TESTIMONY OF BILL SMITH

Please state you name and address for the record.

Bill Smith
33 South Easter Island Circle
Englewood FL 34223

What is the purpose of your testimony?

To discuss the type of thermal demand meters at dispute in this case, the TMT Form 6-S Duncan Landis & Gyr meter, my role in helping design the meter, my work history with the manufacturer of the meters in dispute in this docket, my knowledge of the mechanics of how these thermal demand meters work, and what I believe caused these meters to overregister demand when tested by FPL. I will also discuss the impact that the sun has on thermal demand meters, the proper way these meters should be calibrated, and, how, in my experience, the percentage of error for meters that over-register is calculated.

Please indicate your educational and professional background.

I graduated from North Vernon Indiana High School in 1947. I then served my country in the United States Navy for nine years where I was an Electronics Technician (ET) and a Nuclear Technician. In 1956, I was accepted into Purdue University where I majored in electrical engineering. I graduated from Purdue with a degree in electrical engineering in January of 1961. In 1958, I went to work for Duncan Landis & Gyr. This is the company that made the meters that are in dispute in this docket. I worked there for around 13 years, until 1972. In 1973 I went to work with Anchor Electric. Anchor manufactured meter mounting device. In 1985, I worked with the Astra Corporation, a company that made and sold metering transformer. Shortly thereafter, I worked for the Utility Test Equipment Company (UTEC). UTEC designs, manufactures and distributes meter test equipment. I later returned to Anchor where I finished my career and retired in 1996.

DOCUMENT NUMBER-DATE
07589 JUL 12 04
FPSC-COMMISSION CLERK

TESTIMONY OF BILL SMITH

Have you been involved with meters and meter testing equipment pretty much your whole professional career?

Yes.

What were your duties and responsibilities when you worked with Duncan Landis & Gyr?

As an electrical engineer, I had a host of duties that involved the meters and test equipment that the Company manufactured. With respect to thermal demand meters, like the ones involved in this docket, my responsibilities included working on the design of the meters and ensuring that quality control was maintained. I also tested meters, including the thermal demand meters, against a standard meter. Finally, I oversaw the testing of meters, including thermal demand meters.

Did you gain familiarity with the internal workings of thermal demand meters?

Yes. As I mentioned, part of my job included designing the meters. The Company was always seeking ways to improve the thermal demand meter, and part of my responsibilities was to assist with designing improvements to the meter.

Are you aware that the meters in this case all overregistered demand?

Yes I am. I have reviewed the testing reports for the meters. The testing reflects that the meters have overregistered demand. Mr. Brown's testimony details the particulars of the amount by which each meter overregistered.

One of the issues in this case relates to proving the point in time in which the meters in dispute first started over-registering demand. In your experience in designing and working with thermal demand meters, are you aware of factors that could cause the TMT Form 6-S Duncan Landis & Gyr meter to gradually overregister demand?

The thermal demand meter is a relatively simple measurement tool with few critical parts. I am not aware and do not believe it likely, based upon my knowledge and experience, for the TMT Form 6-S Duncan Landis & Gyr meter to gradually overregister demand. It is my impression, based upon a review of depositions taken in this case; that FPL acknowledges that the TMT Form 6-S Duncan Landis & Gyr meter does not have mechanical components that would cause the meter to run fast.

Why do you say this?

In the deposition of Keith Herbster, who has worked for FPL for nearly 31 years, with between 15 to 18 of those years being involved with meters, he was asked questions about what mechanically might cause a KWD or kilowatt demand meter to run fast. He answered, correctly in my view, that other than adjustments, there was nothing he is aware of that would cause the kilowatt demand meter to overregister or run fast. See excerpt of deposition testimony of Keith Herbster, pages 86-87 (attached hereto as Exhibit A). Also, Brian Faircloth, who states he has tested around 8,000 thermal demand meters, more than anyone at FPL since he has worked in the meter testing center, states "No" in response to the question, "Are you aware of anything that could make these 1V meters gradually or suddenly read high in the field?" See excerpt of the deposition testimony of Brian Faircloth at page 64 (attached hereto as Exhibit B). Jim Teachman, another FPL employee responsible for meter testing, also could not identify anything that would cause a thermal demand meter to gradually overregister demand. See excerpt of deposition testimony of Jim Teachman at page 96 (attached hereto as Exhibit C).

What is the likely cause of a thermal demand meter to overregister?

I believe that the most likely reason a thermal demand would overregister or read high is due to error in calibrating the meter prior to placing it into service.

Why?

Again, the structure of the meter is pretty basic. It really does not have mechanical parts that are likely to cause the meter to over-register gradually over time. However, the process of calibrating a meter, which involves human manipulation, can result in calibration errors that can cause the meter to either over-register or under-register if miscalibrated.

Explain how you could properly calibrate a meter with today's technology:

This testing example will apply to a gang thermal board that has been set up to test and calibrate a TMT form 6S, two stator, transformer rated meter. A single-phase source is used for potential voltage in parallel and for current in series. A reference standard of known accuracy is used for comparison to meters being tested ("meters under test"). Preferably the standard would be an electronic auto-ranging meter of the same form and programmed with the appropriate thermal response curve as the meters to be tested.

INSPECTION

1. Inspect the meter for any visible damage that may cause a hazard or unsafe condition if tested.
2. Inspect the meter for any sign of tampering.
3. If possible correct the problem. If there are no safety concerns continue.

ZERO CHECK and Adjustment

4. Remove the original equipment manufacturer (OEM) canopy. Check the black maximum pointer for proper friction while moving it up-scale away from zero. Replace the OEM canopy with a test cover.
5. Place the meter under test in a test socket with the test canopy (test cover) securely in place.
6. Apply potential voltage only (voltage to match the meter form and type 120V, 240V, 277V, etc.) for a minimum of 2 hours. The black maximum needle should not be in contact with the red instantaneous needle at any time during this test, nor should any current be applied.
7. At the end of two-hours record the zero reading. (AS FOUND) If adjustment is necessary, insert a flat slot screwdriver through the test cover hole corresponding to the zero adjustment on the left side of the meter when facing the meter. If adjusting is necessary, adjust

the zero to within the blade edge width of the indicating red needle on the zero scale point. If adjusting upscale, move the red pointer slightly past the zero then back to zero. This will allow for any backlash, which may occur. If adjusting downscale move the red pointer to as close to zero as possible.

FULL-SCALE CALIBRATION

8. If the potential voltage has not been interrupted for at least 2-hours, the full-scale calibration procedure can begin. Otherwise the meter should be preheated again for a minimum of 1 hour.

9. Amperage should be selected that will correspond to at least 75% registration of full-scale reading of the meter under test. (This is so, because the manufacturer has originally calibrated and warranted the accuracy of this meter at 75% of full scale.) In a single-phase series test this will correspond to ¾ of the amperage needed to reach the desired test point on the full-scale.

10. The selected amperage is applied to the circuit that contains the meters under test as well as the reference standard of known accuracy. The black maximum pointer is moved back to a position that will make contact with the red pointer while testing.

11. The applied amperage and voltage should be monitored closely to maintain their values within 2% of desired test point. This condition should be maintained for 1 hour.

12. At the end of 1 hour, the reference standard is read as closely as possible to two decimals and recorded. Each meter in the test circuit is read to as closely as possible to two decimals and recorded (AS Found). The percentage of error is calculated by dividing the meter under test reading by the standard reading. Any meters under test that register above or below the reading of the reference standard should be adjusted to as close as possible to 100% accurate.

13. If it is necessary to adjust any meters in the thermal gang board, the test load must be maintained throughout the following procedures. Any adjustment to the full-scale should be

done through the hole in the test cover located on the right side of the meter as one faces the meter. This prevents cool air from rushing into the meter that would otherwise occur if the canopy were removed for adjustment that would affect the temperature differences in the thermal elements. A flat-slot screwdriver is inserted in the full-scale adjustment screw. If the meter is to be adjusted upward on the scale, the screw is turned clockwise to the desired point. If adjusting downscale, the adjustment screw is adjusted counterclockwise past the calibration point then slowly back to the calibration point. The black maximum pointer should be in contact with the red indicating pointer. This allows for any backlash, which could occur. If an adjustment has been made, and it is desired to check accuracy of adjustment, reset the red and black needles slightly down scale, this places the black needle back in contact with the red needle. The meter should be maintained at test voltage and current for an additional 45 minutes. At the end of 45-minutes if the meter does not read accurately readjust the meter again and repeat the 45-minute check again.

What are the steps at which an error could occur?

1. To begin with, the known accuracy of the board standard must be confirmed with a transfer standard from the National Institute of Standards and Technology (NIST).

2. The standard must be in the same circuit as the meters under test. This can be accomplished most conveniently by using an electronic auto ranging meter programmed to replicate the thermal response curve. Otherwise it is most likely a correction factor must be applied between the thermal board standard and the meters under test.

3. The zeroing of the meter is important to the accuracy of the full-scale test if the full-scale test is performed in the lower half of full-scale. A thermal demand meter's zero accuracy can influence the lower portion of the scale more so than the upper half of full scale because any deviation in accuracy at zero will decline as the meter is tested higher on the full-scale.

4. Maintaining proper test voltage and current is somewhat critical if the standard is of the thermal type. If the response curve of the standard is not exactly that of the meters under test, the standard could read above or below the meters under test. It should be noted that FPL's thermal board standards do not utilize the black maximum pointer. This can have two effects. First, without the black maximum in contact with the red instantaneous needle there is less resistance in movement of the red pointer that may result in a standard registration slightly higher than the indication that would occur if the black maximum indicator were in contact with the red pointer. Second, on the other hand if the voltage and current are not maintained closely and they are allowed to drift low over the test period it is possible the maximum point of the standard may not be the maximum point reached by the meters under test. That could result in the standard indicating a reading lower than obtained during the test period. That is why the preferred method of testing would be with an electronic auto-ranging meter of known accuracy. It would always read accurately to the maximum level of energy recorded over the test period.

5. Reading the standard board meter and the meters under test can influence the relative reported accuracy of the test results. The thermal standard utilized by FPL has a resolution of 100 increments. Therefore if read to the nearest increment without interpolation the test result would be skewed one way or the other. To aid in making this point I have reviewed a 56 page report on test results of all ~3,900 1V thermal demand meters completed in early 2003. In that report the standard reading was read at even increment in all 3,900 tests except for 49 tests, which read at ½ increment readings. It is highly unlikely that the standard meters maximum indicating needle pointed to an exact increment in 99% of the tests. The same would be true for reading the meters under test. To yield an accurate assessment of the meters being tested, their maximum indicated reading must be interpolated as closely as possible. Otherwise their accuracy will be skewed one way or the other.

6. It has been pointed out that some of the meter test technicians at FPL physically tap the thermal board standard meter at the end of the one-hour test period. The standard should be of a known accuracy and should not require any external manipulation to acquire an accurate reading. According to Mr. George Brown who has witness a number of tests at FPL's meter test center, that tapping of the reference standard has always resulted in the standard reading slightly higher. A higher standard reading skews the accuracy of the meters under test as well as the standard reference meter.

7. The utilization of a test cover is critical for accuracy and efficiency when a meter must be adjusted. However, if the cover is removed and cool air rushes into the meter the hot coil or element could be influenced greater than the cold element. If the hot element cools slightly and begins to drop slightly and at the same time a technician is attempting to adjust the meter upward or downward, he will be chasing a moving target. It would be impossible to adjust the meter accurately.

8. If the above were to occur and the meter is not allowed to continue at rated load for 45-minutes it is unlikely a miscalibration would be detected. The meter is designed to respond to 99.9% of any change over a 45-minute period. That is why it is recommended by Landis & Gyr to leave the meters under test at test load for an additional 45-minutes if adjustments are made.

Did you review the written materials that FPL used to train its metermen regarding how to properly calibrate a thermal demand meter?

Yes, I reviewed some sheets that were attached to the thermal meter test board. I also reviewed FPL test plans and procedures.

Do you have any concerns about mistakes being made during testing and calibration of meters at FPL's meter testing center?

Yes, I do, based on my review of some of the depositions and FPL documents. I have not yet been granted access to the FPL test meter board or the individual meters, but hope to have the opportunity to review them before or during the hearing.

What concerned you?

I was concerned about a number of things:

Brian Faircloth, who has tested many thermal demand meters at FPL, when asked about the Landis & Gyr manual, which spells out recommended procedures for calibrating meters, testified that he had never seen the manual before. (Exhibit B, page 30, lines 22-25). He testified in his deposition he does not follow FPL's procedure as posted on the meter board and that he taps the cover of the standard and has instructed others to do the same. (Exhibit B, page 48, line 8 through page 50, line 10.)

Furthermore, with Mr. Faircloth's testimony, he says every meter he tests goes out of his shop at 100% (Exhibit B, page 25 line 22 thru page 26 page line14), that he calibrates every meter to 100% (Exhibit B, pages 53 and 71); however, test records provided by FPL to the PSC in response to questions posed by PSC staff and as supporting their allegation that 1V meters gradually go high and low over time, shows that a JC Penny meter number 1V-5879D last tested in 1999 by Mr. Faircloth, was tested as found at 2.28 and was left at 2.28. (FPL answer to staff request for data 8-18-2003, attached hereto as Exhibit D). I question whether Mr. Faircloth does calibrate EVERY meter.

I also noted that FPL did not use a test cover when calibrating thermal demand meters. The manufacturer indicated accuracy and efficiency is improved by using a meter test cover when calibrating a thermal demand meter. The meter test cover keeps the heat contained within the meter and allows for the meter to be adjusted carefully and precisely. Landis & Gyr states specifically: "The efficiency and accuracy of calibrating thermal demand meters can be improved by the use of test covers that have 3/8 diameter holes located over the zero and full scale calibration adjusting screws, allowing the meter to be calibrated at zero and the calibration point without removing and replacing the cover.") Using a test cover improves accuracy when calibrating a meter for a couple of reasons. When the cover is removed from the meter, the cooler outside air rushes in and cools the so-called hot element of thermal unit much faster than it does the cold element. This causes a rapid change in the reading of the meter. FPL decided not to use this recommended test cover. Instead, it would have its testers remove the actual canopy cover, allowing the heat to escape from the meter itself, and then hurriedly make a full scale screw adjustment. FPL's test plan states "When necessary to make an adjustment, do so as quickly as possible and put the canopy back on the meter so as not to lose the heat." (maximum 20 seconds)." Not using test covers allows the cool air to affect the meter, and rushing to make an adjustment, time after time, is likely to lead to more mistakes than if a test cover were used. The accuracy of the meters was affected by the failure to use test covers. See Landis & Gyr manual (attached hereto as Exhibit E). I believe that it is somewhat telling, according to FPL documents, that 15% of its V class meters failed outside the range of tolerance. SEE 160 TDM (attached hereto as Exhibit F).

I was also concerned when I learned upon reviewing the deposition of Brian Faircloth, the FPL meterman who tested around 8,000 thermal meters. Mr. Faircloth testified that when adjusting calibration adjustment screws, he would bring the meter directly to the point of adjustment without compensating for backlash. (Exhibit B, pages 103-106.) The proper method, as clearly indicated in the Landis & Gyr manual, is to move the indicating pointer downscale past the calibration point and then adjust the indicating pointer up scale very slowly to the point of calibration with the maximum pointer in contact with the indicating pointer. This helps compensation for any backlash. (See Exhibit F.) This failure to follow the adjustment procedures outlined in the manual is, to me, further cause for concern that these meters were miscalibrated.

I noticed another instance in which the policy for calibration posted by FPL on its meter board, which the metermen were supposed to follow, spelled out a key procedure in a much different way than recommended by the manufacture of the meter. Specifically, FPL's meter test board procedure, step 10, states: "If a meter has been adjusted, the test board should be left energized, with a stable load, for approximately 10 minutes, to check for proper calibration." See Meter Test Center Operations, 9-23-93 (attached hereto as Exhibit G) and undated document entitled Thermal Meter Board Procedures (attached hereto as Exhibit H). The Landis & Gyr manual, at page 5 of the section related to Calibration of Thermal Demand Meters, indicates that if the calibration point is going to be rechecked after the cover has been removed and replaced, the present load on the meter must remain constant for a minimum of 45 minutes after replacing the cover before a reading is taken. This indicates to me that FPL's calibration procedure in this respect was not in keeping with the specifications of the manufacturer's manual for calibrating thermal demand meters. Since FPL only waited "approximately 10 minutes" as compared to the manufacturer's recommended "minimum of 45 minutes" the effects of the cool air on the meter were likely to have more of an impact on the proper calibration of the meter than if FPL metermen had followed the manufacturer's instructions and waited at least 45 minutes.

Given the failure to use a test cover, the need to quickly make adjustments and replace a canopy on a meter within 20 seconds, the failure to follow the procedures for calibrating a meter by waiting only 10 minutes, not 45-minutes when checking for proper calibration, the failure to set the calibration point by moving past the calibration point and then slowly adjusting upward to that point as recommended by the manufacturer, the fact that at least one key FPL meterman had never seen the Landis & Gyr manual, and thus not seen the calibration procedures contained in that manual, all add up to make it likely that the meters in this docket were miscalibrated and thus overregistered demand prior to the date of placing the disputed meters into service. This is especially so when one considers that there is really nothing that can cause these thermal demand meters to over-register gradually over time.

One final note as to why I believe this case involves meter calibration error. In my experience around meter testing operations, if things are misplaced and not handled properly, it is often reflective of how a meter test shop is run and is likely to reflect a lack of attention to detail. I noted that FPL's internal document 0162-0164 TDM (attached hereto as Exhibit I) indicates that FPL lost or could not locate 60 1-V thermal demand meters that were supposed to be tested. These meters were lost after the entire class of 1-V meters failed testing, so you would expect particular care would be paid to the status and location of these meters.

The factors set forth above, when viewed in a cumulative fashion, suggest that the evidence supports the thermal demand meters in this docket over-registering from the date of installation as compared to going bad gradually over time in the field through some unexplained reason.

Did anything else indicate to you that meters in dispute were miscalibrated?

Well, as noted above, a lot of other things point in that direction. If you review the billing records of the accounts involved, once the thermal demand meter was replaced, all of the accounts experienced a significant decrease in demand compared to the demand levels registered previously. These thermal demand meters are all essentially the same. In one case, the Kings Point account, the customer retained his own billing records. Reviewing these records, and the graph that Mr. Brown prepared, permits one to view the energy demand before the thermal meter was installed, view the demand readings during the entire time a confirmed erroneous thermal demand meter was in use, and then see the significant drop in demand once the thermal demand meter was replaced. This indicates that the demand reading was high or overregistering for the entire time that the thermal meter was being used. Again, I don't believe that FPL will dispute that this type of evidence suggests you can ascertain the point in time in which a change in metering did occur. (See Kings Point billing, history and chart, attached hereto as Exhibit J).

Why not?

Well in reviewing certain of FPL's own internal documents, they appear to recognize that a customer's before and after demand readings are meaningful in determining the amount of refund that should be provided. For example, in FPL document 0161 TDM that starts with the phrase "1 V meter issues", the following question is asked: "What are the conditions that must be satisfied to provide a refund greater than 1 year?" After a reference to Rule 25-6.103(1), FPL states: "FPL methodology – Compared new electronic demand readings to similar months in the previous years to determine if error could be identified; if not, was there a material/consistent difference in the "new" and "old" demands? If so, offered refunds back over that period. Used higher of meter test results or "new vs. old" readings; used average difference for affected years;" (see Exhibit K attached hereto).

Have you reviewed the billing records of the meters in dispute in this case, including comparing new electronic demand readings to similar months in the previous years?

Yes, I have, for all customers.

What has that reviewed indicated to you?

It reflects that the demand meters were in error for a considerable period of time longer than 12 months and that the meters were likely misreading when installed. It also indicates that if FPL used this approach which I presume they did, that it probably should be applied to the meters in this case, since those meters reflect a difference that is both material and consistent in the new demand meters versus the old thermal demand meters. I would think FPL would want to treat similarly affected customers the same.

There is an issue in this docket concerning what impact the sun can have on the thermal demand meters. Are you aware as to whether or not the sun can have an impact on thermal demand meters?

The thermal demand meter is affected by heat, so yes, it is possible for the sun to have an impact. At Duncan Landis & Gyr, it was recommended that meters installed in states with extreme heat, such as Florida and Arizona, use sun shields to minimize the sun's impacts on thermal demand meters. I know that one particular meter, the Commercial Insulated Door account showed the effect that the sun can have on thermal demand meters. It should also be pointed out that FPL document 66-113 TDM "FACTS ABOUT DEMAND METERS" (attached hereto as Exhibit L) which is a scholarly article on thermal demand meters clearly reflects that the sun can have an impact on thermal demand meters. It states in document 96 TDM as follows: "A sun shield placed over the measuring element (Figure C-28) assures that direct rays of the sun will not produce an ambient temperature difference between the coils." Also, an email from an FPL employee, Jim DeMars states, "If potential is applied to the meter and there is no current flow, thermal meters have demonstrated the ability to register a little demand due to thermal heating from direct sunlight." FPL Doc. 158 TDM (attached hereto as Exhibit M). Thus, based on my experience, coupled with these recognitions that the sun can impact thermal demand meters, I have to say that the sun can cause the thermal demand meter to register a slightly higher demand than would otherwise be the case.

Is this significant in your view?

Well, if I was a customer who had a meter over-registering due the solar influence I could be over billed and a shop test would likely never detect there was any error on my meter.

Do you have concerns about the accuracy of FPL's meter test boards?

Yes, I do. I was involved in testing certain FPL meters in an independent test in Bradenton, Florida. These nine meters had previously been tested at the FPL Meter Test Center, and had tested high in the neighborhood of +1.83% to +3.83% with an average of +2.7%. (See METERSFORINDEPENDENTTESTING3-29&302004REV.XLS attached hereto as Exhibit N) FPL brought the previously tested meters with them to the independent testing center. FPL also brought with them a traveling standard that was tested against the standard in the independent test board. The two standards matched. When the disputed meters were independently tested, the range of error on the meters tested in the neighborhood of –3.7% to +3.3% with an average of +. 25%. If the two meter test boards were both accurate, you would not see this type of disparity when replicating a test. The meters were sealed following the independent testing, since I understood the parties would return to Miami to test the meters again on FPL's test board to see if the meters again tested high in the neighborhood of +1.83% to +3.83%. If this were the test result, it would suggest a problem with either the FPL test board or the independent test board. If the sealed meters were returned to Miami and tested on the FPL test board, and measured in the neighborhood of –3.7% to +3.3%, consistent with the independent test board results, this could mean the meters may have been tampered with from the point in time they were originally tested in Miami to the point in time they were tested at the independent test board. After all, none of the meters were sealed when they arrived in Bradenton. You will note, in my guideline for proper calibration of a thermal meter, an inspection of the meter is conducted to detect if any tampering may have occurred. I understand that FPL was not willing to retest these meters on its Miami test board and allow the independent standard meter used in the Bradenton test to be compared to the standard meter used at the Miami Testing Center thermal test board.

The most telling information related to accuracy of the thermal standard meter is found in FPL Doc. 149-150 TDM. That document is a report of tests conducted on June 12, 2002 on the meter removed from Commercial Insulated Door of Sarasota. FPL's Jim Teachman attempted to replicate the effect of heat from the sun on that meter to determine if heat could cause a thermal meter to over register. Three meters were involved in the tests: The thermal board standard, the meter in dispute form Commercial Insulated Door and an electronic meter. According to the report four tests were run in sequence. Oddly enough, the thermal standard and the electronic meter never matched. In fact their degree of difference ranged from 1.1% to 1.84%. I cannot conclude which meter was wrong. Perhaps if permitted to review the thermal test board and standard that will be determined.

I also reviewed the deposition transcript of Mr. Dave Bromley who was asked questions about this testing sequence. He indicates that he is not willing to let the independent standard meter be tested against the FPL standard meter at its thermal meter test board in Miami. When asked if an investigation was conducted into the disparity between the test results in Bradenton and the original test results in Miami, Mr. Bromley said he thought that information was privileged and refused to answer any more questions on the subject. See Deposition of David Bromley, page 68-74 (attached hereto as Exhibit O).

Finally, in reviewing the deposition transcript of Mr. Faircloth, who had worked in the meter test center for over 6 years, since March of 1998, tested around 8,000 thermal demand meters, and presumably would be aware of events affecting the thermal test board meters, I was surprised to read the following at page 95 of his deposition (see Exhibit B):

Q. Do you know when the – How often the standard meters are tested or checked?

A. No.

Q. Have you ever tested a standard meter for accuracy?

A. No.

Q. Do you know if anybody who has tested a standard meter for accuracy?

A. No.

So, given what I have described, I have concerns about the accuracy of the meter test board. I understand that there may be some efforts to review those meter boards, and if allowed to participate in those reviews, assuming they are permitted, In my opinion may be further developed at hearing.

Does this conclude your testimony?

Yes.

BEFORE THE FLORIDA PUBLIC SERVICE COMMISSION

DOCKET NO. 030623
FILED: JANUARY 8, 2004

In re: Complaints By SOUTHEASTERN UTILITIES SERVICES, INC. on behalf of various customers agaisnt Florida Power and Light Company concerning thermal demand meter error.

COPY

Miami, Florida
January 27th, 2004
9:25 A.M. - 12:20 P.M.

DEPOSITION
OF
KEITH HERBSTER

Taken Before Ronni M. Koebel-Immerman
Notary Public in and for the State of Florida
at Large, pursuant to Notice of Taking Deposition
in the above cause.

warming them up before you test them.

A. As far as that goes, as far as I know it shouldn't have anything to do with that.

Q. All right.

With respect to the meters that might read fast or over read over the 104 percent, thermal demand meters, what would be the causes of that, if you would know?

A. I don't know.

Q. The mechanical causes that you could look to that would cause them to run or read fast?

A. If it ran fast, I'm not -- I don't look to see what caused it to run fast.

Q. Based on your experience what mechanically could cause it to run fast?

A. Maybe bearings.

Q. Anything else?

A. That's all I know offhand.

Q. How could the bearings have it run fast?

A. Being too loose.

Q. How would you check that or fix it?

A. I didn't.

Q. But if I said to you, hey, this meter is running fast, I think the bearings are loose, could I give it to you and look at it, you go, woe, you're right, they do have loose bearings, or could you say, I don't know?

A. I might be able to look at it and tell.

Q. What would you look to?

A. Now, as far as running fast, the load I'm talking about running fast doesn't have to do with the demand, it has to do with the KWH. That comes to where the disc is in here (indicating). It's got a shaft that goes straight through, and it sits on what they call jewels, and that's some people call it a bearing, some people, actually a jewel. It's a little needle. And the disc floats in between, sits on that.

Q. That only applies to KWH?

A. That's for your KWH.

Q. How about KWD, anything that could mechanically cause it to run fast that you're aware of?

A. Not that I know of. Other than adjustments.

Q. Do you know why, if FPL is continuing to use thermal demand meters?

A. I know there's some still in the field. That's all I know.

Q. Do you know if any of them are being put back in the field? When you test them are any of them going back out?

BEFORE THE FLORIDA PUBLIC SERVICE COMMISSION

DOCKET NO. 030623
FILED: JANUARY 8, 2004

In re: Complaints By SOUTHEASTERN UTILITIES SERVICES, INC. on behalf of various customers against Florida Power and Light Company concerning thermal demand meter error.

X

Miami, Florida
January 27th, 2004
1:30 P.M. - 4:20 P.M.

DEPOSITION
OF
BRIAN FAIRCLOTH

Taken Before Ronni M. Koebel-Immerman Notary Public in and for the State of Florida at Large, pursuant to Notice of Taking Deposition in the above cause.

Q. Have you ever seen anybody not do them one at a time?

A. No.

Q. You say you had to fine tune them when you **make this setting. Is there skill involved in making** that adjustment to zero?

A. Be able to see. That's it.

Q. Again, I don't know what these are like, but would it be like if I were screwing in a screw on a piece of wood, you just tighten it down all the way, or do you try to tighten it so the screw is a certain amount in the wall?

A. There's no tightening. It goes one way or the other.

This arm right here, if this is sitting, you take this screw (indicating), this is your zero screw. Do you see where it says zero?

Q. Right.

A. On this one it says what, full scale (indicating).

Q. Right?

A. So this is supposed to run at 2, and I've adjusted this to zero with the zero screw on the back, right, this is supposed to read 2, according to all my calculations on the computer, tells me it should be reading 2 at what I'm testing it at, this screw, and it's coming up here and it's 1.95, right, this screw here will adjust it to 2. All you do is go tweak (indicating).

You go through and do all of them, you let them sit. What you're doing is you're making sure when you come back, if it's still sitting on 2, you don't touch it. Maybe for some reason a little height, whatever, I don't know. Maybe it went over a little bit. So what you want to do is fine tune it back to 2.

Because you want that meter to go out at 100 percent. That's what I did with every meter I ever tested (indicating).

Q. The part where you were describing about 2 and being close to 2, what not, that's the calibration part?

A. Right.

Q. And in part, taking the red number to zero, that's the --

A. Pre-heat. That's the zero adjustment. That's why it has zero below it, so you know (indicating).

Q. Does it matter when you pre-heat those meters, you can pre-heat them and then you take them

A. I don't. I just thermal it, tell them what it reads.

Q. Is the process that you used for current diversion test the same as a shop test, or different?

A. Same.

Q. Let me show you a document that's been marked as Exhibit 2.

(Whereupon, the above-referenced exhibit was handed to the witness.).

It's from a previous deposition. Have you seen this document before?

A. No.

Q. Okay. Just for the record, this is entitled Test Procedures And Test Plans For Metering Devices. Correct?

A. Test Procedures And Test Plans For Metering Devices.

Q. April 3, 1997 it's dated. Right?

A. Yes.

Q. And you started working in when?

A. '98.

Q. Let me show you an exhibit that's been marked as Exhibit 6, Landis & Gyr Manual (indicating).

Have you ever seen that document before?

A. Nope.

Q. How long before do you turn it on, before you put the meters in it?

A. It varies. Minute, two minutes. I don't know.

Q. Is it ever longer than 10 minutes?

A. I don't know. It could be. But I don't know.

Q. When you are testing or calibrating meters do you ever tap the canopy of the meter with your finger or some device?

A. No.

Q. How about the standard?

A. Yes.

Q. Why do you do that?

A. That's the way I was shown.

Q. Who showed you that?

A. Mr. Fifrilingos.

Q. What is the result when you tap the standard meter?

A. Not much. It settles maybe just a little bit.

Q. Does it settle up or down?

A. I don't know.

Q. Do you do that regularly every time you test?

A. Every time I've ever tested one.

Q. But you don't know whether the needle adjusts slightly.

You said it moves light slightly. You don't know whether it's a slight movement up or downward?

A. Didn't pay attention.

Q. I presume if we were to go into that lab and test and tap, we could probably see which way it would move, couldn't we?

A. I assume.

Q. Do you know what the tapping of the meter does?

A. No.

Q. Have you ever tapped the meter being tested?

A. No.

Q. You only tapped the standard?

A. Correct.

Q. Do you know if that's a practice that's commonly used in the meter testing center?

A. I don't know.

Q. Do you know if it's in the policies and procedures?

A. It's not there.

Q. Have you ever given instruction to anybody else as to how to test thermal demand meters?

A. Basic instructions.

Q. As part of the basic instructions have you told them to that he should tap the standard meter?

A. Correct.

Q. And who have you told that to?

A. I believe Mister -- I'll say I don't know, because I don't remember who.

Q. You don't remember who, but you remember --

A. I don't remember if I said it. In other words, I don't know. I don't remember that exact day.

Q. But if we were trying to figure out the best way to test meters, and the Commission, the Public Service Commission asked you to make sure you have an accurate test, should you tap the standard meter, what would your answer be?

A. I would tap it.

Q. And the reason is?

A. It's the way I was shown.

Q. Do you know, has the protocol for testing V meters changed recently?

A. What do you mean?

Q. Has there been any change with respect to the V meters when you test them, what you do with them after you test them?

A. I test them, and I put them on a rack and I around them in for a long time.

But when you do the calibration, if I understood your testimony, that if you would find that a meter was in error about more than 4 percent, you would put a red sticker on it and set it aside. Is that correct?

MR. HOFFMAN: Objection. Asked and answered.

MR. MOYLE: You can go ahead and answer.

MR. HOFFMAN: You can go ahead and answer.

THE WITNESS: Let me stop and think now.

