THE EASTERN SPECIALTY COMPANY

Learning the Language

(Meter Testing 101)

Prepared by Tom Lawton, TESCO

For Mid-South Electric Metering Association Meter School
Monday, May 6, 2019
3:00 p.m., Group 1

Our Goal Today

- To give you enough background to be able to understand the basic concepts being introduced or to refresh you on the basic concepts about to be introduced and in both cases give you some level of background to help better understand each of them.

Learning the Language

Over the next three days you will have a series of Metering 101 presentations. These will include classes on;

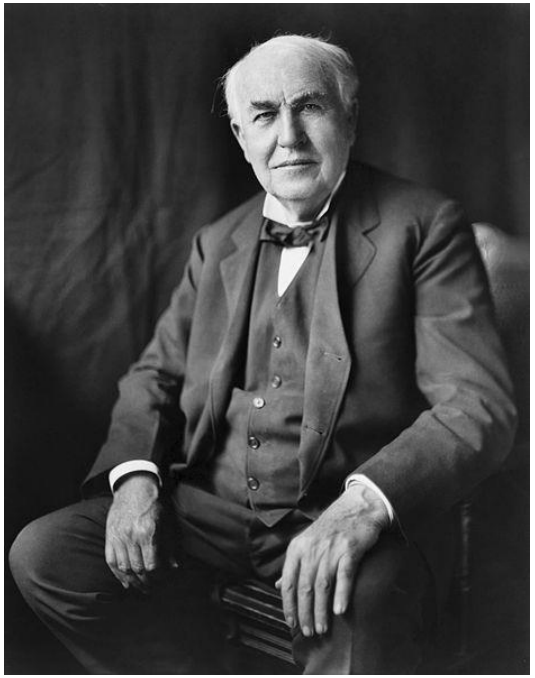
- Basic Electricity
- Form Numbers
- Wiring Diagrams
- AC Circuits
- Self Contained Metering
- Demand Metering
- Transformer Rated Metering

Basic Electricity

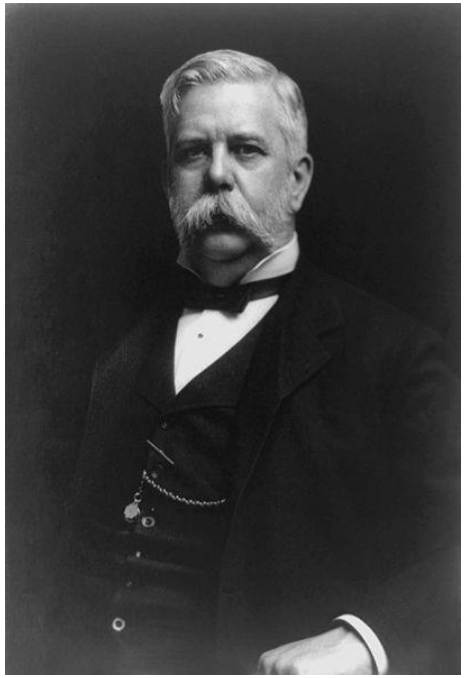
Direct Current (DC) – an electric current that flows in one direction.(IEEE100)

Alternating Current (AC) – an electric current that reverses direction at regularly recurring intervals of time. (IEEE100)

