METHODS TO REVERSE OR SLOW DOWN YOUR ELECTRIC UTILITY METER.

ENCLOSED ARE LEGAL AND ILLEGAL METHODS.

DO NOT USE THIS INFORMATION TO BREAK ANY LAWS OR REGULATIONS. YOU ARE RESPONSIBLE FOR YOUR OWN ACTIONS.

In this document you will learn about how to reverse your electric meter legally. In the documents which follow this, you will learn how an induction motor works and how an electric meter (watthour) works, using this you will know how to physically and internally slow down the meter which is illegal but you probably wont get caught if you do it slowly over an extended time frame. Once you read this entire packet you should be able to get a job with the utility company with your knowledge.

Enclosed are 2 methods and 2 informational packets which will help you slow your meter down. They all work. The induction motor method works the best…it will actually reverse your electric meter and it does it legally.

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1. Over driving an induction motor to use as a generator that can be phase locked to the grid. This simple method allows you to become an independent power producer to feed your excess power back to the grid, turning your meter backwards, thus making you money. Most utility meters are actually small induction motors… generally they turn in the direction that power flows.

2. The electric meter originally used was invented by Nikoli Tesla but was changed slightly for use in metering power consumption.

3. An induction motor has no brushes or rubbing parts and will last for many many years. It will operate in almost any environment. It is the standard motor used in industry and is very easily acquired. You can pick one up from an appliance repair store or take on out of an appliance. You can even get them from a scrap yard for a couple bucks.

4. You want to buy an induction motor which is rated at the same horsepower that you expect to get from your power source… ie what you will consume. You also need to buy one that is rated at grid voltage… ie about 220 or 240vac single phase. So you may need roughly a 220vac single phase 5 horsepower induction motor.

5. An induction motor will not act as a generator unless you over drive it. It must receive an outside signal in order to spin up. This means it will always be in phase with the utility grid frequency because it is supplying the signal or frequency to spin the induction motor. In-phase means the motor and the grid frequencies match up and since the grid is supplying the frequency or signal for the motor…they both stay in phase. This is soooo important for proper operation…

6. So if the grid goes down, your induction motor will go down also unless you hook up a relay to disconnect your motor from the grid once the grid goes down. Then you can supply your own signal to the motor and keep it running, thus generating power.

7. If you are an independent power producer, the utility company will require you to have phase matching equipment so your power matches theirs…but with this setup you do not need that expensive equipment because they are supplying the signal to

keep everything in phase already…the utility company already knows about this method because they use it at most power stations or power plants for boosting and generating power.

8. The induction motor will reverse your power meter if you are not using more than it is producing… thus if you are generating only 2000watts of power with your motor and you are using 2500 watts of power, then you will still be charged by the utility company for 500watts of usage. This ability to over drive an induction motor allows people who know any better to generate their own power.

HOOK UP

Simple… you can just wire up the motor and plug it into the wall or hard wire it into your breaker. You will need to wire up to the 220 or 240vac line. And for God's sake make sure you ground your motor.

The actual implementation of the motor as a generator must be exact.

You should attach a speed sensor to shut off the motor if it runs too slow. For example. If you run an 2000 rpm motor at it normal synchronous speed of around 1800 or 1925 rpm, it will act as a motor and will use power. But if you run the motor at 2000 rpm it will act as a generator. Generally if a motor is rated to have a sync speed of 2000, ideally it should use no power at it's sync speed. This is kind of like having resonance in your motor. The motor will operate optimally at it's sync or resonance speed. You should not over drive an induction motor more than 8-10% of it's rated sync speed or it may generate more power than it can handle thus heating up and may pose a hazard.

As the motor is over driven above it's sync speed it will produce a slightly higher voltage and more power. The frequency will stay phase locked with the grid. We have found that the best method for keeping track of the speed of your induction motor is to use an optical sensor with a break wheel. The break wheel is attached to your shaft. The wheel has a small hole drilled in it so that each time the hole passes by the sensor, the sensor will register a break, thus here is your speed sensor. Just hook up the proper tach electronics and your in business. Other methods are hall effect sensors, inductive, etc… it would control a relay to shut off the grid from the motor if the motor runs too slow.

Here is some vital information for the understanding of induction motors…

Induction Motor Control Theory.

1. **Induction Motor Design** has a major effect on the behavior and performance of an induction motor. Very often the details or class of design of a motor are not well understood or promoted.

i) **Stator design**.. The stator is the outer body of the motor which houses the driven windings on an iron core. In a single speed three phase motor design, the standard stator has three windings, while a single phase motor typically has two windings. The stator core is made up of a stack of round pre-punched laminations pressed into a frame which may be made of aluminum or cast iron. The laminations are basically round with a round hole inside through which the rotor is positioned. The inner surface of the stator is made up of a number of deep slots or grooves right around the stator. It is into these slots that the windings are positioned. The arrangement of the windings or coils within the stator determines the number of poles that the motor has.

A standard bar magnet has two poles, generally known as North and South. Likewise, an electromagnet also has a North and a South pole. As the induction motor Stator is essentially like one or more electromagnets depending on the stator windings, it also has poles in multiples of two. i.e. 2 pole, 4 pole, 6 pole etc.

The winding configuration, slot configuration and lamination steel all have an effect on the performance of the motor. The voltage rating of the motor is determined by the number of turns on the stator and the power rating of the motor is determined by the losses which comprise copper loss and iron loss, and the ability of the motor to dissipate the heat generated by these losses.

The stator design determines the rated speed of the motor and most of the full load, full speed characteristics.

ii) **Rotor Design.** The Rotor comprises a cylinder made up of round laminations pressed onto the motor shaft, and a number of short-circuited windings. The rotor windings are made up of rotor bars passed through the rotor, from one end to the other, around the surface of the rotor. The bars protrude beyond the rotor and are connected together by a shorting ring at each end. The bars are usually made of aluminum or copper, but sometimes made of brass. The position relative to the surface of the rotor, shape, cross sectional area and material of the bars determine the rotor characteristics. Essentially, the rotor windings exhibit inductance and resistance, and these characteristics can effectively be dependent on the frequency of the current flowing in the rotor.

A bar with a large cross sectional area will exhibit a low resistance, while a bar of a small cross sectional area will exhibit a high resistance. Likewise a copper bar will have a low resistance compared to a brass bar of equal proportions.

Positioning the bar deeper into the rotor, increases the amount of iron around the bar, and consequently increases the inductance exhibited by the rotor. The impedance of the bar is made up of both resistance and inductance, and so two bars of equal dimensions will exhibit a different A.C. impedance depending on their position relative to the surface of the rotor. A thin bar which is inserted radialy into the rotor, with one edge near the surface of the rotor and the other edge towards the shaft, will effectively change in resistance as the frequency of the current changes. This is because the A.C. impedance of the outer portion of the bar is lower than the inner impedance at high frequencies lifting the effective impedance of the bar relative to the impedance of the bar at low frequencies where the impedance of both edges of the bar will be lower and almost equal.

The rotor design determines the starting characteristics.

iii) **Equivalent Circuit.** The induction motor can be treated essentially as a transformer for analysis. The induction motor has stator leakage reactance, stator copper loss elements as series components, and iron loss and magnetizing inductance as shunt elements. The rotor circuit likewise has rotor leakage reactance, rotor copper (aluminum) loss and shaft power as series elements. The transformer in the center of the equivalent circuit can be eliminated by adjusting the values of the rotor components in accordance with the effective turns ratio of the transformer.

From the equivalent circuit and a basic knowledge of the operation of the induction motor, it can be seen that the magnetizing current component and the iron loss of the motor are voltage dependent, and not load dependent. Additionally, the full voltage starting current of a particular motor is voltage and speed dependent, but not load dependent.

iv) **Starting Characteristics.** In order to perform useful work, the induction motor must be started from rest and both the motor and load accelerated up to full speed. Typically, this is done by relying on the high slip characteristics of the motor and enabling it to provide the acceleration torque.

Induction motors at rest, appear just like a short circuited transformer, and if connected to the full supply voltage, draw a very high current known as the "Locked Rotor Current". They also produce torque which is known as the "Locked Rotor Torque". The **L**ocked **R**otor **T**orque (**LRT**) and the **L**ocked **R**otor **C**urrent (**LRC**) are a function of the terminal voltage to the motor, and the motor design. As the motor accelerates, both the torque and the current will tend to alter with rotor speed if the voltage is maintained constant.

The starting current of a motor, with a fixed voltage, will drop very slowly as the motor accelerates and will only begin to fall significantly when the motor has reached at least 80% full speed. The actual curves for induction motors can vary considerably between designs, but the general trend is for a high current until the motor has almost reached full speed. The LRC of a motor can range from 500% **F**ull **L**oad **C**urrent (FLC) to as high as 1400% FLC. Typically, good motors fall in the range of 550% to 750% FLC.