No, I would put a red sticker on it so it would not go back in the field.

Let the next man know it would not go back in the field.

BY MR. MOYLE:

Q. But the written policy says that you would recalibrate these meters. Correct?

A. That's what it says in your procedure.

Q. Okay.

And with respect to meters that were less than 4 percent error, you would recalibrate them and

A. Do I remember, no.

Q. Have you heard anybody express concerns about the accuracy of the thermal demand meters?

A. No.

Q. Do you know if FPL has made a decision to discontinue use of thermal demand meters?

A. No.

Q. Has anybody tested more V meters than you have?

A. Lately?

Q. Just en toto.

A. I don't know.

Q. How about since the time you've been working there, has anybody tested more V meters?

A. No.

Q. No?

A. No.

Q. Are you aware of anything that could make these V meters gradually or suddenly read high --

A. No.

Q. -- In the field?

A. No.

Q. If a meter was miscalibrated and then put out to the field, you would agree that could result in erroneous readings.

documents we've identified?

A. You mean would I test it differently from the way the procedure tells me to test it?

Q. Right.

A. Besides the fact that I adjust all my meters back to 100 percent? No.

I follow the procedures. The only thing I do is I like 100 percent meter to go out to the customer.

Q. Do you know why there was a comment in the document I showed you about not adjusting it if it was within plus or minus 2 percent?

A. I do not know.

Q. Have you ever seen the meter test plan, FPL's meter test plan?

A. No.

Q. The thermal demand meters, the V meters, how were they tested in the old days with respect to the meters going on the front of the board?

Would you intermix the high scale meters with the low scale meters?

A. How did I test them as to calibrating?

Q. Yes.

A. Did I put high scale and low scale together, yes.

A. One per board.

Q. How many boards do you have?

A. Three.

Q. So there's three standard meters.

A. Correct.

Q. Are they all of the same vintage, do you know?

A. I don't know.

Q. Do you know when the -- How often the standard meters are tested or checked?

A. I do not know.

Q. Have you ever tested a standard meter for accuracy?

A. No.

Q. Do you know if anybody who has tested a standard meter for accuracy?

A. No.

Q. We talked earlier, you described it as your board and you being the person who works most with that board.

A. FPL's board, my area.

Q. Your area. Predominantly your area. Correct?

A. Until I leave.

answer?

MR. HOFFMAN: You can answer.

MR. MOYLE: Yes.

THE WITNESS: I was double checking. You're saying how do I adjust this when it's under load if I bring it beyond the thing, back to it, or whatever?

BY MR. MOYLE:

Q. Right.

A. It's according to where it is. It could be above at the start, so I bring it down. If it's below, I bring it up.

Q. Let's say it's at 3 here and you need to adjust it to the 2, describe for me --

A. I wouldn't adjust it to the 2. It's over the 4 percent. That meter is gone.

Q. All right. Let's say, what number would you take --

THE COURT REPORTER: One at a time.

THE WITNESS: You want it bring it to the 2.5, I would bring it down to the 25.

BY MR. MOYLE:

Q. Would you bring it straight to the 25 or 24 and back?

A. Right to it.

MR. HOFFMAN: Excuse me. Same objection. Outside the scope.

Now go and answer.

THE WITNESS: I'd bring it to the 25. That's where it belongs.

MR. MOYLE: With respect to, I think, it's within the scope in that you asked him the timeframe in which it takes him to calibrate the meter.

I'm asking him what's entailed in that 10 or 15 seconds that he testified to. Whether he takes it straight there, whether he takes it past that point and brings it back.

MR. HOFFMAN: I asked him how long it takes.

THE WITNESS: Right.

MR. MOYLE: Right.

BY MR. MOYLE:

Q. So it's your testimony that when you do the calibration, you don't move it down scale and then move it back up, you just take it right to the point. Is that correct?

A. That's what I try and do.

Q. Let me show you a portion of this technical manual. Exhibit 6. Just read for the record starting where it says when.

(Whereupon, the above-referenced exhibit was handed to the witness.)

A. When adjusting down scale, the indicating pointer should be moved down scale past the calibration point and then adjusted up scale very slowly to the calibration point with the maximum pointer in contact with the indicating pointer. Care must be taken not to wrap the calibration spring.

These are FPL procedures?

Q. Yes. Do you do that?

MR. HOFFMAN: Hold on. They're not FPL procedures.

THE WITNESS: No.

MR. HOFFMAN: Make sure the record is clear, Jon.

MR. MOYLE: Okay. I'm showing you Landis & Gyr --

THE WITNESS: I don't work for them.

MR. MOYLE: I understand.

BY MR. MOYLE:

Q. But do you follow this --

A. Never seen it before.

Q. So you don't follow it?

A. Never seen it. I can't follow it if I've never seen it.

Q. And I think your testimony before was you didn't take it down below and move it back up. Correct?

A. I moved it right to it.

Q. Okay. When it says --

A. Or I moved it up.

Q. What does wrap in the calibration spring mean?

MR. HOFFMAN: Objection. This is outside the scope of my very brief re-direct.

But under this process you can answer that question.

THE WITNESS: Can I answer it?

MR. HOFFMAN: Yes.

THE WITNESS: I don't know.

BY MR. MOYLE:

Q. So you don't know whether you wrap the calibration spring or not, I guess, over the years?

MR. HOFFMAN: Objection. Beyond the scope of my very brief re-direct.

THE WITNESS: Do I get to answer?

MR. HOFFMAN: You can answer.

BEFORE THE FLORIDA PUBLIC SERVICE COMMISSION

DOCKET NO.: 030623
FILED: April 28, 2004

IN RE: Complaints by SOUTHEASTERN UTILITIES SERVICES, INC., on behalf of various customers against FLORIDA POWER and LIGHT COMPANY concerning thermal demand meter error.

\- X

9250 West Flagler Street
Room 1606
Miami, Florida 33174
May 5, 2004
8:50 a.m. - 12:45 p.m.

COPY

DEPOSITION OF JIM TEACHMAN,
Taken before Michael Jay Kugler
Notary Public in and for the State of
Florida at Large, pursuant to Notice of
Taking Deposition in the above cause.

Q I've been asking you.

You've been in the meter shop for twenty years.

In your experience --

A I've seen it both ways.

Q Has it been more high than low, or more low than high?

A I don't keep a record of that.

Q So you don't have any idea whether there have been more high readings than low readings?

MR. HOFFMAN: Objection, asked and answered.

A No, I don't.

Q An error as a percentage of full scale due to a full scale adjustment condition, will it increase as the meter's tested closer to full scale, based on your experience?

MR. HOFFMAN: Object to the form of the question.

Vague and ambiguous.

A Unfortunately you're killing me with your question.

What was it again?

Q An error as a percent of full scale due to a full scale adjustment condition, will it increase as the meter is tested closer to full scale?

MR. HOFFMAN: Reiterate the objection, and it calls for speculation.

A It actually sounds to me like you're asking the same question you've already asked me.

If the error is four, it stays four.

That's the way I understand the question you just read to me.

Q You consider yourself an expert in meters and meter testing?

A No, I don't.

I wouldn't be working for FP&L if I was.

I'm sorry, that slipped.

Q Do you know what could cause the thermal element of a thermal demand meter to gradually read high, if anything?

A No, I don't.

Q Do you know or are you aware of anything that could cause the thermal element of a thermal demand meter to suddenly read high?

A No, I don't.

Q If I asked you the same two questions with respect to a thermal demand meter, either gradually reading low, or suddenly reading low, would your answers be the same?

A No.

Q Well, let me ask them.

Do you know what could cause a thermal element of a thermal demand meter to slowly or gradually begin to read low?

A Heat.

Q Why do you say that?

A Because I've seen the sun light produce the heat, and the demand go down.

Q When did you see this?

A In the field and in the lab.

Q Where in the field?

A Don't remember the name, but George Brown knows the address.

Q So you saw the sunlight affect the readings of the thermal demand meters in the field?

A Yes.

Q And you saw the same type of issue occur in the lab?

A Actually, in the shop, yes.

I shouldn't say the lab. It's in the shop.

It's in the same building together.

Q When did you see it in the shop, approximately?

A When we were asked to produce heat onto it.

Q How much did it cause the meter to misread, if you will?

A It varied.

Q Within what ranges?

A Because I didn't look at it, at the percentages.

It could go from one, I don't know if the word is tick or line, to four lines.

Q Do you know if the meters that you tested in the lab, were they ever field tested?

A Not to my knowledge.

Q Who would know if they were field tested?

A I have no idea.

Q Would you know if they were field tested, typically?

A Only when George Brown requested the ones, but not the ones that I tested.

Q Do you know if FP&L ever had a field test unit on the trucks, that they could use in the field?

A For what?

Q To test the accuracy of these thermal demand meters?

A Not to my knowledge.

Q We talked about the sunlight issue.

Do you know what could cause a thermal

element of a thermal demand meter to suddenly read low?

A No.

Q Have you communicated with the manufacturer, or any other persons, regarding the effects of sunlight on thermal demand meters?

A Years ago.

Q Who did you communicate with?

A I don't remember their names.

Q Was it --

A Somebody at --

MR. HOFFMAN: Let him finish the question, okay.

Q Who do you recall, whether a company, or an individual that was communicated with years ago, regarding the effects of sunlight on thermal demand meter?

A Someone at Landis and Gyr, or Duncan.
I don't remember which they were.

Q How many years ago?

A Top of my head, ten, twelve years ago.

Q Did you communicate with them?

A I did, yes.

Q Did you have any correspondence going back and forth relating to the issue of sunlight?

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August 18, 2003

HAND DELIVERY

Cochran Keating, Esq.
Division of Legal Services
Florida Public Service Commission
2540 Shumard Oak Boulevard
Room 370
Tallahassee, FL 32399-0850

Re: Docket No. 030623-EI

Dear Cochran:

Enclosed is an original and one copy of Florida Power & Light Company's Responses to the Commission Staff Data Requests dated July 29, 2003. Enclosed also is a copy of FPL's Notice of Intent to Request Confidential Classification of FPL's response to Staff Data Request No. 3. The unredacted response to Staff Data Request No. 3 has been filed with the Commission Clerk in an envelope marked "CONFIDENTIAL."

Sincerely,

Kenneth A. Hoffman

KAH/rl
cc: Daniel Joy, Esq., with enclosures
Robert Vandiver, Esq., with enclosures
Mr. Bill Feaster, Esq., with enclosures

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RECEIVED
AUG 20 2003

FPL's RESPONSE TO
COMMISSION STAFF DATA REQUEST
DOCKET NO. 030623-EI
RECEIVED JULY 29, 2003

1. **Please provide all data or analyses, from the meter manufacturer(s) or other sources, that would support the conclusion that the only way thermal demand meters in question may over-register (i.e., read too high) is if the meter was improperly calibrated at initial installation. Alternatively, provide all data or analyses to support the conclusion that such meters may gradually or suddenly read too high over time, even if properly calibrated at the time the meter was set. Include any engineering analyses, articles from journals, trade publications, or expert testimony, including documented experience of other utilities.**

FPL does not have or know of any data that supports the conclusion that thermal demand meters only over-register if the meter was improperly calibrated at initial installation.

To support that meters may gradually or suddenly read high, FPL offers the following information: (1) A presentation by A. R. Jenny of Westinghouse Electric Corp., Meter Division, used at a Public Utility Short Course for Electrical Metermen at the Oklahoma State Meter School, Oklahoma State University; and (2) FPL's own experience and test results.

(1) Attached in the presentation mentioned above, the author discusses the various components of a thermal meter. In particular, two bi-metal springs, which act as a thermometer, are the "heart" of the thermal meter. The difference in the heat of these two opposing bi-metal springs is proportional to the power of the load being measured and it is this difference that is measured on the scale. On page 28 of the presentation, referring to these two bi-metal springs, it is noted,

"The heaters themselves are closely matched and have nearly the same resistance when installed in the circuit. Any differences in their resistance may be compensated for by the adjustments of the meter".

FPL suggests that the author is acknowledging that calibration adjustments may be necessary. FPL also notes that the author does not state that these adjustments will only go in one direction.

(2) FPL's own experience indicates that thermal meters can gradually read high or low after being calibrated. FPL believes that is the reason that adjustment screws (screws that can be turned in either direction) were placed on these meters. This is unlike a solid state meter, which has no such adjustment mechanism for the user. Below, FPL has included meter test results for some of Mr. Brown's clients. In Columns D and J (Test - As Found % Error) you will find the % error when the meters were brought in from the field and tested. In Columns E and K (Test - As Left), it shows the meter test results after the meter was calibrated. As can be seen, multiple tests for the same meter over time indicate that these meters can drift in either direction once they have been calibrated.

1V Meters

	Meter Number	Year Tested	Test - As Found % Error	Test - Left	As
	Target				
1	55773	2003	0.77	0	
		2003	0.62		
2	5192D	1992	-1.4	0	
		2003	2.68		
3	5211D	1996	0.7	0	
		2002	-1.55		
4	5774D	1997	5.7	0	
		2002	-0.03		
5	7505D	1992	-1.4	0	
		2002	1.93		
6	7745D	1992	1.7	0	
		1995	1.4	0	
		1996	-2.1	0	
		2002	-1.12		
7	5871D	1996	0.7	0	
		2003	2.21		
	Walmart				
8	5221D	1998	0.08	0	
		2002	-2.92		
9	5249D	1993	-0.71	0	
		2002	0.73		
10	7014D	1992	1.4	0	
		1993	-1.43	0	
			2.03		

	Meter Number	Year Tested	Test - As Found % Error	Test - As Left
	Best Buy			
11	55381	1993	2.06	0
		2003	2.96	
12	58467	1992	1.8	0
		2003	-0.31	
13	79210	1993	2.8	0
		2003	3.07	
14	59682	1996	1.4	0
		2003	0.39	
	J C Penney			
15	52475	1995	-1.4	0
		2003	3.01	
16	59515	1993	1.1	0
		2003	-1.26	
17	72305	1994	-2.8	0
		2003	2.06	
18	3024D	2000	-0.53	0
		2003	0.78	
19	5879D	1999	2.28	2.28
		2003	-1.74	
20	36787	1994	1.1	0
		2003	-1.69	
	Ocean Property			
21	74963	1997	2.3	0
		2003	3.77	
22	70077	2001	3.93	0
		2003	1.26	
23	59333	1993	-1.43	0
		2003	-0.15	0
		2003	-1.68	

PRINCIPLE OF THERMAL AND MECHANICAL DEMANDS

By A. R. Jenny
Westinghouse Electric Corporation
Meter Division
Raleigh, North Carolina

For Presentation at
Public Utility Short Course
for
Electrical Metermen
Oklahoma State Meter School
Oklahoma State University
March 24, 1966

Thermal Demand Meters

Introduction

As stated at the outset, there are three classes of demand meters which are Class 1, curve drawing instruments; Class 2, integrating demand meters or block interval, mechanical demand meters; and Class 3, lagged demand or thermal demand meters.

First of all, just what is a thermal demand meter? It has been described as a measuring device which transforms electrical energy to heat and measures this heat by a thermometer. To be more specific, the circuit is such that the difference in heat developed in two sets of heaters is proportional to the power of the load being measured. The thermometer (a pair of opposing bi-metal springs) measures the difference in temperature and indicates this difference on the scale. The scale, of course, is not calibrated in degrees but in kilowatts or numbers that can be readily converted to kilowatts by a simple multiplier. At this point, let's take a simple thermal meter, from the start describe all parts involved and see how each part contributes to the heat principle of determination of KW demand.

Theory

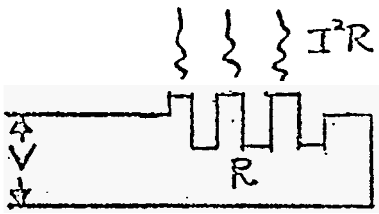


Figure 12

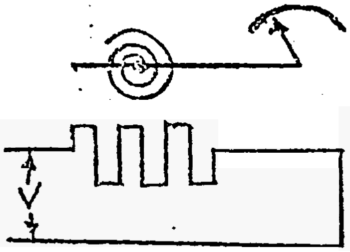


Figure 13

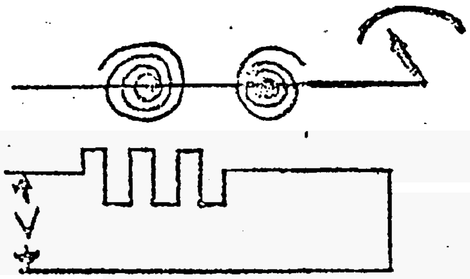


Figure 14

To start with, let's take a heater of a known resistance and attach it to a source of voltage of a known value. If the voltage and resistance are so chosen, a current of sufficient value will flow through the resistance and will give off heat which is proportional to the current flowing through the resistance. Another way of saying this is, the amount of heat or watts dissipated would be proportional to the current and resistance or in formular form expressed as I^2R. (See Figure 12.)

If we now take two pieces of metal with two different coefficients of linear expansion, join them together, and wind them in a helical coil, we form what is commonly referred to as a bi-metal coil or spring. Referring to Figure 13, if we place this bi-metal spring so that one end is anchored to a fixed object, attach a free moving shaft to the other end of the bi-metal with a pointer attached, and place this whole assembly in close proximity to the heater described in Figure 12, we would note that the bi-metal would expand, moving our free-moving shaft and pointer assembly as it expanded. Further, if we placed a scale behind our pointer, we could by careful calibration and control of the resistance and voltage determine the units of heat and thereby calibrate the scale and have in effect a thermometer. We can vary the degrees of deflection of the pointer by either raising or lowering the voltage or raising or lowering the resistance value of the heater circuit. In practice in meters, however, the voltage is for all practical purposes constant as well as the resistance of the heater circuit being constant with the variations in deflection caused by the load which is attached to the voltage supply and in whose circuit the resistance "R" is placed.

One of the difficulties of this type of circuit, though, is that ambient temperature could also affect our singular bi-metal as shown in Figure 13 and could cause some small degree of error. To compensate for the ambient temperature error, we wind a second bi-metal, placing it in direct opposition to the original bi-metal, as shown in Figure 14, so that any change in ambient temperature will drive each bi-metal with the same strength. Since they are in direct opposition, this would cancel any effect of the ambient temperature change.

As a matter of interest, Figure 14 is the actual basic component for a thermal ampere meter whose scale can be calibrated in amperes so as to deflect proportional to the current flowing through the heater circuit.

In order to produce a watt demand circuit so that the current flowing will produce heat to drive a pointer proportional to KW of the circuit, we need a somewhat different or modified setup which is shown in Figure 15.

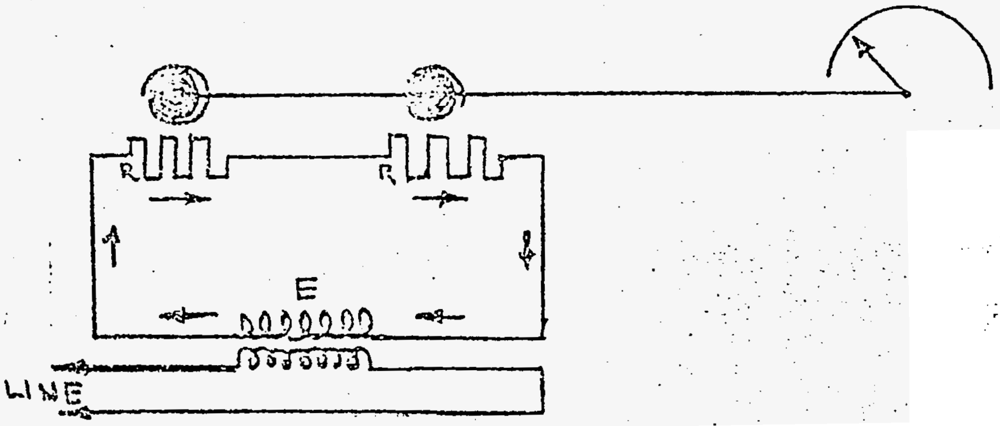


Figure 15

So as to not confuse ourselves with the many parts and connections within the circuitry, let's take a look at the basic components and see what we have gained over those shown in Figure 14. First of all, we still have two bi-metals wound in opposite directions anchored to a fixed point in each case and attached to a movable shaft to which a pointer and scale assembly is set. The first change we note is that we now have two heater circuits whereas in Figure 14 we had a singular heater circuit. The next major change we see is that our voltage now comes from the secondary of a potential transformer whose primary is attached to a line voltage of some value. Looking at the current which flows in the loop formed by the secondary of the potential transformer and the two resistance heater circuits, we find that the value of this current could be found by dividing the voltage of the secondary of the potential transformer by the sum of the resistance in this circuit, or expressed another way, $I = \frac{E}{2R}$. Note also that the current as shown in Figure 15 flows from left to right in both of the resistances. **Now let's** add a few more connections to our circuit as shown in Figure 16.

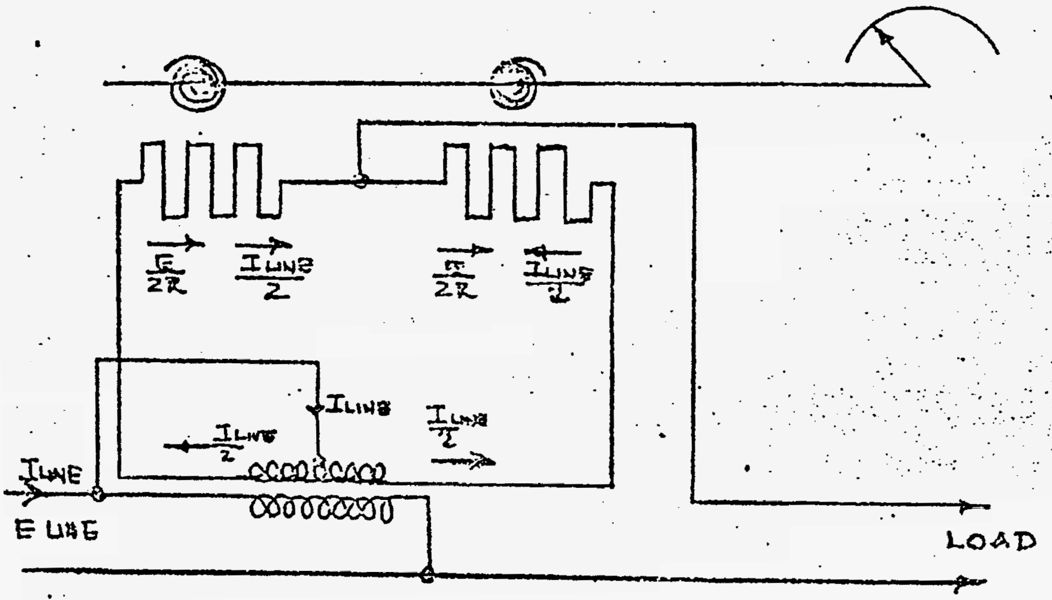


Figure 16

Notice that we have found a midpoint of the secondary of our potential transformer, brought out this point and attached it to the line side of our supply voltage. **Further, we have** taken the center point of our two resistances and connected it to one side of our load. The other side of our load we have taken back to the remaining line of our supply voltage. As our load is applied to the system, a current I_L will flow coming into the center point of our transformer's secondary and dividing it into two portions, $\frac{I_L}{2}$ both left and right.

The $\frac{I_L}{2}$ flows through its respective resistance arm, rejoins at the midpoint of the heater circuit, and through the load goes back to the other side of the line. Formerly, we only had $\frac{E}{2R}$ in each of the two heater circuits; and as explained, these two currents (since they are equal in magnitude and work on heaters which produce heat in equal proportions and they in turn act on bi-metals wound in opposite directions) produce no reflection of scale. When the line current in introduced in the left heater, we note that the arrows point in the same direction; therefore, these two currents will add. However, the currents in the right heater, as shown in Figure 16, are in opposite directions and, therefore, will subtract from each other thereby producing a lesser current than originally was found without the line current applied. Likewise, we would find that the lefthand portion would have a greater current because of the adding effect as noted before. Since we are interested in heat developed in each of the heater circuits, by mathematical manipulation we can see that the heat in the left and the heat in the right heaters will add as seen in the following equations.

$$W_L = \left(\frac{E}{2R} + \frac{I_L}{2}\right)^2 R = \frac{E^2}{4R} + \frac{EI}{2} + \frac{I^2R}{4}$$

$$W_R = \frac{E}{2R} \quad \frac{I_L}{2}\Big)^2 R = \frac{E^2}{4R} - \frac{EI}{2} + \frac{I^2R}{4}$$

By adding the heat in the left and the heat in the right, we come out with the following equation.

$$W_L - W_R = \left(\frac{E^2}{4R} + \frac{EI}{2} + \frac{I^2R}{4}\right) - \left(\frac{E^2}{4R} - \frac{EI}{2} + \frac{I^2R}{4}\right)$$

$$W_L - W_R = \frac{EI}{2} + \frac{EI}{2}$$

$$W_L - W_R = EI$$

The difference between the two comes out EI which we immediately recognize as being watts of the circuit.

We might make note here that in the above equations when we multiplied the current and resistance together that we should use vector notation so that in actual practice when E and I are multiplied the phase angle between E and I should be taken into consideration where the phase angle is actually the power factor of load.

We can by various examples both at unity and other than unity power factor show that the above condition applies.

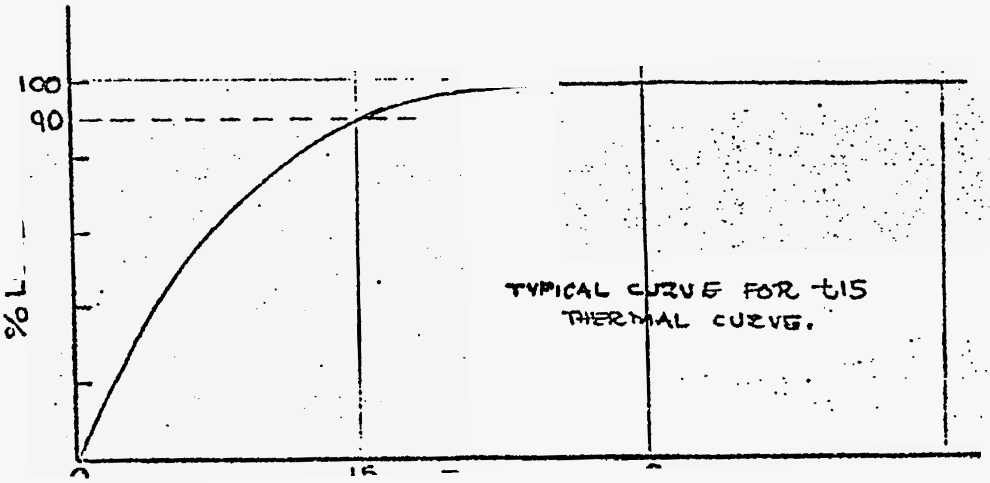
At this time, we should make some mention of the components which make up the thermal meter as to their physical makeup as opposed to their location in the circuit. First of all, the potential transformer that we have been describing is actually a winding placed on the potential coil of the meter which in effect first reduces the size and number of components used and secondly cuts down the watts loss of the potential circuit in general. As described before, this potential circuit and its resulting secondary voltage is used to produce the short circuit current which flows at all times in the resistance circuit composed of the two heaters. We might add that this current flows not only at various loads but at a no-load condition.

The value of the secondary voltage applied to the heater circuit is chosen to reduce the watts loss in the circuit at high load conditions on the meter and to not overheat the resistances which give us our upscale deflection at various loads.

The bi-metal springs, so far taken for granted, are really the heart of the thermal and must be closely matched both as to torque and deflection for a given temperature change. These metals are usually chosen with great care with two bi-metal springs wound from the same singular piece. This is to achieve a near perfect match in deflection per degree temperature rise and to eliminate any possible error due to not over the ambient temperature but the heat as applied from the heater circuits.

The heaters themselves are closely matched and have nearly the same resistance when installed in the circuit. Any differences in their resistances may be compensated for by the adjustments of the meter.

So far, no mention has been made of the enclosure in which the bi-metal springs themselves and the heaters are placed. The enclosure must also be chosen with care insofar as material and design considerations are concerned. The enclosure must have a certain heat-storage value so as to follow the specifications as were laid down by MS-5 or other similar specifications. In general, the specification states (and as stated in the earlier part of the paper) that the thermal meter should respond to load at a rate such that 90%



a similar curve can be expected from a t30 meter.

It is also interesting to note that when the load is disconnected or line current goes to zero, the thermal indicator will go back down scale at a rate which closely approximates the rate of rise as when load was applied. That is, when a load is disconnected at the end of 15 minutes (on a t15 meter), the pointer would have gone downscale approximately 90% of the value of a load applied at the time of disconnection.

Mechanical and Thermal Comparison

So far, we have concerned ourselves only with the single phase thermal demand meter. Thermal meters are made for a wide variety of applications--both single phase and polyphase. Thermal meters of course are available either as a separate unit or as a combination meter with the latter being the most popular of the types available. Thermal meters also are available as recording meters even though we have mentioned before only the indicating type.

Having covered the fundamentals of thermal meters and the mention of their various types, we are now in a position to evaluate their merits relative to other forms of meters such as the mechanical meter.

First of all, their costs, speaking strictly from the combination types thermal as compared with the mechanical type demand meter which is actually a demand attachment of the mechanical type, are the same.

Insofar as maintenance is concerned, the single phase thermal takes a lead in that it has been shown that maintenance of the thermal meter is remarkably low. Usually it is considered that the testing period can be the same as that of the watthour meter. However, the fundamental, of course, is that the only moving parts are the bi-metal springs, shaft, and the maximum demand pointers. It is almost axiomatic that the maintenance of demand devices varies directly with the number of moving parts. While this is only one of the factors in the choice of either a thermal or mechanical, it is generally considered so important that it will outweigh other disadvantages. Actually, in a thermal meter there are no high speed shafts, clutch mechanisms, motors, or cam arrangements. In short, the parts of mechanical devices which require the bulk of maintenance are not present in the thermal.

Insofar as useful life is concerned, it is sometimes closely allied with maintenance. Here again, the single phase thermal meter has a slight edge over the mechanical. We are still getting experience from the thermal meters since they were introduced, but we seem to lean a little toward the thermal in that a longer life is obtainable by a thermal device. The simplicity of the thermal meter again is its main asset as the parts which wear out do not exist.

Insofar as accuracy is concerned, the mechanical is somewhat in the lead as there are more factors involved in ascertaining accuracy on the mechanical versus thermal. That is to say, in the thermal meter, even the selection of the bimetal springs, heaters, and the housings are such that we assume equality; however, there is no such thing as a 100% identical unit in their characteristics. This makes differences in scale distributions and obvious inaccuracies. However, this is not intended to imply that the thermal meter is inaccurate but merely that it is not a precision device as in the case of the mechanical meter. Actually, this is one of the cases of getting something for nothing, that is, a small sacrifice in accuracy enables us to gain largely in other respects.

Insofar as versatility is concerned, the thermal can be adapted to all types of metering; but on the other hand, the thermal demand unit cannot be pulled off and placed on another type of meter as in the case of a mechanical demand register. This practice is an important factor in the selection of demand equipment with some utilities.

The possibility of peak splitting by block interval device is well known and need not be elaborated. The fact that a thermal meter will not split peaks has often been decided as a major advantage of thermal meters. However, this reason is certainly not a compelling one to influence the use of thermal meters rather than block interval devices. Despite all the argument that has been advanced on this score, the fact remains that actual comparison of the readings of two types of devices on the same load shown little difference in most installations. This is not intended to discredit the principle of the thermal meter but to place it in its proper perspective.

Insofar as the response of the thermal meter is concerned, sometimes called logarithmic or expotential, the thermal meter is nearly a duplicate of the heating characteristics of the apparatus which must be provided to supply the load, that is, the transformers, generators, etc. Since the temperature rises, this equipment is also essentially expotential; we might make this statement, and while this is true, the time interval for such equipment is in general a great deal longer than that of a meter. Also the concordance of the different types of demand meters illustrates that this factor is immaterial. If the two devices indicate the same maximum demand, the rate of rise is of no consequence.

The fundamental reason for the concordance of different types of devices on various loads is probably that so many intervals occur during a month that peak splitting is not a factor. While the general picture indicates that the thermal meter has a minor advantage in this respect, it is of course true that on certain types of loads it may have a pronounced advantage. Overall, however, these considerations are of minor importance.

