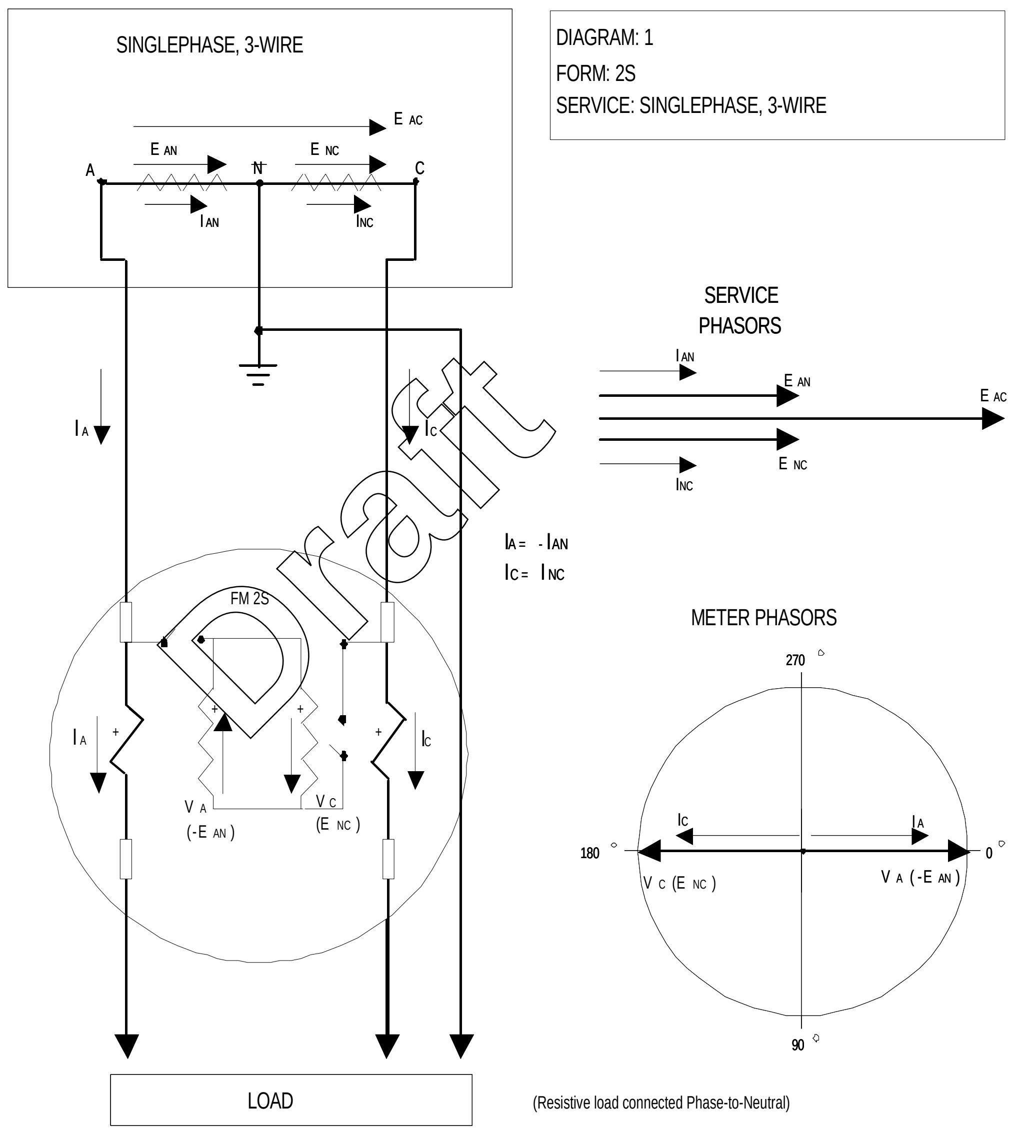


Figure 6.4 Form 2S Singlephase, 3-Wire Self-Contained SENTINEL Meter

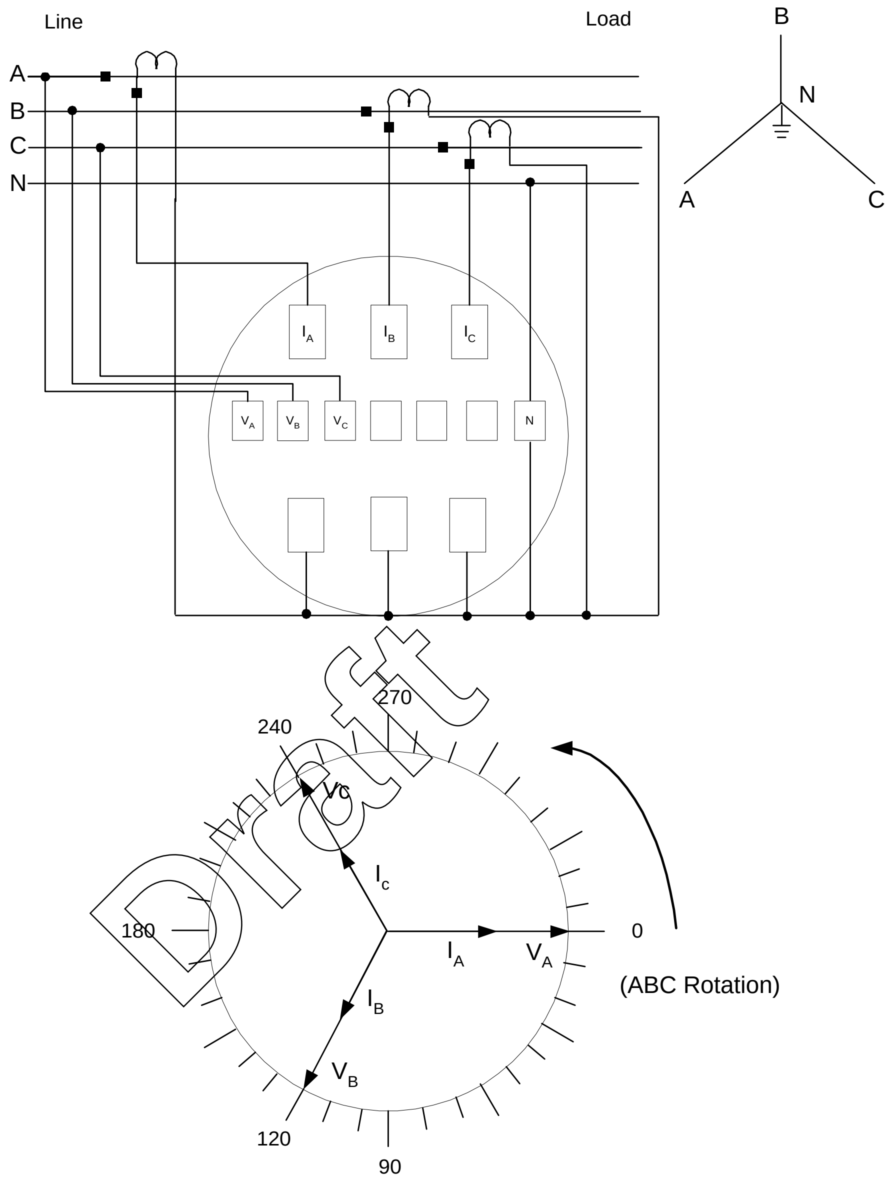
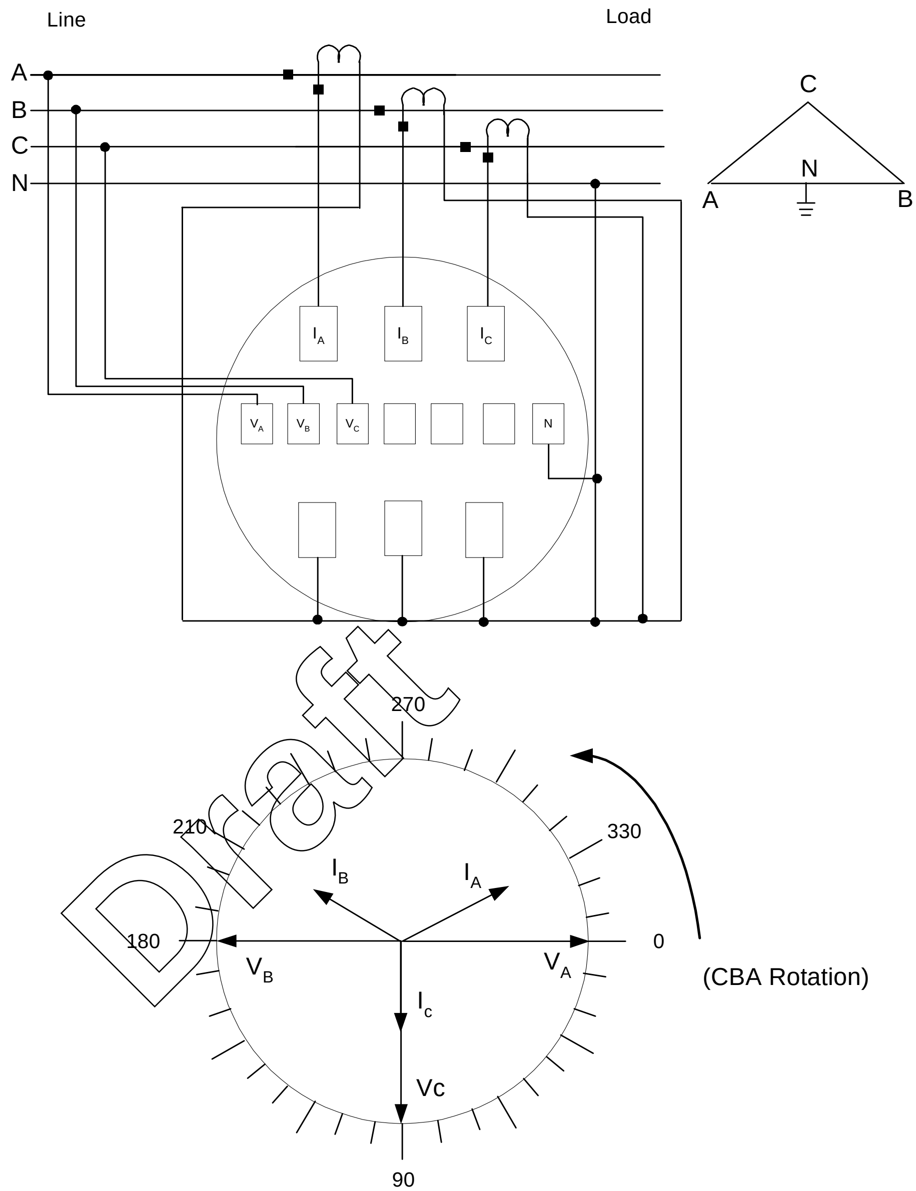


Figure 6.5 Form 8S/9S SENTINEL Meter in a 4-Wire Wye Service – Phasor Diagram



Expected vector diagram at unity power factor with load connected line-to-neutral

