ALL IN ONE

The Elster Electricity Meter And ABB Instrument Transformer Application Guide

12th Edition
(reprint)

ABB

ELSTER

About the reprint
The contact information has been modified since the original publication of the 12th edition. Company names, addresses, and telephone numbers are current as of September 2003. Additionally, the copyright notice and the disclaimer of warranties and limitiation of liability notice have been modified to reflect both Elster Electricity, LLC, and ABB Inc. All other information has not changed since the first release of the 12th edition in September 1999.

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INTRODUCTION

This book is intended as a suggested ABB metering application, installation, testing, and ordering information guide. While these subjects are covered in great detail, these instructions cannot be substituted for proper operation and service practices. Competent, well-trained, and experienced personnel with adequate technical and safety knowledge of the metering equipment are most essential for successful and safe meter usage. Unusual and special situations will require consulting other meter publications, handbooks, instruction guides, and/or proper ABB representatives. Because of these factors, ABB cannot be responsible or liable for consequential damages which may result from misuse, misinterpretation, or errors relating to this publication.

IMPORTANT APPLICATION INFORMATION

All ABB meters are calibrated and sealed before shipment. To assure safe installation, good accuracy, and maximum life of the meter, the following procedures are suggested.

Socket Connected "S" Type Meters

1. Grounding of meter lightning arrester ground straps with socket rim should be ensured by scraping off paint, if any, from socket rim at point of contact.

2. Make certain socket terminal wiring is as shown in appropriate diagrams herein.

3. Meter class rating is the maximum current rating. Meter and socket class rating should be compatible.

4. Install meter in upright position with rotor shaft vertical and free from heavy vibration.

WARNING

Dangerous high voltage results from open-current transformer secondaries. Therefore, make use of circuit closing devices or equipment to avoid electrical shock and/or bodily injury.

Bottom Connected "A" Type Meters

1. A reversible meter hanger is attached to the rear of the base and can be adjusted for external or concealed mounting. For a concealed mounting, located, and insert in the mounting surface, the top supporting screw. A keyhole slot is provided for the supporting screw which should be a size No. 12 or larger.

2. A 0.280-inch diameter mounting hole is located on each side of the base just above the terminal block for two bottom supporting screws. Level the meter, insert the two screws, and tighten. The screws should be a size No. 12 or larger.

3. An electrical grounding of the meter base is recommended to assure safety. Attach a No. 12 AWG copper wire (or larger) to the external surface of the base by using one of the mounting screws or a self-tapping screw in the base. WARNING: Grounding should be completed before external connections to the meter are made to avoid electrical shock.

4. All connections to the meter should be made as shown in the appropriate diagram herein. Connecting of accessories are covered in individual instruction leaflets. All connections should be made right-to-left to assure connection of the meter to the load circuit before the line potential is applied.

5. The terminal holes for current leads will accept No. 2 (0.292-inch diameter) standard wire. Use proper adapters for larger wire size.

CAUTION

Since the current terminals will only accept a maximum size No. 2 conductor, continuous load current from 150 to 200 amperes will require the use of a proper adapter or heat sinks not to exceed the maximum operating meter temperature, thereby presenting a fire hazard.

NOTE: For calibration, test and maintenance information, consult the appropriate meter instruction leaflet.

CAUTION

For safety — DO NOT insert apparatus into an energized socket of improper connections or voltage. DO NOT service the apparatus while energized. DO NOT energize the apparatus with the cover removed. Failure to follow these precautionary steps may lead to bodily injury and/or property damage.

[1] You will note that each metering scheme on the various pages indicates the type of meter and socket required.

[2] The diagram headings show "Most Economical" and "Conventional" metering schemes. The use of the "Most Economical" schemes result in no reduction in accuracy, however, it reduces the number of current transformers needed by one and permits the use of simpler, less expensive watthour meters. Use of either system depends on wire size, physical layout, and your utility practices.

[3] In general —

— Use self-contained single phase meters up to 48 KVA

— Use self-contained polyphase meters up to 96 KVA (except 480 volts delta)

— In all cases, do not exceed 200 amperes on class 200 meters

— Above these respective ratings, use transformer-rated meters.

[4] Current transformers should be selected so that the meter is approximately 80% loaded; allowing 20% additional capacity for further growth.

CAUTION: Never leave energized current transformer secondaries open. Open circuited current transformers secondaries may develop high voltages that are dangerous to personnel and equipment. Sockets having automatic short circuiting devices are recommended.

[5] Transformer-rated meters are class 20, except where noted and give straight line accuracy up to 20 amperes and are recommended for use with 5 ampere transformer secondaries. These class 20 meters are also recommended for class 10 applications.

[6] METHOD FOR DETERMINING THE PROPER SELECTION OF METERS AND INSTRUMENT TRANSFORMERS ALONG WITH SOCKETS ...

You should know the following information before making a selection:

Six Basic Questions	Available Selections		
1. Type MOUNTING desired.	A. Socket		
	a. 1-phase, 3-wire		
2. Type SERVICE to be metered.	b. 2-phase, 2-wire		
	c. 3-phase, 3-wire DELTA		
	d. 3-phase, 3-wire NETWORK		
	e. 3-phase, 3-wire URBAN NETWORK		
	f. 3-phase, 4-wire DELTA		
	g. 3-phase, 4-wire WYE (2-stator meter)		
	h. 3-phase, 4-wire WYE (3-stator meter)		
3. Meter TEST AMPS or CLASS required.	B. Maximum Current to be Metered	Meter TEST AMPS	Meter CLASS
NOTE: Meter CLASS is the maximum continuous amperage to meter coils.	a. 100 amperes	15	100
	b. 200 amperes	30	200
	c. Over 200 amperes	2.5	20
4. FREQUENCY AND VOLTAGE	C. Frequency — 50 or 60 Hertz		
	D. Voltage		
	a. 72 volts		
	b. 120 volts		
	c. 240 volts		
	d. 480 volts		
5. Type REGISTER desired.	E. Registers		
	a. Type		
NOTE: Current and Voltage transformer ratios must be obtained and included in the order entry.	(1) Clock Dial		
	(2) Drum Cyclometer		
	(3) Drum Odometer		
	b. Number of DIALS		
	(1) 5		
	(2) 4		
6. Type COVER desired.	F. Covers		
	a. Glass (single-phase and network polyphase only)		
	b. Polycarbonate (plastic)		

After arriving at this information, turn to the following pages which show diagrams for self-contained meters:

Single phase ... page 7
Network ... page 12
3-phase, 3-wire ... page 15
3-phase, 4-wire Delta ... page 20
3-phase, 4-wire Wye ... page 26

If load exceeds the capacity of the self-contained meter, the following pages should be used, which incorporate the use of instrument transformers:

Single phase ... page 9
Network ... page 13
3-phase, 3-wire ... page 16
3-phase, 4-wire Delta ... page 22
3-phase, 4-wire Wye ... page 30

CAUTION: Use instrument transformers when voltage exceeds the limits of secondary metering (480 volts). For maximum safety, instrument transformers are recommended above 240 volts.

PRODUCT BULLETINS

600 VOLT CURRENT TRANSFORMERS

Primary Current	Type	Product Bulletin
50 thru 1000	**IMC**	42-810
200 thru 800	**CBT**	42-811
200 thru 400	**CBH**	42-812
200 thru 600	**CSF**	42-813
200 thru 800	**CSH**	42-814
200 and 300	**CMS**	42-815
100 thru 1200	**CMF**	42-818
200 thru 4000	**CMV**	42-820
600 thru 4000	**CLC**	42-824
1000 thru 6000	**CLE**	42-826
600 thru 4000	**RLC**	42-828
Multi-Ratio	**Auxiliary**	42-850
Multi-Ratio	**A-Auto**	42-852
600 thru 3000	**Ext. BCT**	42-858

600 VOLT VOLTAGE TRANSFORMERS

Primary Voltage	Type	Product Bulletin
240 thru 600	**PPW**	42-871
240 thru 600	**PPM**	42-873
60 thru 480	**PPX**	42-873

5KV-34.5V CURRENT TRANSFORMERS

Class	Type	Product Bulletin
15 Kv Indoor	**KIR-11**	42-914
5-8.7 Kv Outdoor	**KOR-60/75**	42-920
15 Kv Outdoor	**KOR-11**	42-922
15 Kv Outdoor	**KOR-11**	42-949
25 Kv Outdoor	**KOR-15**	42-926
34.5 Kv Outdoor	**KOR-15B**	42-926A
34.5 Kv Outdoor	**KOR-20**	42-928
5-25 Kv Outdoor	**KOT**	42-930
15-34.5 Kv Outdoor	**KOTD**	42-940

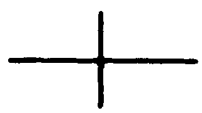
5KV-34.5KV VOLTAGE TRANSFORMERS

Class	Type	Product Bulletin
5 Kv Indoor	**VIY-60**	42-951
8.7-15 Kv Indoor	**VIZ-75/11**	42-955
25 Kv Indoor	**VIZ/VIY-12G**	42-976
5 Kv Outdoor	**VOY-60**	42-961
8.7-15 Kv Outdoor	**VOZ-75/11**	42-963
15 Kv Outdoor	**VOY-11**	42-964
15 Kv Outdoor	**VOG-11**	42-965
25 Kv Outdoor	**VOZ-15**	42-971
	VOY-12	42-966
	VOG-12	42-967
	VOY-15/15G	42-970
	VOZZ-15/15G	42-978
34.5 Kv Outdoor	**VOZ-20**	42-975
	VOY-20/20G	42-974
	VOHD200/200G	42-977
	VOZZ-20/20G	42-979
25 Kv Outdoor	**VIZ/VIY-12G**	42-976

GLOSSARY OF SYMBOLS

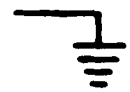
VT	Voltage Transformer(s)
CT	Current Transformer(s)
2-Wire CT	Single Primary-Single Secondary CT
C	Current
P	Potential
G	Ground
N	Neutral

NO CONNECTION

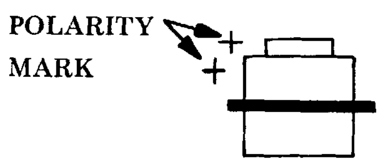


SOLID CONNECTION

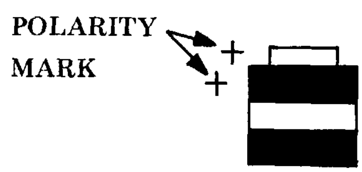
GROUND



BAR OR WOUND PRIMARY TYPE CT

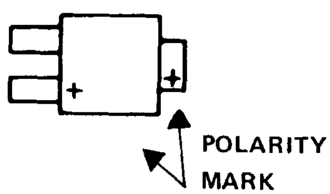


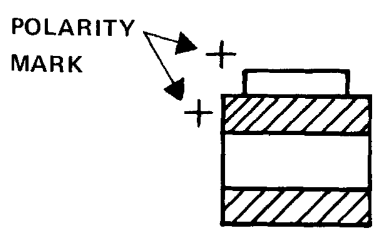
WINDOW OR THROUGH TYPE CT



Effective Ratio Same As Nameplate

VOLTAGE TRANSFORMER

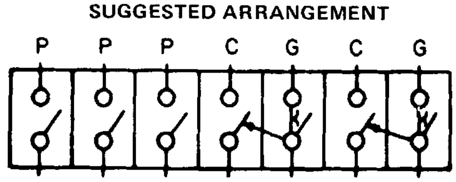




Effective Ratio Not Same As Nameplate

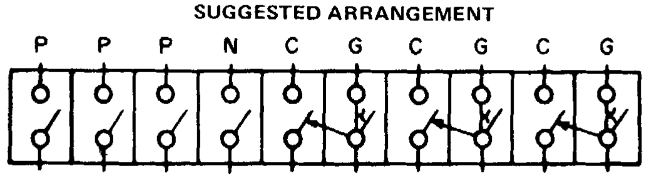
SEVEN POLE TEST BLOCK

SUGGESTED ARRANGEMENT



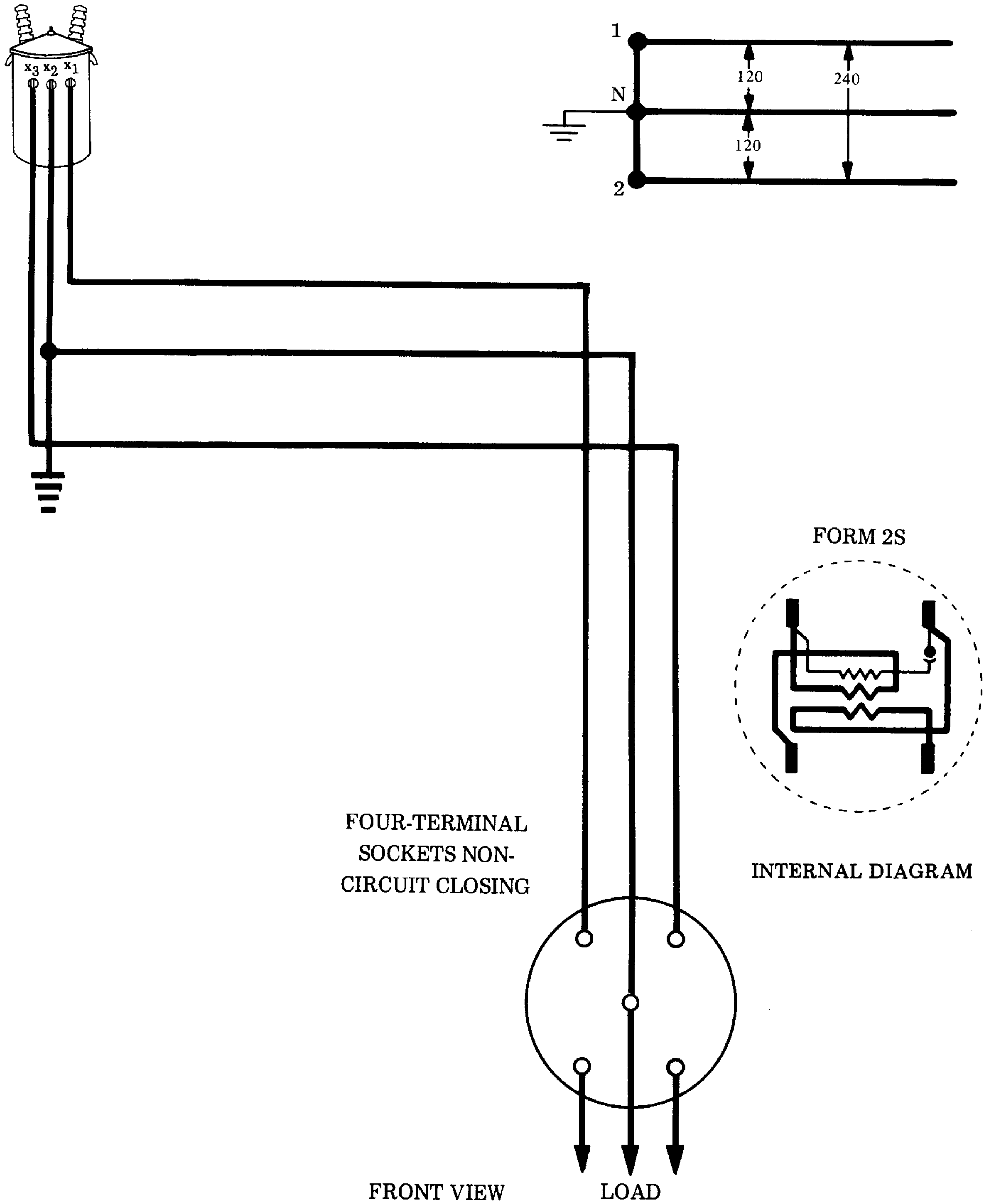
TEN POLE TEST BLOCK

SUGGESTED ARRANGEMENT



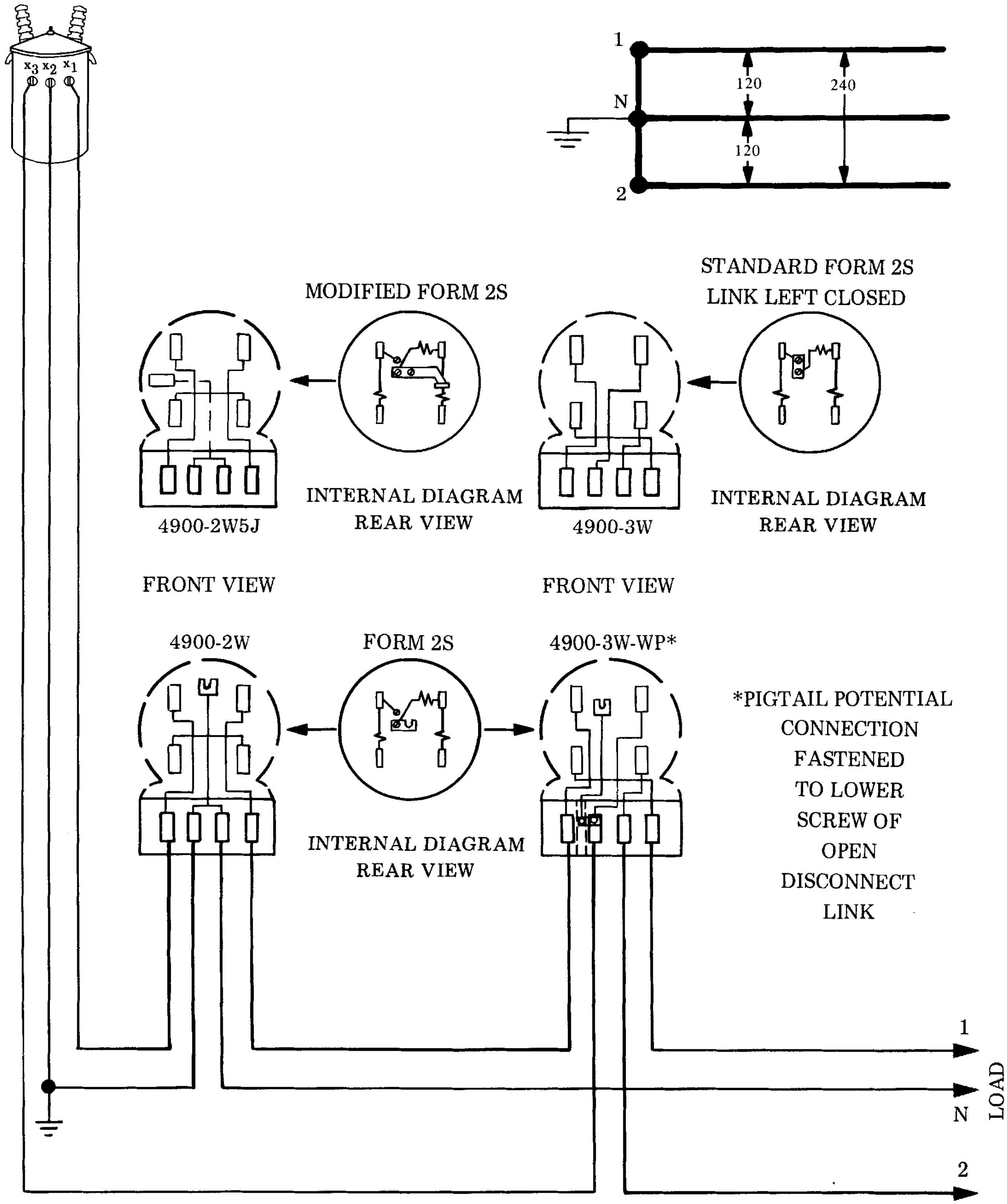
Measurement of energy from a grounded neutral — 120/240 volt single-phase, three-wire supply.
3-wire service

SINGLE-PHASE, TWO- AND THREE-WIRE



SINGLE-PHASE, TWO- AND THREE-WIRE

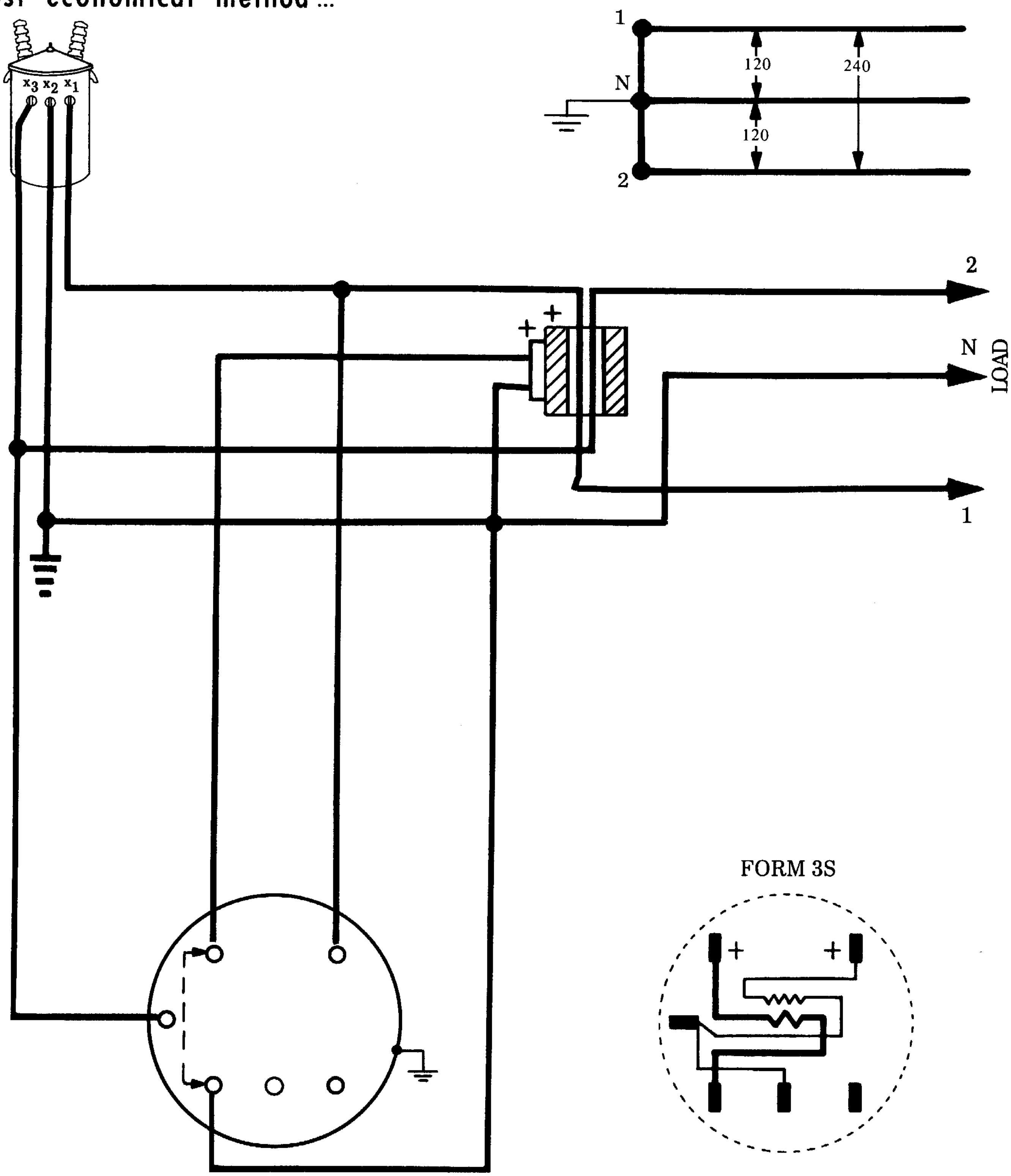
Measurement of energy from a grounded neutral 120/240 volt single-phase, two-wire or three-wire supply. Alternate configurations for using A-to-S adapter packages with a three-wire socket type meter for measurement of two-wire and three-wire services in A-base wired installations.



SINGLE-PHASE, THREE WIRE, WITH ONE WINDOW-TYPE CT

Measurement of energy on a single-phase, three-wire circuit
with 1 CT and a two-wire, single-phase meter.

most economical method ...



5-TERMINAL CIRCUIT CLOSING SOCKET
FRONT VIEW

FORM 3S

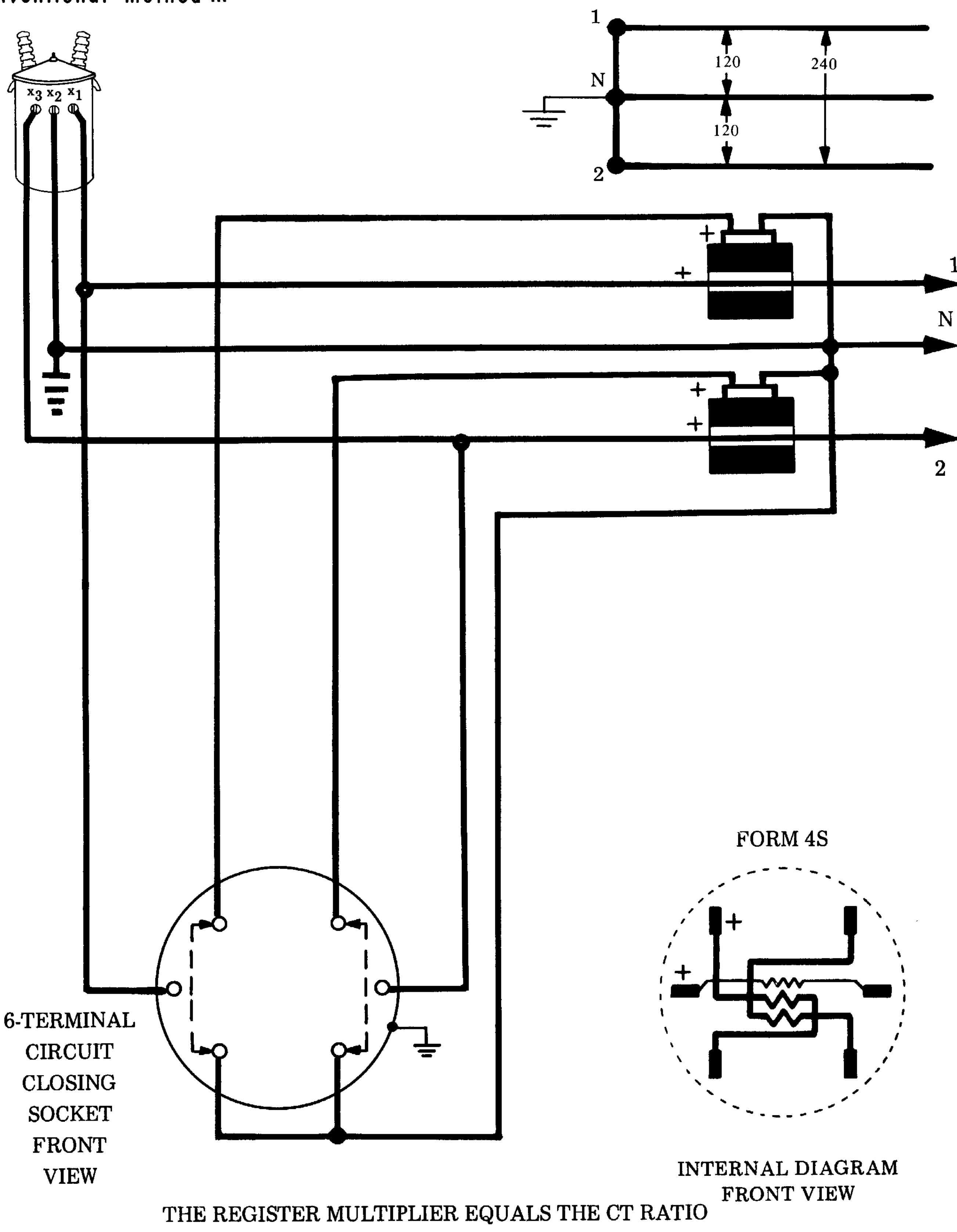
INTERNAL DIAGRAM
FRONT VIEW

THE REGISTER MULTIPLIER EQUALS 1/2 TIMES CT RATIO
FOR SECONDARY-RATED METERS

SINGLE-PHASE, THREE WIRE, WITH TWO WINDOW-TYPE CT'S

Measurement of energy on a single-phase, three-wire service with 2 CT's and a three-wire, single-phase meter.

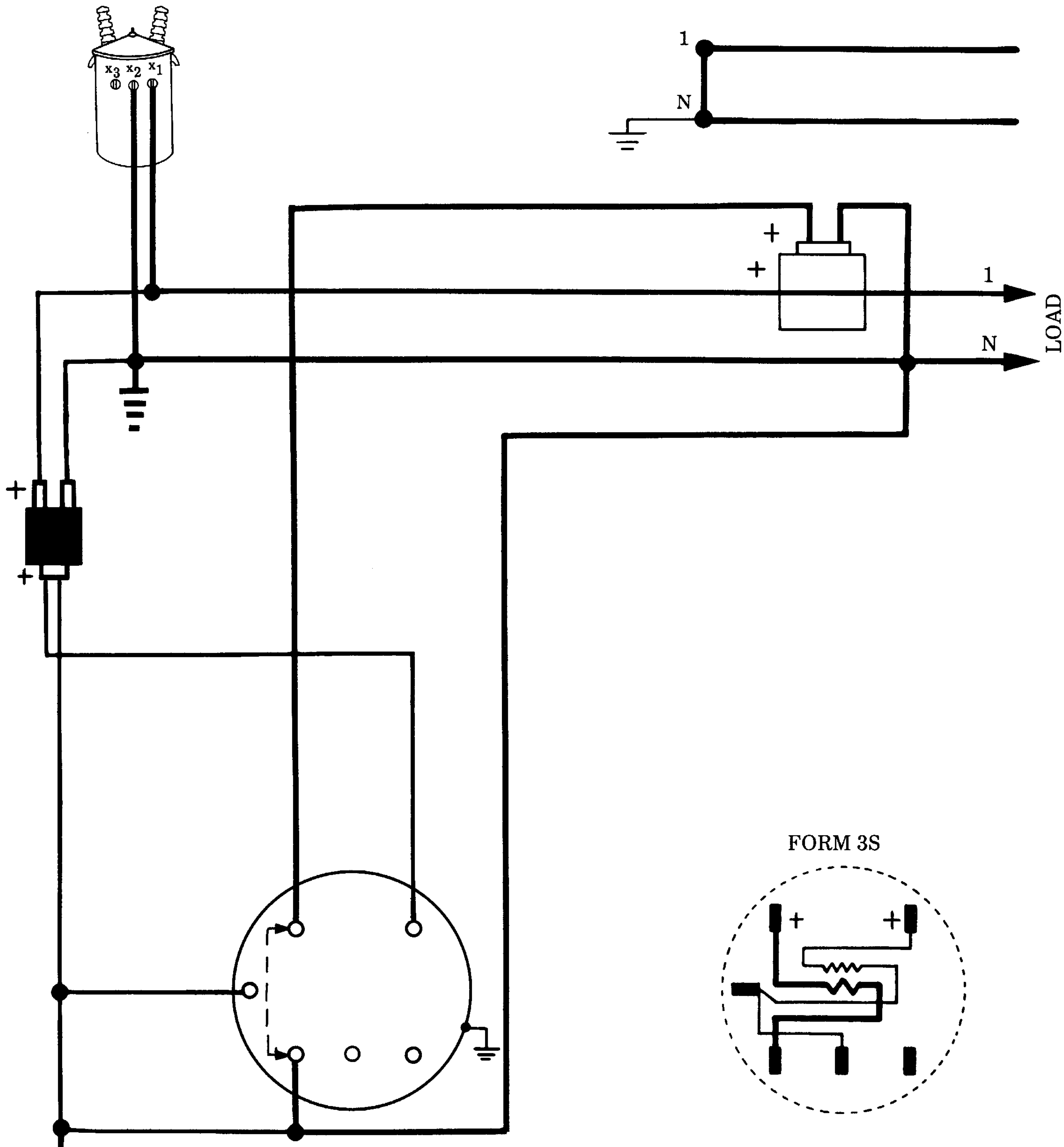
conventional method ...



