TESCO METERING

ANSI Meter Forms & Blondel's Theorem

July 2025

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AGENDA

Meters 101 - Electro-Mechanical vs Solid-State

ANSI

Meter Face Plate

Meter Forms

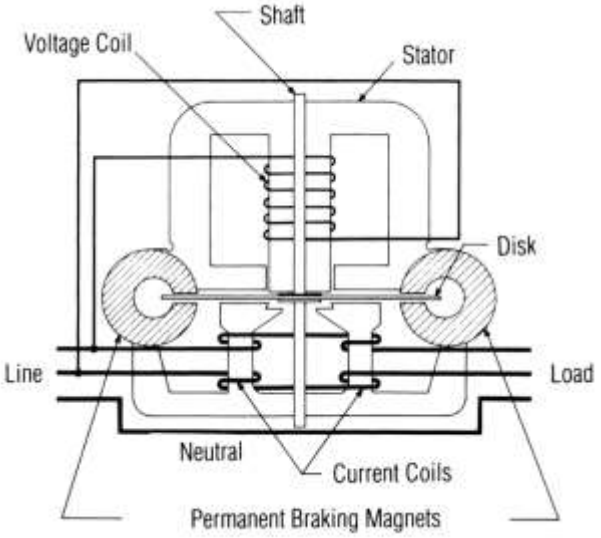
Self-Contained vs Transformer Rated

Blondel's Theorem

Examples

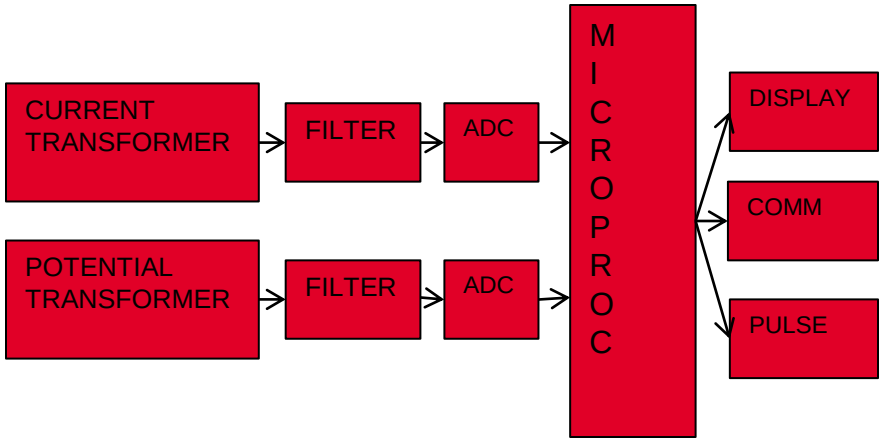
ELECTRO-MECHANICAL METERS

- Works on Induction
- Moving Parts
- Eddy currents proportional to energy flow cause disk motion
- Disk rotation turns the gears attached to the meter register
- Each disk rotation is proportional to a set number of Watt-hours, while the register reading is proportional to Kilowatt-hours



Computer under glass

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

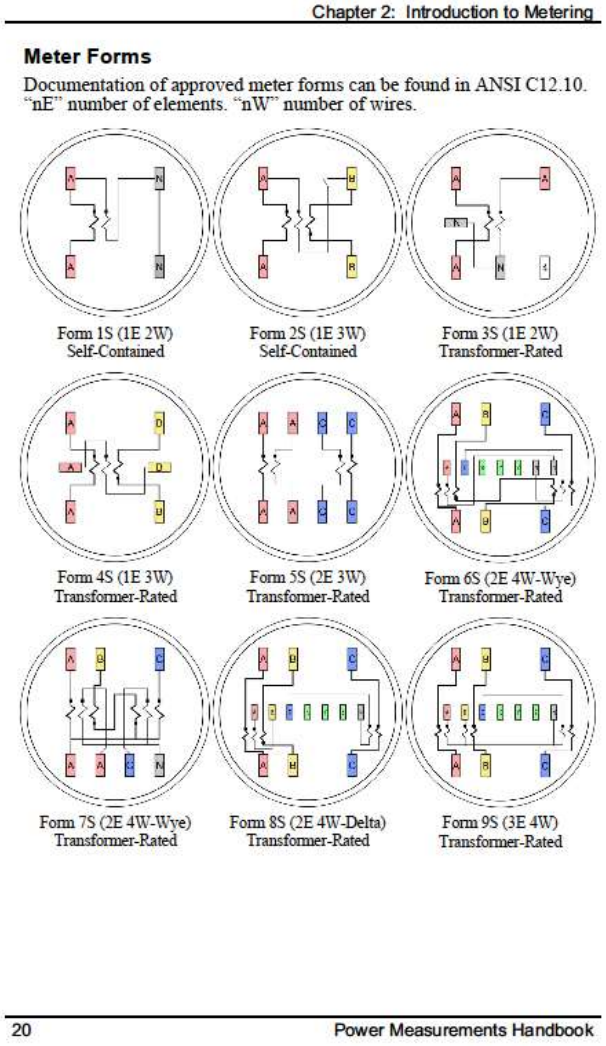


METER FORMS

American National Standards Institute
ANSI standard C12.10

This Standard covers the physical aspects of both detachable and bottom-connected watthour meters and associated registers. These include ratings, internal wiring arrangements, pertinent dimensions, markings, and other general specifications.

- Meters with the same form, rated voltage and class are interchangeable between manufactures.



References

- Power Measurements Handbook, Dr. Bill Hardy
- UGLY's Electrical References
- Handbook for Electricity Metering
- Pocket Guide to Watthour Meters
- Manufacturer's websites

METER FORMS

A-base

S-type

K-base

METER FORMS

SELF-CONTAINED

- EX- 1s, 2s, 12s (Network),12s Delta,15s,16s
- Services between 120 to 480 volts
- CL100, CL200 or CL320 (max amps)
  - Older (K-base meters = CL400)
- Typical size homes and smaller commercial services
- Voltages and Currents connected to the same terminals
- Self-contained meters have a multiplier of 1. Meter read is actual KWH usage.

TRANSFORMER-RATED

- EX- 3s, 4s, 5s, 6s, 8s, 9s, 36s, 45s
- All Voltages
- CL10 or CL20
- Large homes, large commercial and Industrial services
- Requires Instrument Transformers

  Potential and/or Current Transformers
- Voltages and Currents connected to separate terminals on meter
- Meter read X CT/PT ratios (multiplier) is KHW usage

FACE PLATE

CL200- Refers to the max amperage the meter is designed to handle.