Figure 6.6 Form 8S/9S SENTINEL Meter in a 4-Wire Delta Service – Phasor Diagram

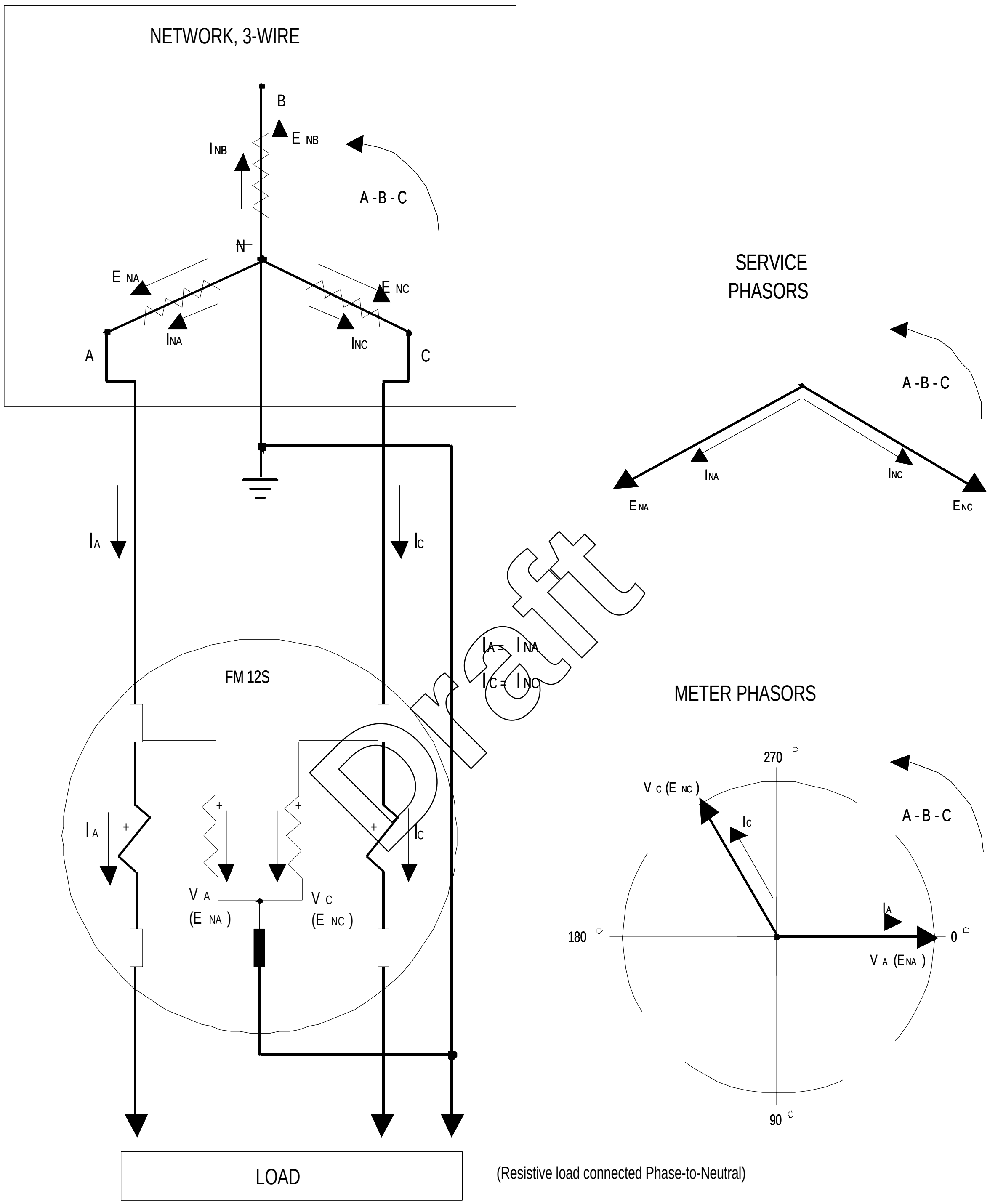


Figure 6.7 Form 12S 3-Phase, 3-Wire Network Self-Contained SENTINEL Meter

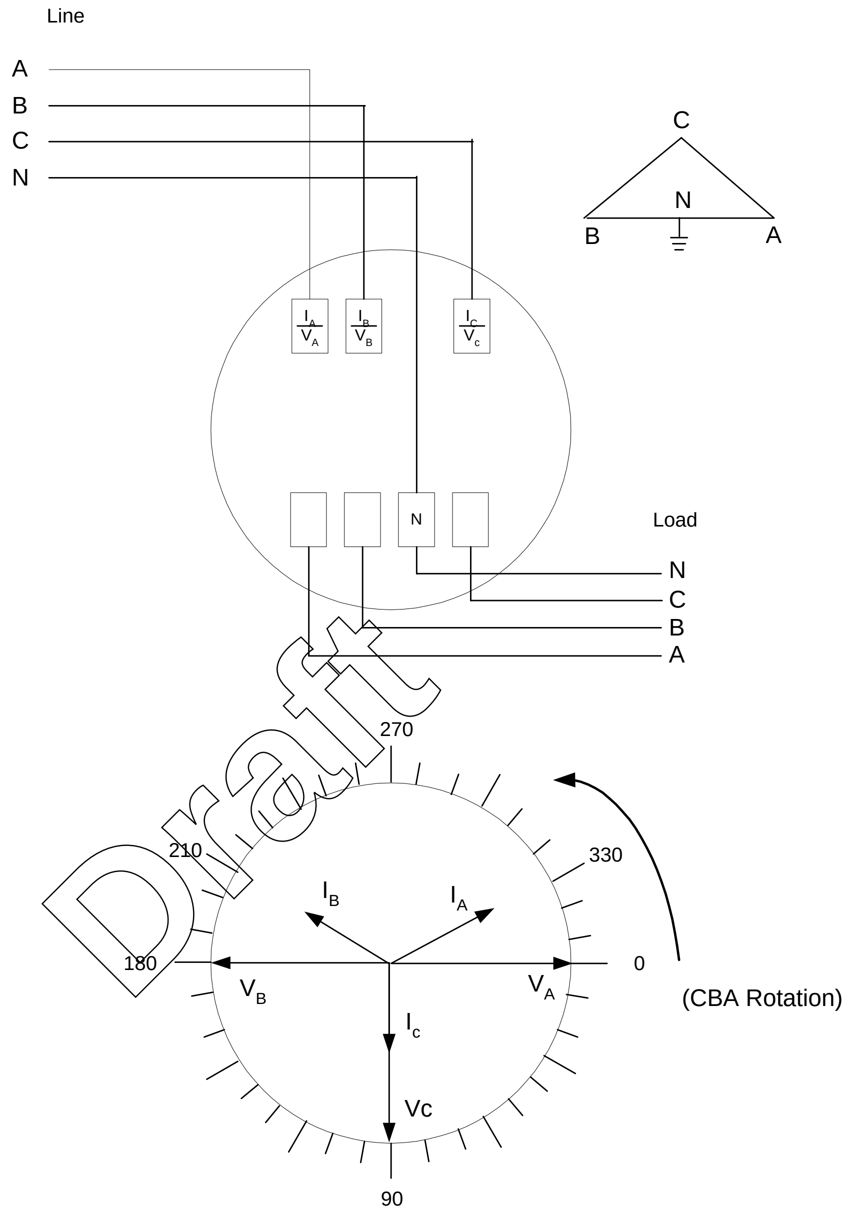
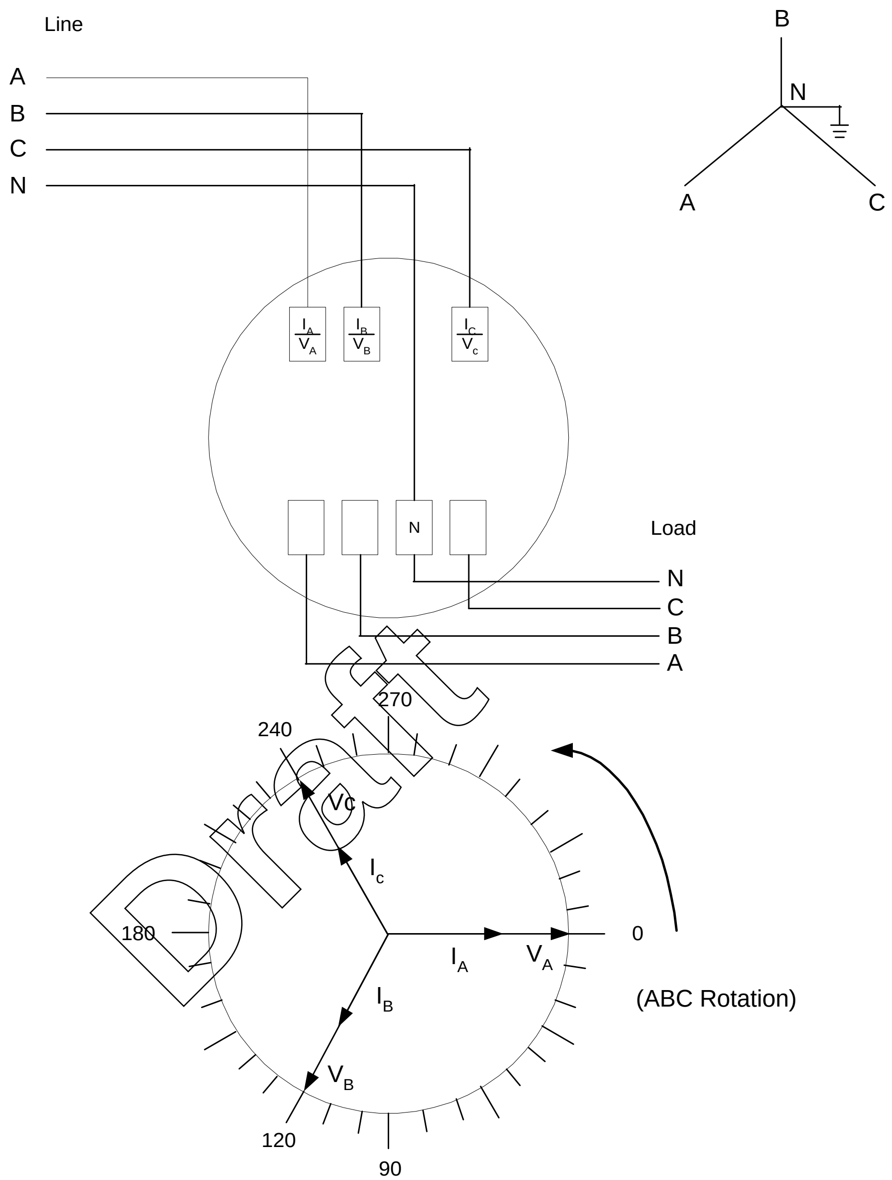


Figure 6.8 Form 15S/16S SENTINEL Meter in a 4-Wire Delta Service – Phasor Diagram



Expected vector diagram at unity power factor with load connected phase-to-neutral

Figure 6.9 Form 16S SENTINEL Meter in a 4-Wire Wye Service – Phasor Diagram

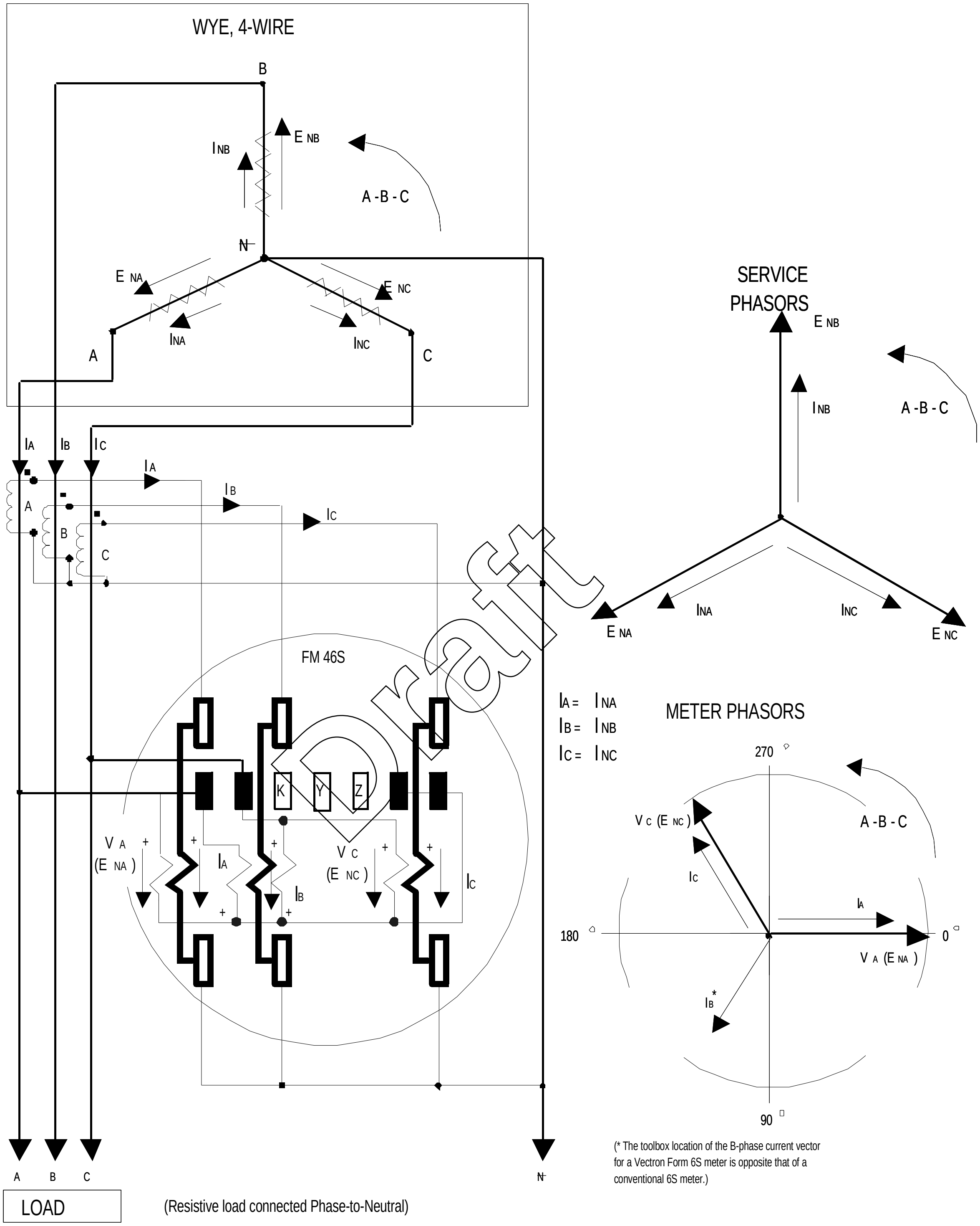
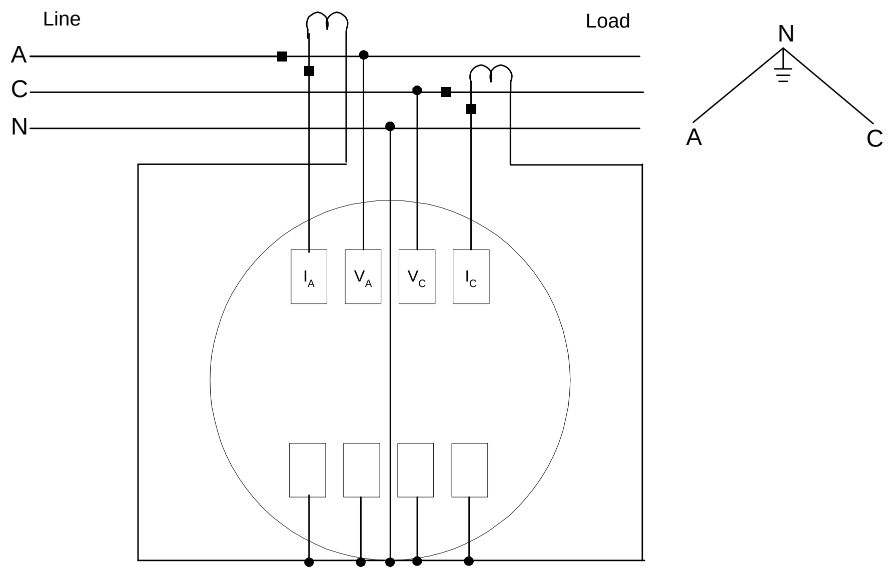
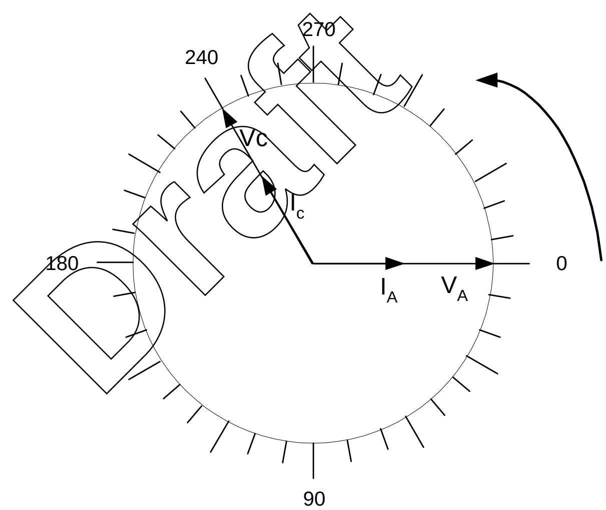


Figure 6.10 Form 46S, Wye, 4-Wire, ABC Phase Rotation Diagram





Expected vector diagram at unity power factor with load connected line-to-neutral

