Introduction to CTs and PTs

THE EASTERN SPECIALTY COMPANY

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The Eastern Specialty Company

For MEUA Meter School 102
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8:00 a.m. – 9:30 a.m.

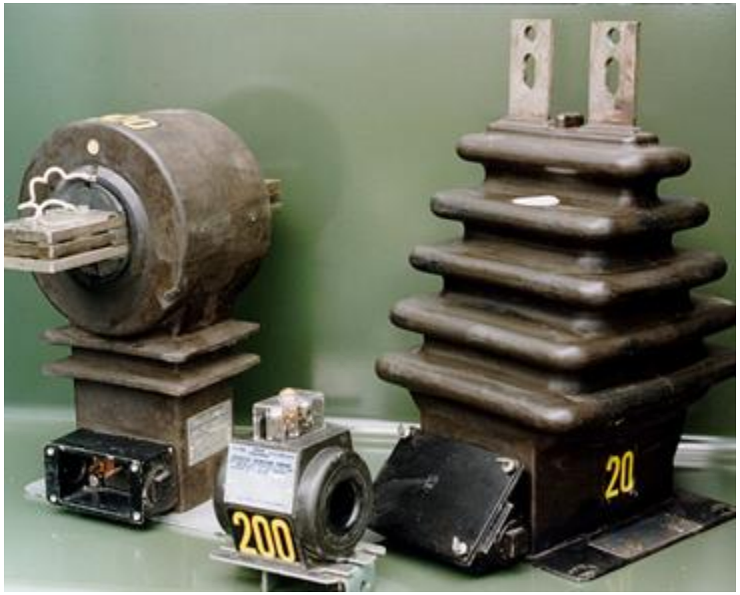
Definitions

- Instrument Transformer: A transformer that reproduces in its secondary circuit in a definite and known proportion, the voltage or current of its primary circuit with the phase relation substantially preserved.
- Current Transformer: An instrument transformer designed for the measurement or control of current. Its primary winding, which may be a single turn or bus bar, is connected in series with the load. It is used to reduce primary current by a known ratio to within the range of a connected measuring device.
- Potential Transformer: An instrument transformer designed for the measurement or control of voltage. Its primary winding is connected in parallel with a circuit. It is used to reduce primary voltage by a known ratio to within the range of a connected measuring device.

Three Types of ITs

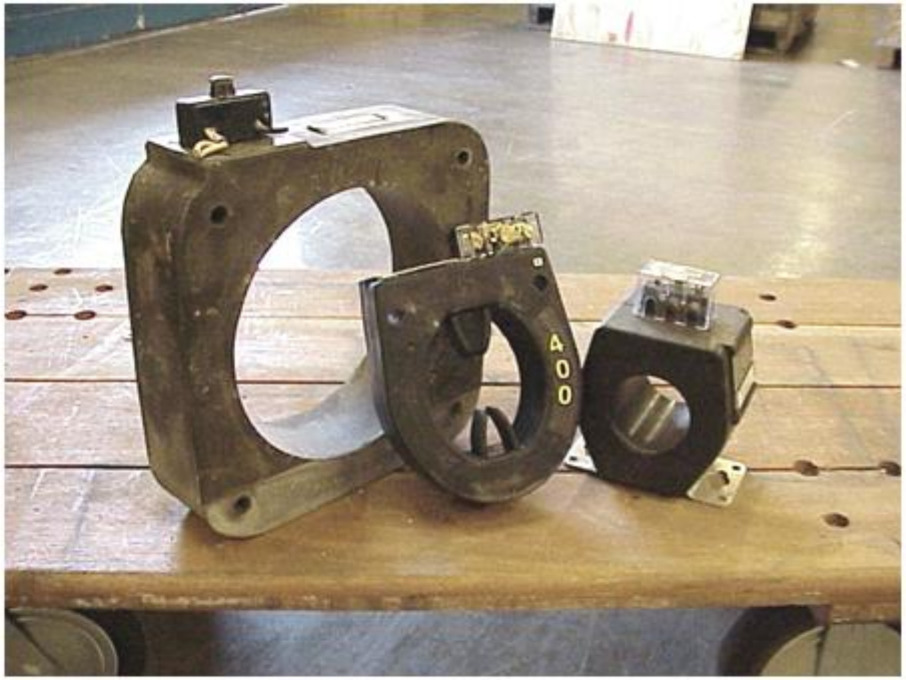
- Three basic types of instrument transformers:

1. Window type (applies to CT's only)
2. Bar type (applies to CT's only)
3. Wound type (applies to CT's and PT's)



Window Type CT “Pass through type”

- Definition: A current transformer that has a secondary winding insulated from and permanently assembled on the core, but has no primary winding as an integral part of the structure. (The secondary winding of all CT’s is intended for connection to the meter or other measuring device.) The line conductor can be passed through the window to provide the primary winding.



Bar Type CT

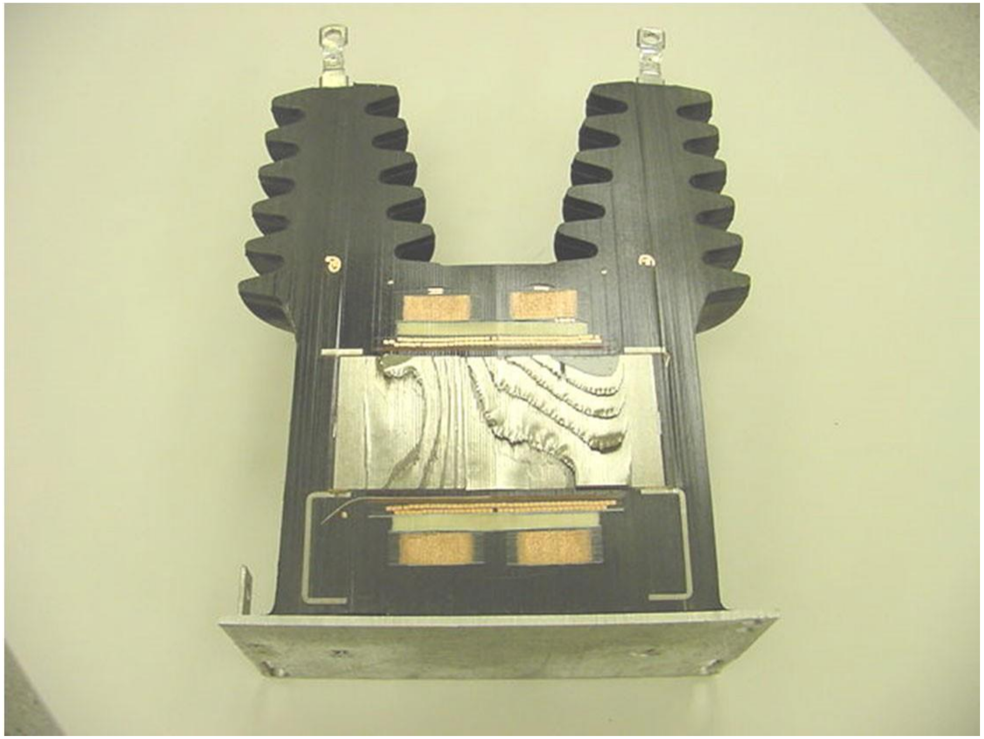
- Definition: A current transformer that has a fixed, insulated straight conductor in the form of a bar, rod, or tube that is a single primary turn passing through the magnetic circuit and that is assembled to the secondary core and winding.

Wound Type CT

- <u>Definition</u>: A current transformer that has a primary winding consisting of one or more turns mechanically encircling the core. The primary and secondary windings are insulated from each other and from the core and are assembled as an integral structure.

Wound Type PT

- All potential transformers are of the wound-type. The definition of a wound-type potential transformer would essentially be the same as a wound-type current transformer, having both the primary and secondary windings encircling the core and insulated from each other.



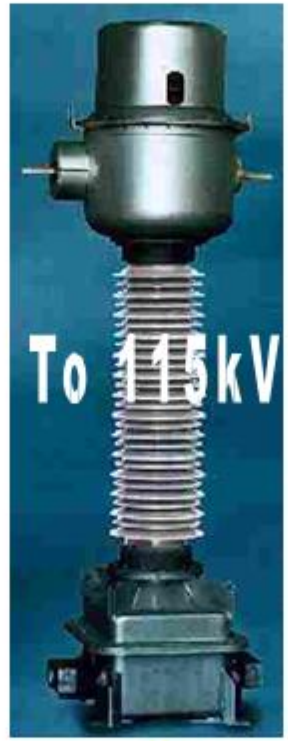
High Voltage Instrument Transformers

- Transmission Voltages
  - 46 to 500 kV

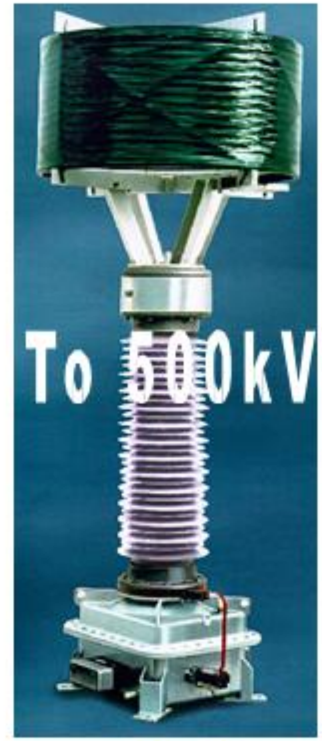
25kV to 500kV Oil-filled Instrument Transformers

VT'S

CT'S



M/U'S



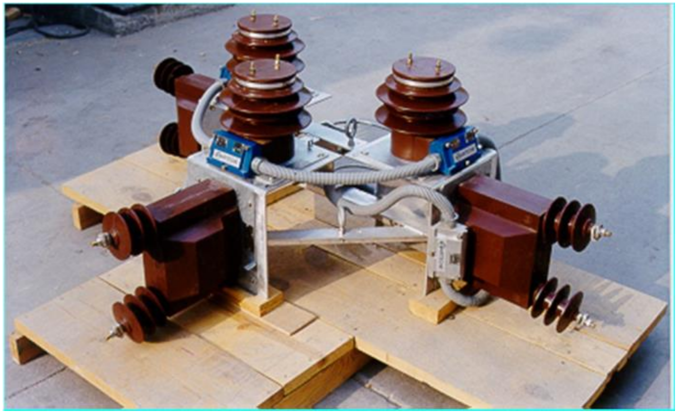
CCVT'S

SSVT'S

TESCO

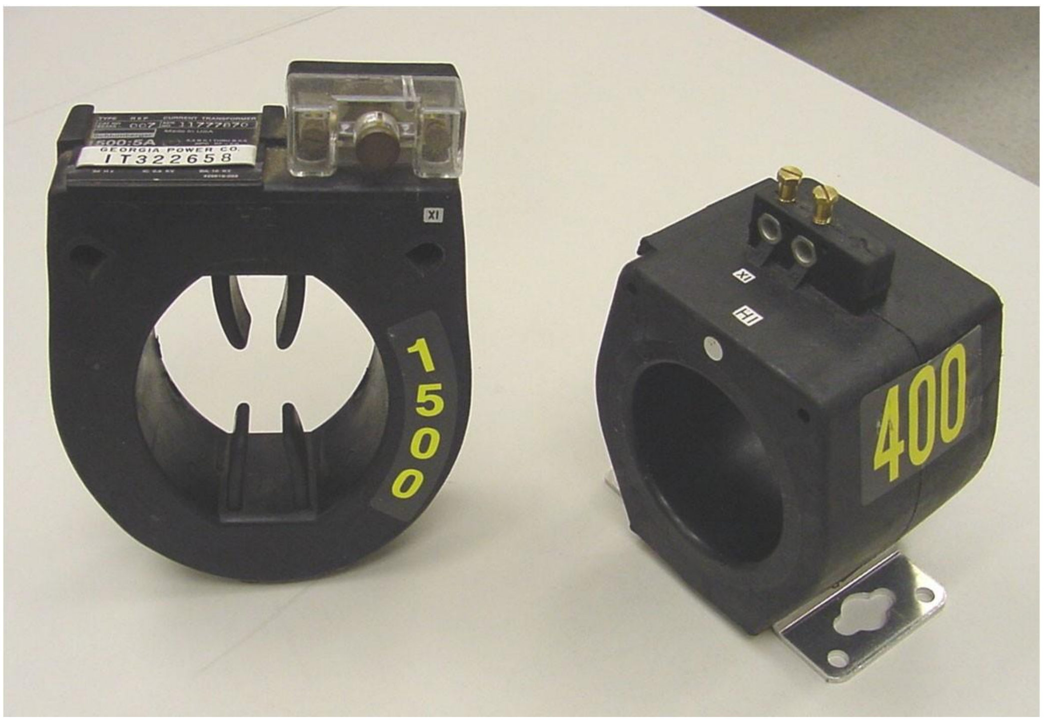
Medium Voltage Instrument Transformers

- Distribution Voltages
- 4 to 25 kV



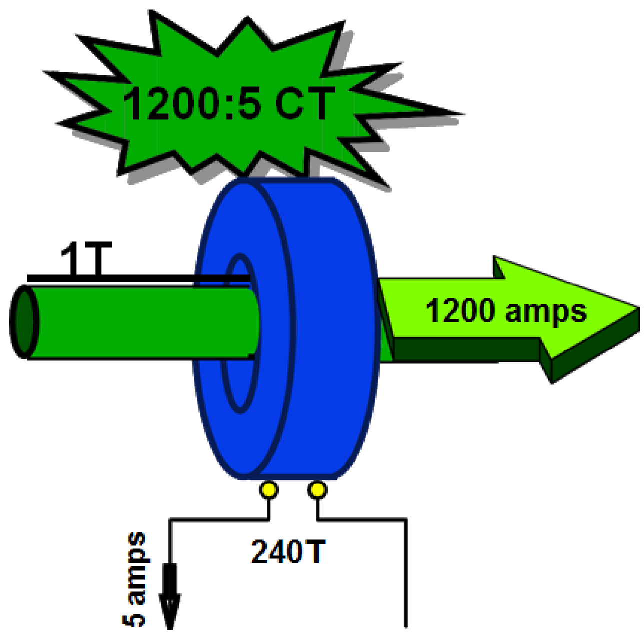
Low Voltage Instrument Transformers

- Secondary Voltages
- 600 Volts or Less



Current Transformer Ratio

- A current transformer's ratio is typically expressed with a secondary rating of 5 amps.
- The current transformer illustrated here would have a ratio of 1200 to 5.
- 1200 amps flowing through its primary winding (line wire) would cause 5 amps to flow to the meter



Current Transformer Turns Ratio

- A current transformer will have few primary turns and many secondary turns.
- The window-type CT to the right will have one primary turn (the customer's line wire) and 120 secondary turns.
- The turns ration is 120:1

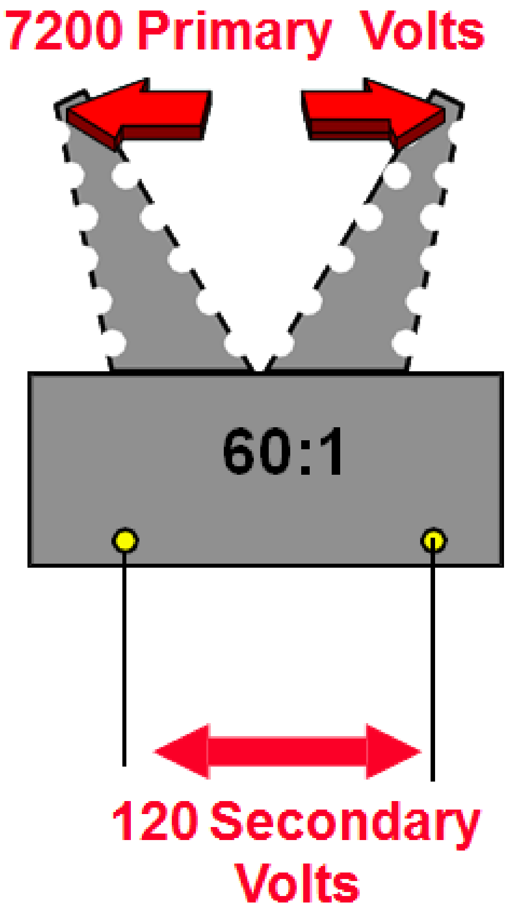
$$\frac{Primary\ \ current}{Secondary\ \ current} = \frac{Secondary\ \ turns}{Primary\ \ turns} = Turns\ \ Ratio$$

Current Transformer Turns Ratio

- The wound-type current transformer to the right has two primary turns.
- The conductor making up the primary winding consists of multiple layers of thin copper strapping approximately four inches wide.
- The secondary winding consists of many turns of small copper wire.