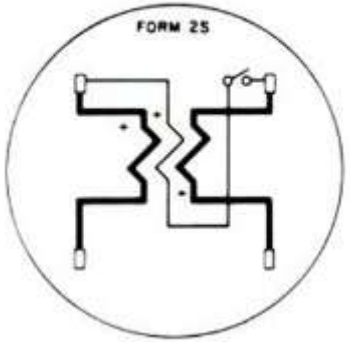
240v- The rating of the potential coil in the meter.

3w- Number of service conductor.

60hz- AC cycles per second.

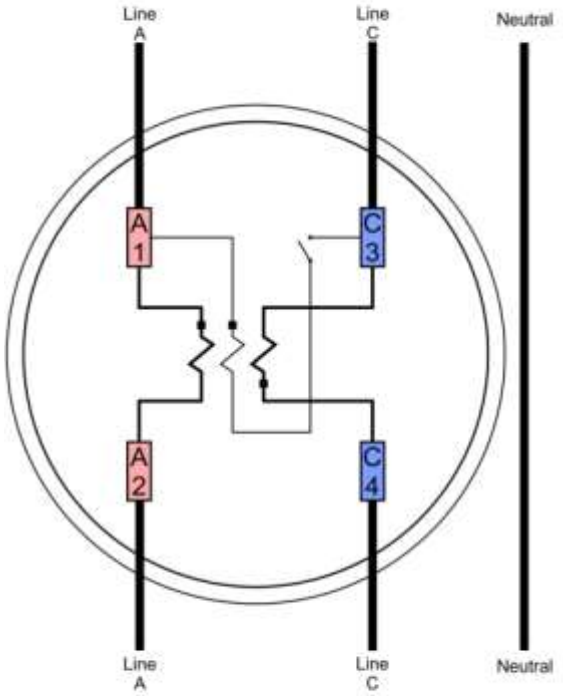
K_h- Watt-hours per disk rotation.

FM2S- Indicates meter form. Standardized to help identify service type the meter is used for and internal meter wiring.



Internal Wiring Diagram

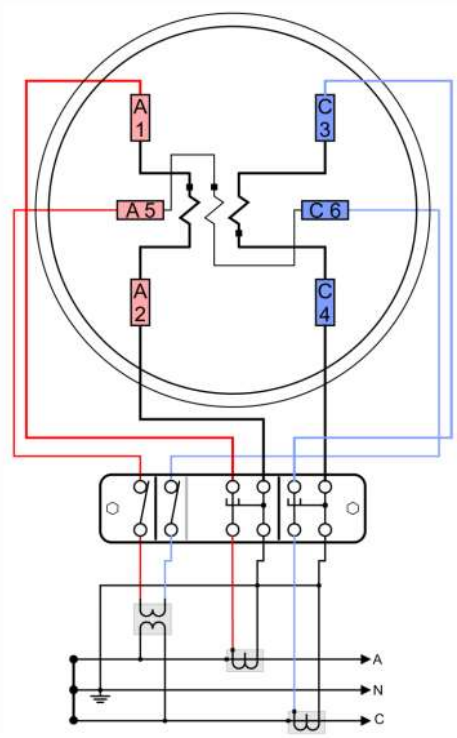
2S Wiring Diagram



1 PH, 3 WIRE

- Self-Contained or Instrument Rated
- Identifies Meter not Service
  - Some forms may be used to meter more than one service configuration
  - Always verify utility practice
- Shows number and arrangement of meter terminals
- Shows internal connections and number of meter elements
- Current and Potential Coils (along with their polarity)
- Socket clip configuration

4S Wiring Diagram

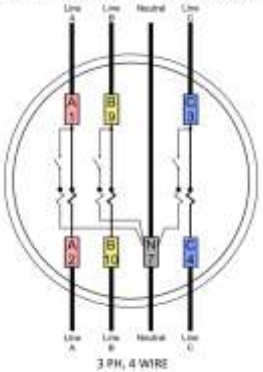


1 PH, 3 WIRE (1 PT, 2 CT)

➢ Understanding Internal wiring can make it easier to understand power calculations.

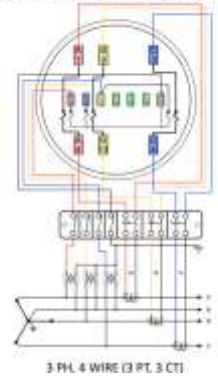
METER FORMS

16S Wiring Diagram (4 WIRE WYE)



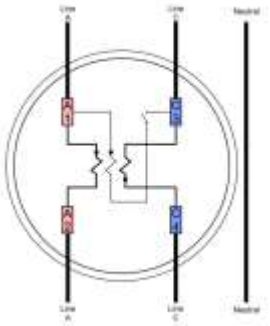
14s,15s

9S Wiring Diagram (4 WIRE WYE)