Figure 6.11 Form 45S SENTINEL Meter in a 3-Wire Network Service – Phasor Diagram

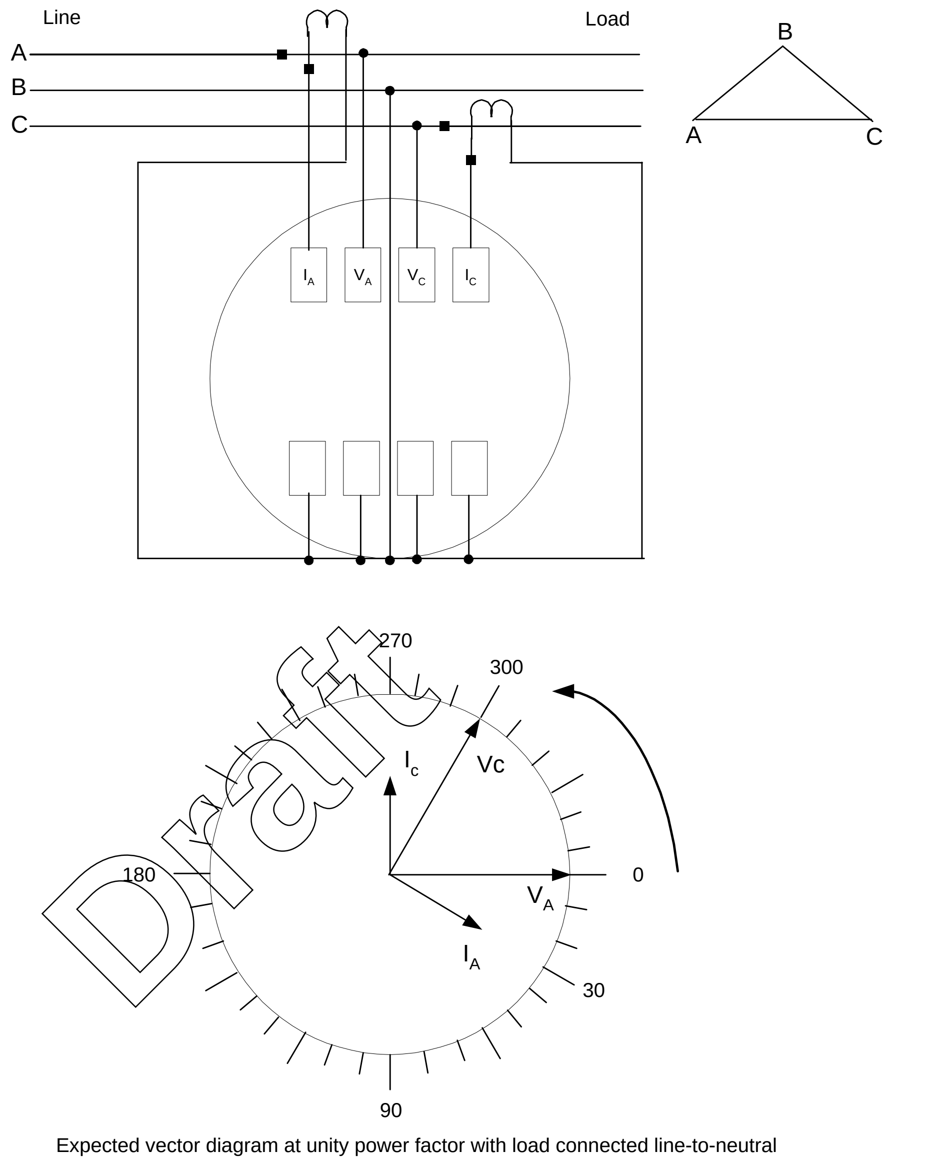
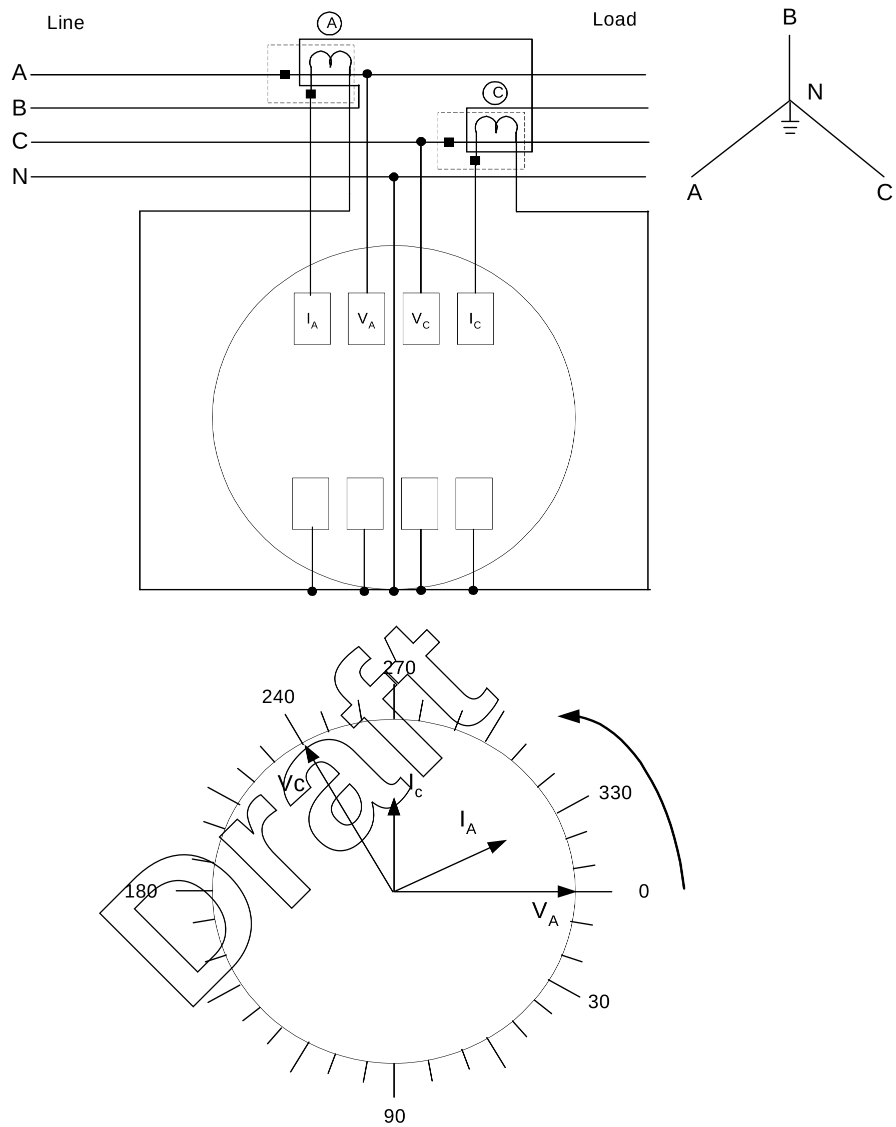


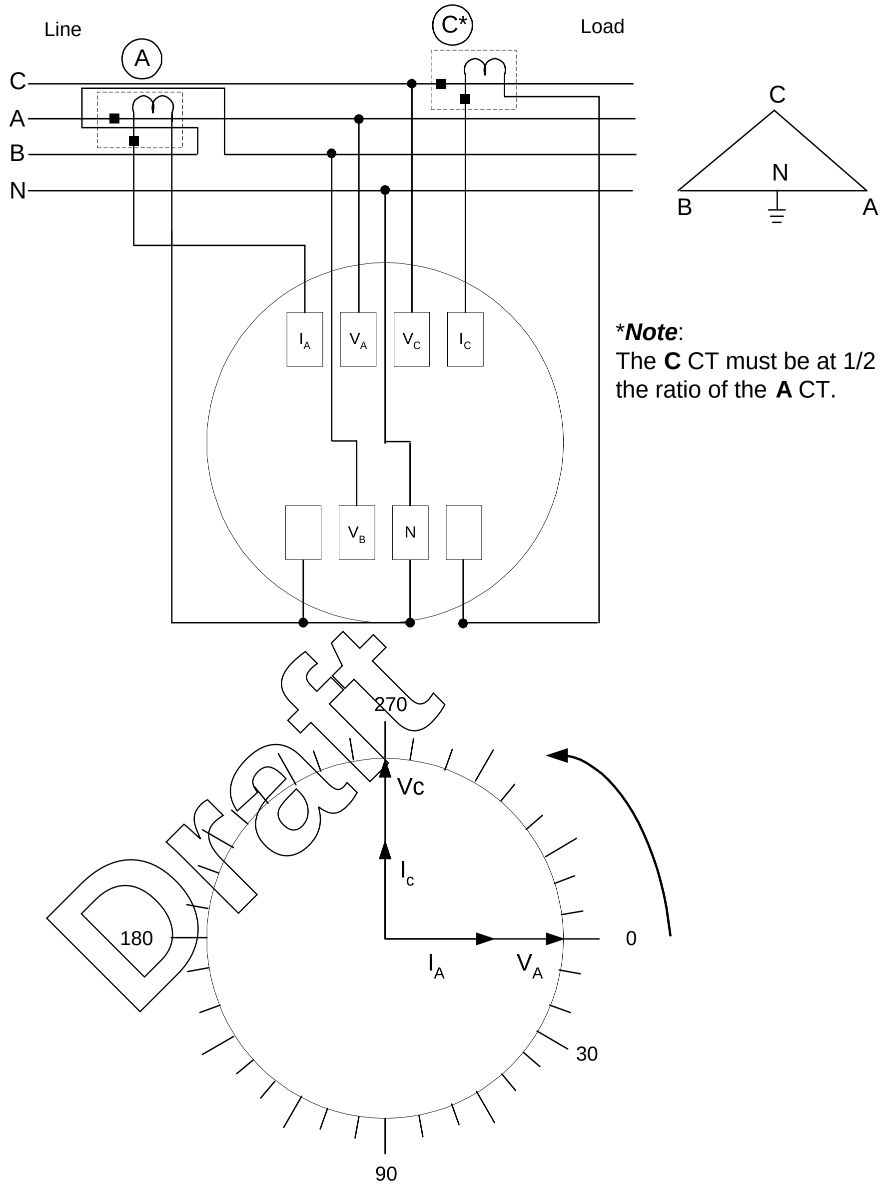
Figure 6.12 Form 45S SENTINEL Meter in a 3-Wire Delta Service – Phasor Diagram



Expected vector diagram at unity power factor with load connected line-to-neutral