Potential Transformer Ratio

- Potential transformers are always designed to step the primary voltage down to 120 volts, or 115 volts in the case of high voltage transformers.
- Potential transformers will have a designated primary voltage rating.
- The PT illustrated at the right is designed to step 7200 volts down to 120 volts. Its ratio is 60 to 1.
- Potential transformers are designed for specific line voltages. A PT with a ratio of 2:1 is only designed to step 240 volts down to 120 volts. It should never, for example, be used to step 480 volts down to 240 volts. Voltages higher than rated may cause saturation of the core, resulting in large errors and excessive heating.



Potential Transformer Ratio

- Due to mislabeling of a substation transformer 14,400 volts was applied to these 60:1 potential transformers.

Potential Transformer Ratio

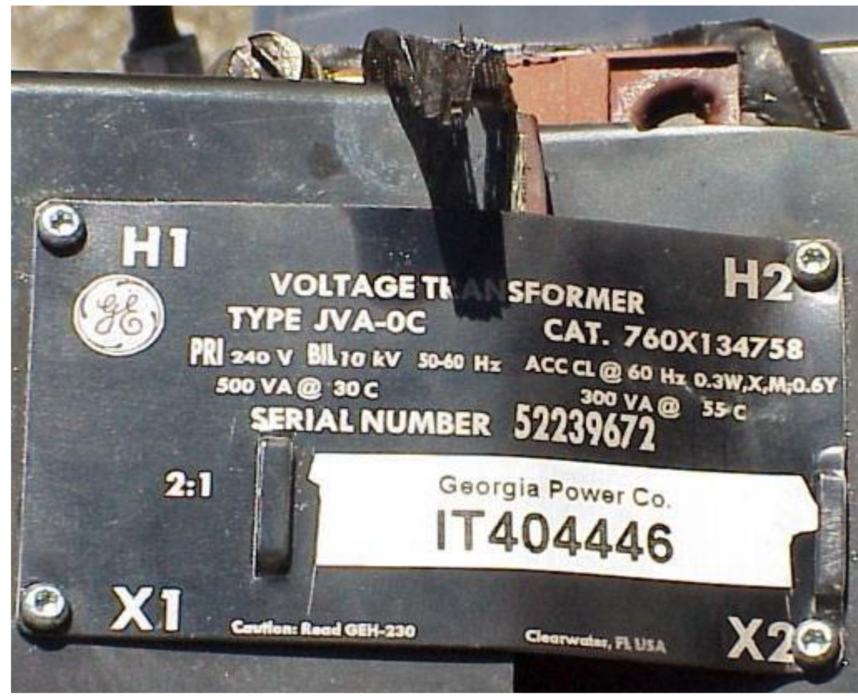
- Miscommunications resulted in this cluster with 20:1 PTs being installed on the high side of a 12470/7200V transformer bank.

Potential Transformer Ratio

- 4160 Volts was applied to this 20:1 PT.

Potential Transformer Ratio

- 480 Volts was applied to this 2:1 PT.



Potential Transformer Over Voltage

IEEE Standard C57.13-2008

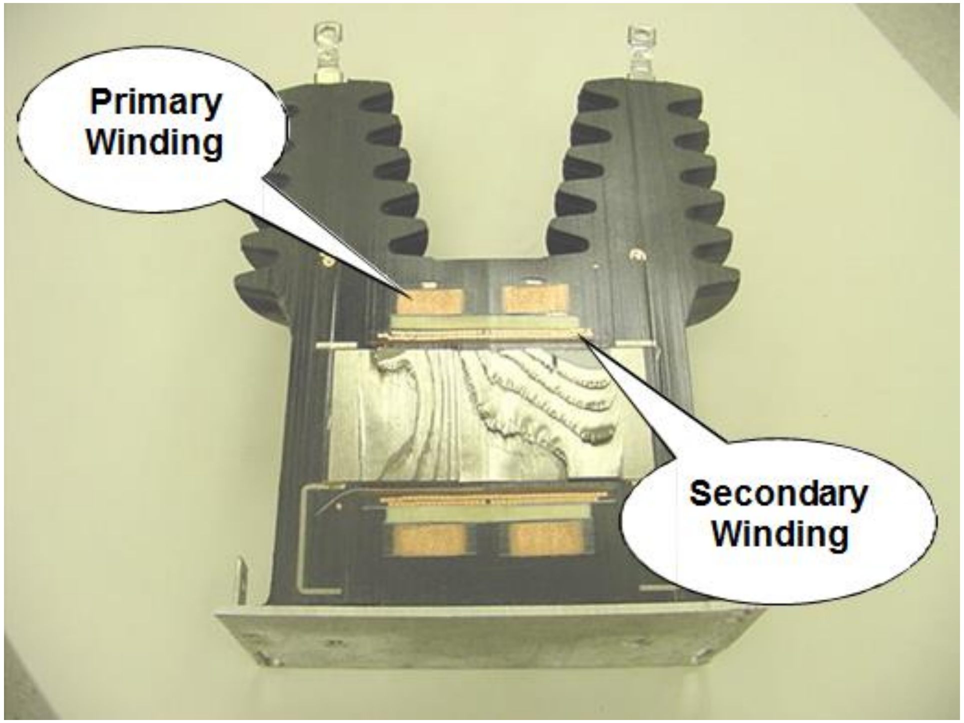
- The IEEE Standard defines five distinct groups of voltage transformers and provides ratings for each group. All must be capable of operating accurately at 110% above rating voltage continuously provided the secondary burden in VA at this voltage rating does not exceed the thermal rating.

- “Group 1” Voltage Transformers are the most commonly used.

- Primary voltage may be connected line-to-line or line-to-ground.
- Capable of operations at 125% of rated voltage on an emergency basis. (eight hours)
- Operation in emergency range will reduce life expectancy.

Potential Transformer Turns Ratio

- The primary winding of a potential transformer will consist of many turns of small wire.
- The secondary winding will be fewer turns of larger wire.



$$\frac{Primary\ \ voltage}{Secondary\ \ voltage} = \frac{Primary\ \ turns}{Secondary\ \ turns} = Turns\ \ ratio$$

Burden

- Burden is the term used to refer to the load on the secondary circuit of instrument transformers.
- An instrument transformer's "rated burden" is the load which may be imposed on the transformer secondary circuit by associated meter coils, leads and other connected devices without causing an error greater than the stated accuracy classification.
- Current transformer rated burdens are normally expressed in ohms impedance such as B-0.1, B-0.2, B-0.5 or B-1.8.
- Potential transformer rated burdens are normally expressed in volt-amperes at a designated power factor. This VA rating is typically represented by the letters W, X, M, Y, Z, or ZZ. For example, the letter "Y" designates a burden of 75 VA @ .85 power factor.

ANSI Standard Burdens for Voltage Transformers

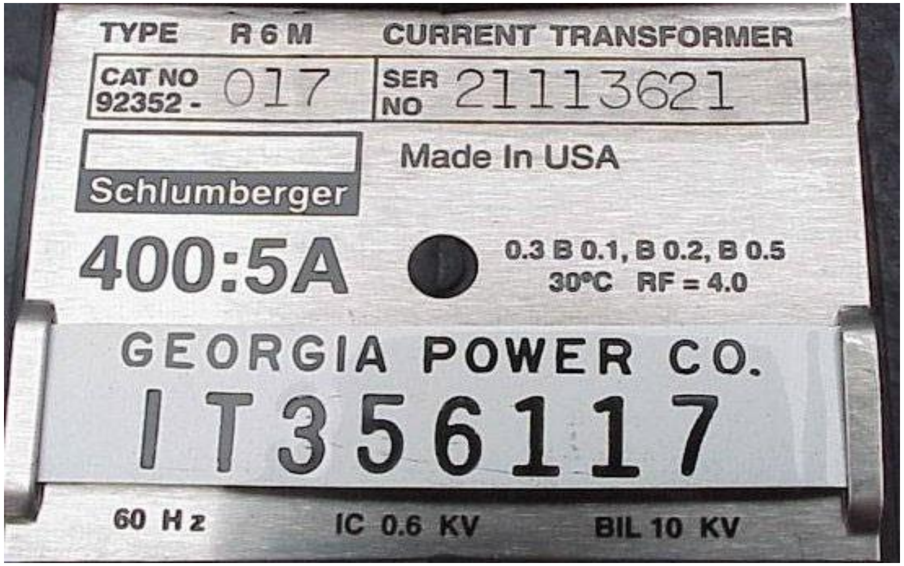
Burden	Volt-Amps at 120V Secondary	Power Factor
W	12.5	.01
X	25	.70
M	35	.20
Y	75	.85
Z	200	.85
ZZ	400	.85

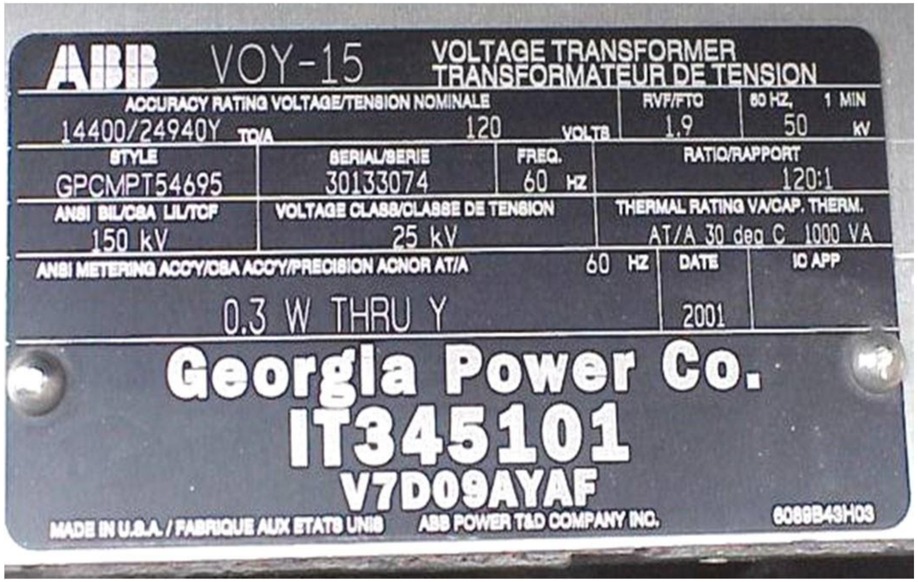
Accuracy of Instrument

- Two sources of error determine the accuracy of instrument transformers:
    - (1) Ratio error
    - (2) Phase angle error
- The "accuracy classification" of instrument transformers includes a correlation between ratio correction factor and phase angle so as to show the overall effect on meter registration.
- The ratio correction factor (RCF) is the ratio of the true ratio to the marked ratio.
- The phase angle of an instrument transformer is the phase displacement, in minutes, between the primary and secondary values.
- The transformer correction factor (TCF) is the correction for overall error due to both ratio error and phase angle.
- ANSI has established accuracy classes for both current and potential transformers. Typical classifications are 0.3% error for metering, and 0.6% to 1.2% error for indicating instruments. (ANSI C57.13)

Accuracy is Burden Dependent

- An accuracy classification for an instrument transformer includes the standard burden as well as the maximum percent error limits for ratio and phase angle error.
- The standard burdens for which a transformer's accuracy rating applies will be designated along with the accuracy rating.



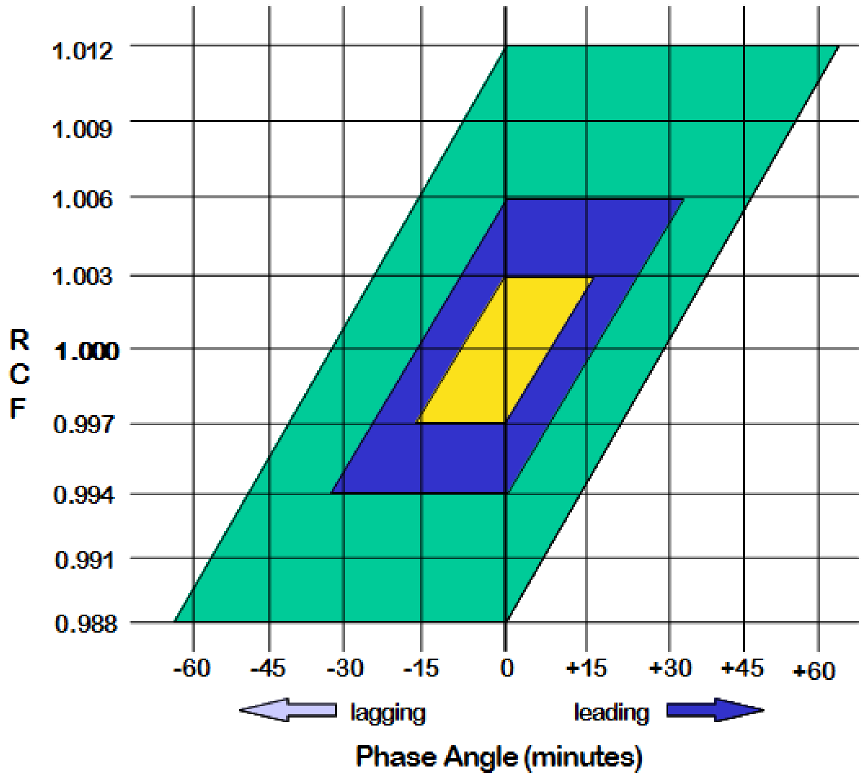


Current Transformer Accuracy

- The corresponding ratio correction factor and phase angle for any point inside the 0.3 class parallelogram for 100% rated current will always give a transformer correction factor between .997 and 1.003.

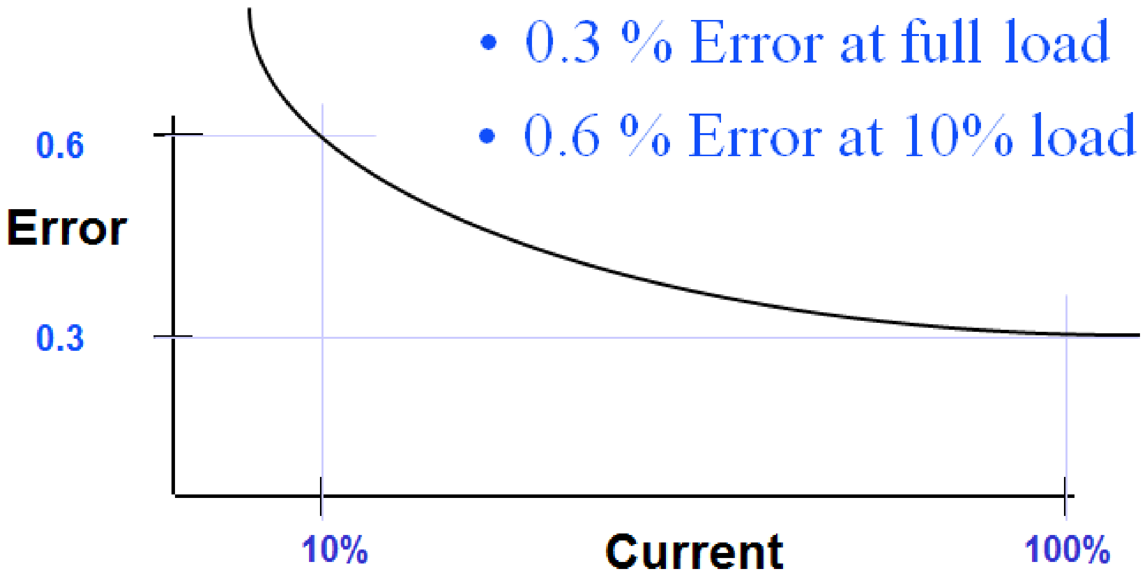
Accuracy

- 0.3 Class for Metering
  - 0.3% @ 100%In
  - 0.6% @ 10% In
- 0.6 Class for Monitoring
  - 0.6% @ 100%In
  - 1.2% @ 10% In
- 1.2 Class for Control
  - 1.2% @ 100%In
  - 2.4% @ 10% In