Insofar as testing is concerned, fundamentally, a thermal meter of a given interval takes a longer time to test than a block interval device of the same interval. Furthermore, mechanical devices can be driven by a synchronous motor with no question as to the proper indications. Also, block interval devices can be conveniently tested in the field.

We might also add that in testing the increase of time does not mean that more man hours are required since constant attendance is unnecessary. However, it does mean increased test facilities to some extent. Further, the thermal equivalent of a synchronous motor drive is an electric load controller which holds the load constant regardless of voltage fluctuations. The other alternate, of course, is the use of a standard with the same characteristics as the meter being tested. This is analogous to the portable standard method of checking watthour meters. Any load fluctuation affects the standards in test meters equally.

Field testing in general seems to be giving way to lab testing as a more effective and efficient method, and this problem does not seem to be a disturbing influence. However, there is certainly room for argument among the various utilities about this particular point.

In conclusion, the above points tend to bring out some of the features of both the mechanical and thermal meters and how they rate in general with various utilities. Further, in utility practices today, we can see the popularity of various types of both mechanical and thermal meters based on the NEMA figures. These figures show that the thermal meter is quite popular on single phase application and that the mechanical meter is more popular for polyphase application. The reasons for their popularity, of course, is not the purpose of this paper as it is strictly a matter of choice of the utility involved and its experiences. Certainly, there is room for argument in either case with each side having their substantiated reasons for their choice.

3. **For Florida Power & Light Company (FPL), please provide detailed calculations used by FPL to determine the refund that it thinks is appropriate for each meter for which a refund is sought by SUSI under a pending complaint before the Commission. If billing history was used in any of the calculations, please show how such records were used. If formula was used to estimate months where no billing data was available with the new meter, please explain the method and all assumptions used.**

Process steps used in developing response:

1. The meter test results were compared (if more than one test done) and the most favorable result for the customer was used to calculate a credit or debit.

2. The result from 1. above was applied to the historical demand/usage for the 12 months prior to the meter change in order to calculate a rebill demand/ usage.

3. The result from 2. above was entered into FPL's billing system (transaction BCOM) to generate a credit or debit.

4. The demand/usage on the account after the meter was changed was compared with the historical demand/usage from the prior years, same months.

5. Within the scheme of negotiations, if the demand/usage level showed consistent and significant change (>10%) consideration was given to providing a credit/debit beyond 12 months.

6. The calculated % changes in demand/usage were applied to the historical demand/usage for the period back to the meter change in order to calculate a rebill demand/usage.

7. The result from 6. above was entered into FPL's billing system (transaction BCOM) to generate a credit or debit.

8. If the demand/usage level did not show a consistent and significant change (>10%), the calculated % change in demand/usage was applied to the historical demand/usage for the 12 months prior to the meter change in order to calculate a rebill demand/usage.

9. The result from 8. above was entered into FPL's billing system (transaction BCOM) to generate a credit or debit.

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Account Name: Target Corporation

	Address	[redacted]	[redacted]	[redacted]	[redacted]	Historical vs. Current Usage - % credit	Historical vs. Current Usage - KW credit *	FPL Refun Offer - dol credit
02873-11708	21637 State Road 7 #Target	[redacted]	[redacted]	[redacted]	[redacted]			
39242-15316	1901 N Congress Ave	[redacted]	[redacted]	[redacted]	[redacted]			
36908-36659	6150 14th St W	[redacted]	[redacted]	[redacted]	[redacted]			
13854-10566	1200 Linton Blvd # Target	[redacted]	[redacted]	[redacted]	[redacted]			
42298-19083	13711 S Tamiami Trl #300	[redacted]	[redacted]	[redacted]	[redacted]			
07710-59334	3251 Hollywood Blvd #300	[redacted]	[redacted]	[redacted]	[redacted]			
10054-45984	1400 Tamiami Trl # Target	[redacted]	[redacted]	[redacted]	[redacted]			
49909-58540	5350 Fruitville Rd	[redacted]	[redacted]	[redacted]	[redacted]			
59543-43371	4271 Tamiami Trl S # Targe	[redacted]	[redacted]	[redacted]	[redacted]			

* Any differences in KW are due to rounding and/or BCOM (FPL Billing System)

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Account Name: Target Corporation

Tariff Rule Worksheet

02873-11708	as billed	rebilled	Out of tol%	KW credit
11/25/2002				
10/25/2002				
9/26/2002				
8/27/2002				
7/29/2002				
6/27/2002				
5/29/2002				
4/29/2002				
3/29/2002				
2/28/2002				
1/30/2002				
12/28/2001				
Totals:				

39242-15316	as billed	rebilled	Out of tol%	KW credit
11/11/2002				
10/11/2002				
9/12/2002				
8/13/2002				
7/15/2002				
6/13/2002				
5/14/2002				
4/15/2002				
3/15/2002				
2/14/2002				
1/15/2002				
12/12/2001				
Totals:				

36908-36659	as billed	rebilled	Out of tol%	KW credit
11/20/2002				
10/22/2002				
9/23/2002				
8/22/2002				
7/24/2002				
6/24/2002				
5/23/2002				
4/24/2002				
3/26/2002				
2/25/2002				
1/25/2002				
12/21/2001				
Totals:				

13854-10566	as billed	rebilled	Out of tol%	KW credit
11/5/2002				
10/7/2002				
9/6/2002				
8/7/2002				
7/9/2002				
6/7/2002				
5/8/2002				
4/9/2002				
3/11/2002				
2/8/2002				
1/9/2002				
12/6/2001				
Totals:				

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Account Name: Target Corporation

Tariff Rule Worksheet

42298-19083	as billed	rebilled	Out of tol%	KW credit
11/20/2002				
10/22/2002				
9/23/2002				
8/22/2002				
7/24/2002				
6/24/2002				
5/23/2002				
4/24/2002				
3/26/2002				
2/25/2002				
1/25/2002				
12/21/2001				
Totals:				

07710-59334	as billed	rebilled	Out of tol%	KW credit
11/4/2002				
10/4/2002				
9/6/2002				
8/7/2002				
7/9/2002				
6/7/2002				
5/8/2002				
4/9/2002				
3/11/2002				
2/8/2002				
1/9/2002				
12/6/2001				
Totals:				

10054-45984	as billed	rebilled	Out of tol%	KW credit
11/15/2002				
10/17/2002				
9/18/2002				
8/19/2002				
7/19/2002				
6/19/2002				
5/20/2002				
4/19/2002				
3/21/2002				
2/20/2002				
1/22/2002				
12/18/2001				
Totals:				

49909-58540	as billed	rebilled	Out of tol%	KW credit
8/30/2002				
8/1/2002				
7/2/2002				
6/3/2002				
5/2/2002				
4/3/2002				
3/5/2002				
2/4/2002				
1/3/2002				
11/30/2001				
10/30/2001				
10/1/2001				
Totals:				

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Account Name: Target Corporation

Tariff Rule Worksheet

59543-43371	as billed	rebilled	Out of tol%	KW credit
11/19/2002				
10/21/2002				
9/20/2002				
8/21/2002				
7/23/2002				
6/21/2002				
5/22/2002				
4/23/2002				
3/25/2002				
2/22/2002				
1/24/2002				
12/20/2001				
Totals:				

CONFIDENTIAL

Account Name: Target Corporation

FPL Offer Worksheet

02873-11708	as billed	rebilled	Out of tol%	KW credit
11/25/2002				
10/25/2002				
9/26/2002				
8/27/2002				
7/29/2002				
6/27/2002				
5/29/2002				
4/29/2002				
3/29/2002				
2/28/2002				
1/30/2002				
12/28/2001				
Totals:				

New meter months	New Meter as billed	Historical meter months	Historical meter as billed	Difference	% of difference
5/29/2003					
4/29/2003					
3/31/2003					
2/28/2003					
1/29/2003					
12/27/2002					

39242-15316	as billed	rebilled	Out of tol%	KW credit
11/11/2002				
10/11/2002				
9/12/2002				
8/13/2002				
7/15/2002				
6/13/2002				
5/14/2002				
4/15/2002				
3/15/2002				
2/14/2002				
1/15/2002				
12/12/2001				
Totals:				

New meter months	New Meter as billed	Historical meter months	Historical meter as billed	Difference	% of difference
5/14/2003					
4/15/2003					
3/17/2003					
2/13/2003					
1/14/2003					
12/12/2002					

CONFIDENTIAL

Account Name:	Target Corporation

02873-11708

New meter months	New Meter as billed	Historical meter months	Historical meter as billed	Difference	% of difference
5/29/2003					
4/29/2003					
3/31/2003					
2/28/2003					
1/29/2003					
12/27/2002					

New meter months	New Meter as billed	Historical meter months	Historical meter as billed	Difference	% of difference
5/29/2003					
4/29/2003					
3/31/2003					
2/26/2003					
1/29/2003					
12/27/2002					

39242-15316

New meter months	New Meter as billed	Historical meter months	Historical meter as billed	Difference	% of difference
5/14/2003					
4/15/2003					
3/17/2003					
2/13/2003					
1/14/2003					
12/12/2002					

New meter months	New Meter as billed	Historical meter months	Historical meter as billed	Difference	% of difference
5/14/2003					
4/15/2003					
3/17/2003					
2/13/2003					
1/14/2003					
12/12/2002					

CONFIDENTIAL

Account Name: Target Corporation

02873-11706

New meter months	New Meter as billed	Historical meter months	Historical meter as billed	Difference	% of difference
5/29/2003					
4/29/2003					
3/31/2003					
2/28/2003					
1/29/2003					
12/27/2002					

New meter months	New Meter as billed	Historical meter months	Historical meter as billed	Difference	% of difference
5/29/2003					
4/29/2003					
3/31/2003					
2/28/2003					
1/29/2003					
12/27/2002					

39242-15316

New meter months	New Meter as billed	Historical meter months	Historical meter as billed	Difference	% of difference
5/14/2003					
4/15/2003					
3/17/2003					
2/13/2003					
1/14/2003					
12/12/2002					

New meter months	New Meter as billed	Historical meter months	Historical meter as billed	Difference	% of difference
5/14/2003					
4/15/2003					
3/17/2003					
2/13/2003					
1/14/2003					
12/12/2002					

4. **For FPL, please identify and describe every known situation which FPL determined that a refund for a period greater than 12 months was appropriate, regardless of whether the situation relates to a pending SUSI complaint. What specific characteristics or events justified departure from the 12-month limit in Rule 25-6.103(1), Florida Administrative Code?**

"Cause Codes" that identify the reasons for refunds are only retained on customers' records for a 24-month period. FPL was able to identify 137 customer accounts that had received a refund for a period greater than 12 months, during the previous 24-month period. However, none of the 137 accounts reviewed, that were issued refunds beyond a year, were associated with "fast meters" as discussed in Rule 25-6.103(1), F.A.C.

5. **For FPL, please provide the detailed calculations that FPL would use to determine the appropriate refund for each meter for which a refund is sought by SUSI under a pending complaint before the Commission, based on strict application of Commission rules. Please identify all assumptions.**

Process steps used in developing response:

1. The meter test results were applied to the historical demand/usage for the 12 months prior to the meter change in order to calculate a rebill demand/usage.

2. The result from 1. above was entered into FPL's billing system (transaction BCOM) to generate a credit or debit.

Docket 030623 - Commission Staff Request Question 5.

Name	Account	Address	First test results	KWD or kWh credit	credited or debited
J. C. Penney Company Inc.	07064-37886	03 US Highway 301 Blvd STE 01	4.31%	206	$1,829.89
J. C. Penney Company Inc.	90964-37216	076 9th St N #Penneys	3.01%	0	$0.00
Dilliard Department Stores	28011-72467	[illegible]	[illegible]	[illegible]	[illegible]
Dilliard Department Stores	51180-46985	1441 Tamiami Trl # Dilliards	2.08 kWh	49266 kWh	$2,262.61
Best Buy Co.	97114-18237	12395 W Sunrise Blvd	2.96%	0	$0.00
Best Buy Co.	30591-38093	20540 State Road 7	4.96%	292	$2,730.28
Best Buy Co.	63169-50366	1880 Palm Beach Lakes Blvd	Under Tol: 47.77 kWh & 19.84% KWD	714,887 kWh & 585 KWD debited	$42,110.10 debited
Ocean Properties Ltd.	70876-34924	100 Riverfront Blvd.	5.78%	289	$2,995.63
Target Corporation	02873-11708	21637 State Road 7 #Target	2.73%	0	$0.00
Target Corporation	39242-15316	1901 N Congress Ave	4.61%	298	$3,086.67
Target Corporation	36908-36659	5150 14th St W	2.68%	0	$0.00
Target Corporation	13854-10566	1200 Linton Blvd # Target	1.73%	0	$0.00
Target Corporation	42298-19083	13711 S Tamiami Trl #300	4.22%	268	$2,481.81
Target Corporation	07710-59334	3251 Hollywood Blvd #300	2.02%	0	$0.00
Target Corporation	10054-45984	1400 Tamiami Trl # Target	3.25%	0	$0.00
Target Corporation	49909-58540	5350 Fruitville Rd	3.14%	0	$0.00
Target Corporation	59543-43371	1271 Tamiami Trl S # Target	3.11%	0	$0.00

BULLETIN 84
841

LANDIS & GYR

DUNCAN
WATTHOUR AND
THERMAL DEMAND METERS

TMS & TMT

TECHNICAL MANUAL

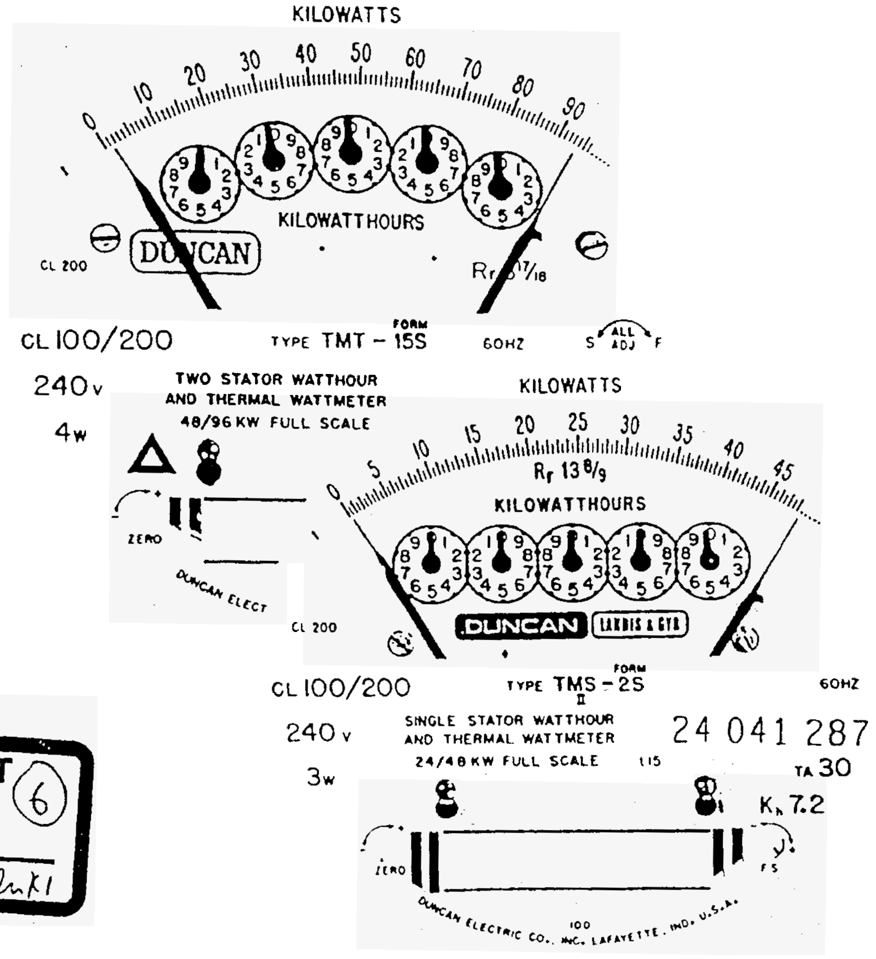


EXHIBIT 6
1/27/04
RnK1

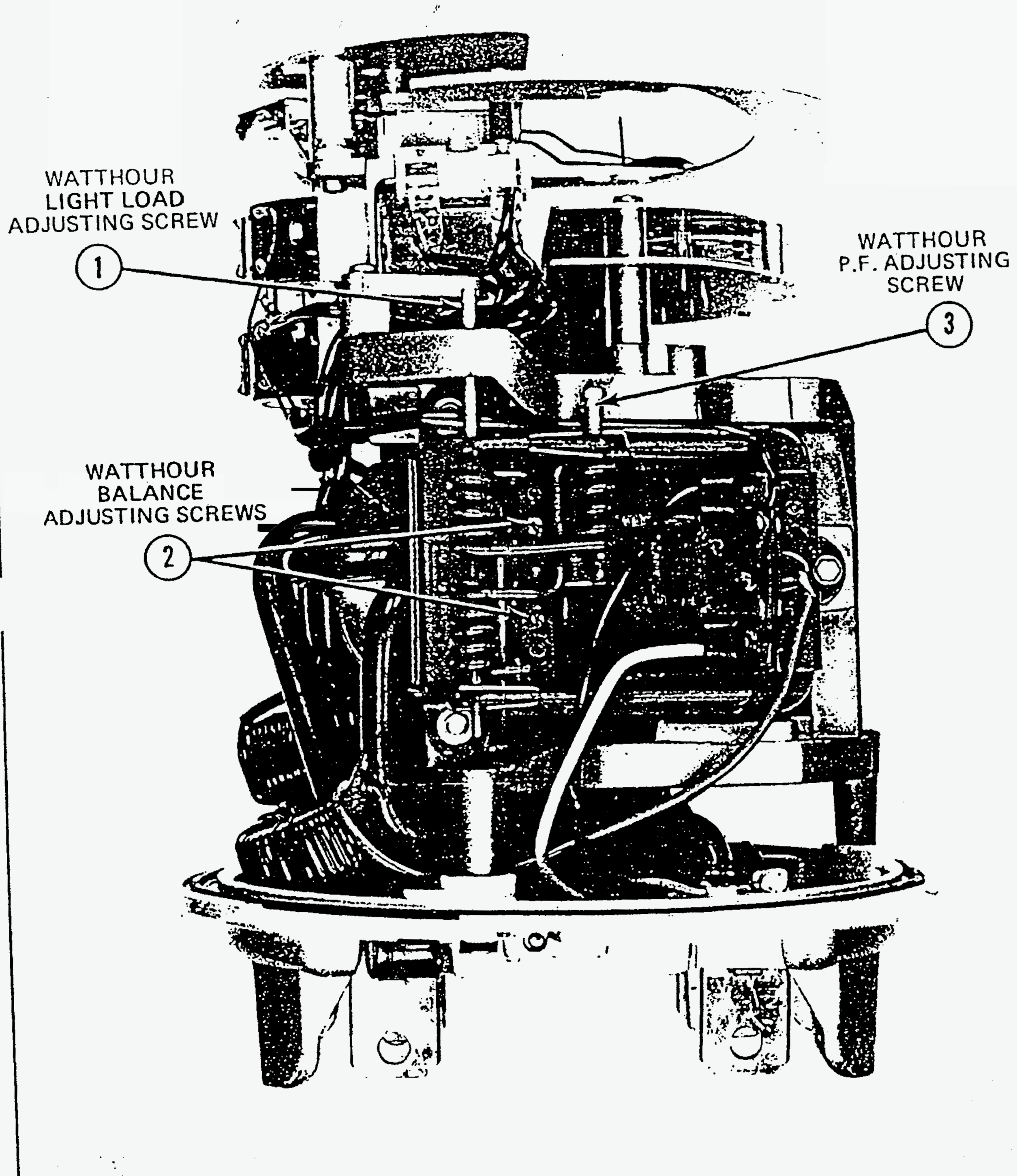

WATTHOUR LIGHT LOAD ADJUSTING SCREW
①
WATTHOUR P.F. ADJUSTING SCREW
③
WATTHOUR BALANCE ADJUSTING SCREWS
②

FIGURE 1

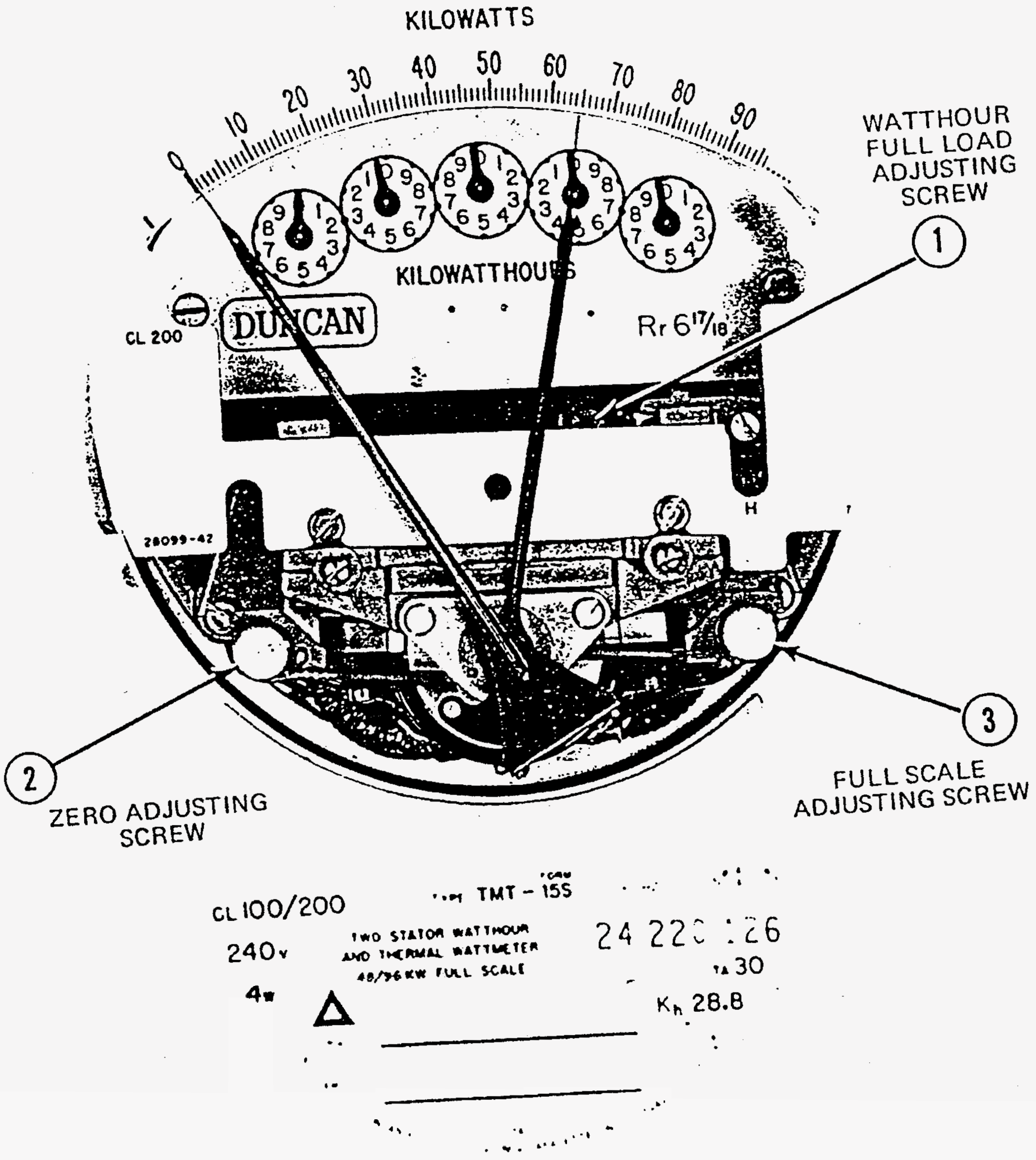

KILOWATTS
0
10
20
30
40
50
60
70
80
90
WATTHOUR FULL LOAD ADJUSTING SCREW
①
KILOWATTHOURS
DUNCAN
CL 200
Rr 6 17/18
28099-42
H
②
ZERO ADJUSTING SCREW
③
FULL SCALE ADJUSTING SCREW
CL 100/200
TYPE TMT - FORM 15S
240v
4w
TWO STATOR WATTHOUR AND THERMAL WATTMETER
48/96 KW FULL SCALE
24 220 126
TA 30
Kh 28.8

FIGURE 2

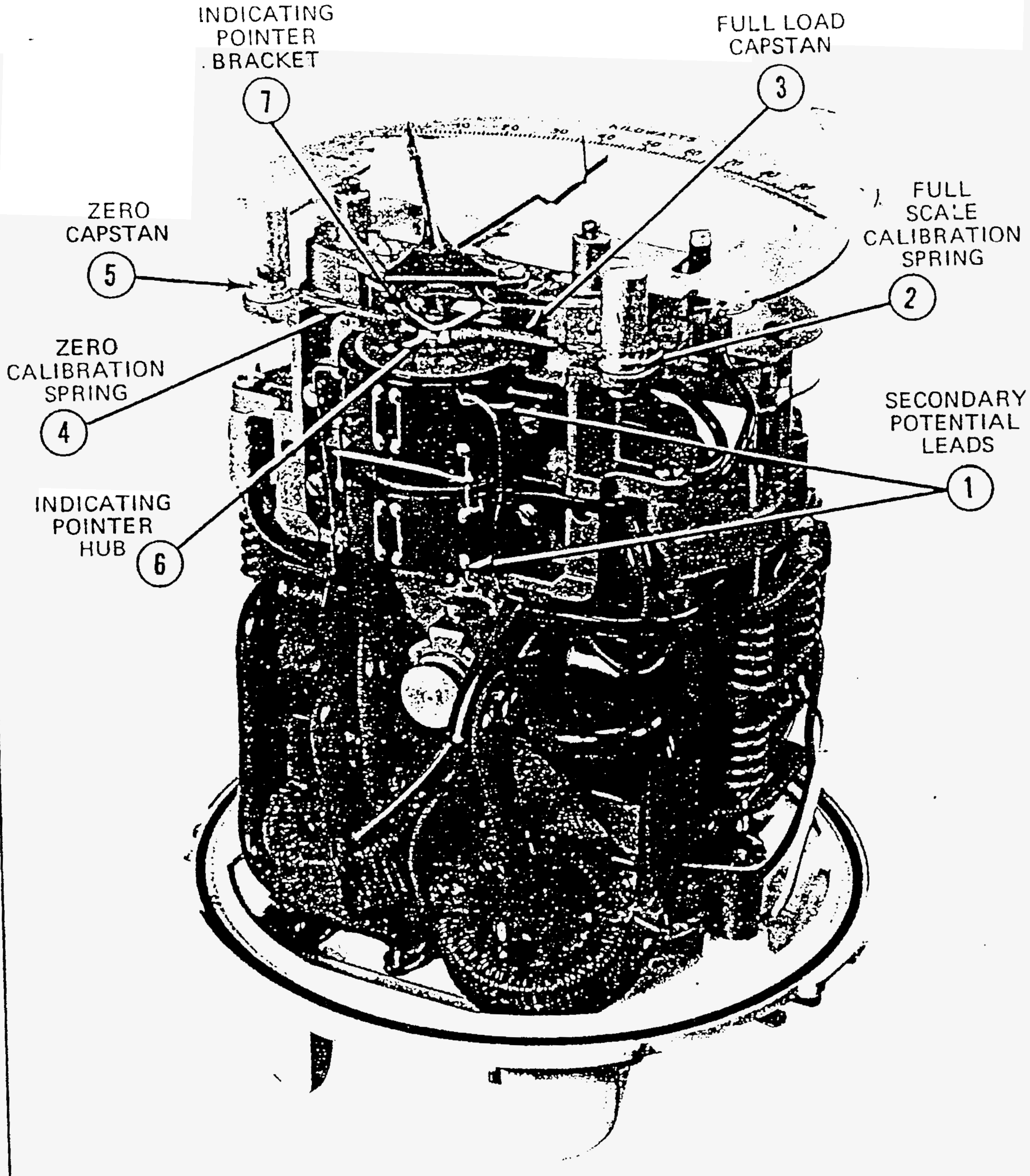

INDICATING POINTER BRACKET
7
FULL LOAD CAPSTAN
3
ZERO CAPSTAN
5
FULL SCALE CALIBRATION SPRING
2
ZERO CALIBRATION SPRING
4
SECONDARY POTENTIAL LEADS
1
INDICATING POINTER HUB
6
KILOWATTS

FIGURE 3

GENERAL INFORMATION

The Duncan Type TMS singlephase and TMT polyphase meters are combination watthour and thermal watt demand meters. With the exception of adding current transformers to the current leads and potential secondaries to the potential stators to supply current and potential for the thermal unit, the construction and circuitry of these meters is basically the same as the corresponding MS and MT meters. The addition of the thermal unit also requires a deeper cover. Polycarbonate covers are standard on all socket, "K," and "B" type thermal meters. Glass covers are standard on "A" base type and the T-9S meters. Standard MS and MT watthour registers are used to record the kilowatt hours on their respective meters.

All combination watthour and thermal watt demand types are supplied with a dual range switch. The switching arrangement includes an interlocking feature between the scaleplate and the location of the range changing switch contact screw, which insures that the current transformers are connected correctly for the selected scale. The reset wire in the cover is insulated to electrically isolate it from the meter frame. A frame ground strap is also provided on all "S" type thermal meters to give added protection for the meter reader when resetting the maximum pointer.

Both the watthour and thermal are in accordance with ANCI C-12 standards. The watthour section of the TMS and TMT meters conform to ANCI C-12.10 standards and ANCI C-12.5 standards for the thermal unit.

The TMT has all the advantages of the MT; improved stability; linearity and uniformity of adjustment response. See Table B for range and sensitivity adjustments. See Figures 1 and 2 for location of adjustments. When checking or recalibrating the watthour section of TMS or TMT meters, follow the same procedure as used on MS or MT meters.

CHECKING ZERO CALIBRATION ON TMS AND TMT METERS

After a thermal meter has been de-energized for some time, it may not read exactly zero. No adjustment should be made until the meter has been warmed up as follows:

Step 1. Connect all potential circuits in parallel.

Step 2. Apply rated voltage only for 2.0 hours. (Current circuit should be disconnected.) The cover must be in place and the maximum (black) pointer must not be in contact with the indicating (red) pointer for this test.

Step 3. If the indicating pointer is not indicating zero after the two hour period of potential only, it can be adjusted to zero by turning the zero adjustment, Item 2, Figure 2, in the + direction (clockwise) to move the pointer upscale, or in the – direction (counter-clockwise) to move the pointer downscale.
Care must be taken not to wrap the zero calibration spring, Item 4, Figure 3, around the capstan, Item 5, Figure 3, when making this adjustment.

If the thermal unit has had extensive repair, the following procedure for setting zero is as follows:

Step 1. Completely release the zero and full scale adjusting springs, Items 4 and 2, Figure 3, by turning the zero adjustment screw, Item 2, Figure 2, counter-clockwise, and by turning the full scale adjusting screw, Item 3, Figure 2, clockwise.

Step 2. Replace cover and apply rated voltage only (no current) for 2 hours.

Step 3. Remove cover. While holding the indicating pointer hub, Item 6, Figure 3, with a ¼" end wrench, grasp the indicating pointer bracket, Item 7, Figure 3, and rotate the pointer so that when the pointer is in its free position, the upper end of the pointer will point to the graduation mark located to the left of zero. Replace cover immediately.
NOTE: Setting of the indicating pointer must not take more than one minute after cover has been removed.

Step 4. Let meter set for a minimum of one more hour with rated voltage only. This will be a total of 3 hours with voltage only.

Step 5. Recheck the indicating pointer setting. If the pointer indication has changed more than the width of the mark at the left of zero, rerun Steps 3 and 4 before continuing the test. If the pointer has not changed, remove cover and turn the zero adjusting screw clockwise until the pointer is pointing to the zero graduation mark. Tap meter lightly while making this adjustment. Setting pointer should be done within 20 seconds after cover has been removed.
CAUTION: Be certain no current is connected to the meter during these five steps. Any line current in the circuit during this test will cause an error in the zero setting.

CALIBRATION OF THERMAL WATT DEMAND UNIT

Thermal demand meters are defined as lagged demand meters, or those which operate in a manner that requires a specific time for the indication to reach a point corresponding to the value of the applied load. The indicating pointer has an approximate exponential response to the applied load. The time characteristic of a lagged demand meter is considered to be the time required for the indicating pointer to reach 90% of final indication after a constant load has been suddenly applied. (See Figure 4.)