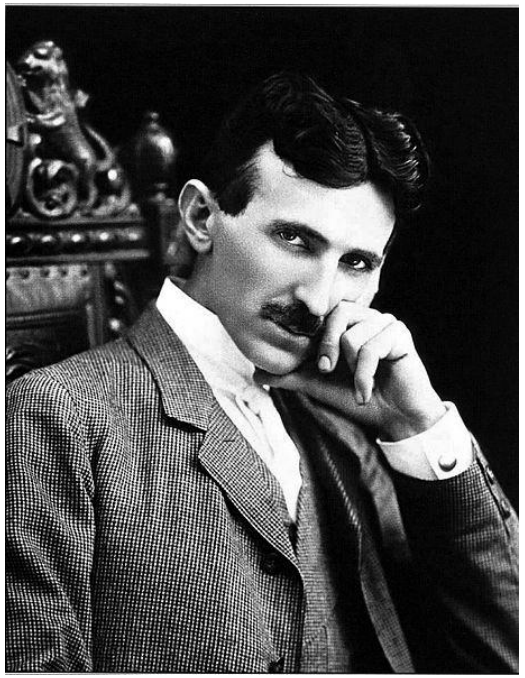
War of the Currents



Thomas Edison



George Westinghouse



Nikola Tesla

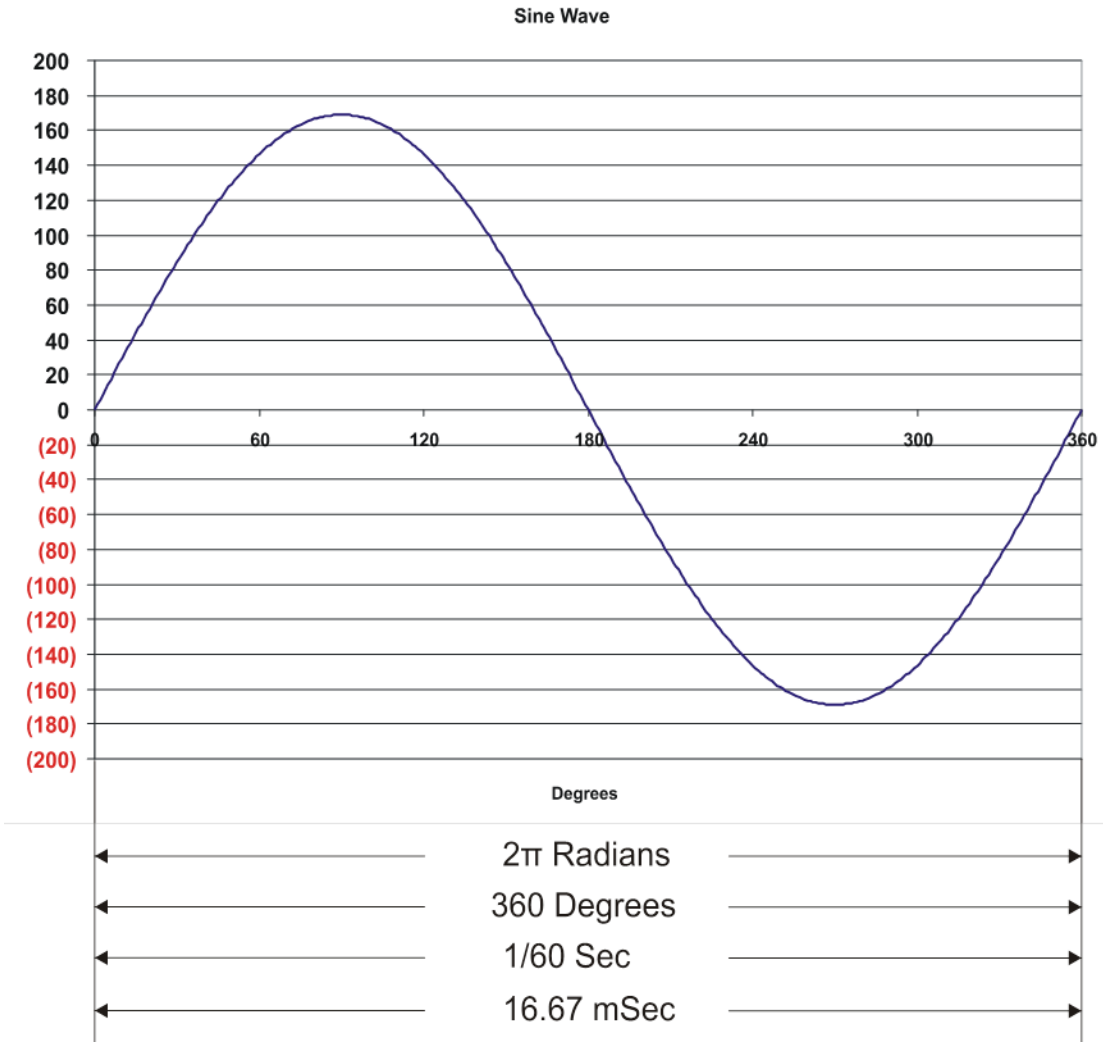
AC Theory - History

- By 1900 AC power systems had won the battle for power distribution.
  - Transformers allowed more efficient distribution of power over large areas.
  - AC motors were cheaper and easier to build.
  - AC electric generators were easier to build.

AC Circuits

- An AC circuit has three general characteristics
  - Value
  - Frequency
  - Phase
- In the US, the household value is 120 Volts with other common voltages being 208, 240, 277 and 480 Volts. The frequency is 60 Hertz (cycles per second).

AC Theory – Sine Wave



$$V = V_{pk} \sin(2\pi ft - \theta)$$

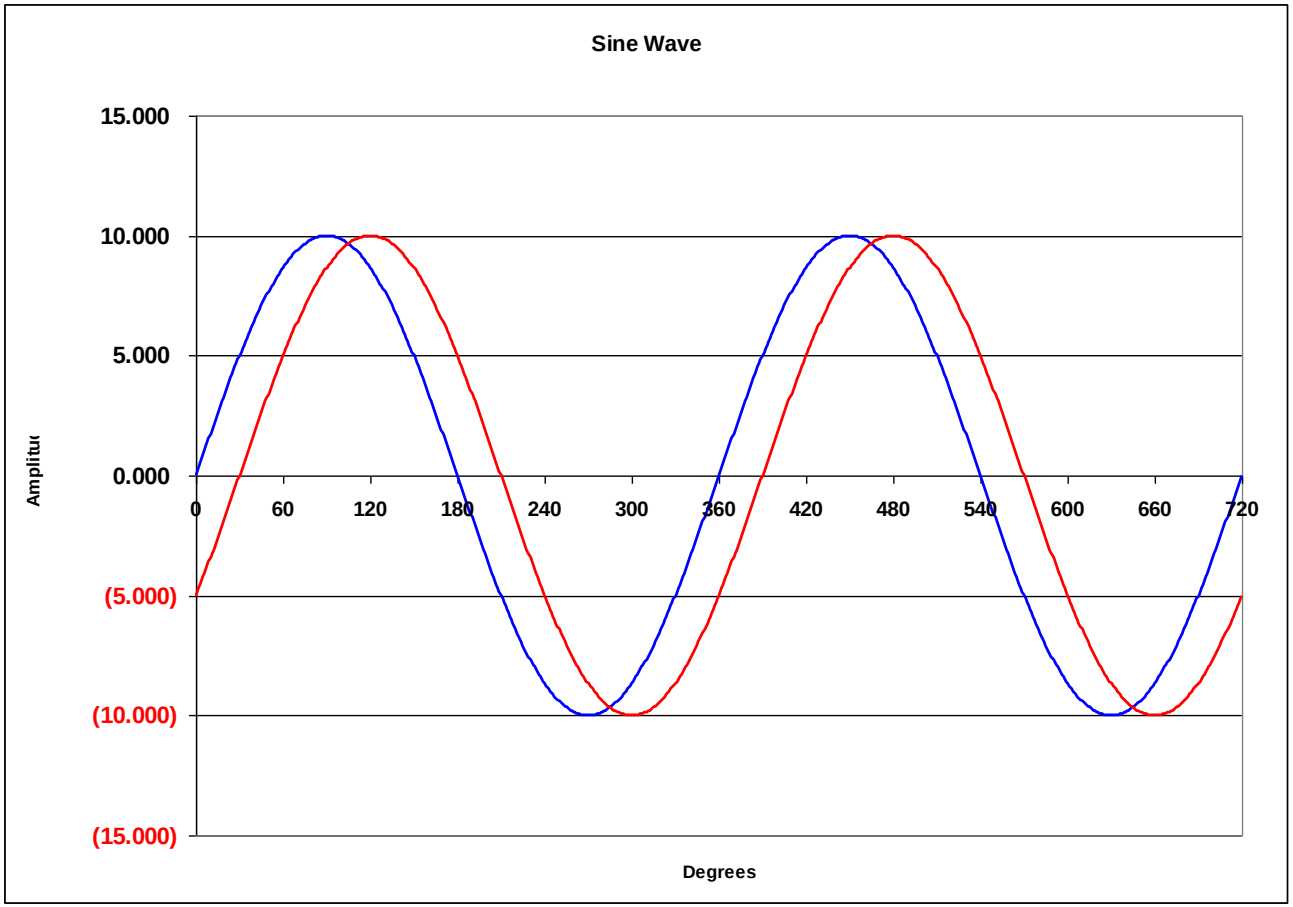
$$V = \sqrt{2} V_{rms} \sin(2\pi ft - \theta)$$

$$V_{rms} = 120$$

$$V_{pk} = 169$$

$$\theta = 0$$

AC Theory - Phase



$$V = 10\sin(2\pi ft)$$

$$I = 10\sin(2\pi ft - 30)$$

Here current LAGS voltage.

AC Theory – Active Power

- **Active Power** is defined as P = VA
- Power is a rate, i.e. Energy per unit time.
- The Watt is the unit for Power
  - 1 Watt = 1000 Joules/sec
- Since the voltage and current at every point in time for an AC signal is different, we have to distinguish between **instantaneous power** and **average power**.
- Generally when we say “power” we mean average power.