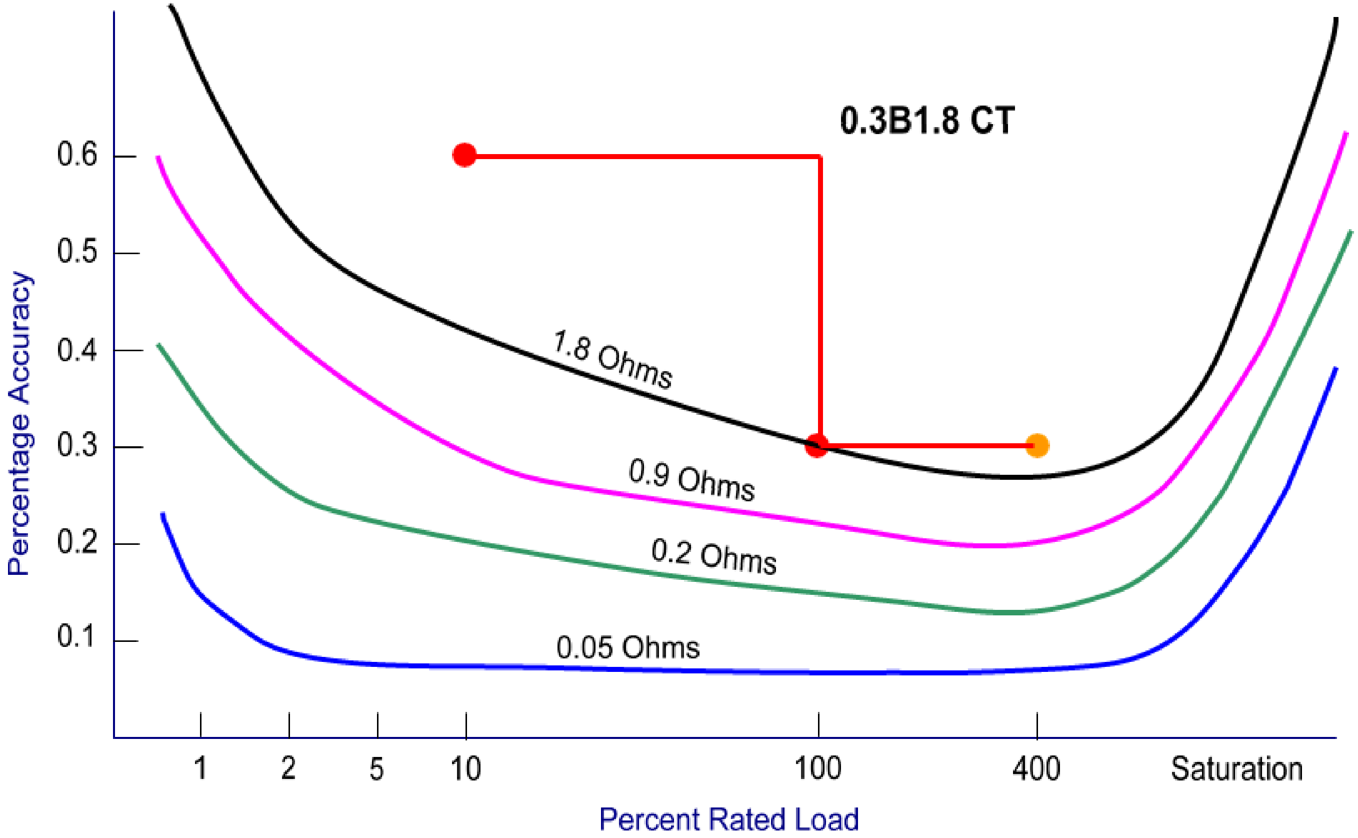
Current Transformer Accuracy

- In addition to burden (secondary load), a CT's accuracy is affected by the Metered Load (primary current).
- The limit of permissible error in a current transformer for a given accuracy class has one value at 100% rated current and twice that amount of error at 10% rated current.
- Below 10 % rated current, error may be as much as 5 – 10 %.



Current Transformer Accuracy

- Example of a CT with a rating factor of 4 and a rated burden of 1.8



Current Transformer Accuracy

- Summary of Main Points:

- A CT's accuracy is best between 100% rated load and it's maximum rated load with rating factor applied.

- Below 10% rated load, a CT's accuracy is unknown and errors can be significant.

- Above maximum rated load (with rating factor applied), a CT's core can become saturated and errors can be significant.

- A CT's accuracy improves as secondary burden decreases.

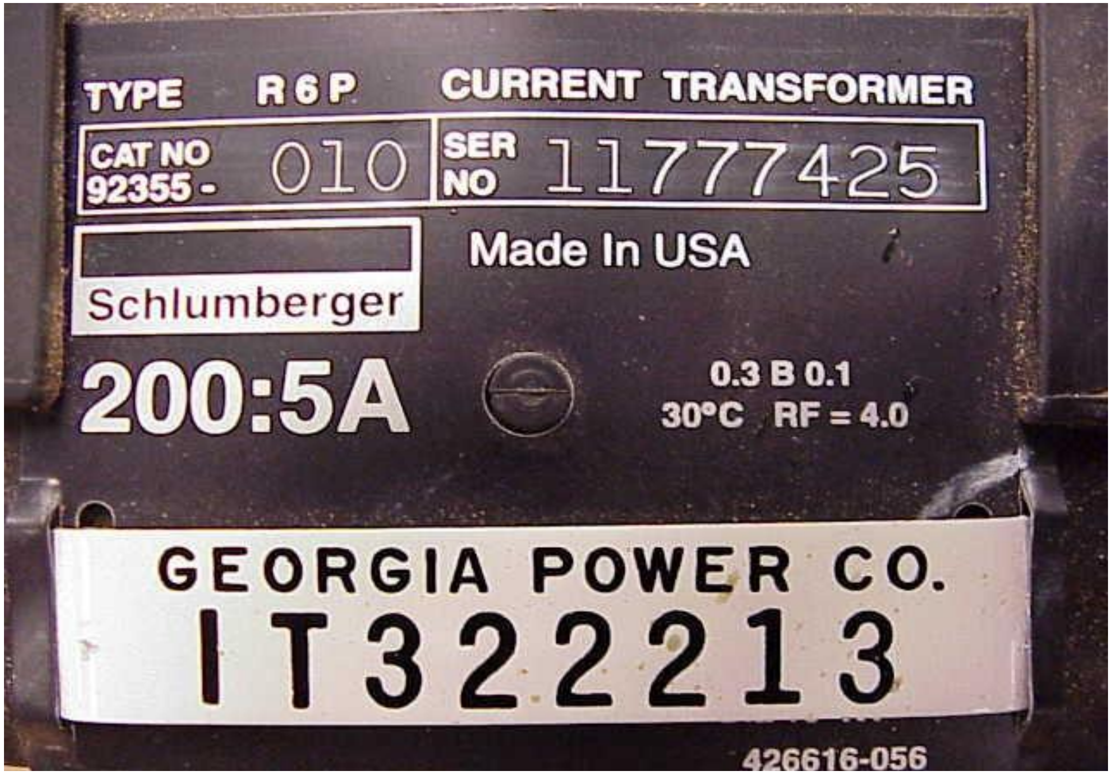
- Errors in Current Transformer accuracy from any of the above conditions <u>always</u> result in a <u>loss</u> for the utility.

Sources of Burden on CTs

- 1. Size & Length of metering control cable.
- Resistance for # 12 copper wire is approximately .0018 Ohms per foot.
- 50 feet of control cable = .09 Ohms burden.
- 2. Connections
- How many connections are in a CT's secondary circuit?
- Quality of connections: Are they tight? Is there oxidation or corrosion?
- 3. Meter
- The current coils in the meter are considered equivalent to a short circuit and the burden imposed on the circuit is insignificant.

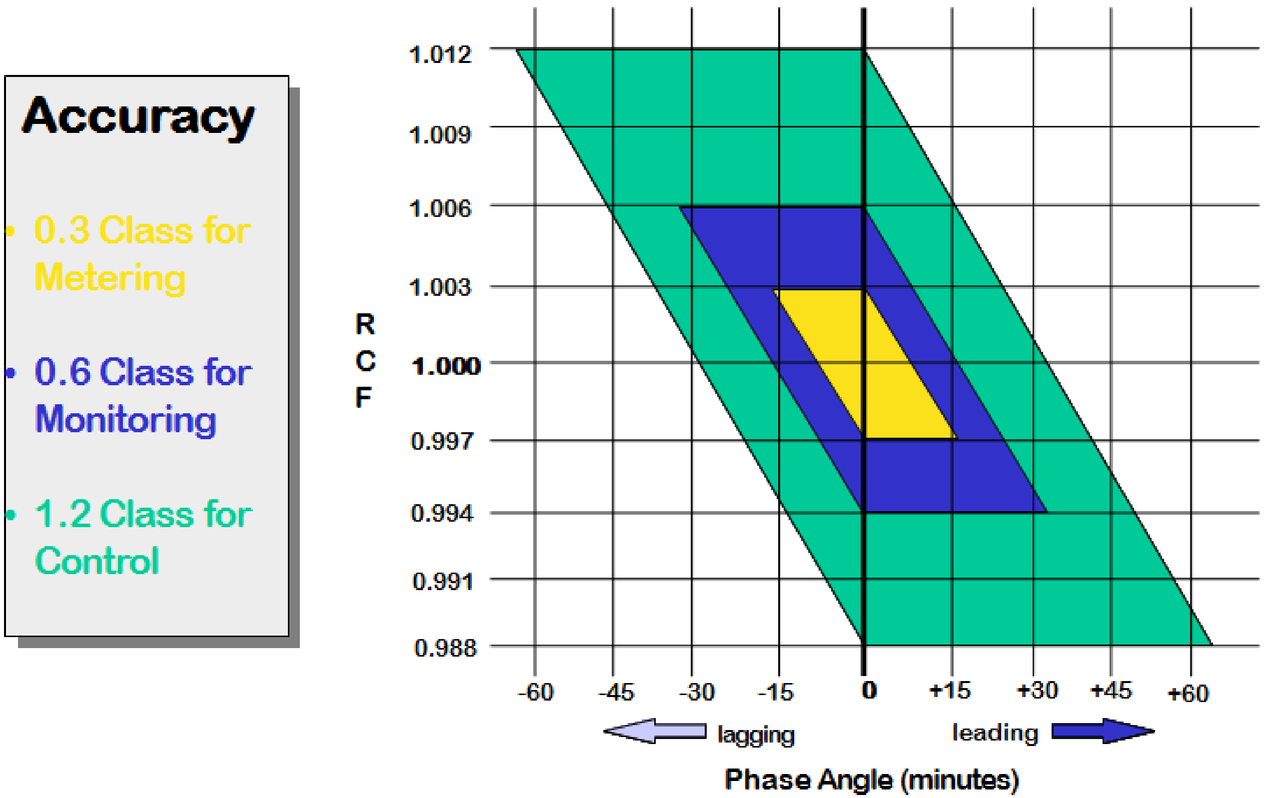
Sources of Burden on CTs

- 50 feet of control cable will account for nearly all of the burden rating of this CT.
- Any additional burden could easily exceed the accuracy rating.



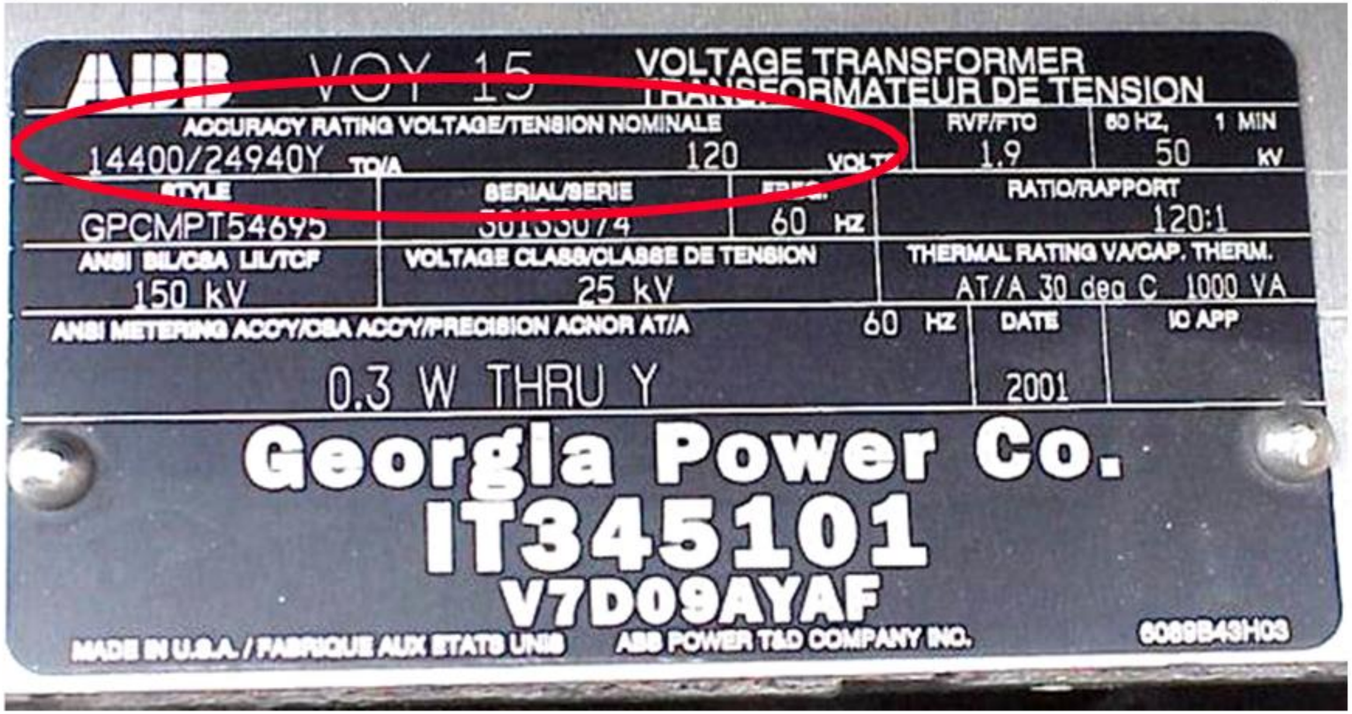
Potential Transformer Accuracy

- The corresponding ratio correction factor and phase angle for any point inside the 0.3 class parallelogram will always give a transformer correction factor between .997 and 1.003.



Potential Transformer Accuracy

- The limit of permissible error in a potential transformer for a given accuracy class remains constant over a range of voltage from 10% below and 10% above rated voltage.

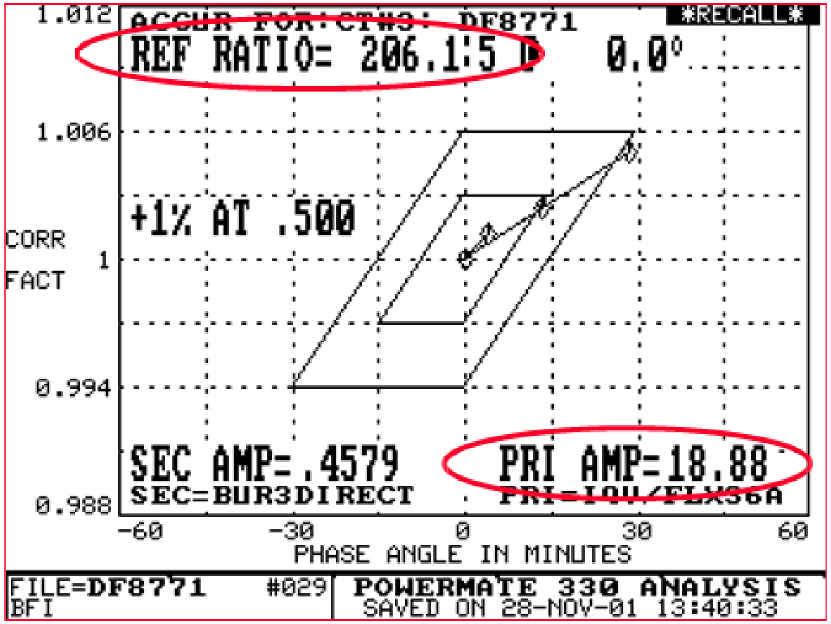


Potential Transformer Accuracy

- The primary source of errors with potential transformers is overloading the transformer.
- If the load on the PT exceeds the burden rating, metering errors can result.
- The measured voltage will be low thereby reducing the billing to the customer.