THE REGISTER MULTIPLIER EQUALS THE CT RATIO FOR SECONDARY-RATED METERS

SINGLE-PHASE, TWO-WIRE WITH CT AND VT

Measurement of energy on a single-phase, two-wire service with 1 CT, 1 VT, and a two-wire, single-phase transformer-type meter.



5-TERMINAL CIRCUIT CLOSING SOCKET
FRONT VIEW

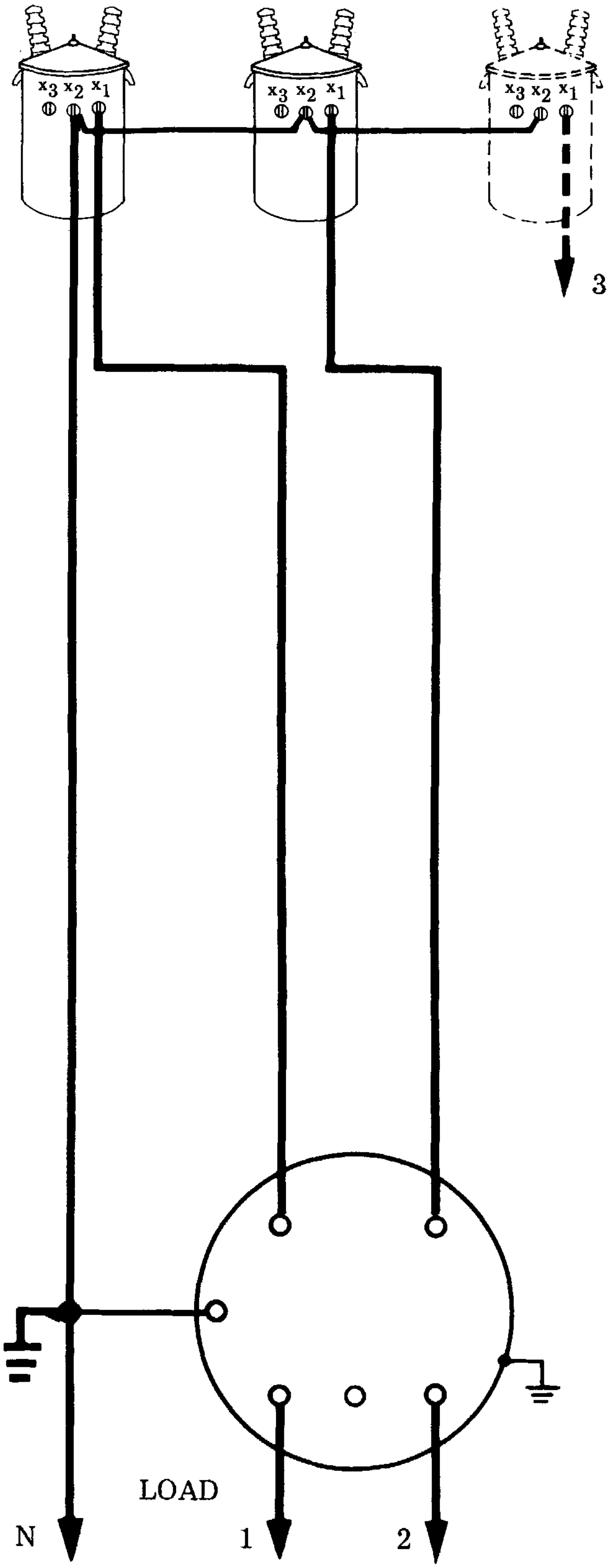
FORM 3S

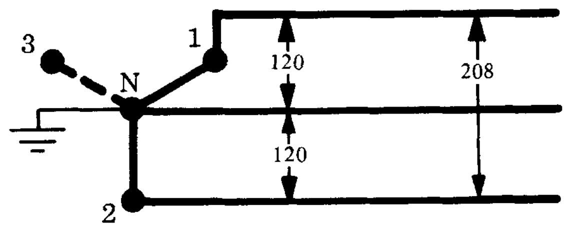
INTERNAL DIAGRAM
FRONT VIEW

THE REGISTER MULTIPLIER EQUALS THE PRODUCT OF THE CT AND VT RATIOS FOR SECONDARY-RATED METERS

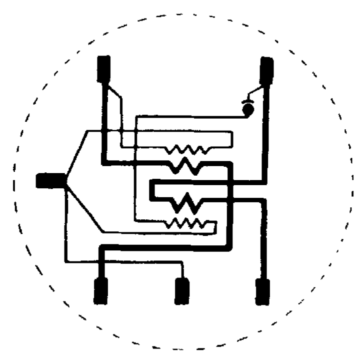
NETWORK, THREE-WIRE

Measurement of energy on a network, three-wire, 120/208-volt service with a 2-stator meter.





FORM 12S

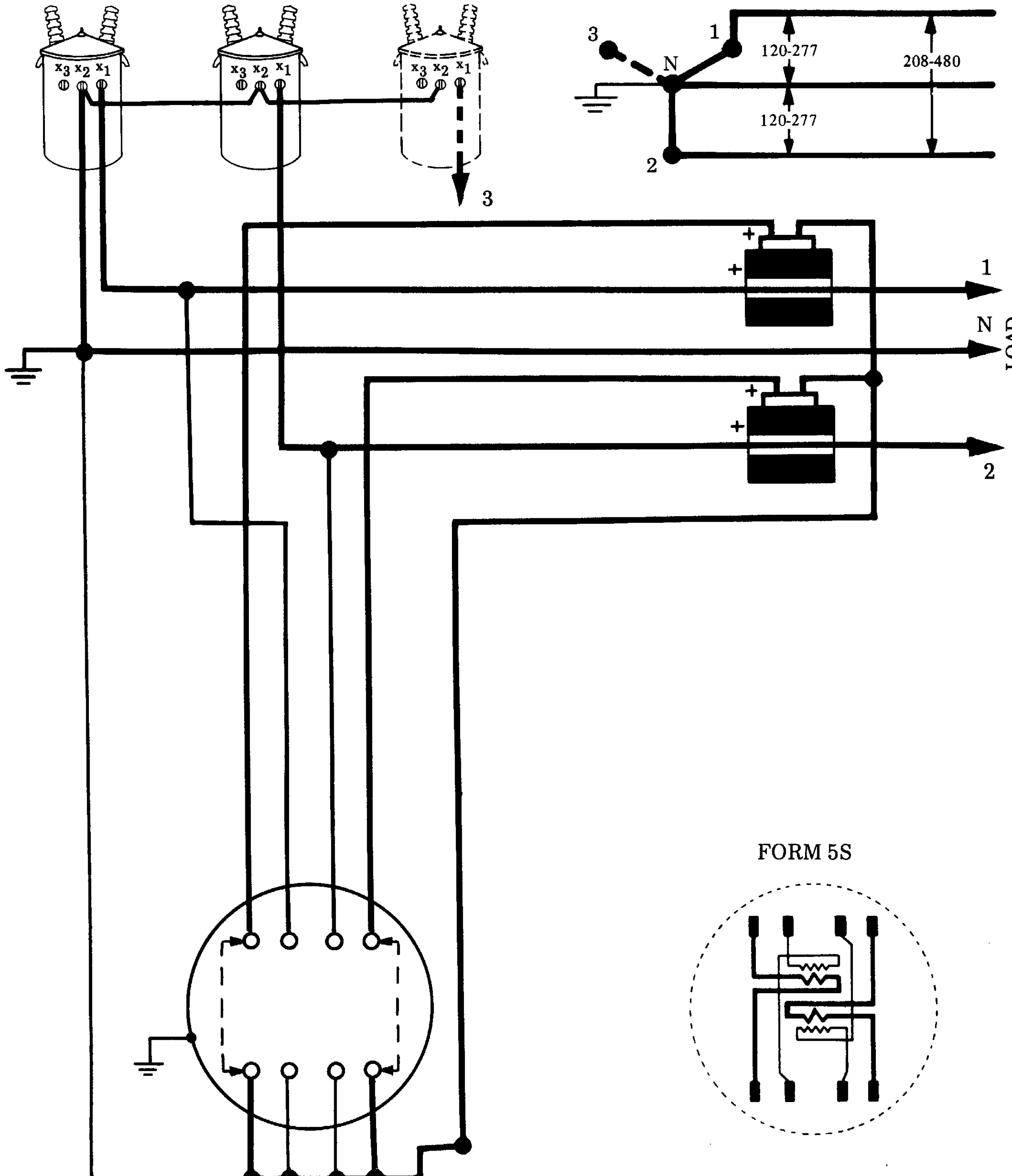


INTERNAL DIAGRAM
FRONT VIEW

5-TERMINAL NON-CIRCUIT CLOSING SOCKET
FRONT VIEW

Measurement of energy on a network, three-wire service,
120/208-volt and 277/480-volt with
2 CT's and a 2-stator meter.

NETWORK, THREE-WIRE



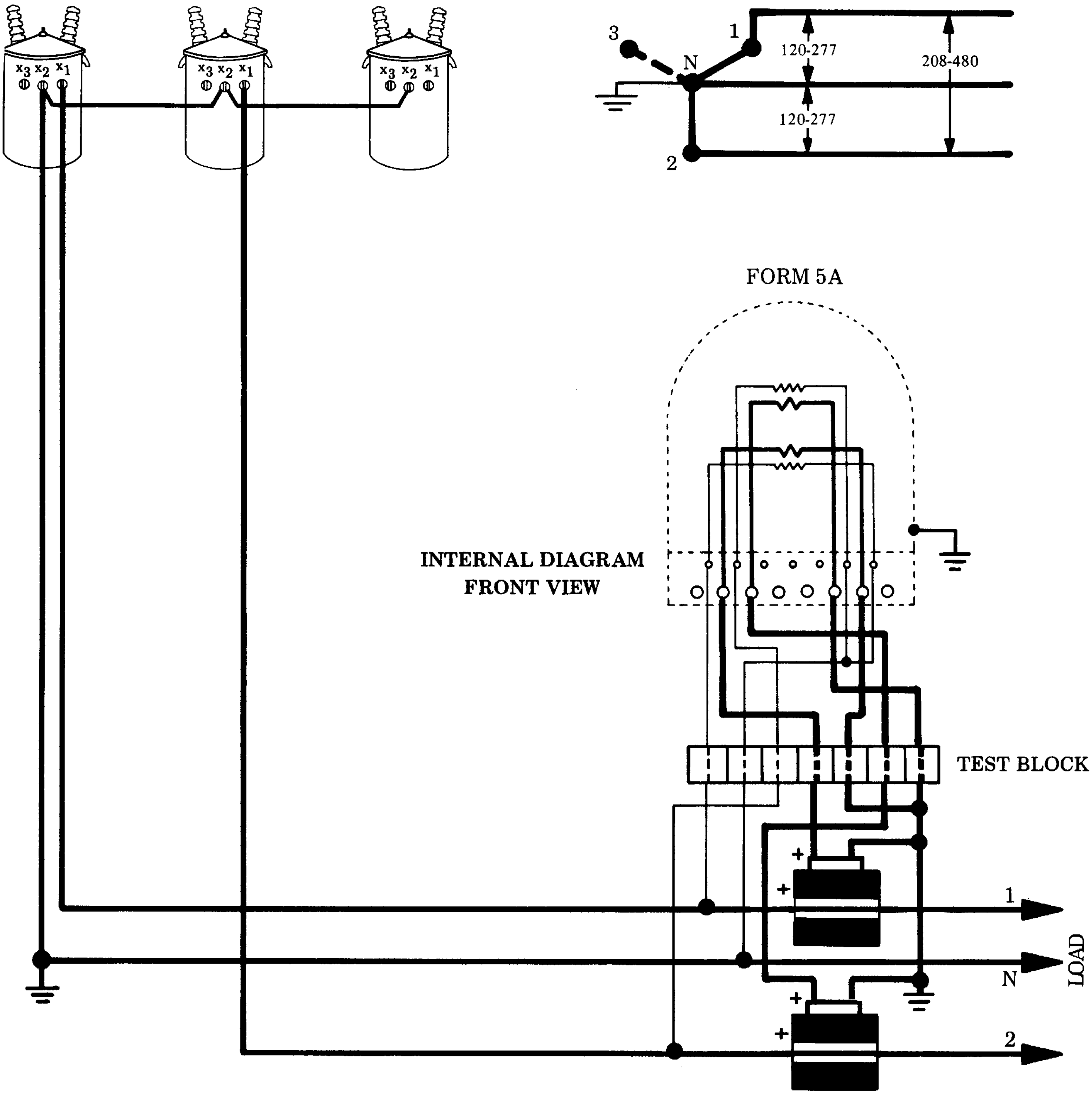
8-TERMINAL CIRCUIT CLOSING SOCKET
FRONT VIEW

INTERNAL DIAGRAM
FRONT VIEW

THE REGISTER MULTIPLIER EQUALS THE CT RATIO
FOR SECONDARY-RATED METERS

NETWORK, THREE-WIRE WITH TWO WINDOW-TYPE CT'S

Measurement of energy on a network, three-wire service, 120/208-volt and 277/480-volt with 2 CT's and a 2-stator meter.

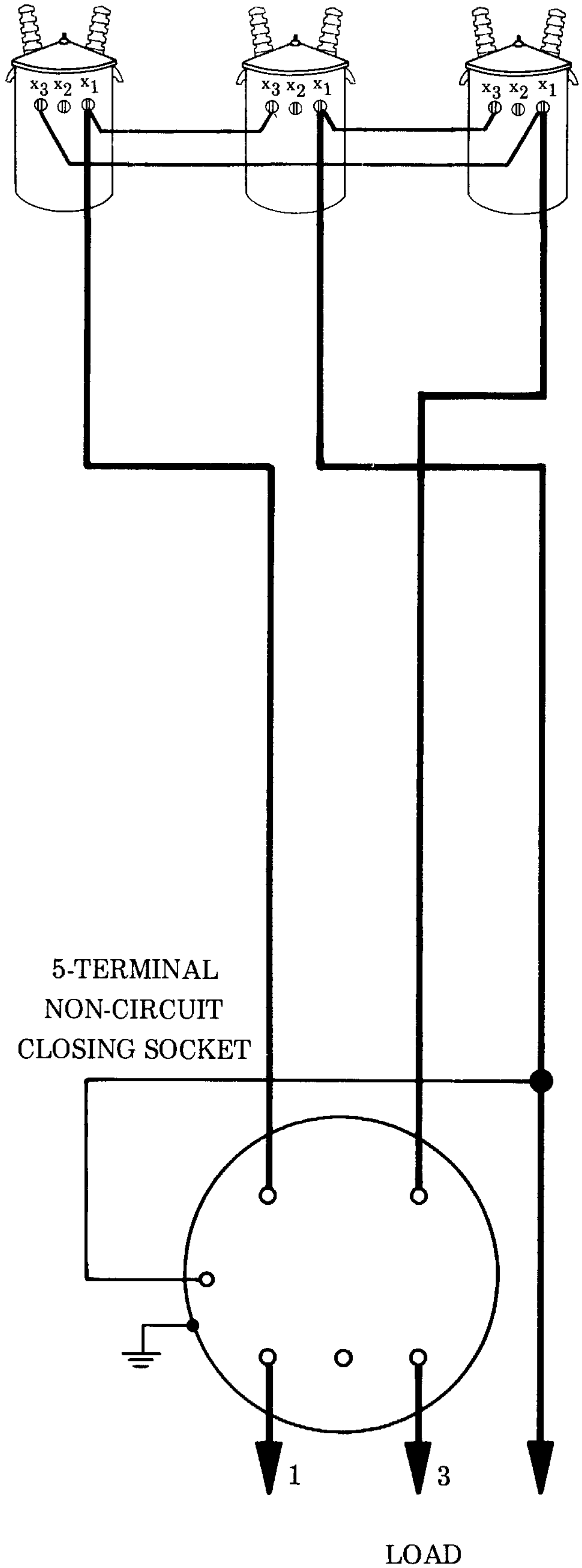


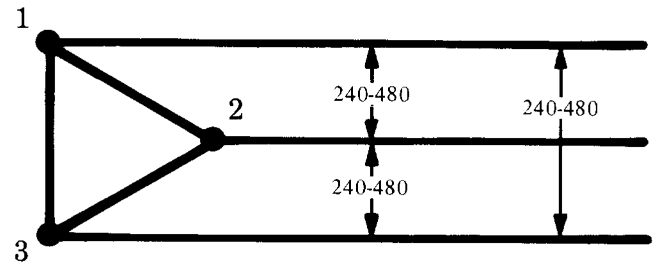
THE REGISTER MULTIPLIER EQUALS THE CT RATIO FOR SECONDARY-RATED METERS

Measurement of energy on a three-phase, three-wire Delta service with a 2-stator meter.

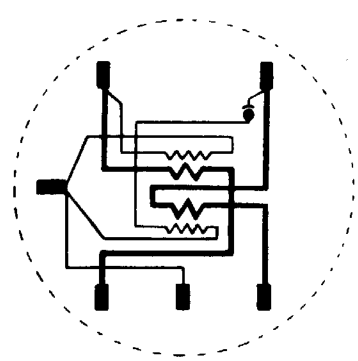
THREE-PHASE, THREE-WIRE DELTA

most economical method...





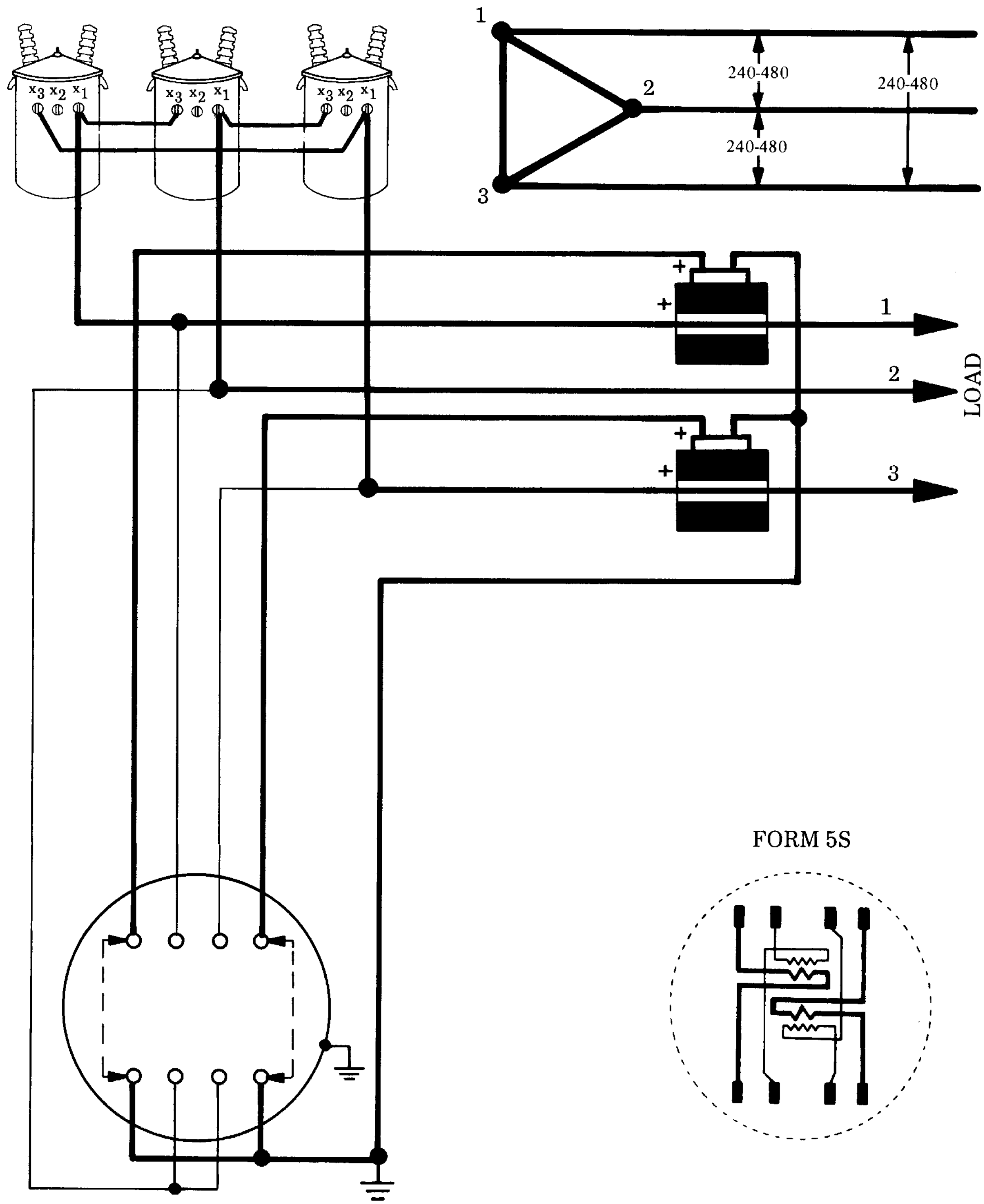
FORM 12S



INTERNAL DIAGRAM
FRONT VIEW

THREE-PHASE, THREE-WIRE DELTA

Measurement of energy on a three-phase, three-wire Delta service with 2 CT's and a 2-stator meter.



8-TERMINAL CIRCUIT CLOSING SOCKET, FRONT VIEW

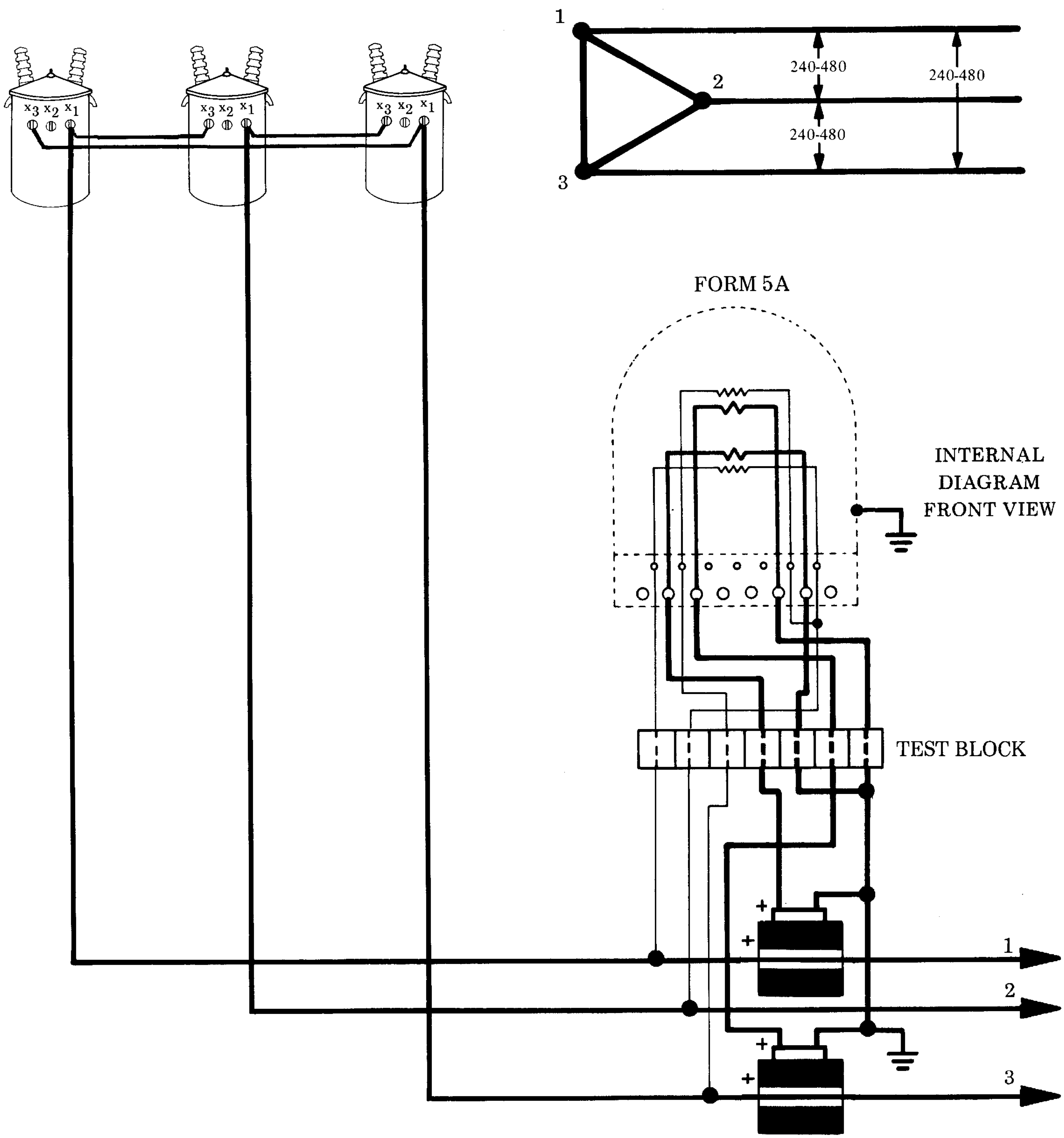
FORM 5S

INTERNAL DIAGRAM FRONT VIEW

THE REGISTER MULTIPLIER EQUALS CT RATIO FOR SECONDARY-RATED METERS

THREE-PHASE, THREE-WIRE DELTA WITH TWO WINDOW-TYPE CT'S

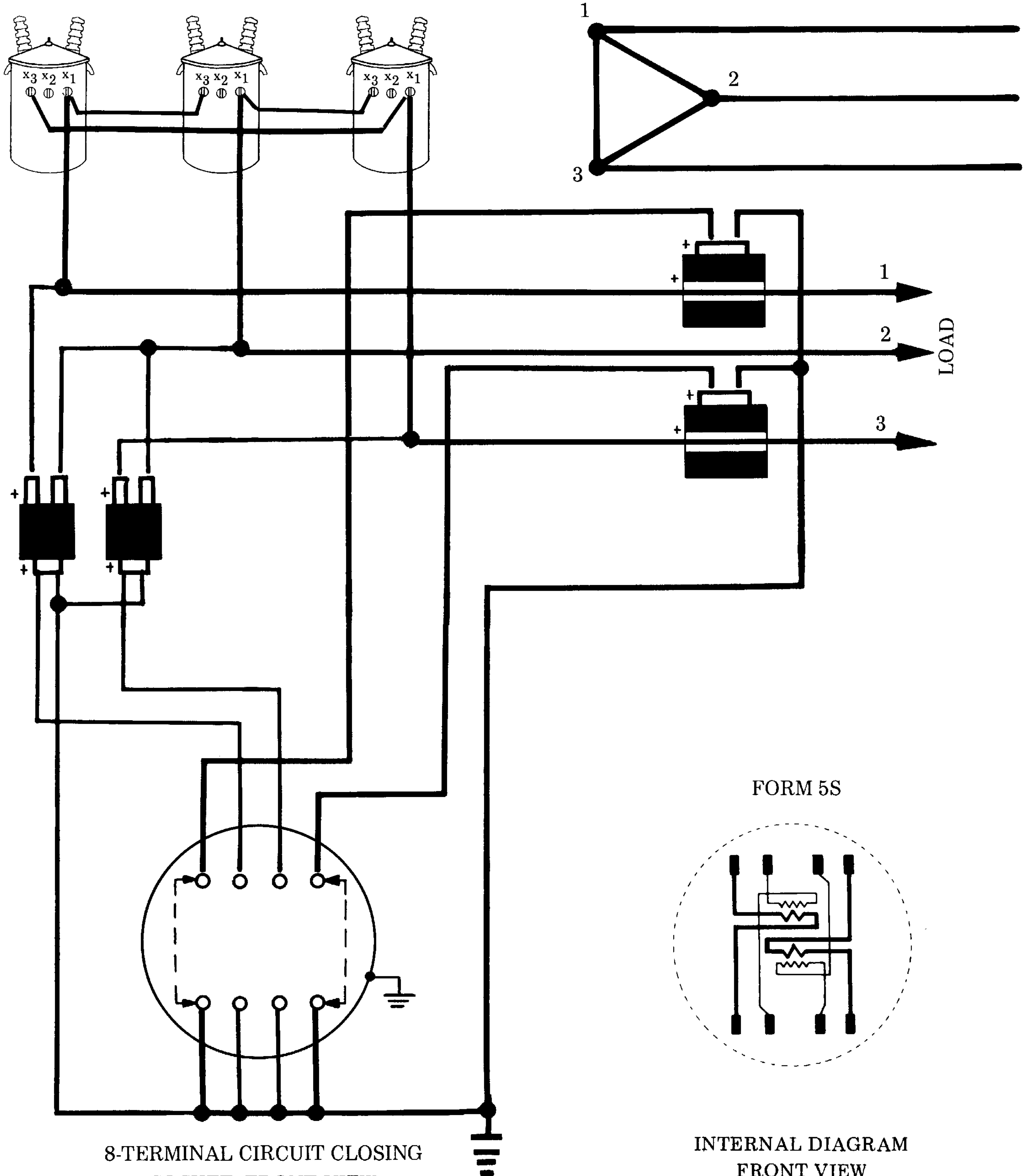
Measurement of energy on a three-phase, three-wire Delta service with 2 CT's and a 2-stator meter.



THE REGISTER MULTIPLIER EQUALS THE CT RATIO FOR SECONDARY-RATED METERS

THREE-PHASE, THREE-WIRE DELTA

Measurement of energy on a three-phase, three-wire Delta service with 2 CT's, 2VT's, and a 2-stator meter.