The starting torque of an induction motor starting with a fixed voltage, will drop a little to the minimum torque known as the *pull up* torque as the motor accelerates, and then rise to a maximum torque known as the *breakdown* or *pull out* torque at almost full speed and then drop to zero at synchronous speed. The curve of start torque against rotor speed is dependent on the terminal voltage and the motor/rotor design. The LRT of an induction motor can vary from as low as 60% **F**ull **L**oad **T**orque (**FLT**) to as high as 350% FLT. The pull-up torque can be as low as 40% FLT and the breakdown torque can be as high as 350% FLT. Typical LRTs for medium to large motors are in the order of 120% FLT to 280% FLT.

The power factor of the motor at start is typically 0.1 - 0.25, rising to a maximum as the motor accelerates, and then falling again as the motor approaches full speed.

A motor which exhibits a high starting current, i.e. 850% will generally produce a low starting torque, whereas a motor which exhibits a low starting current, will usually produce a high starting torque. This is the reverse of what is generally expected.

The induction motor operates due to the torque developed by the interaction of the stator field and the rotor field. Both of these fields are due to currents which have resistive or in phase components and reactive or out of phase components. The torque developed is dependent on the interaction of the in phase components and consequently is related to the I^2R of the rotor. A low rotor resistance will result in the current being controlled by the inductive component of the circuit, yielding a high out of phase current and a low torque.

Figures for the locked rotor current and locked rotor torque are almost always quoted in motor data, and certainly are readily available for induction motors. Some manufactures have been known to include this information on the motor name plate. One additional parameter which would be of tremendous use in data sheets for those who are engineering motor starting applications, is the starting efficiency of the motor. By the starting efficiency of the motor, I refer to the ability of the motor to convert amps into Newton meters. This is a concept not generally recognized within the trade, but one which is extremely useful when comparing induction motors. The easiest means of developing a meaningful figure of merit, is to take the locked rotor torque of the motor (as a percentage of the full load torque) and divide it by the locked rotor current of the motor (as a percentage of the full load current).

i.e

$$\text{Starting efficiency} = \frac{\text{Locked Rotor Torque}}{\text{Locked Rotor Current}}$$

If the terminal voltage to the motor is reduced while it is starting, the current drawn by the motor will be reduced proportionally. The torque developed by the motor is proportional to the current squared, and so a reduction in starting voltage will result in a reduction in starting current and a greater reduction in starting torque. If the start voltage applied to a motor is halved, the start torque will be a quarter, likewise a start voltage of one third will result in a start torque of one ninth.

v) **Running Characteristics.** Once the motor is up to speed, it operates at low slip, at a speed determined by the number of stator poles. The frequency of the current flowing in the rotor is very low. Typically, the full load slip for a standard cage induction motor is less than 5%. The actual full load slip of a particular motor is dependant on the motor design with typical full load speeds of four pole induction motor varying between 1420 and 1480 RPM at 50 Hz. The synchronous speed of a four pole machine at 50 Hz is 1500 RPM and at 60 Hz a four pole machine has a synchronous speed of 1800 RPM.

The induction motor draws a magnetizing current while it is operating. The magnetizing current is independent of the load on the machine, but is dependent on the design of the stator and the stator voltage. The actual magnetizing current of an induction motor can vary from as low as 20% FLC for large two pole machines to as high as 60% for small eight pole machines. The tendency is for large machines and high speed machines to exhibit a low magnetizing current, while low speed machines and small machines exhibit a high magnetizing current. A typical medium sized four pole machine has a magnetizing current of about 33% FLC.

A low magnetizing current indicates a low iron loss, while a high magnetizing current indicates an increase in iron loss and a resultant reduction in operating efficiency.

The resistive component of the current drawn by the motor while operating, changes with load, being primarily load current with a small current for losses. If the motor is operated at minimum load, i.e. open shaft, the current drawn by the motor is primarily magnetizing current and is almost purely inductive. Being an inductive current, the power factor is very low, typically as low as 0.1. As the shaft load on the motor is increased, the resistive component of the current begins to rise. The average current will noticeably begin to rise when the load current approaches the magnetizing current in magnitude. As the load current increases, the magnetizing current remains the same and so the power factor of the motor will improve. The full load power factor of an induction motor can vary from 0.5 for a small low speed motor up to 0.9 for a large high speed machine.

The losses of an induction motor comprise: iron loss, copper loss, windage loss and frictional loss. The iron loss, windage loss and frictional losses are all essentially load independent, but the copper loss is proportional to the square of the stator current. Typically the efficiency of an induction motor is highest at 3/4 load and varies from less than 60% for small low speed motors to greater than 92% for large high speed motors. Operating power factor and efficiencies are generally quoted on the motor data sheets.

vi) **Design Classification.** There are a number of design/performance classifications which are somewhat uniformly accepted by different standards organizations. These design classifications apply particularly to the rotor design and hence affect the starting characteristics of the motors. The two major classifications of relevance here are *design A*, and *design B*.

Design A motors have a shallow bar rotor, and are characterized by a very high starting current and a low starting torque. Typical values are 850% current and 120% torque. Shallow bar motors usually have a low slip, i.e. 1480 RPM.

Design B motors have a deeper bar rotor and are characterized by medium start current and medium starting torque. Typical design B values are 650% current and 180% torque. The slip exhibited by design B motors is usually greater than the equivalent design A motors. i.e. 1440 RPM.

Design F motors are often known as Fan motors having a high rotor resistance and high slip characteristics. The high rotor resistance enables the fan motor to be used in a variable speed application where the speed is reduced by reducing the voltage. Design F motors are used primarily in fan control applications with the motor mounted in the air flow. These are often rated as AOM or **A**ir **O**ver **M**otor machines.

vii) **Frame Classification.** Induction motors come in two major frame types, these being **T**otally **E**nclosed **F**orced air **C**ooled (TEFC), and Drip proof.

The TEFC motor is totally enclosed in either an aluminum or cast iron frame with cooling fins running longitudinally on the frame. A fan is fitted externally with a cover to blow air along the fins and provide the cooling. These motors are often installed outside in the elements with no additional protection and so are typically designed to IP55 or better.

Drip proof motors use internal cooling with the cooling air drawn through the windings. They are normally vented at both ends with an internal fan. This can lead to more efficient cooling, but requires that the environment is clean and dry to prevent insulation degradation from dust, dirt and moisture. Drip proof motors are typically IP22 or IP23.

viii) **Temperature Classification.** There are two main temperature classifications applied to induction motors. These being Class B and Class F.

The temperature class refers to the maximum allowable temperature rise of the motor windings at a specified maximum coolant temperature.

Class B motors are rated to operate with a maximum coolant temperature of 40 degrees C and a maximum winding temperature rise of 80 degrees C. This leads to a maximum winding temperature of 120 degrees C. Class F motors are typically rated to operate with a maximum coolant temperature of 40 degrees C and a maximum temperature rise of 100 degrees C resulting in a potential maximum winding temperature of 140 degrees C.

Operating at rated load, but reduced cooling temperatures gives an improved safety margin and increased tolerance for operation under an overload condition. If the coolant temperature is elevated above 40 degrees C then the motor must be derated to avoid premature failure. Note: Some Class F motors are designed for a maximum coolant temperature of 60 degrees C, and so there is no derating necessary up to this temperature.

Operating a motor beyond its maximum, will not cause an immediate failure, rather a decrease in the life expectancy of that motor. A common rule of thumb applied to insulation degradation, is that for every ten degree C rise in temperature, the expected life span is halved. Note: the power dissipated in the windings is the copper loss which is proportional to the square of the current, so an increase of 10% in the current drawn, will give an increase of 21% in the copper loss, and therefore an increase of 21% in the temperature rise which is 16.8 degrees C for a Class B motor, and 21 degrees C for a Class F motor. This approximates to the life being reduced to a quarter of that expected if the coolant is at 40 degrees C. Likewise operating the motor in an environment of 50 degrees C at rated load will elevate the insulation temperature by 10 degrees C and halve the life expectancy of the motor.

ix) **Power factor correction** is achieved by the addition of capacitors across the supply to neutralize the inductive component of the current. The power factor correction may be applied either as automatic bank correction at the main plant switchboard, or as static correction installed and controlled at each starter in such a fashion that it is only in circuit when the motor is on line.