AC Theory - Energy

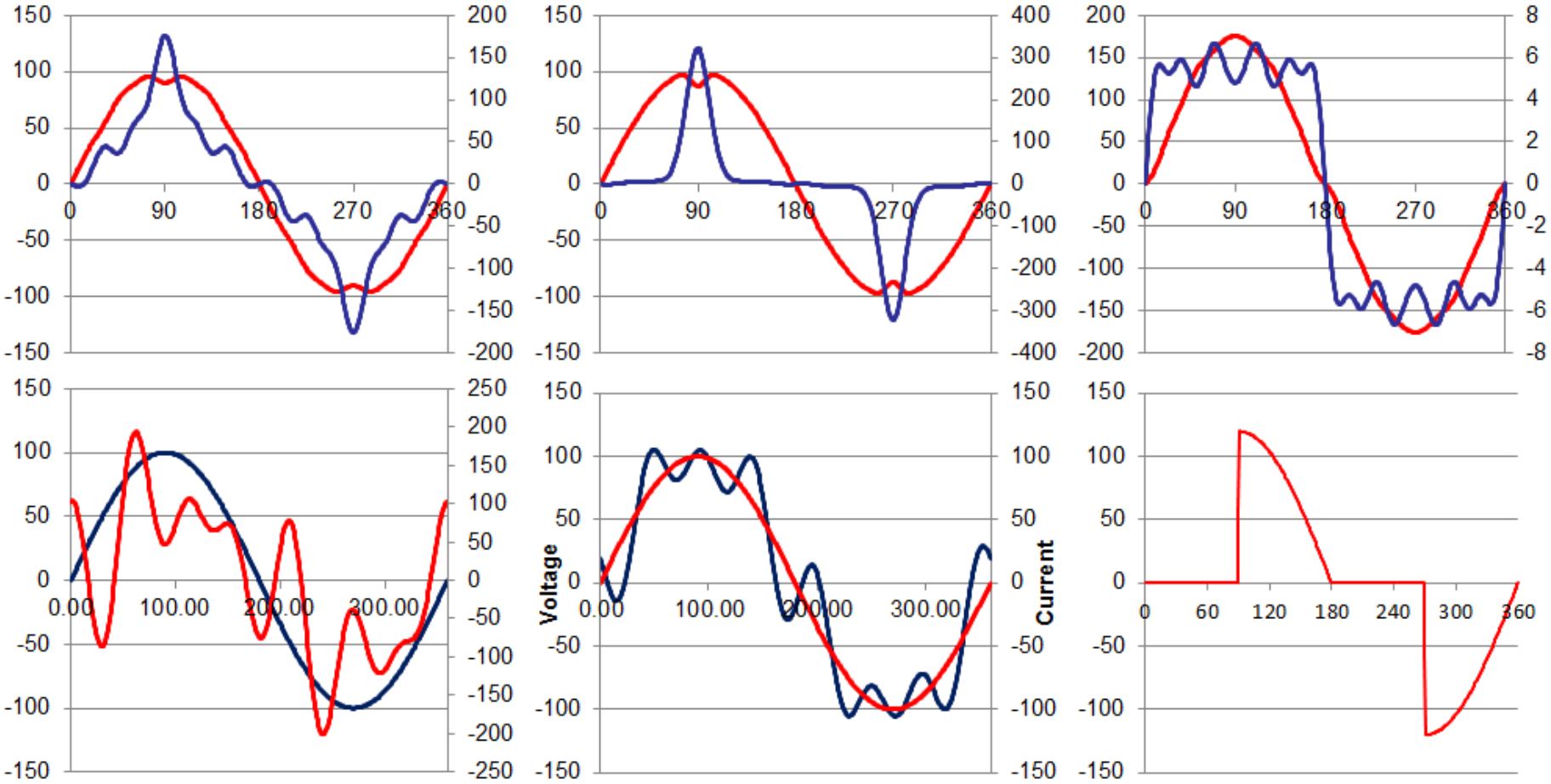
- Energy is power integrated over a period of time.
- The units of Energy are:
  - Watt-Hour (abbreviated Wh)
  - Kilowatt-Hour (abbreviated kWh)
- A Wh is the total energy consumed when a load draws one Watt for one hour.

Harmonics
Curse of the Modern World

- Every thing discussed so far was based on “Linear” loads.
  - For linear loads the current is always a simple sine wave. Everything we have discussed is true.
- For nearly a century after AC power was in use ALL loads were linear.
- Today, many loads are NON-LINEAR.

Harmonic Load Waveforms

ANSI C12.20 now addresses harmonic waveforms as well as sinusoidal.



Active vs. Apparent Power

Apparent Power - S

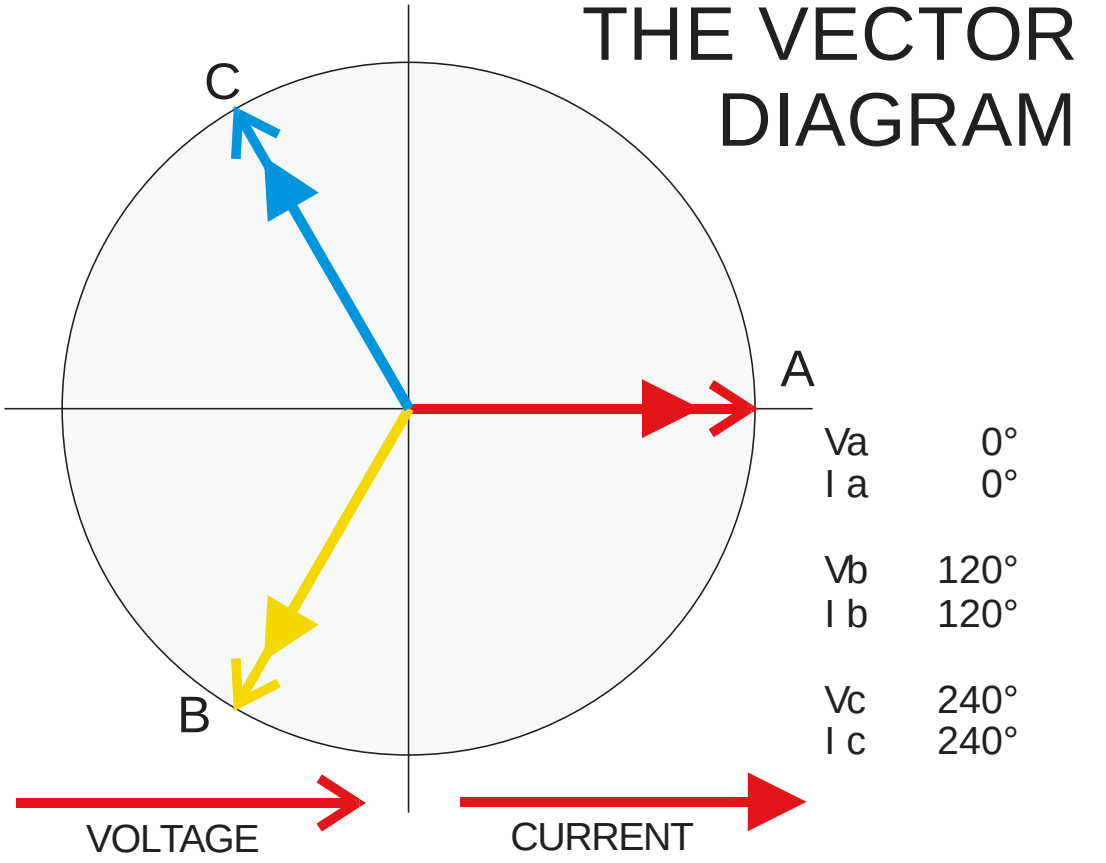
- The apparent power is the power supplied to the electric circuit - typical from a power supplier to the grid - to cover the real and reactive power consumption in the loads. Measured in VA.