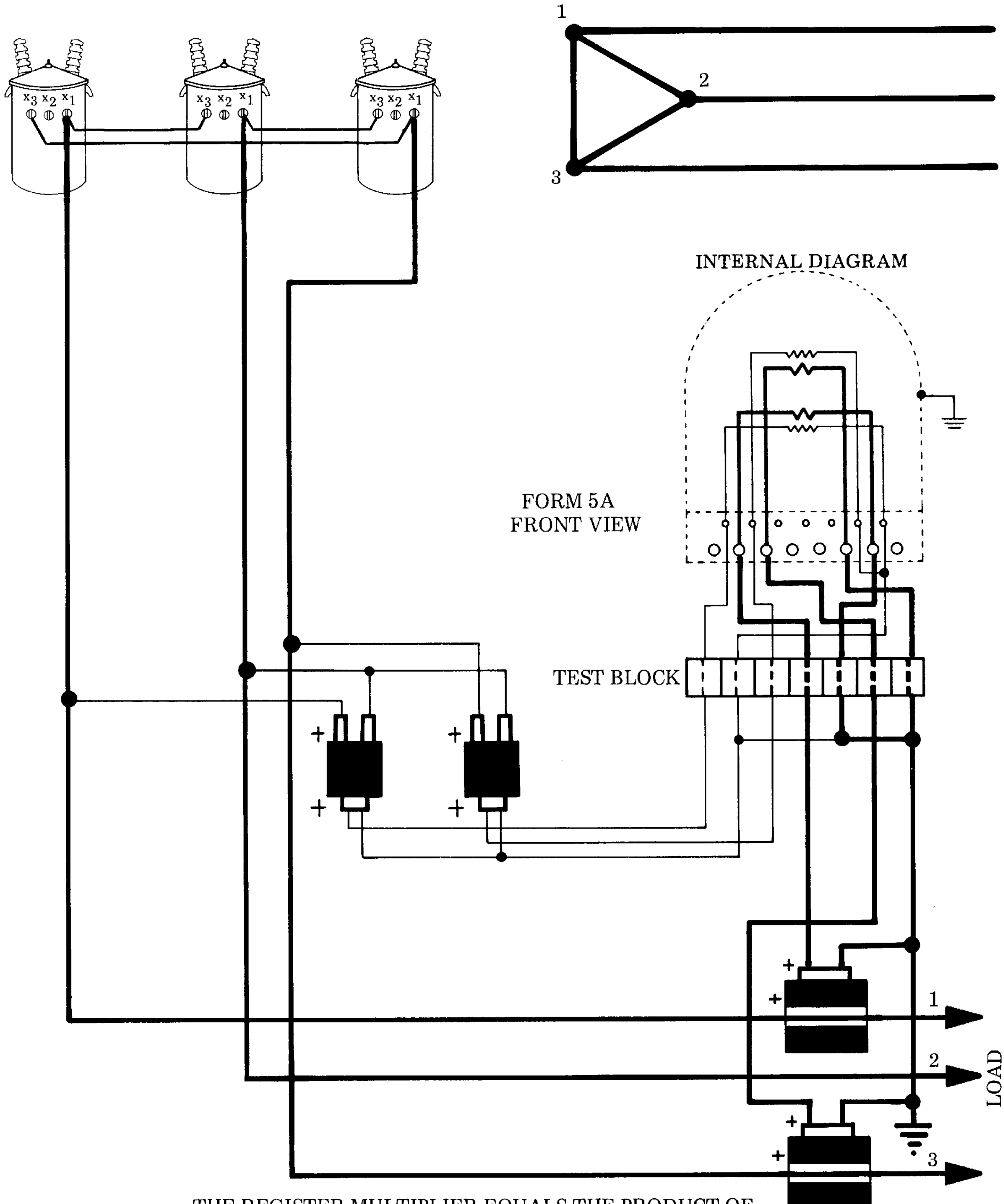
8-TERMINAL CIRCUIT CLOSING SOCKET, FRONT VIEW

INTERNAL DIAGRAM FRONT VIEW

THE REGISTER MULTIPLIER EQUALS THE PRODUCT OF THE CT AND VT RATIO FOR SECONDARY-RATED METERS

THREE-PHASE, THREE-WIRE DELTA WITH CT'S AND VT'S

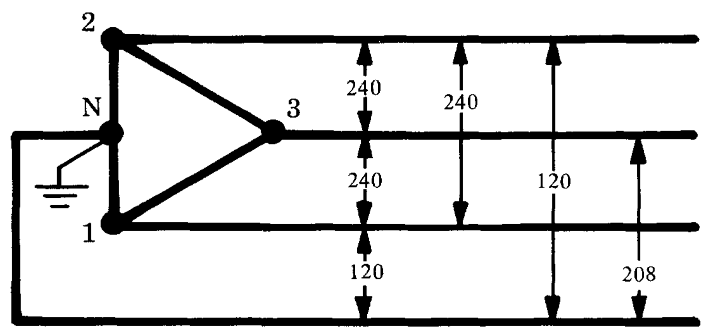
Measurement of energy on a three-phase, three-wire Delta service with 2 CT's, 2 VT's, and a 2-stator meter.

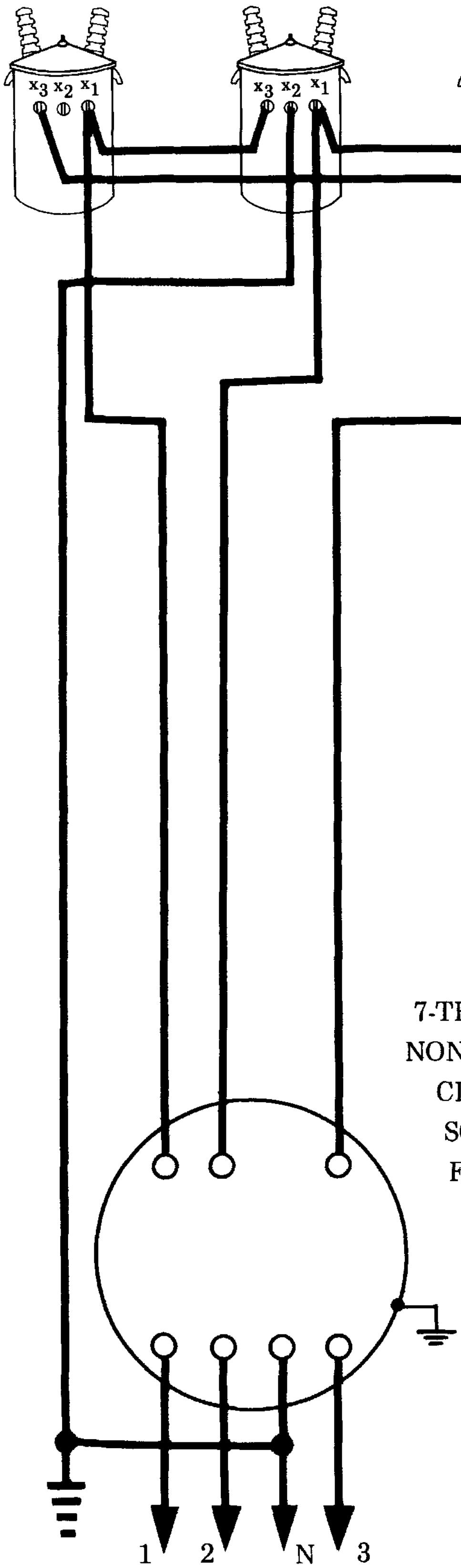


THE REGISTER MULTIPLIER EQUALS THE PRODUCT OF CT AND VT RATIOS FOR SECONDARY-RATED METERS

THREE-PHASE, FOUR-WIRE DELTA

Measurement of energy on a three-phase, four-wire Delta service with a 2-stator meter.

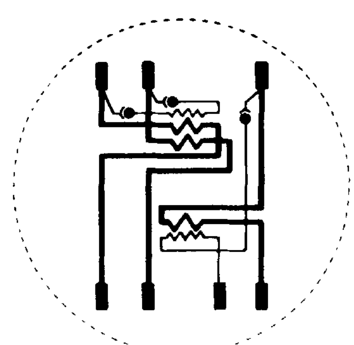




LOAD

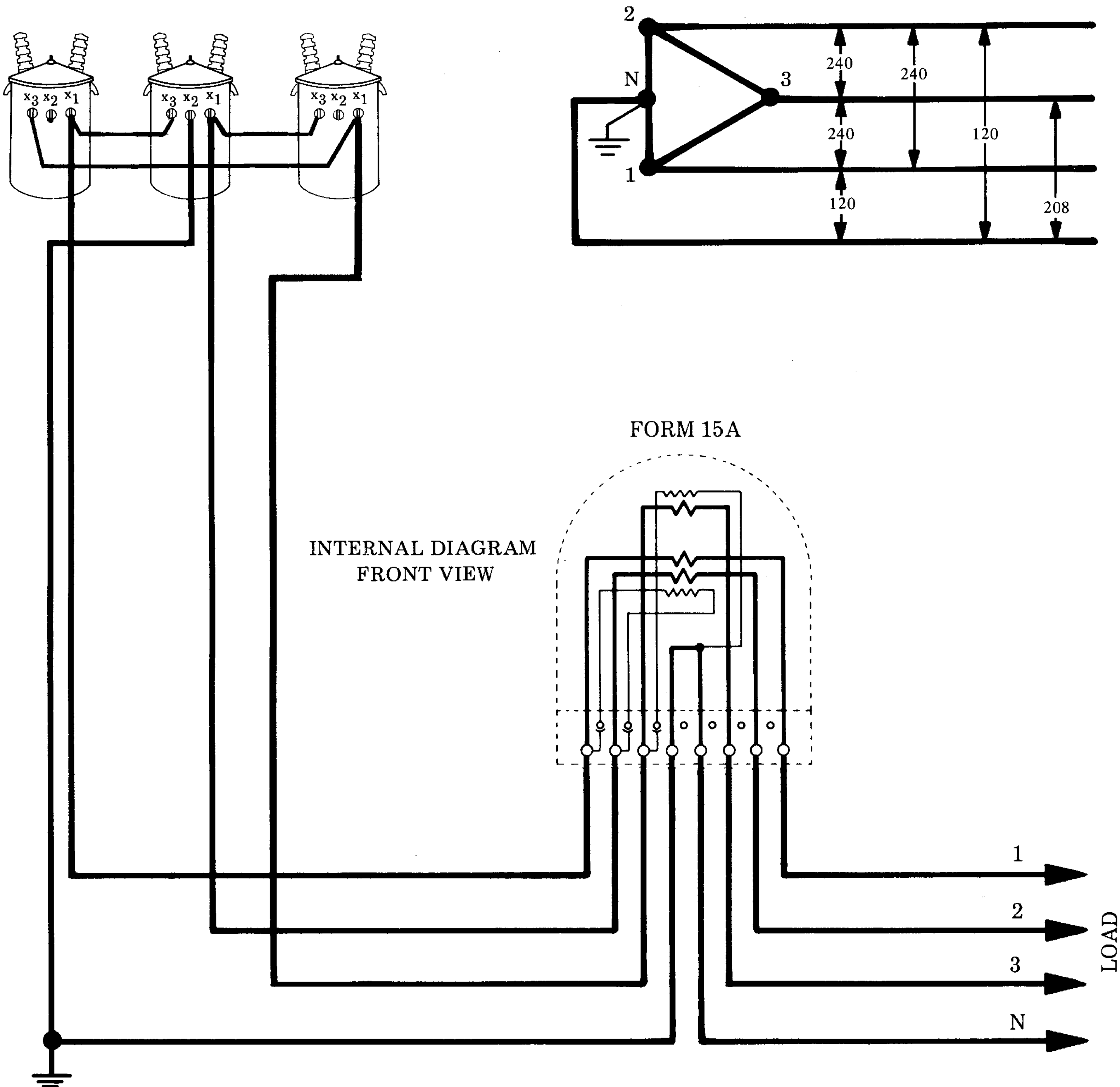
7-TERMINAL
NON-CIRCUIT
CLOSING
SOCKET
FRONT
VIEW

FORM 15S



INTERNAL DIAGRAM
FRONT VIEW

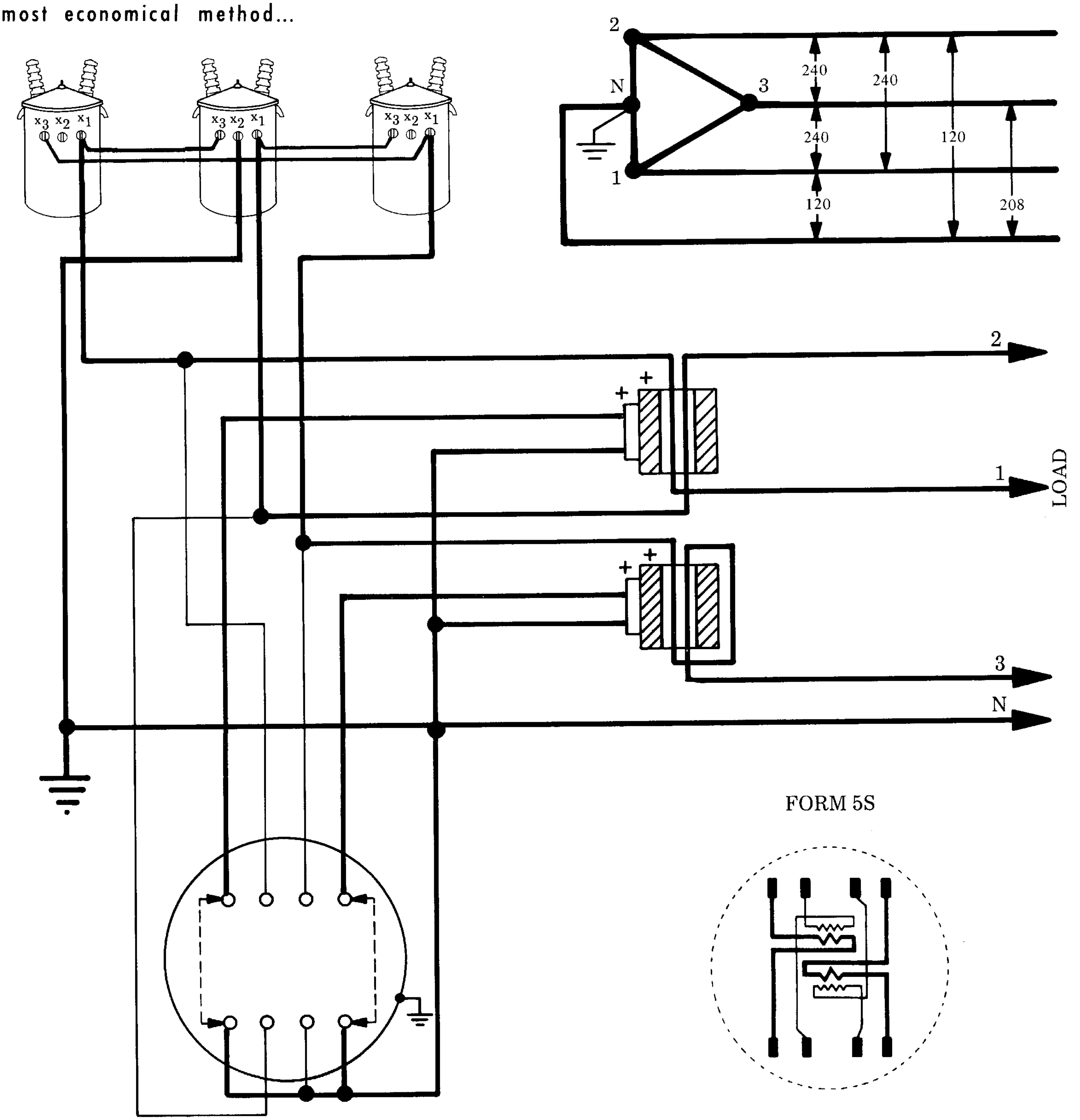
Measurement of energy on a three-phase, four-wire Delta service with a 2-stator meter.



THREE-PHASE, FOUR-WIRE DELTA

Measurement of energy on a three-phase, four-wire Delta service with two matched ratio CT's and a 2-stator meter.

most economical method...



8-TERMINAL CIRCUIT CLOSING SOCKET, FRONT VIEW

INTERNAL DIAGRAM FRONT VIEW

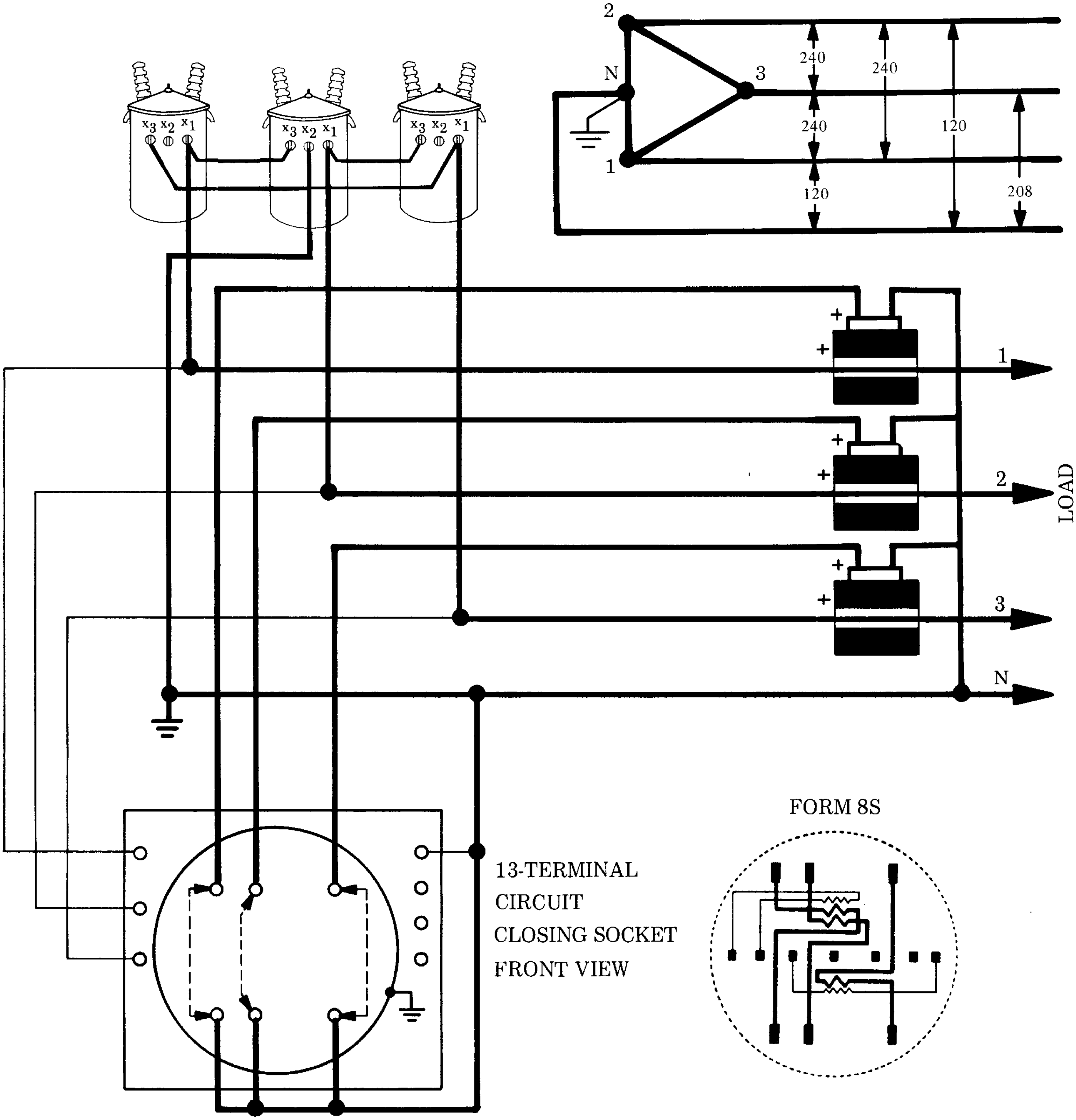
THE REGISTER MULTIPLIER EQUALS 1/2 CT RATIO FOR SECONDARY-RATED METERS

Measurement of energy on a three-phase, four-wire Delta service with 3 CT's and a 2-stator meter.

Should be considered where wire size is too large to be used in "Most Economical Method."

THREE-PHASE, FOUR-WIRE DELTA

conventional method...



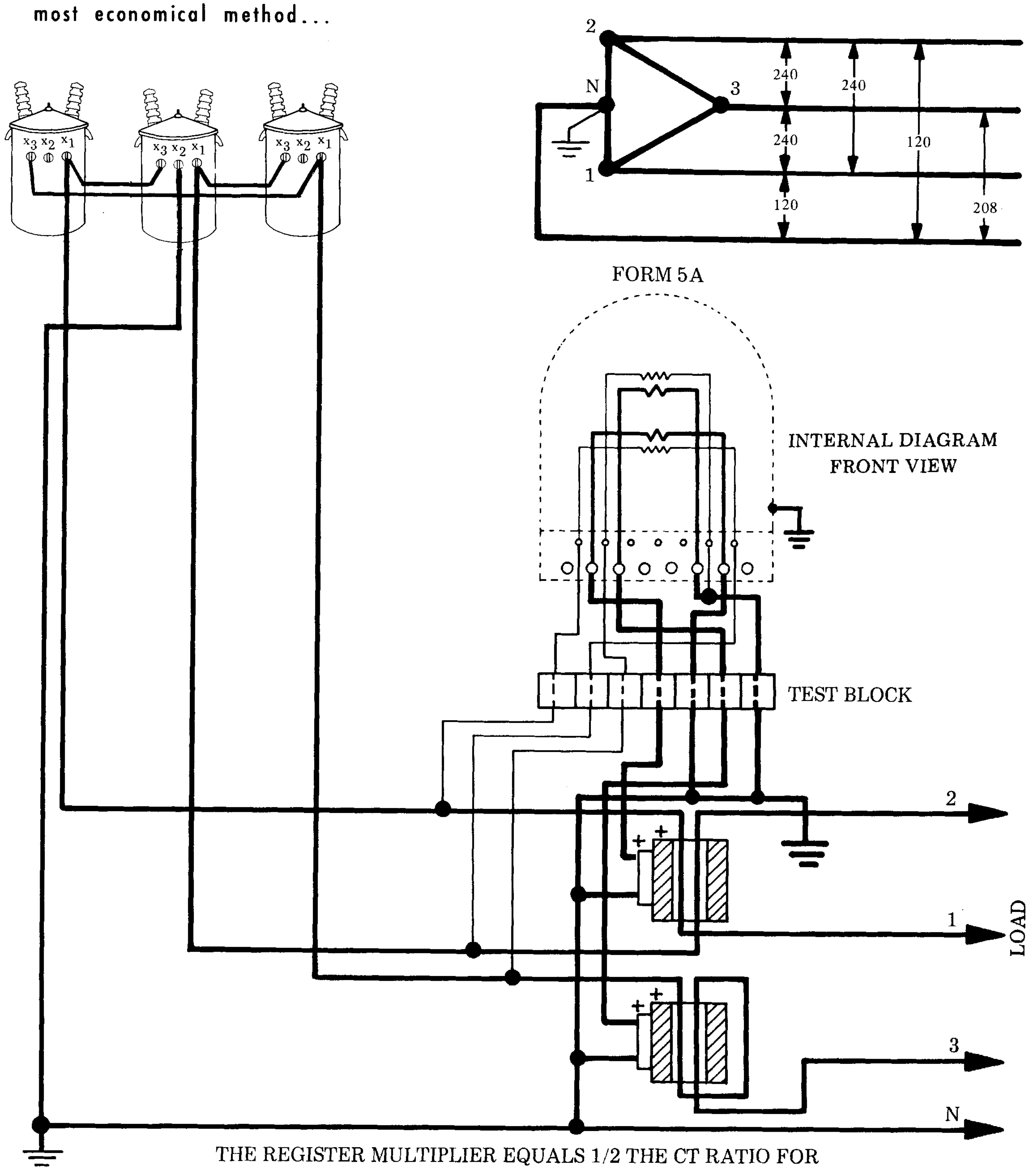
INTERNAL DIAGRAM
FRONT VIEW

THE REGISTER MULTIPLIER EQUALS THE CT RATIO
FOR SECONDARY-RATED METERS

THREE-PHASE, FOUR-WIRE DELTA WITH TWO MATCHED RATIO WINDOW-TYPE CT'S

Measurement of energy on a three-phase, four-wire Delta service with two matched ratio CT's and a 2-stator meter.

most economical method...

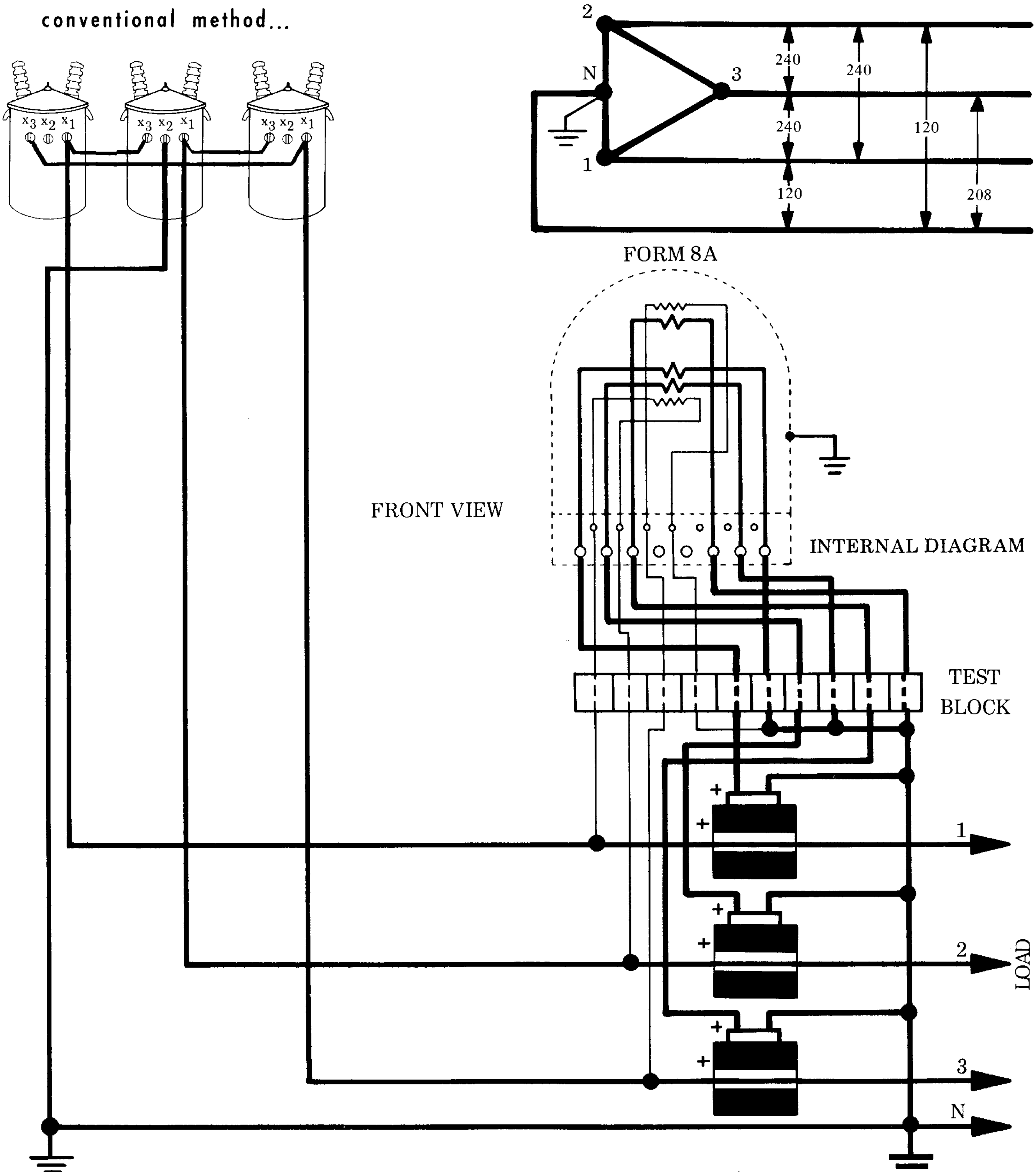


THE REGISTER MULTIPLIER EQUALS 1/2 THE CT RATIO FOR MATCHED TRANSFORMERS AND SECONDARY-RATED METERS

Measurement of energy on a three-phase, four-wire Delta service with 3 CT's and a 2-stator meter.

Should be considered where wire size is too large to be used in "Most Economical Method."

FOUR-WIRE DELTA WITH THREE WINDOW-TYPE CT'S

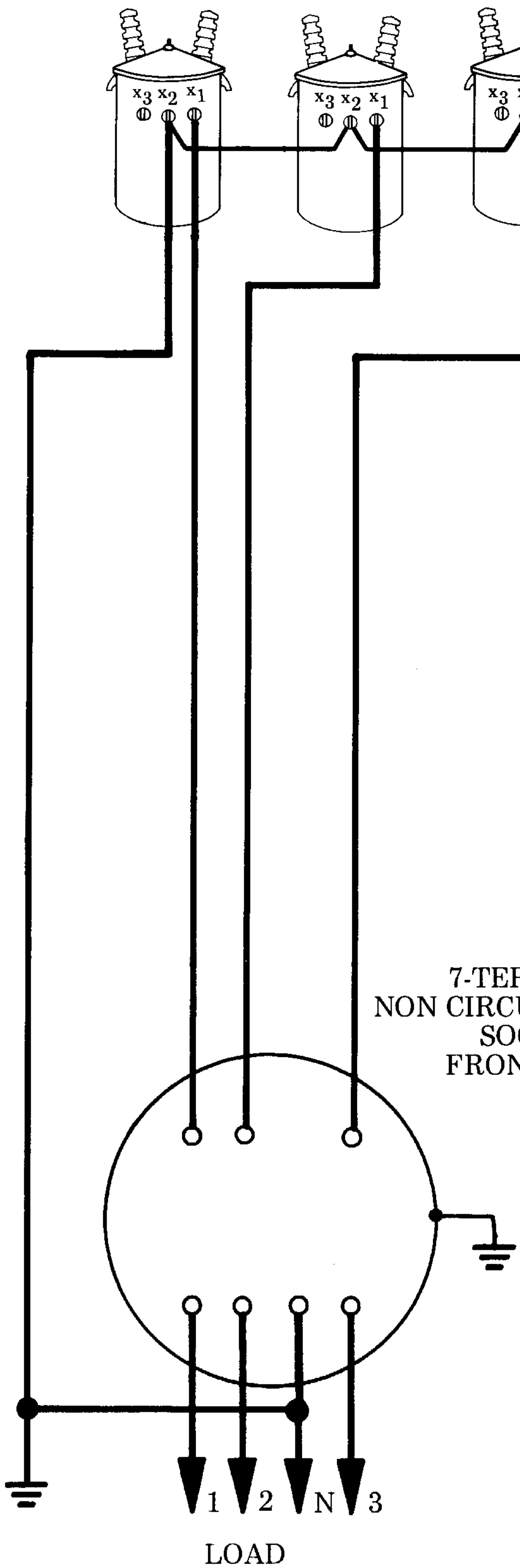


THE REGISTER MULTIPLIER EQUALS THE CT RATIO FOR SECONDARY-RATED METERS

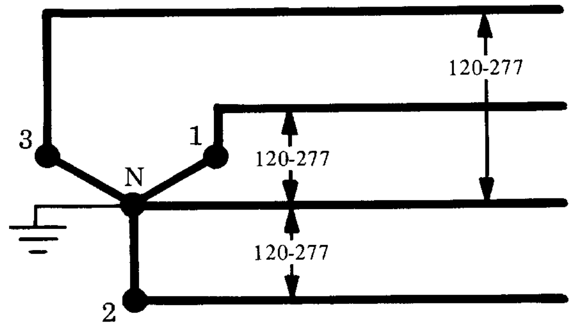
THREE-PHASE, FOUR-WIRE WYE

Measurement of energy on a three-phase, four-wire Wye service with a 2-1/2-stator meter.

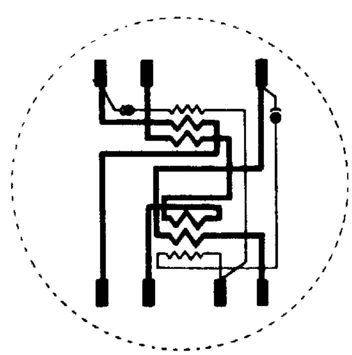
most economical method...