Automatic bank correction consists of a number of banks of power factor correction capacitors, each controlled by a contactor which in turn is controlled by a power factor controller. The power factor controller monitors the supply coming into the switchboard and adds sufficient capacitance to neutralize the inductive current. These controllers are usually set to adjust the power factor to 0.9 - 0.95 lagging. (inductive)

Static correction is controlled by a contactor when the motor is started and when the motor is stopped. In the case of a Direct On Line starter, the capacitors are often controlled by the main DOL contactor which is also controlling the motor. With static correction, it is important that the motor is under corrected rather than over corrected. This is because the capacitance and the inductance of the motor form a resonant circuit. While the motor is connected to the supply, there is no problem. Once the motor is disconnected from the supply, it begins to decelerate. As it decelerates, it generates voltage at the frequency at which it is rotating. If the capacitive reactance equals the inductive reactance, i.e. unity power factor, we have resonance. If the motor is critically corrected (pf = 1) or over corrected, then as the motor slows, the voltage it is generating will pass through the resonant frequency set up between the motor and the capacitors. If this happens, major problems can occur. There will be very high voltages developed across the motor terminals and capacitors causing insulation damage, high resonant currents can flow, and transient torque's generated can cause mechanical equipment failure.

The correct method for sizing static correction capacitors, is to determine the magnetizing current of the motor being corrected, and connect sufficient capacitance to give 80% current neutralization. Charts and formula based on motor size alone can be totally erroneous and should be avoided if possible. There are some power authorities who specify a fixed amount of KVAR per kilowatt, independent of the size or speed. This is a dangerous practice.

x) **Single phase motors.** In order for a motor to develop a rotating torque in one direction, it is important that the magnetic field rotates in one direction only. In the case of the three phase motor, there is no problem and the field follows the phase sequence. If voltage is applied to a single winding, there are still multiples of two poles which alternate between North and South at the supply frequency, but there is no set rotation for the vectors. This field can be correctly considered to be two vectors rotating in opposite directions. To establish a direction of rotation for the vector, a second phase must be added. The second phase is applied to a second winding and is derived from the first phase by using the phase shift of a capacitor in a capacitor start motor, or inductance and resistance in an induction start motor. (sometimes known as a split phase motor.) Small motors use techniques such as a shaded pole to set the direction of rotation of the motor.

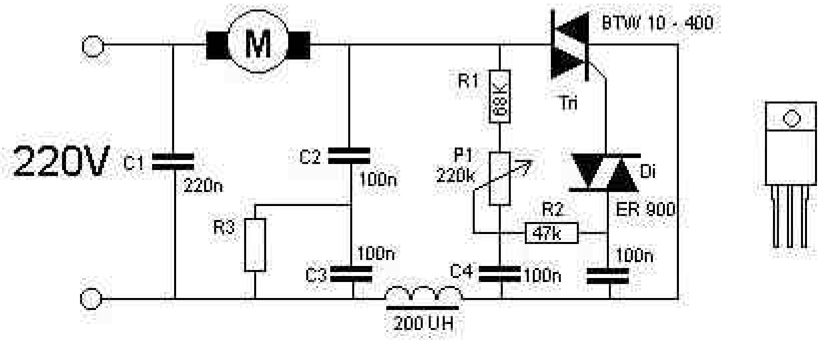
xi) **Slip Ring Motors.** Slip ring motors or wound rotor motors are a variation on the standard cage induction motors. The slip ring motor has a set of windings on the rotor which are not short circuited, but are terminated to a set of slip rings for connection to external resistors and contactors. The slip ring motor enables the starting characteristics of the motor to be totally controlled and modified to suit the load. A particular high resistance can result in the pull out torque occurring at almost zero speed providing a very high locked rotor torque at a low locked rotor current. As the motor accelerates, the value of the resistance can be reduced altering the start torque curve in a manner such that the maximum torque is gradually moved towards synchronous speed. This results in a very high starting torque from zero speed to full speed at a relatively low starting current. This type of starting is ideal for very high inertia loads allowing the machine to get to full speed in the minimum time with minimum current draw.

The down side of the slip ring motor is that the sliprings and brush assemblies need regular maintenance which is a cost not applicable to the standard cage motor. If the rotor windings are shorted and a start is attempted, i.e the motor is converted to a standard induction motor, it will exhibit an extremely high locked rotor current, typically as high as 1400% and a very low locked rotor torque, perhaps as low as 60%. In most applications, this is not an option.

Another use of the slipring motor is as a means of speed control. By modifying the speed torque curve, by altering the rotor resistors, the speed at which the motor will drive a particular load can be altered. This has been used in winching type applications, but does result in a lot of heat generated in the rotor resistors and consequential drop in overall efficiency.

220V motor speed control

This is the schematic for 220V. motor speed control. It can be used for controlling the RPM of a ball mill and star rolling machine motors, or electro drills .The coil is 200UH toroid,C1 is a 400V, ceramic capacitor. The triac (Tri) should be installed on an aluminum heat sink to prevent overheating.



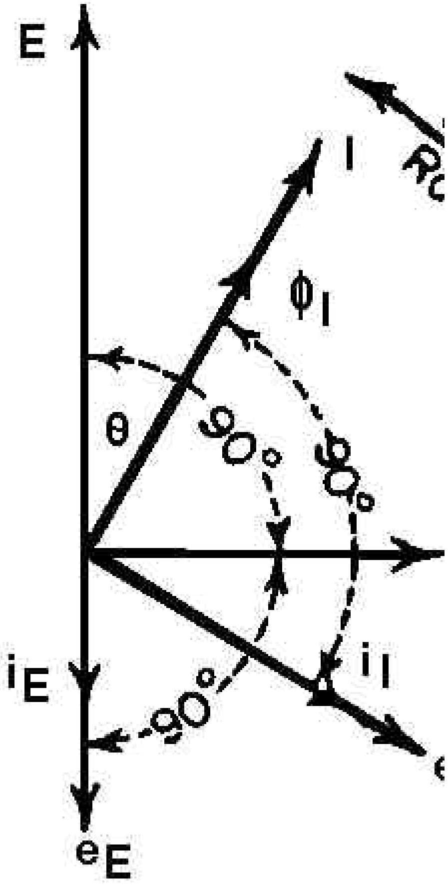
III. WATT-HOUR METER OPERATING PRINCIPLES AND CONSTRUCTION

3.1. GENERAL. For the sake of simplicity, the discussion in this section will be mainly based on a single-element (single-phase) meter. Two- and three-element meters are simply two or three single elements having a common shaft and register, which serve to totalize the energy measured by each element.

3.2. BASIC SINGLE-PHASE METER. A single-phase watt-hour meter is essentially an induction motor whose speed is directly proportional to the voltage applied and the amount of current flowing through it. The phase displacement of the current, as well as the magnitude of the current, is automatically taken into account by the meter. In other words, the power factor influences the speed, and the moving element (disk) rotates with a speed proportional to true power. The register is simply a means of registering revolutions, and by proper gearing is arranged to read directly in kilowatt-hours. (Note: In some cases, the meter reading must be multiplied by a factor called the "register constant" or "meter multiplier" to obtain total kilowatt-hours. See "Register constant (K), "Paragraph 3.9.4.

3.3. DISK DRIVING TORQUE. As stated above, the meter operates similarly to an induction motor. The aluminum disk acts as a squirrel-cage rotor, torque being produced as a result of eddy currents induced in it by the potential (voltage) and current coils on the electromagnet. In order that registration be correct, the torque (and speed) must be greatest at a power factor of 1.0. To have maximum speed at unity power factor, it is necessary that the current in the potential coil lag exactly 90º behind that in the current coil, or in other words 90º behind the voltage applied to the potential coil. This is also necessary if the meter is to register correctly at power factors less than unity. (See Figure 3.) To get this exact 90º displacement, a short- circuited (lag) coil is placed on the voltage coil pole. (See Figure 4.) The resistor in the circuit of this coil may constitute the "lag" or power-factor adjustment of the meter, but in many meters this adjustment is obtained by movement of a "lag plate," and the resistor should not be disturbed.

Do not confuse this 90º lag within the meter at unity power factor, which is necessary for proper functioning of the meter, with the current and voltage supplied to the meter by the instrument transformers. These are in phase (0º displacement) at unit (1.0) power factor.



E = Voltage on potential coil.
ϕ_E = Potential coil flux.
e_E = Disk voltage induced by ϕ_E.
i_E = Disk current due to e_E.

I = Currer
ϕ_I = Curre
e_I = Disk v
i_I = Disk c
θ = Powe

Disk torque is due to 2 components - the inter
i with ϕ. Note that phase opposition of i

Figure 3. Vector diagram of watt-hour meter element.

