Meter Forms: Wiring and Uses

THE EASTERN SPECIALTY COMPANY

Pennsylvania Rural Electric Association

Prepared by Rob Reese, TESCO
The Eastern Specialty Company

For PREA

March 14, 2023

Agenda

Meters 101 - Electro-Mechanical vs Solid-State

Meter Forms

Self-Contained vs Transformer Rated

Blondel’s Theorem

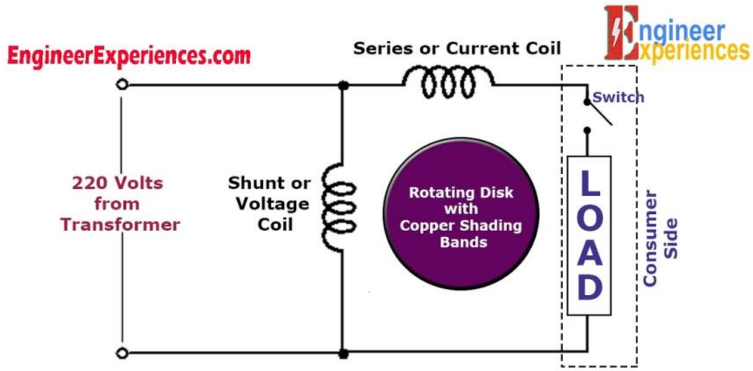
Available References (Hardy’s, UGLY’s Elect Ref)

Examples

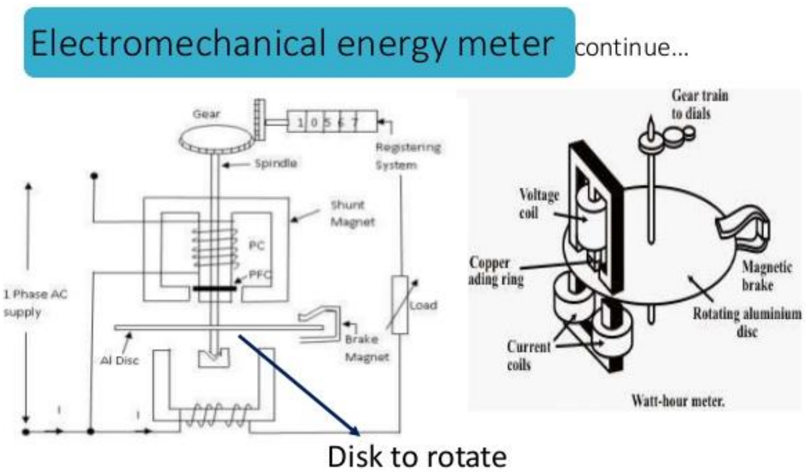
1S, 2S, 9S, 16S

Meters 101 – Electro-mechanical

Overview of Functionality



Equivalent Circuit of Electro-Mechanical Energy Meter

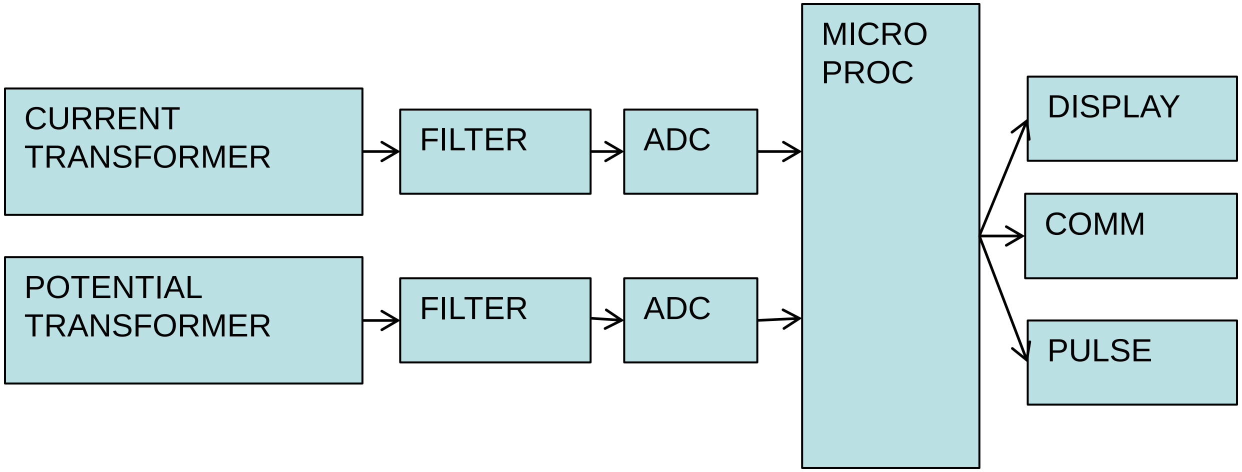


- The electromechanical induction meter operates through electromagnetic induction
- A non-magnetic, but electrically conductive, metal disc which is made to rotate at a speed proportional to the power passing through the meter
- The disc is acted upon by two sets of induction coils, which form, in effect, a two phase linear induction motor.
- One coil is connected in such a way that it produces a magnetic flux in proportion to the voltage
- The other coil produces a magnetic flux in proportion to the current.
- The field of the voltage coil is delayed by 90 degrees, due to the coil's inductive nature, and calibrated using a lag coil
- This produces eddy currents in the disc and the effect is such that a force is exerted on the disc in proportion to the product of the instantaneous current and instantaneous voltage
- A permanent magnet acts as an eddy current brake, exerting an opposing force proportional to the speed of rotation of the disc
- The equilibrium between these two opposing forces results in the disc rotating at a speed proportional to the power or rate of energy usage
- The disc drives a register mechanism which counts revolutions, much like the odometer in a car, in order to render a measurement of the total energy used.
- The amount of energy represented by one revolution of the disc is denoted by the symbol Kh which is given in units of watt-hours per revolution.
- A Kh of 7.2 is typical. In this example, each full rotation of the disk is equivalent to 7.2Wh of energy.