7-TERMINAL
NON CIRCUIT CLOSING
SOCKET
FRONT VIEW



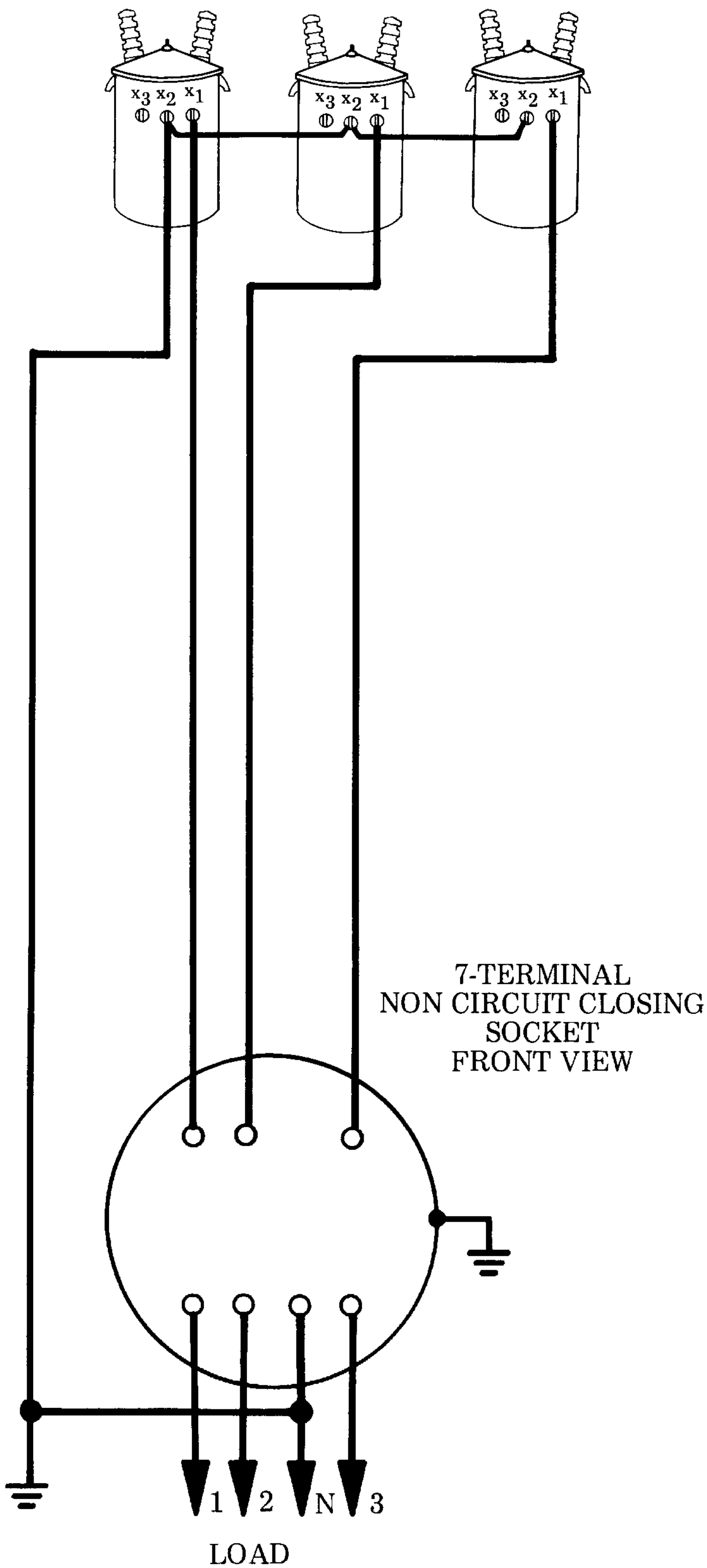
FORM 14S

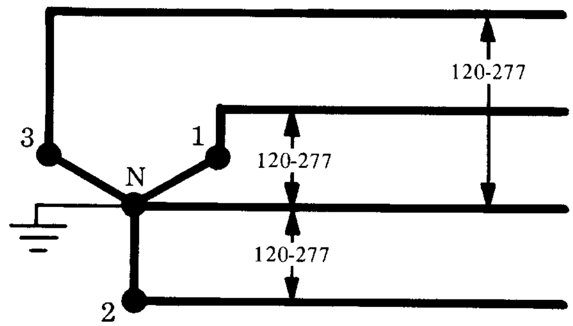


INTERNAL DIAGRAM
FRONT VIEW

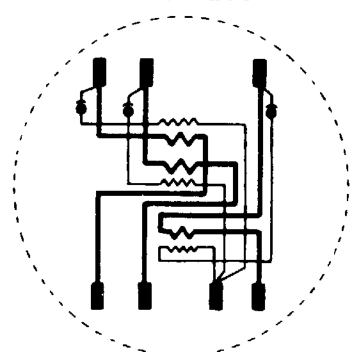
Measurement of energy on a three-phase, four-wire Wye service with a 3-stator meter.

conventional method...





FORM 16S

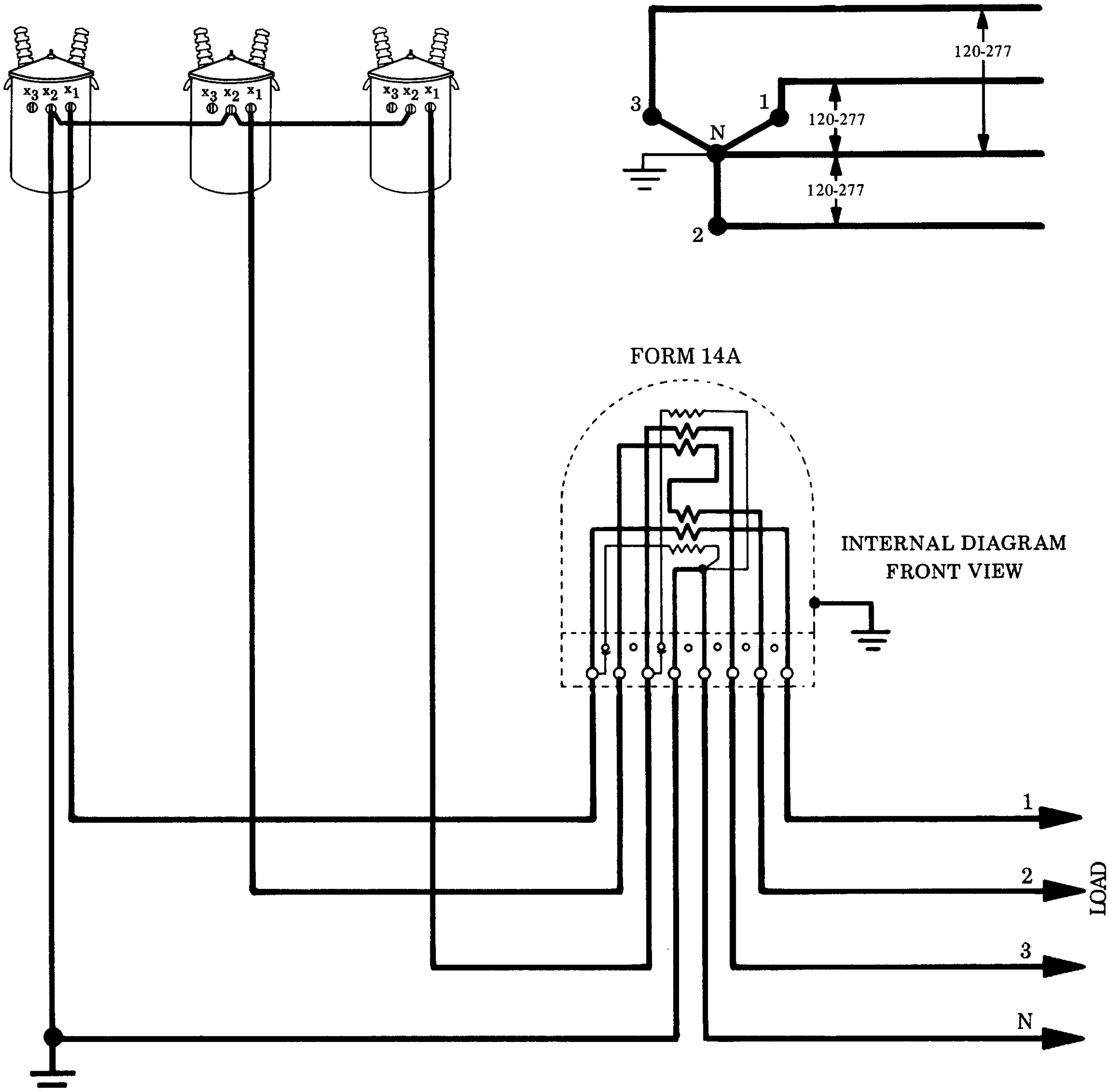


INTERNAL DIAGRAM
FRONT VIEW

THREE-PHASE, FOUR-WIRE WYE

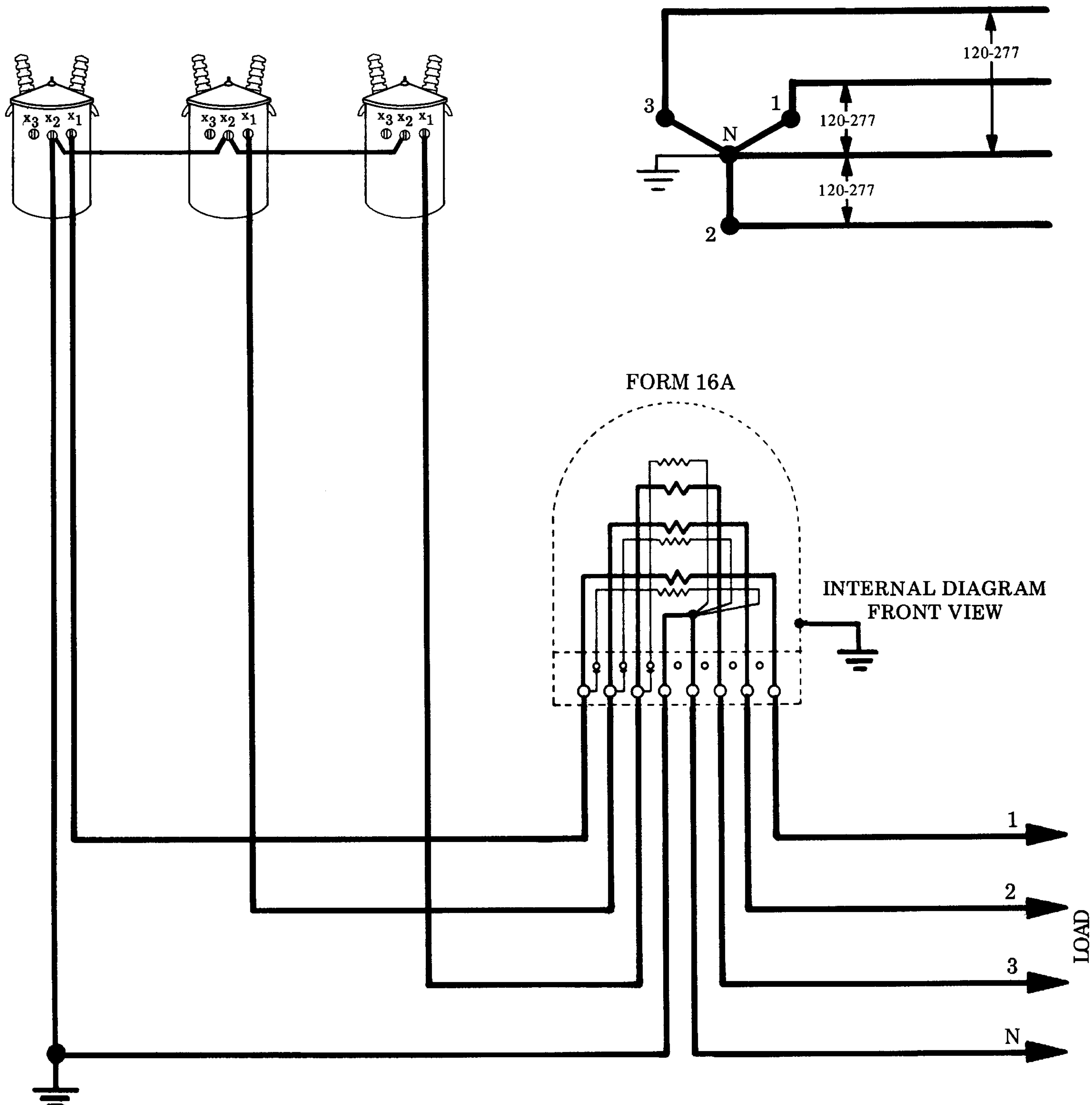
Measurement of energy on a three-phase, four-wire Wye service with a 2-1/2-stator meter.

most economical method...



Measurement of energy on a three-phase, four-wire Wye service with a 3-stator meter.

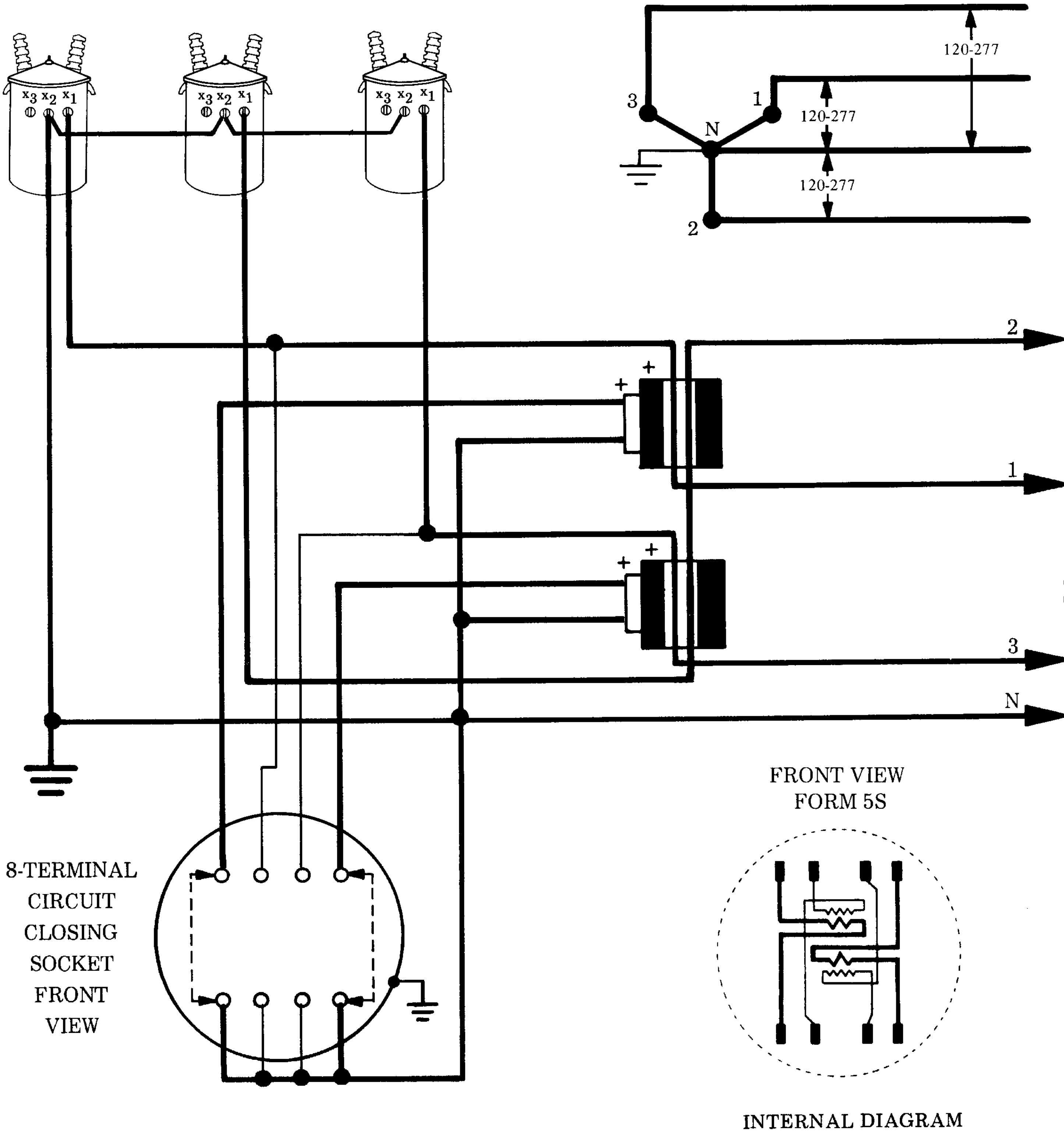
conventional method...



THREE-PHASE, FOUR-WIRE WYE

Measurement of energy on a three-phase, four-wire Wye service with two matched ratio CT's and a 2-stator meter.

most economical method...

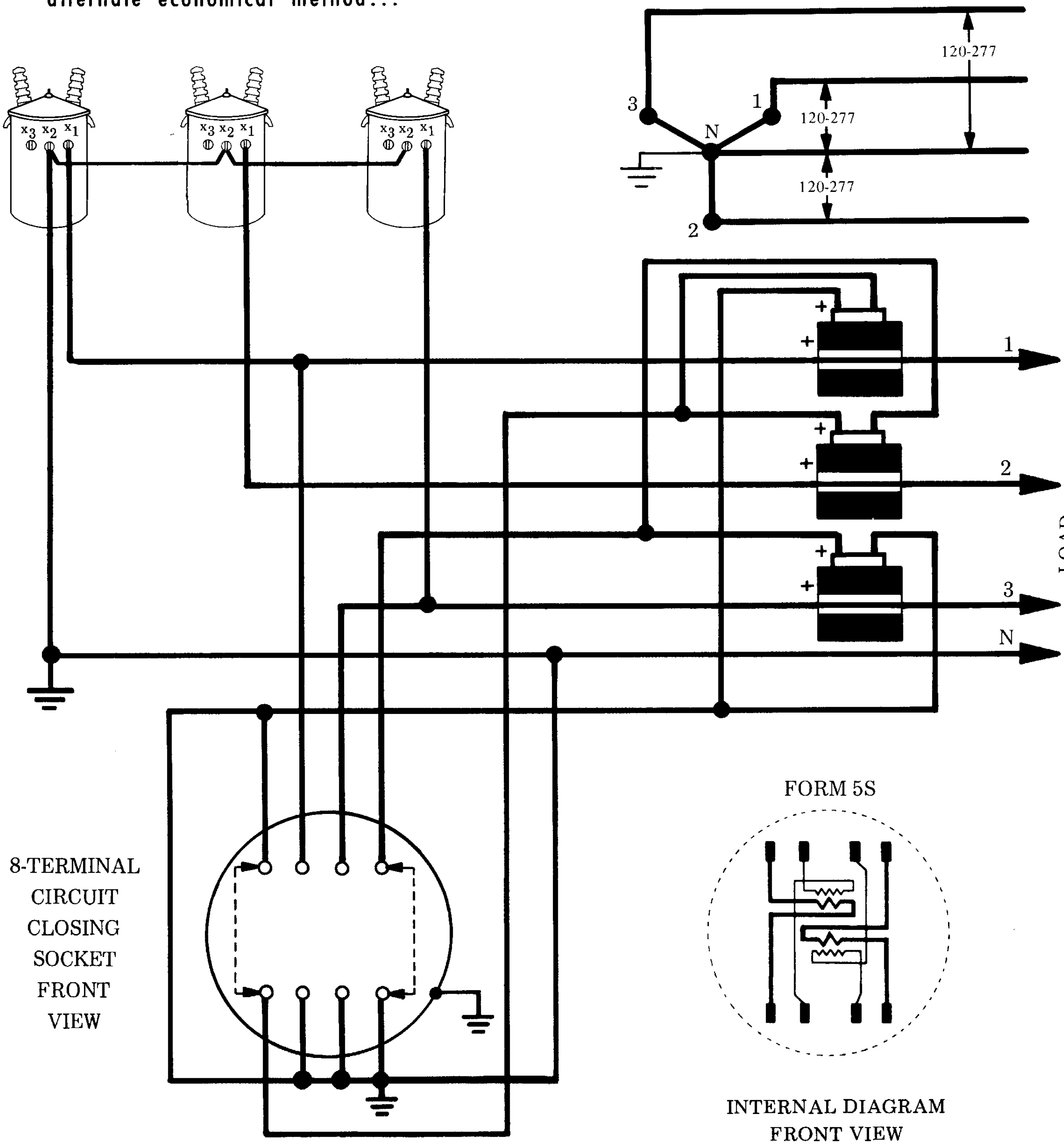


THE REGISTER MULTIPLIER EQUALS THE CT RATIO
FOR SECONDARY-RATED METERS

THREE-PHASE, FOUR-WIRE WYE

Measurement of energy on a three-phase, four-wire Wye service with 3 CT's (Delta connected secondaries) and a 2-stator meter.

alternate economical method...

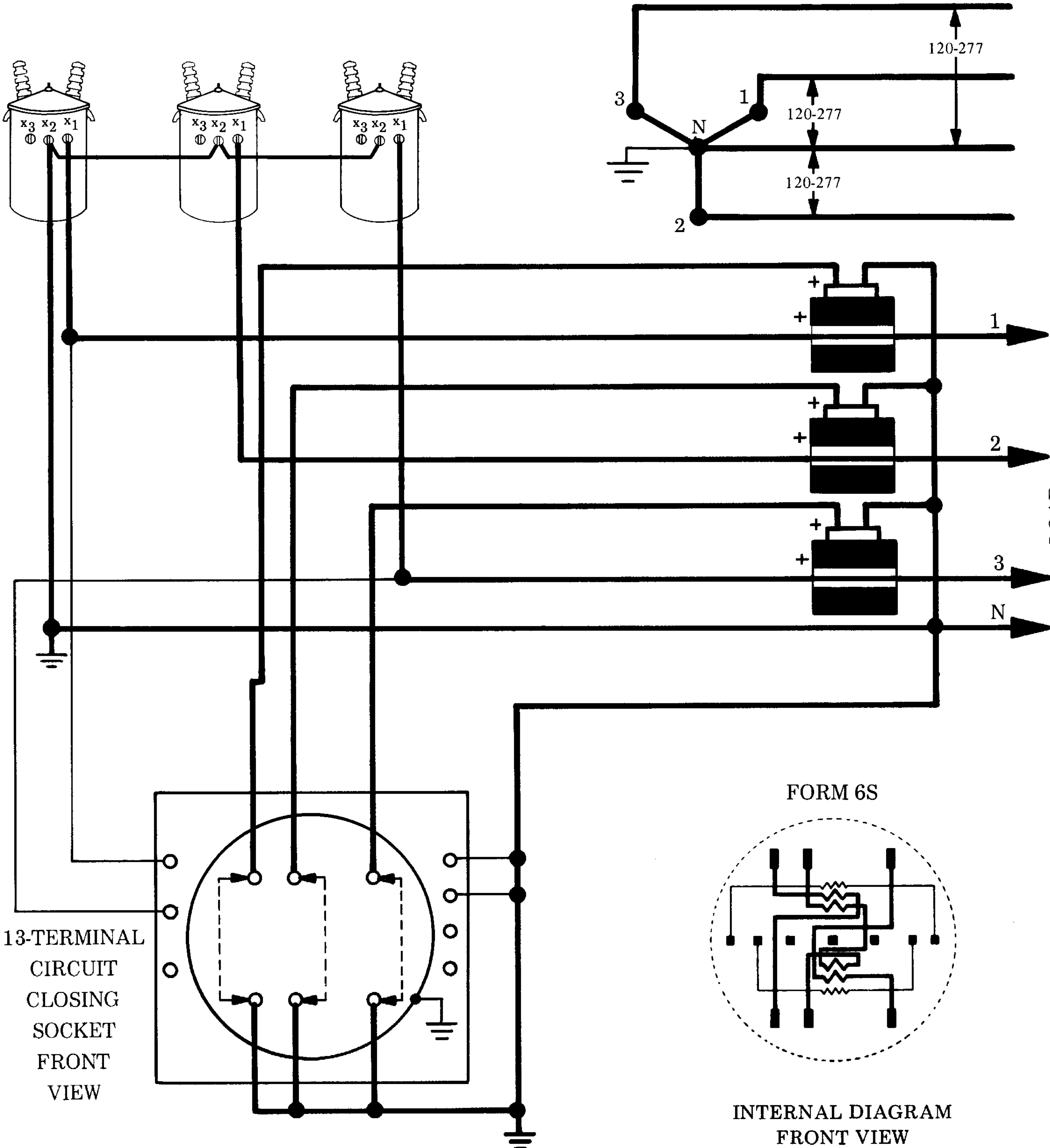


THE REGISTER MULTIPLIER EQUALS THE CT RATIO
FOR SECONDARY-RATED METERS

THREE-PHASE, FOUR-WIRE WYE

Measurement of energy on a three-phase, four-wire Wye service with 3 CT's and a 2-1/2-stator meter.

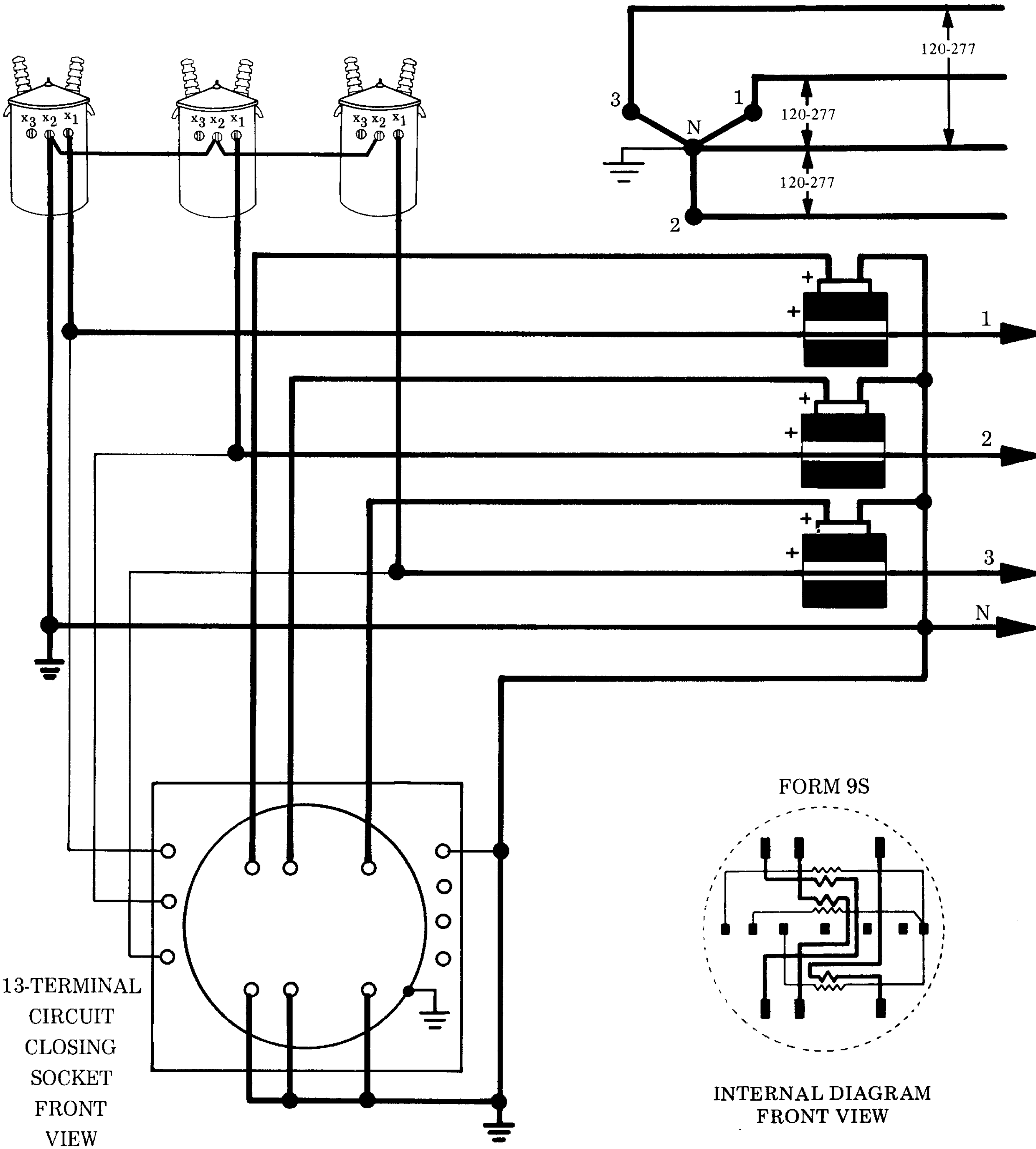
conventional method...



THE REGISTER MULTIPLIER EQUALS THE CT RATIO FOR SECONDARY-RATED METERS

Measurement of energy on a three-phase, four-wire Wye service with 3 CT's and a 3-stator meter.

alternate conventional method...

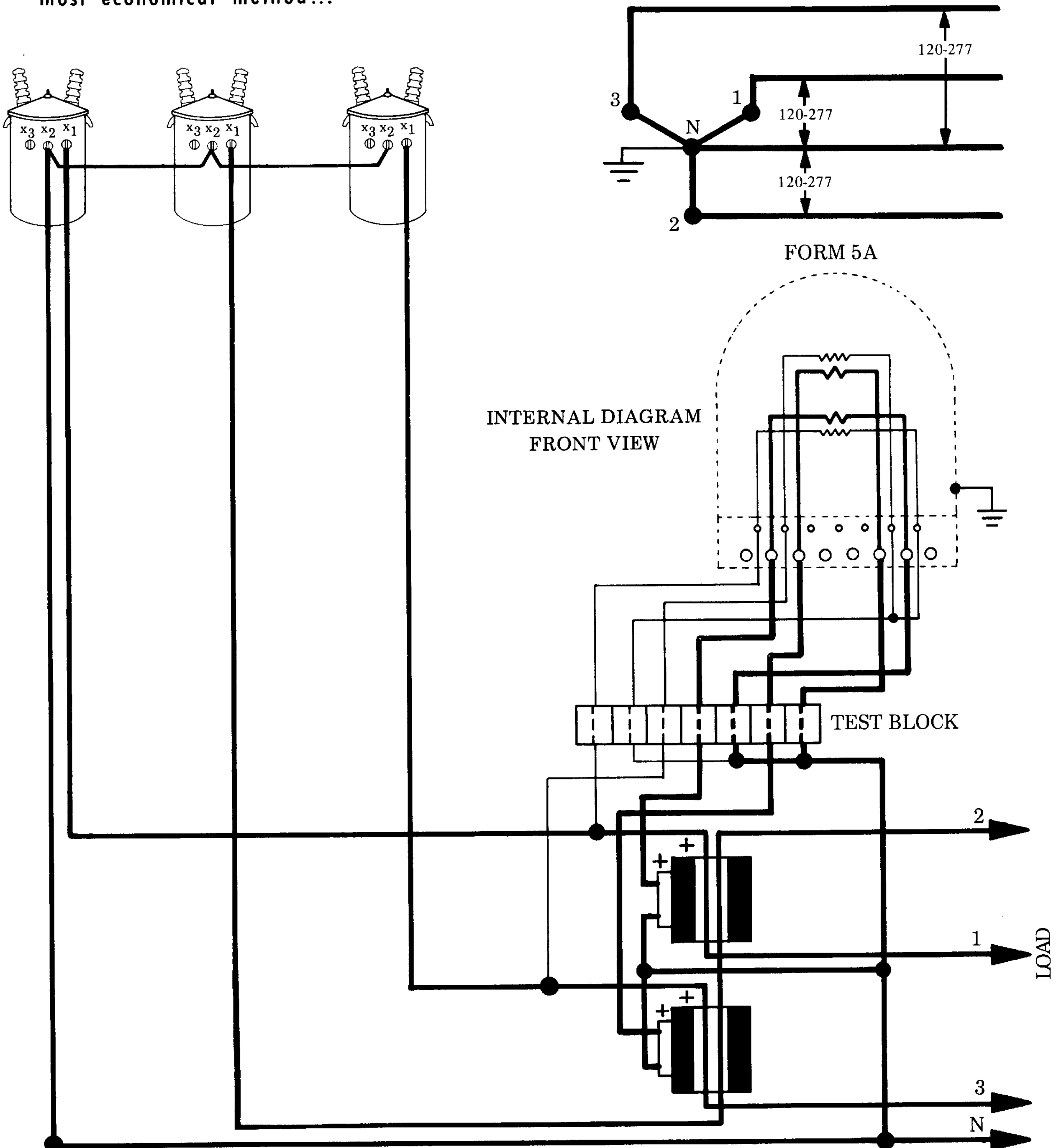


THE REGISTER MULTIPLIER EQUALS THE CT RATIO FOR SECONDARY-RATED METERS

THREE-PHASE, FOUR-WIRE WYE WITH TWO WINDOW-TYPE CT'S

Measurement of energy on a three-phase, four-wire Wye service with two matched ratio CT's and a 2-stator meter.

most economical method...