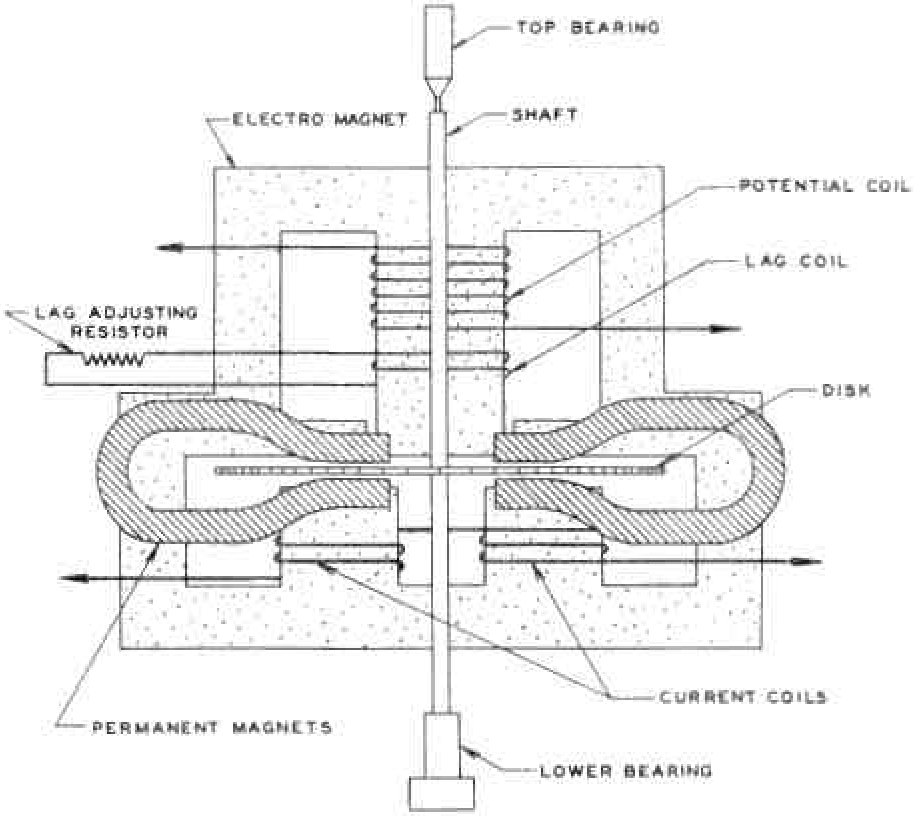


Figure 4. Fundamentals of a single-phase induction watt-hour meter.

3.4. FRICTION. To compensate for friction, additional torque must be introduced. This usually is accomplished by placing a movable short-circuited turn of large cross section in part of the field of the voltage (potential) coil. This also serves as a "light-load" adjustment.

3.5. BRAKING MAGNETS. Normally there is very little friction present in meters, and if no additional retarding force other than friction were placed in the meter, the rotating element would travel at a relatively high speed. The necessary retarding action is provided by a magnetic brake consisting of a permanent magnet operating on the aluminum disk. This retarding action is adjustable and is known as the "full load" meter adjustment. Two methods of varying the braking effect of the magnet are in common use. The first is to adjust the position of the magnet; moving it outward radially toward the edge of the disk increases the braking effect and decreases speed and registration. In the second method, the magnet is fixed, and the braking effect is adjusted by a magnet shunt which bypasses part of the magnet flux of the permanent magnet, as shown in Figure 5.

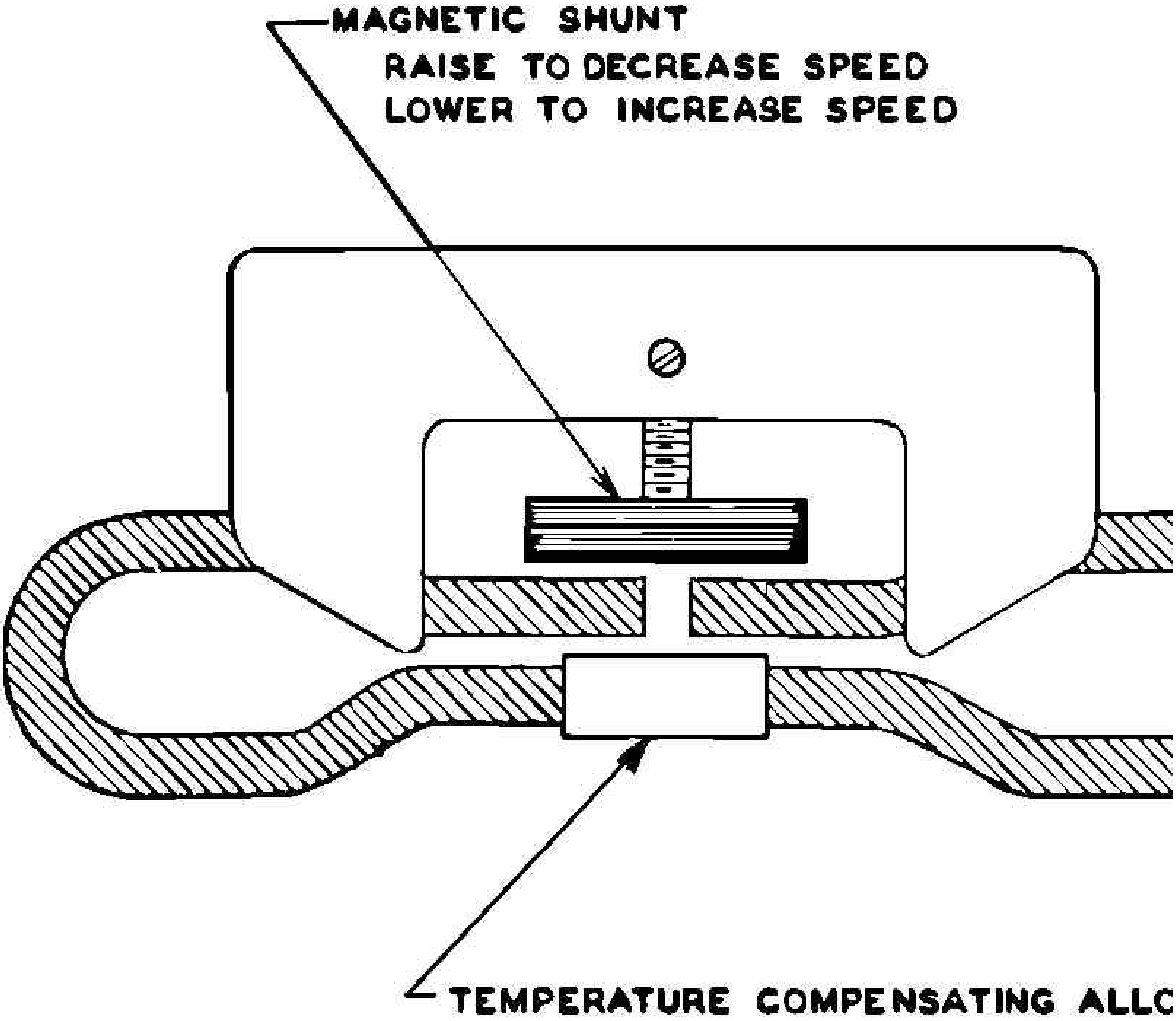


Figure 5. Magnetic shunt method of adjusting speed of disk.

3.6. BEARINGS. Figure 4 shows the basic mechanical arrangement and relationship of the moving element, bearings, permanent magnets, and electromagnet. The register which is geared to the shaft is not shown. The moving element consists of an aluminum disk on a shaft. The bottom bearing may be either of two types - two cupped jewels with a steel ball between or a cone-shaped pivot on the shaft which rotates in a cupped jewel bearing. The top bearing is usually a hardened steel needle-like pin fitting loosely inside the hollow shaft.

3.7. MULTIELEMENT METERS. Multielement meters usually consist of additional elements stacked vertically, with two or more disks on the same shaft, although meters may be encountered which have more than one electromagnet system acting on the same disk. Usually there is a set of permanent magnets per disk, but they may not all be capable of adjustment.

> 3.7.1. **Balance adjustment.** - In multielement meters, an adjustment must be provided to equalize the torque of the various elements. This is the "balance" adjustment and may be a magnetic shunt or a means of adjusting the position of the whole element radially with respect to the disk.

3.8. DETENTS. A detent or ratchet is sometimes attached to meters to prevent rotation in a reverse direction when it is desired not to register reverse power flow. This usually consists of a collar having notches or pins which is placed on the disk shaft and a pawl attached to some fixed part of the meter which engages the notches or pins upon reverse rotation but slides easily over them in the forward direction. The slight amount of friction introduced by the installation of a ratchet may affect the light-load registration and require that the meter be readjusted.

3.9. METER CONSTANTS. A knowledge of register and gear ratios and of watt-hour and register constants is required in order to check the correctness of kilowatt-hours as read from the register. (See also Paragraph 3.1 1.)

3.9.l. **Watt-hour constant (Kh)**. - The watt-hour constant is the registration of one revolution of the rotating disk element expressed in watt-hours. The watt-hour constant is also sometimes called the *disk* constant. The Kh will usually be found marked on the meter nameplate or on the rim of the disk. Values of secondary Kh (see Paragraph 3.10) (per 5-ampere, 115 volt element) commonly used by various manufacturers for transformer-rated meters are listed below. Some other values that may be encountered are listed in parentheses.