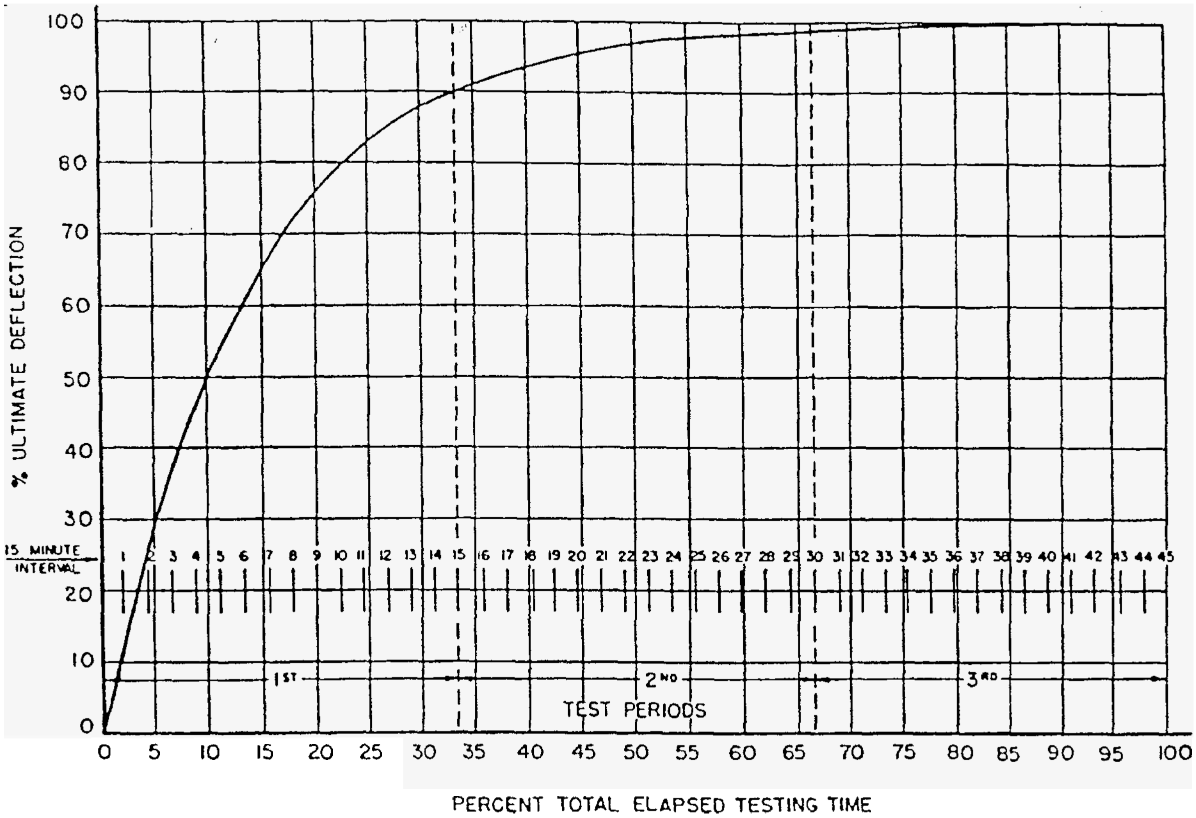


FIGURE 4

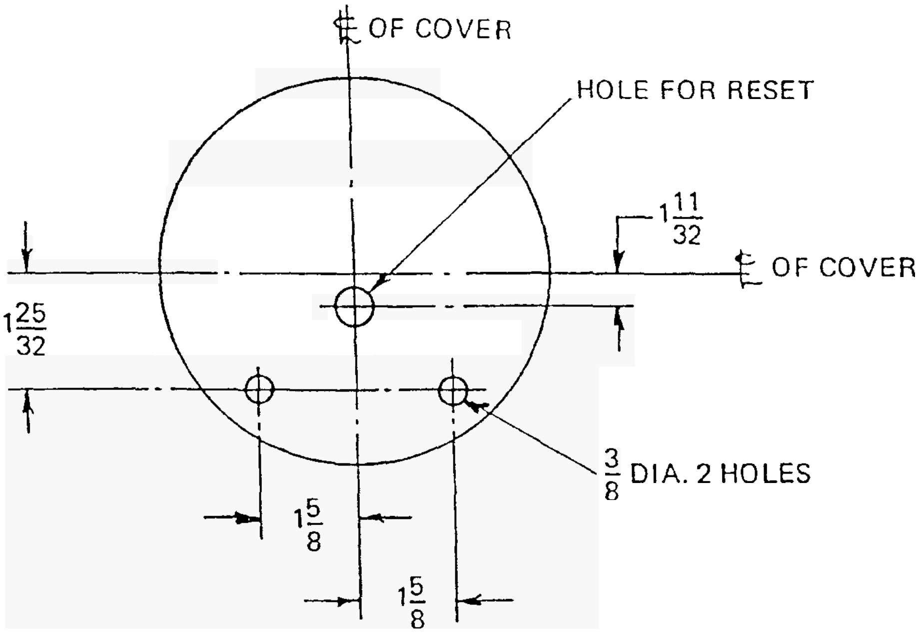
Thermal meters are most conveniently tested on gang racks with provision for 5 to 20 meters. Either of two methods of providing a standard reading is recommended. One method involves the use of a master thermal demand meter of correct rating, and of known calibration, connected in series with the meters under test. With this method, the meters under test are calibrated to read the same as the master or standard meter.

A second method involves the time-load principle. Here the load is held constant at a predetermined level by reference to a watt-meter, and the meters under test are calibrated to indicate this load correctly.

It is necessary to maintain the load for a minimum of 45 minutes, which is approximately three times the time characteristic described above. The range over which the load may vary during a test is determined by the method of testing used. Where a master meter is used, the load may be allowed to vary over limits as wide as plus or minus 4%, whereas for time-load testing, the load should be controlled within plus or minus 1% of the nominal value. When controlling the load manually, it is necessary to hold the load within close limits only during the last one-third of the 45 minutes. The load is set and occasionally checked to see that it is within 2% during the first part of the test, and within the limits as determined by the method of test during the last 15 minutes.

Thermal demand meters should always be tested with the covers in place. When the cover is removed from the meter, the cooler outside air rushes in and cools the so-called hot element of the thermal unit much faster than it does the cold element. This causes a rapid change in the reading of the meter. For this reason, any calibration of the meter must be done quickly after the cover has been removed, preferably within 20 seconds. If other tests are to be made, the cover should be replaced as soon as possible. If it is desired to recheck a calibration point after the cover has been removed and replaced, the present load on the meter must remain constant for a minimum of 45 minutes after replacing the cover before a reading is taken.

The efficiency and accuracy of calibrating thermal demand meters can be improved by the use of test covers that have 3/8" diameter holes located over the zero and full scale calibration adjusting screws, allowing the meter to be calibrated at zero and the calibration point without removing and replacing the cover.



TEST COVER FOR TMS & TMT METERS

FULL SCALE CALIBRATION

The calibration test point is a point on the scale at which the meter is adjusted to read correctly.

Thermal meters have two adjustments, namely, zero and the full scale adjustment. Normally when making acceptance and periodic checks, they are limited to these two points. However, when desired, additional checks may be made at 50% lagging power factor, and for equality of current circuits.

NOTE: All errors in registration are figured in % of full scale.

Example: A one division error any place on a 100 division scale would be an error of 1.0%

All external mounting dimensions, terminal arrangements and circuitry on thermal TMS and TMT meters are the same as their respective MS and MT watthour meters. See Pages 21 through 30 for wiring diagrams.

The calibration test point can be made at any point from 50% of full scale to 100% full scale. Duncan thermal meters are calibrated during factory calibration at 50% of full scale KW for the convenience of using this point on the scale as a comparison for other tests. The cover must be in place and the maximum pointer must be in contact with the indicating pointer for all tests other than zero.

It is possible to test polyphase thermal meters in the shop on polyphase loads, but the elaborate testing equipment needed for such tests is seldom warranted since singlephase test results can be correlated to polyphase performance. Therefore, polyphase meters are tested singlephase by connecting the potential circuits in parallel and the current circuits in series.

After the zero setting has been completed, the calibration test point can be checked by the following procedure:

Connect the potential circuits in parallel and the current circuits in series.

Suddenly apply a singlephase load at unity power factor equal to the KW desired to calibrate or check the meter under test. This load must be held for a minimum of 45 minutes. The accuracy of this load must be held, depending on the method being used for testing, as described in a previous paragraph.

Calibrate the meter at the KW selected for the calibration point by means of the full scale calibration adjusting screw, Item 3, Figure 2. When adjusting downscale, the indicating pointer should be moved downscale past the calibration points and then adjusted upscale very slowly to the calibration point with the maximum pointer in contact with the indicating pointer. Care must be taken not to wrap the calibration spring, Item 2, Figure 3, around the capstan, Item 3, Figure 3.

It will not be necessary to recheck the zero setting after the calibration point has been set since the zero and full scale adjustments are independent of each other.

An exception to the above procedure must be made when making the calibration test load or applying a singlephase load to the 3 phase, 4 wire wye, 2 stator meters, i.e., Forms 6S, 7S, and 14S. These meters have three current circuits, one of which is associated with both potential circuits. When applying a singlephase test load, this current circuit gives 50% full scale reading with only 75% of full scale current at unity power factor. The other two current circuits are associated with one potential circuit, and each circuit gives 25% full scale reading when energized separately with 75% full scale singlephase current at unity power factor. Therefore, when testing by the singlephase method, apply only 75% of the current for any test point selected.

CHANGING FULL SCALE DEMAND RATING

To change the full scale demand rating, the following steps must be done. (See Figure 6 for identification of parts.):

1. Loosen the two nameplate screws, Item 20, Figure 6, ½ turn and remove the nameplate.
2. Remove contact screw, Item 8, Figure 6.
3. Loosen the two scaleplate screws, Item 21, Figure 6, a minimum of ¾ turns.
4. Remove scaleplate by raising it approximately 1/16" and lift nameplate upward.
5. Turn scaleplate over and position it into the recess in the thermal unit frame. Before tightening the scaleplate screws, orient the scale down and to the right against the screws, Item 21, Figure 6.
   NOTE: Care must be taken to prevent bending the pointers and to keep from trapping the indicating pointer under the scaleplate.
6. Remove switch lug, Item 10, Figure 6, from switch block and move to the opposite location so that the contact screw will align with the notch, Item 22, Figure 6, in the nameplate. This will assure that the KW rating showing will match the correct thermal current transformer ratio.
7. Replace nameplate and tighten screws, Item 20, Figure 6.

The calibration performance of both sides of the scale are checked on all meters during factory testing. Therefore, no touch-up or recalibration is required when the scale is reversed for class change.

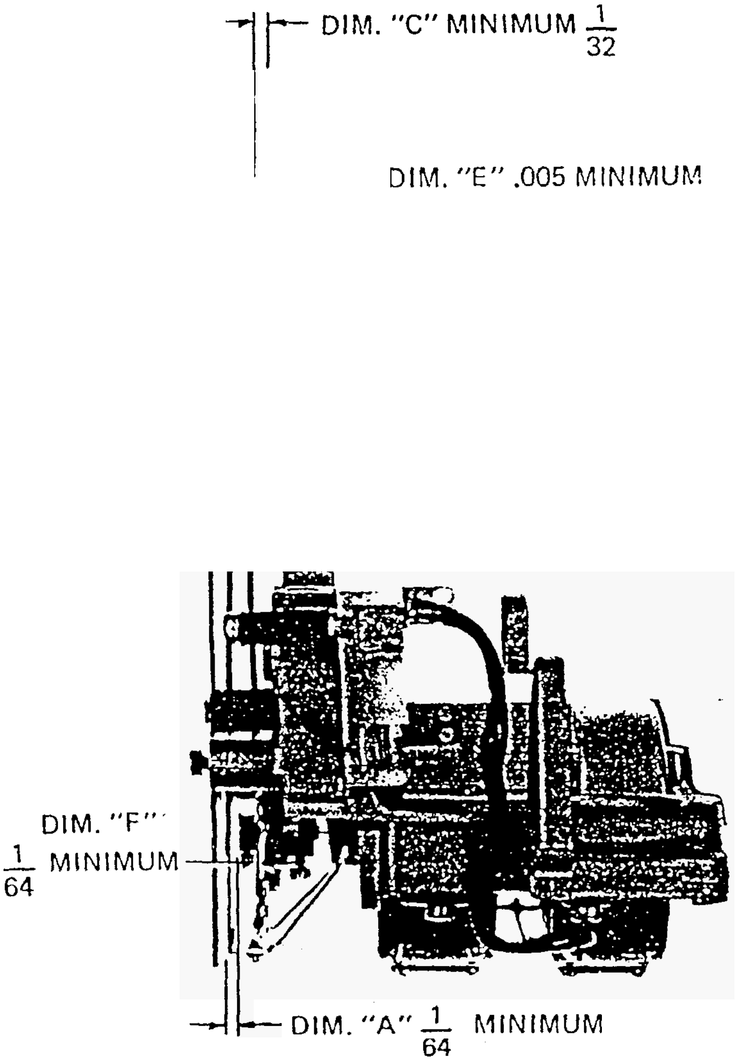


FIGURE 5

MAINTENANCE PROCEDURES FOR TMS AND TMT METERS

Replacement of Indicating (Red) Pointer

Replacement of the indicating pointer requires the removal of the nameplate and the two 0-80 screws at the lower end of the pointer where it is attached to the indicating pointer bracket. After replacing the new pointer, it will be necessary to check the clearance between the underside of the indicating pointer and the maximum pointer hub, Dim. "A", Figure 5. If it is touching, grasp the pointer approximately where it touches the maximum pointer hub and raise it up until it reforms the 90° bend at the lower end of the pointer enough so that it will clear the maximum pointer hub a minimum of 1/64." Then check to make sure the indicating pointer and the maximum pointer touch only at the flag, Dim. "B," Figure 5, on the maximum pointer and the knife edges of the pointers align with each other and the indicating pointer is approximately 1/32" above the scaleplate, Dim. "C," Figure 5. Replace the nameplate. There should be approximately 1/32" clearance between the indicating pointer and the back side of the nameplate, Dim. "D," Figure 5. The meter should be in its operating position when making this adjustment.

Replacement of Maximum (Black) Pointer

To replace the maximum pointer, Item 2, Figure 6, remove the nameplate and the two 4-40 x 7/32 screws, Item 16, Figure 6, holding the grease damping unit in place. Push the maximum pointer to the full scale reading, grasp the maximum pointer at the lower edge of the scaleplate and raise the grease damping unit, Item 3, Figure 6, forward and up. Remove the old pointer by loosening the 0-80 screw in pointer hub. Put new pointer on staff and tighten screw. The underside of the pointer should clear the top of the grease damping unit a minimum of 1/64," Dim. "F," Figure 5. To reassemble, push the pointer and grease damping unit under the indicating pointer into the proper mounting place and reassemble the two 4-40 x 7/32 screws. After the unit has been reassembled, check to make sure the end of the pointer does not touch the scaleplate over the entire length of the pointer travel, Dim. "E," Figure 5, with the scaleplate firm against its lower stops.

Check to make sure the pointers touch only at the flag, Dim. "B," Figure 5, on the maximum pointer, and the hub on the maximum pointer does not touch the underside of the indicating pointer, Dim. "A," Figure 5. The maximum pointer must be flush with the front surface of the scaleplate or not more than 1/32" behind the front surface. With the meter in its operating position, the flat portion of the upper ends of the pointers must align with each other and must be vertical to the front surface of the scaleplate when the indicating pointer is against the flag on the maximum pointer.

Replacement of Grease Damping Unit

When replacing the grease damping unit, Item 3, Figure 6, use the same procedure as replacing the maximum pointer.

Replacement of Scaleplate

When ordering replacement scaleplates, be sure to specify the code numbers on the lower left and right hand corners of both sides of the plates. When installing the scaleplates, be sure to position them in the recess in the thermal frame and, before tightening the scaleplate screws, orient the scale down and to the right against the screws, Item 21, Figure 6.

Replacement of Dual Range Switch Block

Replacing the dual range switch, Item 18, Figure 6.

Step 1. Remove the nameplate.
Step 2. Remove contact screw, Item 8, Figure 6.
Step 3. Remove scaleplate, Item 4, Figure 6.
Step 4. Unsolder current transformer secondary leads from the solder lugs on the switch block assembly.
Step 5. Remove 4-24 x ½ self tapping screw, Item 11, Figure 6. When replacing new switch block assembly use reverse procedure.

Replacement of Calibration Springs

Installing zero springs, Item 5, and/or full scale adjusting springs, Item 6, Figure 6.

Step 1. Attach spring to chain.
Step 2. Before attaching the spring to the indicating pointer bracket, Item 13, Figure 6, let the spring and chain hang free to remove any twist in the chain. Then attach the spring to the indicating pointer bracket without twisting the chain.

Replacement of Capstan

Replacing capstans, Item 7, Figure 6, zero or full scale calibration chain, Item 23, Figure 6, or cup washer, Item 14, Figure 6.

Step 1. Remove the zero or full scale calibration springs, Items 5 and 6, Figure 6, from the indicating pointer bracket, Item 13, Figure 6.
Step 2. Loosen the 2-56 x 3/16 clamping screw, Item 12, Figure 6, on the capstan.
Step 3. Remove the 5-40 x 9/16 screw, Item 15, Figure 6, and cup washer, Item 14, Figure 6.

NOTE: Since the clamping screw distorts the threads on the 5-40 x 9/16 screw, it is difficult to remove. It may be necessary to use a screwdriver in the slot in the capstan or a pair of pliers to hold the capstan while removing the screw. It is recommended that a new screw and cup washer be used when reassembling the capstan. Care must also be taken not to lose the chain anchor, Item 17, Figure 6. This is a 7/32" long phosphor bronze wire #29 B & S gauge .0112 diameter, located in a hole in the end of the capstan.

Step 4. To install new capstan, use reverse procedure as used when removing. The chain and chain anchor wire must be assembled to the capstan before reassembly to the thermal frame.

CAUTION: The turning torque of the capstan and the torque of the 2-56 clamping screw is very critical. If the torque is set too low the thermal element may lose the full scale or zero calibration. If the torque is set too high it may collapse the cup washer and make it very difficult to turn the capstan when calibrating the meter. The torque on the capstan should be set with a torque screwdriver, set at 2½ to 3½ inch pounds. The 2-56 clamping screw should be set at 1.0 to 1½ inch pounds.

See Maintenance Note 4, Page 10.

Replacement of Thermal Element Bearings

If it is necessary to change both front and rear bearings, always keep one bearing in place while changing the other. Do not have both bearings out of the meter at the same time. Keeping one bearing in place will keep the bi-metal coils inside the thermal element centrally located between the heater units.

The following procedure is recommended for changing the bearings.

Step 1. To replace the front bearing, place the meter on bench with the scaleplate facing up.

Step 2. Remove nameplate.

Step 3. Remove indicating pointer, Item 1, Figure 1, by removing the two 0-80 screws from the indicating pointer bracket, Item 13, Figure 6, at the lower end of the pointer.

Step 4. Remove the grease damping assembly, Item 3, Figure 6.

Step 5. Loosen the 2-56 x 3/16 clamping screw, Item 12, Figure 6.

Step 6. Remove bearing, Item 9, Figure 6.
See Maintenance Note 1, Page 10.

Step 7. Install new bearing.

CAUTION: Care must be taken when installing the bearing, or the bearing wire may be bent. Place meter on bench with the indicating pointer bracket, Item 13, Figure 6, facing up and to the right. Grasp the indicating pointer bracket with the left hand and guide the bearing wire into the pivot hole in the end of the shaft as the bearing is being screwed into the frame. After the bearing wire has entered the bi-metal shaft, continue to screw the bearing in until there is no end play of the shaft. As the bearing is being screwed in, continue to work the shaft in and out with the left hand on the indicating pointer bracket until there is no end play. Then back the bearing out a minimum of ¼ turn to a maximum of ½ turn. This will give an end play of .006 to .0125.
See Maintenance Note 2, Page 10.

Step 8. Tighten the 2-56 clamping screw, Item 12, Figure 5, with a torque screwdriver set at 0.5 to 1.0 inch pounds.
See Maintenance Note 1, Page 10.
If the front bearing is the only bearing to be replaced, reassembly the grease damping assembly, indicating pointer and nameplate. If the rear bearing is to be replaced, continue on to Step 9.

Step 9 Unsolder the potential transformer secondary leads, Item 1, Figure 3, from the thermal unit heaters. (Both potential transformers on polyphase meters).

Step 10. Remove contact screw, Item 8, Figure 6.

Step 11. Remove scaleplate, Item 4, Figure 6.

Step 12. Remove the 4-24 x ½ self-tapping screw, Item 11, Figure 6. This will free the range changing switch so that the current transformer leads will not have to be unsoldered.

Step 13. Remove the two 6-32 x ½ thermal unit mounting screws, Item 19, Figure 6.

Step 14. Loosen the rear 2-56 clamping screw, same as Item 12, Figure 6, except on rear of thermal unit.

Step 15. Remove rear bearing, Item 9, Figure 6.
See Maintenance Note 1, Page 10.

Step 16. To replace the rear bearing, place the thermal unit on bench with indicating pointer bracket up and to the left, and guide the bearing wire into the bi-metal shaft by grasping the indicating pointer bracket with the left hand while screwing the bearing into the frame. Using the same method for checking the end play of the bi-metal shaft as used when inserting the front bearing, screw the bearing in until no end play exists. Then back the bearing out a minimum of ¼ turn to a maximum of ½ turn.
See Maintenance Note 1, Page 10.

Step 17. Tighten the 2-56 clamping screw against the bearing with a torque screwdriver set from 0.5 to 1.0 inch pounds.

Step 18. Put thermal unit back on meter frame and reassemble all other parts in reverse order as used when disassembling the unit.
See Maintenance Note 4, Page 10.

MAINTENANCE NOTES

NOTE 1: When the 2-56 clamping screw, Item 12, Figure 6, is tightened against the bearing body, it tends to flatten the threads on the bearing in that area. In some cases this may cause some difficulty in removing the bearing and may require retapping the 5-40 bearing hole in the frame, after removal of the bearing.

NOTE 2: The bearing screw has a 40 pitch thread. This is the same as used on micrometers. Therefore, one turn of the screw will give .025 movement of the screw. This makes it easy to very accurately control the amount of end play of the bi-metal shaft.

NOTE 3: If the thermal element, indicating pointer bracket, or current transformer needs to be replaced, the meter will have to be returned to the Duncan Electric Company for repair.

NOTE 4: Replacing the thermal element bearings, calibration chain, or capstans is very critical to the operation of the thermal section of the meter. If proper tools are not available for these operations, it is recommended that the meter be returned to Duncan Electric Company for these replacements and adjustments.

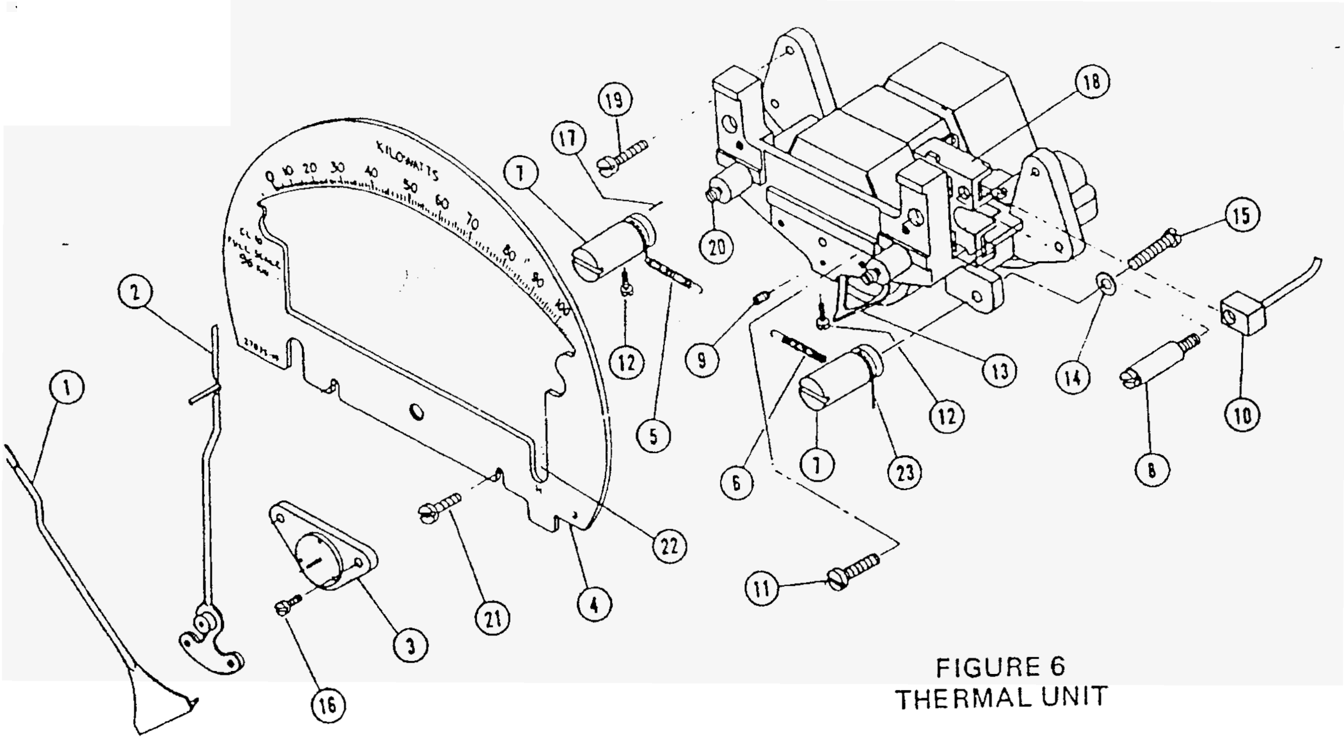


FIGURE 6
THERMAL UNIT

PARTS FOR THERMAL UNIT

m No.	Description	Part Number
1	Indicating pointer†	27946-1
2	Maximum pointer assembly	27949
3	Assembly of grease damping†	27958-1
4	Scaleplate: TMT, T	28099*
	TMS	27935*
5	Zero calibration spring††	27937
6	Full scale calibration spring††	27936
7	Assembly of capstan**	27929-1
8	Assembly of contact screw	28061
9	Assembly of adjustable bearing screw	27926
10	Assembly of switch lug – TMT	27987
	– TMS	27987-
11	4-24 x ½ self-tapping screw	28003
12	2-56 x 3/16 screw	20263
13	Indicating pointer bracket	27948
14	Cup washer	27960
15	5-40 x 9/16 screw	30598
16	4-40 x 7/32 screw	32970
17	Anchor for calibration chain	27927
18	Range changing switch block – TMS & TMT "K" type meters	27982-1
	– TMT except "K" type meters	27982
19	6-32 x ½ thermal unit mounting screw	28023
20	4-40 x 3/16 nameplate screw	106889
21	6-32 x 3/8 scaleplate mounting screw	55659-6
22	Location of slot in scaleplate for contact screw	
23	Calibration chain	23195

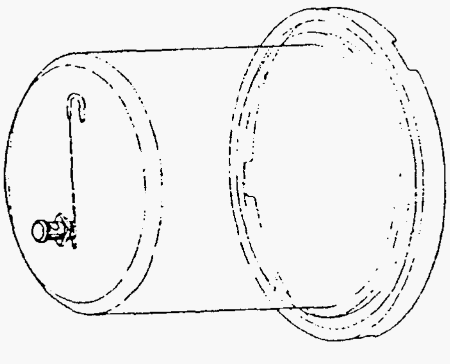
† These parts include mounting screws.

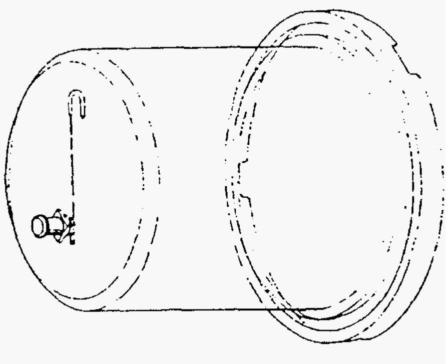
†† Give serial number of meter when ordering calibration springs.

* Specify code numbers and/or letters in lower right and left-hand corners, on front and back of scaleplate.

** Assembly of capstan includes capstan, capstan clamping screw, capstan mounting screw, cup washer, chain, and anchor. The anchor is a 7/32" long phosphor bronze wire (#29 B&S gauge), and for shipment is held in position with a piece of tape. Remove tape and clean end of capstan with naptha, alcohol, or other solvent before assembling capstan to meter.

Description and Application	Part Number	
	Standard Reset	Padlock Reset
Painted polycarbonate for TMS and TMS-K	28022-8	28022-12
Clear polycarbonate for TMT-S and TMT-K	28085	28085-1
Clear glass for TMT-A	28113	28113-1
Clear glass for TMT-B	28190	28190-1
Clear polycarbonate for TMT-B	28327	28327-1
Clear glass for T-A	28153	28153-1
Clear glass for T-9S	28245-1	28245-2


PADLOCK RESET


STANDARD RESET

Type & Form	Part Number	Type & Form	Part Number	Type & Form	Part Number
TMS-2S	27962	TMT-5S	58123-2	TMT-12S	58133-1
TMS-3S	28006	TMT-6S	58131-2	TMT-14S	58127-1
TMS-4S	28007	TMT-7S	58124-2	TMT-15S	58128-1
		TMT-8S	58125-1	TMT-24S	28161

Description	Part Number
Wormwheel assembly for TMT	56339
Gasket for TMS baseplate	56095
Spark gap assemblies for TMS	
left-hand	56636
right-hand	56637
Register mounting post for TMT	27932
Nameplate for TMS	27934*

TABLE A TMT METER CHARACTERISTICS

	Class 5 TA 2.5	Class 10 TA 2.5	Class 100 TA 15	Class 200 TA 30	Class 400 TA 50
Basic Watthour Constant					
K_h for 120V, 2 stator (except wye)*	1.2	1.2	7.2	14.4	28.8
K_h for 120V, 2 or 3 stator wye	1.8	1.8	10.8	21.6	43.2
K_h for 277V, 2 stator wye	3.6	3.6	21.6	43.2	86.4
Disk Speed in RPM** (at TA, 1.0PF, rated volts on balanced polyphase load)					
120, 240, 480V meters	8⅓	8⅓	8⅓	8⅓	$6\frac{17}{18}$
277V meters	9.623	9.623	9.623	9.623	8.019
Torque at TA in mmg					
2 stator meters	50	50	60	60	50
3 stator meters	75	75	75	75	62½
Average Starting Watts in % of Class	0.11%	0.06%	0.07%	0.07%	0.07%
Potential Coil Losses in Watts (per stator at rated volts without indicating lamps)	0.95	0.95	0.95	0.95	0.95
First Reduction (R_s)	50/1	50/1	50/1	50/1	50/1
Weight of Rotor in Grams	32	32	32	32	32

* K_h values for other voltage ratings are proportional.