Meters 101 – Solid-state

Overview of Functionality

- Potential and Current is scaled down and conditioned with transformers and filters
- ADC's (analog to digital converters) digitize the signals
- A micro-processor or DSP executes the calculations
- Resulting data is displayed, sent externally via the communication circuits, and used for the calibrated pulse output



Meter Forms

ANSI C12.10

Meter Forms

14S 39S 17S

1S

2S

3S 12S 35S

4S

25S

10S

76S 46S

45S 66S

11S 32S

6S

5S 26S

16S

9S 13S

15S 24S 56S

Meter Forms

THE EASTERN SPECIALTY COMPANY

Meter Forms

14S 39S 17S

1S

2S

3S 12S 35S

4S

25S

10S

76S 46S

66S

45S

11S 32S

5S 26S

6S

16S

9S

13S

56S

15S 24S

Meter Forms

SELF-CONTAINED

1S
14S
12S
2S
25S
16S
17S
13S
15S
32S

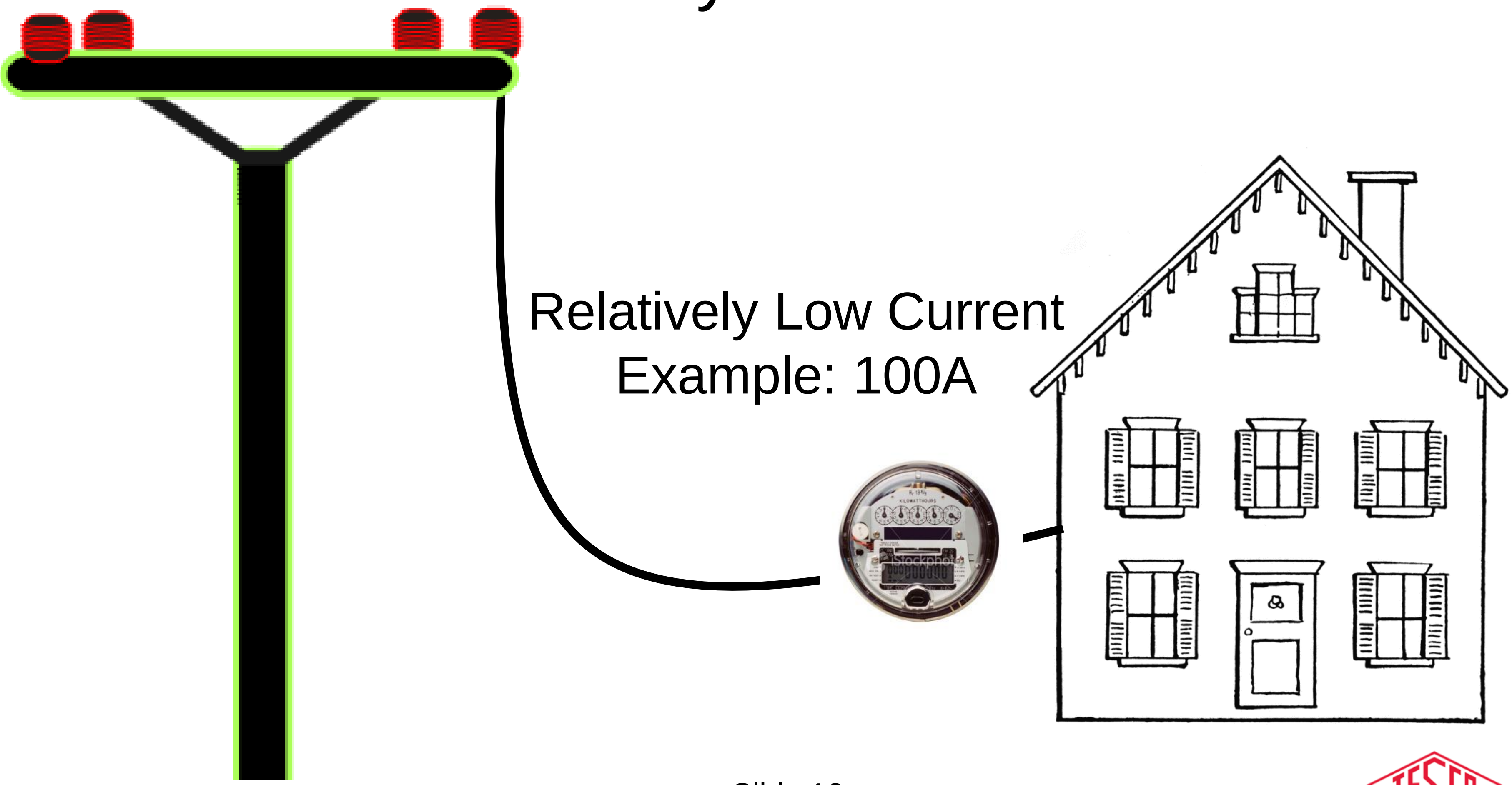
TRANSFORMER-RATED

39S
3S
36S
7S
29S
76S
5S
35S
46S
4S
8S
26S
11S
66S
45S
6S
9S
56S
10S
24S

TESCO THE EASTERN SPECIALTY COMPANY

Self-Contained Meters

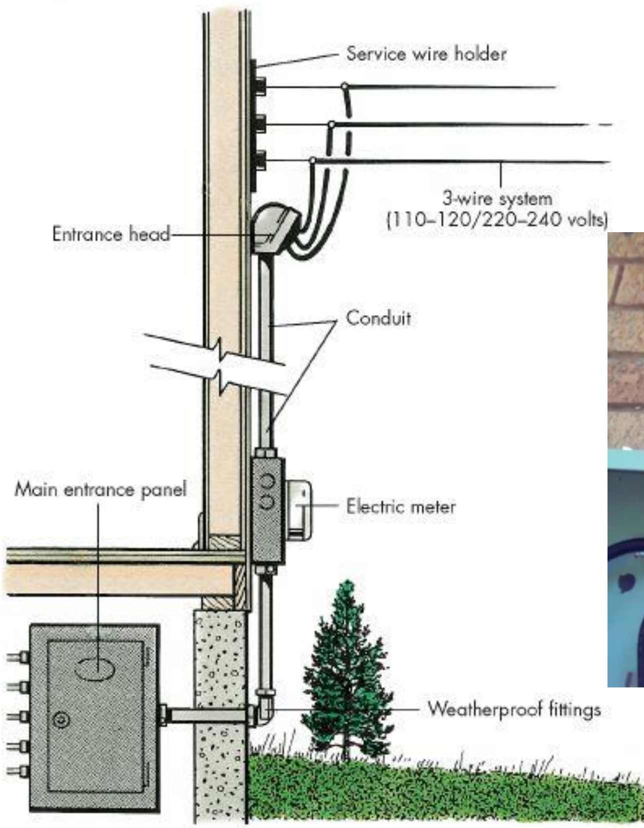
Primarily Residential



Relatively Low Current
Example: 100A

Self-Contained

Primarily Residential

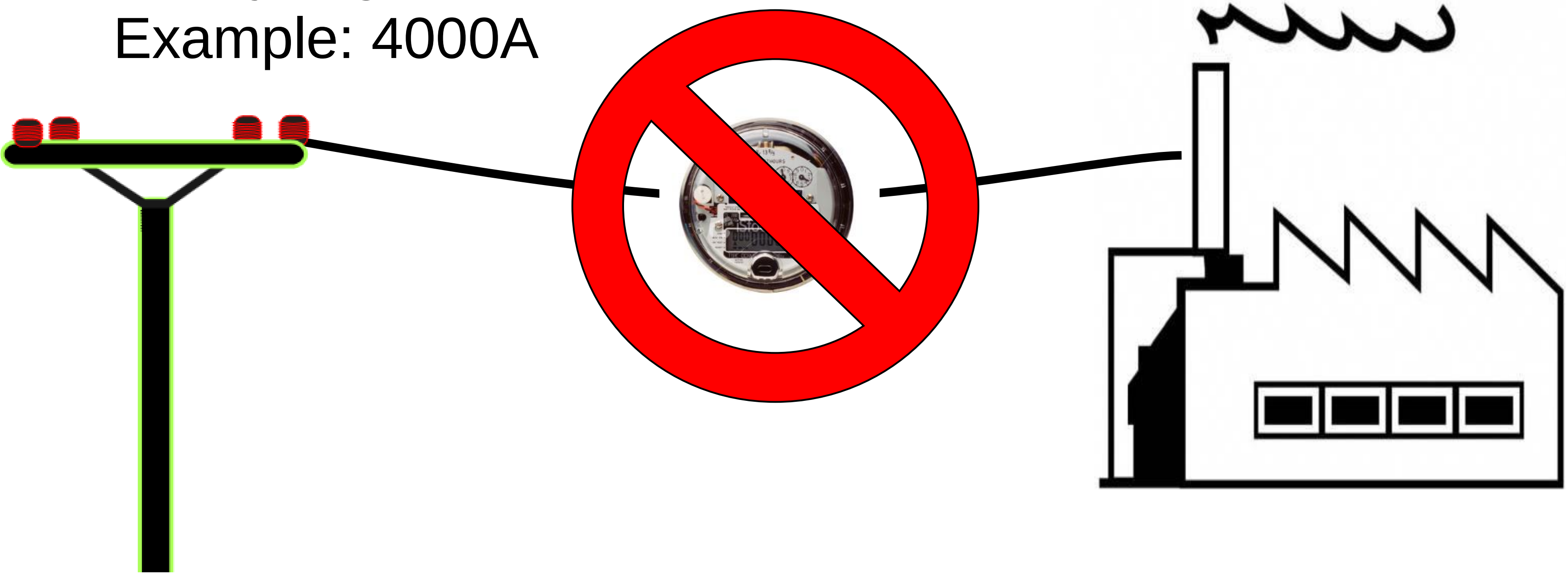


THE EASTERN SPECIALTY COMPANY

Transformer-Rated Meters

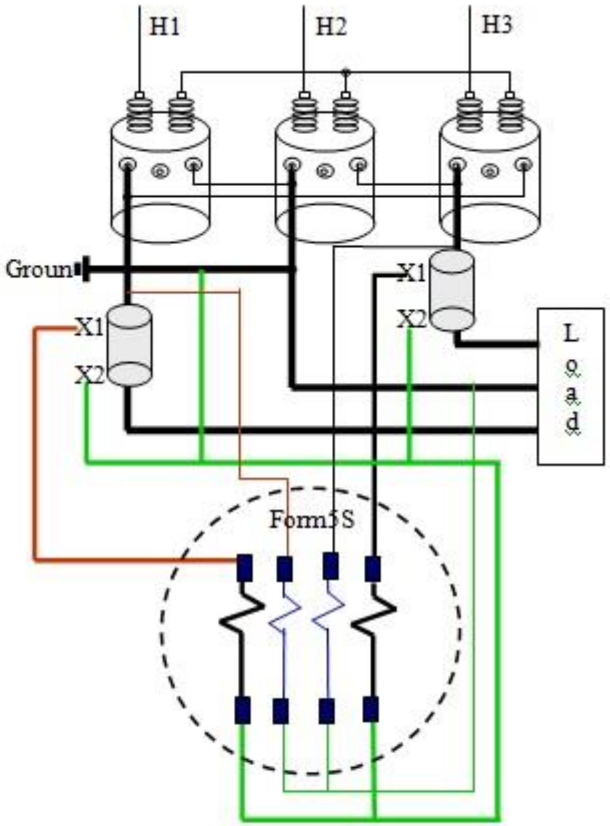
Primarily Commercial/Industrial