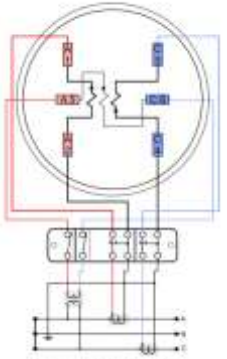


8s

2S Wiring Diagram

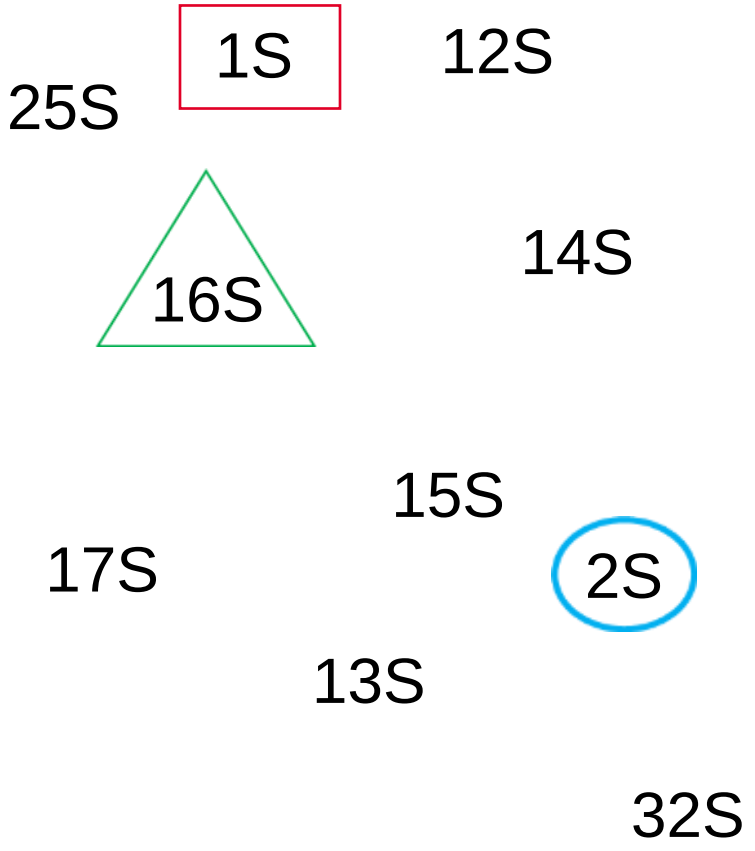


4S Wiring Diagram

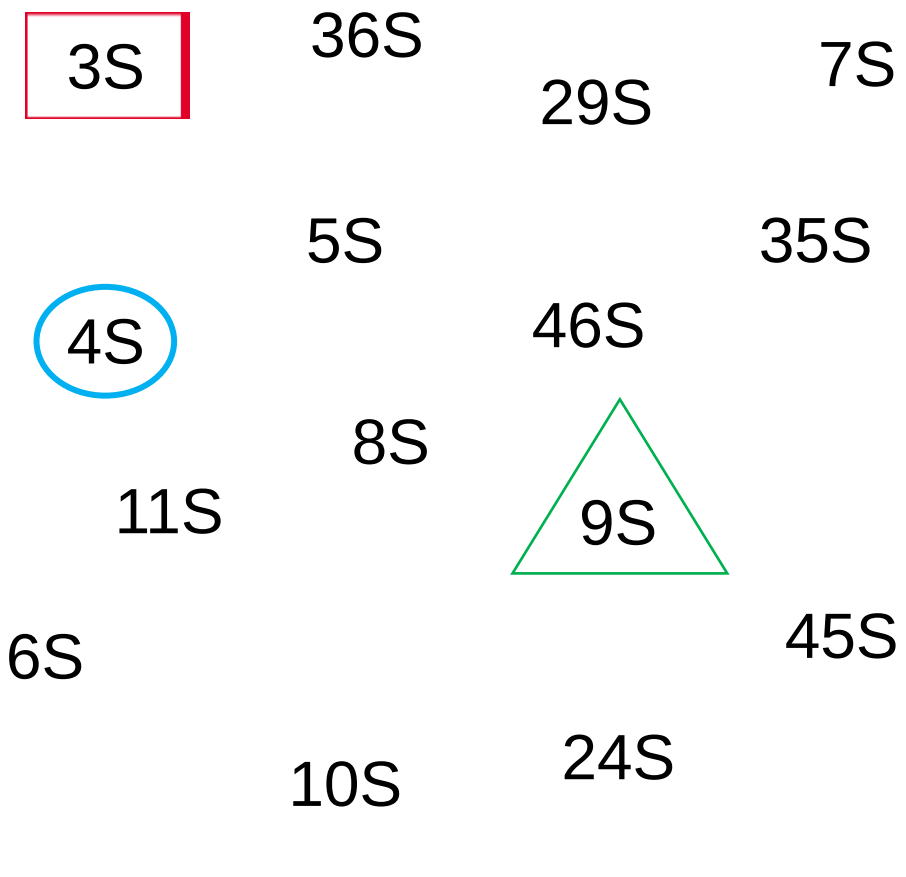


METER FORMS

SELF-CONTAINED

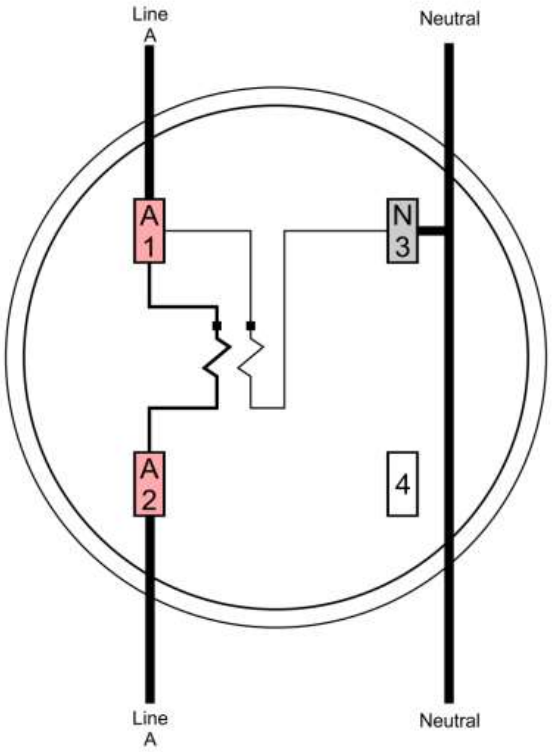


TRANSFORMER-RATED

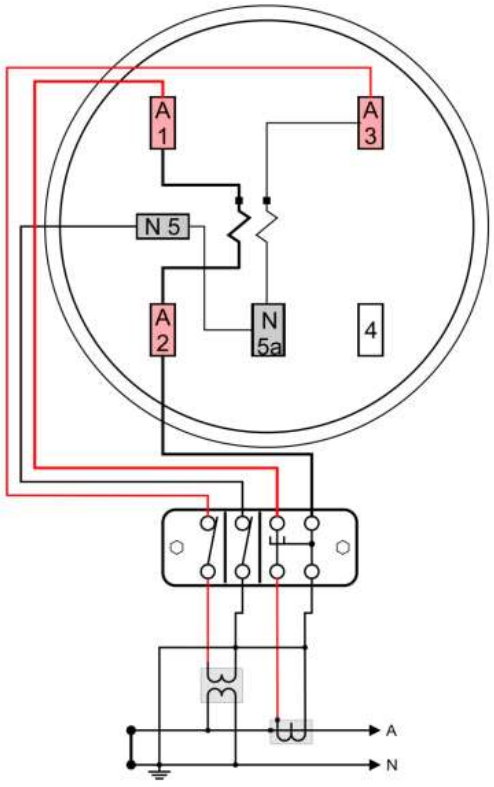


SC vs IR

1S Wiring Diagram

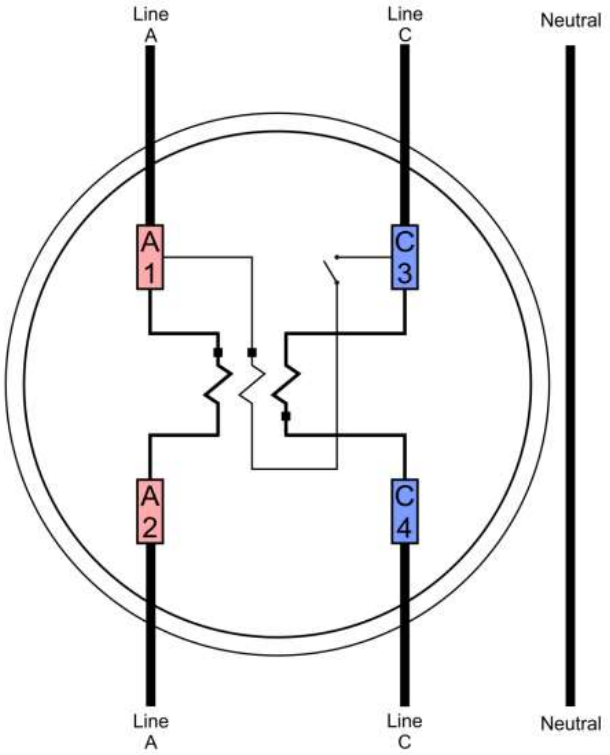


3S Wiring Diagram