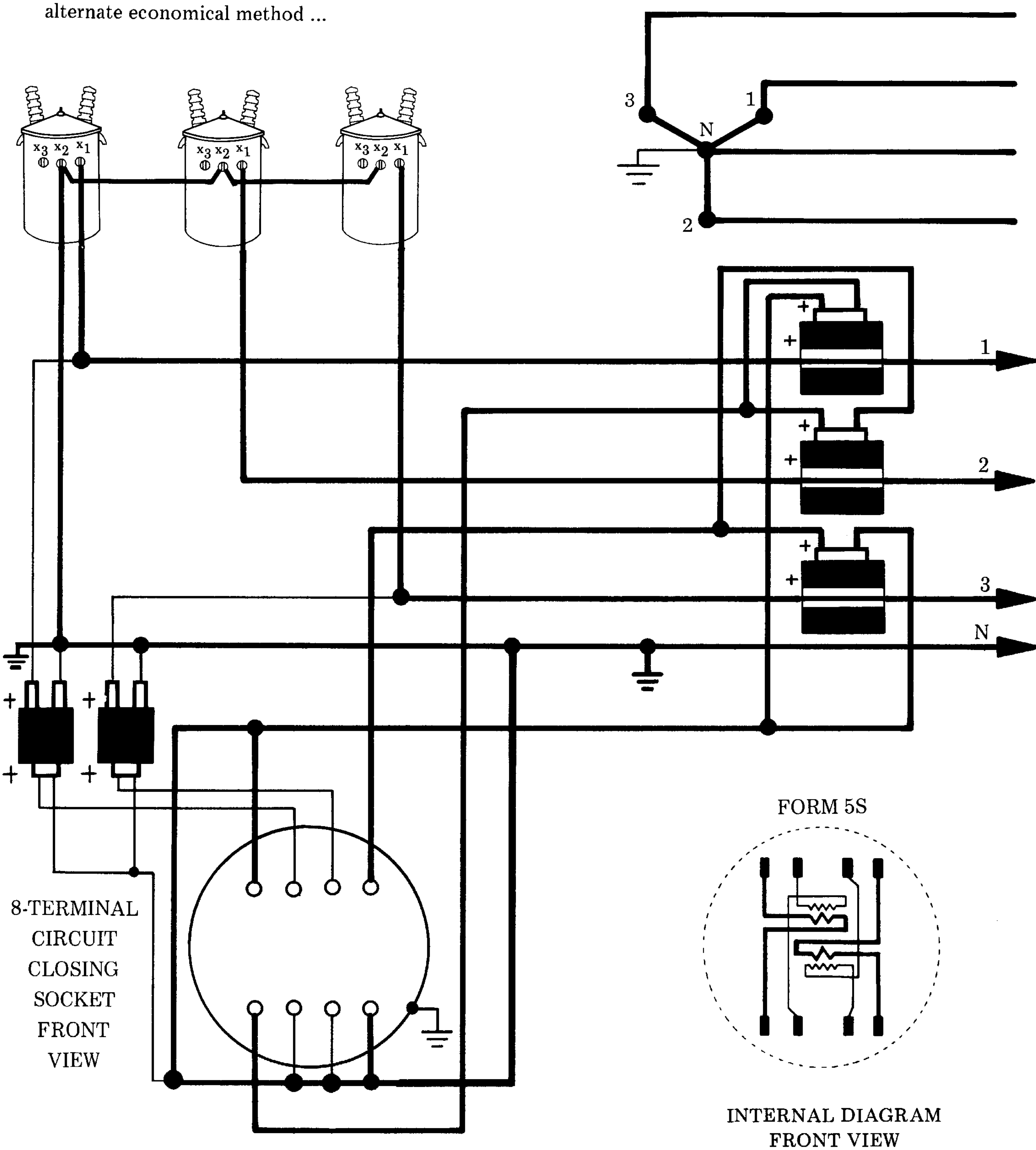


THE REGISTER MULTIPLIER EQUALS THE CT RATIO
FOR SECONDARY-RATED METERS

Measurement of energy on a three-phase, four-wire Wye service with 3 CT's (Delta connected secondaries), 2 VT's and a 2-stator meter.

THREE-PHASE, FOUR-WIRE WYE

alternate economical method ...

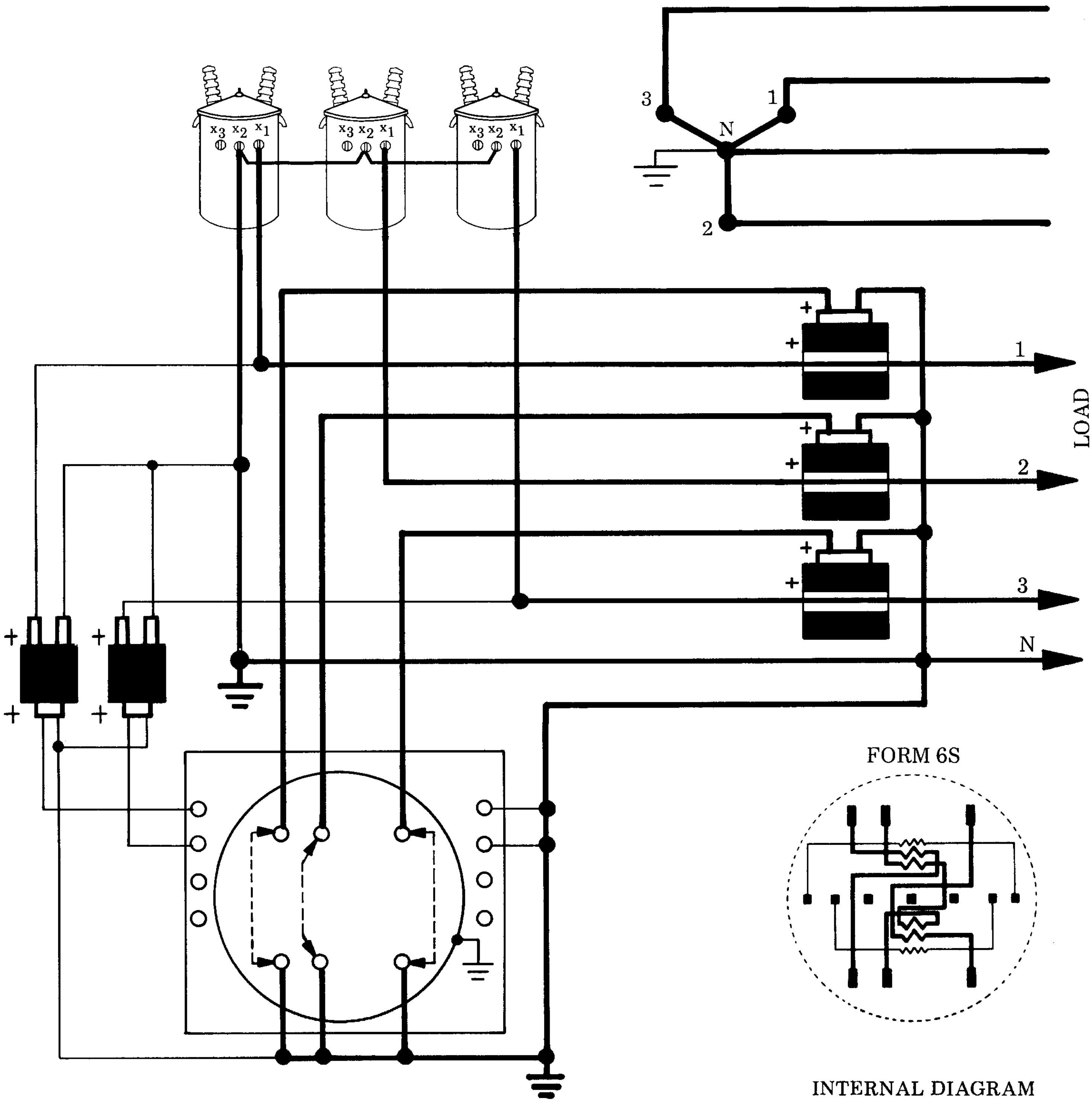


THE REGISTER MULTIPLIER EQUALS THE PRODUCT OF THE CT AND VT RATIOS FOR SECONDARY-RATED METERS

THREE-PHASE, FOUR-WIRE WYE

Measurement of energy on a three-phase, four-wire Wye service with 3 CT's, 2 VT's, and a 2-1/2-stator meter.

conventional method...



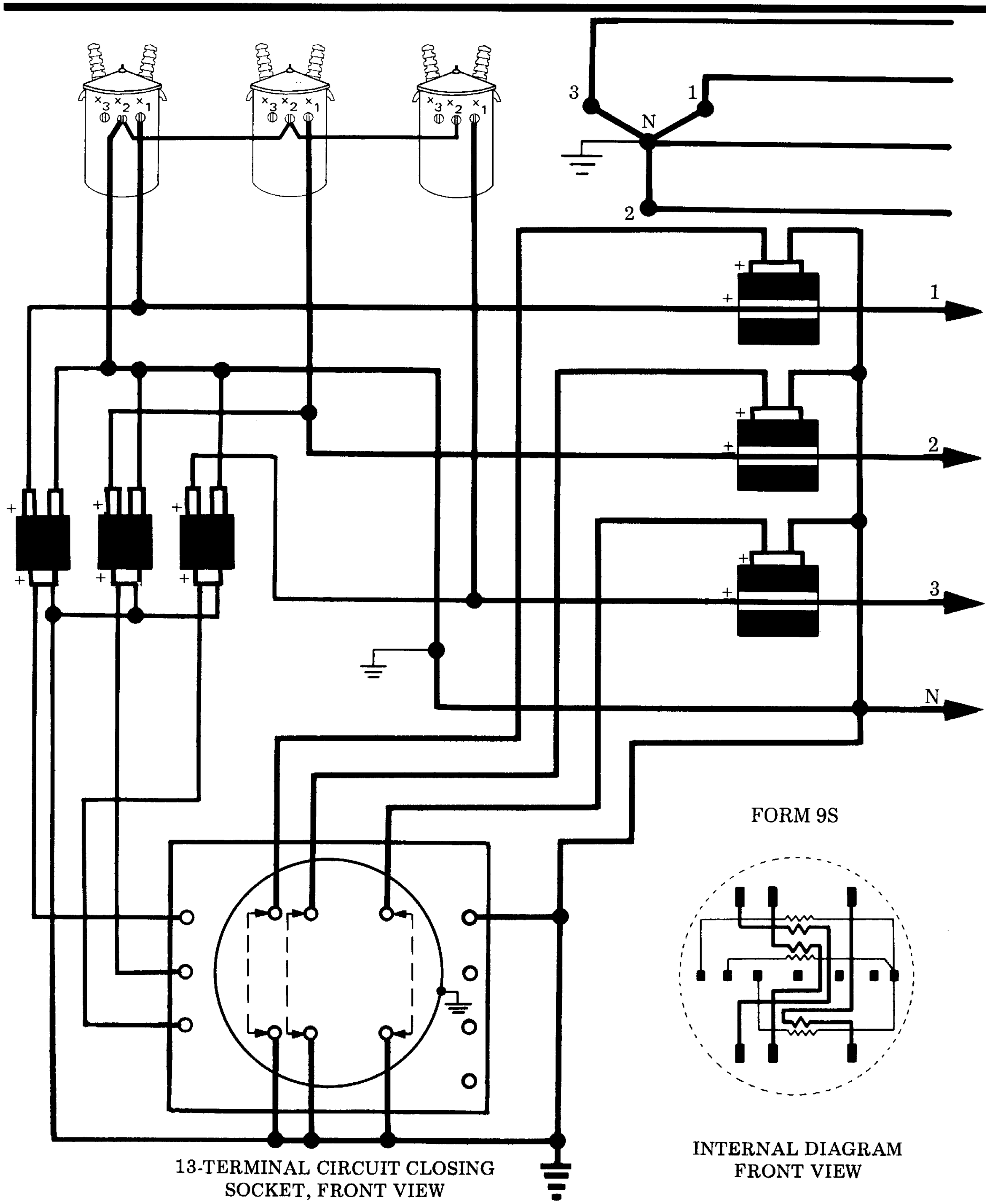
13-TERMINAL CIRCUIT CLOSING SOCKET
FRONT VIEW

INTERNAL DIAGRAM
FRONT VIEW

THE REGISTER MULTIPLIER EQUALS THE PRODUCT OF THE CT AND VT RATIOS FOR SECONDARY-RATED METERS

Measurement of energy on a three-phase, four-wire Wye service with 3 CT's, 3 VT's, and a 3-stator meter.

120-volt meter — Primary voltage determines VT ratio.

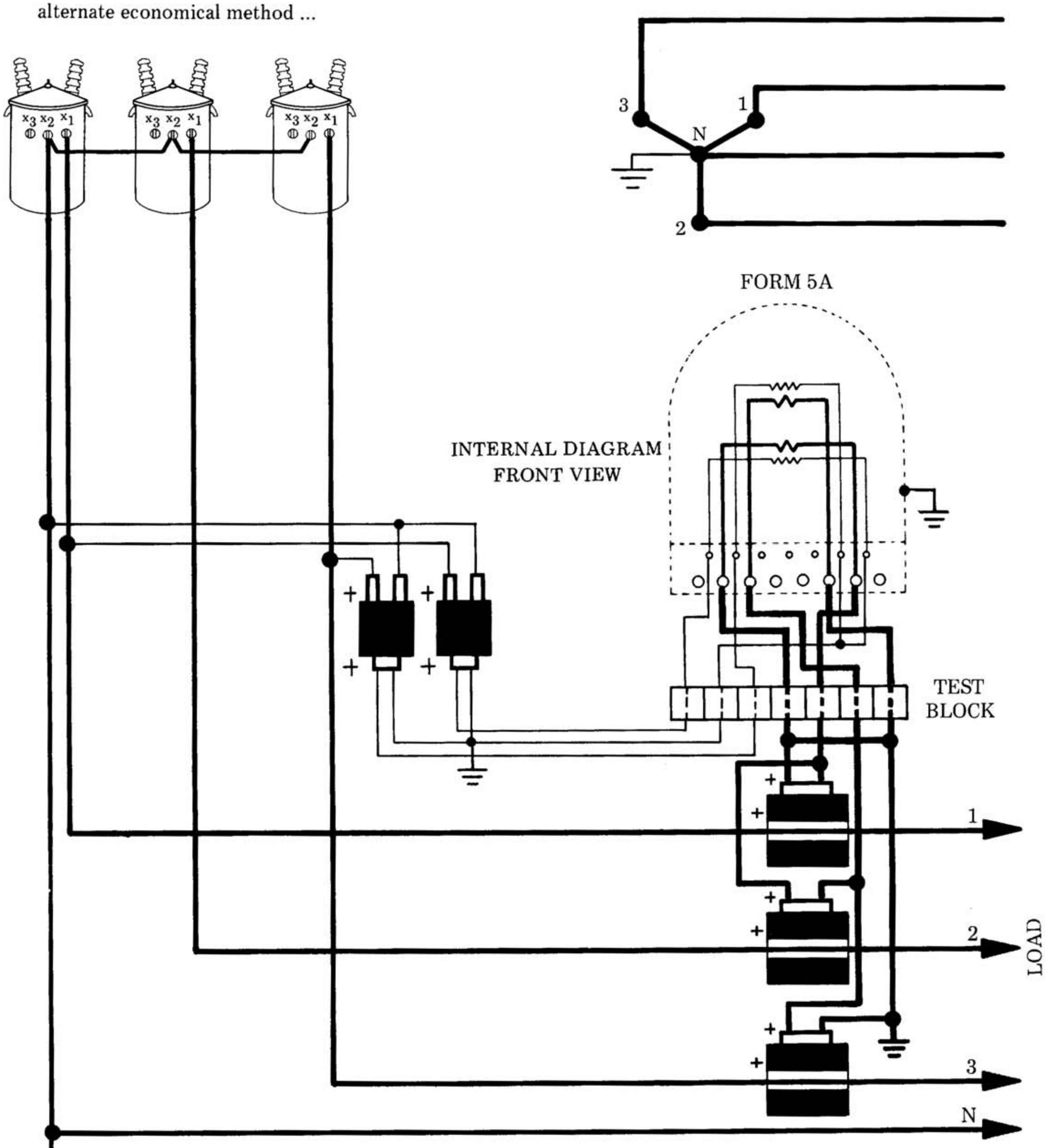


THE REGISTER MULTIPLIER EQUALS THE PRODUCT OF THE CT AND VT RATIOS FOR SECONDARY-RATED METERS

THREE-PHASE, FOUR-WIRE WYE WITH THREE CT'S AND TWO VT'S

Measurement of energy on a three-phase, four-wire Wye service with 3 CT's (secondaries in Delta), 2 VT's, and a 2-stator meter.

alternate economical method ...

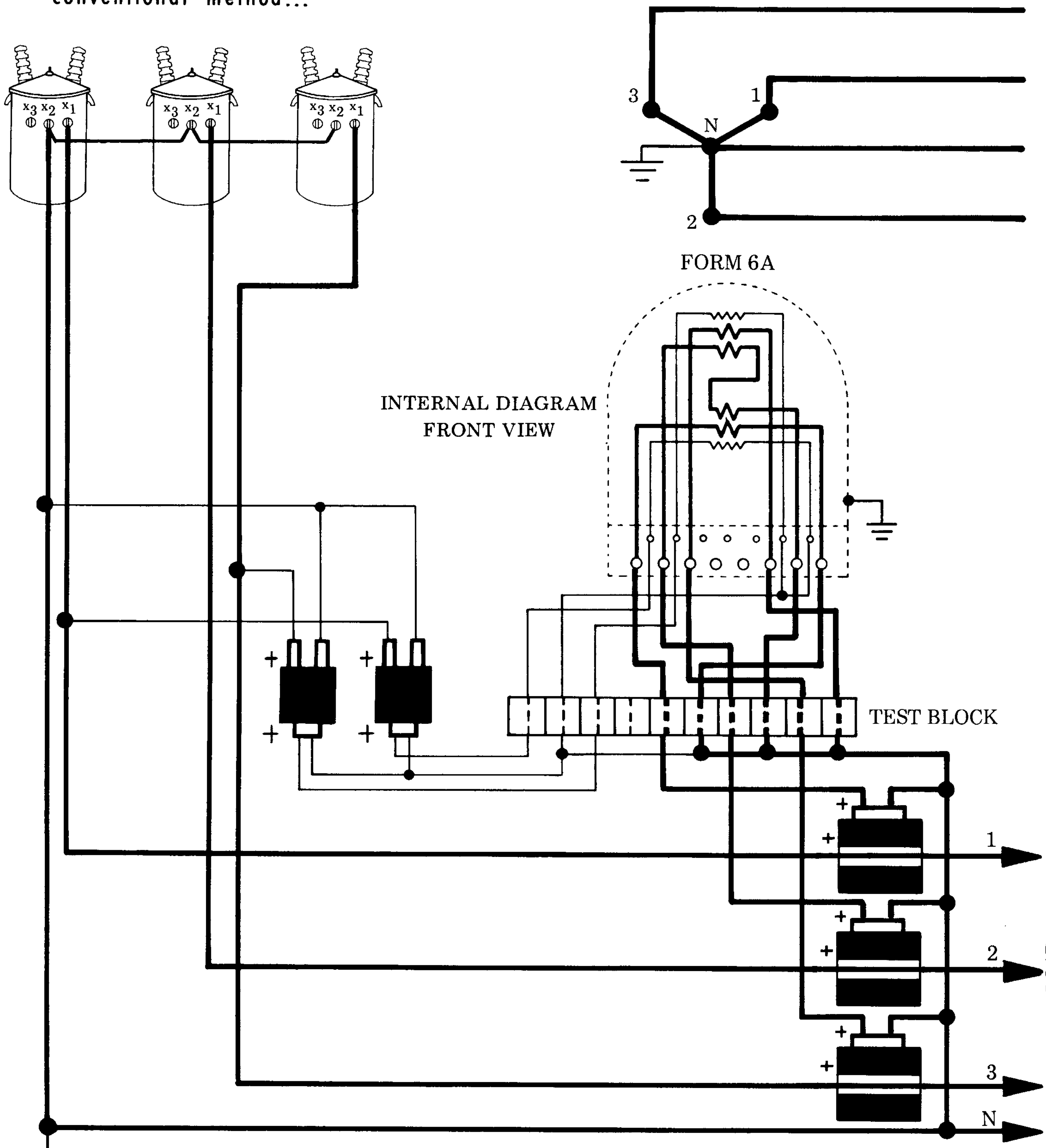


THE REGISTER MULTIPLIER EQUALS THE PRODUCT OF THE CT AND VT RATIOS FOR SECONDARY-RATED METERS

THREE-PHASE, FOUR-WIRE WYE WITH THREE CT'S AND TWO VT'S

Measurement of energy on a three-phase, four-wire Wye service with 3 CT's, 2 VT's, and a 2-1/2-stator meter.

conventional method...

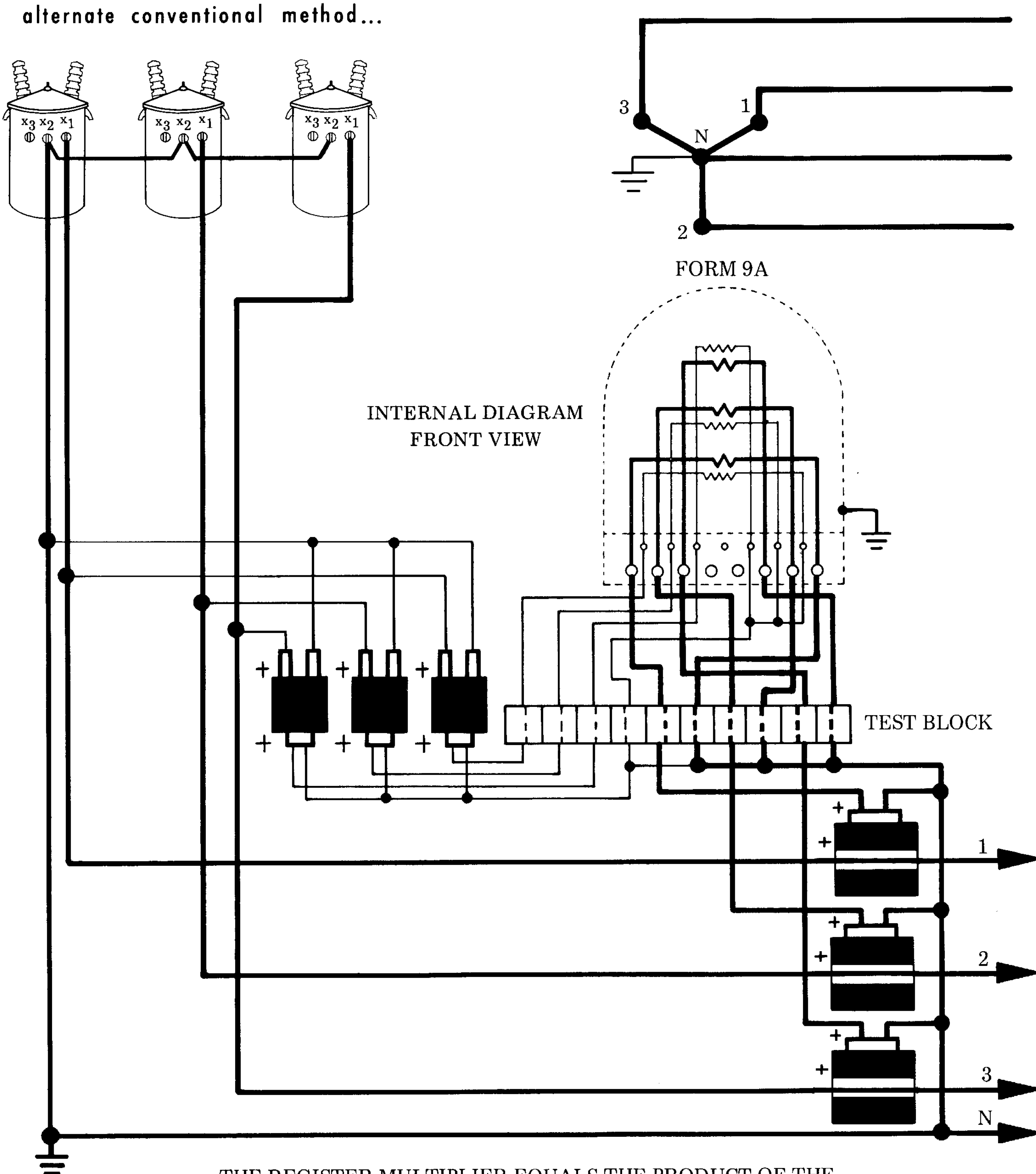


THE REGISTER MULTIPLIER EQUALS THE PRODUCT OF THE CT AND VT RATIOS FOR SECONDARY-RATED METERS

THREE-PHASE, FOUR-WIRE WYE WITH THREE CT'S AND THREE VT'S

Measurement of energy on a three-phase, four-wire Wye service with 3 CT's, 3 VT's, and a 3-stator meter.

alternate conventional method...

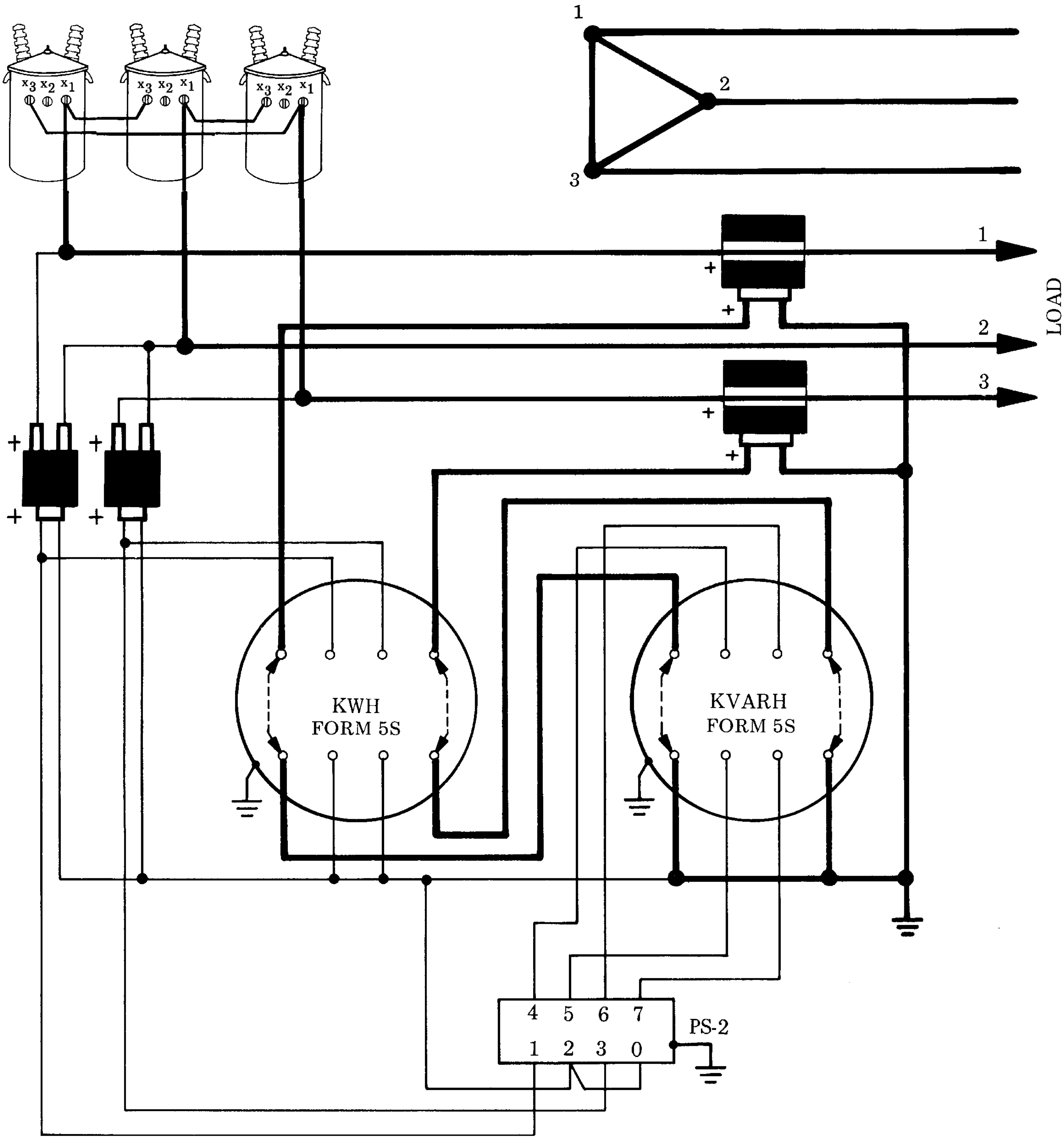


THE REGISTER MULTIPLIER EQUALS THE PRODUCT OF THE CT AND VT RATIOS FOR SECONDARY-RATED METERS

Measurement of KWH (and KW if required) and KVARH on a three-phase, three-wire Delta service with 2 CT's, 2 VT's, a phase-shifting transformer, and two 2-stator meters. **Electromechanical meters only.**

Note — Connections are for 1-2-3 phase sequence.