Relatively High Current
Example: 4000A



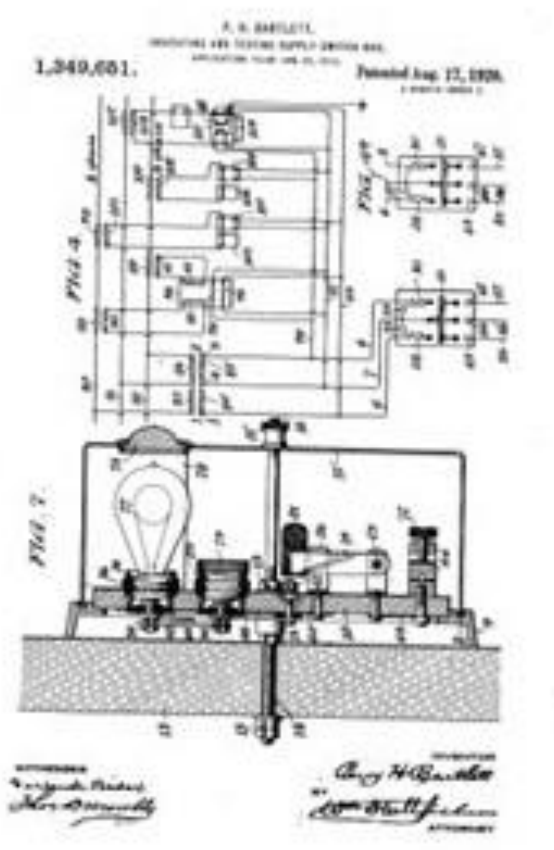
Transformer-Rated Meters

Primarily Commercial/Industrial



Transformer-Rated Meters

Safety Test Switch



- August 17, 1920
- **TESCO** founders Joseph Seaman and Burleigh Currier, along with Percy Bartlett

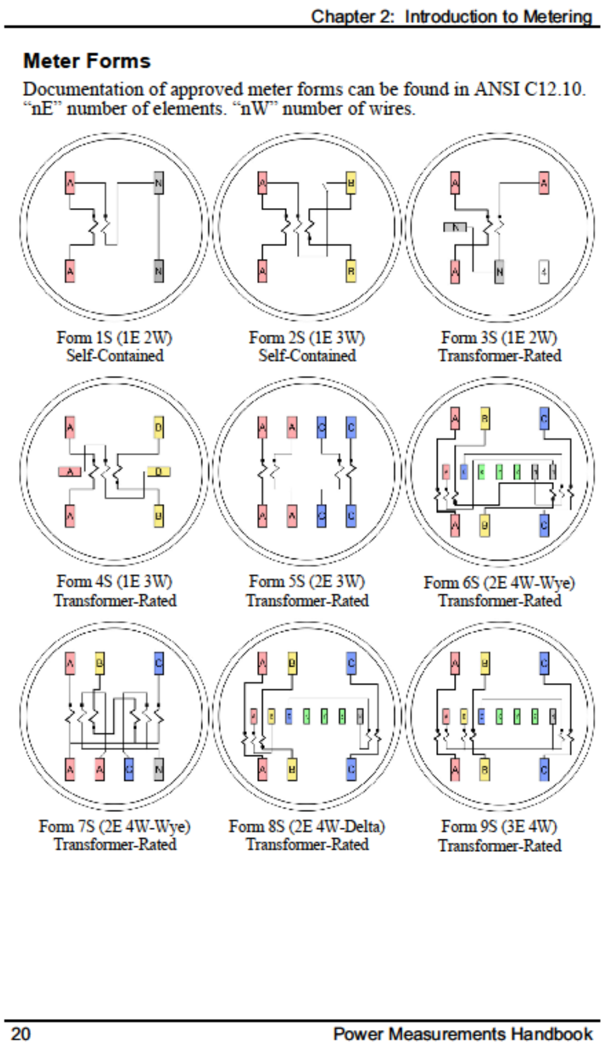
THE EASTERN SPECIALTY COMPANY

Transformer-Rated Meters

Safety Test Switch

THE EASTERN SPECIALTY COMPANY

Diagram Example


Chapter 2: Introduction to Metering

Meter Forms

Documentation of approved meter forms can be found in ANSI C12.10.
"nE" number of elements. "nW" number of wires.