Current Transformer Accuracy

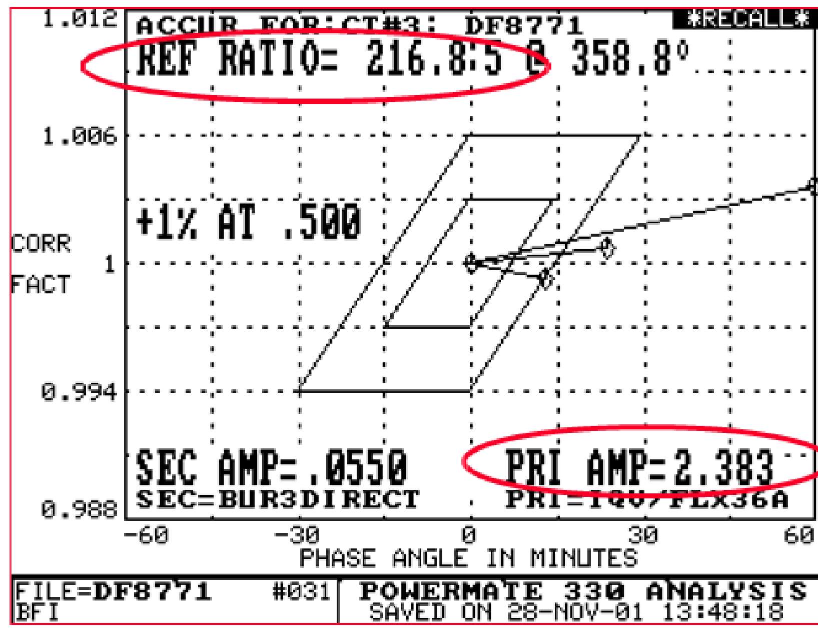
An Example from the field using a Powermate 330



At just below 10% rated current, the CT's reference ratio accuracy is about 97%.

At approximately 1% rated current, the same CT's reference ratio accuracy is about 92%.

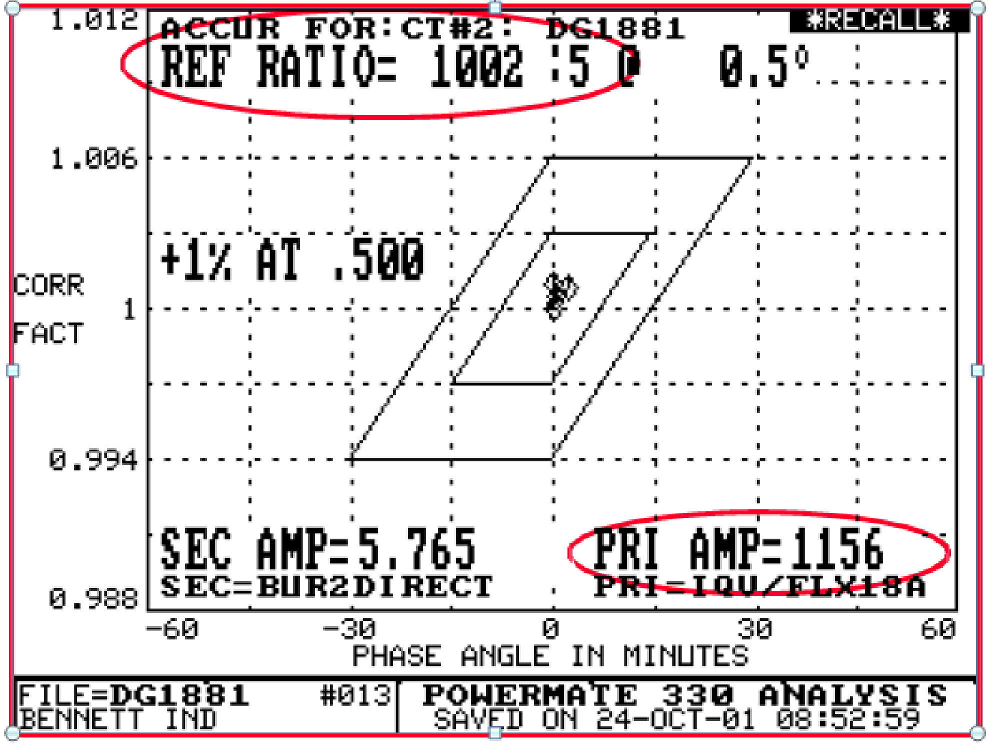
At this small load, the addition of .1, .2, & .5 ohm burden has a much larger effect on the CT's accuracy.



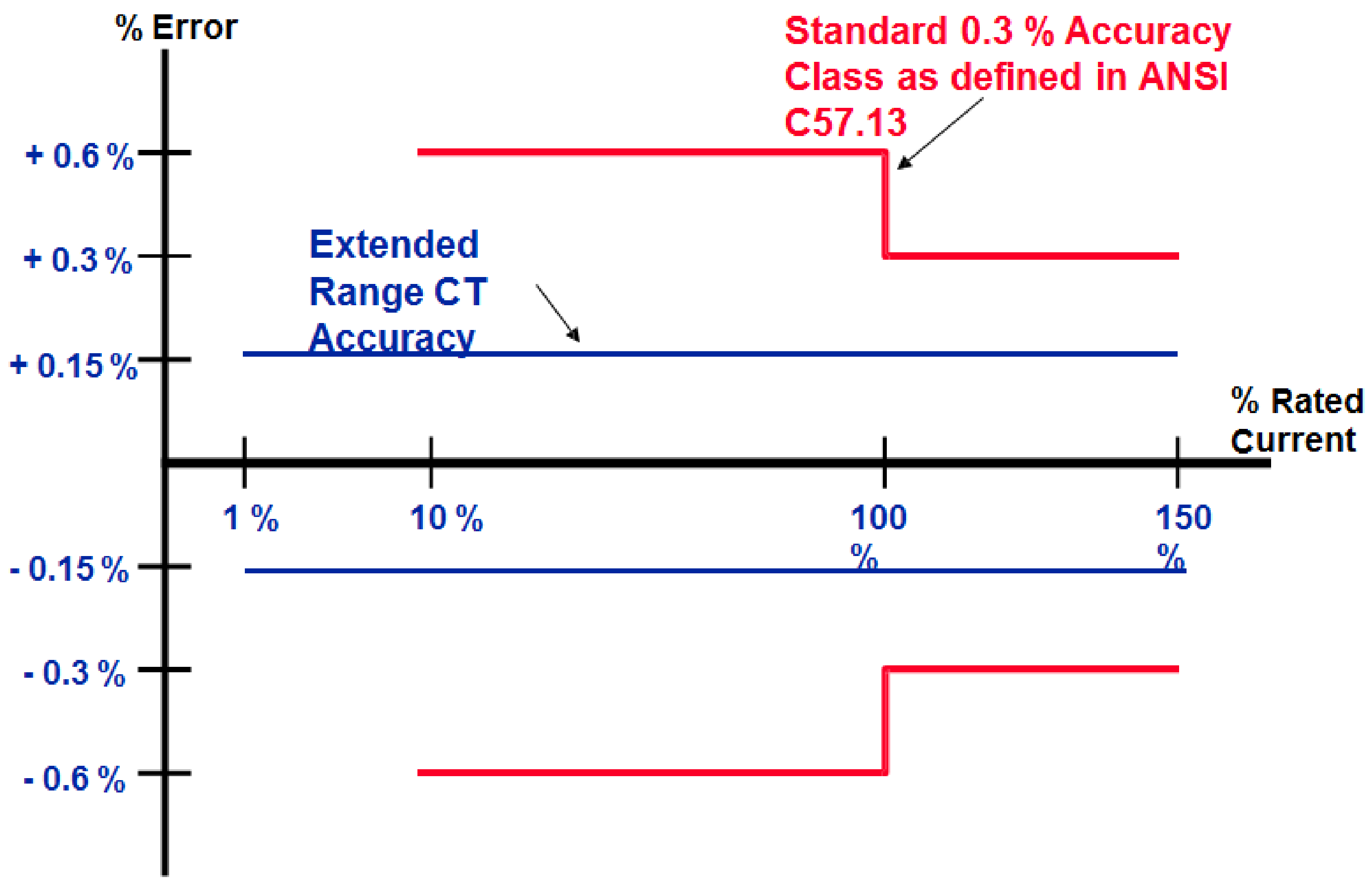
Current Transformer Accuracy

An Example from the Field using a Powermate 330

- At 100% rated current, this CT's reference ratio accuracy is 99.8%.
- The plots in the parallelogram show that the burden added to the CT's secondary circuit had no effect on accuracy.



Extended Range Medium Voltage CTs



Current Transformer Rating Factor

- Rating factor (RF) is a term which applies only to current transformers.
- Also known as “thermal rating factor” or “continuous thermal rating factor.”
- It is the number by which the primary load current may be increased over its nameplate rating without exceeding the allowable temperature rise and accuracy requirements.
- The rating factor is temperature dependent. The ambient temperature at which the rating factor applies will be stated.
- The standard ambient reference levels are at 30 and 55 degrees centigrade. (86 and 131 degrees Fahrenheit)
- Usually the manufacturer will only list the rating factor at 30 degrees ambient.
- It is very important that the ambient temperature be considered when applying CT’s above the nameplate rating.

Current Transformer Rating Factor

•If a current transformer has a rating factor of 4 at 30 degrees centigrade, it will safely carry, on a continuous basis, 4 times the nameplate rating.

•In other words, a 200:5 CT with a RF of 4 will safely carry 800 amps at 30 degrees centigrade ambient temperature.

•We can use the formula below to determine what the CT's rating factor would be at 55 degrees centigrade or at any other temperature:

$$New\ RF = \sqrt{\frac{(stated\ \ RF\ )^2\ (85 - new\ \ Amb\ ^{O}C\ )}{55^{O}C}}$$

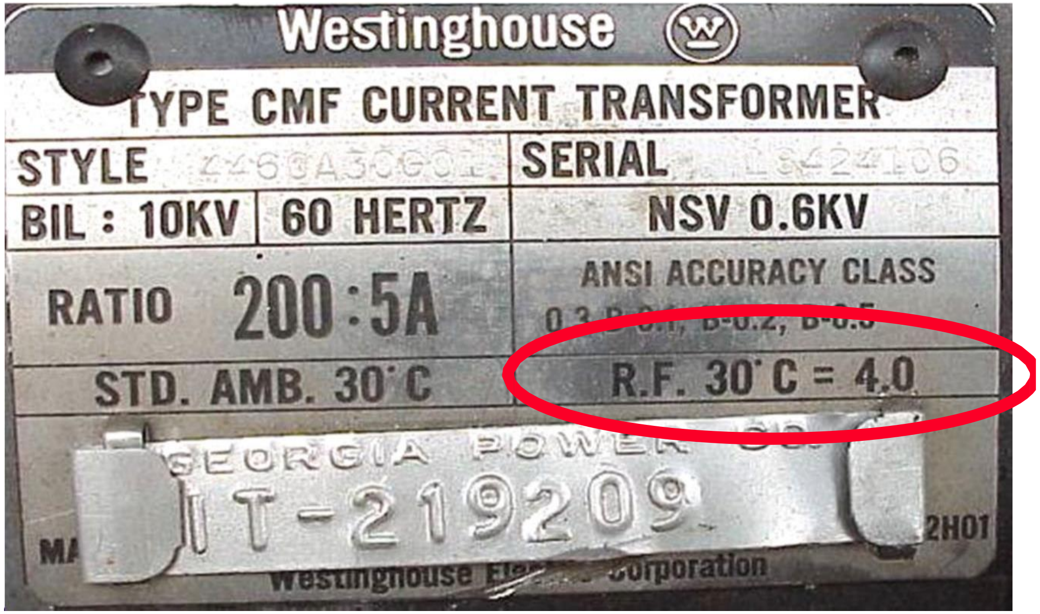
• The rating factor of this CT at 55 degrees centigrade would be:

$$New\ RF = \sqrt{\frac{4^2\,(85-55)}{55}} = 2.95$$

Current Transformer Rating Factor

- This CT pictured below will safely carry 800 amps at 30 degrees centigrade ambient temperature.

- This same CT will only carry 590 amps at 55 degrees centigrade.
- (2.95 X 200 = 590)



Potential Transformer Thermal Rating

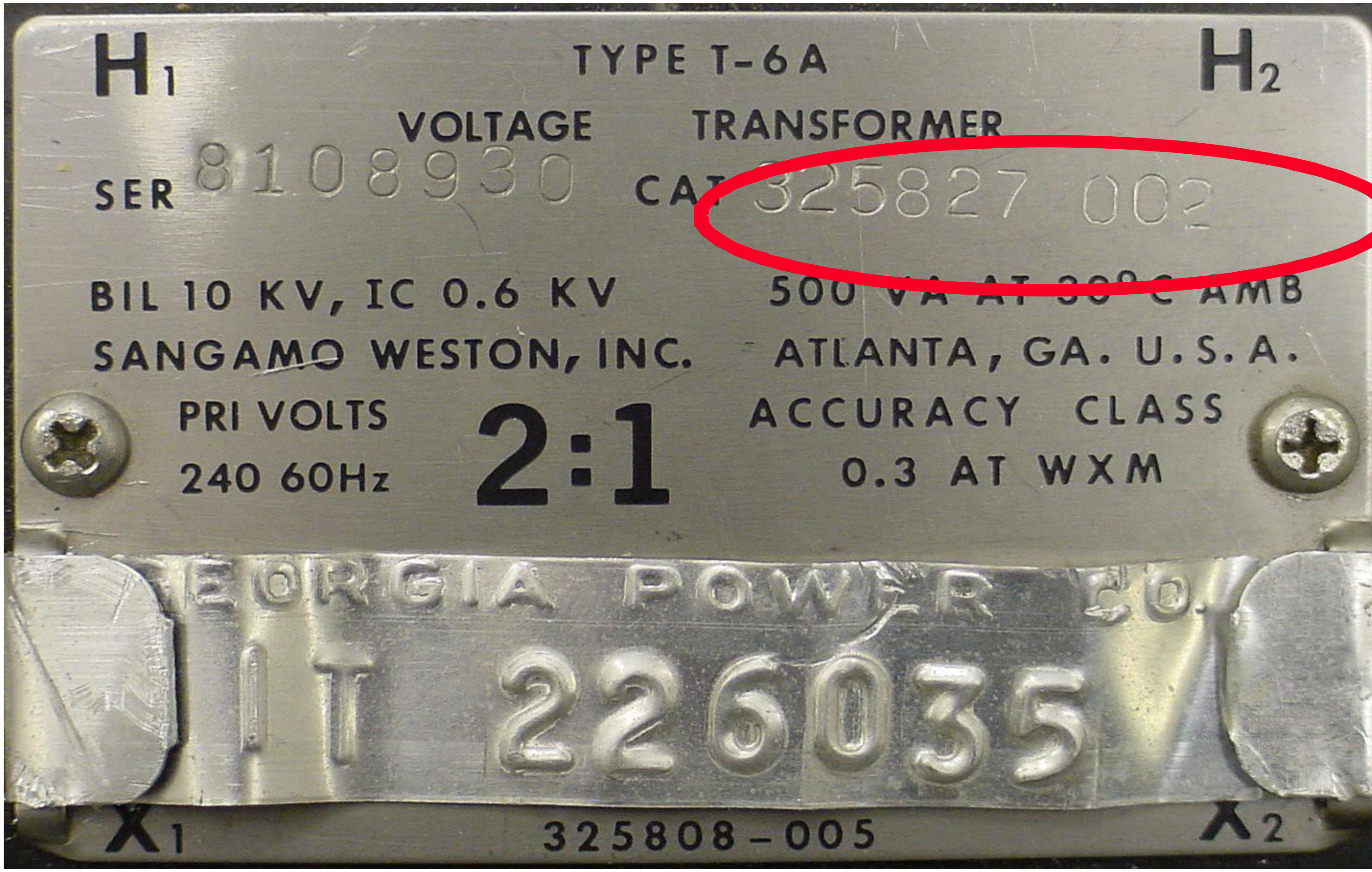
•Potential transformers have a thermal rating rather than a rating factor as with a CT.

•The thermal rating designates the maximum volt-amp burden which may be connected to its secondary without excessive heating and possible damage to the PT.