	RANGE	SENSITIVITY (% change per turn)
Full Load (magnet screw)	5%	0.4%
Light Load (both screws)	20%	1.2%
Balance (per stator)	12%	0.7%
Phasing (per stator)	7%	0.4%

	WATTS	VA	PF	Θ	R	X	Z
With Indicating Lamp	2.1	8.1	.25	75°	450	1700	1800

	WATTS	VA	PF	Θ	R	X	Z
Cl 5 – All meters except 2 stator wye*	2.1	2.3	.92	23°	.085	.035	.092
Cl 5 – 2 stator wye**	2.7	2.8	.97	15°	.11	.030	.11
Cl 10 – All meters except 2 stator wye*	1.4	1.6	.85	32°	.056	.035	.066
Cl 10 – 2 stator wye**	1.5	1.7	.88	29°	.061	.033	.070

	Class 5 TA 2.5	Class 10 TA 2.5	Class 100/200 TA 30	Class 200/400 TA 50	Class 160/320 TA 50
K_h for 120V 1Ø 2 Wire	.3	.3			
K_h for 240V 1Ø 2 Wire	.6	.6			
K_h for 240V 1Ø 3 Wire			7.2	14.4	12
Disk Speed in RPM (at TA 1.0 PF) Rated Volts	16⅔	16⅔	16⅔	13⁸⁄₉	16⅔
Torque at TA in mmg.	38	38	38	32	38
Average Starting Watts in % of Class	.16	.08	.06	.06	.06
Potential Coil Losses in Watts	2.2	2.2	2.2	2.2	2.2
First Reduction (R_s)	100/1	100/1	100/1	100/1	100/1
Weight of Rotor	20 Gms	20 Gms	20 Gms	20 Gms	20 Gms

TABLE E TMS BURDEN DATA FOR TRANSFORMER RATED METERS

Burden On Current Transformers (at 5 amoeres)

Class	Service and Form Numbers	Current Circuit	WATTS	VA	PF	Θ	R	X	Z
5	Singlephase 2 wire 3S	A	2.9	3.8	.76	43°	.11	.097	.150
	Singlephase 2 wire 4S	A or C	1.4	1.9	.72	46°	.056	.054	.078
10	Singlephase 2 wire 3S	A	2.2	3.2	.68	47°	.088	.094	.130
	Singlephase 2 wire 4S	A or C	.76	1.4	.53	58°	.031	.048	.057

WATTS	VA	PF	Θ	R	X	Z
2.2	4.7	.5	62°	1400	2700	3000

Watthour Constants, Gear, and Register Ratios TMS and TMT

The watthour constant K_h is defined as watthours per revolution of the disk, and can be calculated for single stator meters as follows:

$$K_h = \frac{\text{Rated Voltage x Meter TA Rating}}{\text{Base Speed (Rev./hr. of the disk)}}$$

The base speed of Duncan MS and TMS single stator TA 30 meters is 16⅔ RPM or 1000 RPH. The base speed for Duncan type "K" single stator TA 50 meters is 13⁸⁄₉ RPM or 833⅓ RPH.

Example: TMS-3S, 120V, TA 2.5

$$K_h = \frac{120 \times 2.5}{1000} = 0.3$$

The base speed of Duncan MT and TMT 2 stator TA 30 meters is 8⅓ RPM or 500 RPH. The base speed for Duncan type "K," 2 stator TA 50 meters is 6¹⁷⁄₁₈ RPM or 416⅔ RPH.

The K_h for 2 stator MT and TMT meters is calculated as follows:

$$K_h = \frac{\text{*Rated Voltage x Meter TA Rating x *2}}{\text{Base Speed (Rev./hr. of the disk)}}$$

*For Duncan two stator, 3 phase 4 wire wye meters, use a multiplier of 3 instead of 2. Use 240 volts when figuring the K_h on 277V wye meters.

Example: TMT-14S, 277V, TA 30

$$K_h = \frac{240\text{V} \times 30 \times 3}{500} = 43.2$$

Register Ratio Calculations

The units dial on all watthour registers records 10 kilowatt hours, or 10,000 watthours per revolution. The total gear ratio (R_g) between the meter spindle and the first dial shaft is given by:

$$R_g = \frac{10{,}000}{K_h}$$

In all Duncan meters, this reduction is taken in two stages. The first reduction is between the spindle worm and the worm wheel. On Duncan type MS and TMS meters this reduction is a 100/1 ratio. On Duncan type MT and TMT meters this reduction is a 50/1 ratio. Hence, the register ratio (R_r) can be calculated as follows:

$R_r = \frac{R_g}{100}$ for single stator TMS meters

$R_r = \frac{R_g}{50}$ for 2 and 3 stator TMT meters

Example for single stator TMS-2S, 240V, TA 30, K_h 7.2:

$$R_g = \frac{10{,}000}{7.2} \quad 1388\tfrac{8}{9} \qquad R_r = \frac{1388\tfrac{8}{9}}{100} = 13\tfrac{8}{9}$$

Example for a 2 stator TMT-14S, 120V, TA 30, 4 wire wye meter, K_h 21.6:

$$R_g = \frac{10{,}000}{21.6} = 462\tfrac{26}{27} \qquad R_r = \frac{462\tfrac{26}{27}}{50} = 9\tfrac{7}{27}$$

Dial Multipliers K_r

Some registers require a dial multiplier (K_r) to prevent the register from starting to repeat during a billing period. When these constants are necessary, they are printed on the register face, and the gear ratio and register ratio are calculated as follows:

Single stator MS and TMS meters:

$$R_g = \frac{10{,}000 \times K_r}{K_h} \qquad R_r = \frac{R_g}{100}$$

Two or three stator MT and TMT meters:

$$R_g = \frac{10{,}000 \times K_r}{K_h} \qquad R_r = \frac{R_g}{50}$$

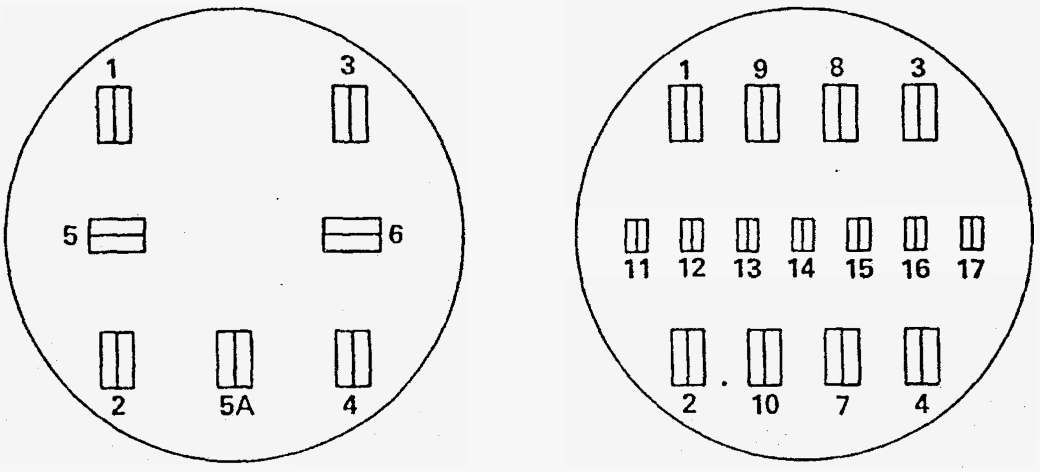
Constants Used With Instrument Transformers

When combination watthour and thermal watt demand meters are to be used with instrument transformers, they usually carry secondary KW ratings and register ratios. These secondary KW readings and watthour register readings must be multiplied by the product of the instrument transformer ratios (T.F.) to determine the maximum demand of the load and kilowatthours. When meters are to be used with instrument transformers, the primary disk constant (KhP) is calculated by multiplying the secondary disk constant (KhS) by the T.F.

Example:

$$\text{T.F.} = \frac{2400V}{120V} \times \frac{400A}{5A} = \frac{20}{1} \times \frac{80}{1} = 1600$$

ANSI C12 STANDARD SOCKET JAW
POSITION IDENTIFICATION



FRONT VIEW OF SOCKET

DUNCAN SOCKET TYPE METERS CORRESPONDING TO STANDARD FORM DESIGNATIONS

ANSI C12 Form Designation	Stator	Current Circuit	External Circuit Wires	Terminals	Duncan Watthour and Thermal Watt Demand Meter Type Designation
2S	1	2	3	4	TMS
3S	1	1	2	5 (1)	TMS
4S	1	2	3	6	TMS
5S	2	2	3 or 4	8 (6)	TMT-5S
6S	2	3	4 Wire Y	13 (2)	TMT-6S
7S	2	3	4 Wire Y (Alt)	7 (6)	TMT-7S
8S	2	3	4 Wire Δ	13 (2)	TMT-8S
9S	3	3	4 Wire Y	13	T-9S
12S	2	2	3	5 (5)	TMT-12S
14S	2	3	4 Wire Y	7	TMT-14S
15S	2	3	4 Wire Δ	7	TMT-15S
24S	2	3	4 Wire Δ	7	TMT-24S

DUNCAN BOTTOM CONNECTED TYPE METERS CORRESPONDING TO STANDARD FORM DESIGNATIONS (A BASE METERS)

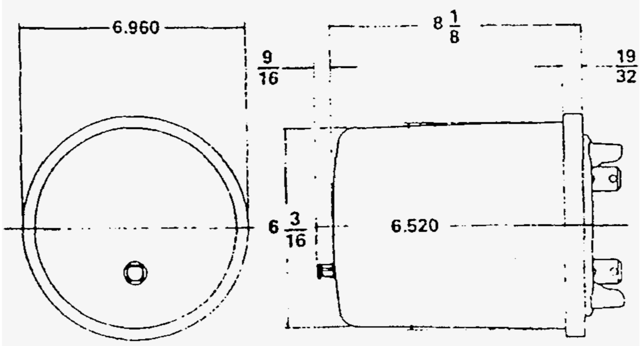
ANSI C12 Form Designation	Stator	Current Circuit	External Circuit Wires	Terminals	Duncan Watthour and Thermal Watt Demand Meter Type Designation
5A	2	2	3 or 4	8*	TMT-5A T-5A
6A	2	3	4 Wire Y	10*	TMT-6A T-6A
8A	2	3	4 Wire Δ	10*	TMT-8A T-8A
9A	3	3	4 Wire Y	12*	T-9A
13A	2	2	3	6*	T-13A
14A	2	3	4 Wire Y	8*	T-14A
15A	2	3	4 Wire Δ	8*	T-15A

* Meters have provision for three additional terminals for contact device connections by request

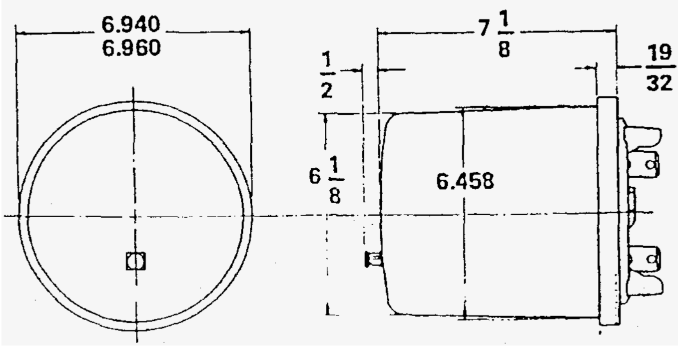
Form Designation	Stator	Current Circuits	External Circuit Wires	Terminals	Duncan Watthour and Thermal Watt Demand Meter Type Designation
2K	1	2	3	4	TMS-2K
12K	2	2	3	5	TMT-12K
14K	2	3	4 Wire Y	7	TMT-14K
15K	2	3	4 Wire Δ	7	TMT-15K
27K	2	2	3	7*	TMT-27K

Form Designation	Stator	Current Circuits	External Circuit Wires	Terminals	Duncan Watthour and Thermal Watt Demand Meter Type Designation
14B	2	3	4 Wire Y	7	TMT-14B
15B	2	3	4 Wire Δ	7	TMT-15B

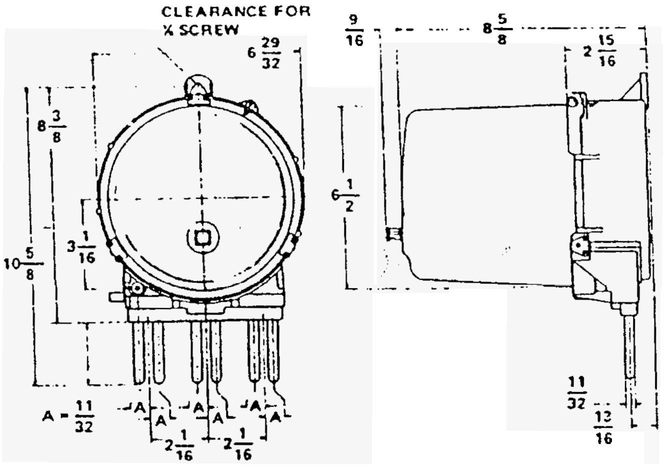
DIMENSIONS



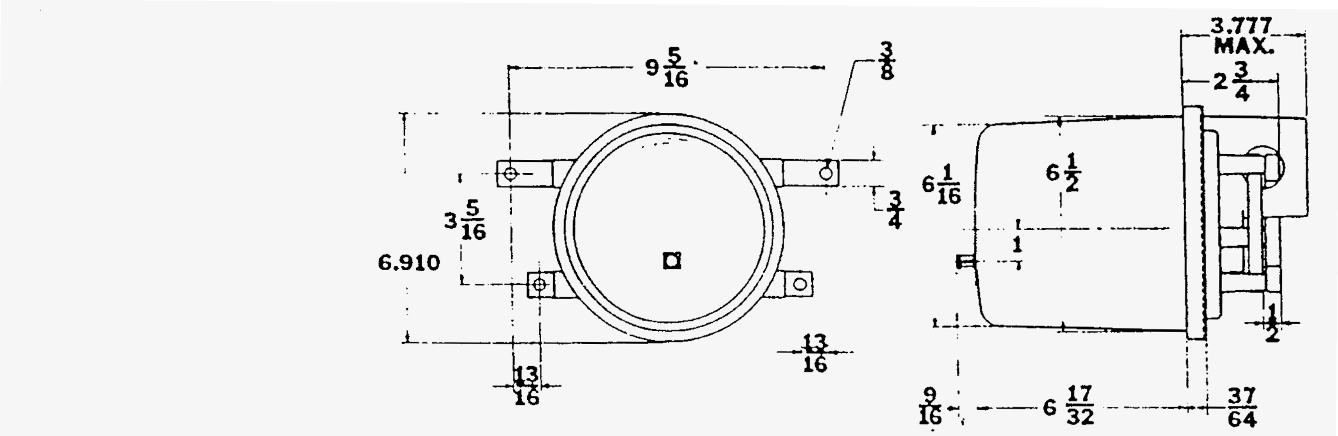
TYPE TMT "S"



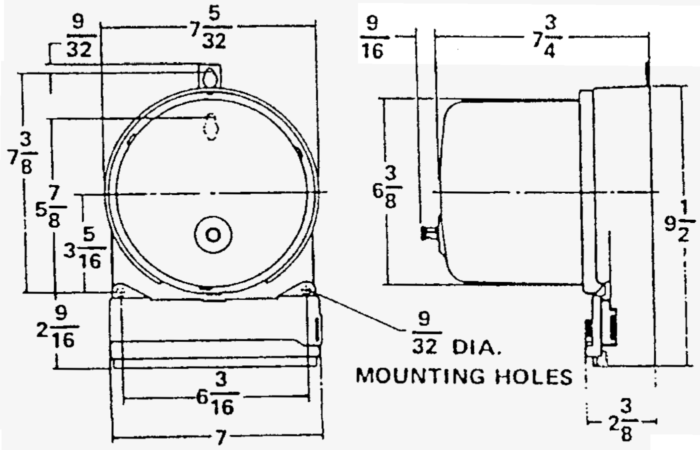
TYPE TM "S"



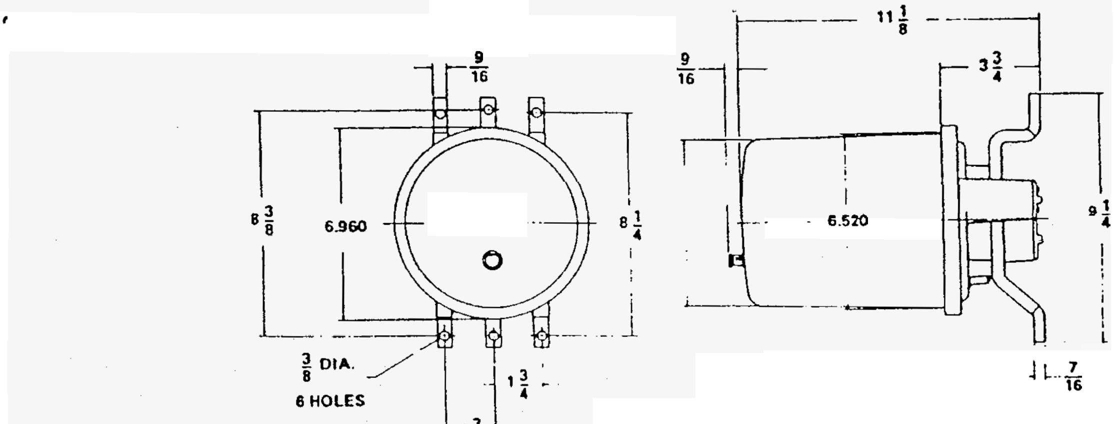
TYPE TMT "B"



TYPE TMS "K"



TYPE TMT "A"



TYPE TMT "K"

INTERPRETATION OF WRONG TEST RESULTS FOR TMS & TMT METERS

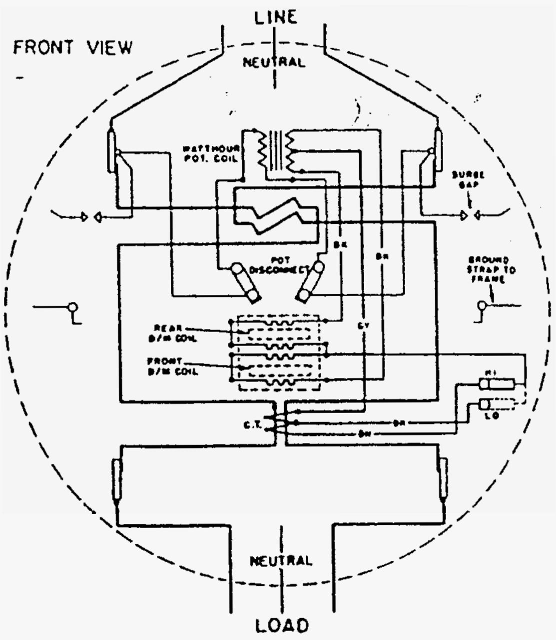
Condition Found	Probable Cause	Corrective Action
KW reading high on test load at calibration point.	If this occurs on 3 Ø 4 wire wye 2 stator meters, test load may be set wrong.	Apply only 75% of the current for the test point selected on these meters.
KW reading low on test load at calibration point.	1. Broken current transformer or potential transformer leads 2. Unsoldered or poorly soldered leads. 3. Broken center tap on current transformer. 4. One or two phases not functioning properly.	1. Solder leads if accessible. 2. Solder leads if accessible. 3. Check balance of meter; then check the wiring or for loose connections or unsoldered joints on the phases not running properly. 4. Check for correct rack wiring.
#1 Phase not running #2 Phase not running #3 Phase not running #2 and #3 Phase not running	1. Unsoldered joints on potential or current transformer secondary. 2. Broken secondary leads on potential or current transformer 3. Open circuited potential coil. 4. May not have had potential coil excited.	1. Solder joints 2. Repair broken wire if accessible. 3. Check continuity of potential coil. 4. Apply correct potential to the phase not running and feel disk with finger for vibration of disk; or check across potential coil terminals with voltmeter.
Thermal element runs backward	1. Broken center tap on current transformer. 2. Broken center tap on potential transformer. 3. Potential transformer leads reversed. 4. C.T. primary leads reversed on transformer rated meters. 5. Meter wired wrong.	1. Solder leads if accessible. 2. Reverse potential transformer secondary leads. 3. Reverse leads. 4. Check wiring with wiring diagram or meter that runs correctly. 5. Check wiring with wiring diagram or meter that runs correctly.
Thermal element runs on low range but will not run on high range.	Broken center tap on current transformer.	Solder leads if accessible.
Thermal not running.	1. Broken center tap on potential transformer. 2. May have lost potential on rack while running. 3. Broken center tap on current transformer. 4. Cold soldered joints. 5. Leads not soldered.	1. Solder leads if accessible. 2. Recheck meter. 3. Solder leads if accessible. 4. Resolder leads. 5. Solder leads.
Low 50% F.S. on flip side of scale on dual range meters.	1. May have bent scaleplate, causing pointer to rub on plate. 2. Scaleplate may not be located correctly on frame.	1. Straighten scaleplate. 2. Relocate scaleplate.

INTERPRETATION OF WRONG TEST RESULTS FOR TMS & TMT METERS

Condition Found	Probable Cause	Corrective Action
Excessive friction in the maximum (black) pointer.	1. Bent staff on grease reservoir. 2. Pointer hub touching cover on reservoir. 3. Counterweight end of pointer touching indicating pointer bracket. 4. Counterweight end of pointer touching reservoir. 5. End of pointer may be touching scaleplate.	1. Put on new grease reservoir. 2. Relocate pointer on staff. 3. Reform pointer bracket. 4. Reform pointer. 5. Check scaleplate positioning.
Not enough friction on maximum pointer.	1. Not enough grease. 2. Pointer loose on staff.	1. Replace grease reservoir. 2. Tighten set screw.
Friction in indicating (red) pointer.	1. Pointer touching scaleplate. 2. Bent red pointer. 3. Bent bearings. 4. Bearings not adjusted properly. 5. Pointer touching nameplate. 6. Red pointer touching maximum pointer hub or shaft. 7. Indicating pointer hub touching end plate.	1. If scale is bent, straighten or replace scale; if pointer is bent, reform pointer. 2. Straighten pointer. 3. Straighten or replace bearings. 4. Check for proper amount of end play. 5. Check for bent nameplate and bent pointer or ~~bent~~ indicating pointer bracket. 6. Indicating pointer bracket not located correctly on B/M shaft, or maximum pointer not located on staff correctly. or Bent indicating pointer bracket; pointers not formed properly. 7. Relocate indicating pointer hub on shaft.
Meter runs ½ scale.	1. Meter wired wrong (brown and black leads reversed at the dual range switch). 2. Test rack may not be set up correctly. 3. On TMT meters one potential coil may be open; or one potential may not be connected.	1. Rewire meter. 2. Check load and all settings on test rack. 3. Check across potential terminals with voltmeter or check continuity of potential coil.
Meter runs full scale with ½ scale current.	1. Meter wired wrong (brown and black leads reversed at the dual range switch). 2. Test rack may not be set up correctly.	1. Rewire meter. 2. Check load and all settings on test rack.
Thermal runs backwards	Broken center tap on potential transformer.	Resolder if accessible and check test rack connections.
Thermal runs ¼ scale with ½ scale current.	Broken center tap on potential transformer.	Resolder if accessible and check test rack connections.

TYPE TMS
SINGLE STATOR WATTHOUR & THERMAL WATT DEMAND METER
FORM 2S

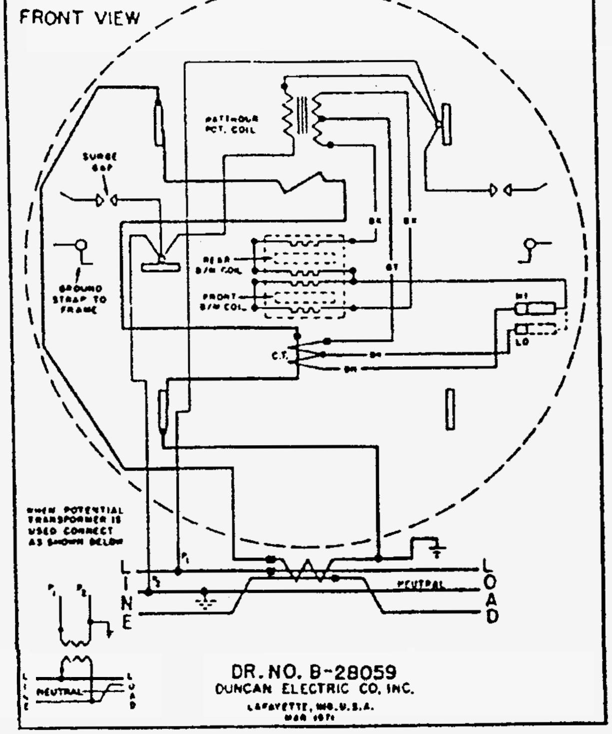
TA 30, CLASS 100-200, 3 WIRE, SELF CONTAINED
TA 2.5, CLASS 5/10, 3 WIRE, SELF CONTAINED
(DUAL RANGE)



DR. NO. B-27913
DUNCAN ELECTRIC CO. INC.
LAFAYETTE, IND. U.S.A.
MAY 1970

TYPE TMS
SINGLE STATOR WATTHOUR & THERMAL WATT DEMAND METER
FORM 3S

TA 2.5, CLASS 5-10, 1-PHASE, 2 WIRE
FOR USE WITH ONE 3-WIRE CURRENT TRANSF. ON A 1-PHASE 3-WIRE CIRCUIT
(DUAL RANGE)

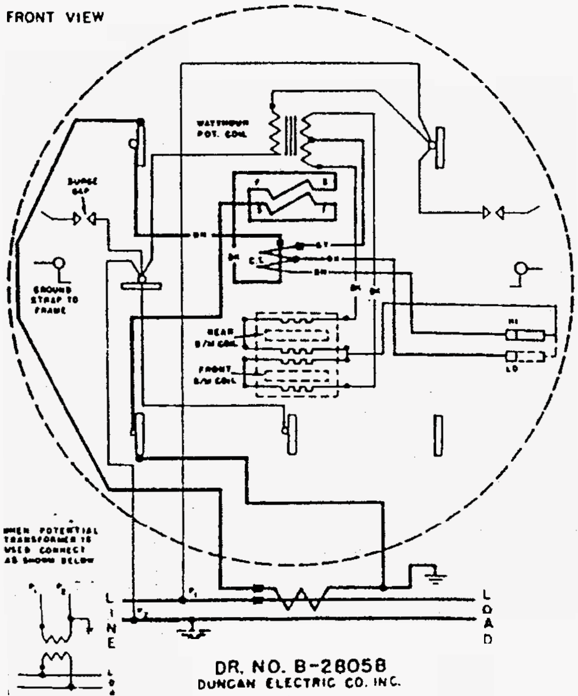


WHEN POTENTIAL TRANSFORMER IS USED CONNECT AS SHOWN BELOW

DR. NO. B-28059
DUNCAN ELECTRIC CO. INC.
LAFAYETTE, IND. U.S.A.
MAR 1971

TYPE TMS
SINGLE STATOR WATTHOUR & THERMAL WATT DEMAND METER
FORM 3S

TA 2.5, CLASS 5-10, 1-PHASE, 2 WIRE
FOR USE WITH ONE 2-WIRE CURRENT TRANSF. ON A 1-PHASE 2-WIRE CIRCUIT
(DUAL RANGE)

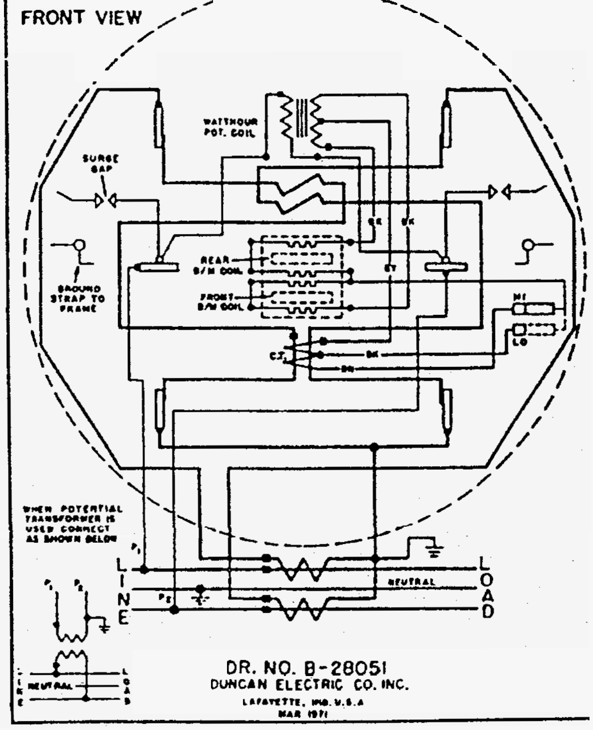


WHEN POTENTIAL TRANSFORMER IS USED CONNECT AS SHOWN BELOW

DR. NO. B-28058
DUNCAN ELECTRIC CO. INC.
LAFAYETTE, IND. U.S.A.
MAR 1971

TYPE TMS
SINGLE STATOR WATTHOUR & THERMAL WATT DEMAND METER
FORM 4S

TA 2.5, CLASS 5-10, 1-PHASE, 3 WIRE
FOR USE WITH TWO 2-WIRE CURRENT TRANSF. ON A 1-PHASE 3-WIRE CIRCUIT
(DUAL RANGE)

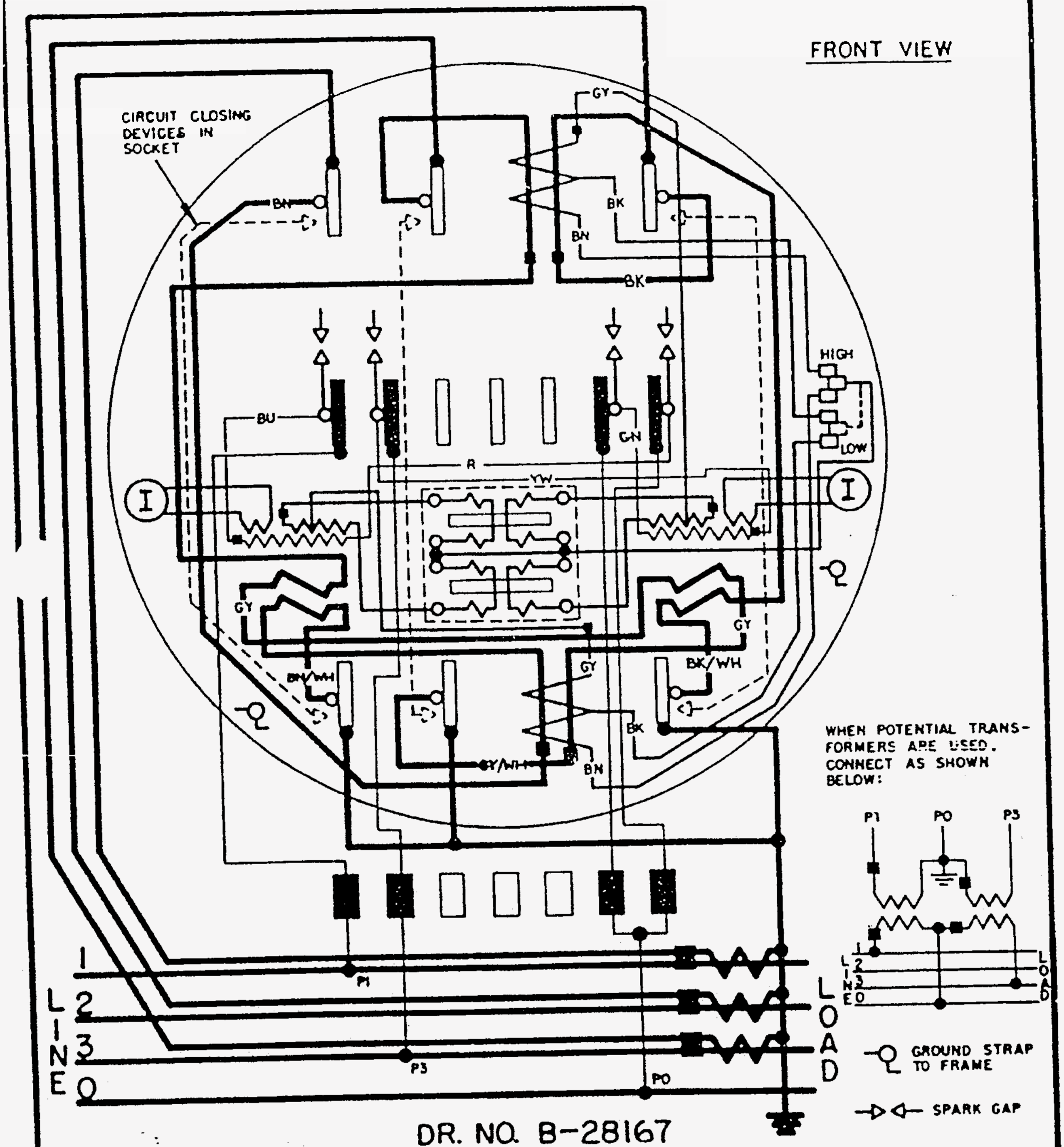


WHEN POTENTIAL TRANSFORMER IS USED CONNECT AS SHOWN BELOW

DR. NO. B-28051
DUNCAN ELECTRIC CO. INC.
LAFAYETTE, IND. U.S.A.
MAR 1971

TYPE TMT-6S TRANSFORMER RATED
TWO STATOR WATTHOUR & THERMAL WATT METER

CLASS 5/10 13-TERMINAL FORM-6S
TA-2.5 DUAL-RANGE 3-PHASE 4-WIRE WYE
WITH POTENTIAL INDICATOR LAMPS



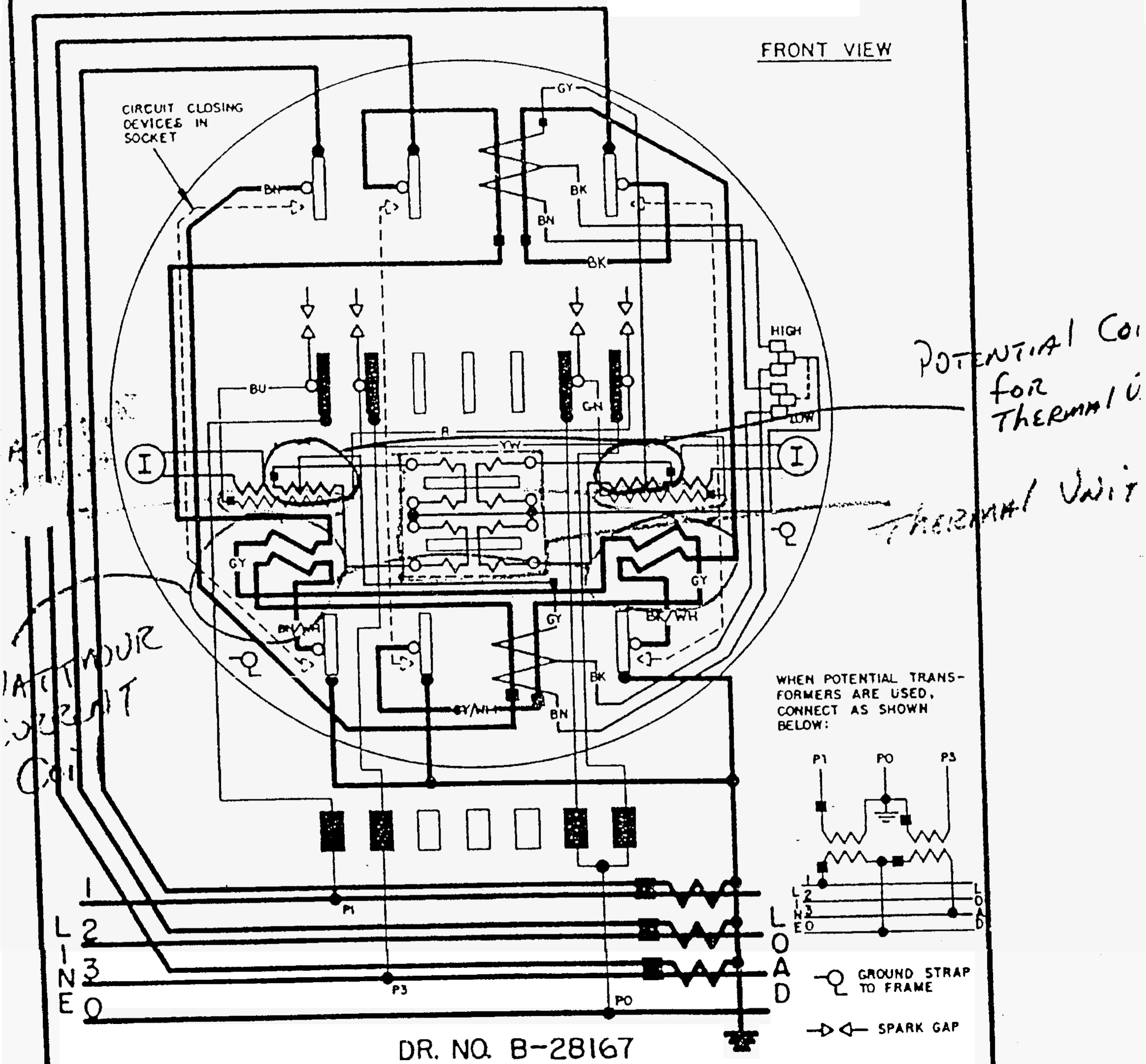
WHEN POTENTIAL TRANSFORMERS ARE USED. CONNECT AS SHOWN BELOW:

POTENTIAL INDICATOR LAMP

DR. NO. B-28167
DUNCAN ELECTRIC CO. INC.
LAFAYETTE, IND. U.S.A.
FEB 1973

TYPE TMT-6S TRANSFORMER RATED
TWO STATOR WATTHOUR & THERMAL WATT METER

CLASS 5/10 13-TERMINAL FORM-6S
TA-2.5 DUAL-RANGE 3-PHASE 4-WIRE WYE
WITH POTENTIAL INDICATOR LAMPS

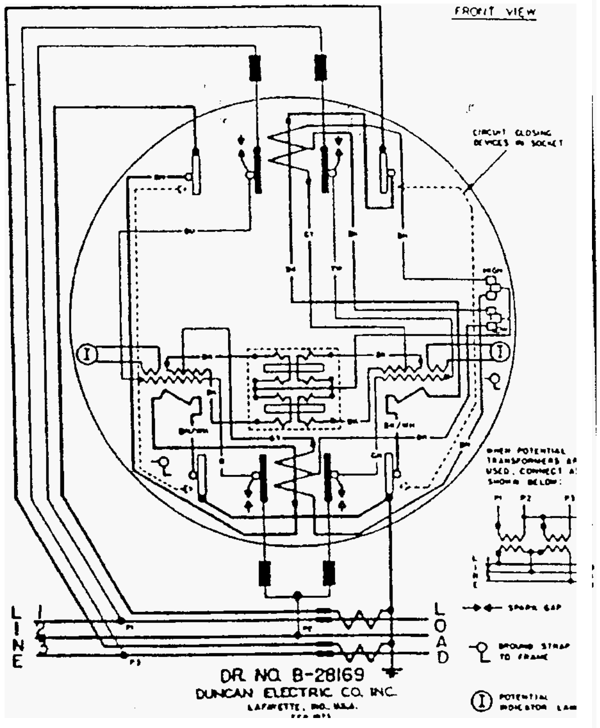


WHEN POTENTIAL TRANSFORMERS ARE USED, CONNECT AS SHOWN BELOW:

DR. NO. B-28167
DUNCAN ELECTRIC CO. INC.
LAFAYETTE, IND. U.S.A.
FEB 1973

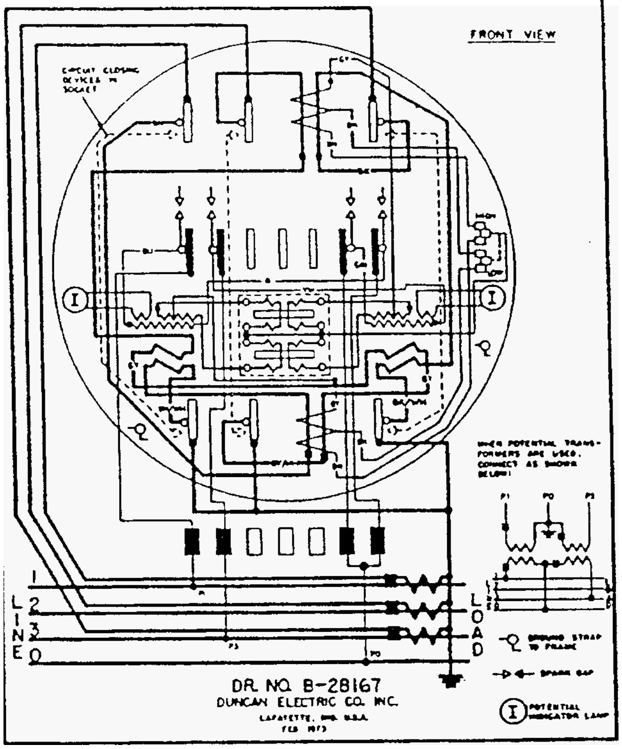
TYPE TMT-5S TRANSFORMER RATED TWO STATOR WATTHOUR & THERMAL WATT METER

CLASS 5/10 FORM-5S
TA-2.5 DUAL RANGE 1, 2, OR 3-PHASE 3-WIRE
WITH POTENTIAL INDICATOR LAMPS



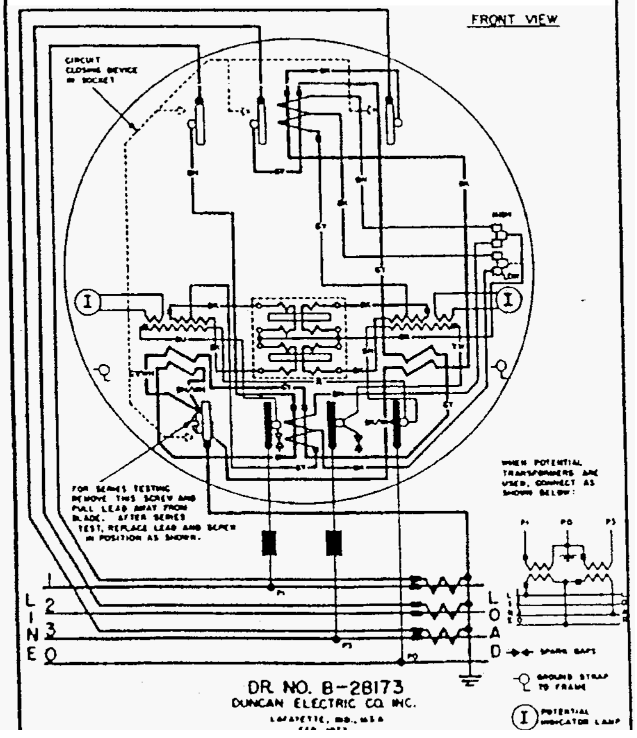
TYPE TMT-6S TRANSFORMER RATED TWO STATOR WATTHOUR & THERMAL WATT METER

CLASS 5/10 13-TERMINAL FORM-6S
TA-2.5 DUAL-RANGE 3-PHASE 4-WIRE WYE
WITH POTENTIAL INDICATOR LAMPS



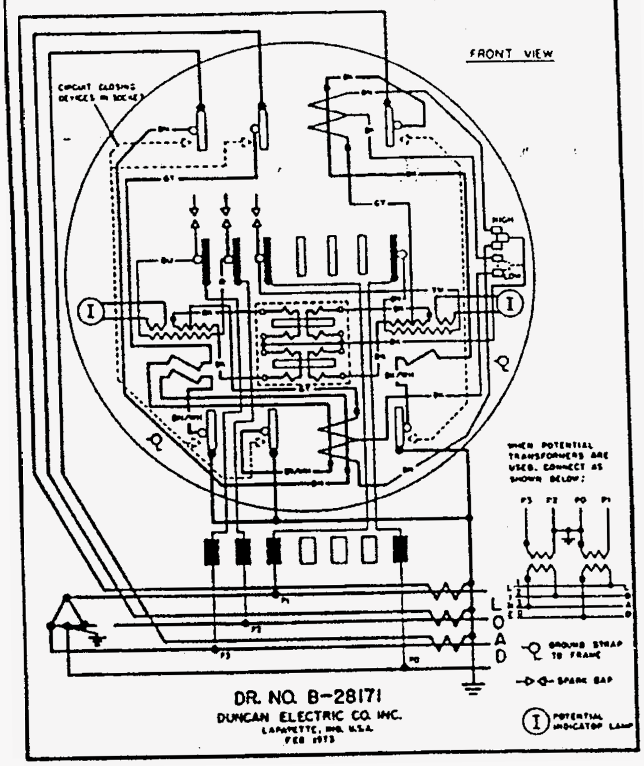
TYPE TMT-7S TRANSFORMER RATED TWO STATOR WATTHOUR & THERMAL WATT METER

CLASS-5/10 7-TERMINAL FORM-7S
TA-2.5 DUAL RANGE 3-PHASE 4-WIRE WYE
WITH POTENTIAL INDICATOR LAMPS



TYPE TMT-8S TRANSFORMER RATED TWO STATOR WATTHOUR & THERMAL WATT METER

CLASS 5/10 13-TERMINAL FORM-8S
TA-2.5 DUAL RANGE 3-PHASE 4-WIRE DELTA
WITH POTENTIAL INDICATOR LAMPS



WHEN POTENTIAL TRANSFORMERS ARE USED, CONNECT AS SHOWN BELOW:

GROUND STRAP TO FRAME

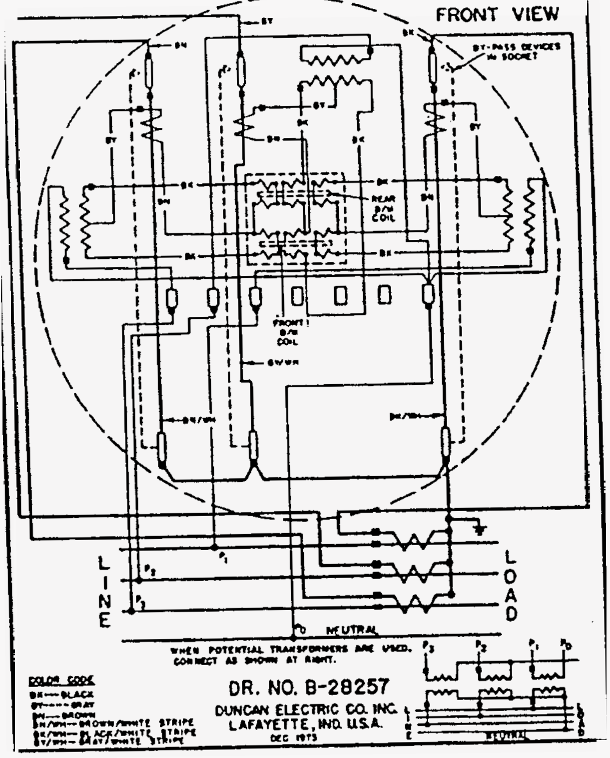
SPARK GAP

POTENTIAL INDICATOR LAMP

DR. NO. B-28171
DUNCAN ELECTRIC CO. INC.
LAFAYETTE, IND. U.S.A.
FEB 1973

TYPE T-9S 3 ELEMENT THERMAL WATT METER

3 PHASE 4 WIRE WYE
FOR USE WITH INSTRUMENT TRANSFORMERS
STANDARD - COMMON POTENTIAL RETURN



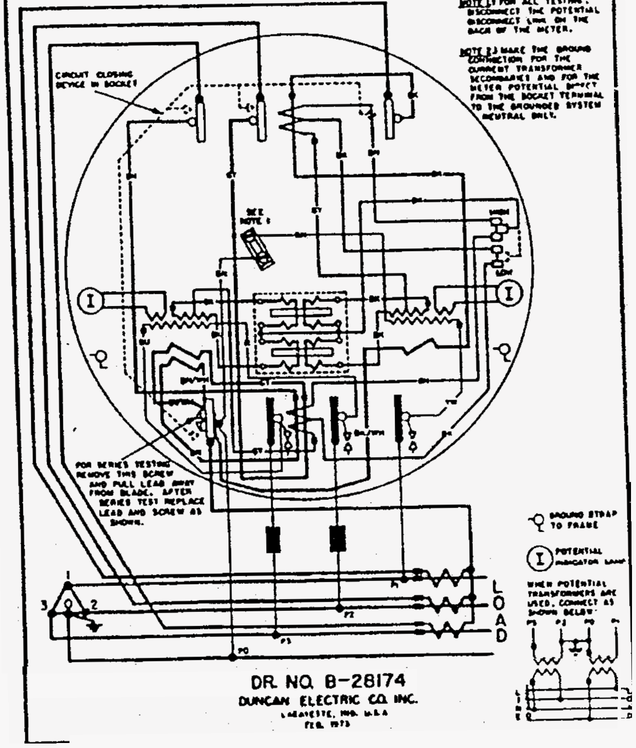
WHEN POTENTIAL TRANSFORMERS ARE USED, CONNECT AS SHOWN AT RIGHT.

COLOR CODE
BK — BLACK
GY — GRAY
BN — BROWN
BN/WH — BROWN/WHITE STRIPE
BK/WH — BLACK/WHITE STRIPE
GY/WH — GRAY/WHITE STRIPE

DR. NO. B-28257
DUNCAN ELECTRIC CO. INC.
LAFAYETTE, IND. U.S.A.
DEC 1973

TYPE TMT-24S TRANSFORMER RATED TWO STATOR WATTHOUR & THERMAL WATT METER

CLASS-5/10 7-TERMINAL FORM-24S
TA-2.5 DUAL RANGE 3-PHASE 4-WIRE DELTA
WITH POTENTIAL INDICATOR LAMPS
(FRONT VIEW)



NOTE 1) FOR ALL TESTING, DISCONNECT THE POTENTIAL DISCONNECT LINK ON THE BACK OF THE METER.

NOTE 2) MAKE THE GROUND CONNECTION FOR THE CURRENT TRANSFORMER SECONDARIES AND FOR THE METER POTENTIAL DIRECT FROM THE SOCKET TERMINAL TO THE GROUNDED SYSTEM NEUTRAL ONLY.

FOR SERIES TESTING REMOVE THIS SCREW AND PULL LEAD AWAY FROM BLADE. AFTER SERIES TEST REPLACE LEAD AND SCREW AS SHOWN.

GROUND STRAP TO FRAME

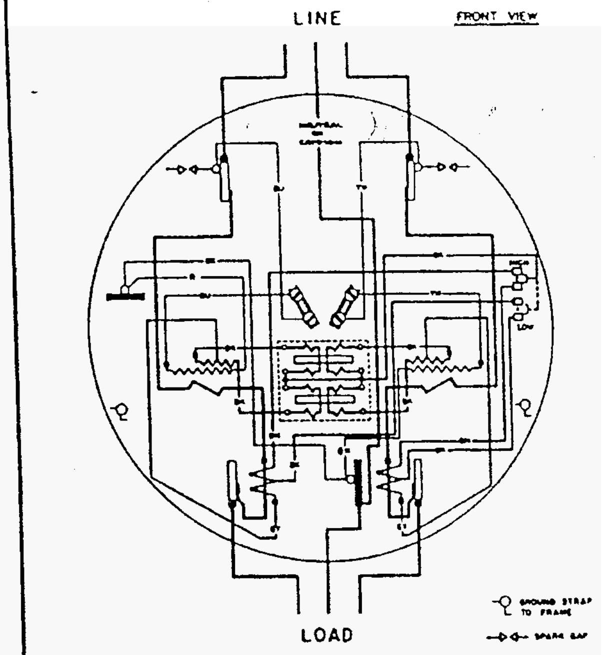
POTENTIAL INDICATOR LAMP

WHEN POTENTIAL TRANSFORMERS ARE USED, CONNECT AS SHOWN BELOW:

DR. NO. B-28174
DUNCAN ELECTRIC CO. INC.
LAFAYETTE, IND. U.S.A.
FEB. 1973

TYPE TMT-12S SELF CONTAINED
TWO STATOR WATTHOUR & THERMAL WATT METER

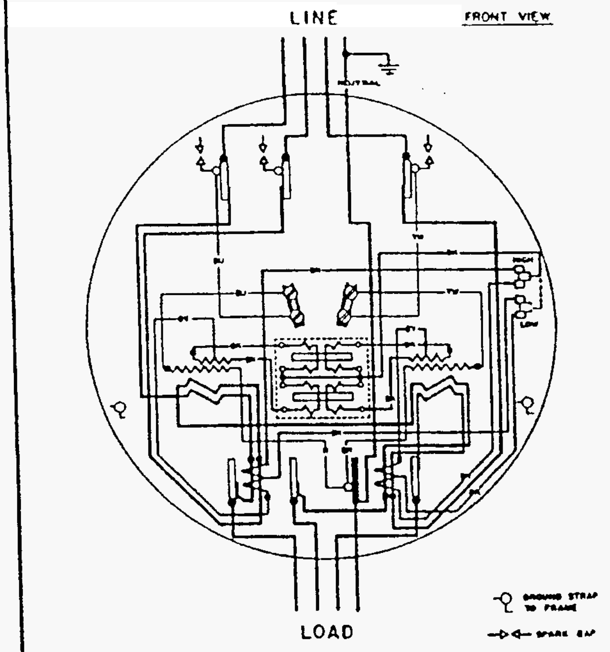
CLASS-100/200   5-TERMINAL   FORM-12S
TA-30   DUAL RANGE   1,2,OR 3-PHASE   3-WIRE   NETWORK



DR. NO. B-28175
DUNCAN ELECTRIC CO. INC.
LAFAYETTE, IND. U.S.A.
FEB. 1973

TYPE TMT-14S SELF CONTAINED
TWO STATOR WATTHOUR & THERMAL WATT METER

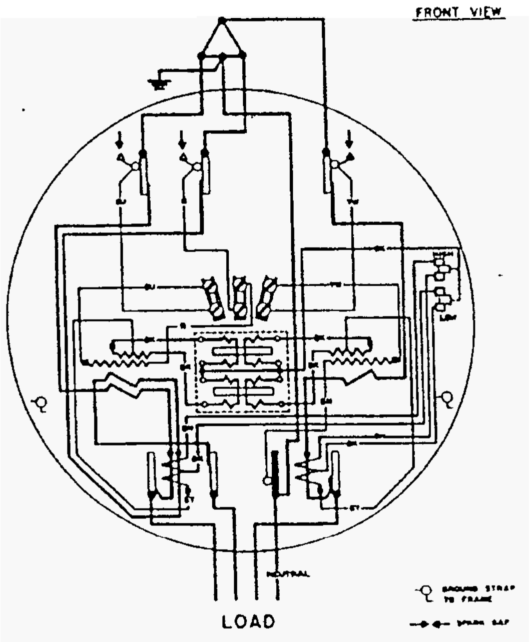
CLASS-100/200   7-TERMINAL   FORM-14S
TA-30   DUAL RANGE   3-PHASE   4-WIRE   WYE



DR. NO. B-28176
DUNCAN ELECTRIC CO. INC.
LAFAYETTE, IND. U.S.A.
FEB. 1973

TYPE TMT-15S SELF CONTAINED
TWO STATOR WATTHOUR & THERMAL WATT METER

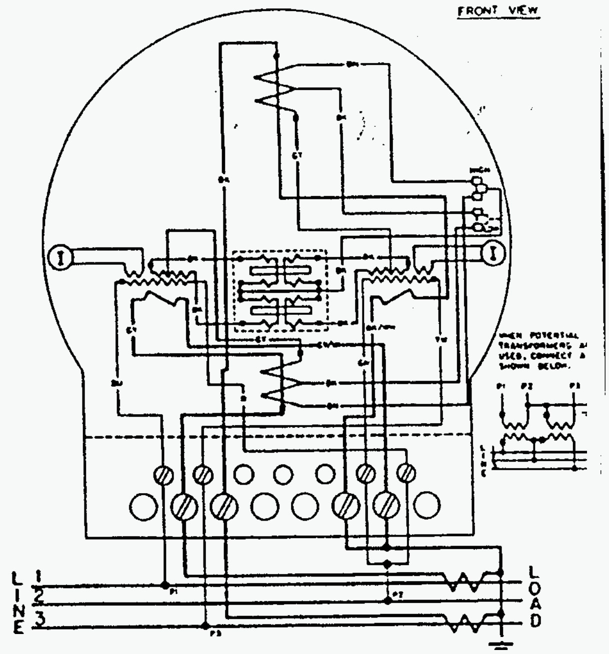
CLASS-100/200   7-TERMINAL   FORM-15S
TA-30   DUAL RANGE   3-PHASE   4-WIRE   DELTA



DR. NO. B-28177
DUNCAN ELECTRIC CO. INC.
LAFAYETTE, IND. U.S.A.
FEB. 1973

TYPE TMT-5A TRANSFORMER RATED TWO STATOR WATTHOUR & THERMAL WATT METER

CLASS 5/10 FORM-5A
TA-2.5 DUAL RANGE 1,2,OR 3-PHASE 3-WIRE
WITH POTENTIAL INDICATOR LAMPS

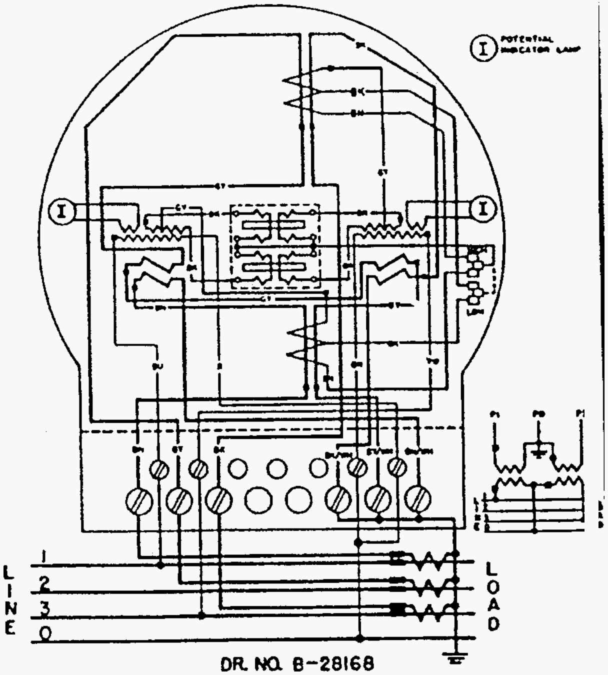


DR. NO. B-28170
DUNCAN ELECTRIC CO. INC.
LAFAYETTE, IND. U.S.A.
FEB 1973

I POTENTIAL INDICATOR L

TYPE TMT-6A TRANSFORMER RATED TWO STATOR WATTHOUR & THERMAL WATT METER

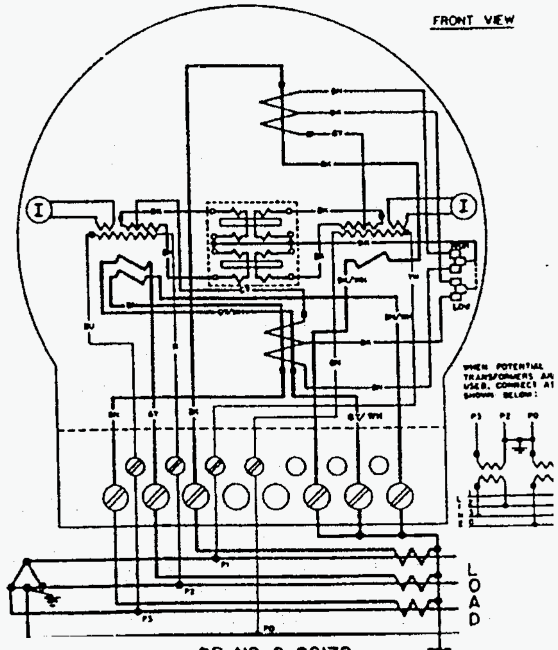
CLASS 5/10 13-TERMINAL FORM-6A
TA-2.5 3-PHASE 4-WIRE WYE DUAL RANGE
WITH POTENTIAL INDICATOR LAMPS



DR. NO. B-28168
DUNCAN ELECTRIC CO. INC.
LAFAYETTE, IND. U.S.A.
FEB 1973

TYPE TMT-8A TRANSFORMER RATED TWO STATOR WATTHOUR & THERMAL WATT METER

CLASS 5/10 10-TERMINAL FORM-8A
TA-2.5 DUAL RANGE 3-PHASE 4-WIRE DELTA
WITH POTENTIAL INDICATOR LAMPS

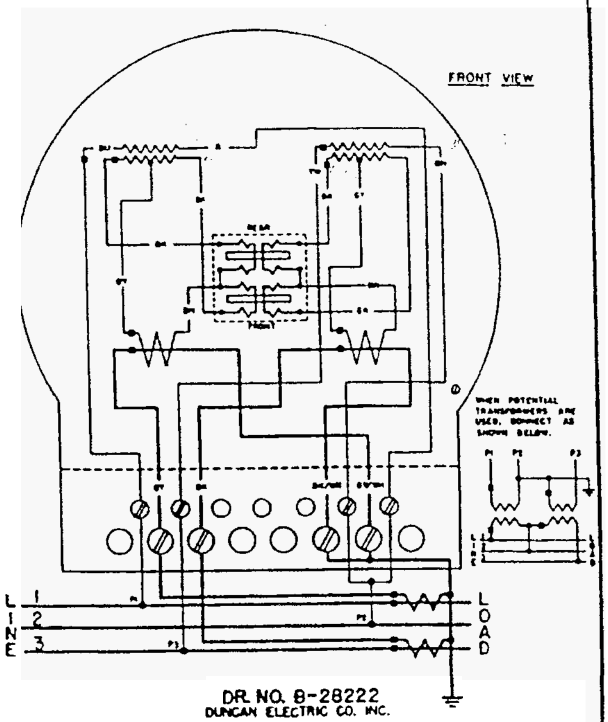


DR. NO. B-28172
DUNCAN ELECTRIC CO. INC.
LAFAYETTE, IND. U.S.A.
FEB 1973

I POTENTIAL INDICATOR LAMP

TYPE T-5A TRANSFORMER RATED TWO ELEMENT THERMAL WATT METER

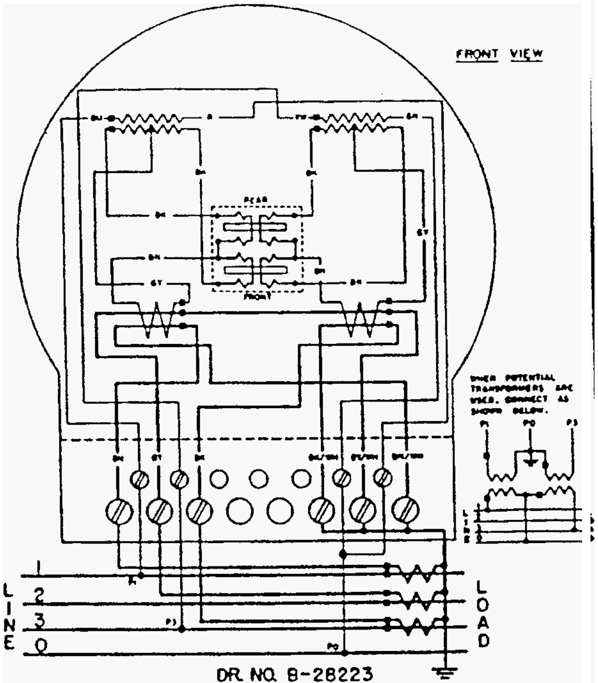
CLASS-10 FORM-5A
TA-2.5 SINGLE RANGE 1, 2, OR 3-PHASE 3-WIRE



DR. NO. 8-28222
DUNCAN ELECTRIC CO. INC.
LAFAYETTE, IND. U.S.A.
SEPT. 1973

TYPE T-6A TRANSFORMER RATED TWO ELEMENT THERMAL WATT METER

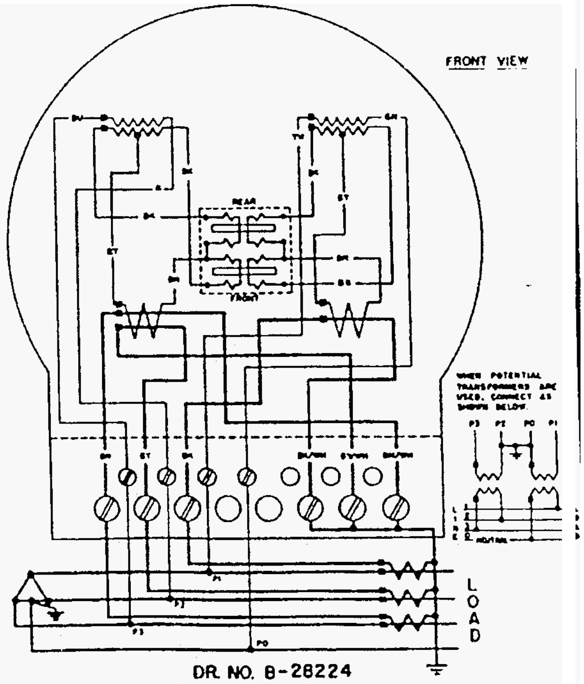
CLASS-10 FORM-6A
TA-2.5 SINGLE RANGE 3-PHASE 4-WIRE WYE