	Values of Secondary Kh
General Electric	0. 7, 0.9, 1.2, 1,8 (0.3, 1/4)
Westinghouse	1/3, 0.9,1.8(1/4)

Sangamo ....0.6, 0.9,1.2,1.8(1/3, 5/24)
Duncan ....
0.9, 1.2, 1.8

3.9.2. **Gear ratio (Rg)**. - The gear ratio of a meter is the number of revolutions of the rotating disk element for one revolution of the first dial pointer.

3.9.3. **Register ratio (Rr).** - The register ratio of a meter is the number of revolutions of the wheel meshing with the worm or pinion on the rotating disk element, for one revolution of the first dial pointer.

The gear or register ratio is often found marked on the rear plate of the register or on the gear train frame. In checking the register and gear ratios, it will probably be found most practical to determine the register ratio by counting the number of revolutions that the wheel meshing with the shaft must make for, say, one-tenth revolution of the first dial pointer. By counting the teeth on this wheel and the number of teeth on the shaft pinion, the "first reduction" is determine. Register ratio times "first reduction" equals gear ratio. In the case of worm on the shaft, the lead or number of threads on the worm should be observed to determine how many teeth the meshing wheel is advanced by one revolution of the shaft.

3.9.4. **Register constant (Kr).** - The register constant is a factor by which the register reading is multiplied to ascertain the number of kilowatt-hours recorded by the meter. The register constant is also sometimes called the *dial constant or multiplier.* The register constant may be 1, 10, 100, or some integral of 10, except that for meters used with instrument transformers, it may be the register constant of the meter alone, multiplied by the product of the ratios of the instrument transformers. The register constant is usually marked on the dial face and may or may not take into account the instrument transformer ratios. Registers should be standardized as much as possible to eliminate the stocking of spares.

3.10 PRIMARY VERSUS SECONDARY CONSTANTS. At this point, a word of caution is in order. If the meter were rated for use with instrument transformers, as indicated by data on the nameplate, the watt-hour constant (Kh) and register constant (Kr) as marked on the meter or nameplate may be "primary constants" and include the product of the instrument transformer ratios. If this is the case, it will be obvious, because the Kh will be much greater than the 1/3, ½, 2/3, 0.6, etc., which is the basic or "secondary" Kh of the meter itself. As stated in the first part of this bulletin, discussion is based on 5-ampere meters. In the case of 15- or 50-ampere meters, such as might be found in Government camp service, the "secondary" Kh would be large. It is also possible that installations will be found where meters are operating with instrument transformers of different ratios than originally intended. For this reason, when checking it is recommended that the meter be considered separately (as if it were not used with instrument transformers), and its constants be determined. Then in the last step - checking the register constant - bring in the factor of instrument transformer ratios.

3.11. FORMULAS FOR CONSTANTS. To recapitulate the foregoing in a different manner, and in a sequence which can be used in a checking procedure, and also to present a useful equation, the following procedure is suggested.

One revolution of the rotating disk element of the meter is equal to Kh watt-hours. The number of revolutions of the rotating disk element for one revolution of the first dial pointer is equal to the gear ratio, Rg, and therefore one revolution of the first dial pointer will represent:

Kh x Rg watt-hours, or

$$\frac{Kh \times Rg}{1{,}000} \text{ kilowatt} - \text{hours}$$

The numerical value of one revolution of the first dial pointer of a standard register is 10; therefore the register constant for kilowatt-hours is:

$$Kr = \frac{Kh \times Rg}{10 \times 1{,}000}$$

and

$$Rg = \frac{Kr \times 10{,}000}{Kh}$$

First determine the *ratio of reduction* between the shaft of the rotating disk element and the shaft of the gear engaging with it. This is called the "first reduction." Next determine the register ratio, Rr, (Paragraph 3.9.3). The gear ratio, Rg, is equal to the register ratio multiplied by the first reduction, and its value may be substituted in the equation. In this checking process, it is recommended that the secondary Kh of the meter be used, and the Kr of the meter alone be determined first, and then multiply it by the transformer ratios to find the factor (multiplier) by which the dial reading must be multiplied for correct measurement of kilowatt-hours.

3.12. BASE-LOAD SPEED. Another useful characteristic of the meter, if known, is the base-load speed. Base-load speed is rpm at 115 volts and 5 (or 2-1/2) amperes, unity power factor. On a steady load, by timing the meter speed with a stopwatch, a very accurate value of kilowatt load may be obtained in the absence of a wattmeter; or the same method may be used to check the accuracy of an indicating wattmeter. (See Paragraph 4.1.4.) Base-load speeds commonly used by various manufacturers follow, but should not be construed as applying in all cases. For example, Westinghouse also uses a speed of 33-1/3 rpm in their Type CA-8 meter.

Base-load speeds - 500 (or 250) watts/element

General Electric	16-2/3 rpm
Westinghouse	25 rpm
Sangamo	16-2/3 rpm
Duncan	25 rpm

Kh and base-load speed are related as follows for single phase:

$$\text{Kh} = \frac{\text{Nominal volts (115) x nominal amps (5 or 2 -1 / 2)}}{\text{Base -load speed (rpm) x 60}}$$

3.13. METER CONNECTION DIAGRAMS. Figures 6 through 14 illustrate typical meter connections. Not all possible meter types are included, but it is believed that in Reclamation powerplants, substations, and pumping plants, instances where other types of meters are encountered will be extremely rare. The meter terminal arrangements shown in the figures were chosen solely for simplicity and clarity. Actual arrangement of terminal studs varies widely with make and model. One thing they all have in common, however, is symmetry, and it is usually quite easy to trace the internal meter connections to determine the identify of studs. For example, in the case of a 2-element meter with horizontal stud arrangements, the two phases are separated by an imaginary horizontal line through the center of the meter, and for the sake of symmetry the voltage studs may be at extreme top and bottom. In some installations the instrument transformers may supply other instruments besides the watt-hour meters.

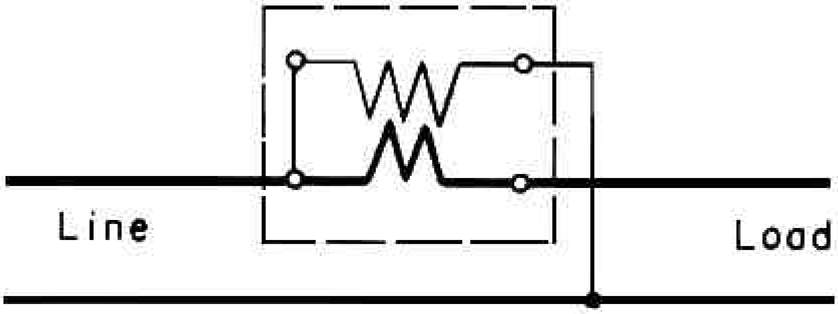


Figure 6. Single-phase, 2-wire meter.

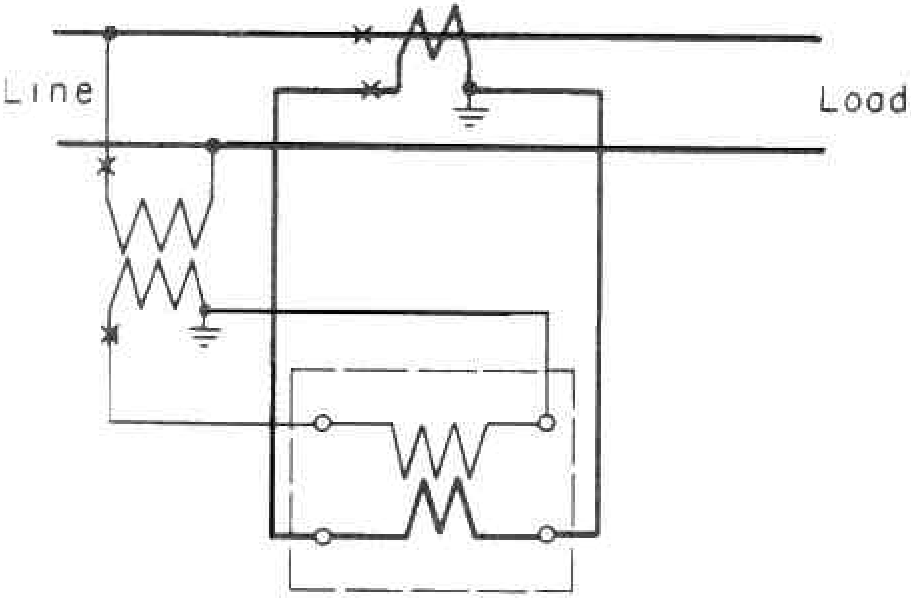


Figure 7. Single-phase, 2-wire meter using instrument transformers.