•The thermal rating of a PT is much higher than the PT's accuracy burden rating, which is also expressed in volt- amps.

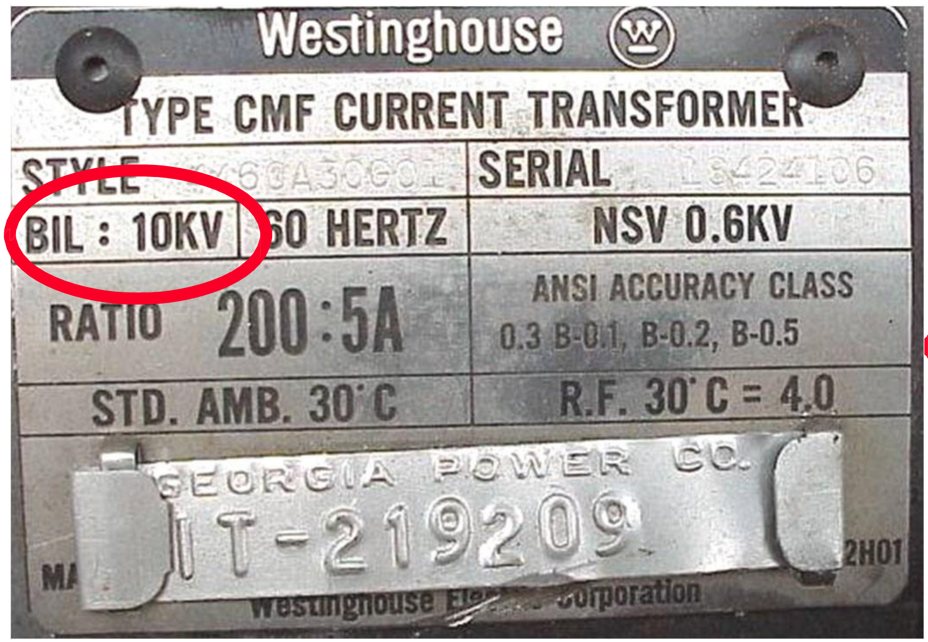
"The thermal burden rating of a voltage transformer is the volt-amperes which the voltage transformer will carry continuously at rated voltage and frequency without causing the specified temperature limitations to be exceeded. " **ANSI C12.11-1978**

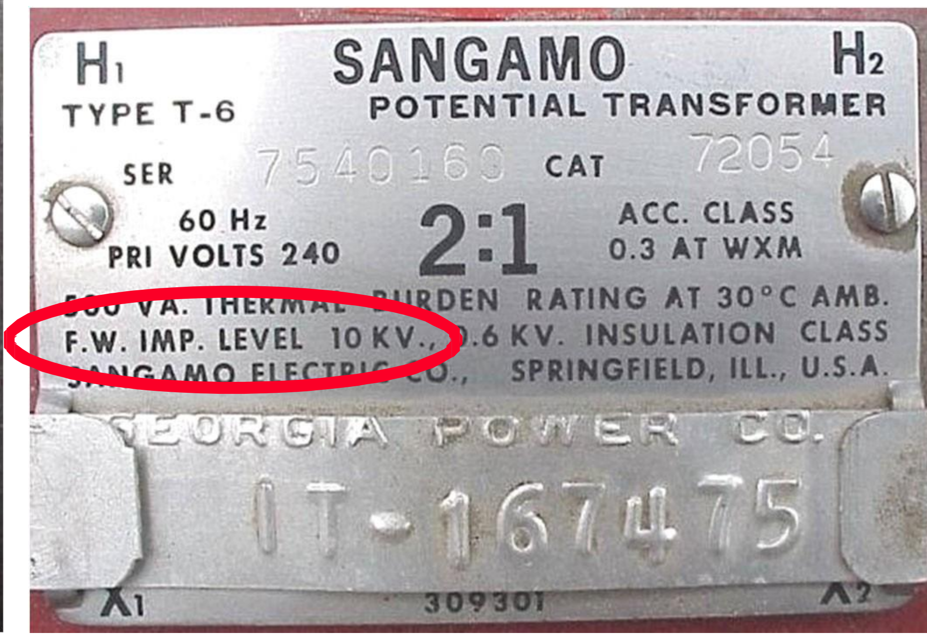
Potential Transformer Thermal Rating



Basic Impulse Level (BIL)

- The BIL rating on instrument transformers are test ratings and never apply to actual in-service voltage.
- These test values are for factory dielectric tests that are designed to check the insulation and workmanship of instrument transformers.





Insulation Class (IC)

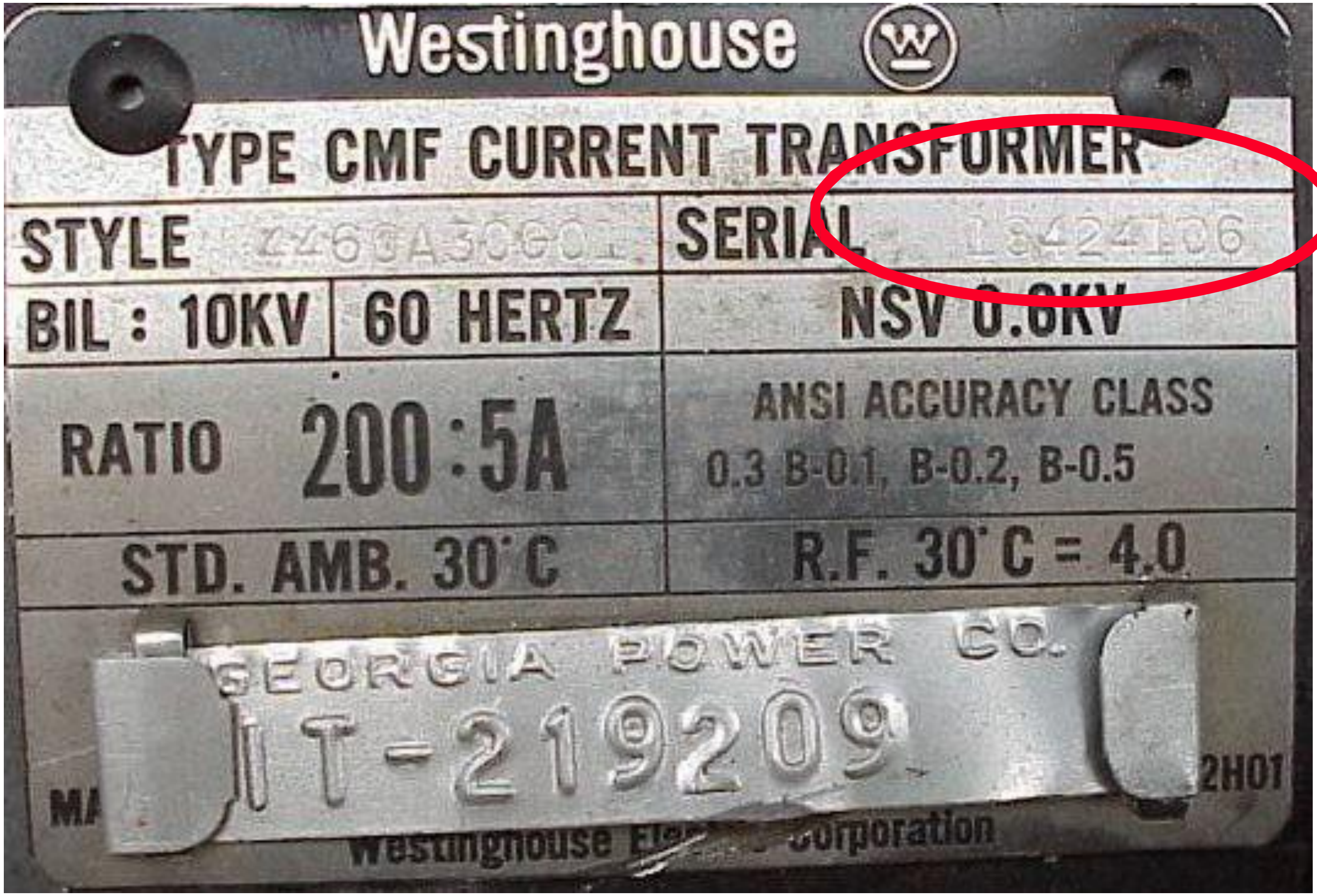
•The insulation class indicates the level of voltage which an instrument transformer can safely withstand between its primary and secondary windings and between its primary or secondary winding and ground.

•Industry recommendations are that the insulation class of an instrument transformer should be at least equal to the maximum line-to- line voltage existing on the system at the point of connection.

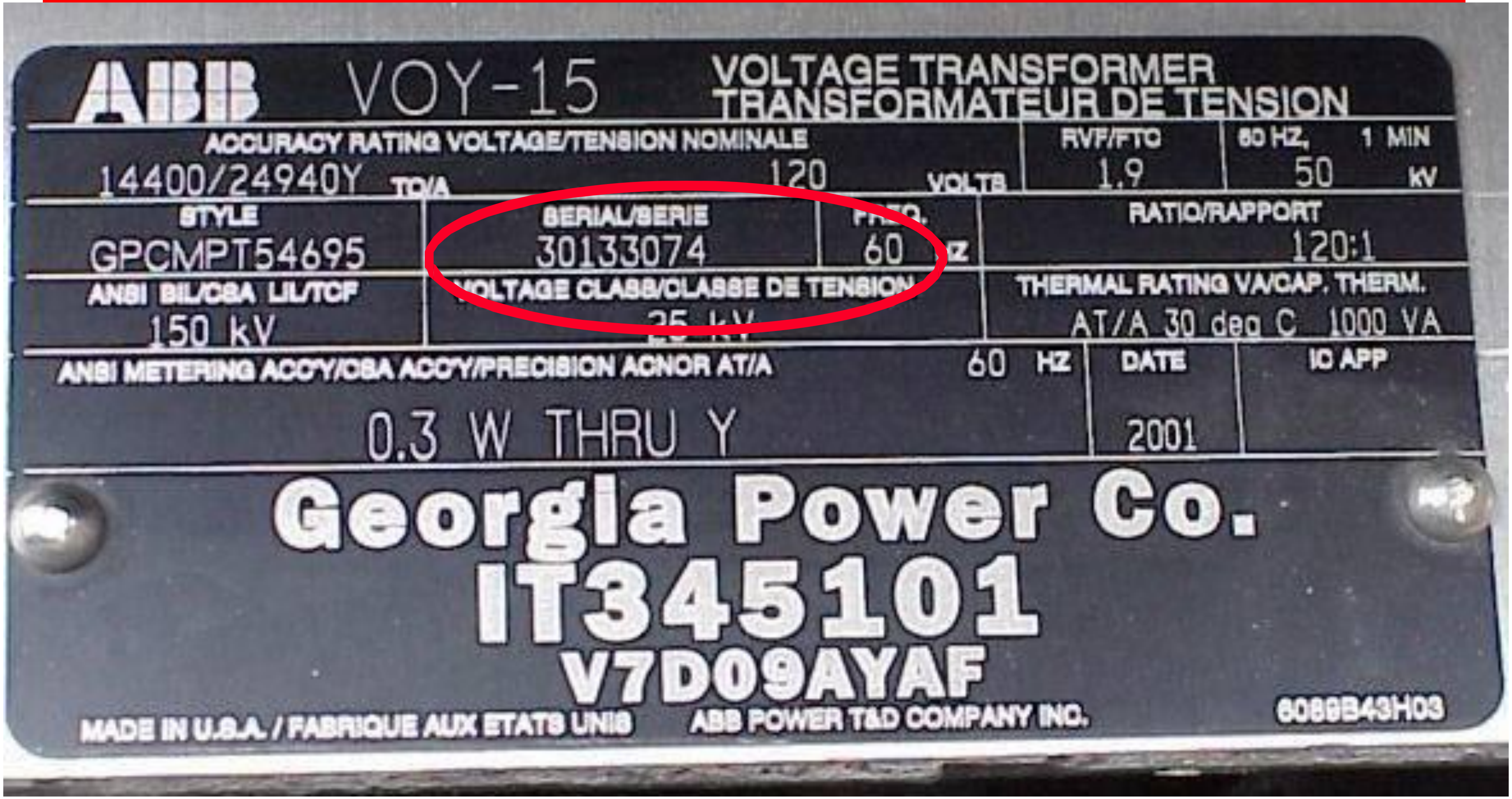
•For example, any current or potential transformer used on a 14400/24940 volt wye system should be of the 25 kV insulation class. Under fault conditions, these units could be subjected to line-to-line voltage.

- The insulation class may be designated on the name plate as:
  - "IC " (Insulation Class)
  - "NSV " (Nominal System Voltage)
  - "Max. Sys. Volt." (Maximum System Voltage)
  - "V_m" (Maximum Voltage – used on Ritz name plates)

Insulation Class (IC)



Insulation Class (IC)



Polarity

•Primary and secondary terminals of instrument transformers are said to have the same polarity when, at a given instant, the current enters the identified or marked primary terminal and leaves the identified or marked secondary terminal in the same direction as though the two terminals formed a continuous circuit.

•In the application of instrument transformers it is necessary to understand and observe polarity markings when connecting watthour meters to them.

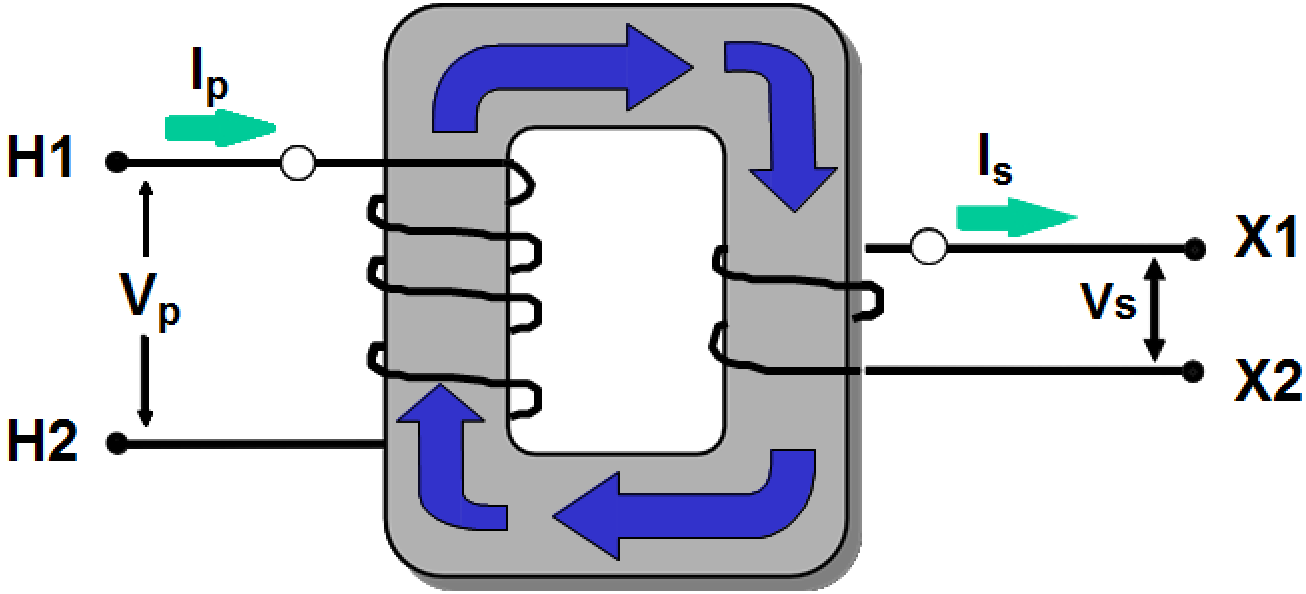
•All instrument transformers, whether current or potential, will have polarity marks associated with at least one primary terminal and one secondary terminal.

• The polarity markings are often white dots.

•The polarity markings are sometimes a letter and number combination. H1 for the primary marking and X1 for the secondary mark.