DR. NO. 8-28223
DUNCAN ELECTRIC CO. INC.
LAFAYETTE, IND. U.S.A.
SEPT. 1973

TYPE T-8A TRANSFORMER RATED TWO ELEMENT THERMAL WATT METER

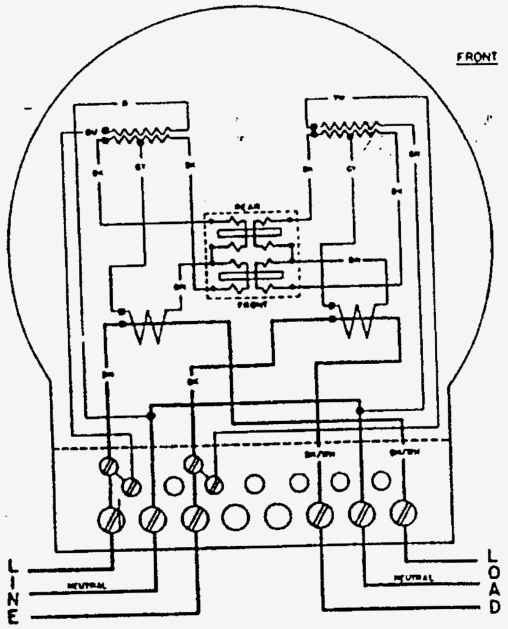
CLASS-10 FORM-8A
TA 2.5 SINGLE RANGE 3-PHASE 4-WIRE DELTA



DR. NO. 8-28224
DUNCAN ELECTRIC CO. INC.
LAFAYETTE, IND. U.S.A.
SEPT. 1973

TYPE T-13A SELF CONTAINED TWO ELEMENT THERMAL WATT METER

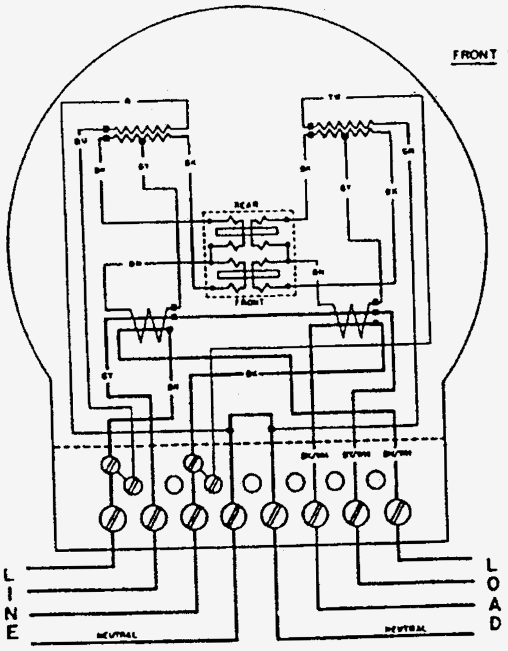
CLASS-100 FORM-13A
TA-15 2 OR 3-PHASE 3-WIRE



DR. NO. B-28225
DUNCAN ELECTRIC CO. INC.
LAFAYETTE, IND. U.S.A.
SEPT 1973

TYPE T-14A SELF CONTAINED TWO ELEMENT THERMAL WATT METER

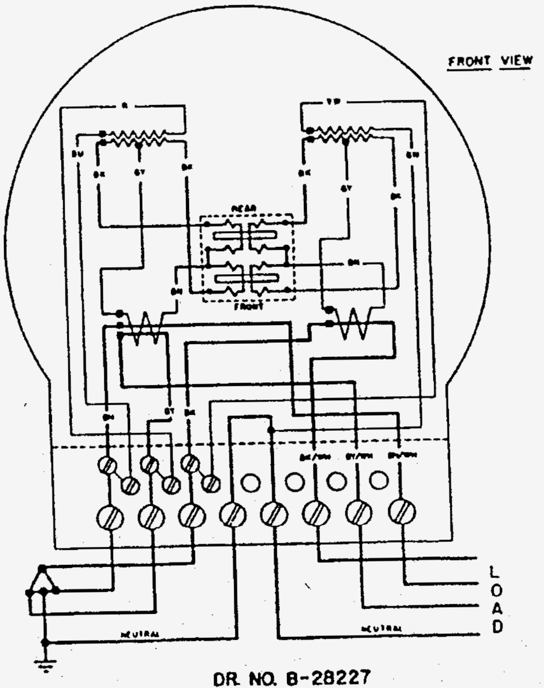
CLASS-100 FORM-14A
TA-15 3-PHASE 4-WIRE WYE



DR. NO. B-28226
DUNCAN ELECTRIC CO. INC.
LAFAYETTE, IND. U.S.A.
SEPT 1973

TYPE T-15A SELF CONTAINED TWO ELEMENT THERMAL WATT METER

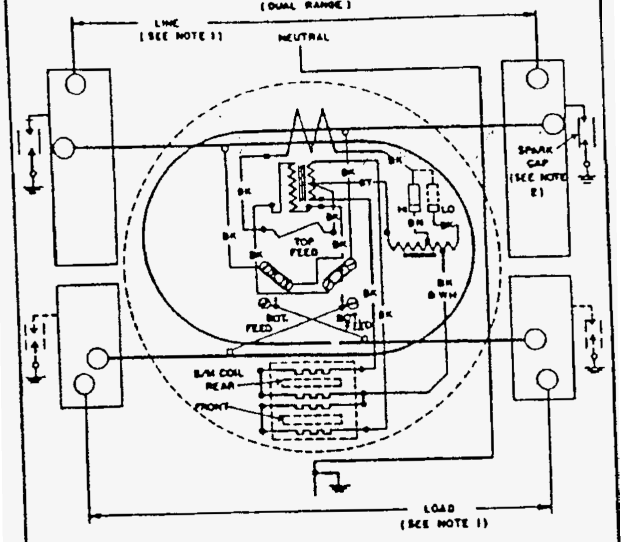
CLASS-100 FORM-15A
TA-15 3-PHASE 4 WIRE DELTA



DR. NO. B-28227
DUNCAN ELECTRIC CO. INC.
LAFAYETTE, IND. U.S.A.
SEPT 1957

TYPE TMS
SINGLE STATOR WATTHOUR & THERMAL WATT DEMAND METER

FORM 2K
TA 30, CLASS 200/400, 3-WIRE, SELF-CONTAINED
(DUAL RANGE)



NOTES:
1.) POT. DIS. LINKS IN TOP FEED POSITION AS SHOWN: {LINE AT TOP / LOAD AT BOTTOM

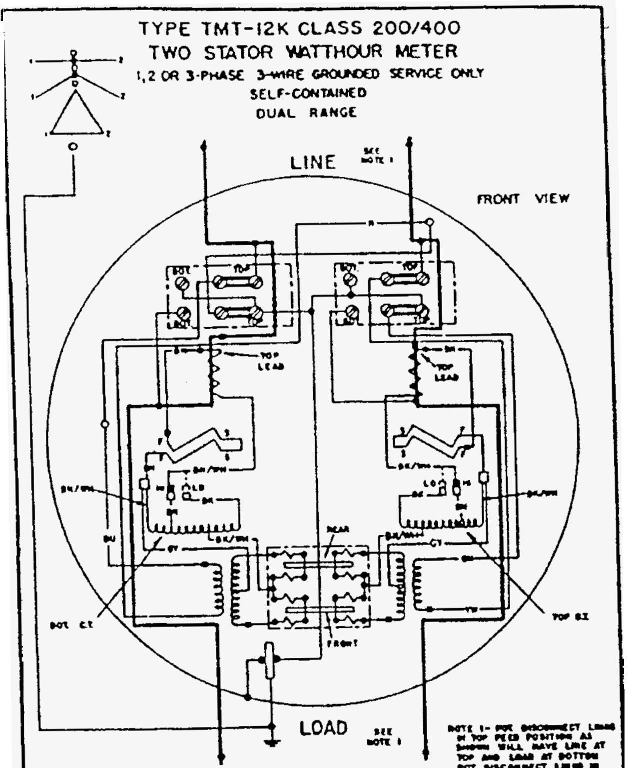
POT. DIS. LINKS IN BOTTOM FEED POSITION {LINE AT BOTTOM / LOAD AT TOP

2.) FOR TOP FEED USE SPARK GAPS IN POSITIONS SHOWN.
FOR BOTTOM FEED USE SPARK GAPS IN POSITIONS SHOWN DOTTED.

DR. NO. B-28049
DUNCAN ELECTRIC CO. INC.
LAFAYETTE, IND. U.S.A.
NOV. 1970

TYPE TMT-12K CLASS 200/400
TWO STATOR WATTHOUR METER

1,2 OR 3-PHASE 3-WIRE GROUNDED SERVICE ONLY
SELF-CONTAINED
DUAL RANGE

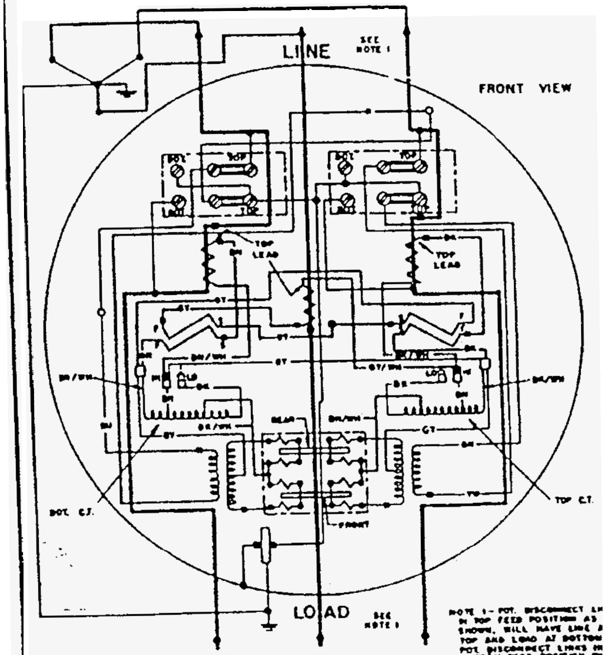


NOTE 1– POT. DISCONNECT LINKS IN TOP FEED POSITION AS SHOWN WILL HAVE LINE AT TOP AND LOAD AT BOTTOM. POT. DISCONNECT LINKS IN BOTTOM FEED POSITION WILL HAVE LINE AT BOTTOM AND LOAD AT TOP

DR. NO. B-28250
DUNCAN ELECTRIC CO. INC.
LAFAYETTE, IND. U.S.A.
DEC 1973

TYPE TMT-14K CLASS 200/400
TWO STATOR WATTHOUR METER

3-PHASE 4-WIRE WYE
SELF-CONTAINED
DUAL RANGE

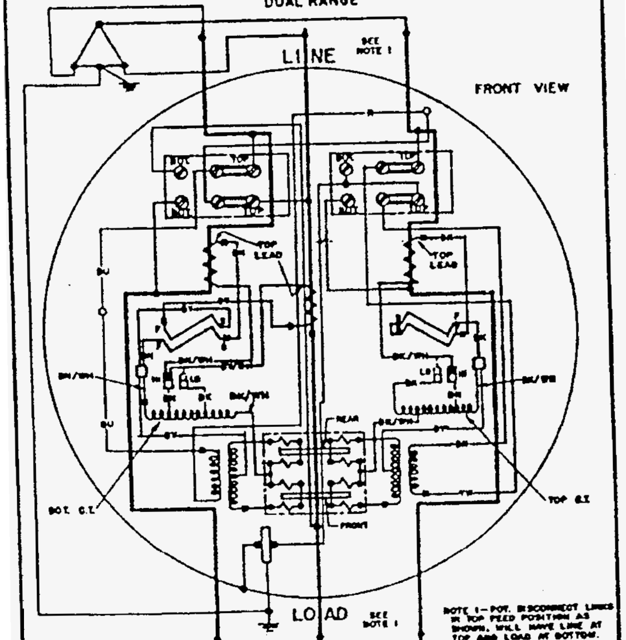


NOTE 1– POT. DISCONNECT LINKS IN TOP FEED POSITION AS SHOWN, WILL HAVE LINE AT TOP AND LOAD AT BOTTOM. POT. DISCONNECT LINKS IN BOTTOM FEED POSITION WILL HAVE LINE AT BOTTOM AND LOAD AT TOP.

DR. NO. B-28251
DUNCAN ELECTRIC CO. INC.
LAFAYETTE, IND. U.S.A.
DEC 1973

TYPE TMT-15K CLASS 200/400
TWO STATOR WATTHOUR METER

3-PHASE 4-WIRE DELTA
SELF-CONTAINED
DUAL RANGE

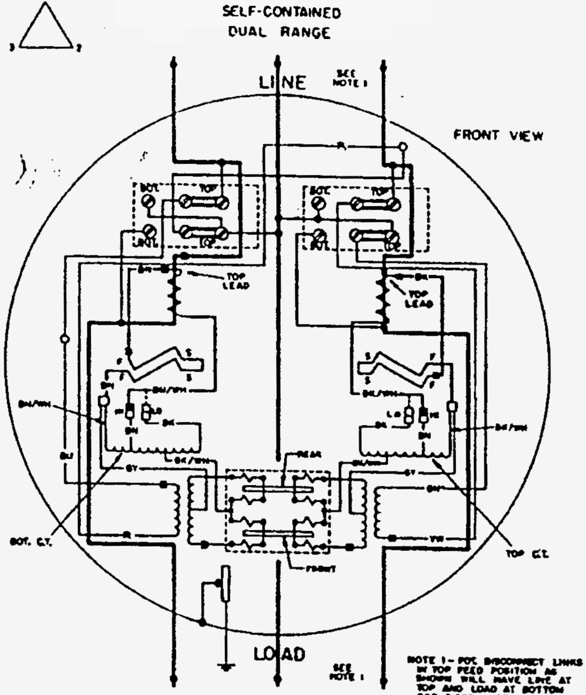


NOTE 1– POT. DISCONNECT LINKS IN TOP FEED POSITION AS SHOWN, WILL HAVE LINE AT TOP AND LOAD AT BOTTOM. POT. DISCONNECT LINKS IN BOTTOM FEED POSITION WILL HAVE LINE AT BOTTOM AND LOAD AT TOP.

DR. NO. B-28252
DUNCAN ELECTRIC CO. INC.
LAFAYETTE, IND. U.S.A.
NOV 1973

TYPE TMT-27K CLASS 200/400
TWO STATOR WATTHOUR METER

3-PHASE 3-WIRE NOT GROUNDED
SELF-CONTAINED
DUAL RANGE



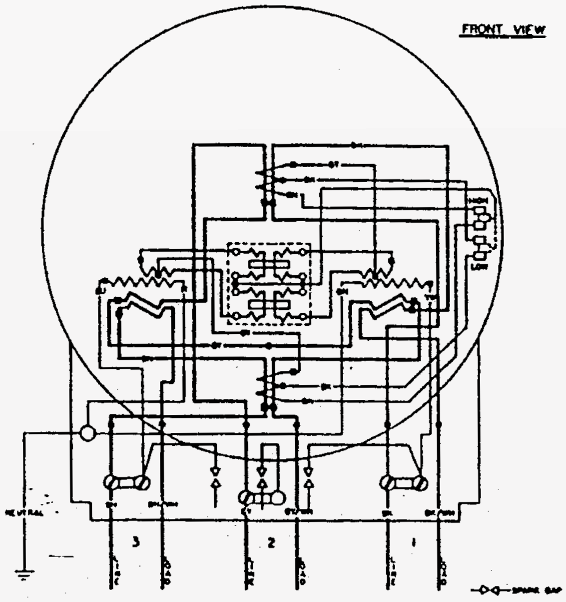
NOTE 1 – POT. DISCONNECT LINKS IN TOP FEED POSITION AS SHOWN WILL HAVE LINE AT TOP AND LOAD AT BOTTOM. POT. DISCONNECT LINKS IN BOTTOM FEED POSITION WILL HAVE LINE AT BOTTOM AND LOAD AT TOP.

DR. NO. B-28301
DUNCAN ELECTRIC CO. INC.
LAFAYETTE, IND. U.S.A.
JULY 1974

TMT-14B SELF CONTAINED
TWO STATOR WATTHOUR & THERMAL WATT METER

FORM 14B
DUAL RANGE CLASS 5/10 3-PHASE 4-WIRE WYE

FRONT VIEW

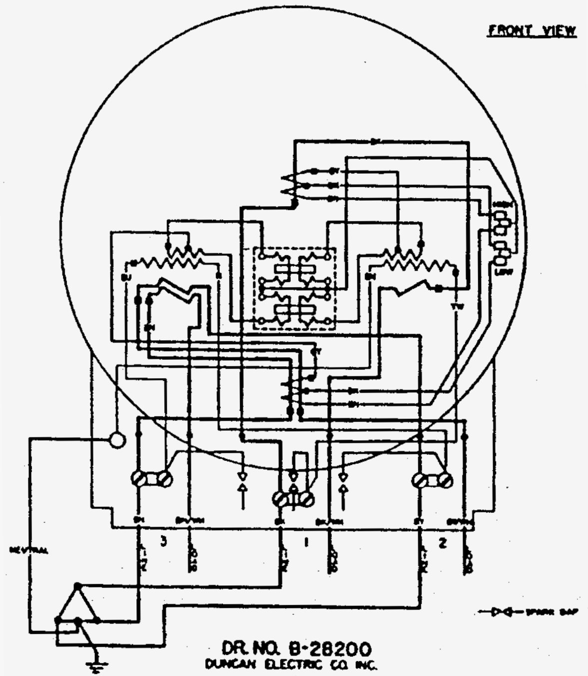


DR. NO. B-28199
DUNCAN ELECTRIC CO. INC.
LAFAYETTE, IND. U.S.A.
AUG. 1973

TMT-15B SELF CONTAINED
TWO STATOR WATTHOUR & THERMAL WATT METER

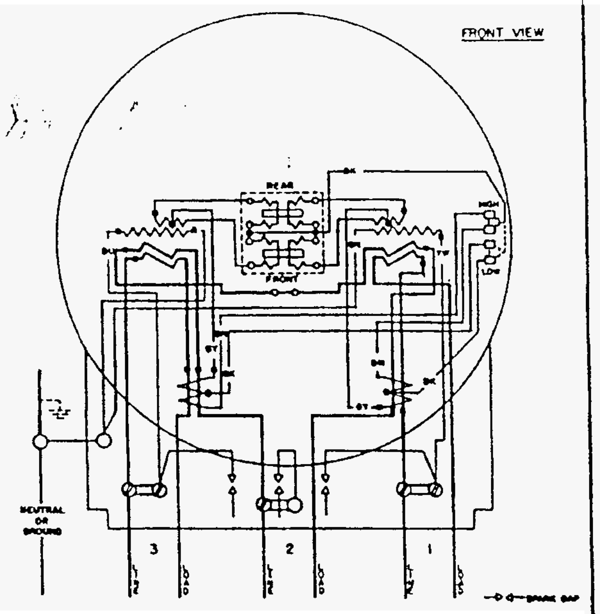
FORM 15B
DUAL RANGE CLASS 5/10 3-PHASE 4-WIRE DELTA

FRONT VIEW



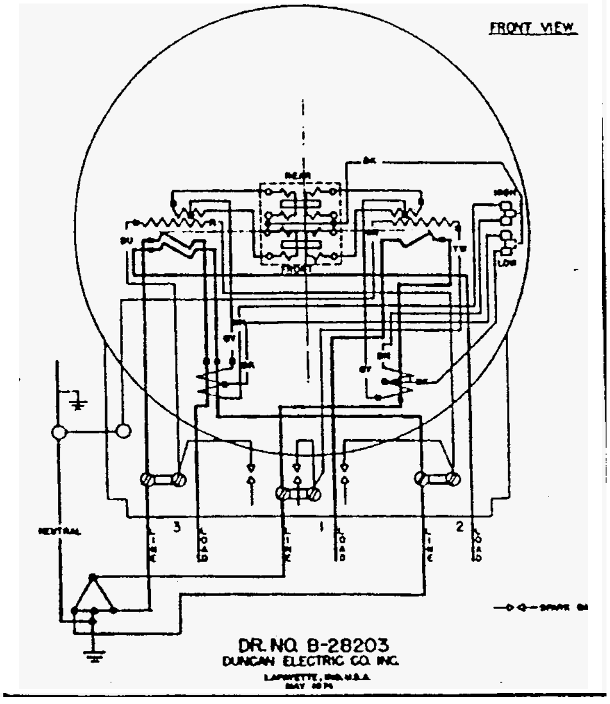
DR. NO. B-28200
DUNCAN ELECTRIC CO. INC.
LAFAYETTE, IND. U.S.A.
AUG. 1973

TMT-14B
TWO STATOR WATTHOUR & THERMAL WATT METER
FORM 14B
DUAL RANGE CLASS 100/200 3-PHASE 4-WIRE WYE



DR. NO. B-28202
DUNCAN ELECTRIC CO. INC.
LAFAYETTE, IND. U.S.A.
MAY 1970

TMT-15B
TWO STATOR WATTHOUR & THERMAL WATT METER
FORM 15B
DUAL RANGE CLASS 100/200 3-PHASE 4-WIRE DELTA



DR. NO. B-28203
DUNCAN ELECTRIC CO. INC.
LAFAYETTE, IND. U.S.A.
MAY 1970

01/18/04

Thermal Meters

In early 2002, consultant (George Brown), representing FPL customer, brought to FPL's attention that a 1V meter's demand registration was over-registering due to temperature changes resulting from sunlight. FPL's tests on meter proved customer's allegations were correct. Refund was made.

50 meter sample on 1V meters and 100 meter sample of 7 other thermal meter types indicated that no other meters demonstrated sensitivity to sunlight. However, sample did indicate that the 1V thermal meter population (3900 meters) was outside of allowed tolerance and needed to be removed and replaced.

Replacement of all 1V meters initiated in 10/02, with all 1V's to be removed by 01/03 and tested by 3/03. No back-billing for meters under-registering. Refunds to customers to be made for meters over-registering – back to point of meter failure or 1 year if not determinable (per FPSC rules). Customers with multiple accounts (Target, Dillards, etc.) will net over-billings with under-billings. 1V plan presented to FPSC Staff.

Sample testing on each of the 7 other thermal meters initiated. Results of 4Nmeter sample available in 10/02. Sample passed but nearing maximum allowed defective rate. Decision made to remove 4N population (4600 meters). Because population passed, no testing of meters removed to be done.

In late 2002, other sample results become available. All pass except 1U meter (11,000 meters). 4L (24,900 meters) and 4J (17,400) nearing maximum allowed defective rate. 2 more 1U samples are initiated to validate first sample that failed.

In 1/03, 2 additional 1U samples pass. However, replacement of 1U meters initiated – half to be replaced in 2003 and the remainder in 2004.

In 3/03, changes were made to the 1V meter refund process to insure all customers are fairly treated – Meters tested at 40% of full scale and over-registering to be re-tested at 80% of full scale registration (700 meters). Also, customers with meters over-registering out of tolerance will get refunds based on the higher of the meter test error or the difference in their consumption since the new meter was installed.

1V meter test results show 85% within tolerance, 10% of meters under-registering (demand and kWh) and 5% over-registering (demand).

George Brown's clients include accounts such as Target, J C Penney, Dillards, Walmart, Best Buy, Home Depot, Kash n Karry, and Food Lion.

FPSC Staff currently reviewing FPL and George Brown positions on issues – key issue is determining when meter error occurred. George Brown position - error occurred when meter was set or last tested because meters were mis-calibrated by FPL – this would result in multiple year refunds. FPL position - error point cannot be determined since error occurred gradually – therefore, refund should be for 1 year. FPSC docket opened in July 2003 – no schedule for docket yet.

Palm Beach Post reporter, contacted by George Brown, prints several recent articles on 1V meter issues. Questions raised about under-registering meters and "line losses". Also initiates dialogue with Public Counsel, who has now requested information on potential fuel clause impacts.

2003 sample results to be available 9/03. Results will influence removal of remaining thermal meter types.

SWAT team initiated to identify all impacts and make recommendations.

Zero Adjustment Test

1. Energize meters to be tested on back of test board.
2. Load all meters of the same form and voltage onto one bank of sockets.
3. Set switches to match the form and voltage of meters for that bank
4. Run test for at least 2 hours.

    OBSERVATION POINTS

    A. Be sure friction pointer is not touching the pusher pointer for this check.

    B. The cover should be in place during this check.

5. Repair and/or adjust the zero position hand if necessary.

Load Calibration

1. Load meters to be tested on the front of the test board.
    - A. Meter to be tested MUST be of the same form and voltage rating. Unused sockets must be jumpered across.
    - B. Covers should be on the meter for this test.
2. Set all switches and controls to positions shown in the "Thermal Test Board Setup Data Sheet" for form of meter under test.
    - A. All variable controls, such as the current control should be fully counter-clockwise.
3. Switch the voltage circuit breaker to ON and adjust the TEST VOLTAGE FINE ADJUST control for a reading of 120 volts on the voltage panel meter.
4. Switch the current circuit breaker to ON and slowly bring up the TEST AMPERES COURSE ADJUST to approximately the reading needed on the ampere panel meter.
5. Adjust the TEST AMPERES FINE ADJUST to bring the current to the amperes called for on the setup data sheet.

EXHIBIT
4
3/5/04

6. The PHASE ANGLE control should always be set to 0 degrees. Adjust the PHASE ANGLE FINE ADJUST control until the POWER FACTOR panel meter reads 1.0%.

7. Run load test for at least one hour.

   OBSERVATION POINTS

   A. The standard meter on the board should read zero before starting the test.

   B. Check that all reset arms are out of the way of the pusher pointers.

   C. Check all meters under test for rotation of the disk.

   D. Check all meters for free movement of the demand hand (friction pointer).

   E. Periodically check panel instruments for variations. Correct any variations as necessary.

8. At the end of 1 hour of load test, calculate the percent error as shown on the "Thermal Test Board Setup Data Sheet" for each meter tested.

9. If the calculated percent error is greater than +/- 4 percent, adjust the meter using the full load adjustment and adjust to 0% error.

   A. This adjustment must be made when the meter is fully energized at test power, and the friction pointer in contact with the pusher pointer.

   B. The meter cover should only be removed long enough to adjust the meter and should be replaced as soon as possible.

10. If a meter has been adjusted, the test board should be left energized, with a stable load, for approximately 10 minutes, to check for proper calibration.

11. After all meters are calculated to be as close to 0% error as possible, the current should be slowly lowered to zero.

12. The voltage and current circuit breakers should be turned OFF.

13. The meters should not be removed from the test socket for the length of cool down time shown the chart below:

Instrument transformer rated	-	0
Self-contained (100 amps)	-	10 minutes
Self-contained (200 amps)	-	15 minutes

OBSERVATION POINTS

A. The back of the test board may be loaded with additional meters at any time during the load calibration test.

B. Self-contained meters should always be allowed to cool down before removal to prevent air line rupture.

3F

THERMAL TEST BOARD PROCEDURES

Zero Adjustment Test

1. Energize meters to be tested on back of test board.
2. Load all meters of the same form and voltage onto one bank of sockets.
3. Set switches to match the form and voltage of meters for that bank.
4. Run test for at least 2 hours.

OBSERVATION POINTS

A. Be sure friction pointer is not touching the pusher pointer for this check.

B. The cover should be in place during this check.

5. Repair and / or adjust the zero position hand if necessary.

Load Calibration

1. Load meters to be tested on the front of the test board.

    A. Meters to be tested MUST be of the same form and voltage rating. Unused sockets must be jumpered across.

    B. Covers should be on the meter for this test.

2. Set all switches and controls to positions shown in the "Thermal Test Board Setup Data" sheet for form of meter under test.

    A. All variable controls, such as the current control should be fully counter-clockwise.

3. Switch the voltage circuit breaker to ON and adjust the TEST VOLTAGE FINE ADJUST control for a reading of 120 volts on the voltage panel meter.

EXHIBIT
3
3/5/04

4. Switch the current circuit breaker to ON and slow up the TEST AMPERES COURSE ADJUST to approximatel reading needed on the ampere panel meter.

5. Adjust the TEST AMPERES FINE ADJUST to bring the current to the amperes called for on the setup data sheet.

6. The PHASE ANGLE control should always be set to 0 degrees. Adjust the PHASE ANGLE FINE ADJUST control until the POWER FACTOR panel meter reads 1.0%.

7. Run load test for at least one hour.

OBSERVATION POINTS

A. The standard meter on the board should read zero before starting the test.

B. Check that all reset arms are out of the way of the pusher pointers.

C. Check all meters under test for rotation of the disk.

D. Check all meters for free movement of the demand hand (friction pointer).

E. Periodically check panel instruments for variations. Correct any variations as necessary.

8. At the end of 1 hour of load test, calculate the percent error as shown on the "Thermal Test Board Setup Data" sheet for each meter tested.

9. If the calculated percent error is greater than ± 4 percent, adjust the meter using the full load adjustment and adjust to 0% error.

A. This adjustment must be made when the meter is fully energized at test power, and the friction pointer in contact with the pusher pointer.

B. The meter cover should only be removed long enough to adjust the meter and should be replaced as soon as possible.

10. If a meter has been adjusted, the test board should be left energized, with a stable load, for approximately 10 minutes, to check for proper calibration.

11. After all meters are calculated to be as close to 0% error as possible, the current should be slowly lowered to zero.

12. The voltage and current circuit breakers should be turned OFF.

13. The meters should not be removed from the test socket for the length of cool down time shown in the chart below;

Instrument transformer rated - 0

Self contained (100 amps) - 10 minutes

Self contained (200 amps) - 15 minutes

OBSERVATION POINTS

A. The back of the test board may be loaded with additional meters at any time during the load calibration test.

B. Self contained meters should always be allowed to cool down before removal to prevent air line rupture.

Dave Bromley
12/09/2003 10:34 AM

To: John Easterling/CS/FPL@FPL, Scott E Davis/CS/FPL@FPL
cc:
Subject: Misplaced 1V Meters - Customer Communications

Draft for our meeting this afternoon:

Possible "script" for the approximate 60 meters that cannot be located (most of these -50 or so were never tested, while the others were due for re-test at 80%):

Remind customer of 1V meter removal plan (affected customers were contacted by letter and/or phone call in latter part of 2002)

Inform them of of our overall testing results for the approximate 3900 meters - 85% tested within tolerance, 11% were under-registering out of tolerance and 5% were over-registering out of tolerance

Unfortunately, their particular 1V meter that was removed cannot be located

In order to appropriately remedy this situation, here's how we're handling the misplaced meters (We should have for each account, prior to the contact, the customer's specifics so that the different scenarios can be discussed with them:

All affected customers will be receiving a 1 year refund

(1) For those meters without **any** meter test results -

FPL will provide a 1 year refund using either 4% or the % change, new vs. old meter, whichever provides the greatest refund

(2) For those meters with an initial meter test result that over-registered (>100%) and no re-test meter result (14 accounts) -

FPL will provide a 1 year refund using 4%, the initial meter test result, or the % change, new vs. old meter, whichever provides the greatest refund

Note - For those meters that were eligible for a re-test we may need to explain that process (this could be somewhat confusing though)

Customer Meetings

Purpose of Meeting (Chuck)

Not to argue positions and issues – ensure customers' understanding of our position/legal process
Where we are in FPL/GB negotiations
FPL's refund determination process
Staff Rec./Applicable FPSC rules – meter errors and refunds
Docket process
What's at risk?