Form 1S (1E 2W) Self-Contained

Form 2S (1E 3W) Self-Contained

Form 3S (1E 2W) Transformer-Rated

Form 4S (1E 3W) Transformer-Rated

Form 5S (2E 3W) Transformer-Rated

Form 6S (2E 4W-Wye) Transformer-Rated

Form 7S (2E 4W-Wye) Transformer-Rated

Form 8S (2E 4W-Delta) Transformer-Rated

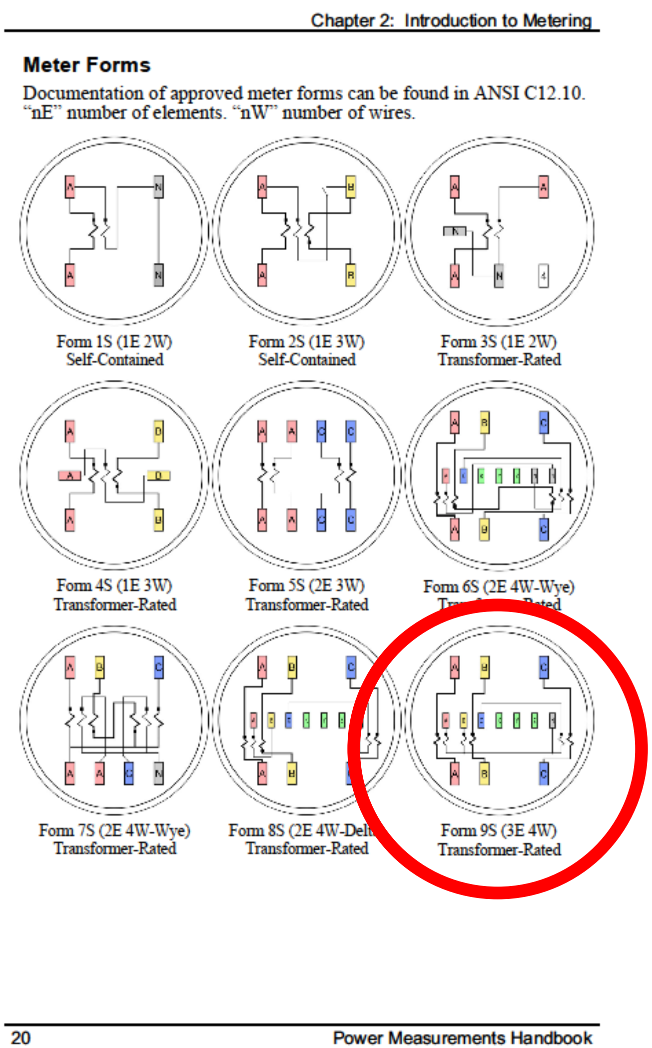
Form 9S (3E 4W) Transformer-Rated

20 Power Measurements Handbook

References

- Power Measurements Handbook, Dr. Bill Hardy
- UGLY's Electrical References
- Meterman's Handbook
- Manufacturer's websites

Diagram Example


Chapter 2: Introduction to Metering

Meter Forms

Documentation of approved meter forms can be found in ANSI C12.10. "nE" number of elements. "nW" number of wires.