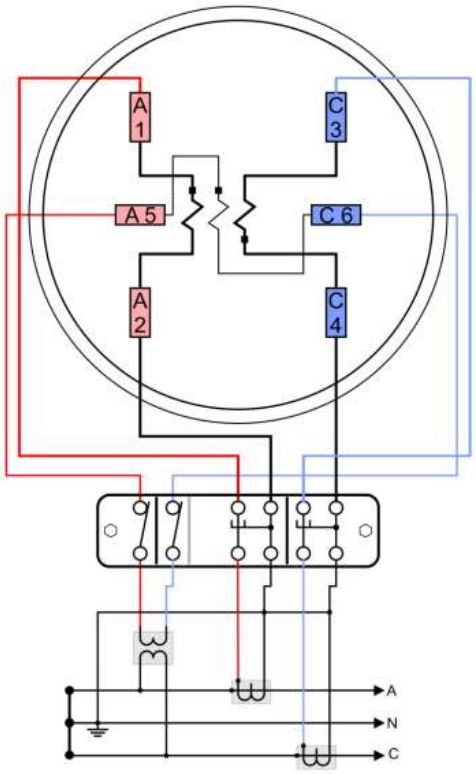


SC vs IR

2S Wiring Diagram

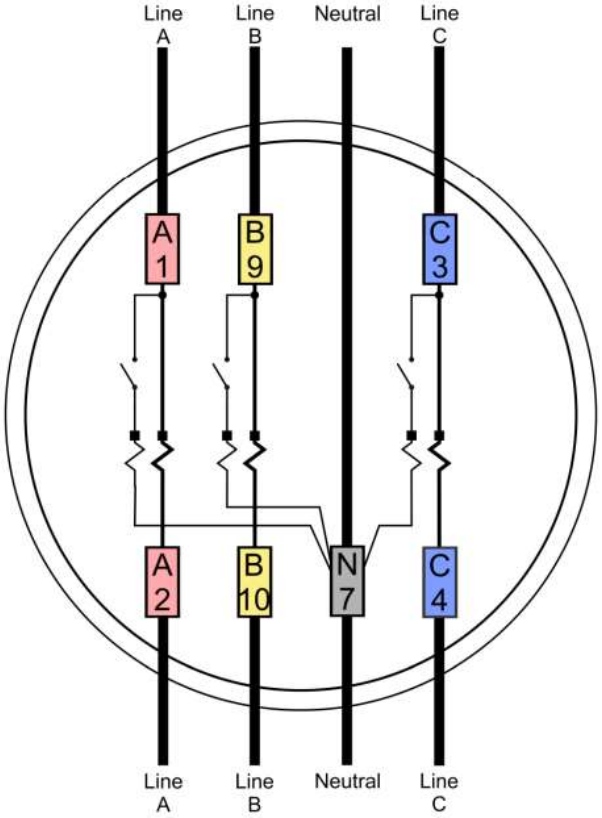


4S Wiring Diagram



SC vs IR

16S Wiring Diagram (4 WIRE WYE)



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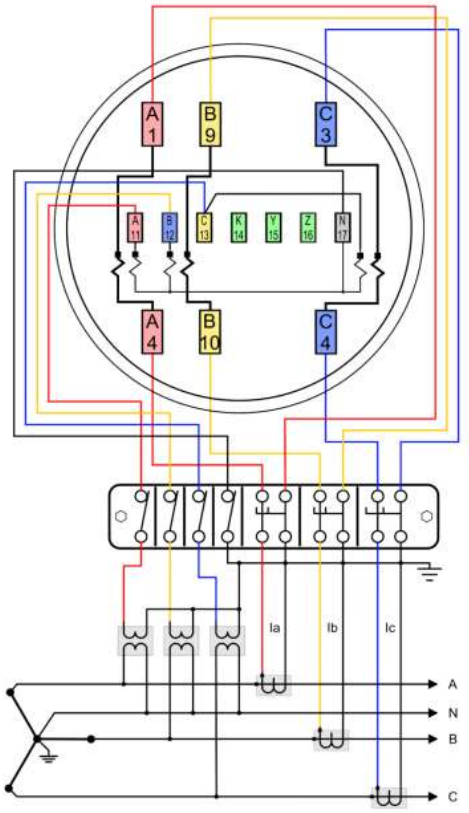


BLONDEL'S THEOREM

- 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. 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.