Figure 6.13 Form 45S SENTINEL Meter in a 4-Wire Wye Service –Phasor Diagram

Circled A	A Phase
Circled C	C Phase



Expected vector diagram at unity power factor with balanced loading

Figure 6.14 Form 45S SENTINEL Meter in a 4-Wire Delta Service – Phasor Diagram

Circled A	A Phase
Circled C	C Phase

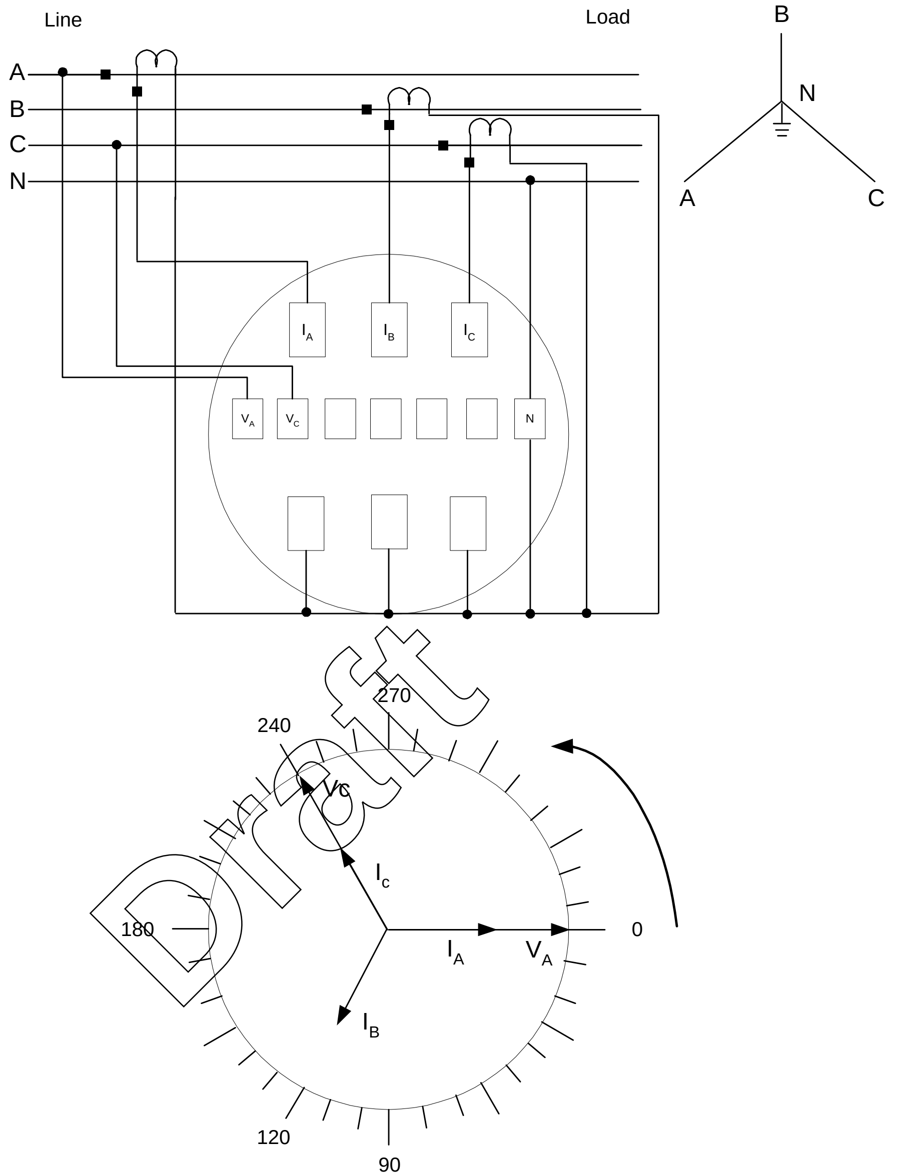


Figure 6.15 Form 46S SENTINEL Meter in a 4-Wire Wye Service – Phasor Diagram

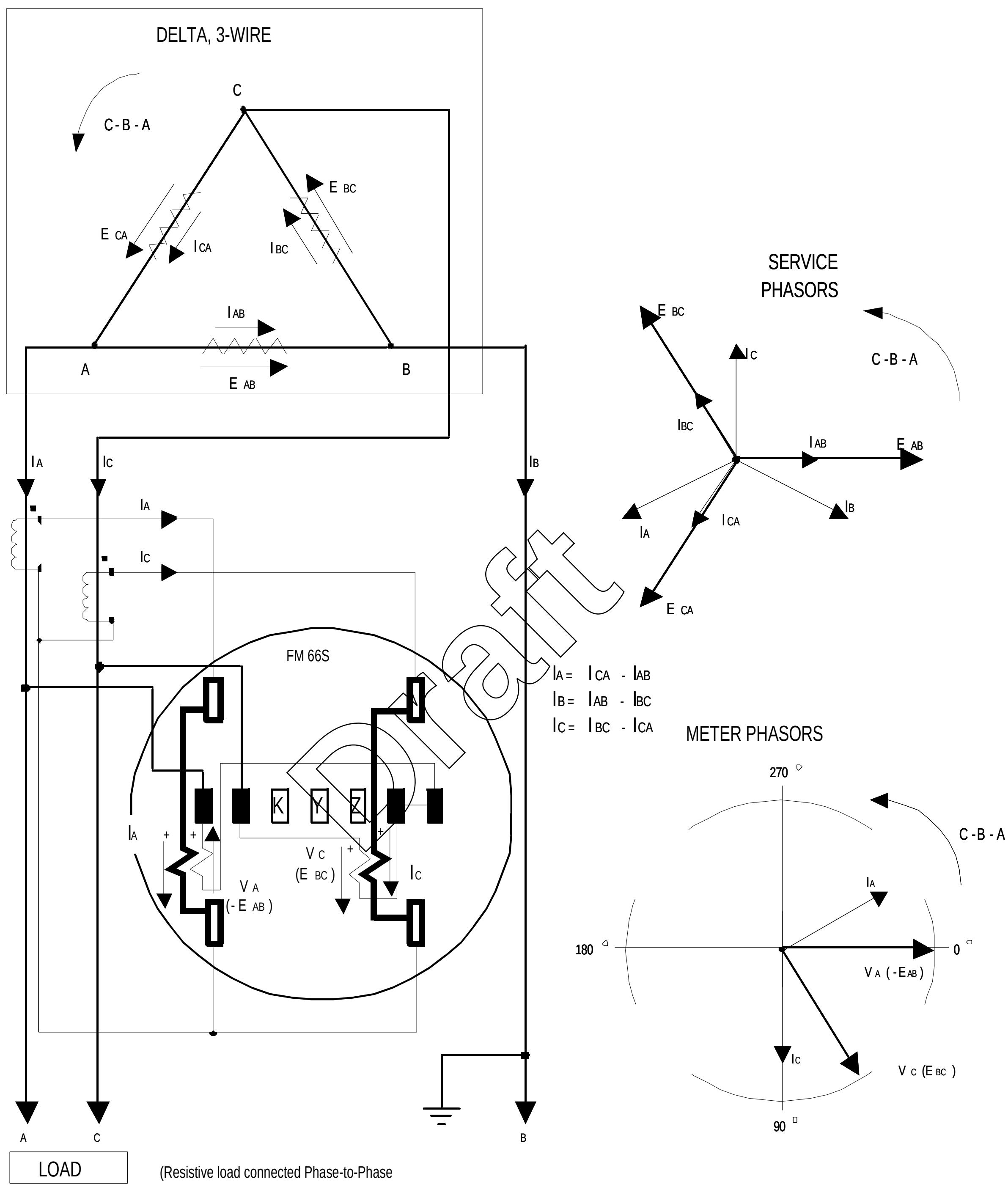


Figure 6.16 Form 66S 3-Phase, 3-Wire SENTINEL Meter

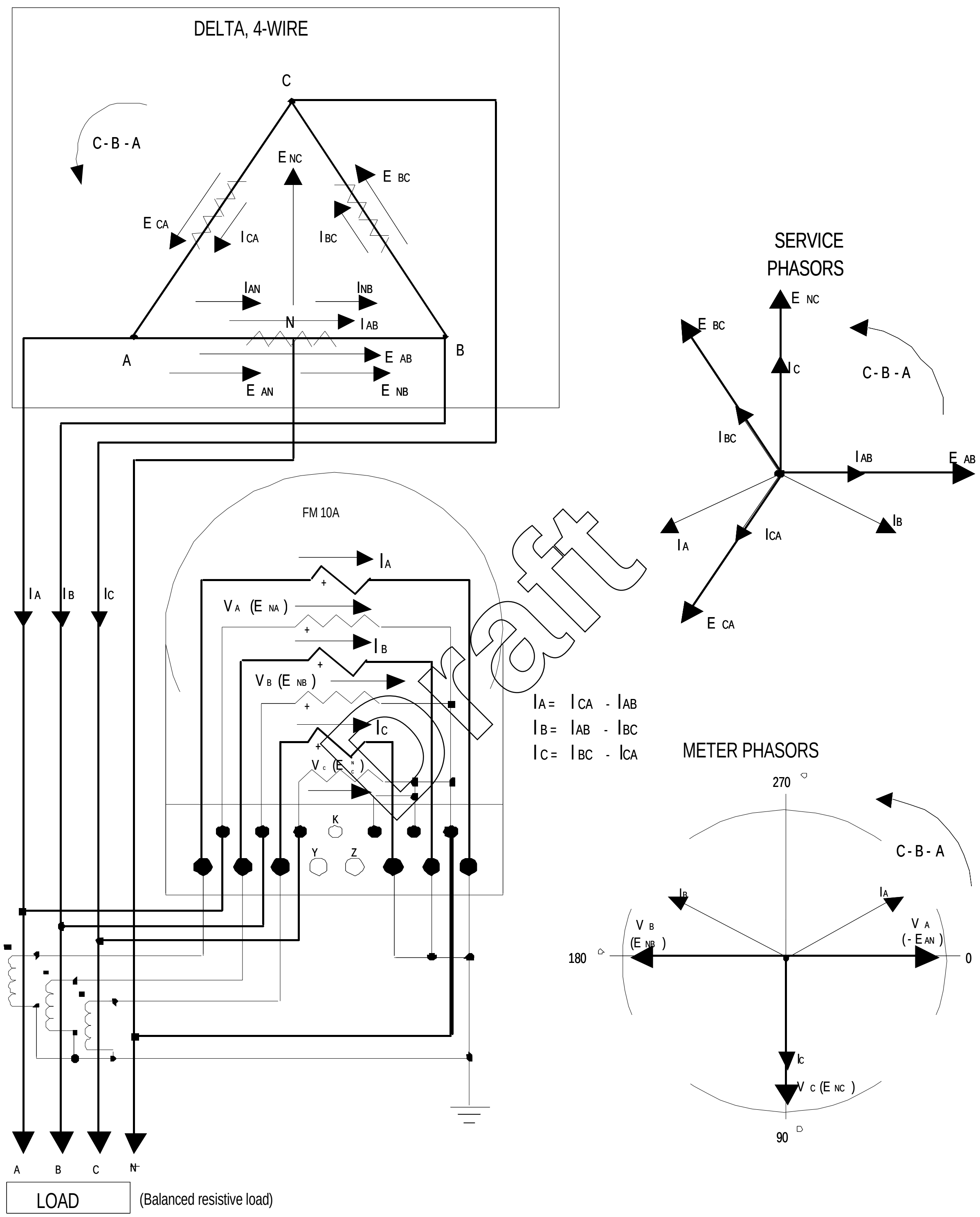
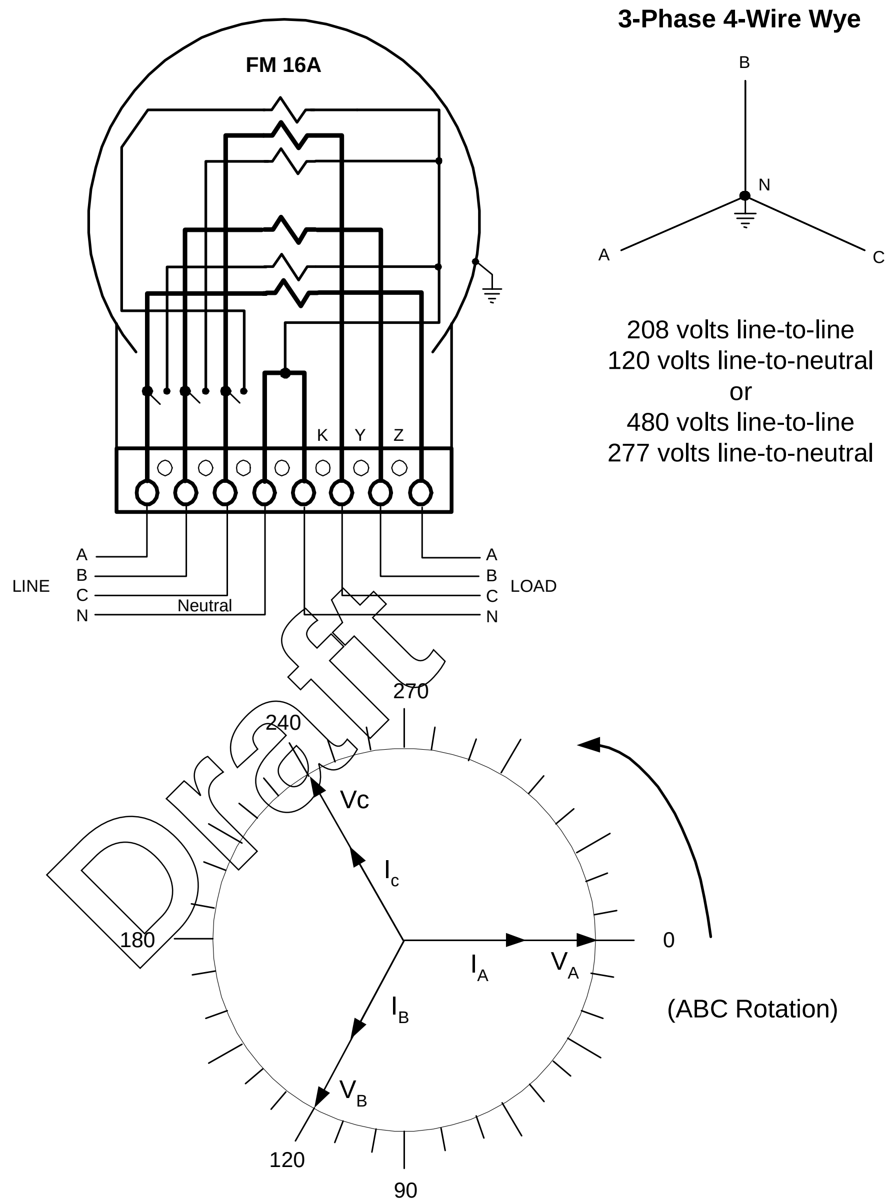


Figure 6.17 Form 10A 3-Phase, 4-Wire Wye, or 3-Phase, 4-Wire Delta SENTINEL Meter



Expected vector diagram at unity power factor with load connected phase-to-neutral