Form 1S (1E 2W) Self-Contained

Form 2S (1E 3W) Self-Contained

Form 3S (1E 2W) Transformer-Rated

Form 4S (1E 3W) Transformer-Rated

Form 5S (2E 3W) Transformer-Rated

Form 6S (2E 4W-Wye) Tra[illegible]Rated

Form 7S (2E 4W-Wye) Transformer-Rated

Form 8S (2E 4W-Delt[illegible] Transformer-Rated

Form 9S (3E 4W) Transformer-Rated

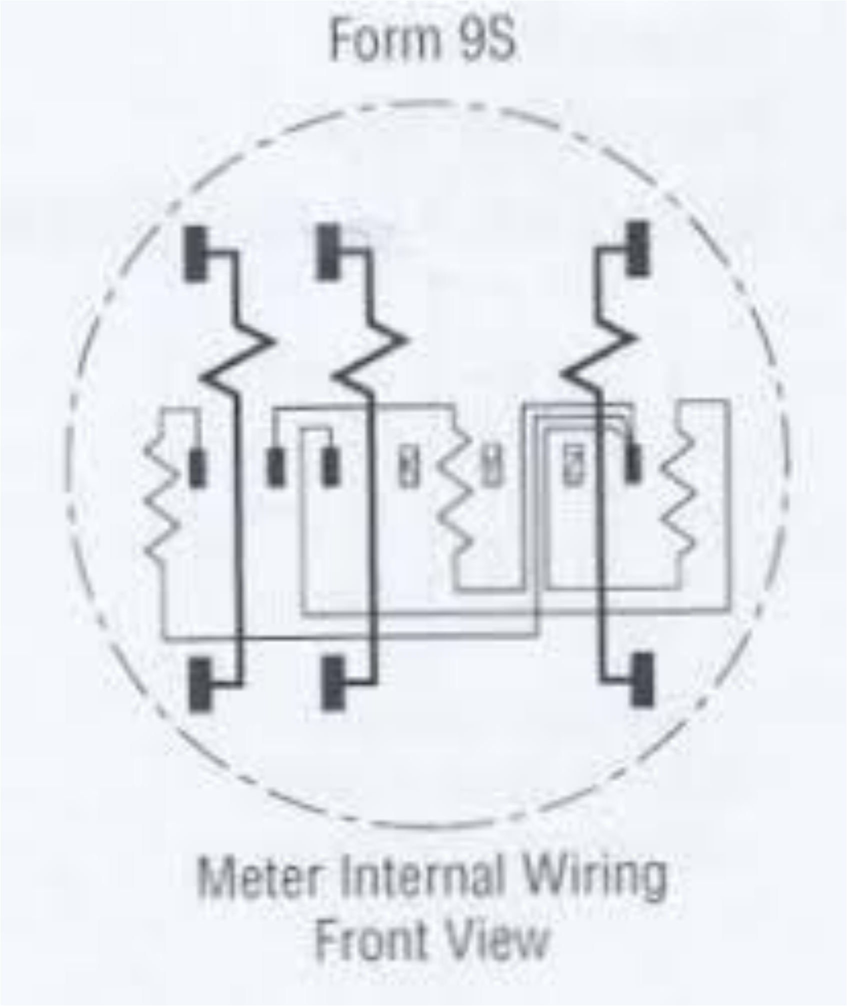
20 Power Measurements Handbook

References

- Power Measurements Handbook, Dr. Bill Hardy
- UGLY's Electrical References
- Meterman's Handbook
- Manufacturer's websites

THE EASTERN SPECIALTY COMPANY

Diagram Example



- 3 Current Coils
- 3 Potential Coils

Blondel’s Theorem

- French Electrical Engineer Andre Blondel
- Attempt to simplify electrical measurements and validation of the results
- Paper submitted to the International Electric Congress in Chicago in 1893.

$$E = n - 1$$

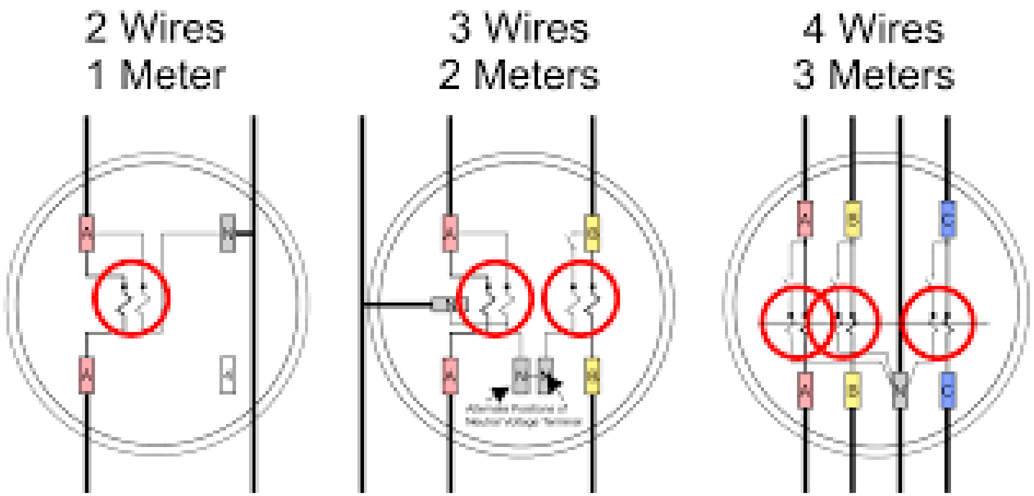
The theorem states that the power provided to a system of N conductors is equal to the algebraic sum of the power measured by N watt-meters. The N watt-meters are separately connected such that each one measures the current level in one of the N conductors and the potential level between that conductor and a common point. In a further simplification, if that common point is located on one of the conductors, that conductor's meter can be removed and only N-1 meters are required.

THE EASTERN SPECIALTY COMPANY

Blondel's Theorem

Blondel Compliant

$$E = n - 1$$



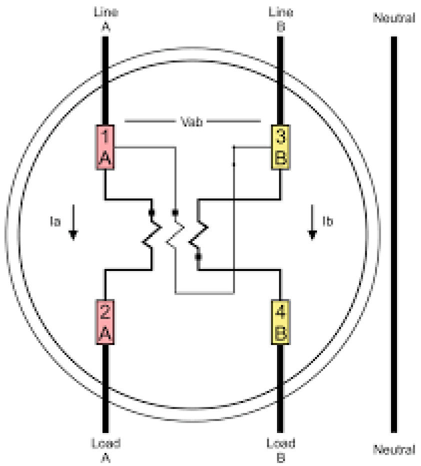
1S   12S   9S

The theorem states that the power provided to a system of N conductors is equal to the algebraic sum of the power measured by N watt-meters. The N watt-meters are separately connected such that each one measures the current level in one of the N conductors and the potential level between that conductor and a common point. In a further simplification, if that common point is located on one of the conductors, that conductor's meter can be removed and only N-1 meters are required.

Blondel's Theorem

Non-Blondel Compliant

$$E = n - 1$$



2S

The theorem states that the power provided to a system of N conductors is equal to the algebraic sum of the power measured by N watt-meters. The N watt-meters are separately connected such that each one measures the current level in one of the N conductors and the potential level between that conductor and a common point. In a further simplification, if that common point is located on one of the conductors, that conductor's meter can be removed and only N-1 meters are required.

Blondel’s Theorem

Why is non-Blondel metering bad?

- Makes assumptions about the service
- Example: balanced voltages
- Assumptions might not be true
- When these assumptions are not true, then there are power measurement errors even if the meter is working perfectly.