SIMPLIFYING BLONDEL'S THEOREM

Blondel's theorem: In a system of N conductors, N-1 meter elements, properly connected, will measure the active power or energy taken. The connection must be such that all voltage coils have a common tie to the conductor in which there is no current coil.

$$E=n-1$$

Number of Stators needed

Number of service conductors

Therefore, a three-wire single-phase service would require a two-stator meter.

$$E=3-1$$

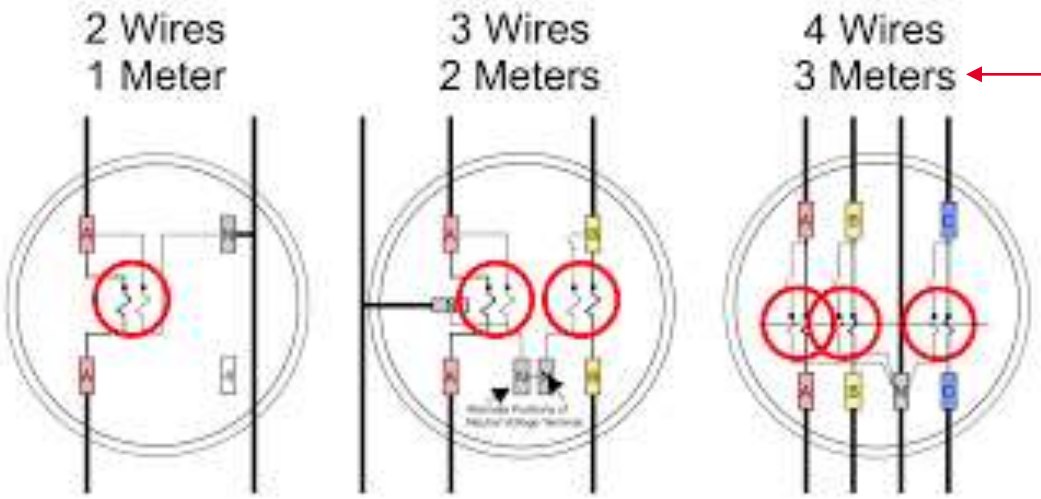
$$E=2$$

- Stators are also referred to as Elements. Stators/Elements are the combination of a current coil/s and a potential coil in a meter.

BLONDEL'S THEOREM

Blondel Compliant

$$E = n - 1$$



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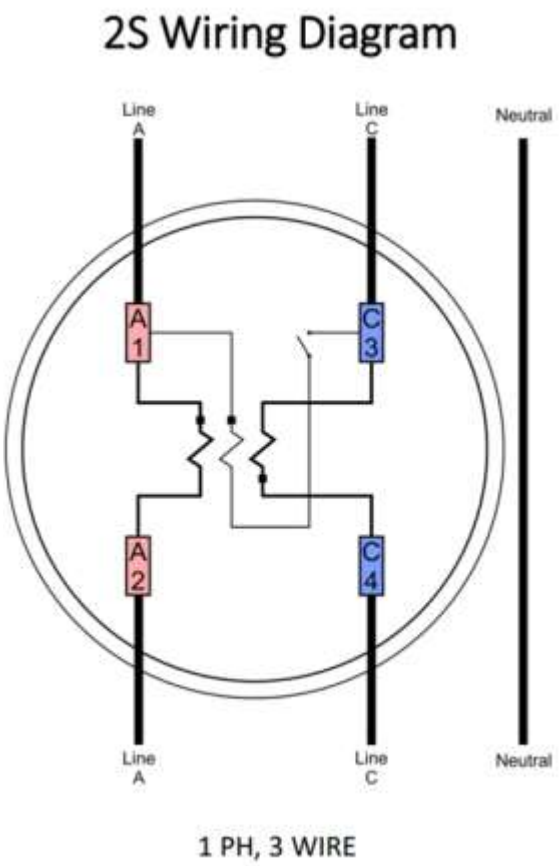
BLONDEL'S THEOREM

Non-Blondel Compliant



Form 2s meter has two current coils and one potential coil.

$$E = n-1$$
$$E = 3-1$$
$$E = 2$$

Problems:

1. The Potential coil does not have a common point across the un-metered conductor (Neutral).

2. Meters require a current and potential coil per stator.

Why is non-Blondel metering bad?

- Makes assumptions about the service
  - Balanced voltages
- When these assumptions are not true, then there are power measurement errors even if the meter is working perfectly.

Why are non-Blondel meters used?

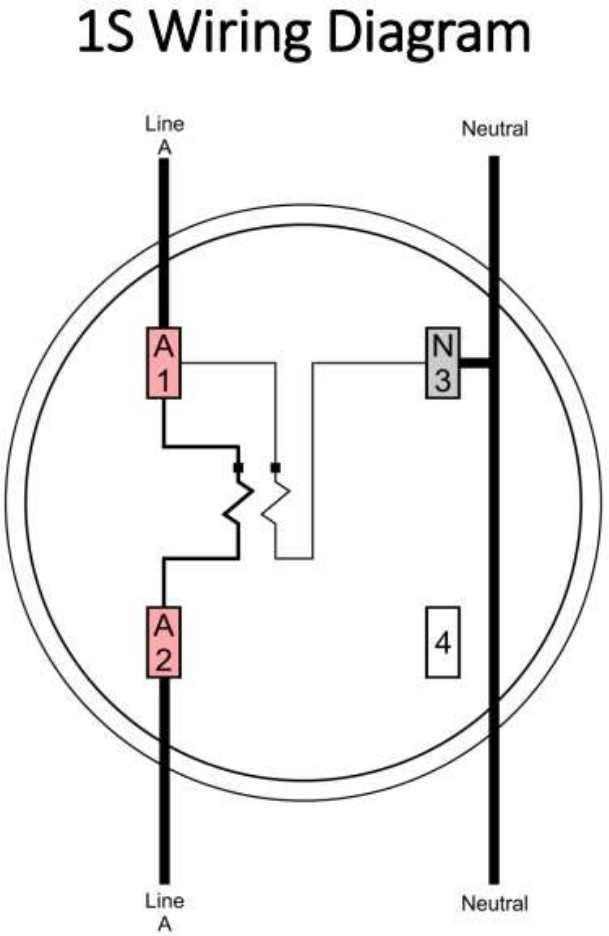
- Fewer elements (meters) = lower cost
- Especially true for electro-mechanical meters
- Fewer CT's and PT's = lower cost
- Less wiring (Material and Time)

METERING EXAMPLES

Blondel Compliant?

YES!