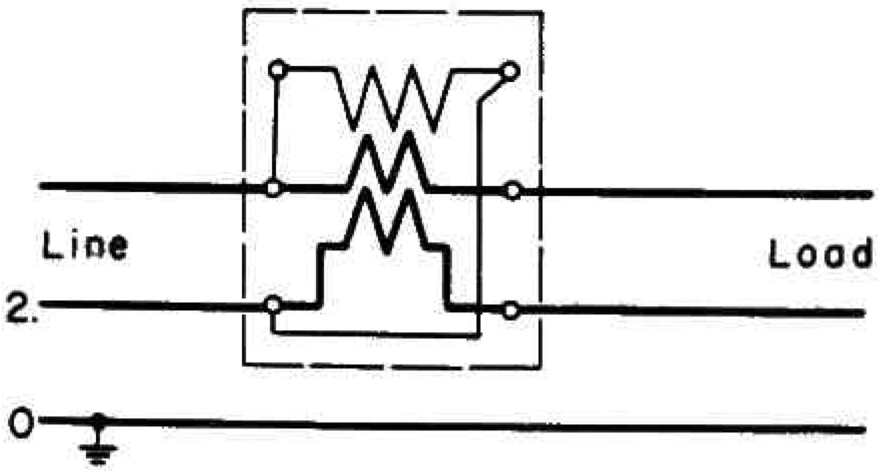


Figure 8. Single phase, 3-wire meter.

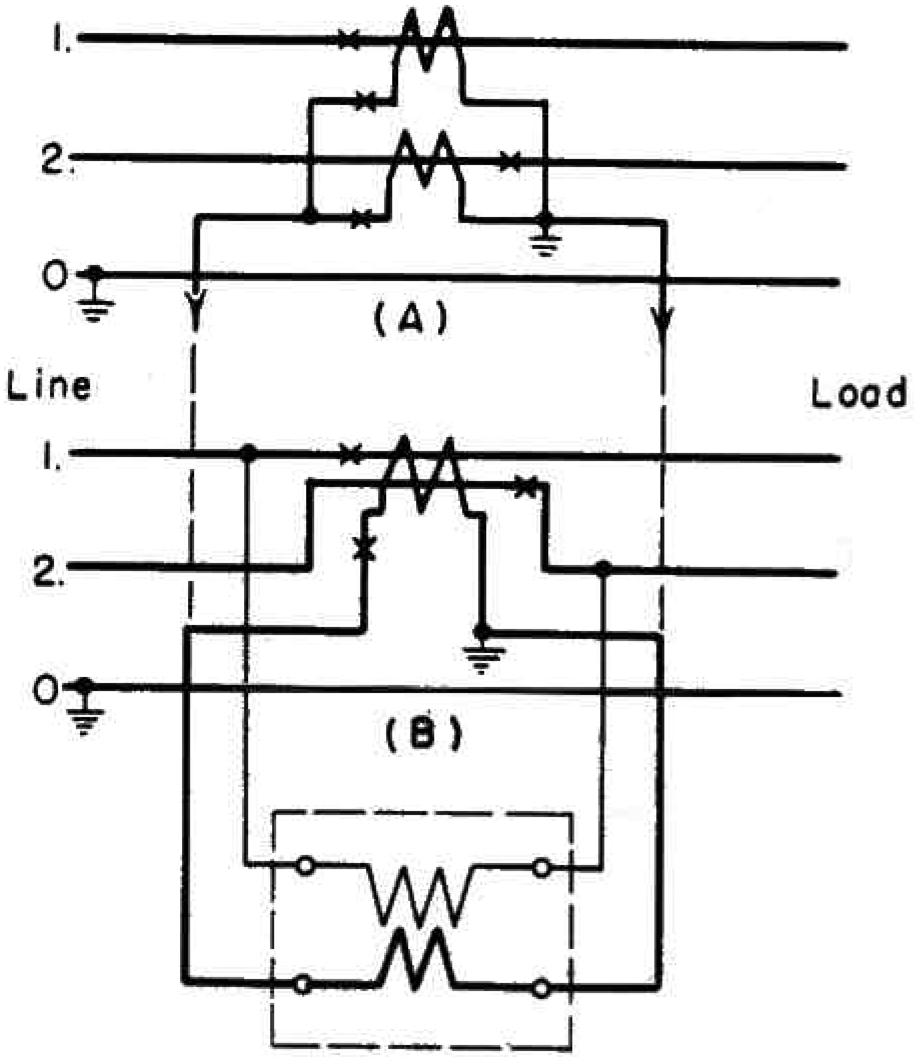


Figure 9. Single-phase, 3-wire circuit using 2-wire meter and current transformers.

(A) Two current transformers. (B) One 3-wire current transformer

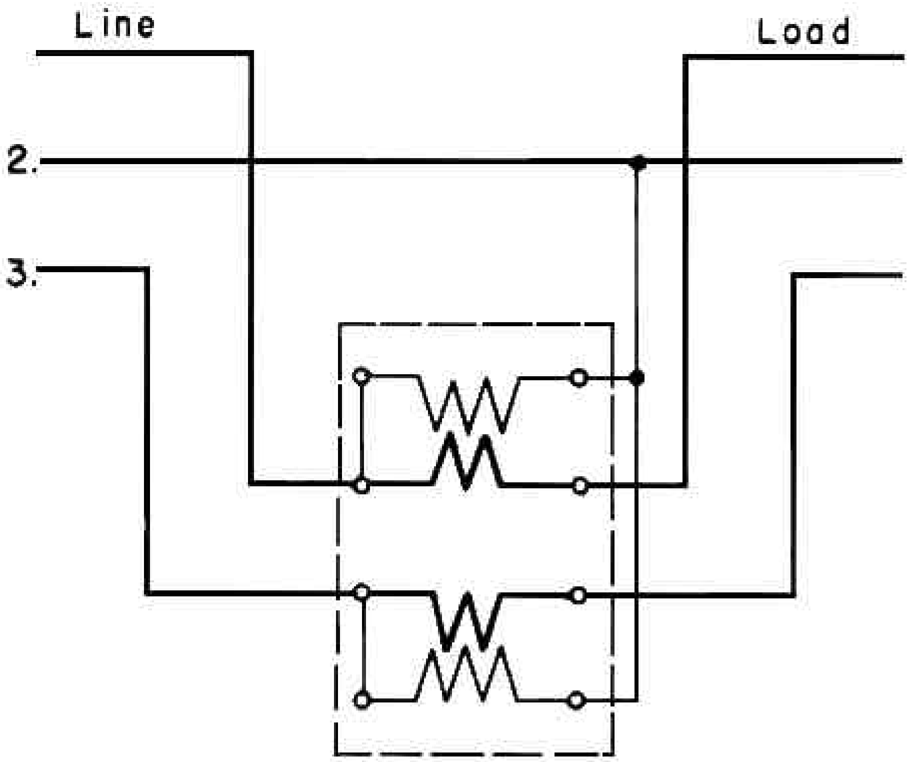


Figure 10. Three-phase, 3-wire, 2-element meter, self-contained.