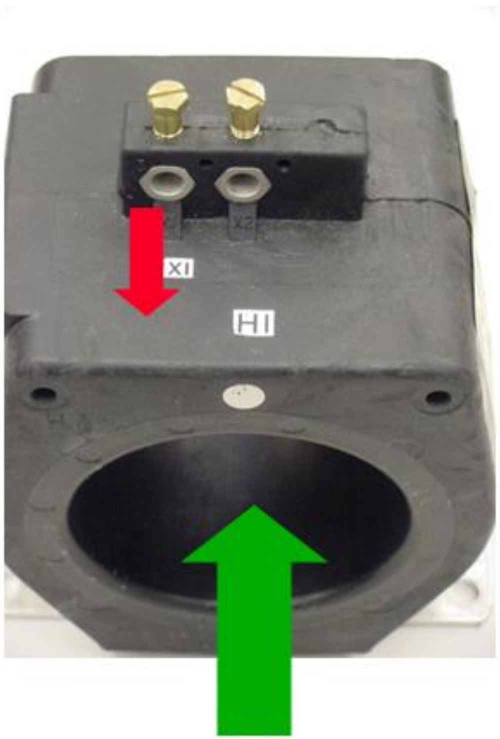
Polarity

When primary current enters H1, secondary current leaves X1.



All IT's are subtractive polarity!

Polarity (Current Transformers)



Primary Current In

Secondary Current Out

Polarity (Potential Transformers)

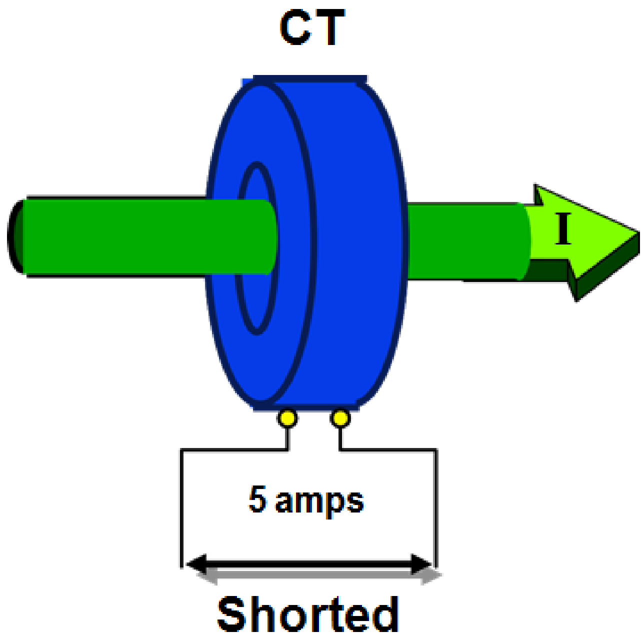
Primary Current In

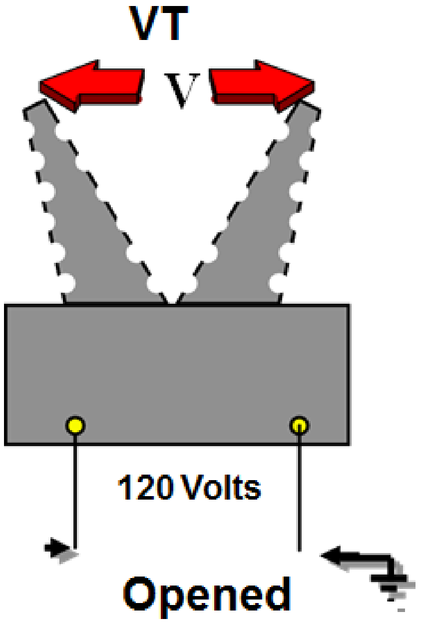
Secondary Current Out

Secondary Circuits: Two Rules to Remember

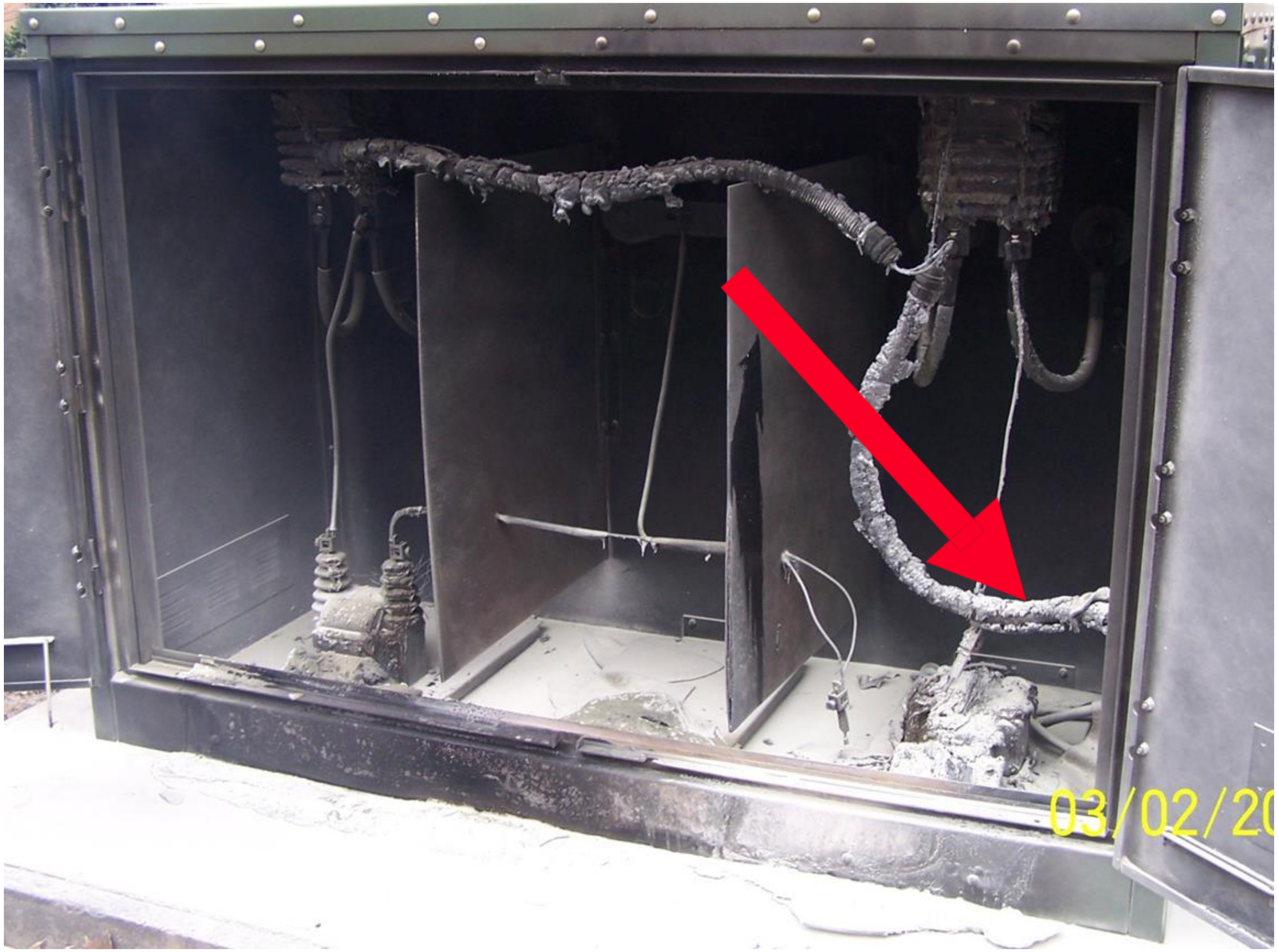
While in service:

1. Never open circuit a CT secondary.
2. Never short circuit a PT secondary.



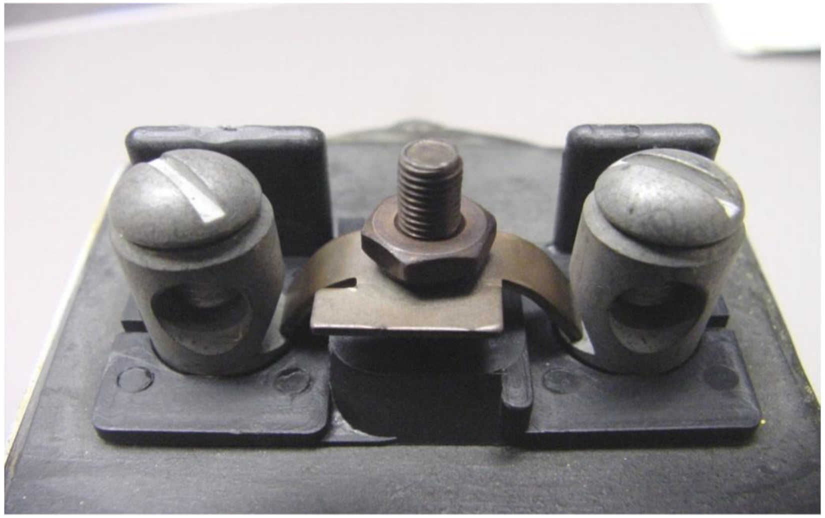


This PT's Secondary Circuit was Shorted When the Wrong Meter was Installed.



Ct Secondary Circuits

- The current transformer has a low voltage secondary as long as the secondary connection is a continuous connection. This continuous connection normally exists through the metering control cable and the current coils in the meter. The meter may be by-passed by closing the shunting device on the CT or by opening the current switches on the test-switch block.



CT Secondary Circuits

- If at any time, the secondary connection is opened and there is current flowing in the primary, the CT becomes a step up voltage transformer and the secondary voltage can rise to very high voltages.

- This can be understood by some basic Ohm's Law calculations.

  - E = I R

- With a continuous secondary connection, the resistance is very low and the voltage remains very low. But, as the secondary circuit is opened, the resistance rises very rapidly and the secondary voltage can quickly rise to thousands of volts. The actual formula is:

$$E = \sqrt{3.5 \bullet Z_b \bullet I_s}$$

- The high voltage that is present on the open secondary of an energized CT poses two hazards. The first is an electrical shock hazard to personnel. The second hazard is the breakdown of the current transformer's insulation resulting in damage or destruction of the transformer.

TESCO

OSHA Standard 1910.269(w)(2)

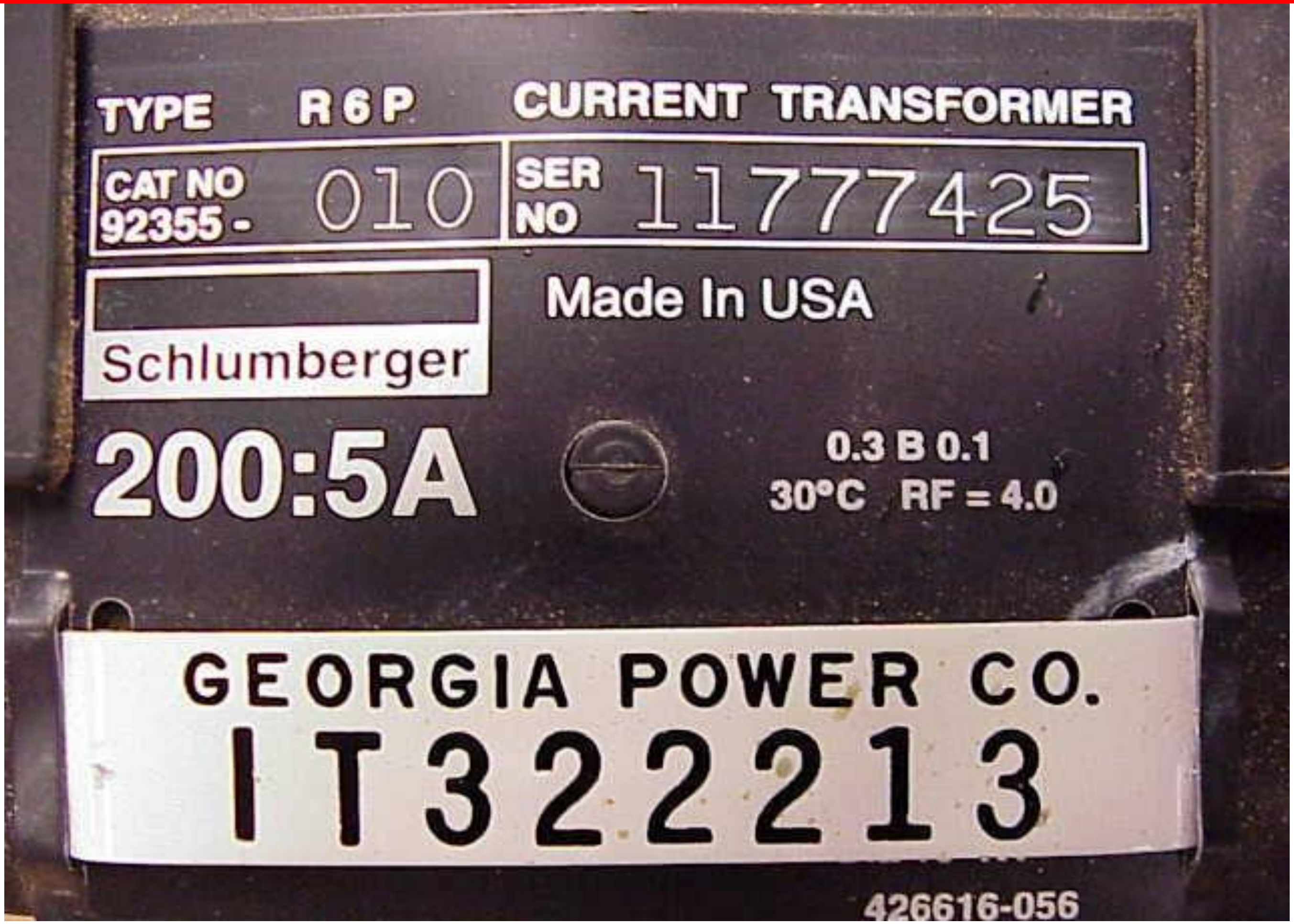
“Current transformer secondaries.” The secondary of a current transformer may not be opened while the transformer is energized. If the primary of the current transformer cannot be de-energized before work is performed on an instrument, a relay, or other section of a current transformer secondary circuit, the circuit shall be bridged so that the current transformer secondary will not be opened.”

TESCO

Grounding IT Secondary Circuits

- It is standard practice to ground the common or neutral secondary wire of Potential Transformers and also the secondary current return wire on Current Transformers.
- The Handbook for Electricity Metering states, “Grounding is a necessary safety precaution for protection against static voltages and insulation failure.”
- IEEE Std C57.13.3 recommends that IT secondary circuits be grounded at only one point – preferably at the first point of application of the circuit (switchboard, meter, etc.)
- Grounding at the IT and at the meter can cause the grounding path to become a parallel path with the IT’s secondary circuit – possibly resulting in the circulation of electrical noise during normal operation or damage from high current flow during ground-fault conditions.