THREE-PHASE, THREE-WIRE DELTA REACTIVE

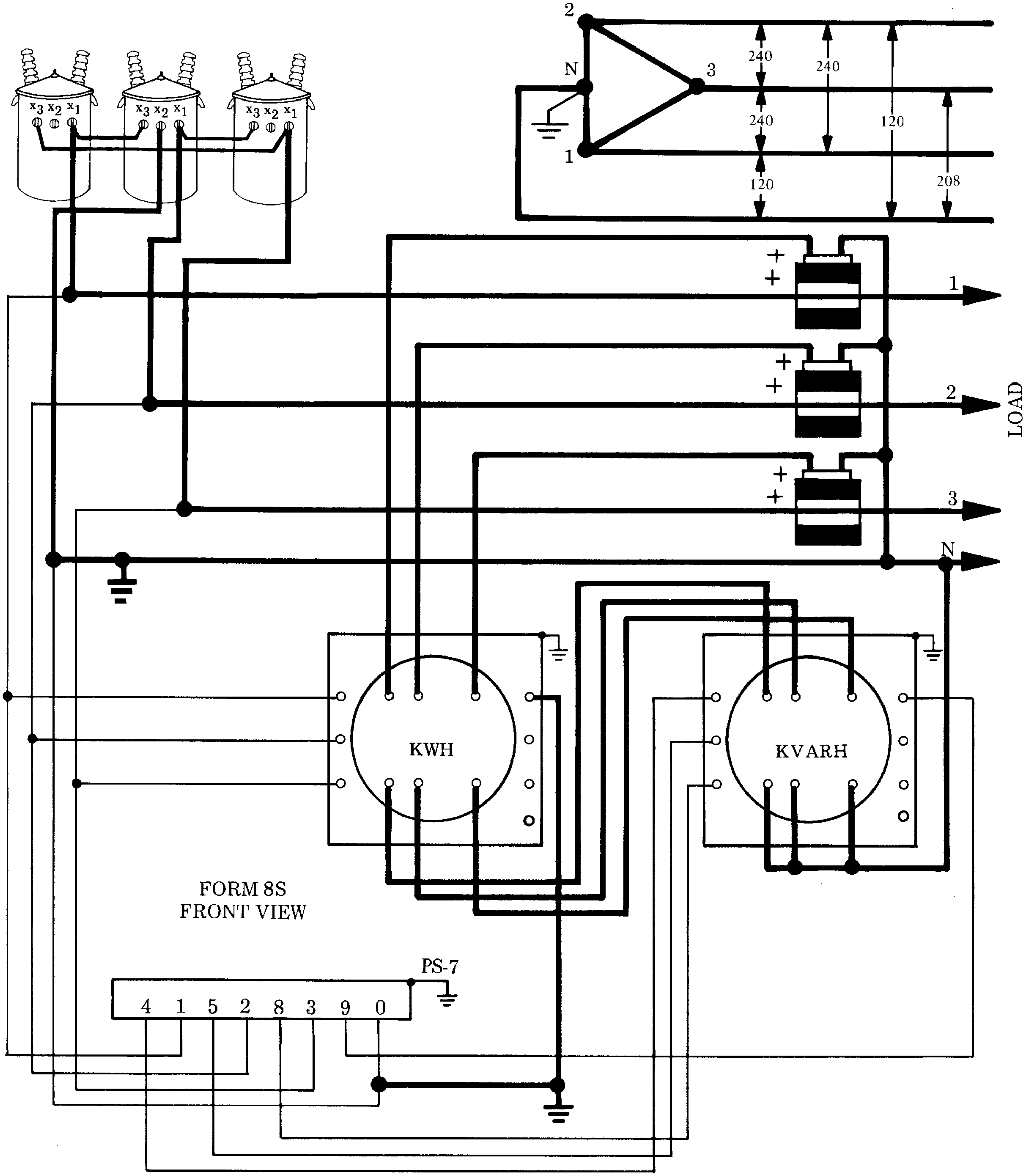


FRONT VIEW

THREE-PHASE, FOUR-WIRE DELTA REACTIVE

Measurement of KWH (and KW if required) and KVARH on a three-phase, four-wire Delta service with 3 CT's, a phase-shifting transformer, and two 2-stator meters.
Electromechanical Meters Only.

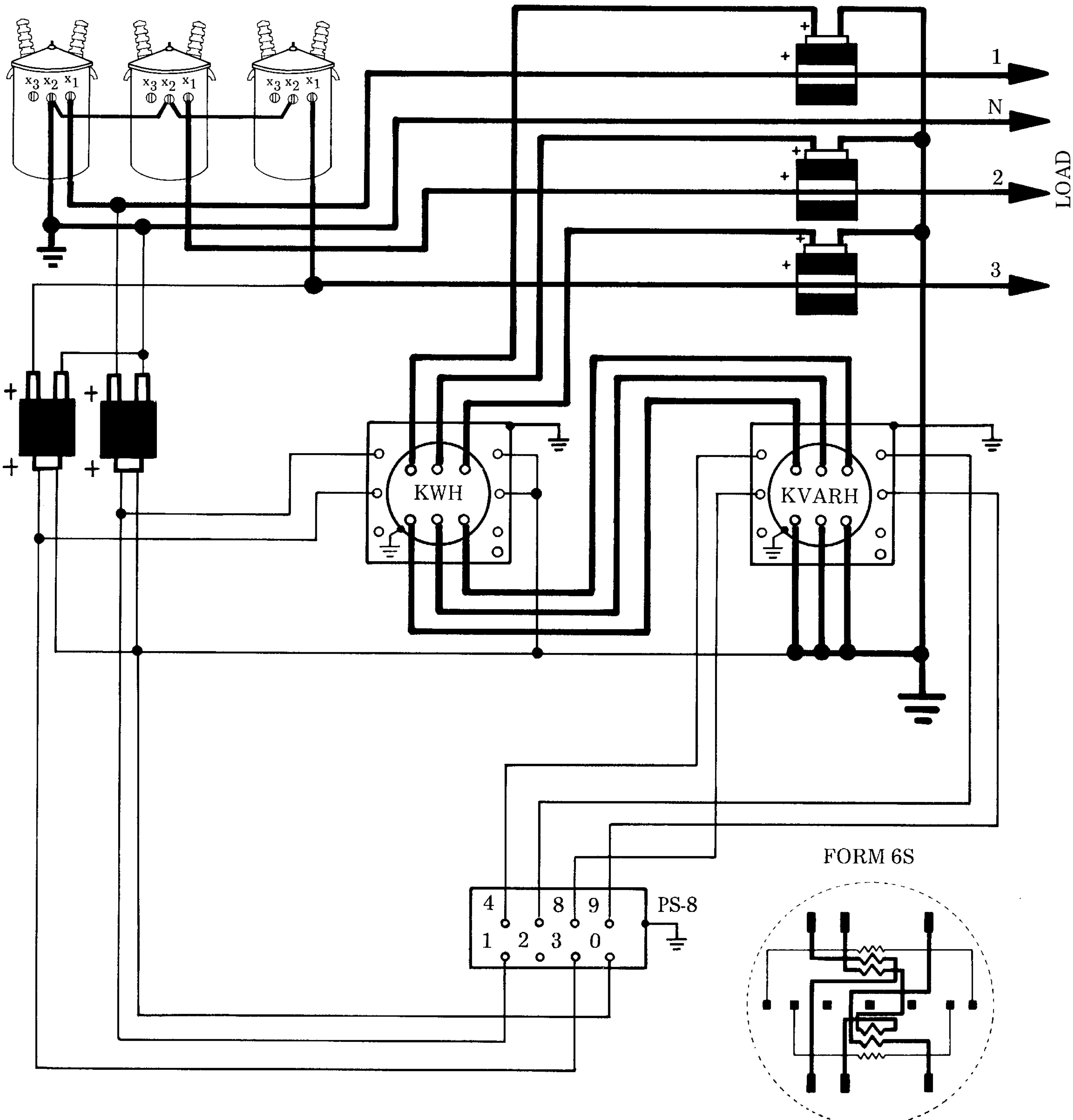
Note — Connections are for 1-2-3 phase sequence.



Measurement of KWH (and KW if required) and KVARH on a three-phase, four-wire Wye service with 3 CT's, 2 VT's, a phase-shifting transformer, and two 2-stator meters. **Electromechanical Meters Only.**

Note — Connections are for 1-2-3 phase sequence.

THREE-PHASE, FOUR-WIRE WYE REACTIVE



FORM 6S

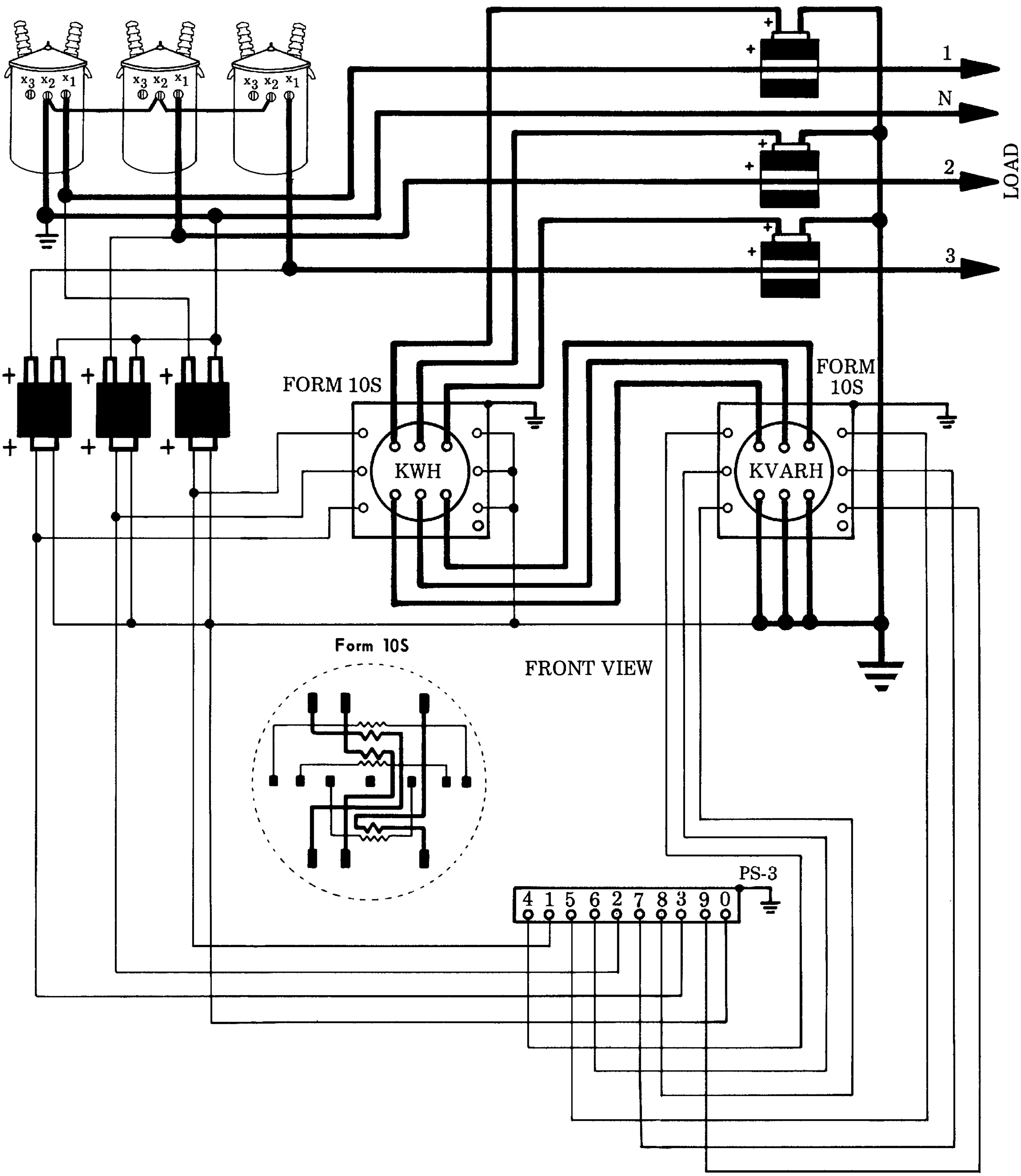
INTERNAL DIAGRAM
FRONT VIEW

THREE-PHASE, FOUR-WIRE WYE REACTIVE

Measurement of KWH (and KW if required) and KVARH on a three-phase, four-wire Wye service with 3 CT's, 3 VT's, a phase-shifting transformer, and two 3-stator meters.

Electromechanical Meters Only.

Note — Connections are for 1-2-3 phase sequence.



METER CONSTANTS

Constants most commonly used in the application and calibration of watthour meters are:

1. Watthour Constants - Kh - A measure of the electrical energy registered per revolution of the meter disk - expressed as watthours per revolution.

$$Kh = \frac{\text{Test Amps x Rated Voltage x No. Stators *}}{\text{Revolutions Per Hour of Disk **}}$$

Ex. $\frac{\text{2.5 Amp, 240 Volt, Single Stator}}{1000}$ (Single-phase meter)

$$Kh = \frac{2.5 \text{ x } 240 \text{ x } 1}{1000} = 0.6 \text{ watthours/revolution}$$

Note: If instrument transformers are not involved, Kh is "secondary."

If instrument transformers are used with meter, Kh = Kh sec. x CT Ratio x VT Ratio, in which case Kh is "primary."

**Revolutions per hour = 1000 for single-phase and 500 for Polyphase meters.

2. Register Ratio - Rr - A gear ratio equal to one revolution of the first (or fastest moving) register pointer shaft to the number of revolutions of the first register gear (pick-off gear) which meshes with the disk shaft.

$$Rr = \frac{\text{Reading of First Dial x Watthours/Kilowatt Hours}}{\text{Watthours of Rev. of Disk x 1st Reduction at Shaft}}$$

$$Rr = \frac{10 \text{ x } 1000}{\text{Kh x Rs}}$$

If multipler Kr is used for register and if CT's and/or VT's are used:

$$Rr = \frac{10 \text{ x } 1000 \text{ x Kr}}{\text{Kh x Rs x CT x VT}}$$

3. First Reduction at Shaft (Rs): A ratio of the number of revolutions of the disk to one revolution of the first register gear (pick-off gear) which meshes with the disk shaft.

ABB meters have a single lead worm on the disk shaft and a 100-tooth pick-off gear. Rs = 100/1.

(*) Use 3 for all two-stator, 3-phase, 4-wire Wye meters.

4. Register Constant (Kr): A multiplier used with register reading to obtain total registration.

   For self-contained meters, Kr is generally 1 or 10.

   For secondary rated transformer type meters, Kr = CT ratio x VT ratio.

   For primary rated transformer type meters, Kr is generally a multiple of 10 (10, 100, 1000, 10,000, etc.). The actual value depends upon CT and VT ratios employed.

   $$Kr = \frac{\text{Kh Sec. x Rr x Rs x CT Ratio x VT Ratio}}{10{,}000}$$

5. Meter Disk Speed - Revolutions per Hour (R/H) - Set by meter design.

   $$\frac{R}{H} = \frac{\text{Test Amps x Rated Voltage x No. Stators}}{\text{Kh}}$$

   For AB1 Single Phase: $\frac{R}{H} = 1000$ (16-2/3 RPM)

   For AB Polyphase: $\frac{R}{H} = 500$ (8-1/3 RPM)

6. Kilowatts (useful for test purposes) - Count disk revolutions of some predetermined number and observe seconds required (for example, 10 revs. in 6 sec.)

   $$KW = \frac{\text{Kh x CT Ratio x VT Ratio x Seconds/Hour x Rev.}}{\text{Watts/Kilowatts x Seconds}}$$

   $$\text{Watts} = \frac{\text{Kh x Rev. x 3600}}{\text{Seconds}}$$

REACTIVE MEASUREMENT FOR ELECTROMECHANICAL METERS

Frequently, utility rates require Power Factor be determined. Generally, a "Weighted Average Power Factor" is utilized and obtained from monthly readings of a KWH meter and a KVARH meter.

Power Factor is expressed as a percent of true power to apparent power (KWH/KVAH). For example, 50% lagging power factor indicates that the load current lags the load voltage by 60°. Since the cosine of 60° equals .50, the true power is 50% of apparent power.

Phase shifting transformers are used in conjunction with a second KWH meter (marked KVARH) to shift voltages 90° in the lag direction. This second meter measures KVARH (it must be detented to prevent reverse rotation caused by leading PF). With monthly KWH and KVARH readings, a KVAH value can be obtained and a weighted average power factor established.

Phase shifting transformers generally have "test run" switches. In the "test" position, the KVARH meter runs as a KWH meter and can be tested as such.

It is necessary to know phase sequence in order to properly connect phase shifting transformers. Wiring shown is for A, B, C (1-2-3) sequence. Special wiring is required if phase sequence is reversed.

KWH meters can be "random" connected without regard to phase sequence since no phase shift is involved in their operation, but reactive measurement does involve phase shift and phase sequence must be considered. The exception to the above is the 4-wire Delta meter which, though not sensitive to phase sequence, must have the 2-wire stator in the "power leg."

As stated, reactive meters are generally detented since they would otherwise reverse their rotation if power factor goes leading. While leading PF loads may at times be desirable in view of system power factor, customer loads are not under the control of the utility and thus are unpredictable.

CALIBRATION INFORMATION

This section gives specific instructions for calibrating AB Single-Phase and Polyphase watthour meters. The order of calibration steps is laid out so that the effect of each adjustment on the others is minimized. Following the suggested order will avoid repetition and save time. The various instruction leaflets accompanying individual types of meters show connections and explain the mechanisms for making the adjustments. The meter nameplates give the ratings and constants. Full load is 100% of test amperes (TA) and light load is 10% of test amperes.

General information on testing all types of meters is given in the "Handbook for Electricity Metering" published by the Edison Electric Institute.

All AB1 single-phase meters operate at 16-2/3 RPM when energized at nameplate voltage and test amperes.

Test 3-wire meters with current winding in series.

See page 53 for proper connections for testing.

■ Calibration Procedure for Single-Phase Meters

a. Observe full load unity P.F. and light load unity P.F. readings.

b. Calibrate light load to full load within acceptable tolerance using the light load adjuster screw; for example: if full load is 100.7%, adjust light load to 100.7%.

c. Calibrate full load unity PF to 100% or acceptable tolerance using the full load adjuster screw.

d. If desired, observe full load 50% Lagging PF calibration. (Power Factor is a fixed factory adjustment.)

■ Calibration Procedure for Polyphase Meters

GENERAL TEST INFORMATION

See pages 52 to 58 for proper connections for testing. All meters are to be tested on single-phase power. Voltage coils are to be connected in parallel with voltage applied to all coils during the entire calibration procedure. Combined stator single-phase test speed at rated voltage and rated current is 8-1/3 RPM. The Form 6 and 14 meters have single-phase test speed of 11-1/9 RPM. Also note that for single element testing, the common or "Z" coil is not energized. When testing meters with 3 wire current windings, both current coils must be connected in series.

CALIBRATION PROCEDURE FOR 2-STATOR METERS

1. Initial Combined Stator Calibration
   a. Connect all current coils in series.
   b. Observed full load unity PF and light load unity PF readings.
   c. Calibrate light load to full load within acceptable tolerance using the left light load adjuster screw (use the right only when necessary). For example, if the full load reading is 100.7%, calibrate light load to 100.7%.

2. Left Stator Calibration
   a. Make the appropriate current coil connections for left stator only operation.
   b. Observe full load unity PF. Do not adjust.
   c. Observe full load 0.5 lagging PF. If necessary, calibrate to the full load unity PF level using the left stator power factor adjuster screw. If an adjustment is made, repeat steps 2b and 2c.

3. Right Stator Calibration
   a. Make the appropriate current coil connections for right stator only operation.
   b. Observe full load unity PF. Do not adjust.
   c. Observe full load 0.5 lagging PF. If necessary, calibrate to the unity PF level using the right stator power factor adjuster screw. If an adjustment is made, repeat steps 3b and 3c.
   d. If necessary, calibrate the right stator full load unity PF to the left stator full load unity PF using the right stator phase balance (torque balance) adjuster screw.

4. Final Combined Stator Calibration
   a. Connect all current coils in series.
   b. Observe full load and light load unity PF and full load 0.5 PF lagging.
   c. If necessary, recalibrate light load to full load within acceptable tolerance using the left light load adjuster screw (use the right only when necessary).
   d. Calibrate full load unity PF to 100% or acceptable tolerance using the full load adjuster screw.
   e. If necessary, calibrate full load 0.5 lagging PF to within acceptable tolerance by adjusting both the left stator and right stator power factor adjustment screws an equal amount. If an adjustment is made, repeat step 4d.

CALIBRATION PROCEDURE FOR 3-STATOR METERS

1. Initial Combined Stator Calibration
   a. Connect all current coils in series.
   b. Observe full load unity PF and light load unity PF readings.
   c. Calibrate light load to full load within acceptable tolerance using the left light load adjuster screw (use the right only when necessary). For example, if the full load reading is 100.7%, calibrate light load to 100.7%.

2. Rear Stator Calibration
   a. Make the appropriate current coil connections for rear stator only operation.
   b. Observe full load unity PF. Do not adjust.
   c. Observe full load 0.5 lagging PF. If necessary, calibrate to the unity PF level using the rear stator power factor adjuster screw. If an adjustment is made, repeat steps 2b and 2c.

3. Left Stator Connection
   a. Make the appropriate current coil connections for left stator only operation.
   b. Observe full load unity PF. Do not adjust.
   c. Observe full load 0.5 lagging PF. If necessary, calibrate to the unity PF level using the left stator power factor adjuster screw. If an adjustment is made, repeat steps 3b and 3c.
   d. If necessary, calibrate the left stator full load unity PF to the rear stator full load unity PF using the left stator phase balance (torque balance) adjuster screw.

4. Right Stator Calibration
   a. Make the appropriate current coil connections for right stator only operation.
   b. Observe full load unity PF. Do not adjust.
   c. Observe full load 0.5 lagging PF. If necessary, calibrate to the unity PF level using the right stator power factor adjuster screw. If an adjustment is made, repeat steps 4b and 4c.
   d. If necessary, calibrate the right stator full load unity PF to the rear stator full load unity PF using the right stator phase balance (torque balance) adjuster screw.

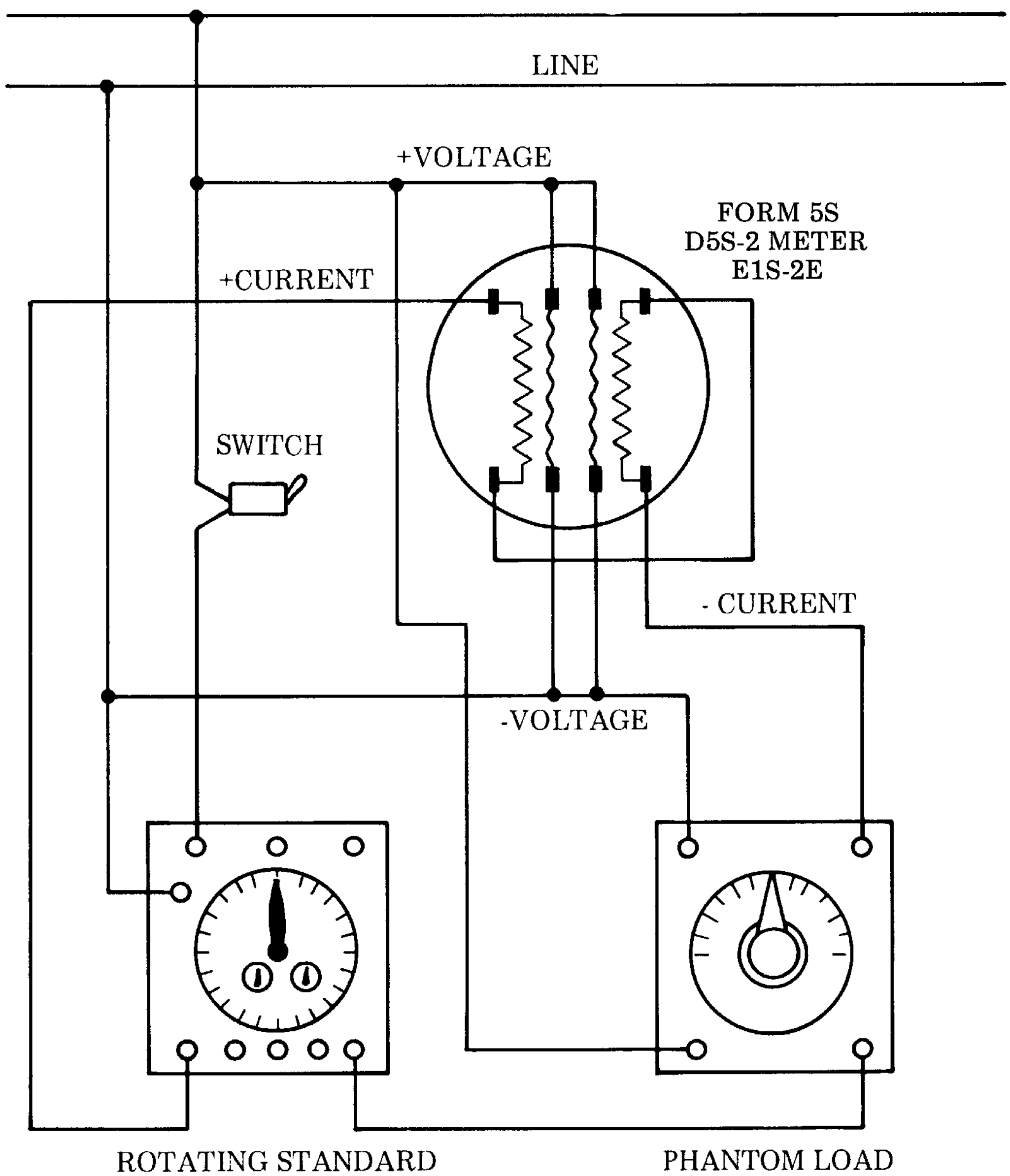
5. Final Combined Stator Calibration
   a. Connect all current coils in series.
   b. Observe full load and light load unity PF and full load 0.5 PF lagging.
   c. If necessary, recalibrate light load to full load within acceptable tolerance using the left light load adjuster screw (use the right only when necessary).
   d. Calibrate full load unity PF to 100% or acceptable tolerance using the full load adapter screw.
   e. If necessary, calibrate full load 0.5 PF to within acceptable tolerance by adjusting both the left stator, right stator, and rear stator power factor adjustment screws an equal amount. If an adjustment is made, repeat step 4d.

TEST SET-UP AND FIELD TESTING FOR ALPHA METERS

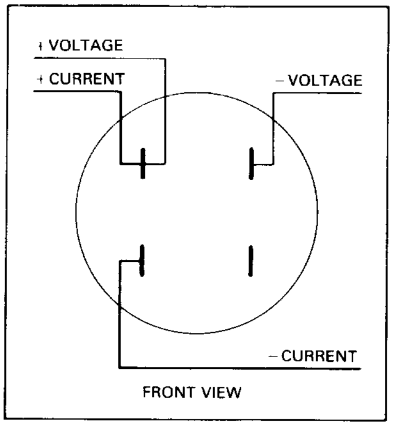
The test set-up for Alpha polyphase meters is the same as that for their equivalent electromechanical polyphase meters. A typical test connection using a rotating standard, phantom load and a form 5S meter for single-phase test is shown on page 51. Test connections for all types are shown on pages 52 through 58 of this publication. Additional test procedures, including field testing and recommended test equipment, are described in the Alpha Solid State Technical Manual, TM42-2180, Section 4.