The theorem states that the power provided to a system of N conductors is equal to the algebraic sum of the power measured by N watt-meters. The N watt-meters are separately connected such that each one measures the current level in one of the N conductors and the potential level between that conductor and a common point. In a further simplification, if that common point is located on one of the conductors, that conductor's meter can be removed and only N-1 meters are required.

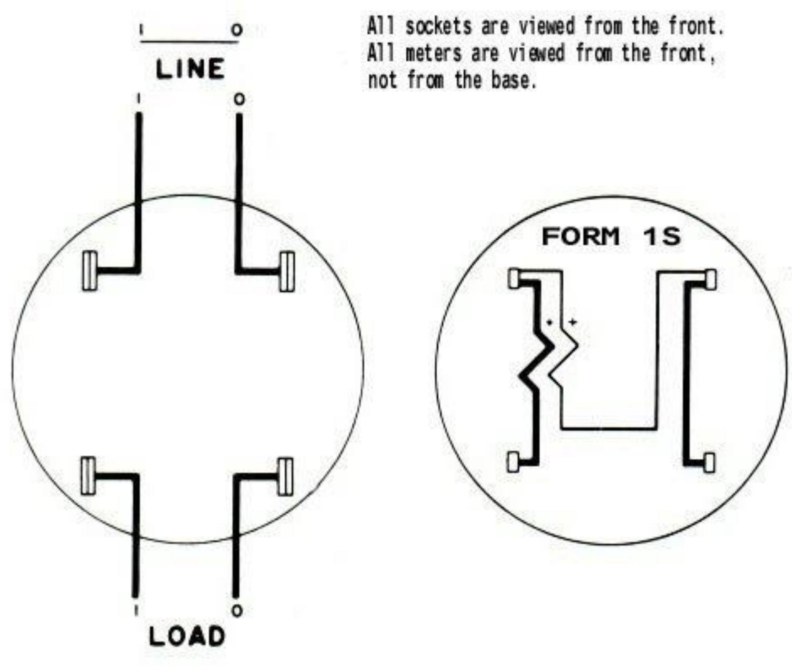
Blondel's Theorem

Why are non-Blondel meters used?

- Fewer elements (meters) = lower cost
- Especially true for electro-mechanical meters
- Fewer CT's and PT's = lower cost
- Less wiring and cheaper sockets

The theorem states that the power provided to a system of N conductors is equal to the algebraic sum of the power measured by N watt-meters. The N watt-meters are separately connected such that each one measures the current level in one of the N conductors and the potential level between that conductor and a common point. In a further simplification, if that common point is located on one of the conductors, that conductor's meter can be removed and only N-1 meters are required.