Review (nameplate information)



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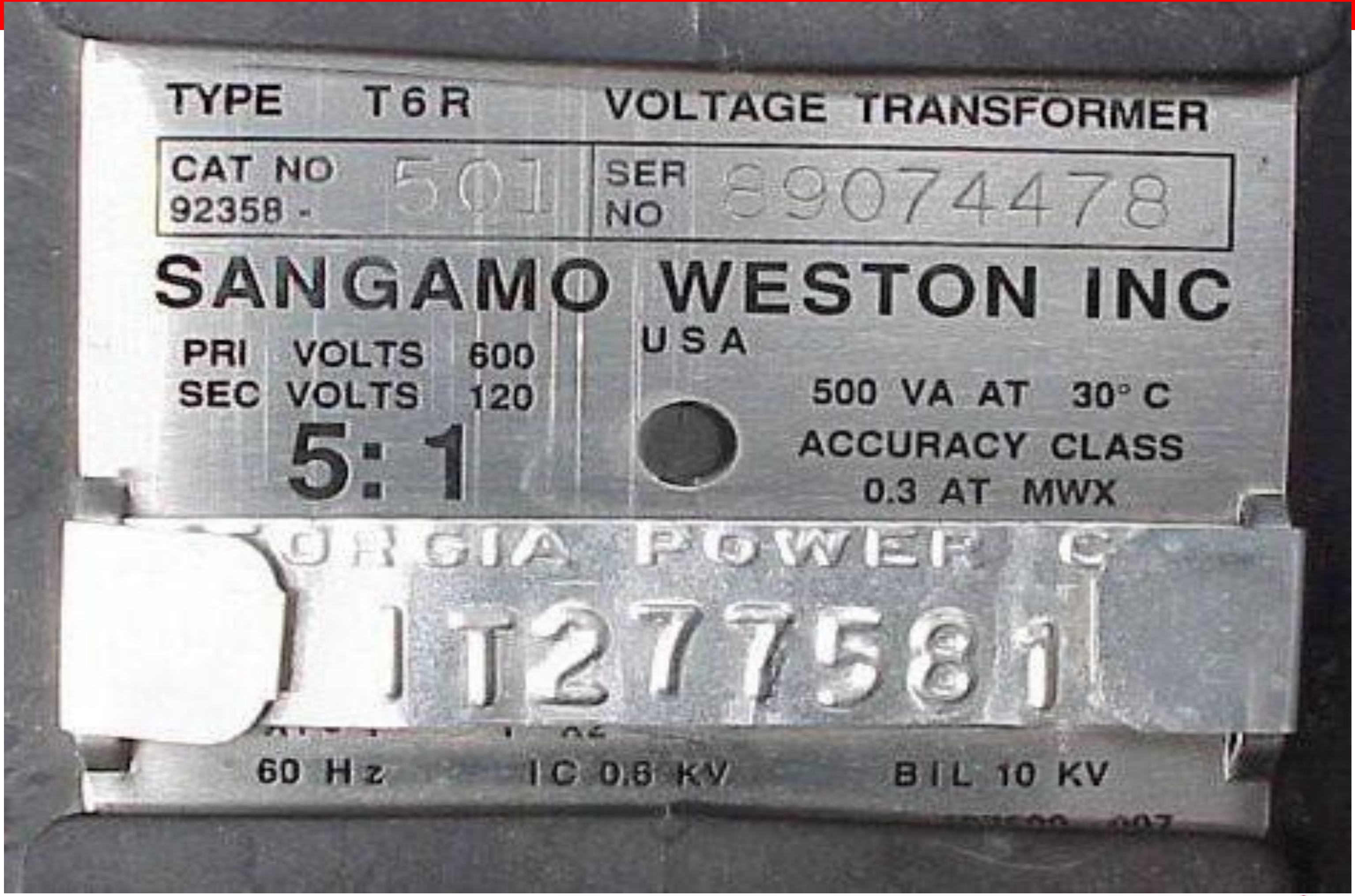

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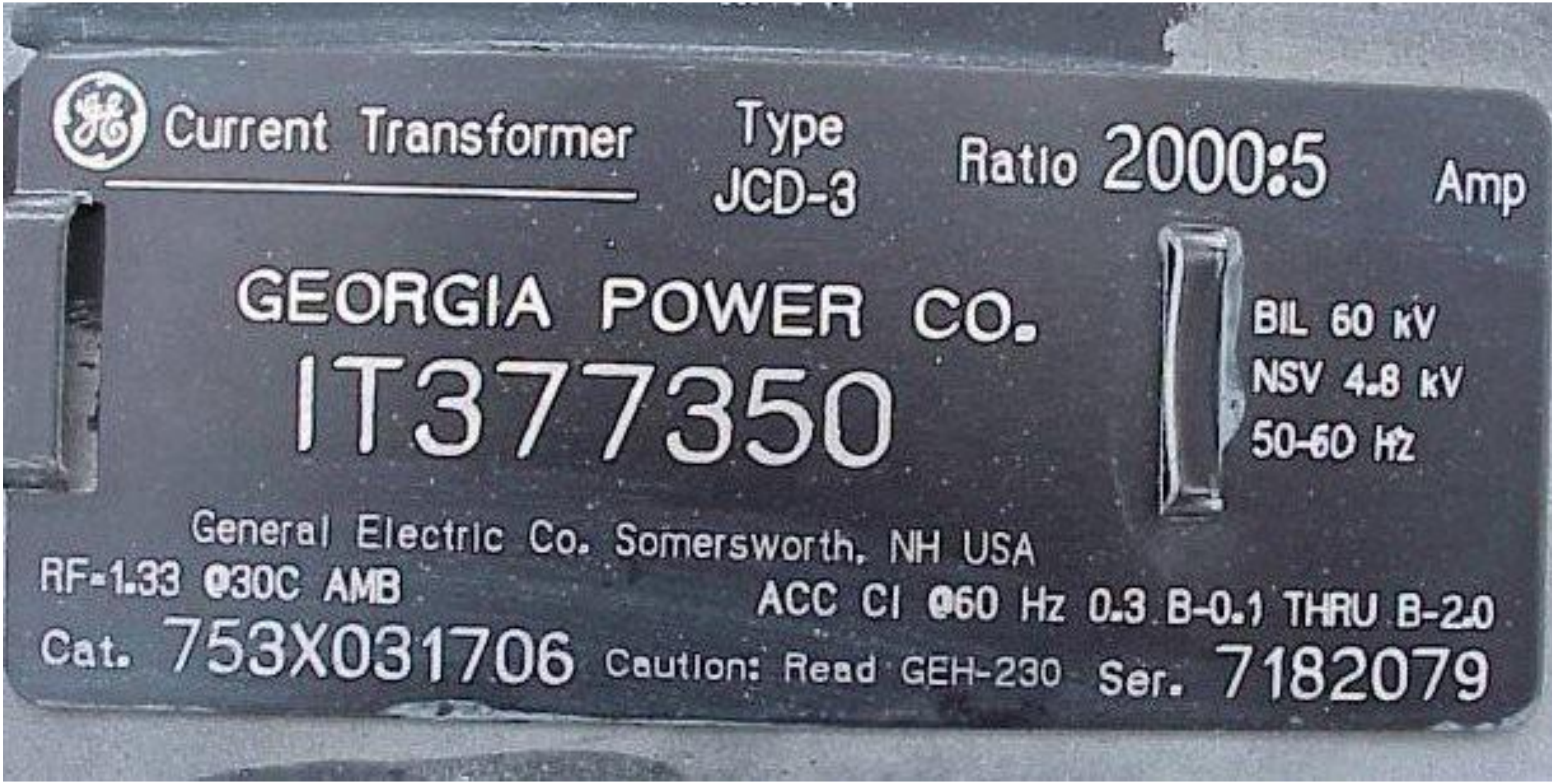

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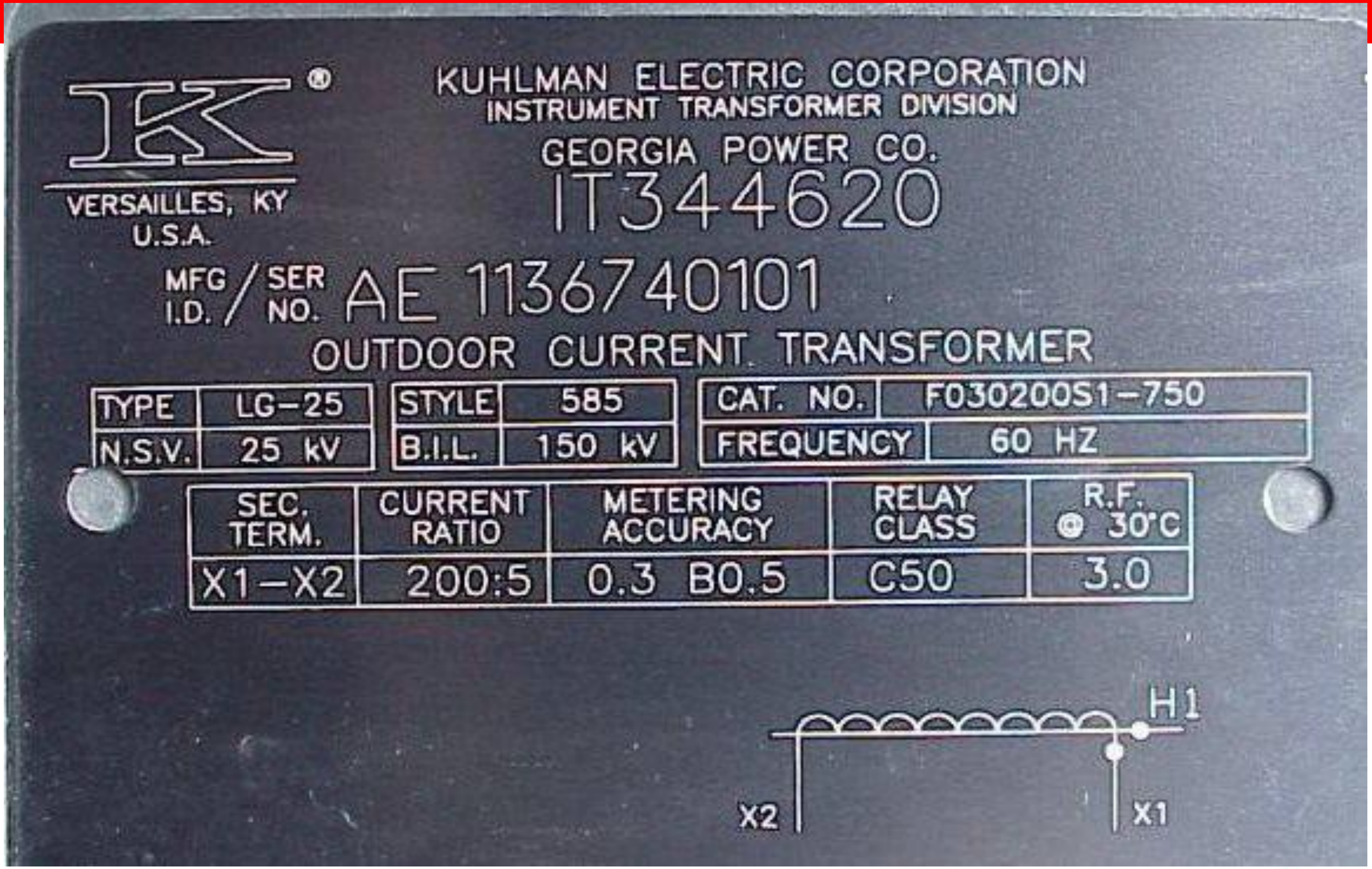

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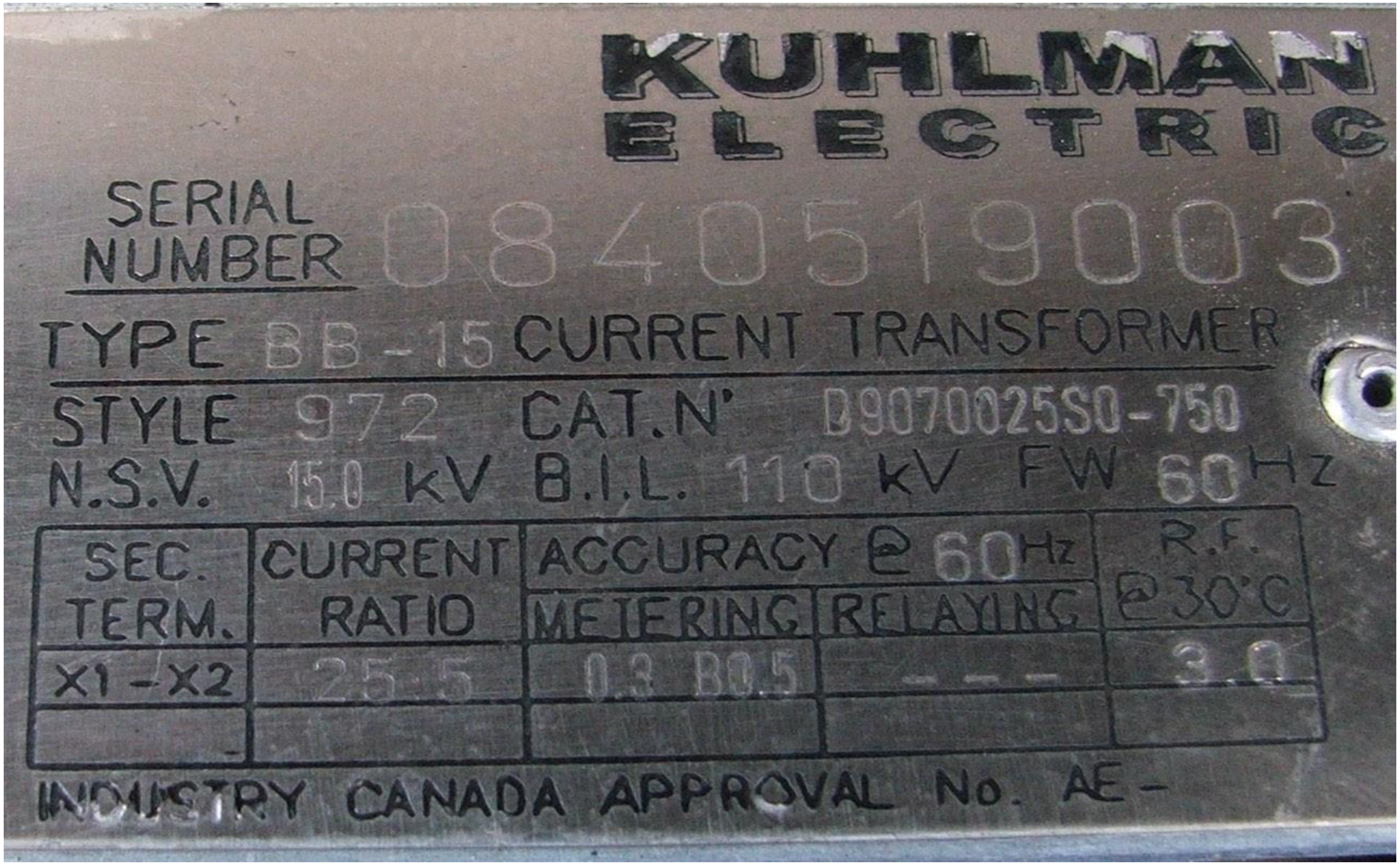

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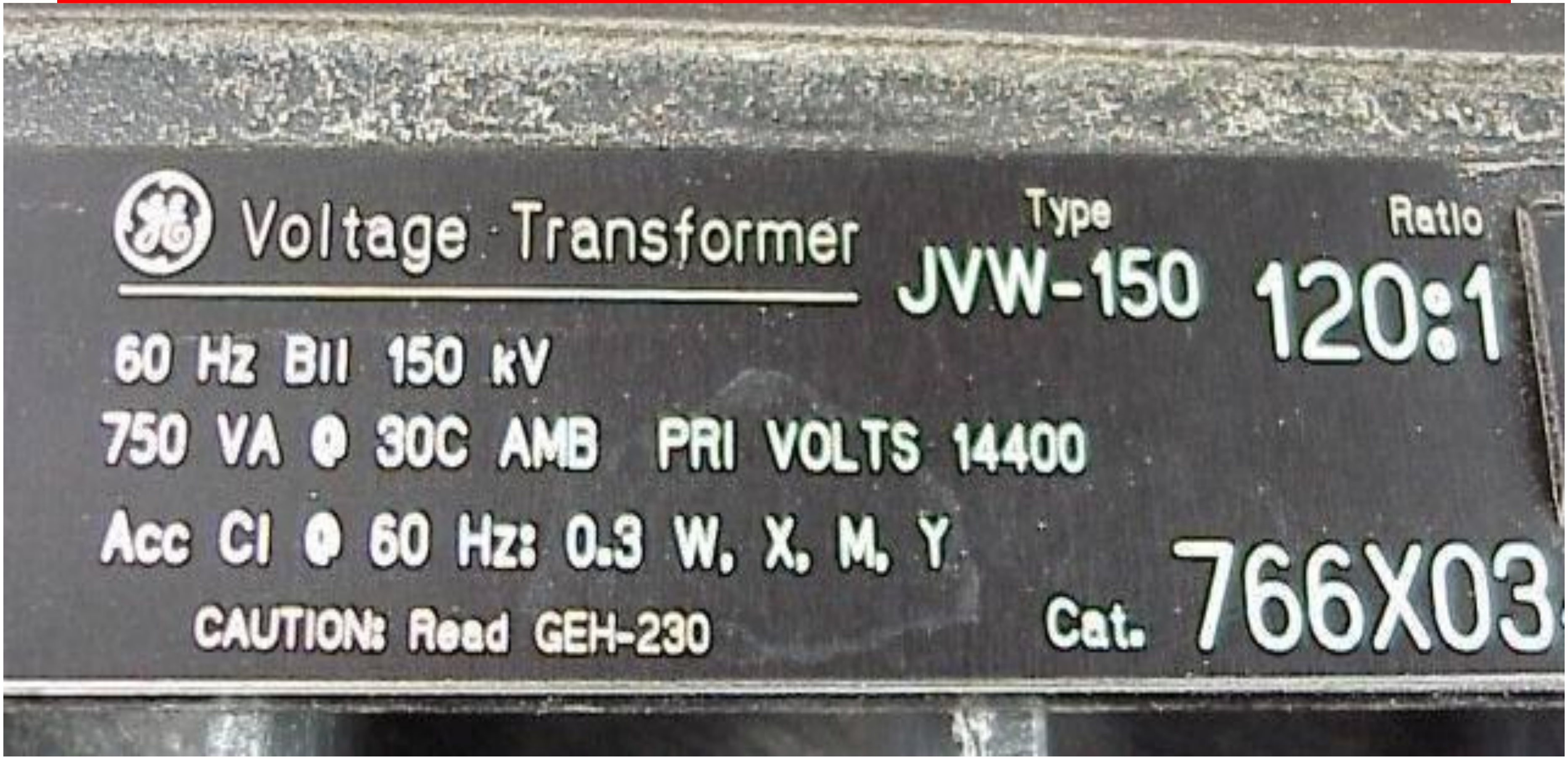