TYPICAL CONNECTION
ROTATING STANDARD PHANTOM LOAD AND METER
FOR SINGLE PHASE TEST

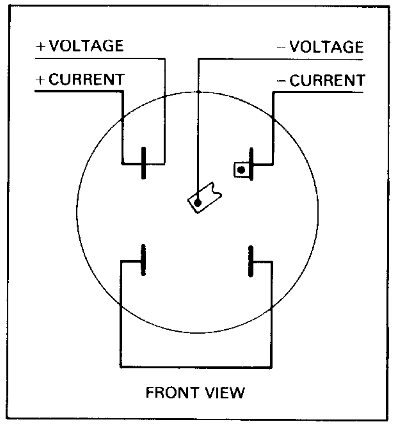
NOTE
VOLTAGE AND CURRENT POLARITY MARKS
ARE FOR REFERENCE ONLY



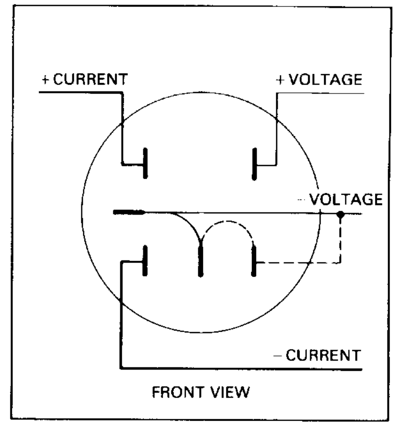
SINGLE-PHASE TEST CONNECTIONS



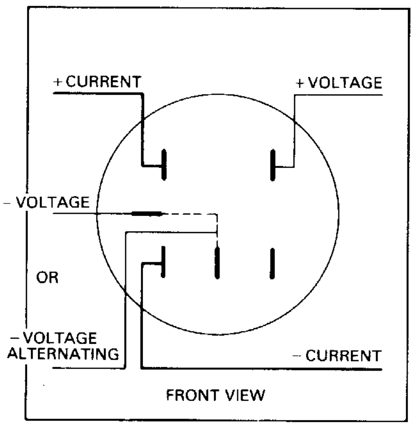
D5S, 2-wire self-contained—
meter test.
Form 1S



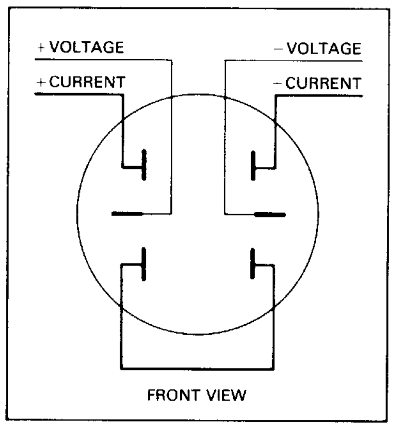
D5S, 3-wire self-contained—
meter test.
Form 2S



D5S, 2-wire, 4- or 5-terminal
transformer-rated—CT and VT test.
Form 3S

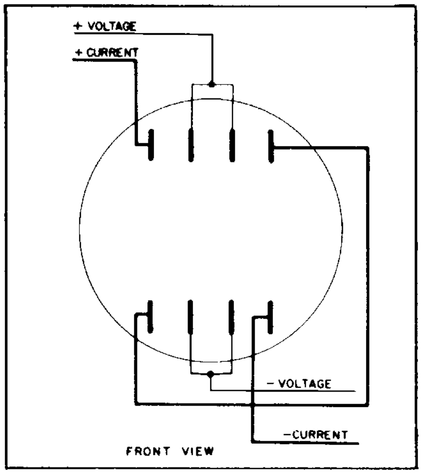


D5S, 2-wire, 5-terminal transformer-
rated—CT test.
Form 3S

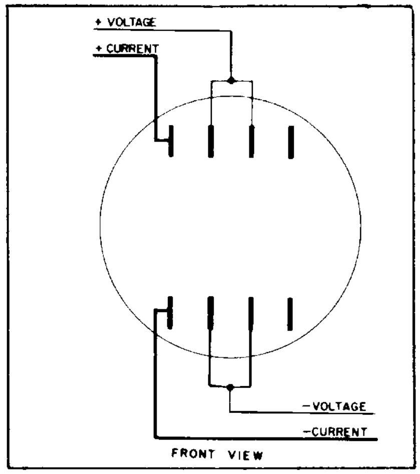


D5S, 3-wire, 6-terminal transformer-
rated—two CTs test.
Form 4S

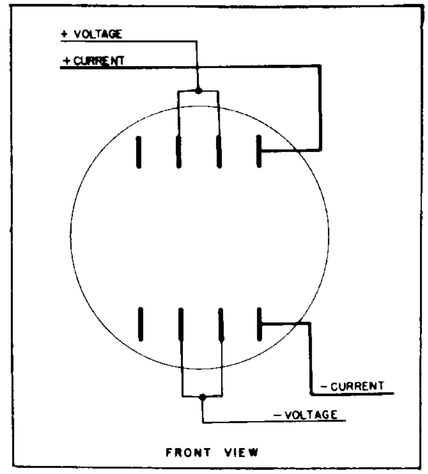
POLYPHASE TEST CONNECTIONS



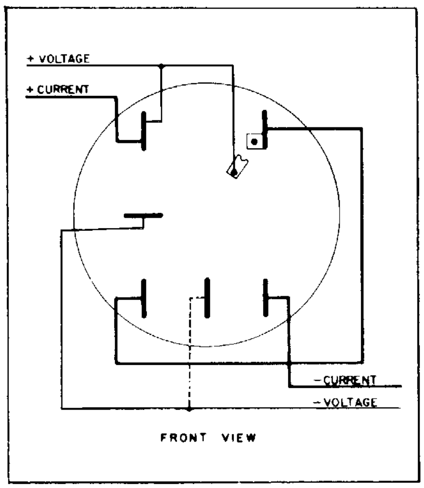
D5S-2, D4S-2, E1S-2E 1-, 2-, or 3-phase, 3-wire, self-contained and transformer-type – Combined Stator Test. FORM 5S



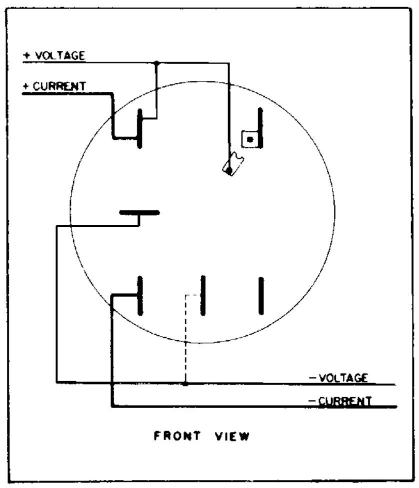
D5S-2, D4S-2, E1S-2E 1-, 2-, or 3-phase, 3-wire, self-contained and transformer-type – Left Stator Test. FORM 5S



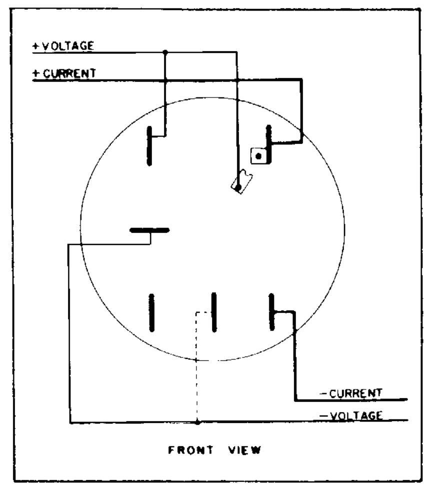
D5S-2, D4S-2, E1S-2E 1-, 2-, or 3-phase, 3-wire, self-contained and transformer-type – Right Stator Test. FORM 5S



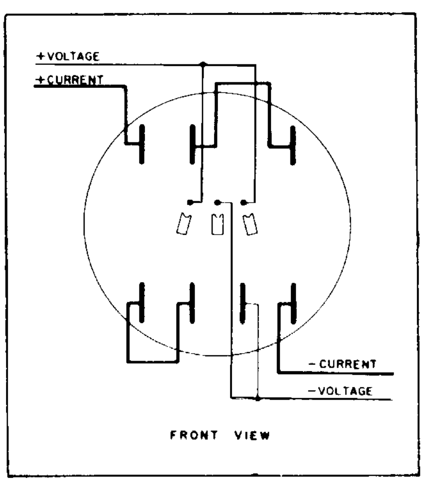
D5S-5, D4S-5, E1S-5E 1-, 2-, or 3-phase, 3-wire, self-contained – Combined Stator Test. FORM 12S



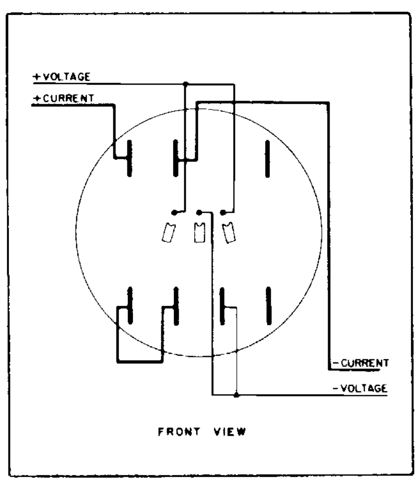
D5S-5, E1S-5E 1-, 2-, or 3-phase 3-wire, self contained – left Stator Test. FORM 12S



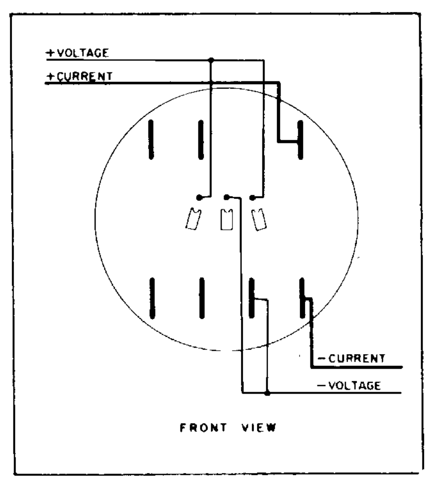
D5S-5, D4S-5, E1S-5E 1-, 2-, or 3-phase 3-wire, self-contained – Right Stator Test. FORM 12S



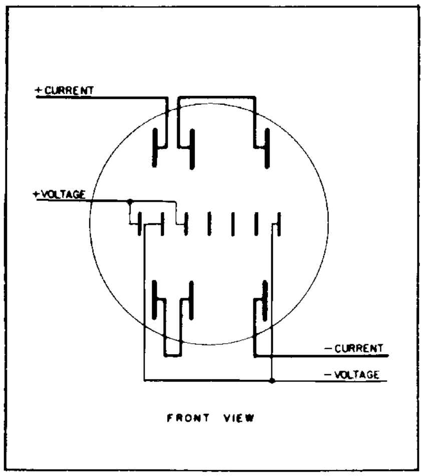
D5S-7, D4S-7, E1S-7E 3-phase, 4-wire, delta self-contained – Combined Stator Test. FORM 15S



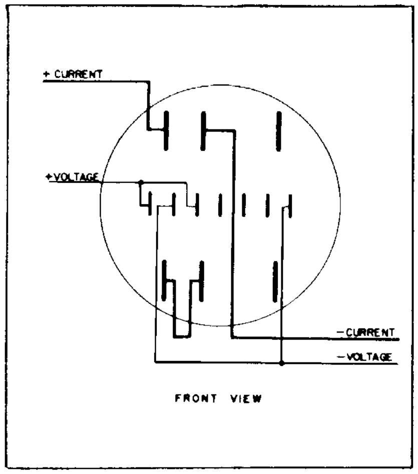
D5S-7, D4S-7, E1S-7E 3-phase, 4-wire, delta self-contained – Left Stator Test. FORM 15S



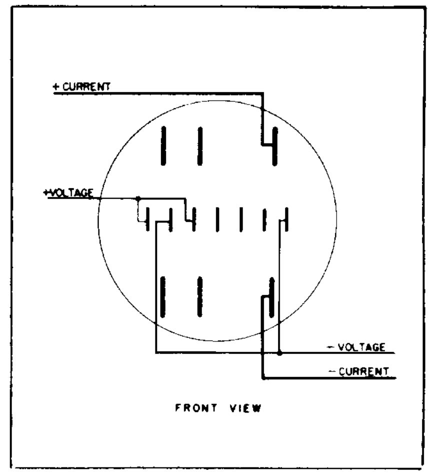
D5S-7, D4S-7, E1S-7E 3-phase, 4-wire, delta self-contained – Right Stator Test. FORM 15S



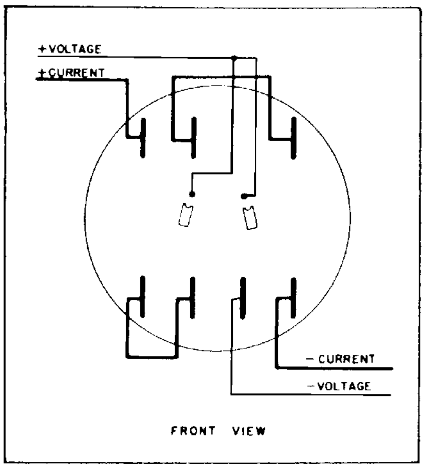
D5S-7, D4S-7, E1S-7E 3-phase, 4-wire, delta transformer-type — Combined Stator Test. FORM 8S



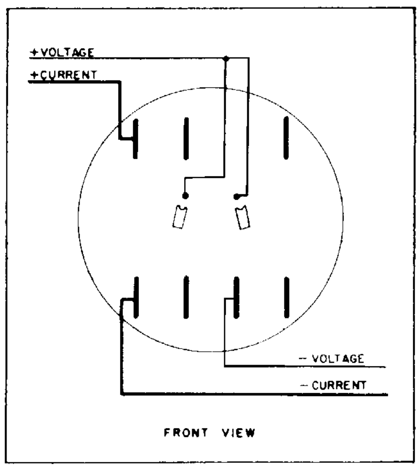
D5S-7, D4S-7, E1S-7E 3-phase, 4-wire, delta transformer-type — Left Stator Test. FORM 8S



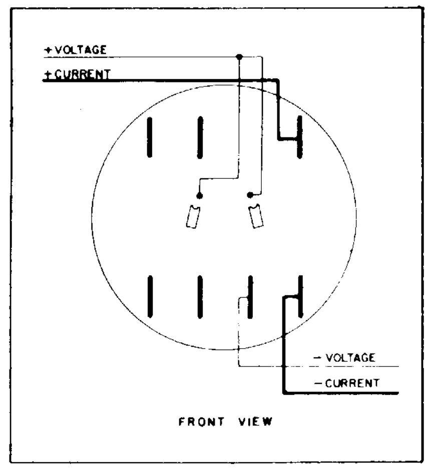
D5S-7, D4S-7, E1S-7E 3-phase, 4-wire, delta transformer-type — Right Stator Test. FORM 8S



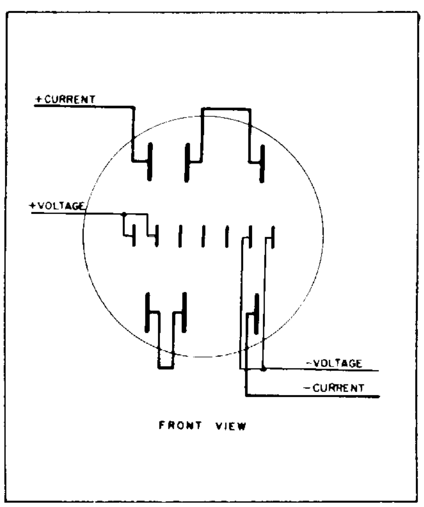
D5S-8, D4S-8, E1S-8E 3-phase, 4-wire, wye self-contained — Combined Stator Test. FORM 14S



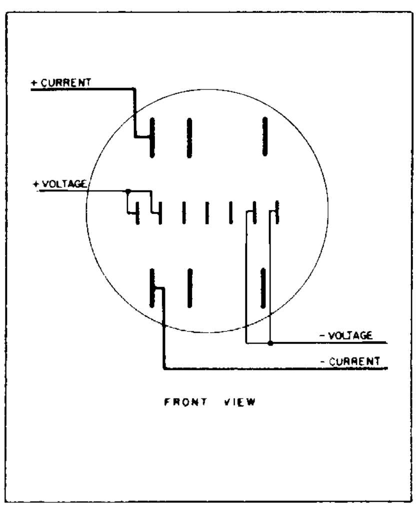
D5S-8, D4S-8, E1S-8E 3-phase, 4-wire, wye self-contained — Left Stator Test. FORM 14S



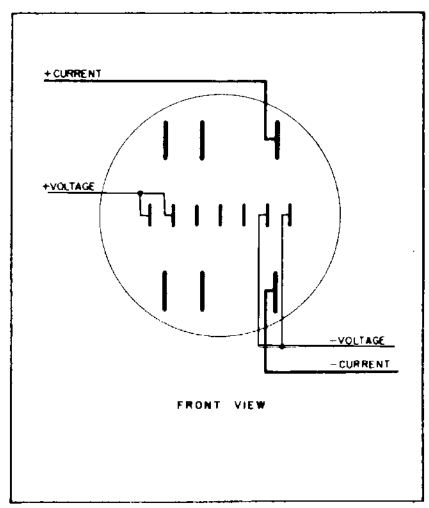
D5S-8, D4S-8, E1S-8E 3-phase, 4-wire, wye self-contained — Right Stator Test. FORM 14S



D5S-8, D4S-8, E1S-8E 3-phase, 4-wire, wye transformer-type — Combined Stator Test. FORM 6S

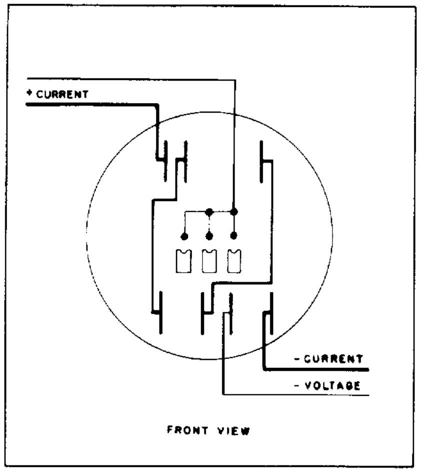


D5S-8, D4S-8, E1S-8E 3-phase, 4-wire, wye transformer type — Left Stator Test. FORM 6S

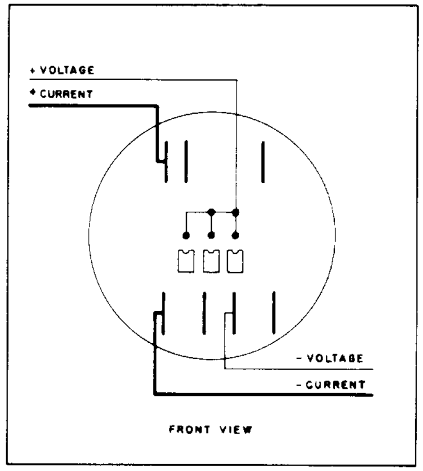


D5S-8, D4S-8, E1S-8E 3-phase, 4-wire, wye transformer-type — Right Stator Test. FORM 6S

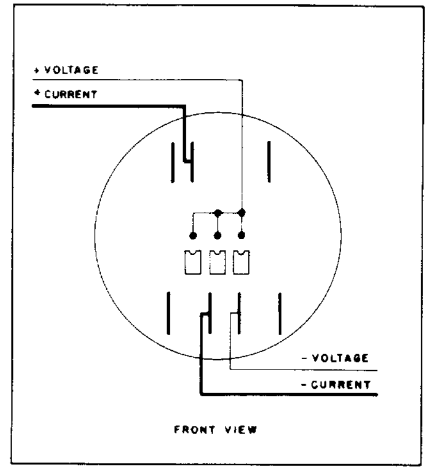
POLYPHASE TEST CONNECTIONS (Continued)



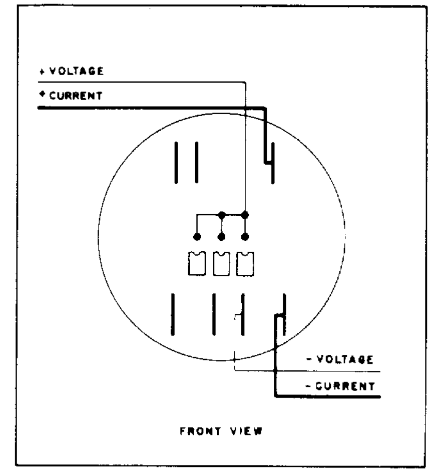
D5S-3, D4S-3, E1S-3E 3-phase, 4-wire wye
self-contained — Combined Stator Test.
FORM 16S



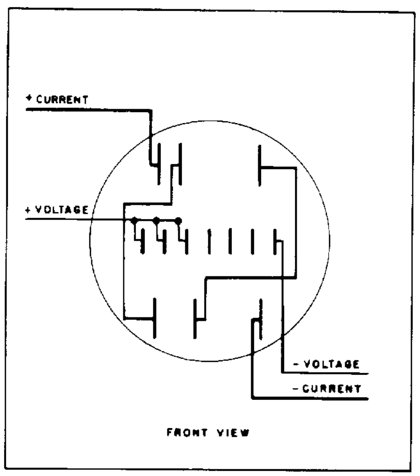
D5S-3, D4S-3, E1S-3E 3-phase, 4-wire, wye
self-contained — Left Stator Test.
FORM 16S



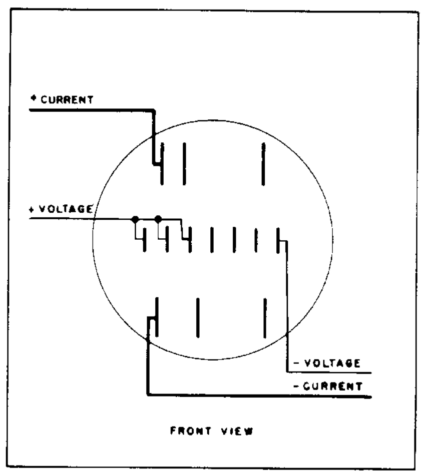
D5S-3, D4S-3, E1S-3E 3-phase, 4-wire wye
self-contained — Rear Stator Test.
FORM 16S



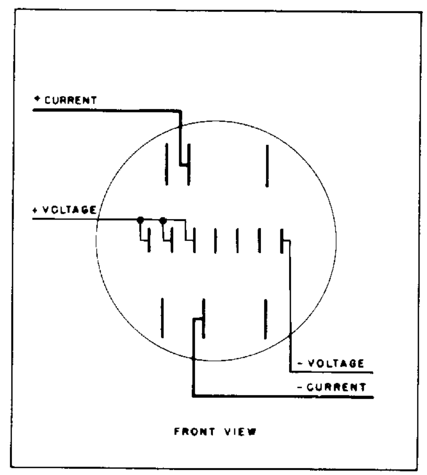
D5S-3, D4S-3, E1S-3E 3-phase, 4-wire, wye
self-contained — Right Stator Test.
FORM 16S



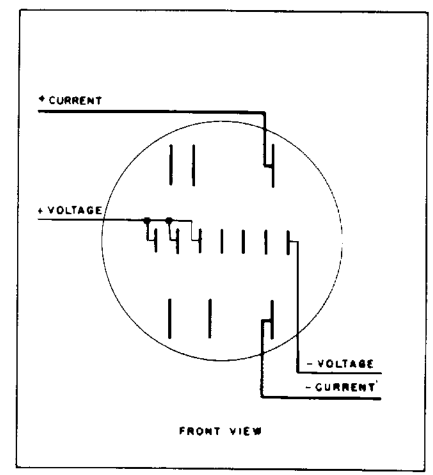
D5S-3, D4S-3, E1S-3E 3-phase, 4-wire, wye
Tx Type — Combined Stator Test.
FORM 9S



D5S-3, D4S-3, E1S-3E 3-phase, 4-wire, wye
Tx Type — Left Stator Test.
FORM 9S

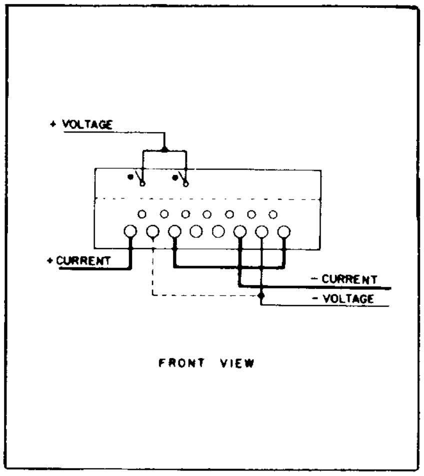


D5S-3, D4S-3, E1S-3E 3-phase, 4-wire wye
Tx Type — Rear Stator Test.
FORM 9S

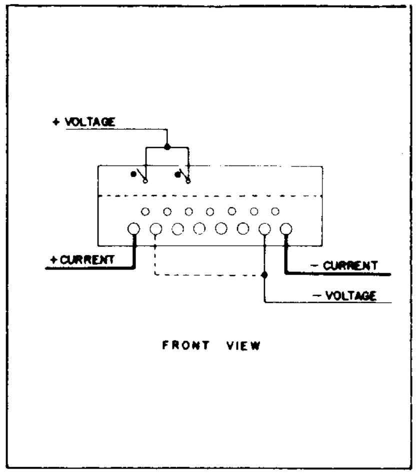


D5S-3, D4S-3, E1S-3E 3-phase, 4-wire, wye
Tx Type — Right Stator Test.
FORM 9S

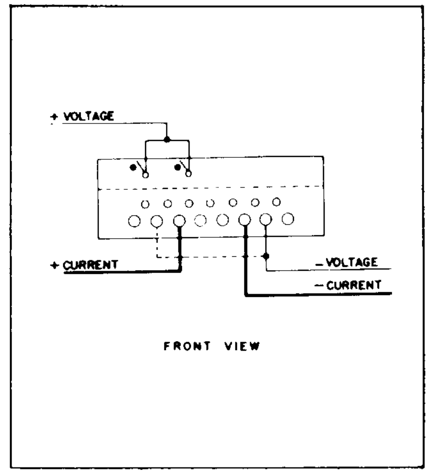
POLYPHASE TEST CONNECTIONS (Continued)



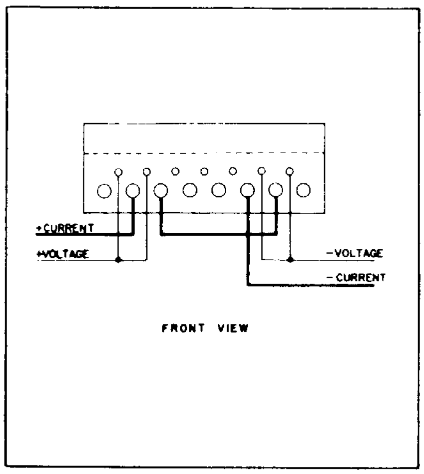
D5A-2, D4A-2 1-, 2-, or 3-phase, 3-wire, self-contained — Combined Stator Test. FORM 13A



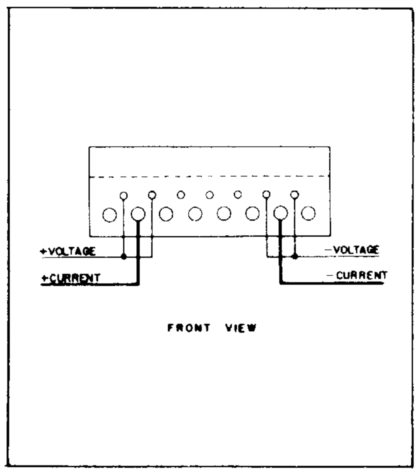
D5A-2, D4A-2 1-, 2-, or 3-phase, 3-wire, self-contained — Left Stator Test. FORM 13A



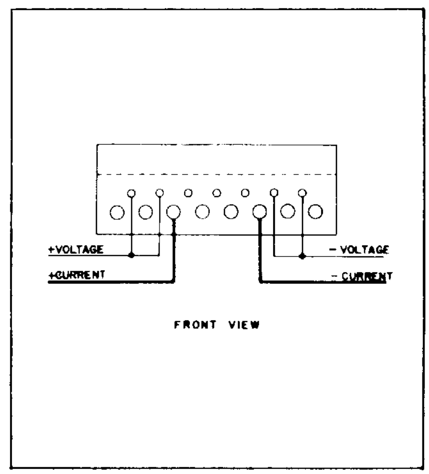
D5A-2, D4A-2 1-, 2-, or 3-phase, 3-wire, self-contained — Right Stator Test. FORM 13A



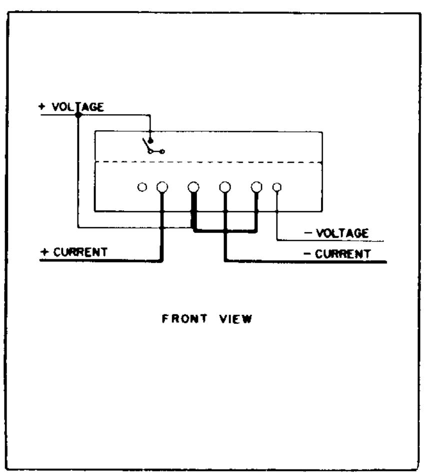
D5A-2, D4A-2, E1A-2E 1-, 2-, or 3-phase 3-wire, transformer-type — Combined Stator Test. FORM 5A



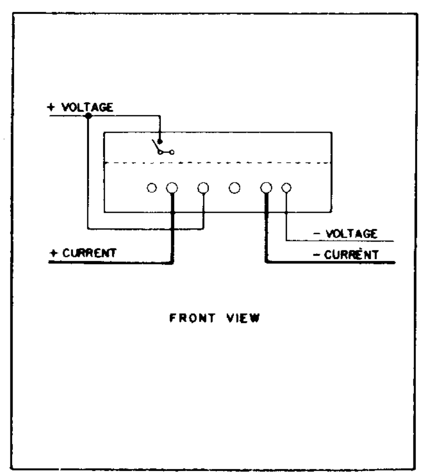
D5A-2, D4A-2, E1A-2E 1-, 2-, or 3-phase, 3-wire, transformer-type — Left Stator Test. FORM 5A



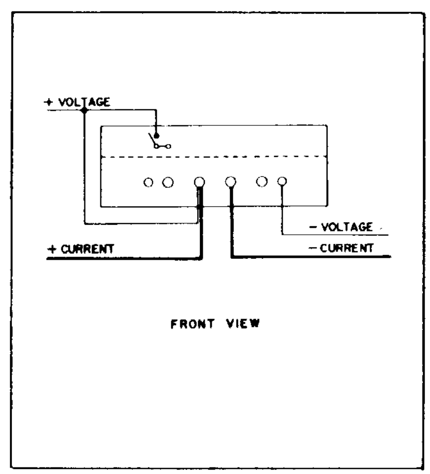
D5A-2, D4A-2, E1A-2E 1-, 2-, or 3-phase, 3-wire transformer-type — Right Stator Test. FORM 5A



D2A-5 1-, 2-, or 3-phase, 3-wire, self-contained — Combined Stator Test. FORM 12A

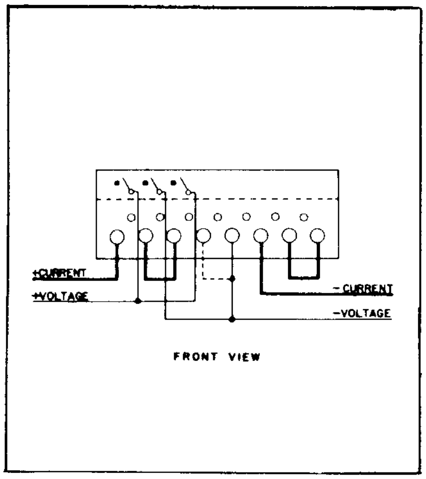


D2A-5 1-, 2-, or 3-phase, 3-wire, self-contained — Left Stator Test. FORM 12A

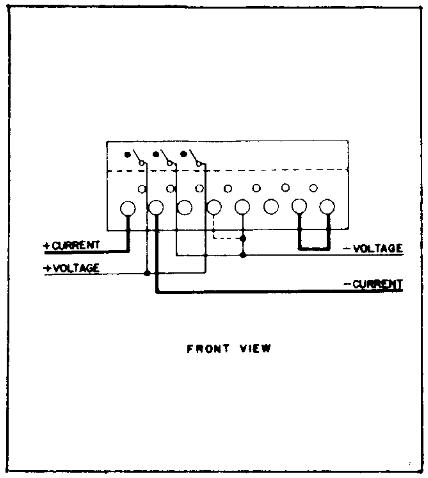


D2A-5 1-, 2-, or 3-phase, 3-wire, self-contained — Right Stator Test. FORM 12A

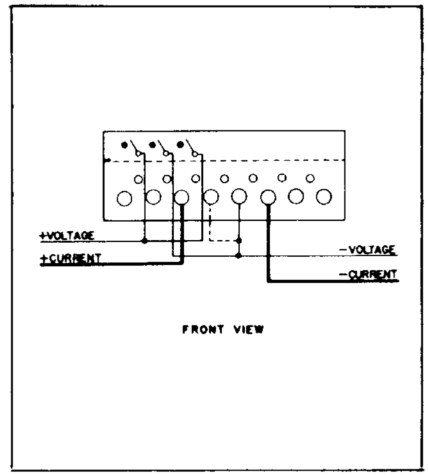
POLYPHASE TEST CONNECTIONS (Continued)



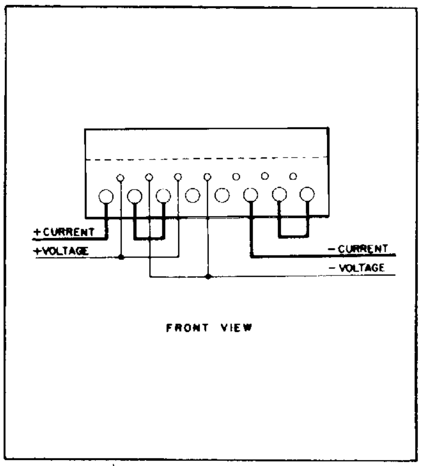
D5A-7, D4A-7 3-phase, 4-wire, delta self-contained — Combined Stator Test. FORM 15A



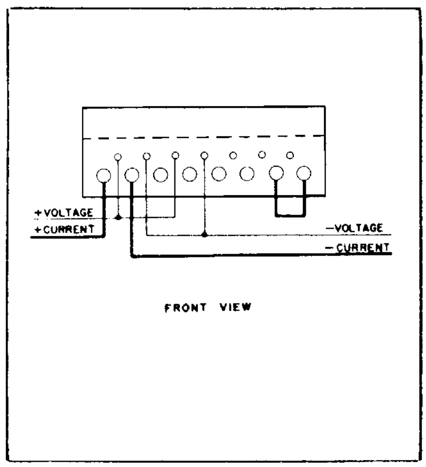
D5A-7, D4A-7 3-phase, 4-wire, delta self-contained — Left Stator Test. FORM 15A