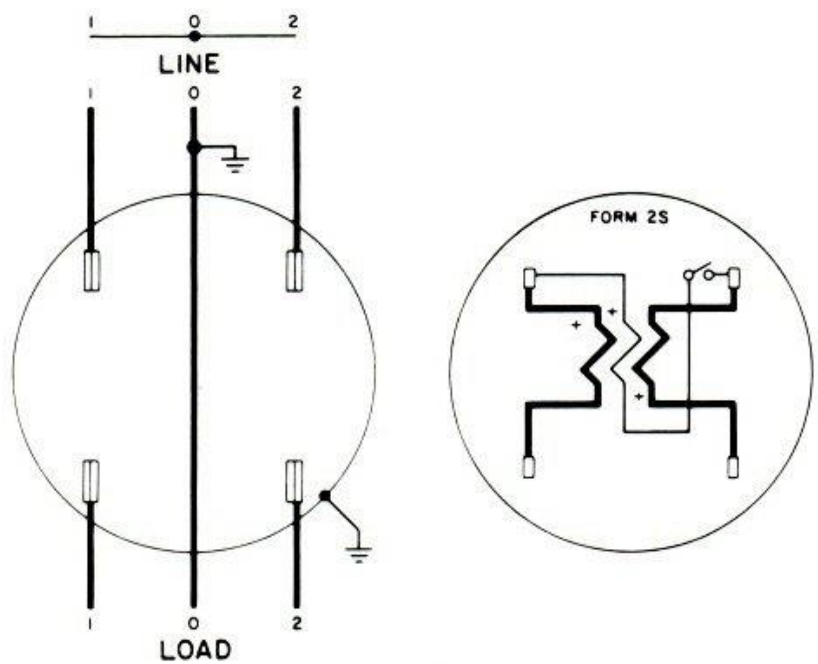
Metering Examples



FORM 1S
1ø, 2 W CIRCUIT
1 Stator, 2 W Meter, Self-Contained

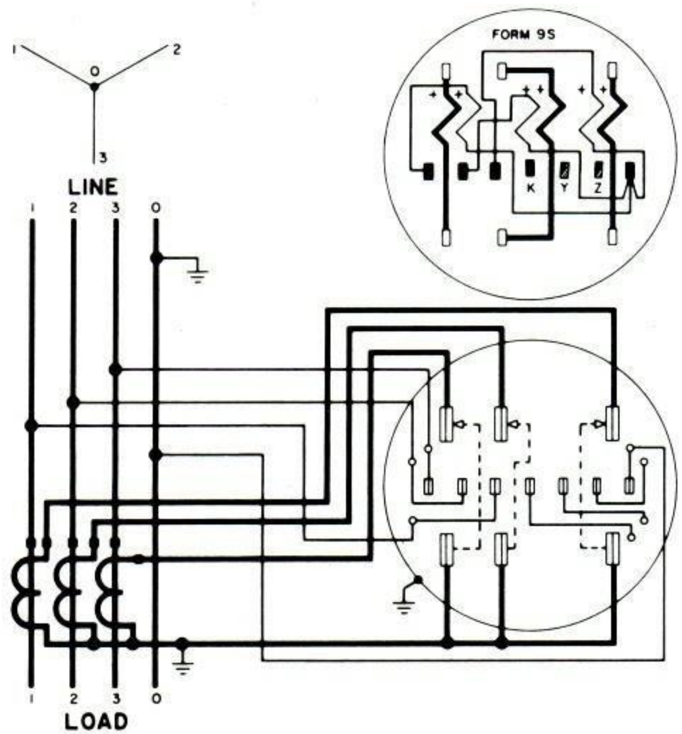
BCM
Bay City Metering
P: 212-575-0785

Metering Examples



1ø, 3 W CIRCUIT
1 Stator, 1ø, 3 W Meter, Self-Contained

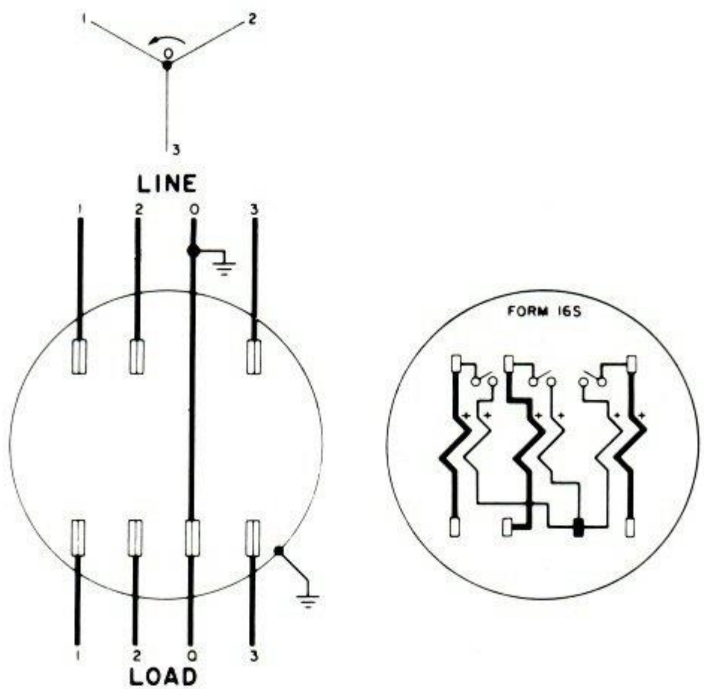
Metering Examples



3ø, 4 W, Y CIRCUIT
3 Stator, 3ø, 4 W, Y Meter with 3-2 W CT's

BCM
Bay City Metering
P: 212-575-0785

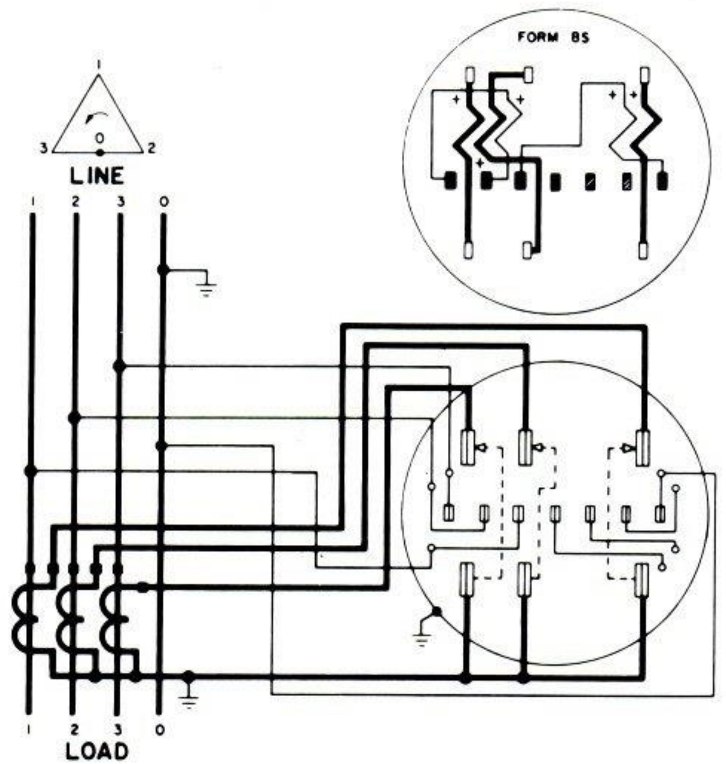
Metering Examples



3ø, 4 W, Y CIRCUIT
3 Stator, 3ø, 4 W, Y Meter, Self-Contained

BCM
Bay City Metering
P: 212-575-0785

Metering Examples



3ø, 4 W, Δ CIRCUIT

2 Stator, 3ø, 4 W, Δ Meter with 3-2 W CT's

References

- https://en.wikipedia.org/wiki/Blondel%27s_theorem
- http://www.powermeasurements.org/library/Presentations/NCMS%202013%20-%20Non-Blondel%20Metering.pdf
- https://www.baycitymetering.com/

Questions and Discussion

Rob Reese

rob.reese@tescometering.com

TESCO – The Eastern Specialty Company

Bristol, PA

215-310-8809 (cell)

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

ISO 9001:2015 Certified Quality Company
ISO 17025:2017 Accredited Laboratory