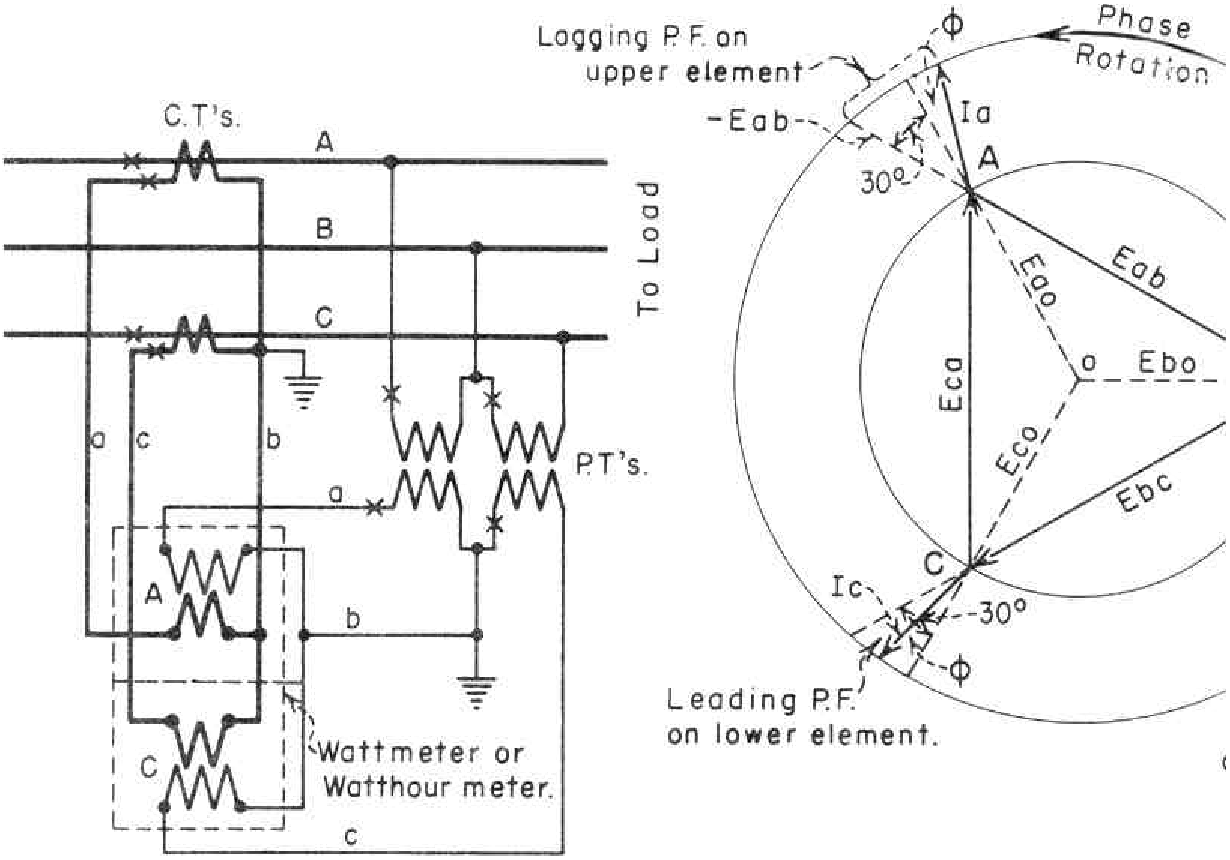


Figure 11. Three-phase, 3-wire, 2-element meter, two current transformers and two potential transformers.

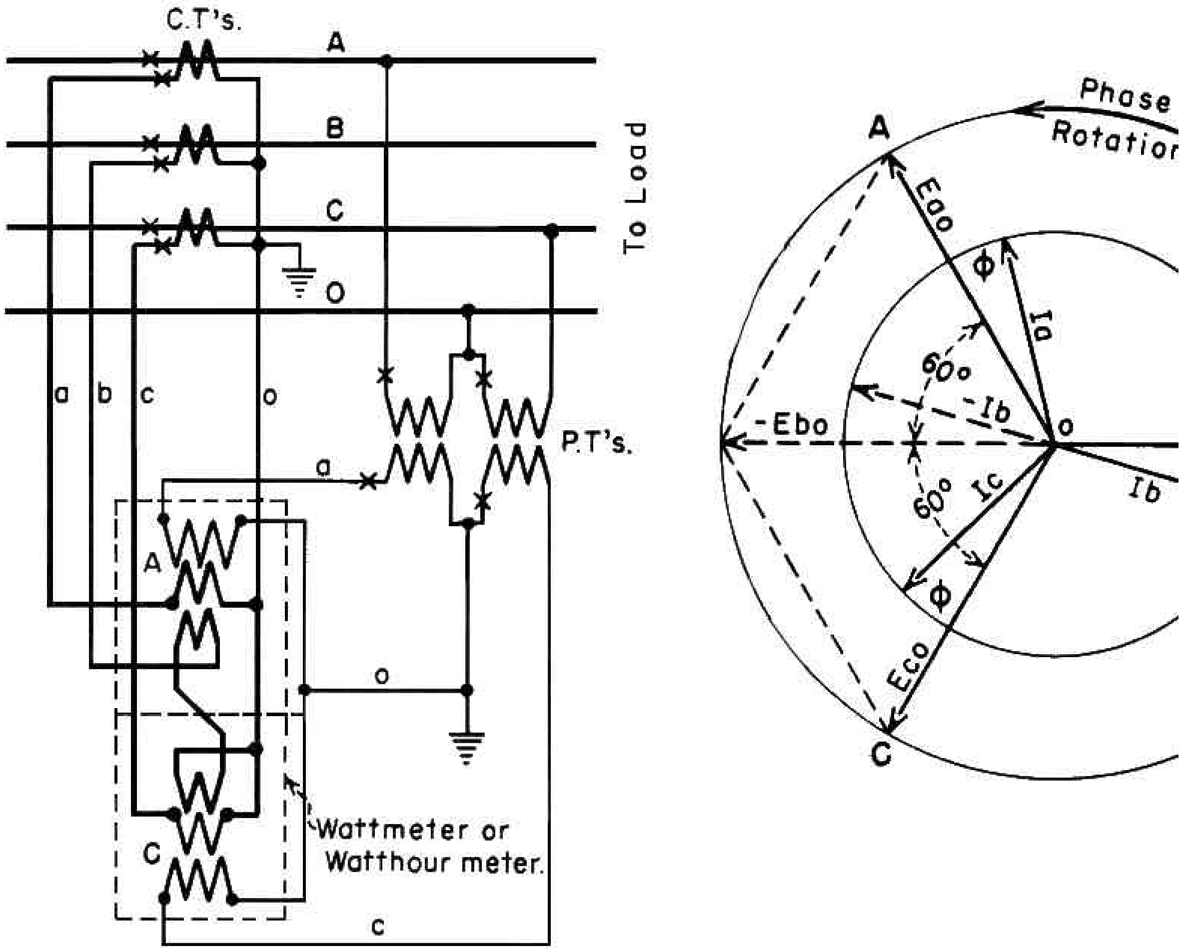


Figure 12. Three-phase, 4-wire, 2-1/2-element meter, three current transformers and two potential transformers.

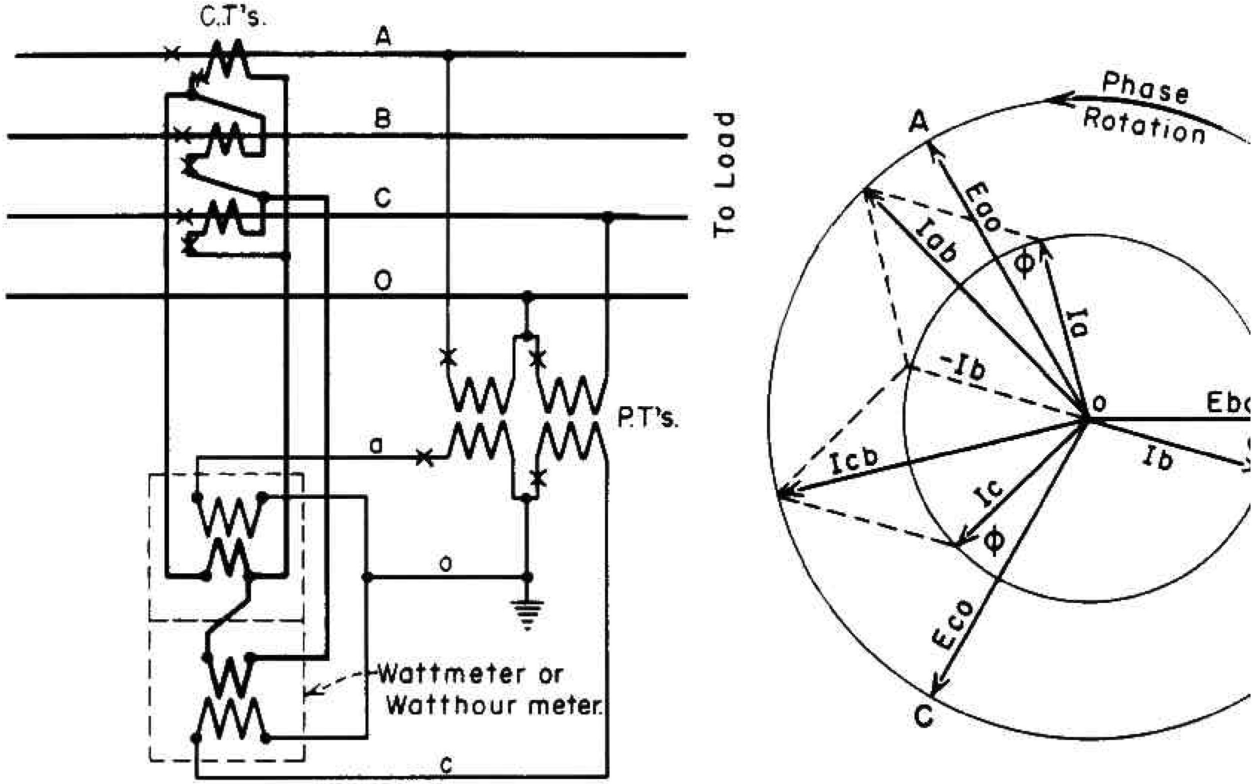


Figure 13. Three-phase, 4-wire, 2-element meter with delta-connected current transformers.