Figure 6.18 Form 16A 3-Phase, 4-W Wye, 3-Phase, 4-Wire Delta SENTINEL Meter

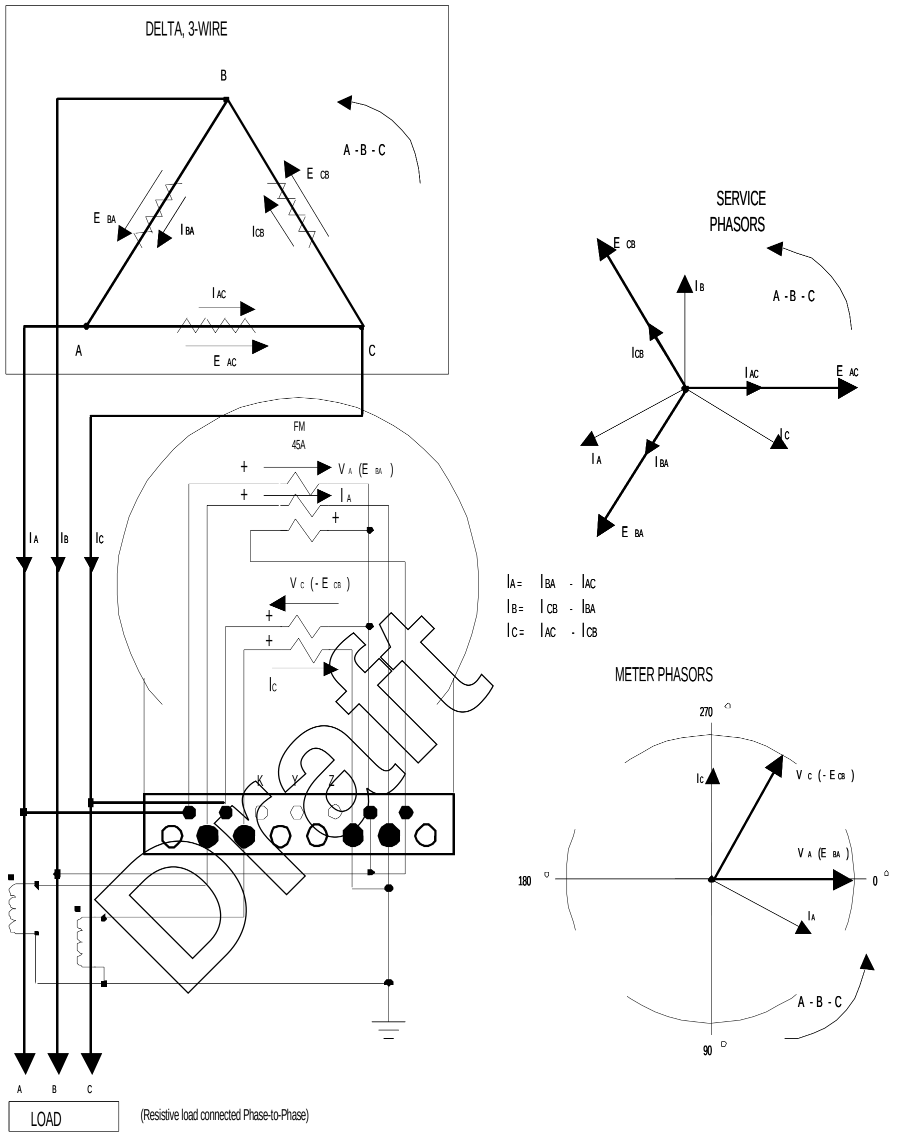


Figure 6.19 Form 45A 3-Phase, 3-Wire Delta SENTINEL Meter

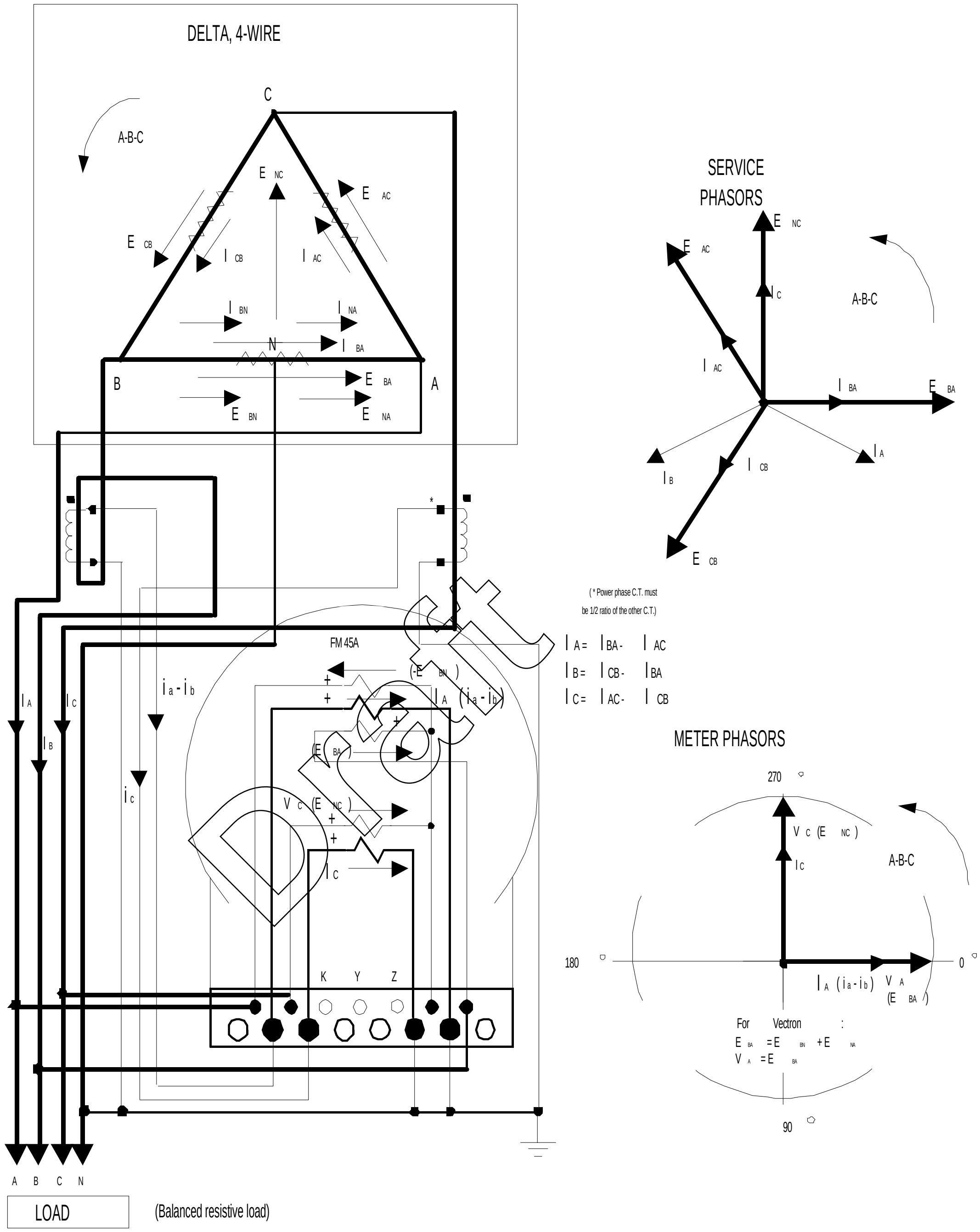


Figure 6.20 Form 45A 3-Phase, 4-Wire Delta SENTINEL Meter

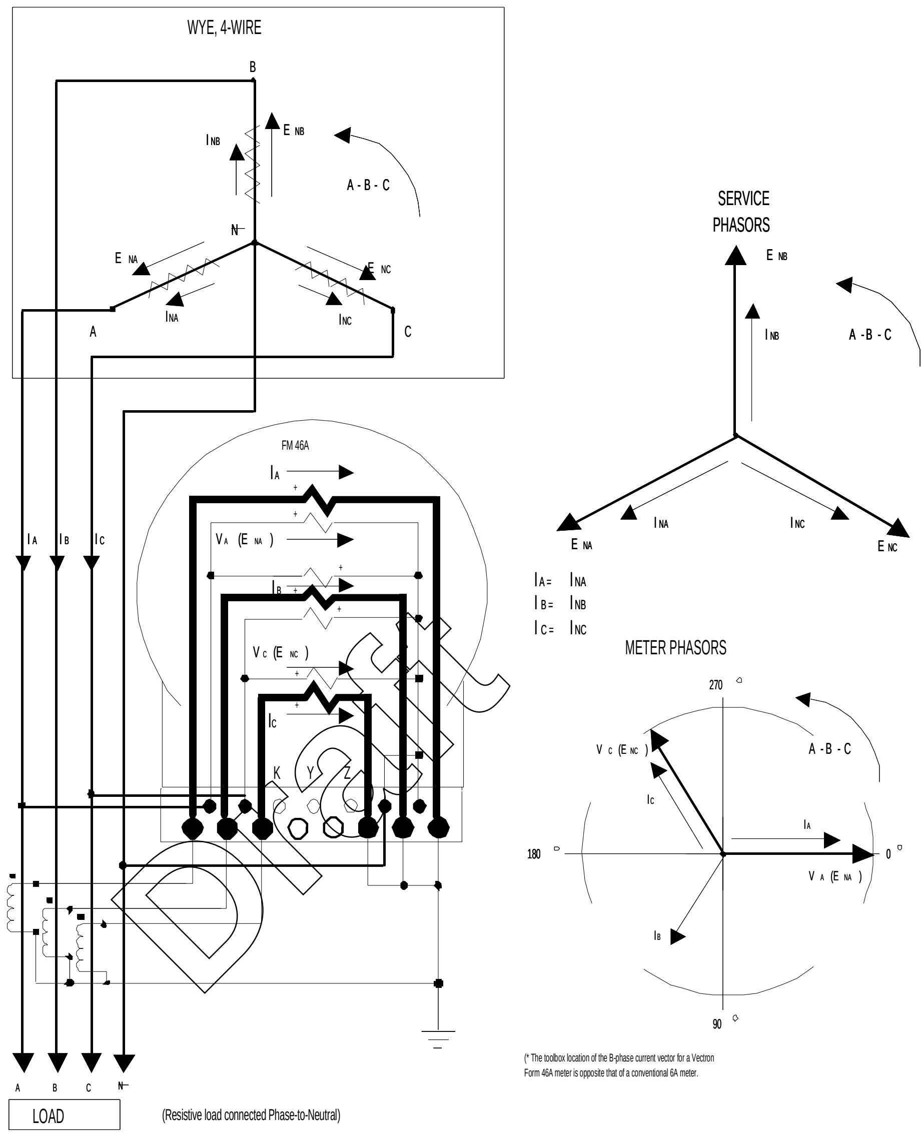


Figure 6.21 Form 46A 3-Phase, 4-Wire Wye SENTINEL Meter

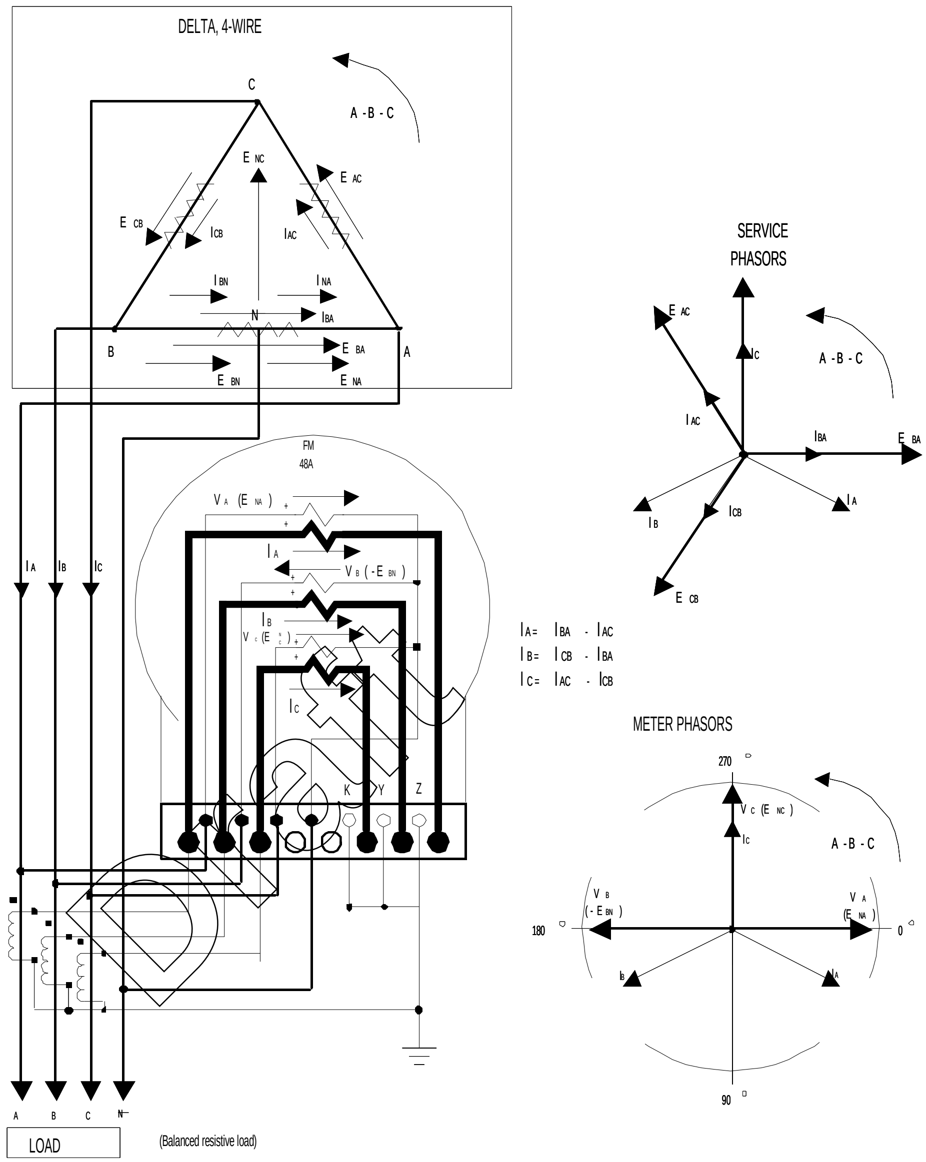


Figure 6.22 Form 48A 3 Stator 3Ø, 4W Delta SENTINEL Meter

SiteScan Diagnostic #1

The purpose of this diagnostic is to verify that all meter elements are sensing and receiving the correct voltage and current for each phase of a specific polyphase electric service. This diagnostic check may indicate one or more of the following problems:

- Cross-phasing of a voltage or current circuit
- Incorrect polarity of a voltage or current circuit
- Reverse energy flow of one or more phases
- Faulty site wiring
- Internal meter measurement malfunction

Polarity, Cross-Phase, and Energy Flow Check

Although the diagnostic check occurs every 5 seconds, once every second the meter determines the angle of each voltage and current phasor with respect to V_A. The meter will not only display this information in the Toolbox Mode, but will determine each phasor angle for validity with respect to the meter's form number and service type. Diagnostic #1 will take the "typical" phasor diagram for a particular form number and service type and place an envelope around each phasor where the actual phasor must be found for the diagnostic check to pass. The envelope for the voltage vectors is fixed at ±10° and the envelope for the current vectors is fixed at ±100°. The meter will recognize ABC or CBA phase rotation and will adjust the SiteScan expected values.

An example would be if a typical diagram has the B phase voltage angle at 120°, and the envelope around that phasor is ±10°, then the actual phasor must be between 110° to 130° from V_A for the diagnostic check to pass that phasor. The system will check each phasor in a similar fashion. The system will define the phasor envelope for each phase.

Figure 6.4 through Figure 6.22 show the ideal phasor diagrams for all possible form numbers and service types. These vector relationships assume site wiring as shown and the special case of unity power factor with balanced phase loading.

A multitude of wiring conventions, phase loadings, and power factors can exist at metering sites. Therefore, the vector diagrams obtained from actual metering sites will most likely vary from those shown here. This should be expected and will cause no metering errors, but some unusual circumstances could necessitate reconfiguration of one or more of the diagnostics. For more information on SiteScan reconfiguration, refer to the PC-PRO+ 98 documentation.

Diagnostic #1 Error Example

This example is for a Form 9S meter wired for a 4-Wire Wye system with ABC phase rotation, but the site was wired with a voltage circuit having the incorrect polarity (reverse VT).

The first step of diagnosing an error is to place the meter into the Toolbox Mode and gather the information.

The following is the information in the Toolbox Mode display while the Diagnostic #1 error is triggered:

	Phase A Display (Left Element)	Phase B Display (Center Element)	Phase C Display (Right Element)
Voltage Phase Angles	PhA 0.0° V	PhB 301.2° V	PhC 240.3° V
Phase Voltage	PhA 120.2 V	PhB 120.5 V	PhC 119.3 V
Current Phase Angles	PhA 9.0° A	PhB 125.5° A	PhC 246.0° A
Phase Current	PhA 6.8 A	PhB 10.2 A	PhC 9.8 A
Diagnostic Counters	**d1 001** d2 000 d3 000 d4 000 d5A 000 d5B 000 d5C 000 d5T 000		

The next step is to graphically plot the above information into a phasor diagram as shown in Figure 6.23.

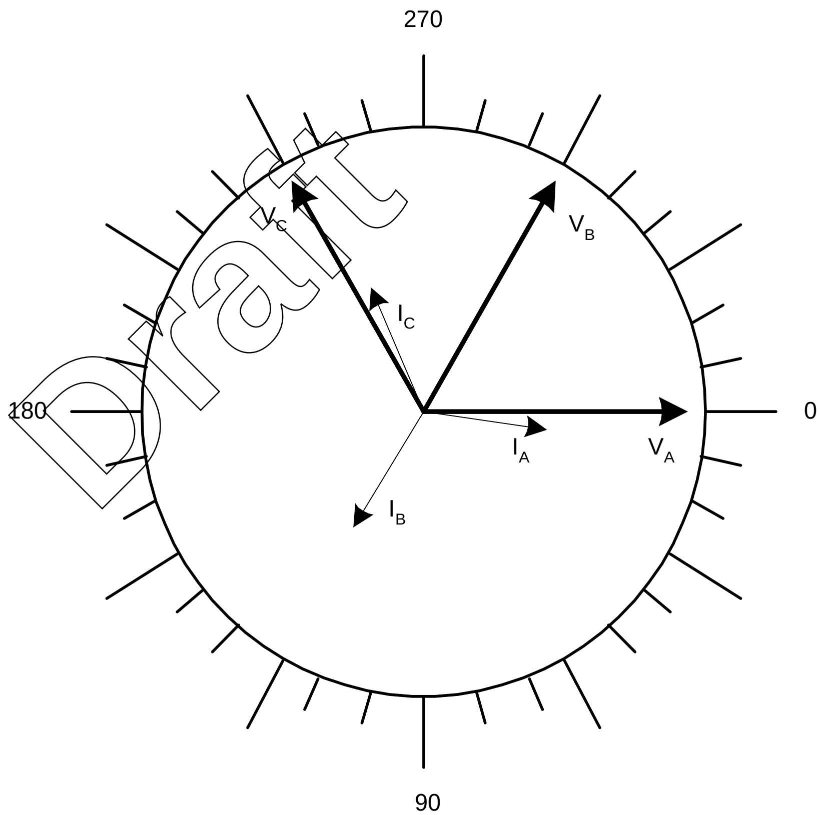


Figure 6.23 Diagnostic #1 Error Diagram

By comparing the phasor diagram drawn from the information found in the Toolbox Mode with the typical phasor diagram, it becomes clear that the B phase voltage is incorrect. The correct phasor should be around 120°, not 300° where the phasor currently is. Since the phasor is approximately 180° off, this most likely represents a polarity problem with the B phase voltage circuit. Also note that diagnostic counter d1 has incremented to “001”.

SiteScan Diagnostic #2

The purpose of this diagnostic is to verify that each individual phase maintains an acceptable voltage level with respect to the other phases. This diagnostic check may indicate one or more of the following problems:

- Loss of phase voltage
- Incorrect voltage transformer ratio
- Shorted voltage transformer windings
- Incorrect phase voltage
- Faulty site wiring
- Internal meter measurement malfunction

Phase Voltage Deviation Check

Diagnostic #2 uses the A phase voltage (left element) as the reference voltage because it is present in all meter forms, and because the meter electronics are powered from this phase. Once every five seconds, the A phase voltage is combined with a user-defined percentage tolerance (x) to determine the upper and lower bounds of the acceptable range for the other voltages.

For Diagnostic #2 to pass, the following equations must be satisfied:

$$V_B \text{ upper} \leq (1 + x\%) \bullet V_A \text{ and } V_B \text{ lower} \geq (1 - x\%) \bullet V_A$$

$$V_C \text{ upper} \leq (1 + x\%) \bullet V_A \text{ and } V_C \text{ lower} \geq (1 - x\%) \bullet V_A$$

If the above equations are not met for three consecutive checks, the diagnostic check will trigger. Although the meter is using V_A as a reference voltage, it does not need to be correct for this check to be valid, because the percentage difference is the determining factor.

Diagnostic #2 Error Example

This example is for a Form 9S meter wired for a 277 Volt, 4-Wire Wye system, but the site has an incorrect voltage transformer ratio. The meter was also programmed with a percentage tolerance of 10%.

The first step in diagnosing an error is to place the meter into Toolbox Mode and gather the information. The following is the information found in the Toolbox Mode display while the Diagnostic #2 error is triggered.

	Phase A Display (Left Element)	Phase B Display (Center Element)	Phase C Display (Right Element)
Voltage Phase Angles	PhA 0.0° V	PhB 119.4° V	PhC 240.9° V
Phase Voltage	PhA 119.2 V	PhB 275.4 V	PhC 279.1 V
Current Phase Angles	PhA 9.0° A	PhB 125.5° A	PhC 246.0° A
Phase Current	PhA 6.8 A	PhB 10.2 A	PhC 9.8 A
Diagnostic Counters	d1 000 **d2 001** d3 000 d4 000 d5A 000 d5B 000 d5C 000 d5T 000		

The second step to diagnose a Diagnostic #2 error is to compare the different phase voltage readings. This can be done several ways by simply comparing the readings or plugging the values into the equation. In this case, A phase is about 120 volts while both B and C phases are about 277 volts. This could indicate an incorrect voltage transformer ratio or a shorted voltage transformer winding for the A phase transformer. This could also indicate that A phase is correct and both B and C phases are incorrect. Also note that diagnostic counter d2 has incremented to “001”.

By using the above equations and substituting in the above voltages for the upper and lower limits, one can also see why the diagnostic check has failed. For Diagnostic #2 to pass, the following equations must be satisfied:

$$275.4 < (1 + 10\%) \bullet 119.2 \text{ and } 275.4 > (1 - 10\%) \bullet 119.2$$

$$275.4 < 131.1 \text{ and } 274 > 107.3$$

and

$$279.1 < (1 + 10\%) \bullet 119.2 \text{ and } 279.1 > (1 - 10\%) \bullet 119.2$$

$$279.1 < 131.1 \text{ and } 279.1 > 107.3$$

One can see in the above equations that 275.4 and 279.1 are not less than 131.1. Further investigation can begin on the circuit to determine the cause of the problem.

SiteScan Diagnostic #3

The purpose of this diagnostic is to verify that each individual phase current maintains an acceptable level. This diagnostic check may indicate one or more of the following problems:

- Current diversion
- Open or shorted current transformer circuit
- Internal meter measurement malfunction
- Faulty site wiring

Inactive Phase Current Check

Diagnostic #3 checks every five seconds to verify that the meter is receiving a customer-specified current level for each individual phase. If the meter fails three consecutive checks, the Diagnostic #3 check will trigger.

Once every five seconds, all phase currents are checked against a user-defined “low current value” to verify that the current value is above this value. If one or more currents fall below the low current value, *and* at least one current remains above this value for 3 consecutive checks, the SENTINEL meter will trigger the error. The error will not be triggered if all the currents fall below or above the user-defined value.

The starting current of:

- transformer-rated meters, CL 20, is 5 mA.
- self-contained meters, CL 200, is 50 mA.
- the CL320 version is 80 mA.