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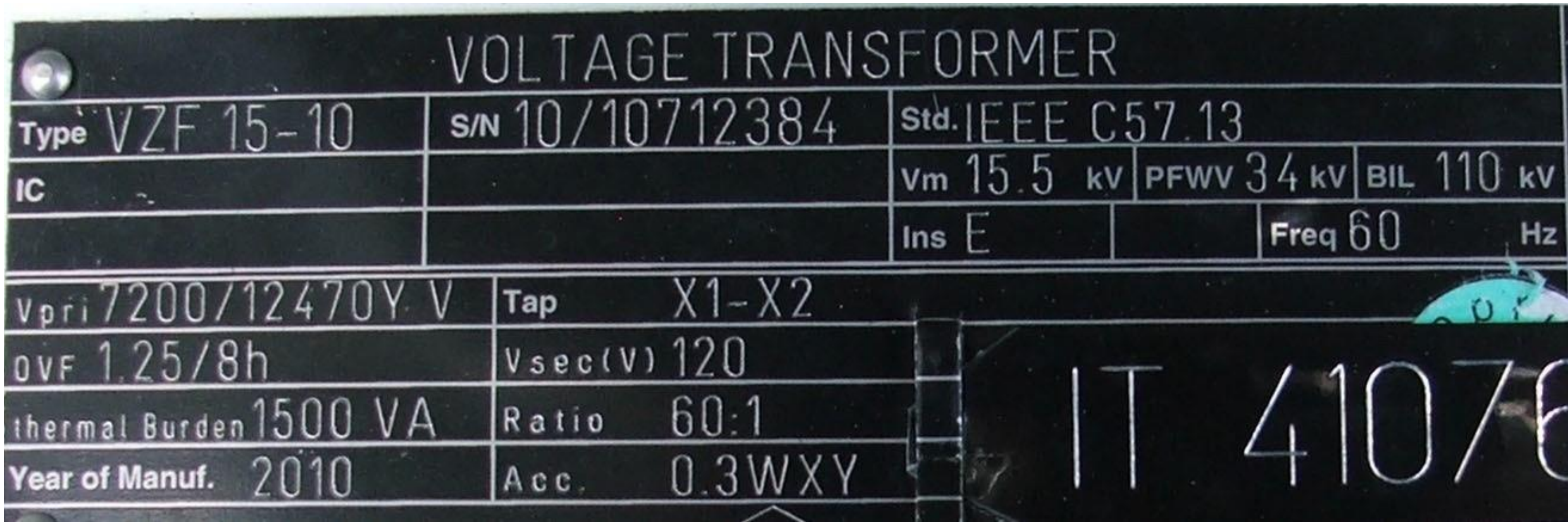

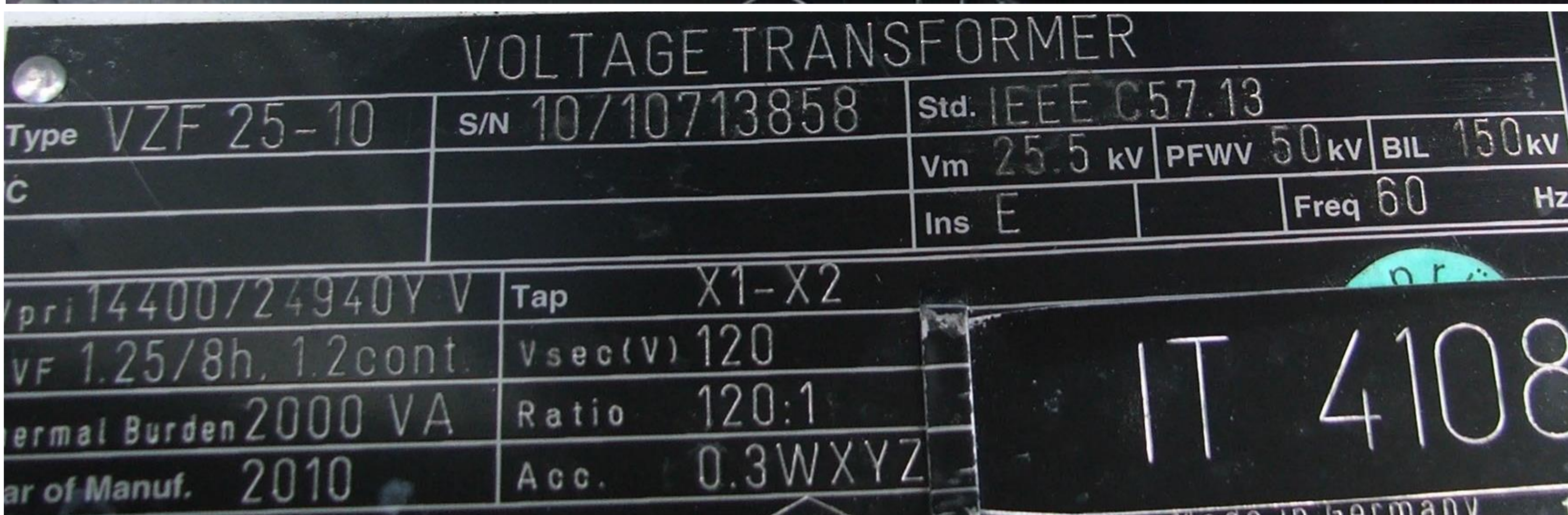

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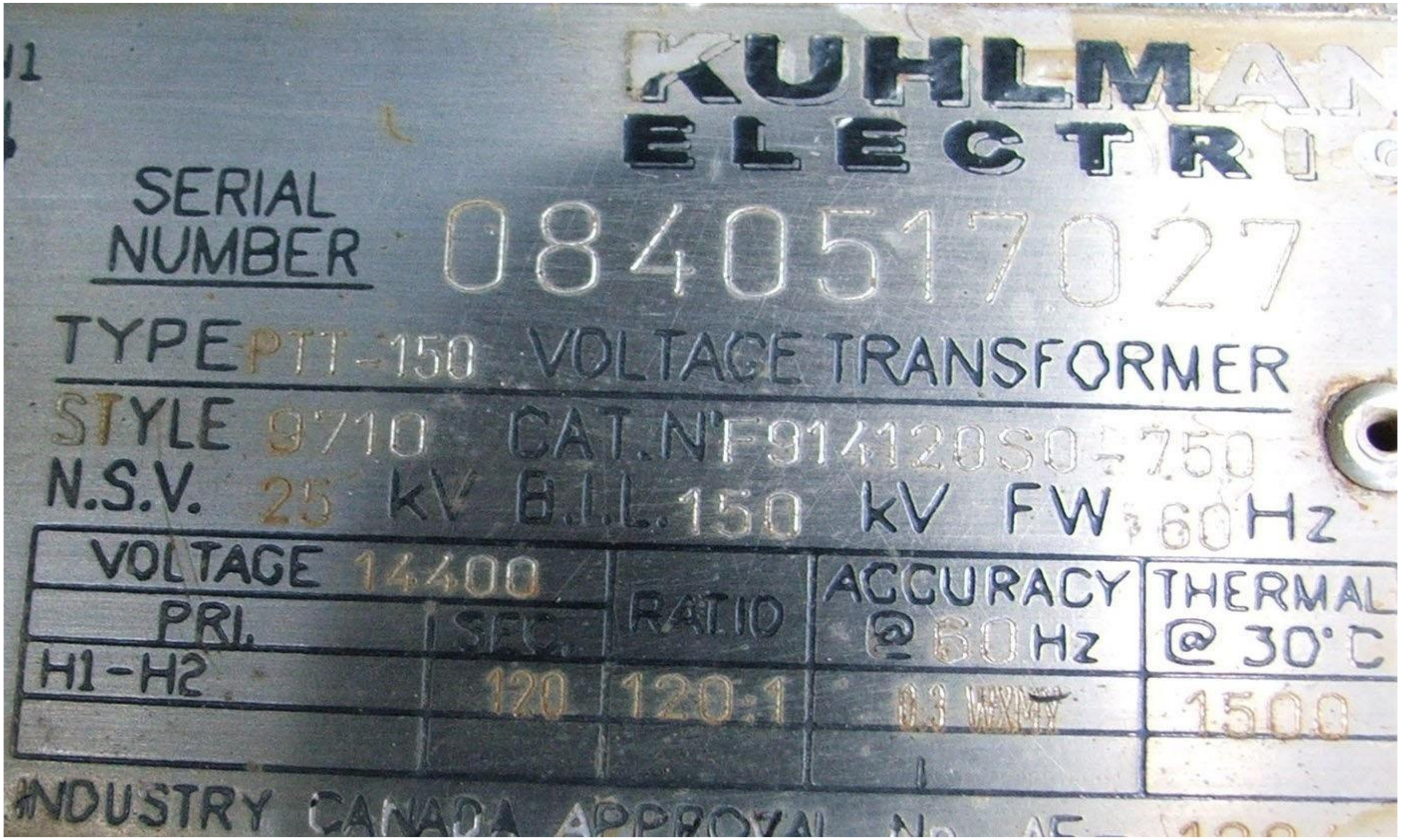

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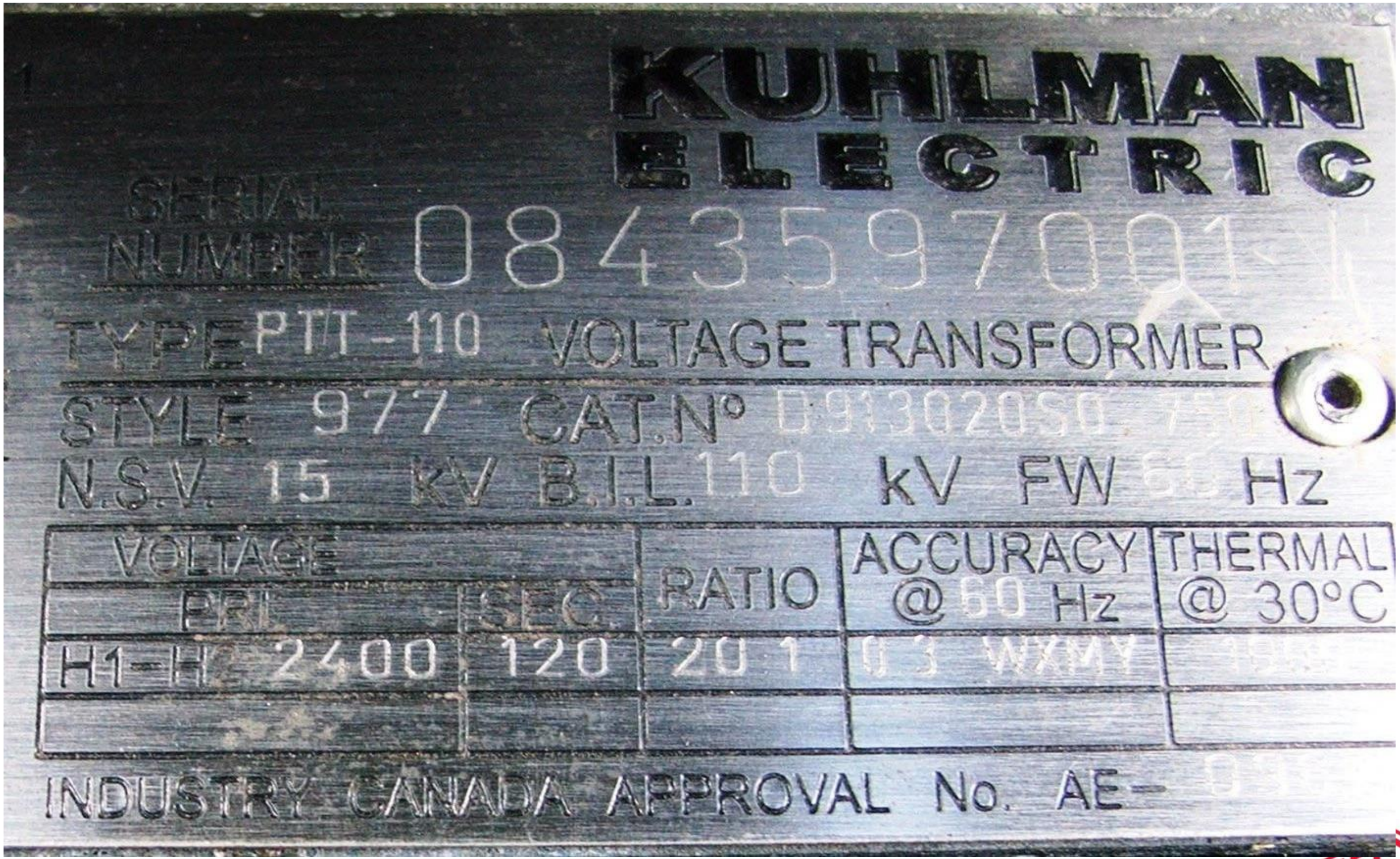

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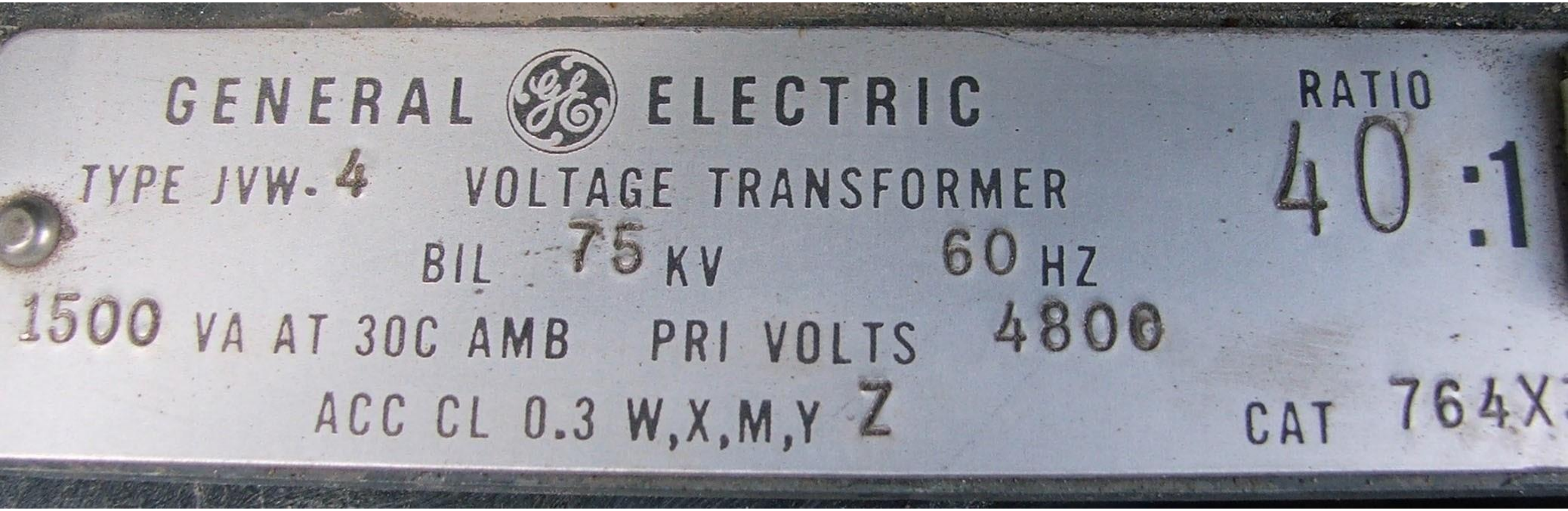

Questions?

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