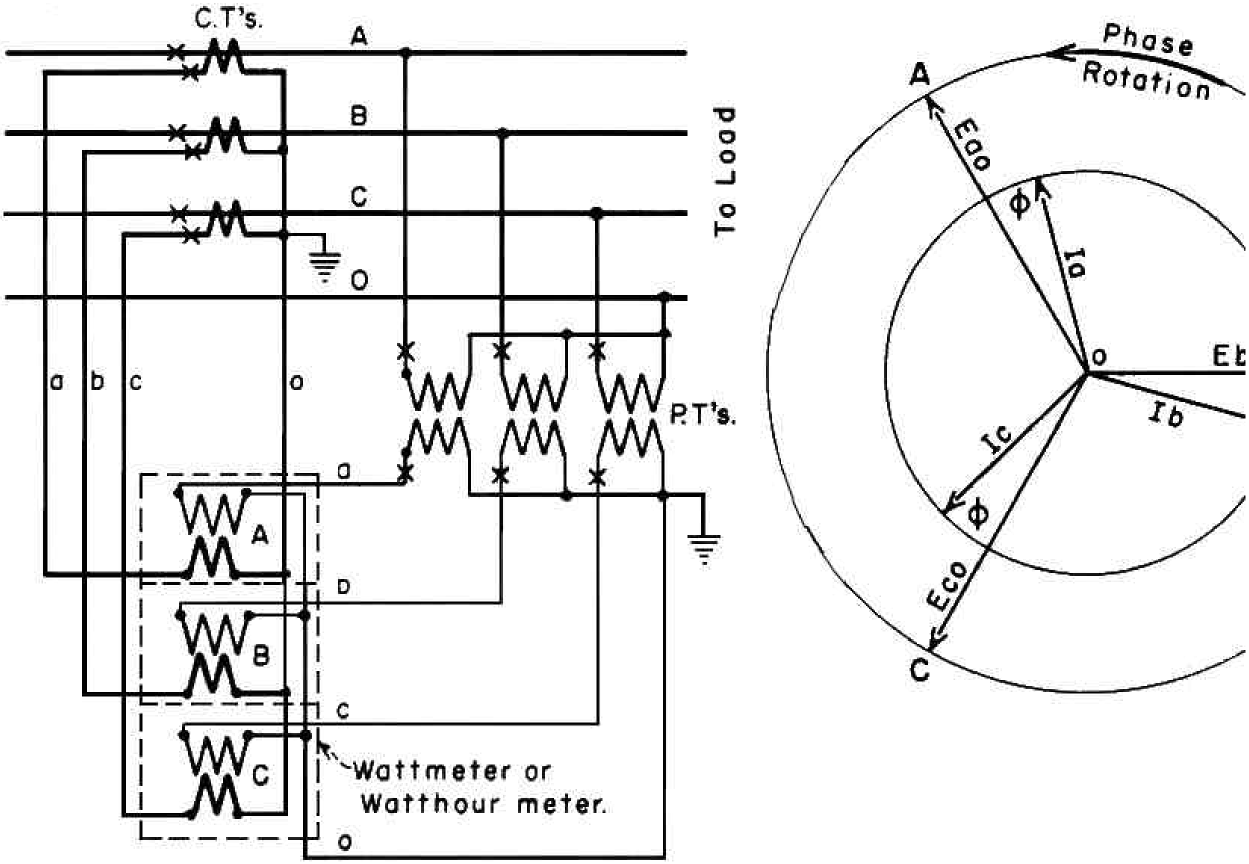


Figure 14. Three-phase, 4-wire, 3-element meter.

ERRORS IN WATT-HOUR METERING

6.1 METER ACCURACY. The watt-hour meter is a precise instrument capable of adjustment within very close limits and with periodic servicing will maintain such accuracy indefinitely. As a Reclamation standard, meters should be adjusted within the following limits:

At rated voltage and frequency	Percent registration
Unity power factor, 100% current	99.7 to 100.3

Unity power factor, 10% current	99.7 to 100.3
Unity power factor, 50% current	99.7 to 100.3
50% lagging power factor, 100% current	99.3 to 100.7

In the recording of meter accuracy, the term "percent registration" is used rather than "percent error."

$$\%\ \text{registration} = \frac{\text{actual registration kWh x 100}}{\text{trueKwh}}$$

The above accuracy limits apply to each element of a polyphase meter and to the combination of all elements when tested on a single phase with the current coils in series.

6.2. INSTRUMENT TRANSFORMER ERRORS. Meters used with instrument transformers can be calibrated to compensate for the errors of the transformers, but with high-accuracy instrument transformers operated within their ratings (burden), the error is small and usually neglected. If necessary, the correction factor (K_f) for ratio and phase-angle errors may be determined from the following if the required data are available on the instrument transformers:

$$K_f=CVK_p$$

where:

$$C = \frac{\text{Actual transformer ratio}}{\text{Marked transformer ratio}}$$
(current transformer);

$$V = \frac{\text{Actual transformer ratio}}{\text{Marked transformer ratio}}$$
(potential transformers);

$$K_p = \text{Phase-angle correction factor for combined potential and current transformers} = \frac{\cos(\theta 2 + B - Y)}{\cos\theta 2}$$

in which

$\cos \theta 2$=Apparent power factor of load as measured on the secondary of the transformers;

B=Angle by which the reversed secondary current leads the primary current;

Y=Angle by which the reversed secondary voltage leads the primary voltage.

In using this formula, care must be taken to use the proper sign with B and Y. Information is available in the Code *for Electricity Metering* from which K_p may be readily obtained, without carrying out the detailed calculations of the formula.

6.3 SOURCES OF METER ERRORS. Aside from the inherent errors due to variations in temperature, frequency, etc., which are factors of design, the most common causes of error within a meter are listed below and may be detected by inspection and corrected.

6.3. 1. **Common causes.** -

(1) Dirt (on the disk; in the air gaps).

(2) Magnetic particles (in the permanent-magnet air gaps).

(3) Gummy oil and/or dirt in bearings.

(4) Broken jewels.

(5) Disk rubbing in air gap.

(6) Improper mesh of gears or dirty gearing.

(7) Improperly adjusted bearings.

(8) Vibration of the meter mounting.

(9) Creeping.

With the exception of (8) and (9) above, it will be noted that all defects listed introduce friction and will cause the meter to register "slow."

6.3.2. **Other causes.** -

(1) External magnetic fields which may add to, or subtract from, the normal meter magnetic flux.

(2) Overloads and short circuits. The effect of overloads and short circuits may be to alter the magnetization of the brake magnets, to magnetize adjacent masses of iron, and in general to disarrange the parts.

(3) Short-circuited turns in meter coils.

6.3.3. **External causes. -** Some of the sources of error which may occur outside the meter itself are:

(1) Instrument transformer phase-angle and ratio errors.

(2) Improper connections such as cross-phasing and reversed polarity.

(3) Broken or high-resistance connections and short circuits in meter wiring and test blocks, blown potential fuses, short-circuiting switches inadvertently closed or left closed, etc.

(4) Improperly calibrated or poorly maintained rotating standards.

And here is the infamous TRON box plans…below.

```
*************************************
*                          *
*        THE HOW TO SERIES        *
*                          *
*           PART III          *
*                          *
*           TRON BOX           *
*                          *
*        BY: CAP'N CRUNCH        *
* CALL /-\PRIL \/\/INE [913] 236-4493 *
*       MONOLITH PRODUCTIONS       *
*************************************
```

```
 ------------------R-----F----
 I    I     I              I
 I    I     I              I-input
(C) (C) (C)
 I    I     I              I-input
 I    I     I              I
 -----------------------------
```

(C)=CAPACITOR
 F =FUSE
 R =RESISTOR
I,- ARE WIRE
 PARTS LIST:
(3) ELECTROLYTIC CAPACITORS
 RATED AT 50V(LOWEST) .47UF
(1) 20-30OHM 1/2 WATT RESISTOR
(1) 120VOLT FUSE (AMP RATING BEST
 TO USE AT LEAST HALF OF TOTAL
 HOUSE CURRENT OR EVEN LESS IT
 KEEPS YOU FROM BLOWING YOUR
 BREAKER JUST IN CASE...)
(1) POWER CORD (CUT UP AN EXTENSTION
 CORD. NEED PLUG PART AND WIRE)
(1) ELECTRICALLY INSULATED BOX

REST OF SIF YOUR DONT FILL COMFORTABLE
ABOUT
ELECTRICITY THEN DONT PLAY WITH THIS
THERE IS VOLTAGE PRESENT THAT WILL
KILL YOU.....................

THE THING WORKS WHEN THE LOAD IN YOUR
HOUSE IS LOW LIKE AT NIGHT TIME. IT
WILL PUT A REVERSE PHASE SIGNAL ON
THE LINE AND CANCEL OUT THE OTHER PHASE
AND PUT A REVERSE PHASE RUNNING EVERY

THING IN THE HOUSE. WELL IF YOU HAVE EVER SWITCHED THE POWER LEADS ON A D.C. (BATTERY POWERED) MOTOR YOU WILL SEE THAT IT RUNS BACKWARDS WELL YOUR ELECTRIC METER SORT OF WORKS THIS WAY...SO REVERSE PHASE MAKES THE METER SLOW DOWN AND IF YOUR LUCKY IT WILL GO BACKWARDS. ANYWAY IT MEANS A CHEAPER ELECTRIC BILL