Active Power - P

- Active - or real or true - power do the actual work in the load. Active power is measured in *watts (W)* and is the power consumed by electrical resistance. Measured in Watts

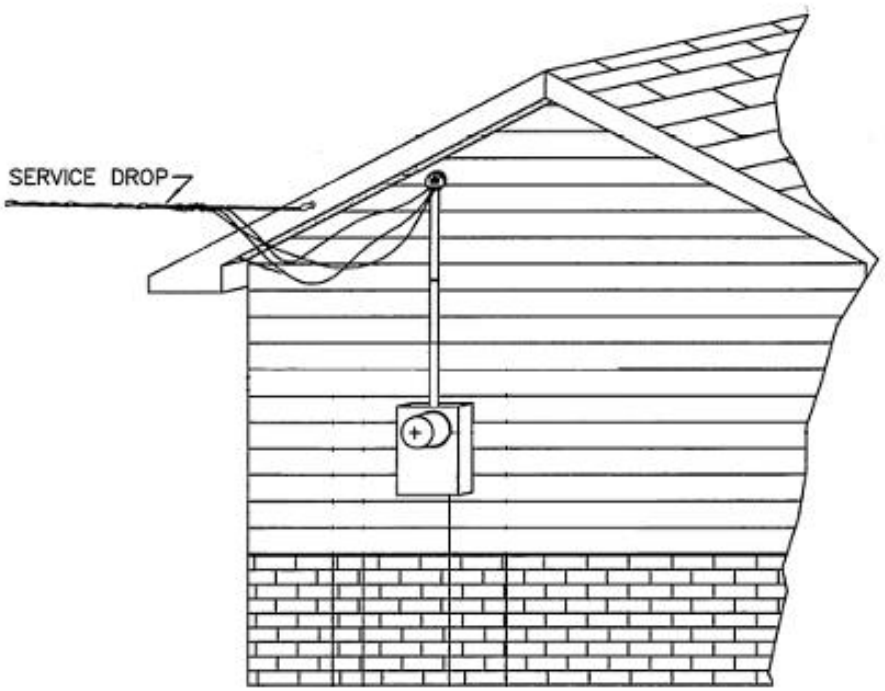
AC Theory – Phasors

An easier way to view AC data



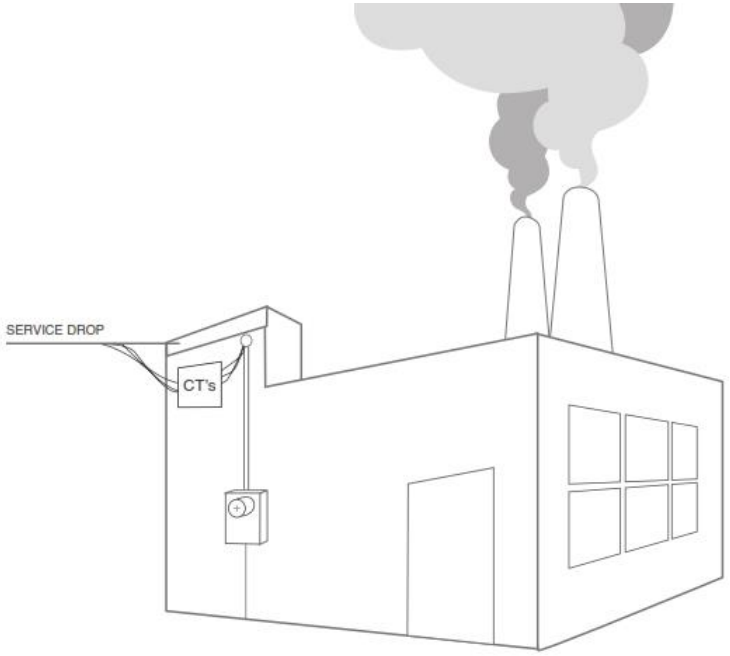
Self Contained Metering

- Typically found in residential metering
- Meters are capable of handling the direct incoming amperage
- Meter is connected directly to the load being measured
- Meter is part of the circuit
- When the meter is removed from the socket, power to the customer is interrupted

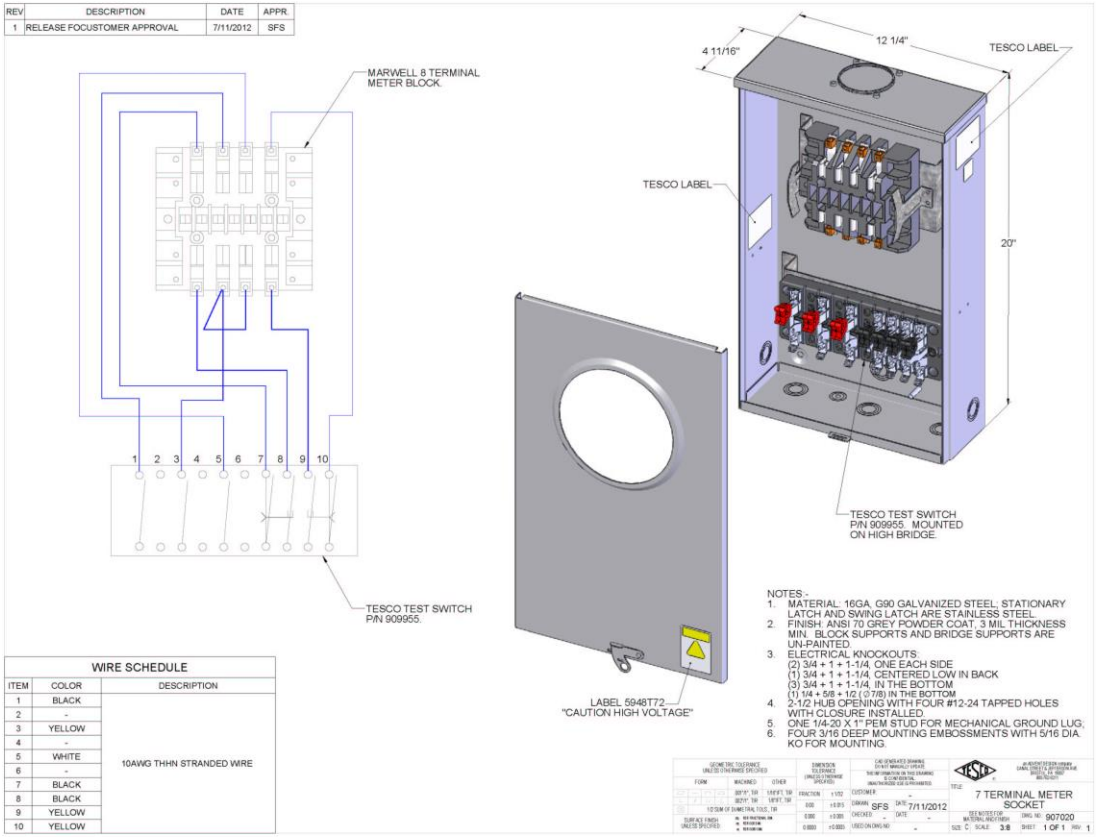


Transformer Rated Metering

- Meter measures scaled down representation of the load.
- Scaling is accomplished by the use of external current transformers (CTs) and sometimes voltage transformers or PTs).
- The meter is NOT part of the circuit
- When the meter is removed from the socket, power to the customer is not effected.