Therefore, a selected “low current value” of 100 mA would require at least one phase above and below the starting current in order to activate the diagnostic.

Refer to the PC-PRO+ 98 documentation for instructions on how to program this value into the SENTINEL meter.

Diagnostic #3 Error Example

This example is for a Form 9S meter wired for a 277 volt, 4-Wire Wye system, but the site has a shorted current transformer. The “low current value” is set at 25 mA.

The first step in diagnosing an error is to place the meter into the Toolbox Mode and gather the information. The following is the information in the Toolbox Mode display while the Diagnostic #3 error is triggered.

	Phase A Display (Left Element)	Phase B Display (Center Element)	Phase C Display (Right Element)
Voltage Phase Angles	PhA 0.0° V	PhB 119.4° V	PhC 240.9° V
Phase Voltage	PhA 276.2 V	PhB 277.7 V	PhC 277.0 V
Current Phase Angles	PhA 9.0° A	PhB ---------	PhC 246.0° A
Phase Current	PhA 11.8 A	PhB ---------	PhC 5.2 A
Diagnostic Counters	d1 000 d2 000 d5A 000 d5B 000	**d3 001** d4 000 d5C 000 d5T 000	

The second step to diagnose a Diagnostic #3 error is to compare the different phase current readings. In this case A and C phases both have current passing through the elements while B phase (center element) has no current. The dashes indicate that current is zero or too low to measure accurately. Accurate measurement is considered to be 0.5% of class rating for the current:

- CL 20 = 10 mA
- CL 200 = 1 Amp
- CL 320 = 1.6 Amps

This could indicate an open or shorted current transformer or current diversion. Also note that diagnostic counter d3 has incremented to “001”.

It is possible to see dashes where the current information should be, but have no Diagnostic #3 error present. See the SiteScan Toolbox Mode on page 6-2 for more information.

SiteScan Diagnostic #4

The purpose of this diagnostic is to verify that the current elements are sensing and receiving the correct current for each phase of a specific polyphase electric service. This diagnostic check may indicate one or more of the following problems:

- Poor load power factor conditions
- Poor system conditions
- Malfunctioning system equipment

Phase Angle Displacement Check

Diagnostic #1 must be enabled and must pass for Diagnostic #4 to be enabled and check for a problem. This will allow the system to make the assumption that all the phasors are in the relatively correct orientation and that there is no wiring problem. Since the voltage angles passed Diagnostic #1, the meter will assign the voltage phasors to be constant at the typical phasor angle. See Figure 6.4 through Figure 6.22 for a description of each phasor diagram.

If Diagnostic #1 passes, the meter will then determine the angle of each current phasor with respect to V_A for Diagnostic #4. The meter will judge each current phasor angle for validity with respect to the meter's form number and service type. Diagnostic #4 will take the "typical" phasor diagram at unity PF for a particular form number and service type and place a user-defined envelope around each current phasor, where the actual phasor must be found for the diagnostic check to pass.

An example would be if a typical diagram has the C phase current angle at 240° and the user has programmed an acceptable envelope of ±45° around that phasor, then the actual current phasor must be between 195° to 285° from V_A for the diagnostic to pass that check. The system will check each current phasor in a similar fashion (Figure 6.24). Here, the current vector must be within ±45° of the voltage vector for Diagnostic #4 to pass.

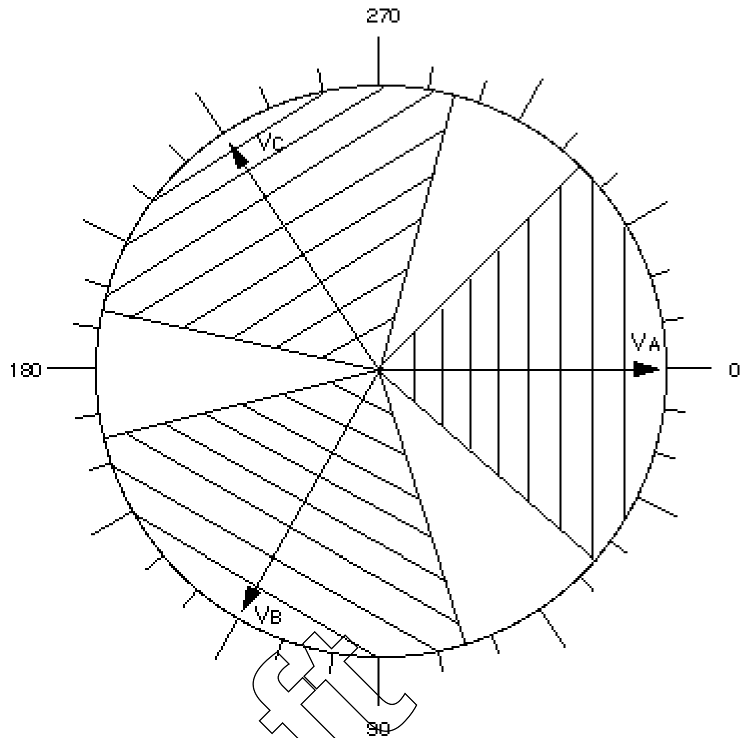


Figure 6.24 Envelope Example

Diagnostic #4 Error Example

This example is for a Form 9S meter wired for a 4-Wire Wye system with ABC phase rotation, but the site has a poor load power factor condition. The meter was programmed with a tolerance level of ±45° for Diagnostic #4 and Diagnostic #1 was also enabled and has already passed.

The first step in diagnosing an error is to place the meter in to Toolbox Mode and gather the information. The following is the information in the Toolbox Mode display while the Diagnostic #4 error is enabled.

	Phase A Display (Left Element)	Phase B Display (Center Element)	Phase C Display (Right Element)
Voltage Phase Angles	PhA 0.0° V	PhB 120.4° V	PhC 239.8° V
Phase Voltage	PhA 120.8 V	PhB 120.0 V	PhC 119.3 V
Current Phase Angles	PhA 2.0° A	PhB 119.8° A	PhC 297.2° A
Phase Current	PhA 6.8 A	PhB 10.2 A	PhC 9.8 A
Diagnostic Counters	d1 000 d2 000 d5A 000 d5B 000	d3 000 d5C 000	**d4 001** d5T 000

The next step is to graphically plot the above information into a phasor diagram as shown in Figure 6.25.

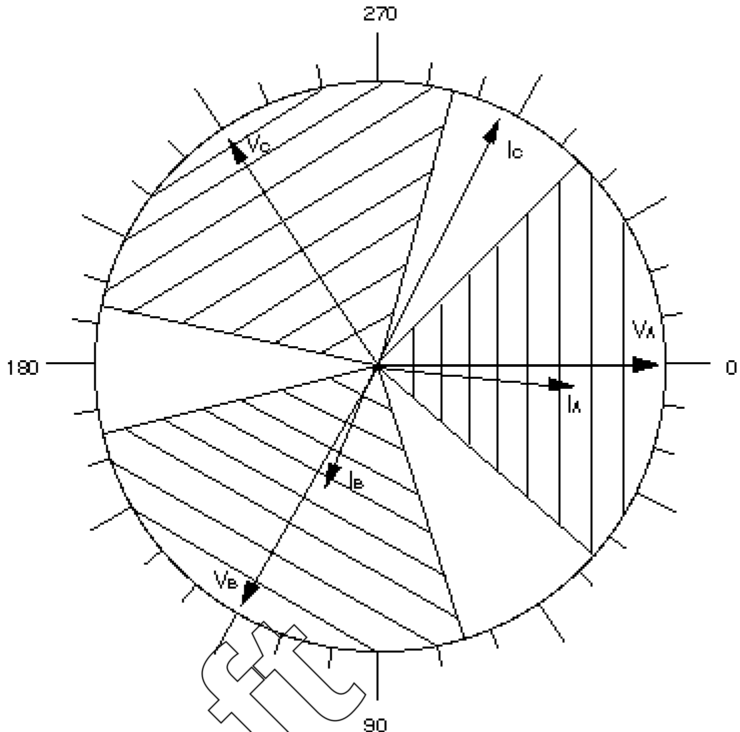


Figure 6.25 Phasor Diagram

By comparing the phasor diagram drawn from the information found in the Toolbox Mode versus the typical phasor diagram, it becomes clear that the C phase current is out of the user-defined envelope. The correct phasor should be around 240.0°, not the 297.0° where the phasor currently is. This is not a problem with the meter or a wiring problem at the site, but it does indicate a poor load power factor condition which may need to be corrected. Also note that diagnostic counter d4 has incremented to “001”.

SiteScan Diagnostic #5

The purpose of Diagnostic #5 is to detect current waveform distortion in any current signal. This distortion most commonly occurs when DC is present. Significant levels of distortion may cause inaccuracies in the measurement of the current signal and thus produce metering errors. The meter takes approximately 45 seconds to display Diagnostic 5.

Current Waveform Distortion Check

Diagnostic #5 detects DC on a per phase basis using what is know as a comb filter method. Rectified loads produce even harmonics which are typically in phase with the voltage signal. The algorithm works by summing current samples, which occur 90° after every zero crossing of the voltage waveform. This information is accumulated for a sample interval. These sample points should represent peak current values. If no DC is present on any of the phases, the current waveforms will be symmetrical and the accumulation of the current samples will be a value near zero. If DC is present on a phase, the current waveform is offset vertically and the accumulation of the current samples will be significantly higher.

Diagnostic #5 will trigger when the level of DC present is such that the accuracy of the SENTINEL could be affected. This level varies for different installations based on the per phase load conditions. When DC current is present, the SENTINEL can be programmed to display the Diagnostic #5 error code in the same manner in which Diagnostics #1 through #4 are programmed (i.e. lock, scroll, ignore). The number of times DC was present is available through meter communications on a per phase basis. The number of times that DC was present on all phases is available by accessing the Toolbox Mode and viewing the Diagnostic #5 counter or through meter communications.

Chapter 7 Testing, Troubleshooting, and Maintenance

This section provides information and instructions to help you test and maintain the SENTINEL meter. Topics covered include:

- Visual indicators
- Energy testing
- Demand testing
- Recommended testing procedures
- TOU schedule testing
- Field testing
- Troubleshooting (fatal and nonfatal errors)
- Maintenance

Visual Indicators

The Infrared Test LED, as well as several other annunciators, assist you in testing and troubleshooting the SENTINEL meter.

Infrared Test LED

The meter is equipped with an Infrared Test Light Emitting Diode (LED) for testing meter accuracy; the LED is located at the three o'clock position on the meter faceplate (Figure 7.1). The pulse weight represented by the LED is programmable through the PC-PRO+ 98 programming software. The programming software allows a different pulse weight value for the LED in the following display modes: Normal, Alternate, Test, and Test Alternate. The meter can be programmed to drive the Test LED with a variety of energy values, depending upon the energy quantities selected in the configuration.

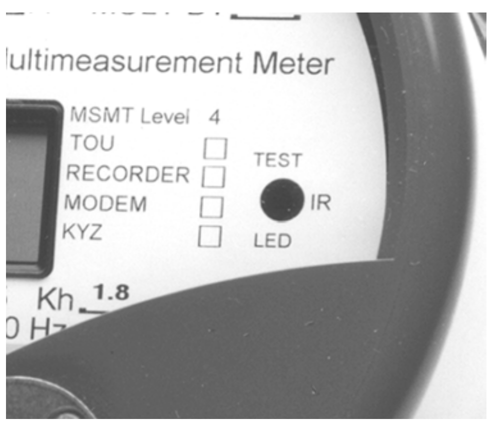


Figure 7.1 Infrared Test LED

Annunciators

The SENTINEL meter is equipped with a variety of annunciators for a more meaningful display.

Load Indication/Direction Annunciator

The SENTINEL meter is equipped with a bidirectional Liquid Crystal Display (LCD) load emulation indicator. The load emulation indicator consists of three segments with two direction arrows located in the lower left portion of the display.

These segments are individually illuminated and traverse left to right for positive (line to load) energy flow. The segments will traverse right to left when received energy is configured. The rate of segment travel is directly proportional to the programmed pulse constant (Kh value).

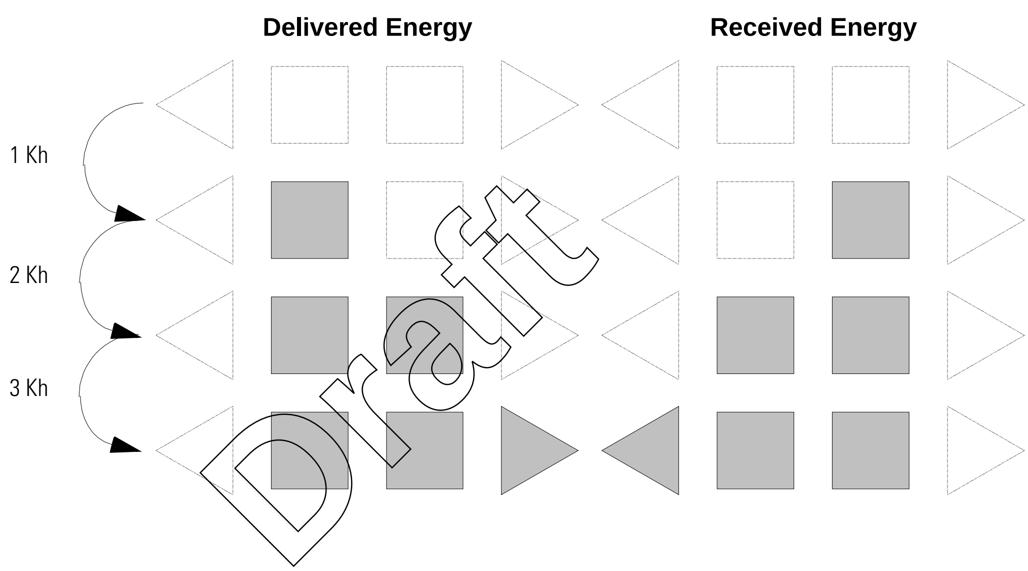


Figure 7.2 Delivered and Received Energy Segments

Phase-Voltage Indication Annunciators

The SENTINEL meter is equipped with three LCD voltage indicator annunciators. They are located in the lower left portion of the LCD display. Illuminated annunciators (V_A, V_B, and V_C) indicate active voltage for these respective phases. Depending on how the user configures the meter, a loss of voltage may be indicated with either a missing or flashing annunciator.

Nominal Voltage Indication Annunciator

The SENTINEL meter is equipped with a nominal voltage indication annunciator. This annunciator indicates the voltage value to which the nominal voltage is nearest. Nominal voltage indication values are 120, 240, 277, and 480.

Test Mode Annunciator

The SENTINEL meter is equipped with a Test Mode LCD annunciator. Located in the lower left portion of the display, this annunciator is present when Test Mode or Test Alternate Mode is activated. The word “TEST” appears on the display during Test Mode activation. The words “ALT” and “TEST” appear on the display during Test Alternate Mode activation. The “TEST” annunciator will also appear when the meter is in Toolbox Mode.

Energy Testing

The SENTINEL is a CL 0.2 accurate meter and requires no calibration adjustments. Verification of accuracy of energy and demand may be verified in many ways.

Testing With the Infrared Test LED

Verification of metered energy values by the meter can be accomplished by using the pulsing infrared (IR) LED located in the 3 o’clock position of the faceplate.

With a constant load applied, the IR LED pulses are compared to the output of a conventional high accuracy watthour standard. This is accomplished using an IR-compatible optical pickup device and a comparator.

Follow these steps to test the Wh with the LED:

1 Program the meter with the desired pulse quantity(ies) and pulse weight(s) Ke.

2 Apply a constant delivered watts load (W_{app}) to the meter.

3 Verify that the LED pulses properly either by counting the pulses or using a comparator to compare pulses from the meter under test to the standard. To determine the number of pulses per second, use the following equation:

$$\#\text{ pulses per second} = W_{app} \times N \times \frac{1\text{ hour}}{3600\text{ seconds}} \times \frac{1}{Ke}$$

where N is the coil factor for single phase test method (Table 7.1).