E = 2-1
E = 1



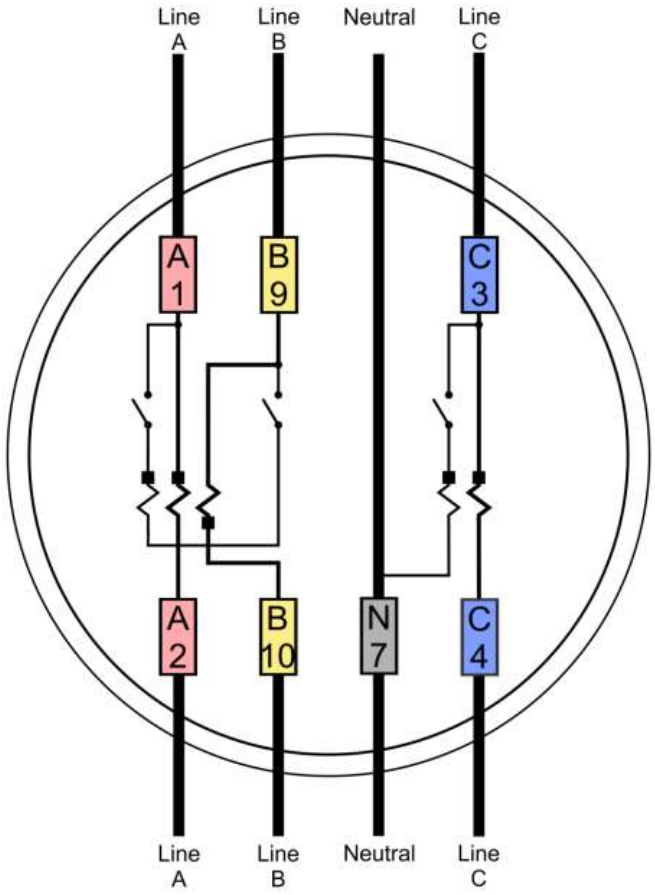
Metering Examples

Blondel Compliant?

NO!

E = 4-1
E = 3

15S Wiring Diagram (4 WIRE DELTA)



3 PH, 4 WIRE

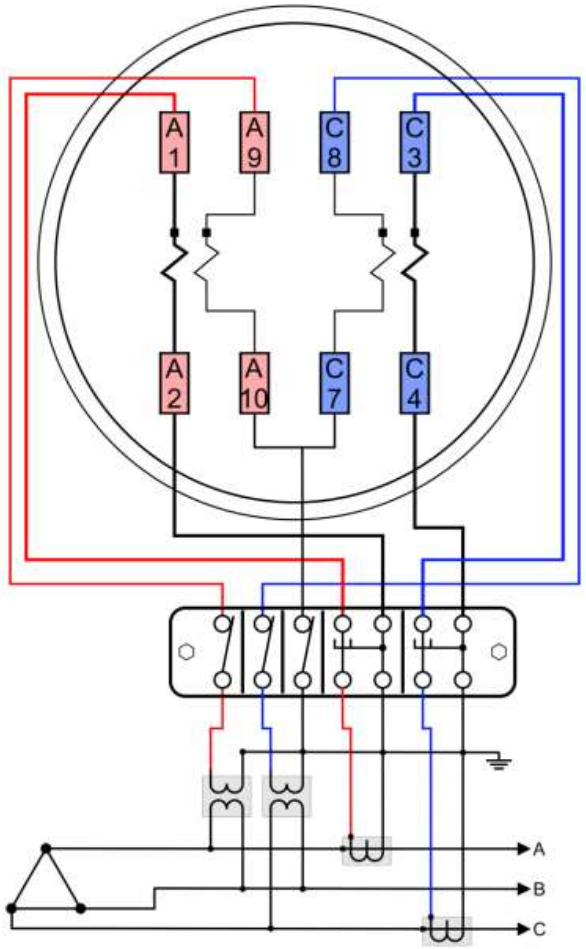
METERING EXAMPLES

Blondel Compliant?

YES!

E = 3-1
E = 2

5S Wiring Diagram (3 WIRE DELTA)



3 PH, 3 WIRE (2 PT, 2 CT)

REFERENCES

- Wikipedia – of course
- https://en.wikipedia.org/wiki/Blondel%27s_theorem

- Power Measurement Handbook – Dr. Bill Hardy – TESCO CTO Emeritus
- http://www.powermeasurements.org/library/Presentations/NCMS%202013%20-%20Non-Blondel%20Metering.pdf

- Third Party meter sites
- https://www.baycitymetering.com/

- Handbook for Electricity Metering
- Pocket Guide to Watthour Meters

TESCO METERING

INTRODUCTION TO WATTHOUR METER TESTING

July 2025

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NVE Metering Electrician/Trainer

Questions to Answer

- Why do we test?
- How do we test?
- What types of meter tests are there?
- How do utility tests differ from customer request tests?
- What is In-Service Testing?
- How do we know meter tests are good?
- What do we do with the test data?

Why Do We Test?

- Meter accuracy establishes “fair” transactions / billing between the utility company and customers.
- Regulatory commissions require meter tests.
  - Meter testing guidelines are taken from ANSI C12.1- American National Standard for Electric Meters – Code for Electricity Metering
  - Final testing guidelines are established by the governing commission, local government, or the utility
- Customers request a test
- Good Business Practice

ANSI
American National Standards Institute

REGULATION

ANSI American National Standards Institute provides guidance rather than enforces standards

- Our regulatory commissions typically require us to test meters for accuracy
  - Regulatory commissions typically take their lead from ANSI C12.1 American National Standard for Electricity Metering
- State regulatory commissions focus on accuracy because they want electric utilities to ensure that no customer is being billed unfairly, and that no subset of customers is being unfairly subsidized by the rest of the rate payers
  - Some states mandate only accuracy tests and others require demand and time of use accuracy tests
- Any tests beyond accuracy tests are tests that are simply good business practice
  - With the integration of AMI, functional testing has taken a high priority for the utility

Meter Testing

- New Purchase Meters
  - Manufacturers tests
  - In-house tests on new shipments
- Recycled Meters
  - Return to Service Testing
- Customer Request
- In-Service Meters
  - Periodic Tests
  - Selective, random, or statistical testing
- End of Life Meters
  - Retirement tests
- Testing of related metering equipment

NEEDED FOR METER TESTING

- Equipment Needed for Testing
  - Reference Standard
  - Test Kit or Load Box
  - Test Jack or Test Switch
  - Multi-Meter
  - PPE & Safety Equipment
- Tests Performed

Test	Voltage	Current	PF
Full Load	Rated V	Rated Test Amps (TA)	1.0
Power Factor	Rated V	Rated TA	0.5
Light Load	Rated V	10% of TA	1.0

- Meter Characteristics - Test Amps, Class, Form, and Voltage are shown on the face of the meter as well as Kh (energy per pulse)

SHOP TESTING

- Done under ideal conditions on a stationary test board.
- Tests meters against an electric power (Shop) standard
- Used for full functional testing capability for all AMI/AMR meters, meter program updates, software revision checking, communications module troubleshooting

Field Testing

- Field testing can be performed with an adapter and site voltage from the meter socket or by removing the meter and testing in a piece of field equipment, that may be contained in a utility vehicle
- IR services can be tested under customer load with the proper test set.