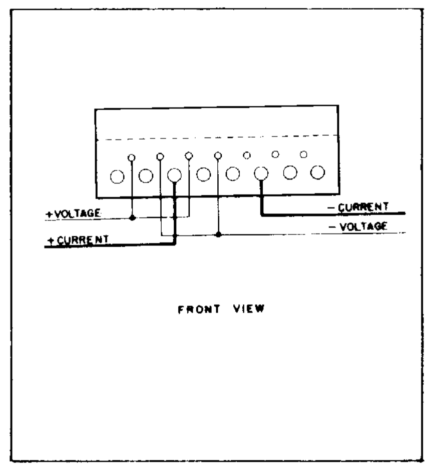
D5A-7, D4A-7 3-phase, 4-wire, delta self-contained — Right Stator Test. FORM 15A



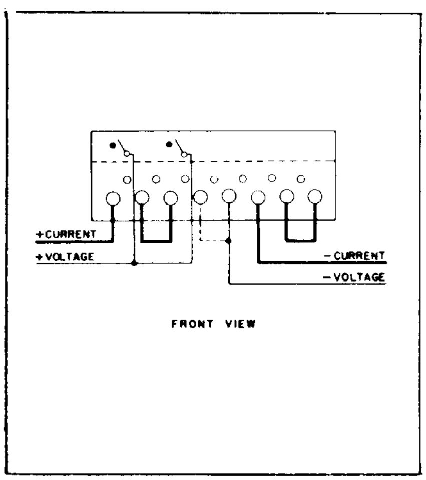
D5A-7, D4A-7, E1A-7E 3-phase, 4-wire, delta transformer-type — Combined Stator Test. FORM 8A



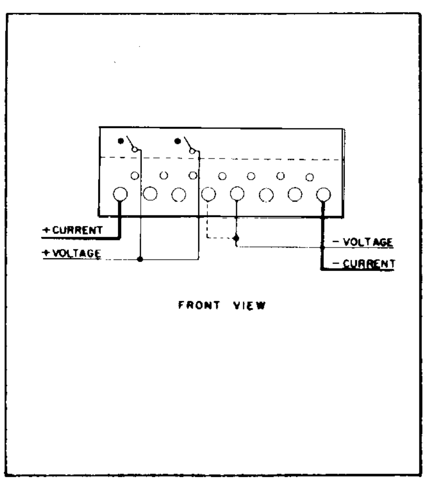
D5A-3, D4A-7, E1A-7E 3-phase, 4-wire, delta transformer-type — Left Stator Test. FORM 8A



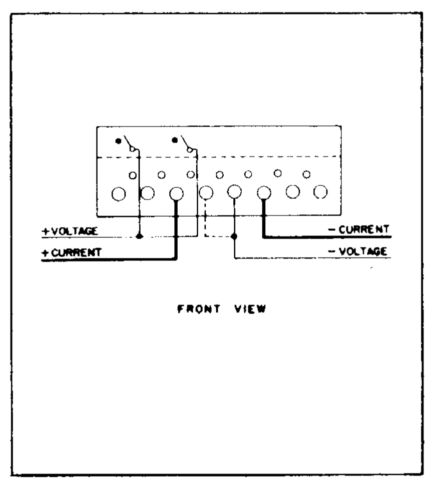
D5A-7, D4A-7, E1A-7E 3-phase, 4-wire, delta transformer-type — Right Stator Test. FORM 8A



D5A-8, D4A-8 3-phase, 4-wire, wye self-contained — Combined Stator Test. FORM 14A

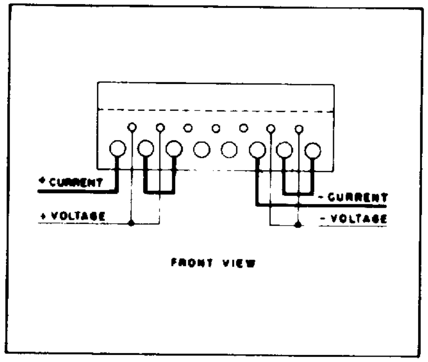


D5A-8, D4A-8 3-phase, 4-wire, wye self-contained — Left Stator Test. FORM 14A

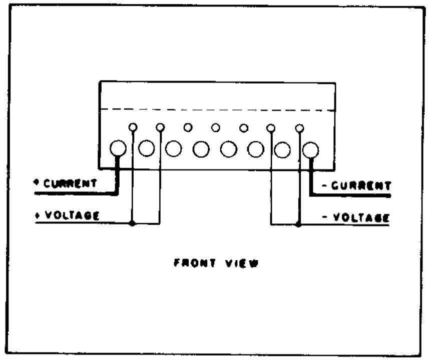


D5A-8, D4A-8 3-phase, 4-wire, wye self-contained — Right Stator Test. FORM 14A

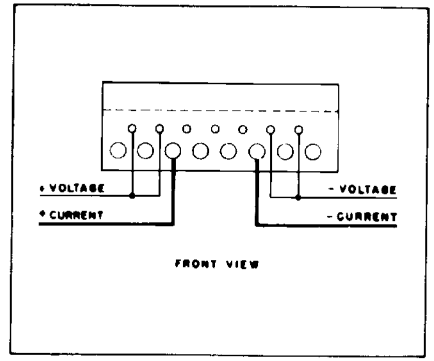
POLYPHASE TEST CONNECTIONS



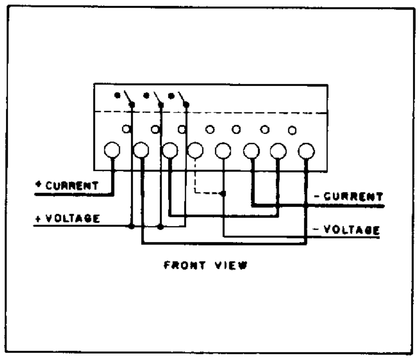
D5A-8, D4A-8, E1A-8E 3-phase, 4-wire, wye transformer-type – Combined Stator Test. FORM 6A



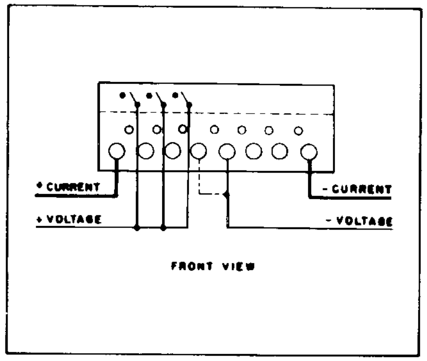
D5A-8, D4A-8, E1A-8E 3-phase, 4-wire, wye transformer-type – Left Stator Test. FORM 6A



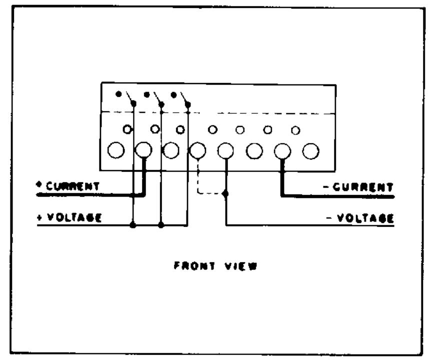
D5A-8, D4A-8, E1A-8E 3-phase, 4-wire, wye transformer-type – Right Stator Test. FORM 6A



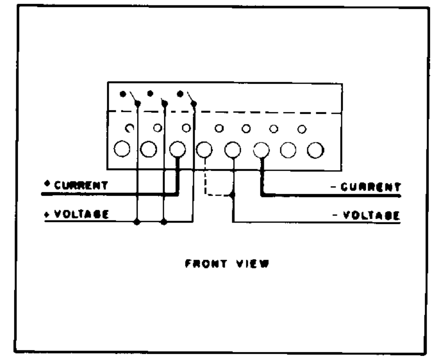
D5A-3, D4A-3 3-phase, 4-wire, wye self-contained – Combined Stator Test. FORM 16A



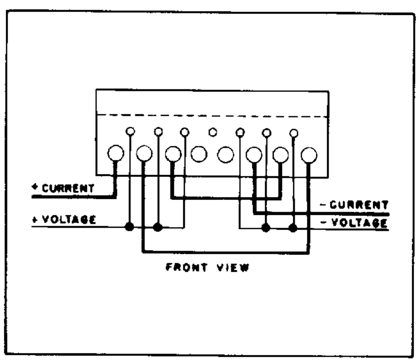
D5A-3, D4A-3 3-phase, 4-wire, wye self-contained – Left Stator Test. FORM 16A



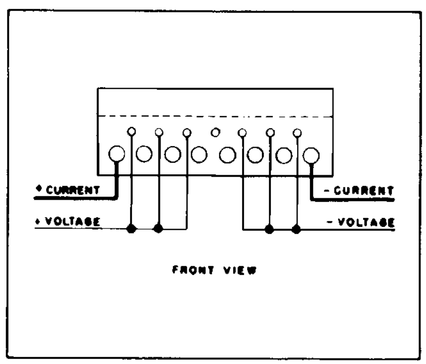
D5A-3, D4A-3 3-phase, 4-wire, wye self-contained – Rear Stator Test. FORM 16A



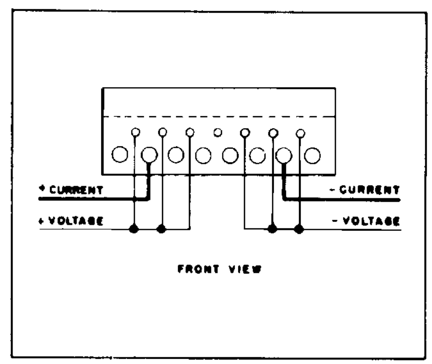
D5A-3, D4A-3 3-phase, 4-wire, wye self-contained – Right Stator Test. FORM 16A



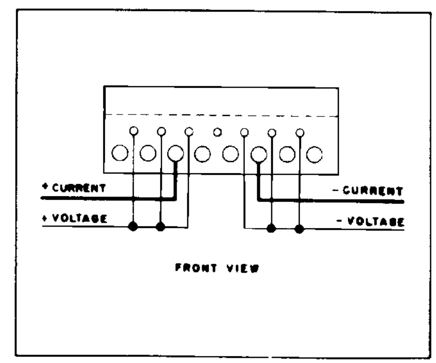
D5A-3, D4A-3, E1A-3E 3-phase, 4-wire, wye Tx Type – Combined Stator Test. FORM 9A



D5A-3, D4A-3, E1A-3E 3-phase, 4-wire, wye Tx Type – Left Stator Test. FORM 9A



D5A-3, D4A-3, E1A-3E 3-phase, 4-wire, wye Tx Type – Rear Stator Test. FORM 9A



D5A-3, D4A-3, E1A-3E 3-phase, 4-wire, wye Tx Type – Right Stator Test. FORM 9A

MAINTENANCE AND TESTING PROCEDURE

Recommended maintenance and testing procedure will vary considerably among the various meter designs. The manufacturer's Instruction Leaflets for each design should always be consulted when establishing a maintenance program.

However, the principle of watthour meter testing is always the same and consists of applying current and voltage to both a rotating standard and the meter under test, observing the revolutions of both, and calculating the meter accuracy by the following formula:

$$\%\text{ meter accuracy} = \frac{\text{Meter Revolutions x Kh of Meter x 100}}{\text{Standard Revolutions x Kh of Standard x N (Number of Stators)}}$$

The usual test points are referred to as full load, light load, and power factor. These are defined as follows:

FULL LOAD: Rated current, test amperes (TA) and rated voltage at unity power factor.

LIGHT LOAD: Ten percent of rated current and rated voltage at unity power factor.

POWER FACTOR: Rated current and rated voltage at 50 percent lagging power factor.

RULES FOR CHECKING METER INSTALLATIONS

(1) Check installation against All In One diagram.

(a) Pay particular attention to polarities—especially on instrument transformer installations.

(2) Check meter against unknown load, using formulas:

$$\text{Watts Load} = \frac{\text{Kh x Rev. x 3600}}{\text{Seconds}}$$ (Use watch with second hand.)

(3) Check line currents. On balanced loads, line currents will be approximately the same. (The above applies for all installations.)

(4) 3-Phase, 3-Wire

(a) Interchange two voltage leads on line side. Meter should stop on balanced loads, regardless of power factor.

(b) Open common potential. On balanced loads, meter should run at half-speed.

(5) 3-Phase, 4-Wire Wye (2-Stator or "Z")

(a) Interchange two voltage leads on line side. Meter should stop on balanced loads, regardless of power factor.

(b) Open common potential. On balanced loads, meter should run at half-speed.

(6) 3-Phase, 4-Wire Delta (2-Stator)

(a) Check one element at a time. On balanced loads, speed should be the same for each element regardless of power factor.

(7) Network

(a) Interchange two voltage leads on line side. Meter should run backwards.

(b) Check one element at a time. Meter should run at same speed on balanced load, regardless of power factor.

FUNDAMENTALS OF INSTRUMENT TRANSFORMERS

Instrument Transformers perform two primary functions:

(a) They transform the line current or voltage to values suitable for standard instrument which normally operate on 5 amperes and 120 volts.

(b) They isolate the instruments and meters from the line voltage. To make this protection complete for both instruments and operators, the secondary circuit should be grounded. See IEEE Standard 52, Application Guide For Grounding or Instrument Transformer Secondary Circuits And Cases.

Instrument Transformers are intended for measurement and control purposes:

(a) Current Transformers: Designed to have its primary winding connected in series with a circuit carrying the current to be measured or controlled. The secondary winding will then deliver a current proportional to the line current for operation of meters, instruments and relays.

(b) Voltage Transformers: Designed to have its primary winding connected in parallel with a circuit, the voltage of which is to be measured or controlled. The secondary winding will then deliver a voltage proportional to the line voltage for operation of meters, instruments and relays.

CURRENT TRANSFORMERS

Types of Current Transformers with respect to mechanical construction

Current transformers are classified as to their construction as follows:

(a) Window type: This type has a secondary winding completely insulated and permanently assembled on the core, but has no primary winding. This type of construction is commonly used on 600 volt class current transformers.

(b) Bar type: Same as the window type except a primary bar is inserted into the window opening. This bar can be permanently fixed into its position or be removable.

(c) Wound (wound-primary) type: This type has the primary and secondary windings completely insulated and permanently assembled on the core. The primary is usually a multi-turn winding.

Types of Current Transformers with respect to electrical connection

(a) Single primary: This term is frequently applied to current transformers having a single primary electrical circuit and is generally used to distinguish them from current transformers having series-parallel primary windings.

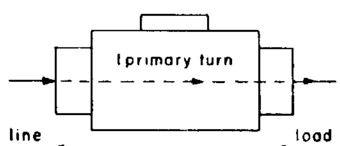
(b) Window type with one or more primary turns: A single conductor straight through a window-type transformer is a "one-turn primary" connection such as described above and shown in Figure 1 below.

If this single conductor is taken through the "window" twice (see Figure 2)—the nameplate primary rating is reduced by 1/2. (Multiply meter reading by 1/2 the CT nameplate ratio.)

If on a single-phase, three-wire circuit, two different leads are taken through the same window transformers (see Figure 3)—the nameplate primary rating is reduced by 1/2. (Multiply meter reading by 1/2 the CT nameplate ratio.)

(c) Double ratio: Double-ratio units are built either with a two-part series parallel winding or with a tap on the secondary winding.

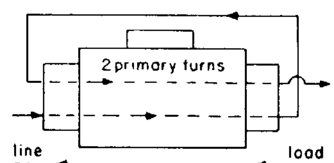
single-phase, two-wire metering



nameplate ratio	actual ratio
200/5	200/5
400/5	400/5
600/5	600/5
800/5	800/5

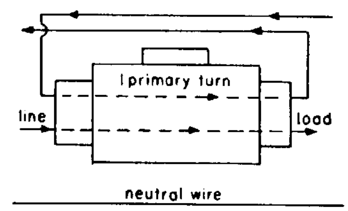
Fig. 1

single-phase, three-wire metering



nameplate ratio	actual ratio
200/5	100/5
400/5	200/5
600/5	300/5
800/5	400/5

Fig. 2



nameplate ratio	actual ratio
200/5	100-100/5
400/5	200-200/5
600/5	300-300/5
800/5	400-400/5

Fig. 3

Current transformer Insulation

Current transformer insulation ratings are expressed in terms of Nominal System Voltage, Maximum Line-to-Ground Voltage and the corresponding Basic Impulse Insulation Level. These ratings are shown in Table (a) from IEEE C57.13-1993.

Table (a): Basic Impulse Insulation Levels for Current Transformers

Nominal System Voltage (kV)	Maximum Line-to Ground Voltage (kV)	BIL and Full Wave Crest kV
0.6	0.38	10
2.4	1.53	45
4.8	3.06	60
8.32	5.29	75
13.8	8.9	110 or 95
25.0	16.0	150 or 125
34.5	22.0	200 or 150
46.0	29.0	250
69.0	44.0	350

Current Transformer Burdens

The burden on a current transformer is the vector sum of resistances and reactances of all instruments connected in series in the secondary circuit, plus the resistance of secondary leads.

The name burden is used to distinguish this from the load on the primary circuit which is being metered or controlled.

Burden is expressed either as total ohms impedance at a certain power factor (not the load power factor), or as total volt amperes and power factor. These values apply for the condition of rated secondary current and frequency.

Standard metering burdens (from ANSI standards) are listed below. These, and the standard accuracy classes, have been established to facilitate comparison of different transformers on a uniform basis.

Table (b): Standard Metering Burdens for Standard 5-ampere Secondary Current Transformers

Standard Metering Burden Characteristics	Impedance, power factor and volt-ampere standard secondary burdens		
	for 60-cycle and 5-amp secondary current		
Burden Designation	Impedance: Ohms	Volt-amperes	Power Factor
B-0.1	0.1	2.5	0.9
B-0.2	0.2	5.0	0.9
B-0.5	0.5	12.5	0.9
B-0.9	0.9	22.5	0.9
B-1.8	1.8	45	0.9

Voltage Transformer Insulation

The insulation ratings for voltage transformers are expressed in terms of Rated Primary Voltage, Marked Ratio and the corresponding Basic Impulse Insulation Level. These values are shown in Table (c) from IEEE C57.13-1993.

Table (c): Ratings of Groups 1, 2 & 5 Voltage Transformers

Group 1 voltage transformers are for application with 100 percent of rated primary voltage across the primary winding when connected line-to-line or line-to-ground. Group 1 transformers shall be capable of continuous operation at 110 percent of rated voltage provided the burden, in volt-amperes at this voltage, does not exceed the thermal burden rating.

Rated Primary Voltage for Rated Voltage Line-to-Line (V)	Marked Ratio	Basic Impulse Insulation Level (kV Crest)
120 for 208Y	1:1	10
240 for 416Y	2:1	10
300 for 520Y	2.5:1	10
2400 for 4160Y	20:1	60
4200 for 7280Y	35:1	75
4800 for 8320Y	40:1	75
7200 for 12 470Y	60:1	110 or 95
8400 for 14 560Y	70:1	110 or 95

Group 2 voltage transformers are primarily for line-to-line service, and may be applied line-to-ground or line-to-neutral at a winding voltage equal to the primary voltage rating divided by $\sqrt{3}$.

Group 2 transformers shall be capable of continuous operation at 110 percent rated voltage, provided the burden, in volt-amperes at this voltage, does not exceed the thermal burden rating.

<u>Table (c) (continued):</u>

Rated Primary Voltage for Rated Voltage Line-to-Line (V)	Marked Ratio	Basic Impulse Insulation Level (kV Crest)
120 for 120Y	1:1	10
240 for 240Y	2:1	10
300 for 300Y	2.5:1	10
480 for 480Y	4:1	10
600 for 600Y	5:1	10
2400 for 2400Y	20:1	45
4800 for 4800Y	40:1	60
7200 for 7200Y	60:1	75
12 000 for 12 000Y	100:1	110 or 95
14 400 for 14 400Y	120:1	110 or 95
24 000 for 24 000Y	200:1	150 or 125
34 500 for 34 500Y	300:1	200 or 150
46 000 for 46 000Y	400:1	250
69 000 for 69 000Y	600:1	350

NOTE: Voltage transformers connected line-to-ground on an ungrounded system cannot be considered to be grounded transformers and must not be operated with the secondaries in closed delta because excessive currents may flow in the delta.

<u>Group 5 voltage transformers</u> are for line-to-ground connection only, and are for use outdoors on grounded systems. They may be insulated-neutral or ground-neutral-terminal type. They shall be capable of operation at 140 percent of rated voltage for 1 min without exceeding 175°C temperature rise.

Group 5 voltage transformers shall be capable of continuous operation at 110 percent of rated voltage, provided the burden, in volt-amperes at this voltage, does not exceed the thermal burden rating.

Rated Primary Voltage for Rated Voltage Line-to-Line (V)	Marked Ratio	Basic Impulse Insulation Level (kV Crest)
7200 for 12 400 Gnd Y	60:1	110
8400 for 14 560 Gnd Y	70:1	110
12 000 for 20 800 Gnd Y	100:1	150 or 125
14 400 for 25 000 Gnd Y	120:1	150 or 125
20 125 for 34 500 Gnd Y	175:1	200 or 150

Voltage Transformer Burdens

The burden on a voltage transformer is expressed in volt-amperes (VA) which is the secondary voltage multiplied by the amperes flowing through the instruments which are connected in parallel in the secondary circuit. The name burden is used to distinguish this from the load on the primary circuit which is being metered or controlled.

Standard burdens (from ANSI standards) are listed below in Table (d). These and the standard accuracy classes have been established to facilitate comparison of different transformers on a uniform basis.

Table (d): Standard Burdens

Burden Designation	Secondary Volt-amperes	Burden Power Factor
W	12.5	0.10
X	25	0.70
Y	75	0.85
Z	200	0.85
ZZ	400	0.85
M	35	0.20

Accuracy

Because of the function they perform, all instrument transformers must be classified as to accuracy. The error in an instrument transformer used in revenue metering is a combination of ratio error and phase angle error. The accuracy the transformer will maintain is given as a certain class—such as 0.3 or 0.6 accuracy class.

Meters can be adjusted to compensate for transformer error. However, in modern metering, the transformer error is small enough that it is neglected.

Polarity

When instrument transformers are used with instruments or relays which operate only according to the magnitude of the current or voltage, the phase position or direction of flow of current is of no consequence; the connection to the secondary terminals may be reversed without changing the indication of the instrument.

When instrument transformers are used with watthour meters in which the operation depends on the interaction of both current and voltage, the direction of current in the primary and secondary windings must be known. This is indicated by marking one primary and one secondary terminal with a distinctive POLARITY MARKER. According to Figure 4, when current is flowing toward the transformer in the marked primary lead, it is flowing away from the transformer in the marked secondary lead.

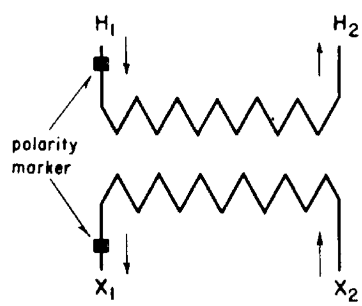


Figure 4 - Arrows indicate instantaneous relative direction of currents in the windings.

SAFETY

Always short a current transformer secondary winding before removing a meter. Never short a voltage transformers secondary winding.

FUNDAMENTALS OF WATTHOUR METERS

Watthour meters measure electrical energy by utilizing interaction of fluxes generated by the current and voltage elements acting to produce eddy currents in the rotor (disk). They eddy current flow produces lines of force which in turn interact with the flux in the air gap to produce turning torque on the disk. The meter is then a carefully calibrated induction motor, the speed of which depends upon the energy being measured. Each revolution of the meter disk has a value in watt-hours. The register counts these revolutions and displays the count as KWH's.

Amps x Volts x Stators (at unity PF) = Watts (capacity)

$$\frac{WH}{H} \div \frac{R}{H} = \frac{WH}{H} \times \frac{H}{R} = \frac{WH}{R} = \text{Kh (test constant – watthours per revolution)}$$

R/H represents design disk speed (speed of the disk with all stators excited with rated current and voltages). Since this design speed is the same for all meters of a given type or design family, a variety of gearing ratios is required to properly represent different current-voltage values and different numbers of stators. Register ratios (Rr) are selected to accomplish this task. A 30 amp, 240 volt, two-stator meter has a different register ratio than does a 15 amp, 120 volt, three-stator meter though both run at the same full load speed.

$$Rr = \frac{10 \times 1000}{Kh \times 1st\ Red.} = \text{One revolution of "pick-off" gear to one revolution of KWH dial.}$$

10 represents one revolution of first dial of register (read as 10 KWH's)

1000 represents WH/KWH - Required to relate disk rotation to dial rotation.

Kh represents value of one revolution of disk expressed in $\frac{WH}{R}$

First reduction at shaft is ratio disk to "pick-off" gear.

For example, if disk shaft has a single lead worm and register pick-off gear has 100 teeth, first reduction at shaft is 100/1.

All meters are wired internally to conform to form numbers which are marked on the meter nameplate. It is possible to relate a circuit diagram to the meter wiring by references to the meter form number.

HANDY TABLES AND FORMULAS

Formulas for determining amperes, hp, kw, and kva

to find	direct current	alternating current		
		single phase	two phase-4 wire*	three phase
amperes when horsepower is known	$\frac{hp \times 746}{E \times \% eff}$	$\frac{hp \times 746}{E \times \% eff \times p\text{-}f}$	$\frac{hp \times 746}{2 \times E \times \% eff \times p\text{-}f}$	$\frac{hp \times 746}{1.73 \times E \times \% eff \times p\text{-}f}$
amperes when kilwatts is known	$\frac{kw \times 1000}{E}$	$\frac{kw \times 1000}{E \times p\text{-}f}$	$\frac{kw \times 1000}{2 \times E \times p\text{-}f}$	$\frac{kw \times 1000}{1.73 \times E \times p\text{-}f}$
amperes when kva is known		$\frac{kva \times 1000}{E}$	$\frac{kva \times 1000}{2 \times E}$	$\frac{kva \times 1000}{1.73 \times E}$
kilowatts	$\frac{I \times E}{1000}$	$\frac{I \times E \times p\text{-}f}{1000}$	$\frac{I \times E \times 2 \times p\text{-}f}{1000}$	$\frac{I \times E \times 1.73 \times p\text{-}f}{1000}$
kva		$\frac{I \times E}{1000}$	$\frac{I \times E \times 2}{1000}$	$\frac{I \times E \times 1.73}{1000}$
horsepower (output)	$\frac{I \times E \times \% eff}{746}$	$\frac{I \times E \times \% eff \times p\text{-}f}{746}$	$\frac{I \times E \times 2 \times \% eff \times p\text{-}f}{746}$	$\frac{I \times E \times 1.73 \times \% eff \times p\text{-}f}{746}$

*For 3-wire, 2-phase circuits the current in the common conductor is 1.41 times that in either of the two other conductors.

Common electrical terms

ampere (I) = unit of current or rate of flow of electricity
volt (E) = unit of electromotive force
ohm (R) = unit of resistance
ohms law—$I = \frac{E}{R}$ (d-c or 100% p-f)
megohm = 1,000,000 ohms
volt amperes (va) = unit of apparent power
= EI (single phase)
= E x I x 1.73 (3-phase)
kilovolt amperes (kva) = 1000 volt-amperes
watt (w) = unit of true power
= va x p-f
= .00134 hp
kilowatt (kw) = 1000 watts
power factor (p-f) = ratio of true to apparent power
$= \frac{w}{va} \circ \frac{kw}{kva}$
watthour (whr) = unit of electrical work
= one watt for one hour
= 3.413 Btu
= 2,655 ft lbs
kilowatthour (kwhr) = 1000 watthours
horsepower (hp) = measure of time rate of doing work
= equivalent of raising 33,000 lbs, one ft in one minute
= 746 watts
demand factor = ratio of maximum demand to the total connected load
diversity factor = ratio of the sum of individual maximum demands of the various subdividions of a system to the maximum demand of the whole system
load factor = ratio of the average load over a designated period of time to the peak load occurring in that period

How to compute power factor

Determining watts:

$$p\text{-}f = \frac{watts}{volts \times amperes}$$

1. From watthour meter.
   watts = rpm of disc x 60 x kh
   Where kh is meter constant printed on face or nameplate of meter.
   If metering transformers are used, above must be multiplied by the transformer ratios.

2. Directly from wattmeter reading.
   where:
   volts = line-to-line voltage as measured by voltmeter
   amps = current measured in line wire (not neutral) by ammeter.

Conversion factors

$C° = \frac{5}{9} \times (F° - 32°)$ $F° = \frac{9}{5}C° + 32°$

C°	–15	–10	–5	0	5	10	15	20
F°	5	14	23	32	41	50	59	68
C°	25	30	35	40	45	50	55	60
F°	77	86	95	104	113	122	131	140
C°	65	70	75	80	85	90	95	100
F°	149	158	167	176	185	194	203	212

1 inch = 2.54 centimeters
1 kilogram = 2.20 lbs
1 square inch = 1,273,200 circular mills
1 circular mill = .785 square mill
1 btu = 778 ft lbs
= 252 calories
1 year = 8,760 hours

VALUES OF COMMONLY USED TRIGONOMETRIC FUNCTIONS

Angle	Sin	Cos	Tan	Cot	Sec	Csc
0	0.000	1.000	0.000	∞	1.000	∞
15	0.259	0.966	0.268	3.732	1.035	3.861
30	$0.500 = \left(\frac{1}{2}\right)$	$0.866 = \left(\frac{\sqrt{3}}{2}\right)$	$0.577 = \left(\frac{1}{\sqrt{3}}\right)$	$1.732 = \left(\sqrt{3}\right)$	$1.155 = \left(\frac{2}{\sqrt{3}}\right)$	2.000
45	$0.707 = \left(\frac{1}{\sqrt{2}}\right)$	$0.707 = \left(\frac{1}{\sqrt{2}}\right)$	1.000	1.000	$1.414 = \left(\sqrt{2}\right)$	$1.414 = \left(\sqrt{2}\right)$
60	$0.866 = \left(\frac{\sqrt{3}}{2}\right)$	$0.500 = \left(\frac{1}{2}\right)$	$1.732 = \left(\sqrt{3}\right)$	$0.577 = \left(\frac{1}{\sqrt{3}}\right)$	2.000	$1.155 = \left(\frac{2}{\sqrt{3}}\right)$
75	0.966	0.259	3.732	0.268	3.861	1.035
90	1.000	0.000	∞	0.000	∞	1.000
120	$0.866 = \left(\frac{\sqrt{3}}{2}\right)$	$-0.500 = \left(-\frac{1}{2}\right)$	$-1.732 = \left(\sqrt{3}\right)$	$-0.577 = \left(-\frac{1}{\sqrt{3}}\right)$	-2.000	$1.155 = \left(\frac{2}{\sqrt{3}}\right)$
150	$0.500 = \left(\frac{1}{2}\right)$	$-0.866 = \left(\frac{-\sqrt{3}}{2}\right)$	$-0.577 = \left(-\frac{1}{\sqrt{3}}\right)$	$-1.732 = \left(-\sqrt{3}\right)$	$-1.155 = \left(-\frac{2}{\sqrt{3}}\right)$	2.000
180	0.000	-1.000	0.000	∞	-1.000	∞
270	-1.000	0.000	∞	0.000	∞	-1.000
360	0.000	1.000	0.000	∞	1.000	∞

∞ = Infinity

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