If the meter is being tested using singlephase test methods, a coil factor must be included in the calculations. See Table 7.1 for the appropriate factor.

Table 7.1 Meter Coil Factors

Form	Series	A Phase Only	B Phase Only	C Phase Only
45[1], 12, 66	2	1	—	1
9(8)[2], 16(15,14)	3	1	1	1
46[3]	4	1	2	1
2	1	0.5	—	0.5

1 When testing Form 45 SENTINEL meters, the two voltage blades or terminals on the load side of the meter must be shorted. If these blades are not shorted, the meter will not power up during testing. In a field installation, the external wiring provides the necessary shorted connection. It is important to note that these two blades are NOT to be shorted when the meter is installed in the field. For applications where a Form 45 SENTINEL meter is to be installed on a 4-wire delta installation, please contact your SchlumbergerSema Sales Representative for information concerning the testing of the third voltage divider on the load side of the meter.

2 When testing under true polyphase conditions, Forms 9 and 16 can only be tested as a 4-Wire Wye. These forms cannot be tested as 4-wire deltas because of present limitation inherent in the test equipment.

3 2 1/2 Element Meter.

If accuracy or repeatability is poor, the Kh may be incorrect or the “settling time” in the test bench must be adjusted. (SchlumbergerSema recommends a 4–5 second settling time.)

Testing Using the Load Indication Annunciator

The SENTINEL meter is capable of visually being tested by using the load emulation annunciator shown in Figure 7.2 on page 7-2. As further discussed in the load emulation annunciator section, the load emulation annunciator scrolls at a rate proportional to the programmed energy constant.

Testing Using the Energy/Time Method

As an alternate to the above methods, the energy accumulated by the registers and a reference standard can be read directly from the display and compared over a period of time. Energy readings displayed while the meter is in the Test Mode are in floating decimal format. This will result in maximum resolution for short duration tests.

Recommended Energy Testing Procedures

Testing solid-state meters on test boards designed primarily for electromechanical meters may sometimes give unexpected results. Erroneous readings could occur on light-load tests when the test sequence calls for a light-load (LL) test following a full-load (FL) or power-factor (PF) test. In some cases, PF readings could also be in error when following a FL test. The errors are always positive and may be a few percent for PF and even greater for LL. The problem is aggravated on lower voltages and when using large test constants, K_t, similar to the typical Kh values of comparable induction meters. This problem does not exist on modern test boards with their latest software.

Test Description

A typical meter test sequence consists of:

1 The voltage and current ramp up at unity power factor to the FL level.

2 A pulse from the meter starts the FL test and another pulse ends it.

3 The phase angle then changes for the PF test. The current may stay at the FL level or ramp down to zero and back up for the phase angle change.

4 A pulse from the meter starts the PF test and another pulse ends it.

5 The current ramps (directly or through zero) to the LL current level at unity power factor.

6 A pulse from the meter starts the LL test and another pulse ends it.

Most test boards use jogging (slewing) immediately following a FL or PF test to shorten the time required for the next test to start. The energy used for jogging may be more than enough to cause the next pulse from the meter even before the ramping of current or changing of phase angle is completed. If the trigger to start the next test is armed and ready during the jogging or transition to the next test level, an unexpected pulse may cause the test to start too soon. This obviously will result in erroneous readings. Some settling time is necessary for the test board power, the reference standard, and the meter under test to stabilize after the change to a new test level.

Most test boards provide a settling time (programmable or fixed) and will not recognize another test pulse following the completion of a test until the jogging, ramping, and settling time have all transpired. The SENTINEL meter needs a settling time of about three to five seconds after the new test level has been reached before the test starts.

Recommendations

Erroneous test results caused by the problems previously described can probably be corrected by implementing one of the following suggestions. Even if there are no bad readings, Solution 3 can cut the total test time significantly without sacrificing test verification certainty. The suggested solutions are:

1 Change the test sequence to avoid jogging before the light-load test.

2 Upgrade the test board to meet the requirements listed previously.

3 Program the meter and test board for a small test constant. This will avoid jogging and also give the added benefit of shorter test time.

Solution 1

Change the test sequence so that the LL test is first, followed by the PF test and then the FL test. This should prevent all jogging from occurring between tests and will probably eliminate the erroneous readings. This is the quickest solution to implement since it requires no changes to the test board or the meter.

Solution 2

Install the latest test board software revision. A test board ideally should recognize no new test pulses after the completion of a test until jogging, ramping, and settling time have all transpired. Settling time should be programmed for three to six seconds. There is nothing to be gained by using settling times greater than six seconds.

Solution 3

This is the preferred solution, since it results in shorter test times and can be implemented simply by programming the meter for a smaller test constant and settling the test board accordingly.

The SENTINEL and most other solid-state meters have the capability of being programmed for a much smaller test constant (K_t), such as one-tenth or one-twelfth of the energy required for one “disk revolution” of the meter. With the test pulses running 10 to 12 times faster, there is the possibility of shortening the test time considerably, but not by a factor of 10 or 12. It still takes a finite amount of time to obtain meaningful results.

Recommended Test Setup for Minimizing Test Time

The following settings are recommended for obtaining test uncertainties of less than 0.1% and at minimum test times:

1 Program the test board settling time for five seconds.

2 Program the meter and test board for a small test constant, K_t, in some convenient fractional value of the traditional Kh. For this example, 1/12 of the traditional Kh of the equivalent electromechanical meter is used. (The use of decimal values may be preferred for simplification of math.)

3 Use 12 pulses (1 rev) for FL.

4 Use 12 pulses for PF.

5 Use 1 pulse for LL.

6 For element tests, the FL and PF pulses can be divided by the number of elements, always rounding up for fractional values.

The total test time for a series FL, PF, LL sequence can be shortened by more than one minute compared to the time required for an electromechanical meter or a solid-state meter using the equivalent test constants. If LL element tests are used, the time savings will be much greater.

Recommendations for Minimum Variability

The variability of testing a SENTINEL meter can be reduced by lengthening the test times (using more pulses). Doubling or tripling the recommended minimum test time will reduce the variability by a factor of two or three. Very little improvement is realized by running longer than about 45 seconds for each test.

Demand Testing

Testing consists of comparing the readings displayed on the SENTINEL meter to the actual demand as determined using a high-accuracy RMS responding reference standard. The standard should have pulse outputs proportional to Wh/pulse (or VAh/pulse).

Pulses from the reference standard are accumulated over one demand interval, and then the total pulse count representing watthours or volt-amperehours is converted to an average demand value using the formulas in "Demand Calculations" on page 7-8.

Because of the high accuracy of the SENTINEL meter, the following is the recommended procedure for testing these meters.

Demand Test Method

1. Connect the meter under test and the reference standard in the same circuit with all voltage coils in parallel and current coils in series as per standard meter testing procedures (Figure 7.3).

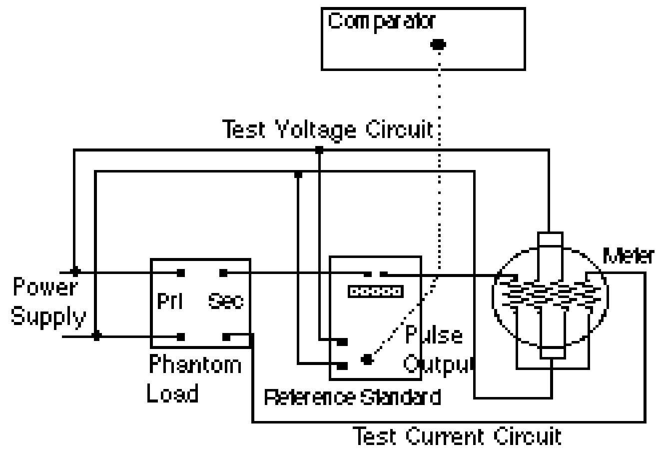


Figure 7.3 Test Connections

2. Apply rated voltage to the meter under test and the reference standard. Set the test current to the desired level (FL, LL, or PF test amps or any desired level within the meter rating). To ensure that the supply polarities are correct, check that the Load Emulation Annunciator is traversing in the forward direction. Switch off only the current to both the meter and the standard.
3. Reset and enable the pulse counting device.
4. Put the SENTINEL meter into Test Mode by pressing the Test switch. Once this has been done, push in the Demand Reset switch to zero the test registers and start a new demand interval.
5. Start the test by switching on the current to all meters and the reference simultaneously.

Table 7.2 Meter Singlephase Test Constants (SPTC)

Form		Series	A Phase Only	B Phase Only	C Phase Only
45 or 12	3Ø, 3W, Δ	0.866	0.866	—	.866
46[1]	3Ø, 4W,wye	1	1	1	1
9 or 16	3Ø, 3W, Δ	0.911	.866	.0866	1
9, 16, or 14	3Ø, 4W, wye	1	1	1	1
45 or 12	3Ø, 3W, wye	1	1	—	1

[1] 2 1/2 Element Meter

6. The End-of-Interval (EOI) flag will appear for five seconds in the display after the end of the demand interval. At this time, switch off the current to all meters simultaneously and stop the pulse count. Do *not* disconnect the voltage to the meter.
7. Record the pulse counter total and the values displayed on the SENTINEL meter.

8 Perform calculations A, B, C, and D (if applicable) in the demand calculations section and compare the results.

This test method is valid for kWh, kVAh, kvarh, kW, kVA, and kvar at any load or power factor.

Demand Calculations

With Solid-State Metering, conducting energy and demand tests may be considered redundant since they are both results of the same measurement.

Calculation A: Actual Active Energy (kWh)

Actual active energy is calculated using the following formula:

$kWh = P_T \times Kh \times N/1000$

where:
- Kh =Watthours per pulse output value from the reference standard. (A watt and/or a VA standard must be used.)
- P_T =Total pulses accumulated from the reference standard
- N =Coil factor (Table 7.1 on page 7-4)

Pre-calculate the total pulses expected with the following formula to ensure that the comparator display does not overflow:

$P_T \times Kh = V \times I \times T/(Kh \times 60)$

where:
- V =Voltage applied to standard
- I =Current applied to standard
- T =Test Mode demand interval length in minutes

If Test Mode display is in watthours (Wh), divide by 1000 to get kWh.

Calculation B: Actual Active Demand (kW)

Actual active demand is calculated using the following formula:

$kW = kWh \times 60/T$

where: T =Test Mode demand interval length in minutes

Calculation C: Actual KVA Hours

$kVAh = P_T \times Kh \times N/ (1000*SPTC)$

where:
- N = Coil factor (Table 7.1 on page 7-4)
- SPTC= Single phase test constant (Table 7.2 on page 7-7)

Calculation D: Actual kVA Demand

kVA = kVAh x 60/T

where: T =Test Mode demand interval length in minutes

Field Testing

Field testing of the SENTINEL meter may be accomplished with conventional methods using either the infrared test pulses or the load emulation annunciator.

Required Hardware

The typical field test setup consists of a phantom load, a portable standard, and an infrared test pulse adapter with counter or snap switch assembly.

Test Method Using Infrared Pulse Adapter

The pulse adapter runs the test for a programmed number of pulses. The number of pulses is set on the test pulse adapter by the use of counter switches. The adapter will automatically start the test when the START COUNT button is pressed.

When the test begins, the test pulse adapter counts the pulses it receives from the meter until the programmed number of pulses have been received.

When this occurs, the pulse adapter automatically shuts off the portable standard. The standard then displays the number of equivalent disk revolutions which is then compared to the number of pulses for the test.

Test Method Using a Snap Switch Assembly

This method is similar to the above except starting and stopping of the standard is performed manually.

To conduct the test, the technician observes the position of the load emulation annunciator and simultaneously starts the standard through the snap switch. After observing a predetermined number of emulated disk rotations, the technician stops the standard with the snap switch. A comparison is then made between the predetermined number of emulated disk rotations and equivalent disk rotations indicated on the watthour standard.

Troubleshooting

With solid-state meters, the computer is in a very unfriendly environment. While the SENTINEL is designed to perform within this harsh environment, things can go wrong with the meter or installation.

Fatal Errors

Fatal errors cause the display to lock on the error code because of the possibility that billing data may have been corrupted or that the meter may not be operating correctly. If multiple fatal errors occur, the one with the lowest number will be the error code that locks on the display.

The SENTINEL meter will check for fatal errors:

- when a meter reconfigure is performed.
- when power is initially energized and upon future power restoration.
- while performing key operations.

Fatal errors are cleared when they are corrected and the meter is reprogrammed.

Error Code	Error	Possible Cause	Error Description
FAtError1	MCU FLASH Error	The meter has detected a problem with the program memory.	If the meter has a MCU FLASH error, the error code will be continuously displayed. If this error occurs, program the meter and check for proper operation. If the error continues to exist, return the meter for repair.
FAtError2	RAM Error	The meter has detected a problem with the RAM.	If the meter detects a RAM problem, return the meter for repair.
FAtError3	DATA FLASH Error	The meter has detected a problem with the data flash.	If the meter has a DATA FLASH error, the error code will be continuously displayed. If this error occurs, program the meter and check for proper operation. If the error continues to exist, return the meter for repair.
FAtError4	Front End Processor Error	Front end processor failure.	An unrecoverable fatal error has occurred upon power up in the front end microprocessor. Return the meter for repair.
FAtError5	Power Down Error	Power Down Error.	A power down error exists when the microprocessor receives a reset before all billing values are correctly saved to nonvolatile memory. If a power down error occurs, the error code will be continuously displayed. If this error occurs, program the meter and check for proper operation through **two complete** power down and power up sequences. If the error continues to exist, return the meter for repair.
FAtError6	File System Error	The meter has detected a problem with the file system	If the meter detects this problem, return the meter for repair.
FAtError7	Operating System Error	The meter has detected a problem with the operating system	If the meter detects this problem, return the meter for repair.

Non-Fatal Errors

Non-fatal errors can be programmed to scroll during the one second display off-time or lock on the meter display. If multiple non-fatal errors occur, the meter will display a combined error message. For example, if a Low Battery error and a Loss of Phase error exist, the error display will read `Err 12----`. In this case, if one of the errors had been programmed to lock, and the other error had been programmed to scroll, the display will lock on the combined error message.

Selecting a display mode by holding the magnet near the cover’s magnet icon at the seven o’clock position allows that display mode sequence to scroll one time during a locked non-fatal error. At the end of the display sequence, the error message locks onto the display again.

Each error check is performed upon initial power-up, upon programming, upon restoration of power after an outage, and at least once each day when performing key operations.