Field Testing	Longer field procedure vs less back-office work
Shop Testing	Quicker field procedure vs more back-office work

Testing of a Meter vs Testing a Site

- Testing of CTs, PTs, and associated site equipment is often overlooked but many times is the key to lost revenue
- IR- Requires a Meter Site Analyzer
    - Verifies
        - Meter Accuracy
        - Correct wiring
        - CT ratio/burden

New Meter Testing Programs

- Accept the Manufacturer's Test results
- Perform a Statistical (Sample) Test of an incoming shipment
- Perform a 100% test of an incoming shipment
- A utility may have more stringent guidelines than the commission
    - 98-102% vs 99.5-100.5% or even 99.7-100.3%

Return to Service Testing

- Meters to be returned to service must always (virtually every utility commission requires this) be accuracy tested before being returned to service
- Best business practices also require that the meter is functionally tested as well

CUSTOMER REQUEST TESTING

- Customers always have the right to request a meter test

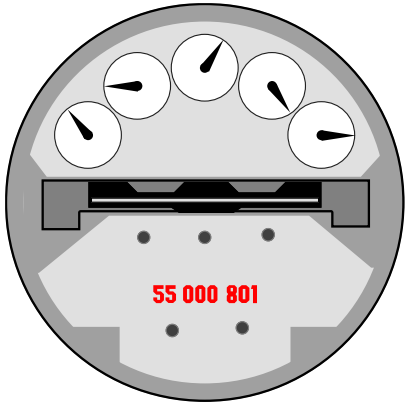
- Depending on utility practice, the test may be done on-site or in the shop
- Some allow the customer to witness the test, and others require the utility commission to witness the test
- Utilities must show that the meter tests within acceptable limits

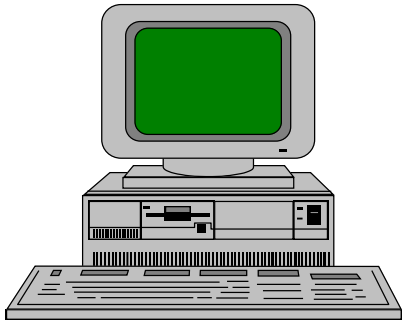
In-Service Testing

- Meter Testing for in-service meters is specified in ANSI C12.1-20xx, *American National Standard for Electric Meters, Code for Electricity Metering*
- Made during the period that the meter is in service. It may be made on the customer's premises without removing the meter from its mounting, or by removing the meter for test either on the premises or in a laboratory or meter shop.

Test Plans for Meters

- The most common test plans for in-service meters include Periodic and Statistical plans
  - Periodic plans may be based on a test every x number of years
    - This is more common with commercial meters
    - This may even be annually on interconnect meters and generation meters
  - Statistical plans generally are based on a subset of the population and broken up by groupings of the population





Periodic Test Plans

- Periodic
  - Varies by State / Jurisdiction / Utility
  - Example provided by ANSI C12.1:
    - Each electromechanical meter is tested once every 8 years
    - All other meters are tested every 16 years
    - Appendix D provides details for other meters & devices
  - With AMI data and consistent performance, some utilities have moved their commercial populations to once every 12 or even 16 years
  - Generally, an average of 12.5% of the population is tested per year

8 Years

16 Years

STATISTICAL TESTING PLAN

- Focuses testing on the specific meters
- Minimizes number of meters to be tested; usually requires less than 30% of what a periodic testing plan requires
- Provides data and analysis for understanding what is happening with installed meters or the purchasing of new meters

HOMOGENEOUS POPULATION(S)

- The groups or populations being tested are made up of the same or similar items, items which operate in the same way and were made in the same manner
- For electric meters, this has traditionally been interpreted as being meters of a specific meter type from a manufacturer (EX: Sensus IconA or Stratus / Honeywell A3TL or A3RAL)
- AMR & AMI programs have helped to make the overall populations more homogenous. This makes a utility with AMR & AMI meters better prepared to take advantage of a statistical sampling plan
    - Some utilities may only have 4-5 groups now where they used to have 20+ groups to test
    - (IE Focus, i210+c, kv2c, centron, etc.)

Sample Test Plans

- ANSI z1.4 and ANSI z1.9 are some of the more commonly accepted sampling plans
  - Z1.4 is more common and may be preferred as it is a sampling procedure based on attributes
    - Meters pass or fail
  - Z1.9 is more granular and may be preferred for aging population as it is a sampling procedure based on variables
    - Meters can fail but there is an average and statistical value calculated for the group

See your utility test plan

METER TESTING TRACEABILITY

- Traceability is defined as the ability to link the results of calibration and measurement to related standard and/or reference (preferably national or international standard) through an unbroken chain of comparisons
- Calibration is typically performed by measuring a test unit against a known standard or reference
- Master standard is kept by National Measurement Institute (NMI)