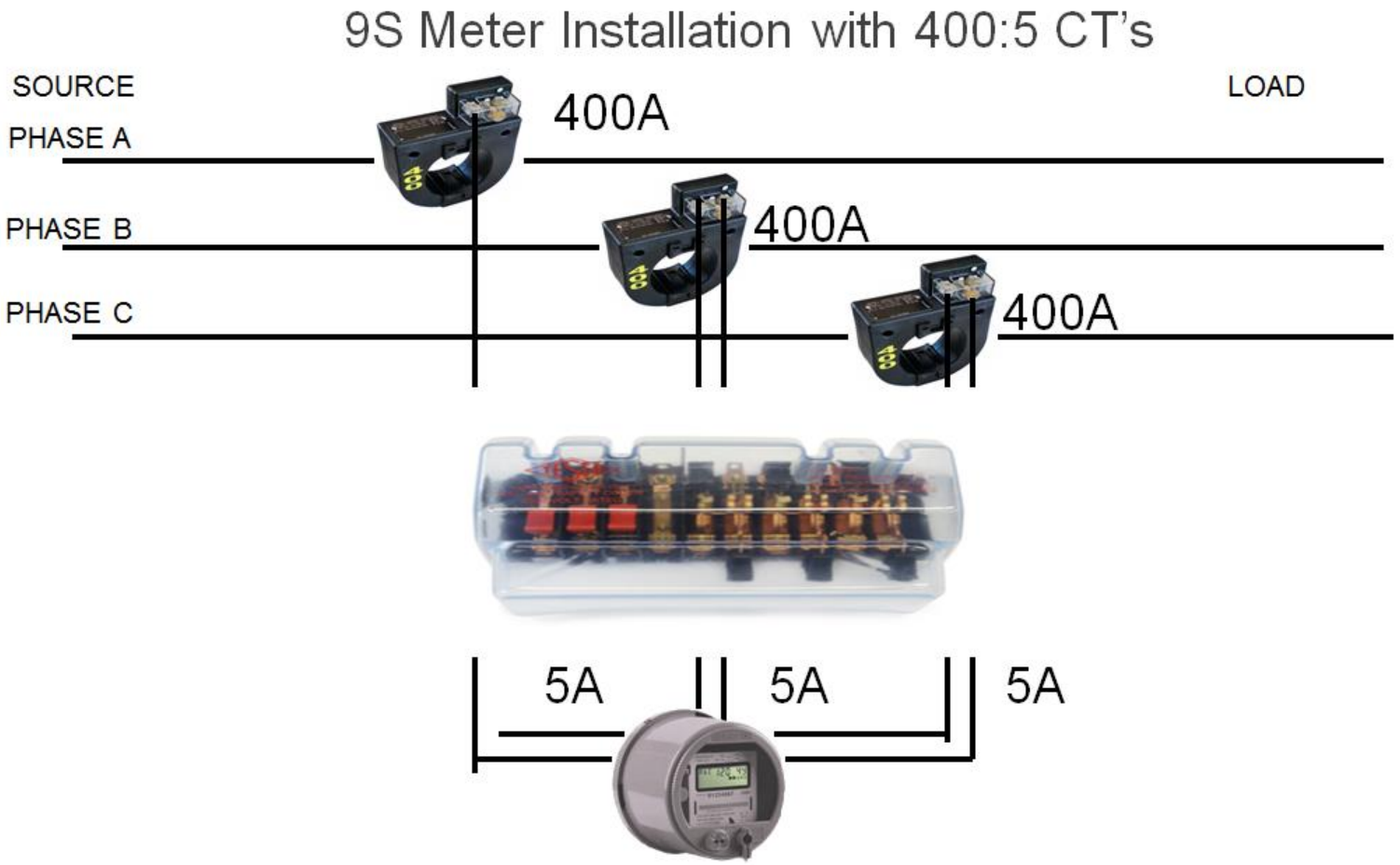


Pre-Wired Transformer Rated Enclosures

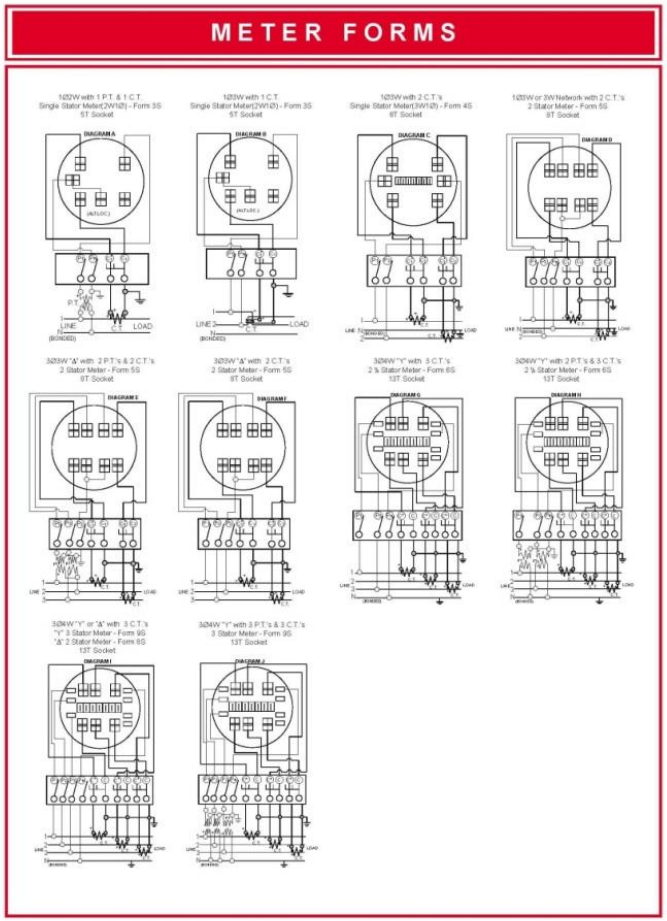


- Cover Types
- Wiring
- Sockets

The Basic Components



Typical Connections



Typical Connections for Common Transformer (Instrument) Rated Meter Forms

ANSI

- American National Standard Institute, Inc.
  - Not a government agency
  - Standards do not have force of Law
  - All compliance is voluntary
  - ANSI doesn't actually generate any standards
  - Each standard is controlled by an industry organization as the "secretariat"
    - For C12 NEMA (National Electrical Manufacturer's Association) is the secretariat
    - Paul Orr has been the NEMA's secretary assigned to C12 for over ten years providing continuity to the process

ANSI

- American National Standard Institute, Inc.
  - NEMA organizes committees to propose and review standards
  - Standards are republished approximately every 5 years
  - Standards codify consensus approaches in common practice
  - Generally, they do not break new ground or deal in controversial issues
    - This is changing. Can't avoid issues any longer.

ANSI C12

- C12 Main Committee
  - General makeup has expanded slightly over last few years
  - 34 voting members with representation from three groups:
    - 12 - Manufacturers: Meter, Socket, Test Equipment, etc.
    - 13 - Users: Utilities
    - 9 - General Interest: PUC, UL, IEEE, Consultants, etc.
  - Meets twice a year in conjunction with EEI/AEIC Meter conference.

ANSI

- C12 Main Committee
  - Has final approval for all activities on any C12 family standard
  - Establishes Subcommittees (SC) and Working Groups (WG) to address various standards and issues
  - Sub committees and Working Groups also meet twice a year in conjunction with EEI Transmission, Distribution and Metering Conference and also hold regular or ad hoc conference calls throughout the year as members put together drafts and other technical material for consideration at the next face to face meeting.