Error Code	Error	Possible Cause(s)	Error Description
`Err 1-----`	Low Battery Error	Battery Voltage Low Battery Connector Not Connected Properly	A low battery check is performed once a day and upon initialization. If a low battery level is detected during this procedure, the error code can be displayed in Normal Mode. This error can be programmed to continuously scroll during the display off time or lock on the meter display. A low battery continues to function; however, its reliability decreases over time. If a dead battery is detected upon restoration of power, the error code will display until the battery is replaced. TOU and load profile functions will be disabled until the battery is replaced and the time is set. Total registers remain functional during a dead battery condition. However, TOU (rates A, B, C, D, E, F, G) registers and Load Profile Channels will not accumulate after an outage with a dead battery. If a dead battery level error occurs during normal operation, TOU and load profile will continue to operate until an outage occurs.
	To retain data for TOU and Load Profile, the battery must be replaced with the power applied to the meter.		
`Err -2----`	Loss of Phase Error	The voltage on one of the phases dropped below 45 volts.	A Demand Reset after the voltage returns will clear this error.
`Err --3---`	Time-of-Use (TOU) Error	A problem was detected in the Time-of-Use Schedule.	TOU functions have stopped because the meter could not interpret the schedule. To correct the problem, correct the problem in the TOU schedule and reprogram the meter.
`Err ---4--`	Reverse Direction Error	Reverse Power was detected on one or more phases.	A Reverse Direction error exists when the meter detects one second of (Active) energy on one or more phases in the reverse direction. This error is applicable to kWh only. Reverse direction detection is a selected feature during programming. This error is reported only when the meter is not measuring kWh received and/or kWh net. The reverse direction error will clear when a demand reset is performed.
	This error is not active with bidirectional measurement.		
`Err ----5-`	Clock/Load Profile Error	Clock/Load Profile Error	This error occurs if the meter is powered up with a dead or no battery when it is configured for load profile. If this error occurs, the error code is displayed in Normal Mode. If a Clock/Load Profile error occurs, the load profile and TOU operations will be discontinued until the meter is reprogrammed. The error will then clear and the meter will resume normal operation.

Error Code	Error	Possible Cause(s)	Error Description
`Err -----6`	Full Scale Overflow Error	Programmed Full Scale Value Exceeded	A Full Scale overflow error exists when the calculated kW demand at an EOI exceeds the meter full scale value. The meter full scale value is selected during programming and only applies to kW (delivered). If an overflow occurs, the error code is displayed in Normal Mode. The full scale overflow error displays after the interval during which the overflow occurred. The maximum demand register continues to accumulate and display kW as long as the format limitations are not exceeded. When a demand reset is performed, the correct maximum kW value will be added to the cumulative registers and the error code will no longer be displayed. If a full scale overflow occurs, check the installation to ensure that the current capacity of the meter has not been exceeded. A full scale overflow in no way affects the existing billing data.

Other Problems

Demand Reset Cannot Be Initiated Through PC or Handheld

Communication cannot be established. See "Programmer Cannot Communicate with Meter" on page 7-13.

Incorrect or No Accumulation of kWh or kW

- *Demand Delay Selected*—kW will not accumulate after a power outage if CLPU (demand delay) has been selected. Accumulation will begin immediately after demand delay has expired. Verify meter program and reconfigure meter.
- *Component Failure*—Return the meter for repair.
- *Meter is not being tested properly*—See “Recommended Testing Procedures” in that section.

Reset Mechanism Does Not Initiate Demand Reset

- *Reset Has Occurred Within Last <Programmable Time Period, e.g., 60 Seconds>*—Manual demand reset cannot occur within 60 seconds of the previous demand reset. Wait 60 seconds and perform a second demand reset.
- *Reset Switch Disabled*—Reset switch may be disabled through software.
- *Register Board not Properly Installed in Upper Housing*—Verify that the Register board is fully engaged with the upper inner cover.

Blank Display

- *Power Not Applied to Meter*—Apply voltage to A phase.
- *Voltage Connector Loose*—Voltage connector of the meter loose from the Register board; re-secure the connector.
- *Component Failure*—Return the meter for repair.
- Voltage too low for meter startup—the SENTINEL requires at least 45 volts to start up.

Time and Date Wrong (TOU Version)

- *Time/Date Wrong in PC or Handheld Device*—Verify and update time/date in programming device and download new time and date to meter. See appropriate software manual for more detailed directions.
- *Wrong Line Frequency*—Verify proper line frequency is selected in setup routine in programming software. Select proper frequency and reconfigure meter.
- *Battery Failure During Power Outage*—Verify battery voltage. Replace battery and download new time and date.
- *Daylight Savings Time Not Programmed Correctly*—Verify DST is selected in program. Reconfigure meter with correct program.
- *Component Failure*—Return meter for repair.

Optional Output Contact Closures Not Occurring

- *Meter Improperly Programmed*—Verify all required programmable values were defined.
- *Output Wiring Not Properly Connected*—Verify wiring and correct.
- *Meter Not Supplied with Output Electronics*—Retrofit proper output circuitry.
- *Option Board Component Failure*—Replace Option Board.
- *Meter Component Failure*—Return meter for repair.
- *Low (or No) Wetting Voltage*—Apply wetting voltage.
- *No Load*—Confirm load should be present.

Programmer Cannot Communicate with Meter

- *Optical Probe Cable Assembly Failure*—Check cable with known meter that communicates. Check meter against known cable that is functioning. Also check batteries in cable assembly (if applicable).
- *COM Port in Programmer Is Set Wrong*—Verify proper COM port number has been selected in the setup routine of the programming software. If the wrong COM port is selected communications will not occur.
- *Security Code in Meter*—If security codes have been downloaded to the meter, the programming device must have the proper code to make connection to the meter. Verify security codes in the setup routine of the programming software.
- *Cable Not Connected Properly*—Verify optical probe lines up properly over the optical connector. Reinstall cover for proper alignment. Verify PC (or handheld) and cable are securely connected and attached to the correct COM port.
- *Incorrect Cable Selection*—Wrong cable selected in **Communications** | **Probes** section of PC-PRO+ 98.
- *Main Register Electronics Failure*—Return meter for repair.

Magnetic Switch Does Not Activate the Alternate or Toolbox Mode

- *Magnetic Field Is Too Weak*—Place magnet closer to switch or use stronger magnet.
- Magnet was not in place for four consecutive seconds.
- *Magnetic Switch Failure*—Return meter for repair.

Test Mode Switch Does Not Place Meter in Test Mode

- Switch deactivated by software—Activate switch in software and reprogram meter.
- *Register Board not Properly Installed in Upper Housing*—Verify that the Register board is fully engaged with the inner cover.
- *Switch or Electronic Failure*—Return meter for repair.
- No display items in Test Mode Display List.

Diagnostic 1 Condition Incorrectly Active

Verify that meter determined the correct service type.

Diagnostic 2, 3, or 4 Condition Incorrectly Active

Verify that thresholds are not set too tight.

Counters Are Too High

Verify that thresholds are not set too tight.

Maintenance

Preventive Maintenance

No scheduled or preventive maintenance (other than battery replacement for TOU/ Load Profile versions) is necessary for the SENTINEL meter.

Line potential may exist on the battery terminals. Follow these precautions:

- **Never short-circuit batteries (such as by measuring current capability with an ammeter).**
- **Do not recharge batteries.**
- **Do not store or transport batteries in metal or other electrically conductive containers.**
- **Keep batteries separated. If stored in a container where they can contact each other, face them in the same direction to prevent short circuits.**
- **Do not operate batteries at temperatures above 85°C (185°F).**
- **Dispose of batteries where they will not be punctured, crushed, or incinerated.**
- **Discard the battery using proper hazardous waste procedures.**

Corrective Maintenance

Because of the high level of integrated packaging and surface-mount components, on-board component repairs are not recommended. The entire meter should be returned to SchlumbergerSema Customer Service for repair.

Notes:

Chapter 8 Replacement Parts and Accessories

This section provides replacement part numbers and order information for accessories.

Cover Assemblies and Cover Components

Part Number	Description
442370-001	Cover Assembly, Standard Reset
442021-002	Cover Assembly, without Reset
442021-005	Cover Assembly, with Keylock Reset
442363-001	Upper Inner Cover
442364-001	Lower Inner Cover
442364-002	Molded Rivet- secures Lower Inner Cover
442364-003	Hanger
442118-001	Standard Reset Plunger

Battery and Accessories

Part Number	Description
513230-001	SENTINEL Battery Assembly (TADIRAN TL-5276/C)
441630-001	Battery Connector Housing

Option Boards

Part Number	Description
442518-001	R300 Board
442507-001	Modem Board
442430-001	Input/Output Main Board (4KYZ, 1KY, 2KY inputs)
442430-002	Input/Output Main Board (2KYZ, 1KY, 2KY inputs)
442430-003	Input/Output Main Board (4KYZ, 1KY)
442430-004	Input/Output Main Board (2KYZ, 1KY)
442430-005	Input/Output Main Board (1KYZ, 1KY)

Part Number	Description
442522-001	Input/Output Supplemental Board (2 KYZ, 1 KY out, 2 KY in)
442522-002	Input/Output Supplemental Board (2 KYZ, 1 KY out)

Wiring Diagrams

Part Number	Description
S15664	Form 9S (8S)Wiring Diagram
S15665	Form 16S 200A Wiring Diagram
S15666	Form 45S 20A Wiring Diagram
S15667	Form 46S 20A Wiring Diagram
S15668	Form 66S 20A Wiring Diagram
S15669	Form 12S 200A Wiring Diagram
S15671	Form 2S 200A Wiring Diagram
S15692	Form 16S (14S, 15S) 320A Wiring Diagram
S15693	Form 2S 320A Wiring Diagram
S15694	Form 12S 320A Wiring Diagram
S15724	Wiring Diagram, 4 KYZ, 1 KY Out, 2 KY In
S15700	Wiring Diagram, R300 Series & 2 KYZ, 1 KY Out, 2 KY In
S15703	Wiring Diagram, 2 KYZ, 1 KY Out, 2 KY In
S15704	Wiring Diagram, 4 KYZ, 1 KY Out
S15705	Wiring Diagram, 2 KYZ, 1 KY Out
S15706	Wiring Diagram, 1 KYZ, 1 KY Out
S15707	Wiring Diagram, R300 Series & 2 KYZ, 1 KY Out
S15709	Wiring Diagram, R300 Series
S15738	Wiring Diagram, Form 10A
S15739	Wiring Diagram, Form 16A
S15740	Wiring Diagram, Form 45A
S15741	Wiring Diagram, Form 46A
S15742	Wiring Diagram, Form 48A

Alternate Mode One of the four modes of register operation used to display quantities that are not needed on a regular basis, for example Kh.

annunciator A Liquid Crystal Display (LCD) label that is displayed to identify a particular quantity being displayed.

autobaud rate sensing The capability of determining the modem band rate for incoming calls (i.e., 300, 1200, or 2400).

auto-service sensing The capability of determining the service type that is installed.

battery carryover The amount of time that the register is energized by the battery to maintain the accuracy of the clock within the microprocessor. All program and billing data are transferred to nonvolatile memory when battery carryover operation is activated.

baud Unit of data transmission signalling speed, roughly analogous to bits per second (bps).

block interval demand Demand based on intervals from 1 to 60 minutes in length. All calculations of demand are based on rolling demand. To calculate block interval demand, program the register to have one subinterval of the same length as the demand interval.

calendar schedule Schedule that determines seasonal changes, Daylight Savings Time changes, holidays, daily switch points, etc.

call on schedule Enables the meter to phone the master station on a schedule.

call windows Time ranges that determine when a meter will answer the phone or place calls to the master station.

cold load pickup See Demand Delay.

cumulative demand The sum of the maximum demand values at each demand reset since the cumulative register was cleared. It is updated at each demand reset by adding the maximum demand register to the cumulative register.

continuous cumulative The sum of the maximum and cumulative demand at any time.

current season The season that defines the present rate schedule.

customer alerts Outputs that can be used, for example, to control external lights indicating the time of use rate in effect.

demand The average value of power over a specified interval of time.

demand delay Cold Load Pickup (CLPU). The programmable amount of time required before demand calculations are restarted after a power outage.

demand interval The specified time over which demand is calculated.

demand reset When the current Maximum Demand is set to zero.

demand subinterval The smaller blocks of time that are used in rolling demand calculations.

demand threshold A programmed value that, when exceeded by calculated demand, initiates a contact closure.

display (LCD) Provides a visual indication of the data accumulated by the register.

display duration The programmed number of seconds that a quantity is displayed on the LCD before it is replaced with the next quantity in the display sequence.

electronic detent	An algorithm in SENTINEL firmware which restricts the SENTINEL to metering energy flow only to the customer (unidirectional metering).
end-of-interval annunciator (EOI)	An annunciator that can be displayed at the end of every subinterval.
end-of-interval output	A contact closure output that can be initiated at the end of each subinterval.
error codes	Monitor operation of the meter. Nine error codes are available for display in Normal, Alternate, and Test display modes.
Event Log	Log used to record historical events that occur in the meter. The events that can be logged must be configured via the PC-PRO+98 programming software.
firmware	Computer programs stored in non-volatile memory chips.
fixed decimal	A display format that always retains the same number of digits to the right of the decimal point.
Flash Memory	A type of EEPROM chip used for easy and fast information storage. It is a solid-state storing device.
floating decimal	A display format that allows a maximum number of digits to the right of the decimal, but can display any number of digits to the right of the decimal equal to or less than that number specified.
full scale value	The demand value that, when exceeded, causes error code Er-----6 to display. This value can be any quantity less than or equal to the largest allowable Maximum Demand Value that can be displayed.
independent outputs/ load control outputs	Outputs that can be used to close a contact to control, for example, a water heater load by following switchpoints independent of the time-of-use registers.
Kh	Determines the rate at which the watt disk emulator scrolls and the infrared LEDs pulse. Does not affect displayed values.
KY input/KY output	A Form A 2-wire, normally open, momentary contact closure. The number of input/output pulses are proportional to the quantity being measured. Pulses toggle between open and closed.
KYZ output	Pulse initiator outputs. A Form C contact closure output that generates pulses per the programmed Ke value.
last season	The season immediately preceding the current season.
LCD	Liquid Crystal Display
LED	Light-Emitting Diode
load profile	The functionality of a meter to accumulate pulses in proportion to accumulated energy in programmed intervals. Often referred to as Mass Memory.
magnetic switch	A solid-state mechanical switch consisting of a thin metal contact which is closed by an external magnetic field.
maximum demand	The largest demand calculated during any interval over a billing period. The Maximum Demand quantity displayed in Test Mode is that value calculated over the test interval only (this can differ from the Normal Mode demand interval).
Mode Timeout	The amount of time the meter will remain in Alternate Mode, Test/Test Alternate Mode, or Toolbox Mode before automatically returning to Normal Mode. This time is programmable.
modem	Connects communication systems and devices from a remote phone outlet to a near device or system.
nonvolatile memory	See Flash Memory.

Normal Mode	One of the four operating modes of the meter. It includes all routine meter operations.
off-hook detect	Programmable feature that allows the meter to use the phone line without interfering with other phone usage.
optical port	Optical interface located on the face of the meter. The meter can be programmed and communicated with through the optical port.
phone home on event	A feature that allows the meter to call the master station when a certain event occurs.
phone line sharing	Connection of up to five auto-answer meters to a single voice grade telephone line for remote interrogation.
power down	To de-energize.
power up	To energize.
primary/direct reading register	A register in which the readings take into account the register multiplier.
pulse initiator outputs	See KYZ output.
R300 Series	A communication media whereby information is transmitted via radio frequency; the data is formatted with ERT IDs, compatible with ITRON ERT reading systems as well as DAP.
register multiplier	A programmable value which is used in calculations of displayed energy and demand readings. This can be used by setting the register multiplier equal to the CT ratio times the PT ratio of the installation.
rolling interval demand	A calculation of maximum demand derived from the moving average of the smaller consecutive subintervals.
RS-232/RS-485	Accepted industry standards for serial communications connections. This Recommended Standard (RS) defines the specific lines and signal characteristics used by serial communications controllers to standardize the transmission of serial data between devices.
season	A programmable amount of time that a rate schedule is in effect. Season start dates are programmed in the format MM/DD (Month/Day).
self-reading registers	Register data that is captured in the meter at a programmed interval of time and is stored in non-volatile memory.
solid-state outputs	Outputs consisting of solid materials as opposed to vacuum and gas tubes.
switchpoint	A programmable time within the rate schedule that de-activates the current register of one rate and activates a second register of a second rate.
Test Mode	One of the four modes of register operation. It allows testing of the register without altering billing data.

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