TEST EQUIPMENT CALIBRATION

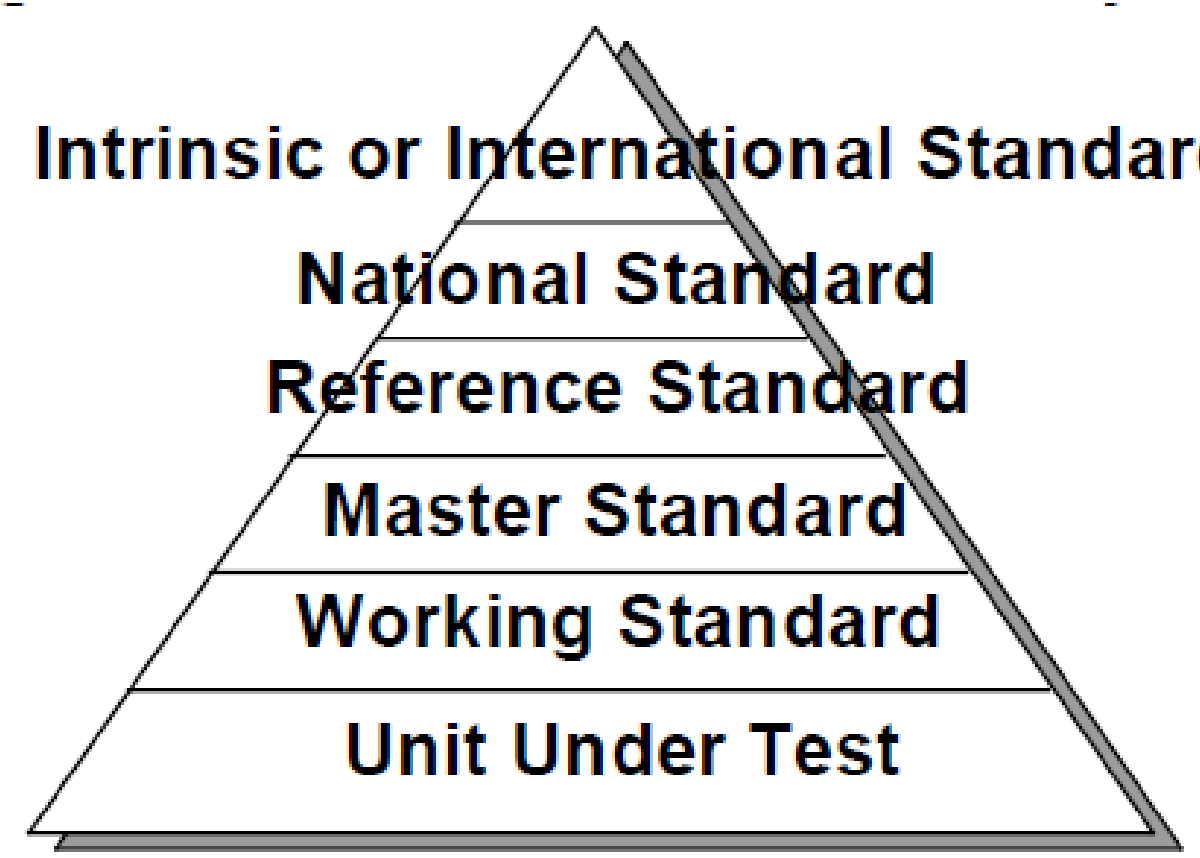
Primary Requirement: Traceable to NIST Standards

- Meter Test Boards, Field Test Kits calibrated to a known master standard maintained at Meter Shop
  - ✓Tested monthly, quarterly, yearly
- Reference or Master standard calibrated by outside vendor traceable to NIST or directly by NIST
  - ✓ Usually annually

METER TESTING TRACEABILITY

- Test equipment to NIST standards
  - National Institute of Standards and Technology (NIST) provides internal tracking numbers, which are often used as evidence of traceability
- Tracking number of meters to be tested per State Commission requirements
- Tracking meter test data
  - Meter Records
  - Meter Data Management System (MDMS)

METER TESTING TRACEABILITY - STANDARDS



METER TESTING TRACEABILITY - STANDARDS

- *National Standard*
  In the US, this is maintained by NIST. Not all countries have a National Standards group.

- *Reference/Master Standard*
  Item of highest metrological quality located at a site where calibration is being conducted.

- *Working Standard*
  Should be compared to Master Standard or Reference Standard on regular basis; used for daily checks/comparisons of the calibrated devices

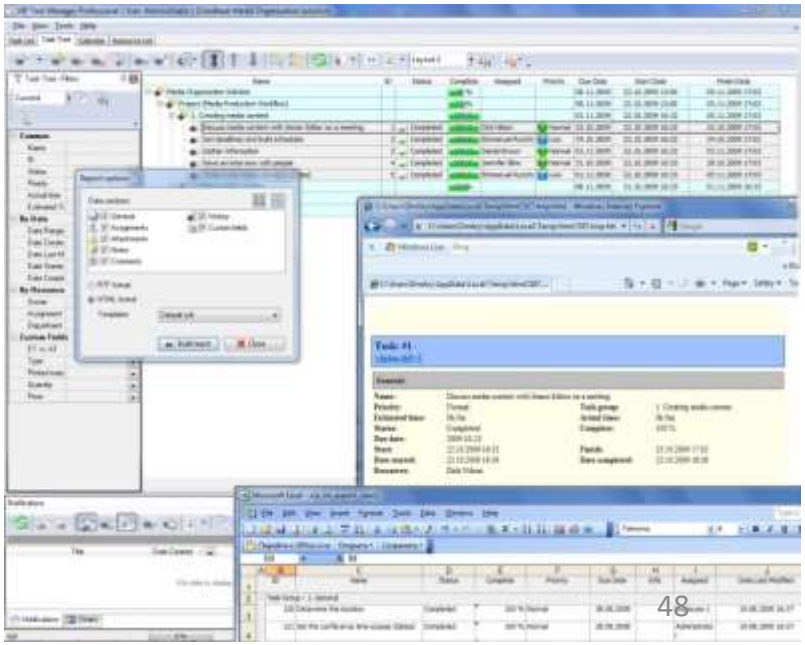
TRACKING METER RECORDS

- AMI programs help to update and overhaul meter record systems

- Having the records for the entire meter population updated allows for a better chance that test data is available to answer questions and that any meter may be selected as part of the sample for testing

METER TEST DATA TRACKING

- Test data should be tracked throughout meter life
  - Certification testing, first article, acceptance testing, in-service (field & shop), retirement
- Meter test data should be linked to meter record data such as meter form, amps, voltage, display type, etc.
- Best time to start to develop the program is before the meters are being installed
- Accuracy test data is usually collected automatically as new meters are tested in meter shops
- Need to consider tracking non-accuracy functional testing (meter software configuration, service disconnect testing, voltage, etc.)



METER TEST DATA TRACKING SYSTEM

- System should track meter test results for ease of future reference or for response to public or utility commission inquiries
- May be part of Meter Data Management System (MDMS) or a separate Meter Records system
- Requires discipline in collecting & entering data, especially field tests

Course Feedback

Please Take a Few Minutes To Provide Feeback About The Course & Instructor

Questions and Discussion

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702-409-1943

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