ANSI

- C12 Subcommittees
  - Various subcommittees have been organized to review specific standards
  - This is where the work is really done
  - Each operates slightly differently
  - Each meets on a schedule of its own choosing
  - Most meet at EEI Biannual Transmission, Distribution and Metering Meetings
  - Communication WG meets more often and longer
  - Various subgroups meet frequently by teleconference

ANSI C12 – Sub-Committees

Sub-Committee	Standards
C12 SC1	C12.1, C12.4, C12.5, C12.10
C12 SC15	C12.6, C12.7, C12.8, C12.9, C12.11
C12 SC16	C12.20, C12.24
C12 SC17	C12.18, C12.19, C12.21, C12.22, C12.23, C12.26
C12 SC29	C12.29 Standard for Field Testing of Metering Sites
C12 SC31	C12.31 VA Measurement Standard
C12 SC46	C12.46 American National Standard for Electricity Meters - 0.1, 0.2 and 0.5 Accuracy Classes for the Measurement of Active, Apparent and Reactive Power

Test Switch Specifications

- ANSI C12 Definitions
- Test Switch Materials
- Plating
- Barriers
- Wiring Connections
- What to look for
- Covers

For Test Switches and Jacks for Transformer-Rated Meters

1 Scope

This standard is intended to encompass the dimensions and functions of meter test switches used with transformer-rated watthour meters in conjunction with instrument transformers and test plugs used in conjunction with the test switch.

2 Definitions

2.1 short-circuiting switch

A single-pole double-throw (make-before-break) transfer switch used to transfer current away from the meter.

2.2 test jack

A spring-jaw receptacle in the current element of a test switch that provides a bipolar test connection in the metering current circuit without interruption of the current circuit.

2.3 test jack switch

A single-pole single-throw disconnect switch used in conjunction with a test jack to provide a parallel current path during normal operating conditions.

2.4 test plug

A bipolar mating plug to a test jack for inserting instrumentation into the metering current circuit.

2.5 voltage switch

A single-pole single-throw switch used to open or close a voltage circuit.

3 Standard ratings

3.1 Current

The current rating shall be 20 A minimum.

3.2 Voltage

The voltage rating shall be 300 V or 600 V.

4 General requirements for test switches

4.1 Material and workmanship

The test switch and its components shall be substantially constructed of suitable material in a workmanlike manner.

4.2 Nameplates

Nameplates are not required on these test switches, but a manufacturer's identifying marking (such as catalog number, trademark, etc.) shall be stamped, printed, affixed, or cast in a convenient place on each test switch. When required, a warning label indicating hidden internal jumpers should be affixed.

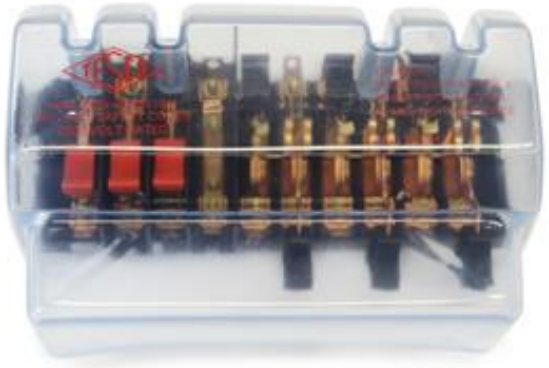
4.3 Movable parts

Movable conducting parts such as blade hinges shall be held in place by locknuts or pins or their equivalent, arranged so that a firm and secure connection will be maintained at any position of the switch blade.

ANSI C12.9 Test Switch Definitions

Test Switch Accessories

- Test Plugs
- Safety Covers
- Test Switch Isolators



On installations that contain Test Switches, test leads terminated with a test switch

safety test probe (test plug) should be used for CT testing. This provides a “make-before-break” connection to prevent accidental opening of the current transformer secondary loop.

4.6 Provision for test plugs

Each double-pole short-circuiting current switch shall incorporate a test jack which is designed to permit the insertion of a test plug. The test-jack switch can be either in the left-hand or the right-hand position. In order to assure proper mating with the test plug the test jack shall conform to Figure 4.

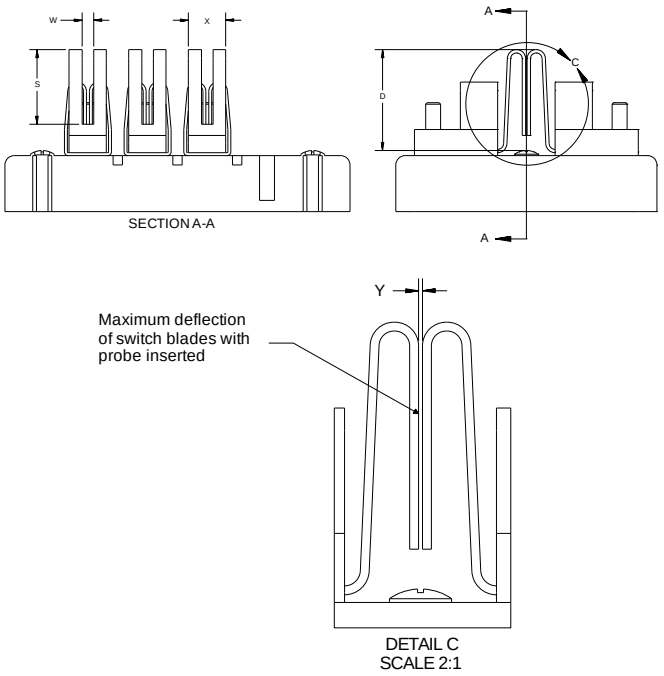


Figure 4 – Test switch typical cross section

Table 1 – Test switch dimensions

TEST SWITCH DIMENSIONS			
DIMENSION	**MINIMUM**	**PREFERRED**	**MAXIMUM**
S	**0.900**	**1.200**	**1.250**
W	**0.125**	**0.140**	**0.175**
X	**0.430**	**0.500**	**0.550**
D	**1.280**	**1.350**	**N/A**
Y			**0.188**

ANSI C12.9 Test Jack Specifications

1 General requirements for test plugs

1.1 Materials and workmanship

The test plug shall be constructed with an insulated handle providing an anti-slip gripping area and a barrier to help prevent the user's gloved hand from slipping into contact with the test switch.

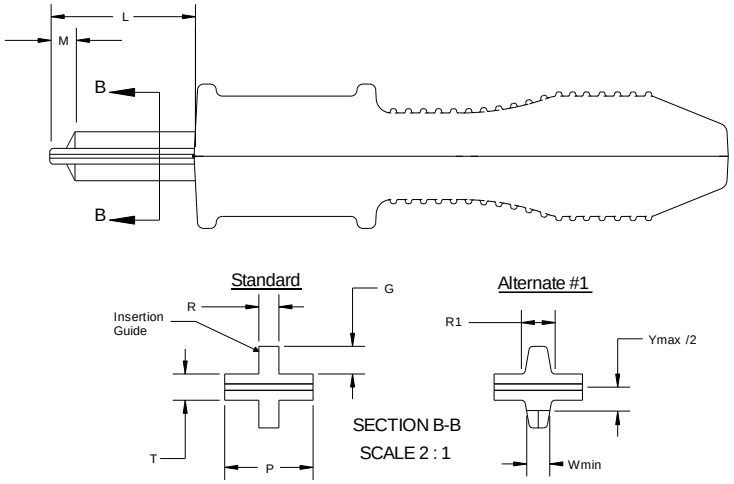


Figure 6 – Typical test plug

Notes:

(1) When the insertion guide takes the form of Section B-B Alternate #1, then for a switch with a slot width Wmin, the switch Jaws shall not be separated by more than Ymax = 0.188" when inserted.

(2) If a positive stop is provided on the probe blade to limit insertion depth of the probe to M by bottoming out against S of the switch, then L may exceed Lmax provided M < Dmin – Smax = 0.030".

Table 3 – Test plug dimensions

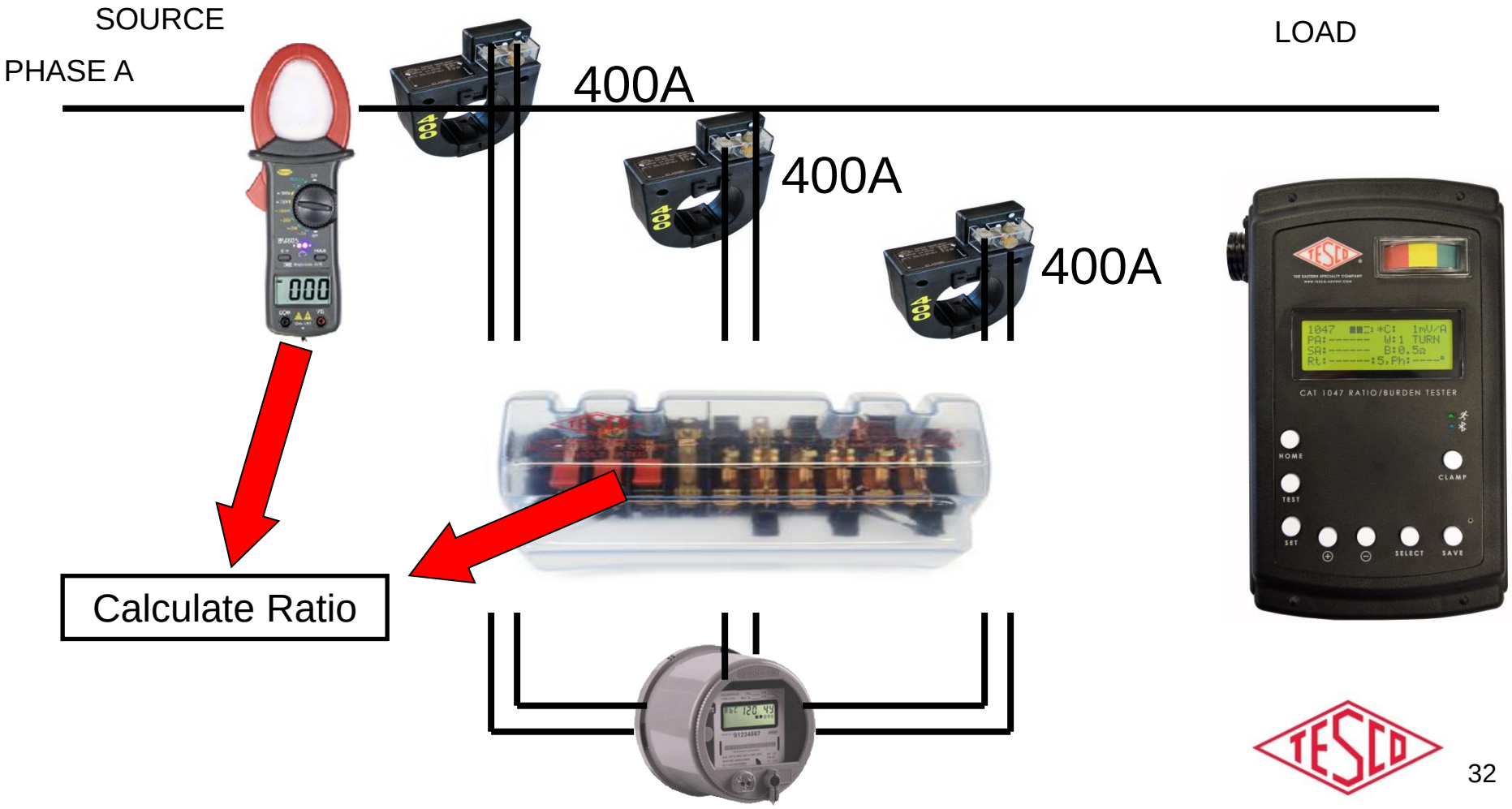
TEST PLUG DIMENSIONS			
DIMENSION	**MINIMUM**	**PREFERRED**	**MAXIMUM**
L	**1.100**	**1.200**	**1.260**
M	**0**	**0.140**	**0.175**
R	**0.090**	**0.110**	**0.120**
R1	**n/a**	**n/a**	**0.156**
T	**0.100**	**0.130**	**0.156**
G	**0.040**	**0.125**	**0.175**

ALERT TO USERS: Prior to adoption of this standard there are known instances of probes and switches where interferences exist which may not allow all probes and switches to mate or which may lead to probes shorting to undesired conductors.

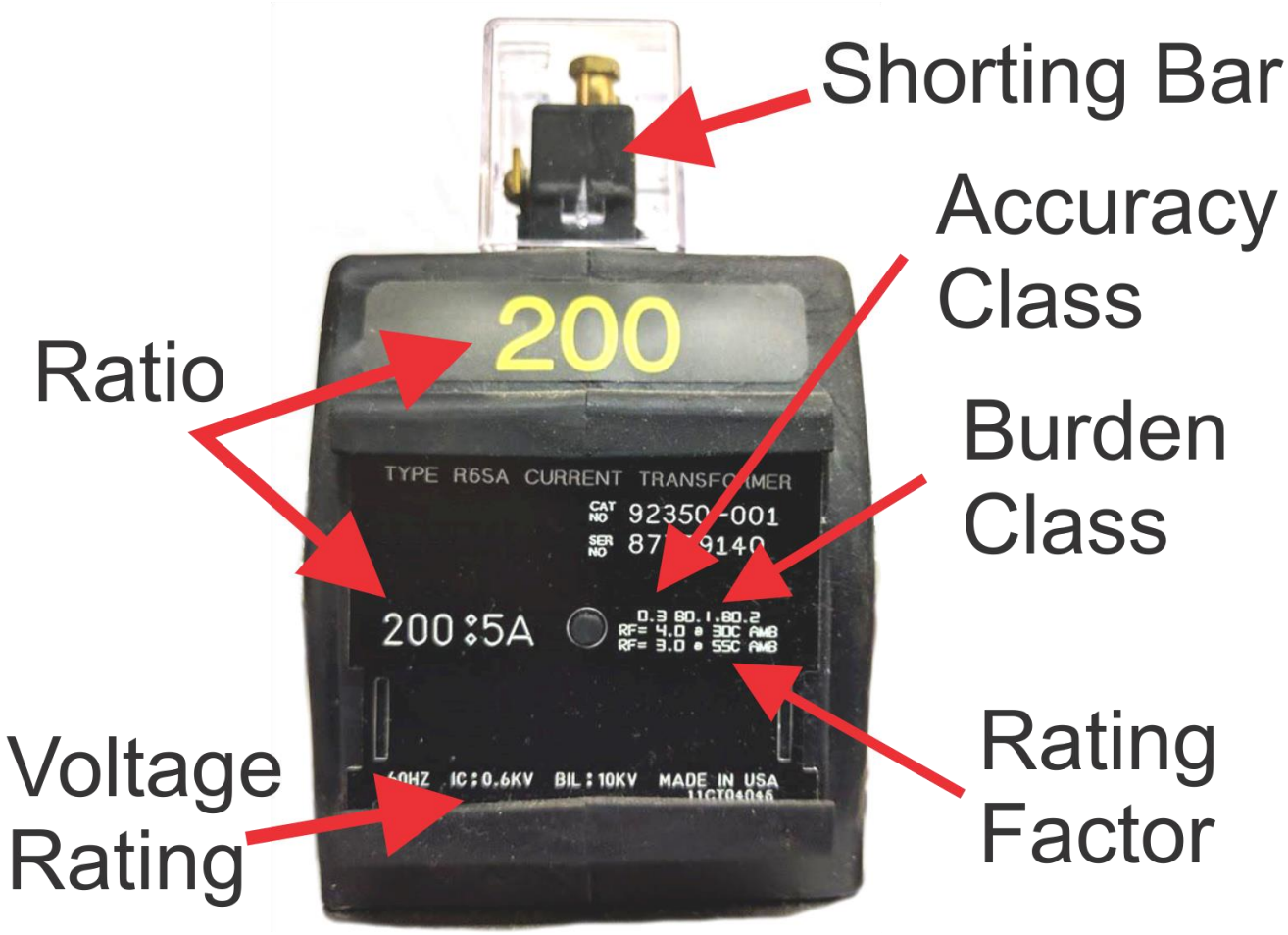
ANSI C12.9 Test Plug Specifications

Fundamentals of Polyphase Field Meter Testing and Site Verification

Ratio of Primary Current to Secondary Current



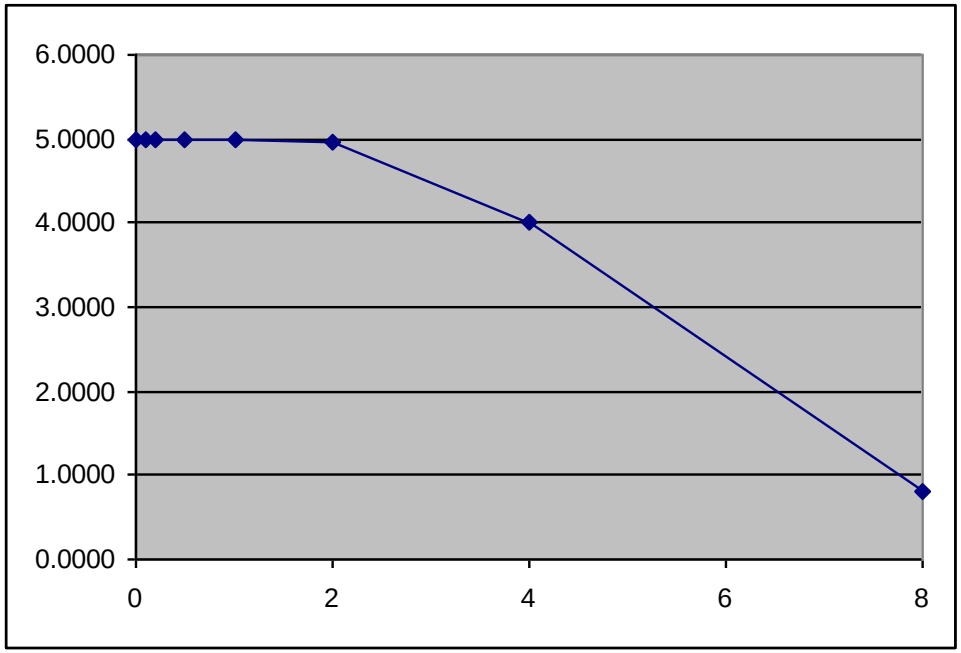
Current Transformers (CTs)



Fundamentals of Polyphase Field Meter Testing and Site Verification

Functionality with Burden Present on the Secondary Loop

0.3% @ B0.1, B0.2, B0.5



Initial Reading = 5Amps
0.3% x 5A = 0.015A
5A – 0.015 = 4.985A

Burden	Reading
0	5.0000
0.1	4.9999
0.2	4.9950
0.5	4.9900
1	4.9800
2	4.9500
4	4.0000
8	0.8000

Three Phase Power
Blondel's Theorem

The theory of polyphase watthour metering was first set forth on a scientific basis in 1893 by Andre E. Blondel, engineer and mathematician. His theorem applies to the measurement of real power in a polyphase system of any number of wires. The theorem is as follows:

- If energy is supplied to any system of conductors through N wires, the total power in the system is given by the algebraic sum of the readings of N wattmeters, so arranged that each of the N wires contains one current coil, the corresponding voltage coil being connected between that wire and some common point. If this common point is on one of the N wires, the measurement may be made by the use of N-1 wattmeters.

Blondel's Theorem

Power Measurements Handbook

Condition	% V	% I	Phase A				Phase B				non-Blondel
	Imb	Imb	V	ϕvan	I	ϕian	V	ϕvbn	I	ϕibn	% Err
All balanced	0	0	120	0	100	0	120	180	100	180	0.00%
Unbalanced voltages PF=1	18%	0%	108	0	100	0	132	180	100	180	0.00%
Unbalanced current PF=1	0%	18%	120	0	90	0	120	180	110	180	0.00%
Unbalanced V&I PF=1	5%	18%	117	0	90	0	123	180	110	180	-0.25%
Unbalanced V&I PF=1	8%	18%	110	0	90	0	120	180	110	180	-0.43%
Unbalanced V&I PF=1	8%	50%	110	0	50	0	120	180	100	180	-1.43%
Unbalanced V&I PF=1	18%	40%	108	0	75	0	132	180	125	180	-2.44%
Unbalanced voltages PF≠1 PFa = PFb	18%	0%	108	0	100	30	132	180	100	210	0.00%
Unbalanced current PF≠1 PFa = PFb	0%	18%	120	0	90	30	120	180	110	210	0.00%
Unbalanced V&I PF≠1 PFa = PFb	18%	18%	108	0	90	30	132	180	110	210	-0.99%
Unbalanced V&I PF≠1 PFa = PFb	18%	40%	108	0	75	30	132	180	125	210	-2.44%
Unbalanced voltages PF≠1 PFa ≠ PFb	18%	0%	108	0	100	60	132	180	100	210	-2.61%
Unbalanced current PF≠1 PFa ≠ PFb	0%	18%	120	0	90	60	120	180	110	210	0.00%
Unbalanced V&I PF≠1 PFa ≠ PFb	18%	18%	108	0	90	60	132	180	110	210	-3.46%
Unbalanced V&I PF≠1 PFa ≠ PFb	18%	40%	108	0	75	60	132	180	125	210	-4.63%

Questions?

Tom Lawton

TESCO – The Eastern Specialty Company

Bristol, PA

215-785-2338

This presentation can also be found under Meter Conferences and Schools on the TESCO website:
www.tescometering.com