Negotiations Status (Chuck)

FPL Offer vs. George Brown claim
Reason(s) for difference

Staff Rec. / Applicable FPSC Rules (Dave)

Staff Recommendation Summary
Determination of refund time period (25-6.103(1) – 1 year unless error cause and date known
Determination of refund % error (Rule 25-6.103(3) – error to be based upon meter test
Slow, partially, and non-registering meters (25-6.103(2)(a,b,c) – allows back-billing for 12 months

FPL Refund Determination Process (Chuck)

Re-test at 80% - use higher of two tests
Higher of meter test % or usage – new meter vs. old
No back-billing, but will net for multi-account customers

Look at each eligible account on it's own
Determine point meter failed, if possible
Review usage since meter was replaced vs. previous year(s) usage
If usage is similar to previous years – 1-year refund, if not, refund adjusted
Use higher of meter test error or actual % difference – new meter usage vs. previous year(s) usage

FPSC Docket Process (Dave)

Staff recommendation
Agenda Conference
PAA Order
Protest/Request for hearing
Discovery/depositions
Testimony
Hearing
Briefs
Staff Recommendation
Agenda Conference
Appeals

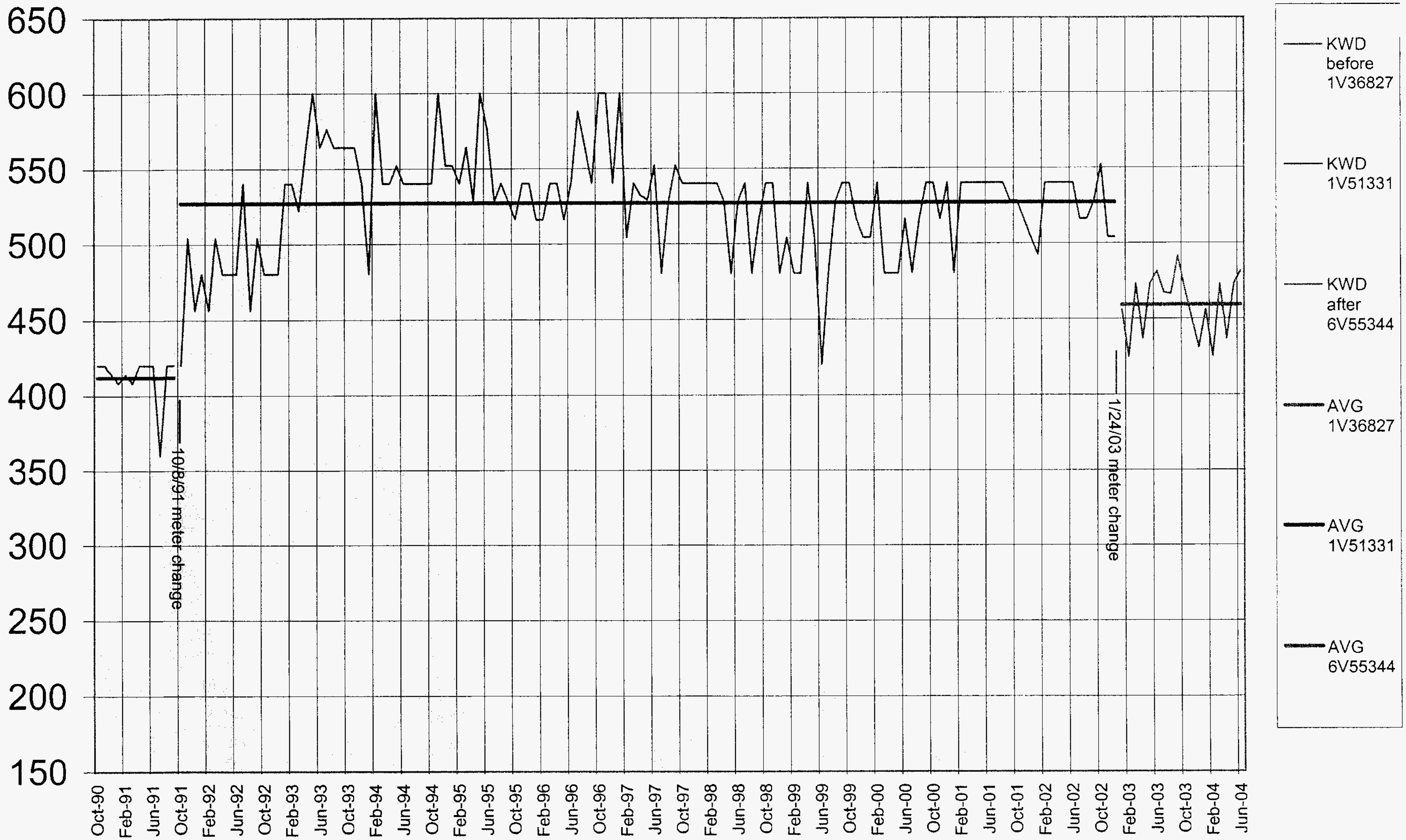
What's at stake? (Chuck)

In certain instances, FPL has gone beyond rules in its offer (> of meter test/actual usage; multiple years vs. 1 year
If litigated, FPL will revert back to rules
Time period for litigation/appeals – could be years (all other customers have received refunds)

Why is FPL's process for handling 1U meters different than the 1V meter process?

Unlike the 1V meter population, which failed, the 1U population passed.

KINGS POINT KWD



I. 1V Meter Issues:

What is the appropriate % of full-scale registration to be used for testing the 1V meters?

Per Rule 25-6.052(2)(a) – "when tested at any point between 25% and 100% of full scale value"

Per FPL 1V Meter Process – all low scale meters were tested at 80% and all high scale meters originally tested at 40%, and over-registering were re-tested at 80%.

When a meter tests out of tolerance, what is the appropriate % error to be used?

Per Rule 25-6.103(3) – "when a meter is found to be in error in excess of the prescribed limits, the figure to be used for calculating the amount of refund or charge in (1) or (2)(b) above shall be that % of error as determined by the test"

Per FPL 1V Meter Process – Refunds based on the meter test result or the difference in customers usage before and after the new meter was set, whichever provides the customer with the greatest benefit

What are the conditions that must be satisfied to provide a refund greater than 1 year?

Per Rule 25-6.103(1) – ½ the period since the last test, said ½ period should not exceed 12 months; except that if it can be shown that the error was due to some cause, the date of which can be fixed, the overcharge shall be computed back to but not beyond such date based upon available records

Per FPL 1V Meter Process – Same as Rule 25-6.103(1)

II. 1V Meter Discussion Items:

Overview of FPL/George Brown's methodology to determine eligibility for /calculation of refunds (contrast approaches - settlement vs. FPSC rules)

FPL Methodology – Compared new electronic demand readings to similar months in previous years to determine if error could be identified; if not, was there a material/consistent difference in the "new" and "old" demands? If so, offered refund back over that period. Used higher of meter test results or "new vs. old" readings; used average difference for affected years; if change in demand affected rate class, used appropriate rate class to compute re-billings

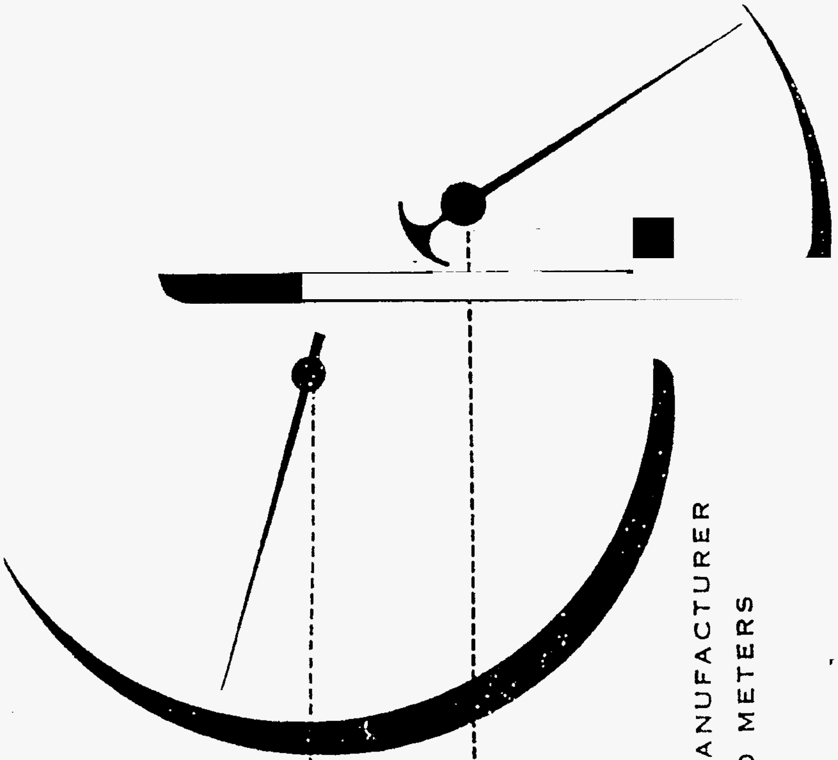
Account by account review of 1V meter complaints (if desirable by Staff)

Chuck to handle (hand out(s)

II. 1U Meter Issues:

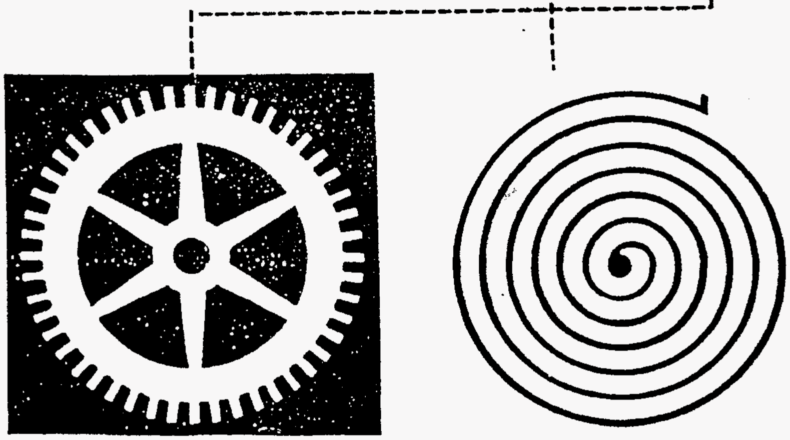
What is FPL's process for handling 1U meters (as well as 4N meters)?

FPL has initiated an active retirement plan for the 1U meters. Once these meters are removed, FPL will retain these meters for at least six months. If a custor
they would like their meter tested, FPL will comply with the request, con
25-6.059. Refunds and backbillings will be determined consistent with R



facts about demand metering

LARGEST MANUFACTURER
OF DEMAND METERS



SANGAMO
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SPRINGFIELD
ILLINOIS

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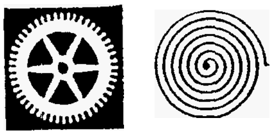
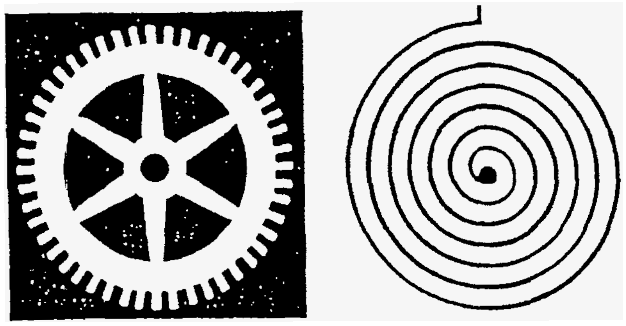




Introduction

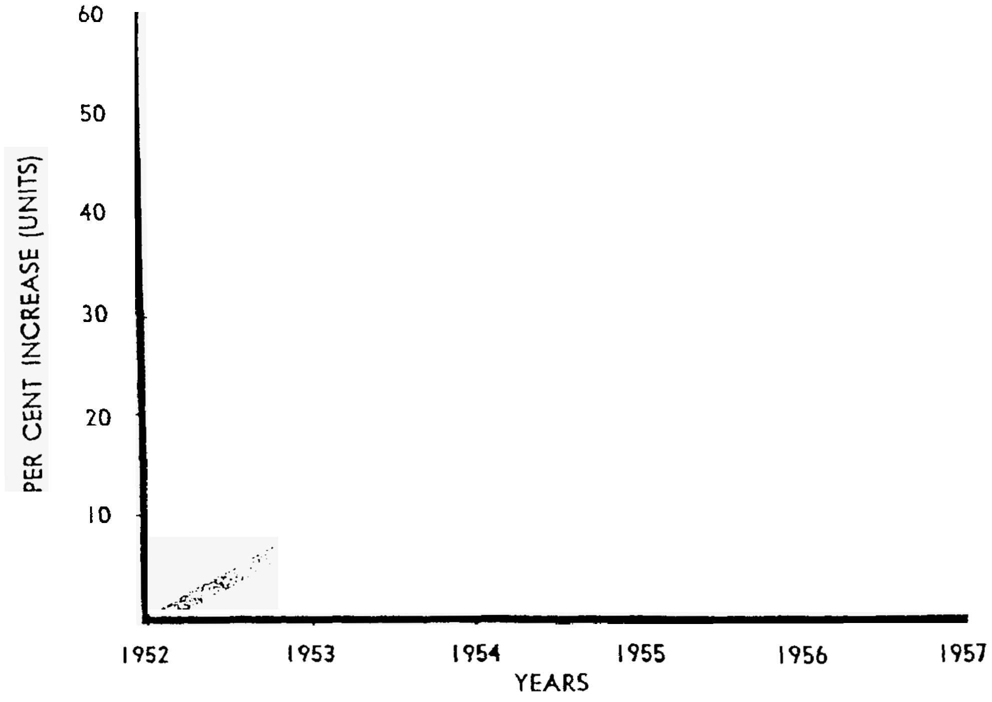
In recent months, much information has been distributed about demand meters. In the enthusiastic promotion of a specfiic product, certain facts have been distorted.

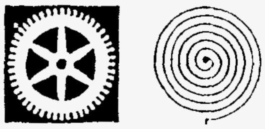
As an example of the misconceptions that arise as a result of promoting one type against the other, one manufacturer announced some time ago that the company was discontinuing its thermal meter because it was inferior to the mechanical demand register. The facts are, this thermal meter never earned more than five percent of the singlephase thermal demand meter market. In addition, the basic design could not be adapted to the manufacture of a polyphase meter. Obviously, the real reason for discontinuing this thermal meter was its limited application and lack of acceptance.

Sangamo, as the largest manufacturer of demand meters and a pioneer of both mechanical registers and thermal meters, is best qualified to present a completely unbiased story on both types of instruments.

The important reason for reviewing facts about demand metering is graphically presented in Figure A-1. The graph illustrates the increasing use of demand metering on a national scale. The upward trend indicates that demand metering is becoming a more significant factor in the operation of an electric utility. In addition to the obvious effect on revenue, the increase in demand metering has broadened the responsibilities of the meter department.

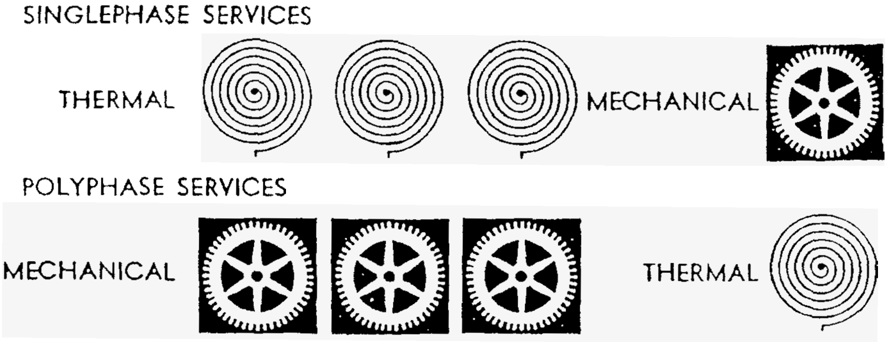
Figure A-1 | **TREND OF TOTAL BILLING DEMAND**





Both mechanical demand registers and thermal demand meters are used for *both* singlephase and polyphase services. Which type of meter should be used, will depend on a number of factors; including test facilities, testing schedules, geographical nature of the electric system, and many others. According to recent industry figures, (Figure A-2) the *ratio* of thermal to mechanical meters measuring singlephase loads is approximately 3 to 1. On the other hand, the ratio of mechanical to thermal meters measuring polyphase loads is approximately 3 to 1.

Figure A-2 PROPORTIONAL APPLICATION OF DEMAND METERS (APPROX.)



The purpose of this presentation is to review the merits and limitations of both thermal and mechanical demand meters so that utilities will have factual information on which to base decisions about demand metering.

Why the term "demand"?

Before discussing demand metering, it seems the first question to ask is "why the term demand?". If psychology has a place in rate making—and it certainly does—then the word "demand" should never have been admitted to the electric utility vocabulary. The term "demand" is applicable here only in the sense that the customer demands that the utility furnish as much power as required by the electrical equipment he may use at any one time. Although demand charges are justified from the standpoint of economics, the utility customer often fails to realize that the charge is based on his demands upon the utility's services.

Although it may be an oversimplification of the problem, a first suggestion would be to drop the word "demand" and substitute in its place a logical and less offensive word such as "capacity," "power," or "load value". The negative aspects of the term "demand" tend to form a psychological barrier to the acceptance of this form of billing. A positive approach might achieve quicker understanding and acceptance by the utility's customers.

Although the Sangamo Electric Company suggests that the use of the term "demand" be discontinued, it will be used in this brochure because it is an expression that already has industry wide acceptance.

What is demand?

Energies expended were equal; but the demands on the "equipment" were different.

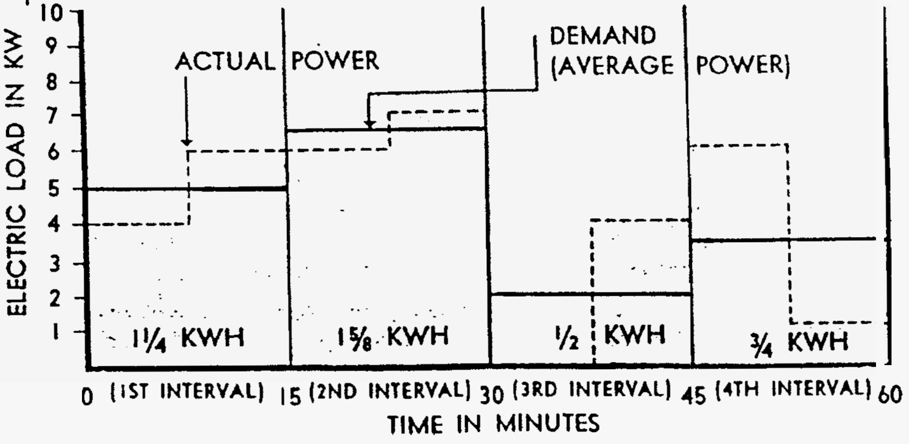
Kilowatt-hours, or energy, can be defined as the electric load expressed in watts, times the number of hours it is used. A kilowatt-hour (kwh) can consist of a 1000 watt load, connected for one hour, or a 100 watt load connected for 10 hours, etc.

Kw demand is defined as the electric load averaged over a specified interval of time. The demand interval during which the load is averaged may be any length of time, but is usually 15 or 30 minutes. Instead of averaging demand over a time interval, it could be measured instantaneously. This, however, would not. result in a realistic basis for billing. The utility does not want to penalize the customer for instantaneous peaks created by the starting load of a motor, etc., as they have little effect on the overall electric system.

This brochure is primarily concerned with kw demand measurement because it is the most common form of demand billing. However, demand can also be measured in terms of kva and kvar.

The relationship between energy and kw demand is shown in Figure A-3, which represents power versus time of the load consumed by a customer during demand intervals. The dotted line shows the electric load (power) being used by the customer at any time. The solid line indicates demand or the average electric load during each interval. The area under the dotted line (power) represents the energy or kilowatt-hours used. Note that in any one time interval, the area under the solid line is equal to the area under the dotted line. Since energy is the product of power and time, either area represents the energy (kilowatt-hours) consumed in the interval. The fact that the areas are equal shows that the demand for the interval is that average value of power which will account for the same consumption of energy (kilowatt-hours) as the actual power.

Figure A-3 | **RELATIONSHIP BETWEEN ENERGY AND DEMAND**



Why maximum demand metering?

Demand metering, as a method of determining customer billing, has become an accepted practice for a number of reasons. According to industry figures, capital investment represents 2/3 of the utility's cost to serve its customers.

To a large extent, the maximum demand of the operating system determines the utilities capital investment. The utility should be reimbursed by the customer at a rate related to the capital investment required to provide service. Another reason for demand metering is that it permits customers to be billed on a more equitable basis.

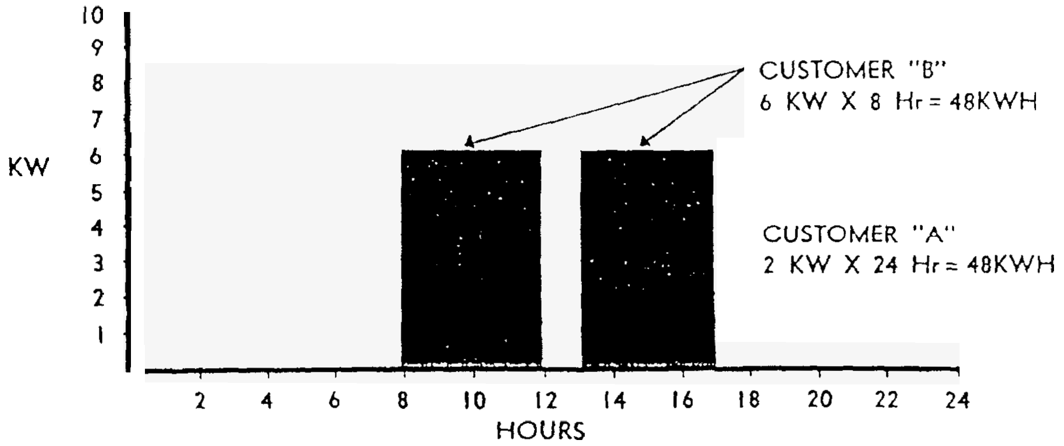
For example, consider two types of customers (figure A-4) who use an equal number of kwh each day. Customer A uses electric energy 24 hours a day and Customer B uses electric energy 8 hours per day.

Customer A: The customer's load is made almost entirely of synchronous motor-driven pumps which operate at rated load continuously. 24 hr. x 2 kw = 48 kwh.

Customer B: This customer uses the same number of kilowatt-hours as Customer A, but they are consumed in an 8-hour period. 8 hr. x 6 kw = 48 kwh.

Customer B requires the utility to have generating and distribution capacity equal to the ratio of 6/2 times the capacity required to supply Customer A. This is 3 times the capital investment that was required to serve Customer A, and Customer B should be billed for this extra investment.

Figure A-4 | **COMPARISON OF TWO CUSTOMERS**



What is maximum demand metering?

As described, demand metering is the measurement of average power requirements in a time interval. Consequently, demand billing consists of measuring a customer's maximum average load during any demand interval of the billing period. There are two methods for obtaining this maximum demand—mechanical and thermal.

The mechanical method of measuring demand can be accomplished

—by the direct counting of watthour disk revolutions with a mechanical register during a mechanically timed interval. (figure A-5)

—and by counting revolutions through impulses which are totalized during a mechanically timed interval on a separate indicating or chart type meter such as the Digital Demand Recorder. (figure A-6)

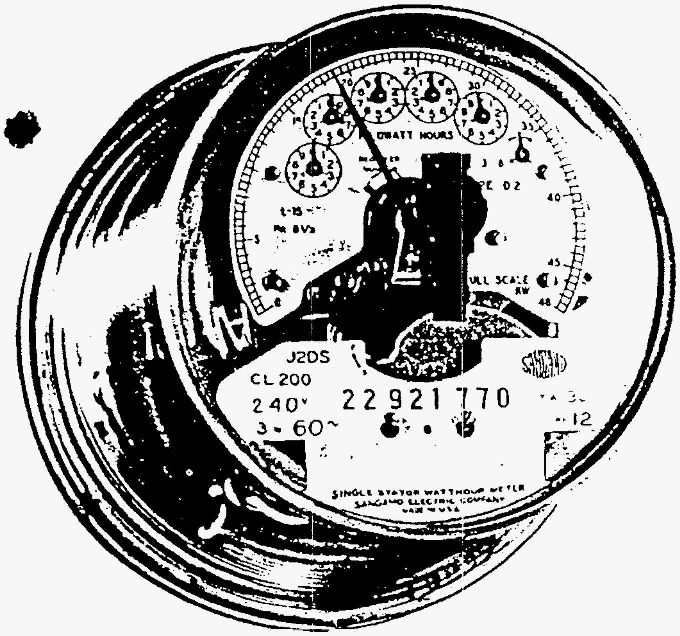


Figure A-5 MECHANICAL DEMAND REGISTER

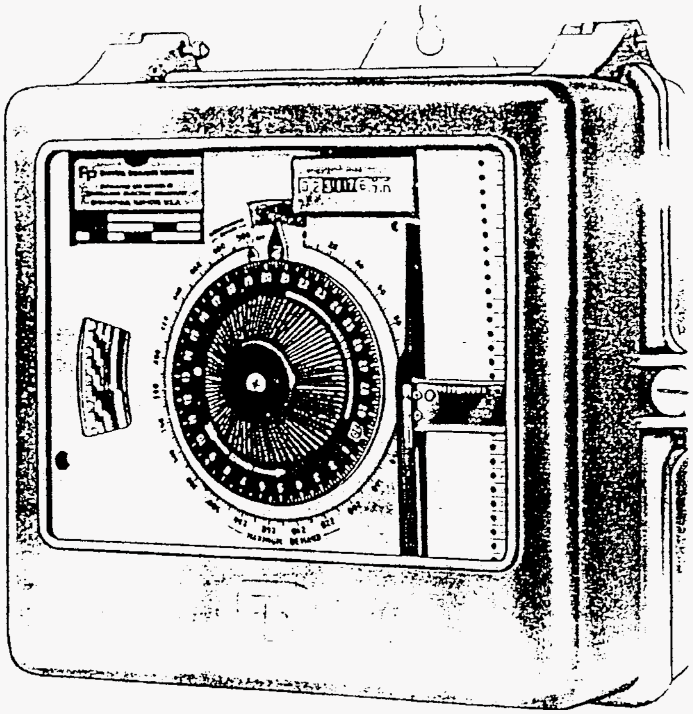


Figure A-6 DIGITAL DEMAND RECORDER

The thermal method measures demand through an arrangement of bimetal coils and electrical heaters, having an inherent time interval based upon the heating effect of the load. Thermal demand measurement is accomplished.

—by indicating demand meters with a maximum demand pointer (figure A-7)

—by graphic demand meters which record demand readings on a chart (figure A-8)

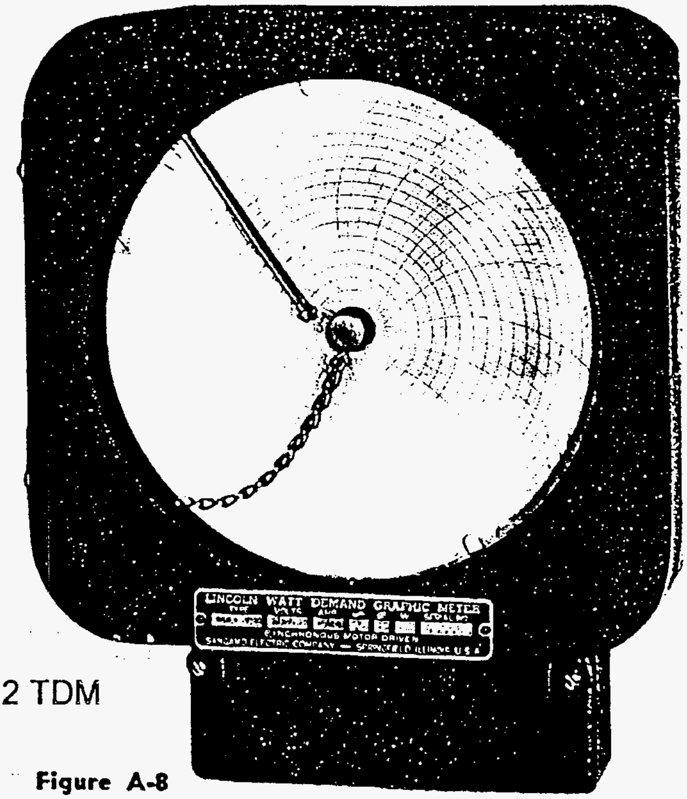
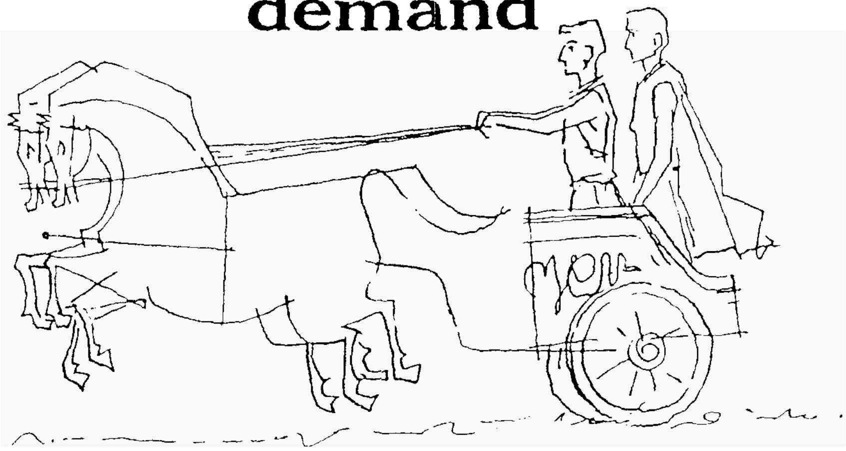


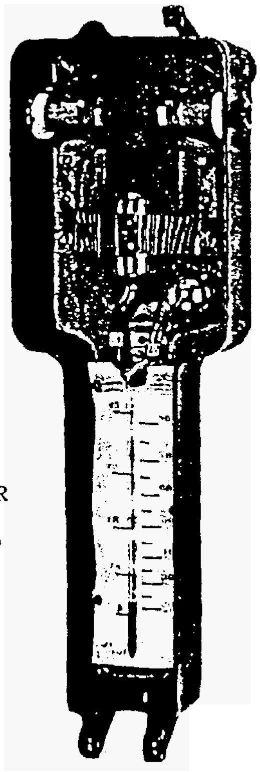
Figure A-7
THERMAL INDICATING DEMAND METER

Figure A-8
THERMAL GRAPHIC RECORDING DEMAND MET

History of demand



One of the first meters known to be used by man was the Calculus. This was a device used in early Roman days to determine the fare for a taxi ride. By a mechanical arrangement connected to the axle of a cart, pebbles were dropped in a jar. At the end of the ride the pebbles were counted to determine the revolutions of the axle and, in turn, the bill. This early meter is analogous to our present energy measuring meter, in that it measured units of distance while the watthour meter measures units of energy. Demand measurement, and charges, might have been applied if the Calculus indicated the maximum speed at which the cart traveled, as demanded by the passenger.



WRIGHT DEMAND METER

Figure A-9

The probable beginning of electrical demand measurement was the Wright Demand Meter (Figure A-9) which was patented in 1897. This meter used glass tubes, air, liquid, and a heating element to measure demand. Current caused an expansion of air which, in turn, forced liquid into a tube which had a scale mounted behind it. The more current used, the higher the level of liquid, hence a higher demand reading.

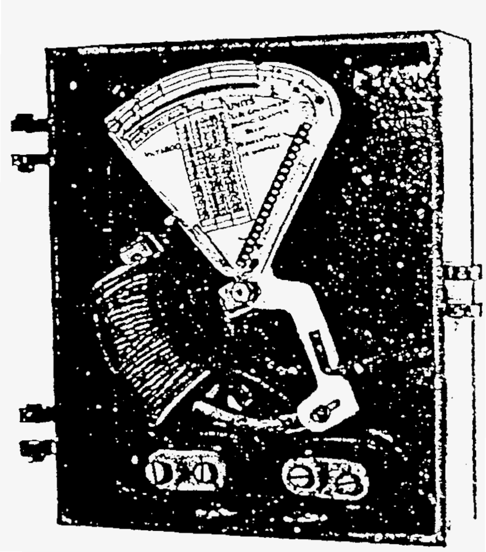


Figure A-10

ATKINSON-SCHATTNER METER

The Atkinson-Schattner maximum demand meter was another early demand device (figure A-10). The meter worked on an electromagnetic principle. Current pulled the core into the solenoid which caused the balls to fall away from the scaled tube as the load increased.

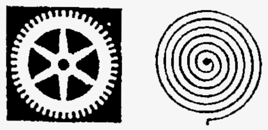
In the early '20's, Sangamo offered to the industry the HM mechanical demand register and from this evolved Sangamo's precise mechanical demand registers of today.

Simultaneously, another development was taking place in the demand measurement field. In Canada, through the developments of Mr. P. M. Lincoln, the first thermal demand meter was offered in 1920. In 1925, Mr. Lincoln became associated with Sangamo Limited in Canada for the purpose of developing a combination kwh and kw meter. Today the thermal type meter is the standard demand meter in Canada.

In 1928, the Lincoln Meter Company, Inc., was organized in the United States. The Sangamo Electric Company purchased all of the outstanding stock of the Lincoln Meter Company in 1940. Since its introduction, the Lincoln (thermal) meter has also firmly established itself in this country as a highly reliable demand billing instrument.

This introduction to "The Facts about Demand Metering" has reviewed some general aspects of the subject. The following sections on mechanical registers and thermal meters are objectively presented to give complete, specific, and unbiased information on both types. Detailed comparative information will be given on:

1. Principles of Operation
2. Design
3. Important Construction Features
4. "Theoretical" Accuracy
5. "Field" Accuracy
6. Maintenance
7. Shop and Field Testing



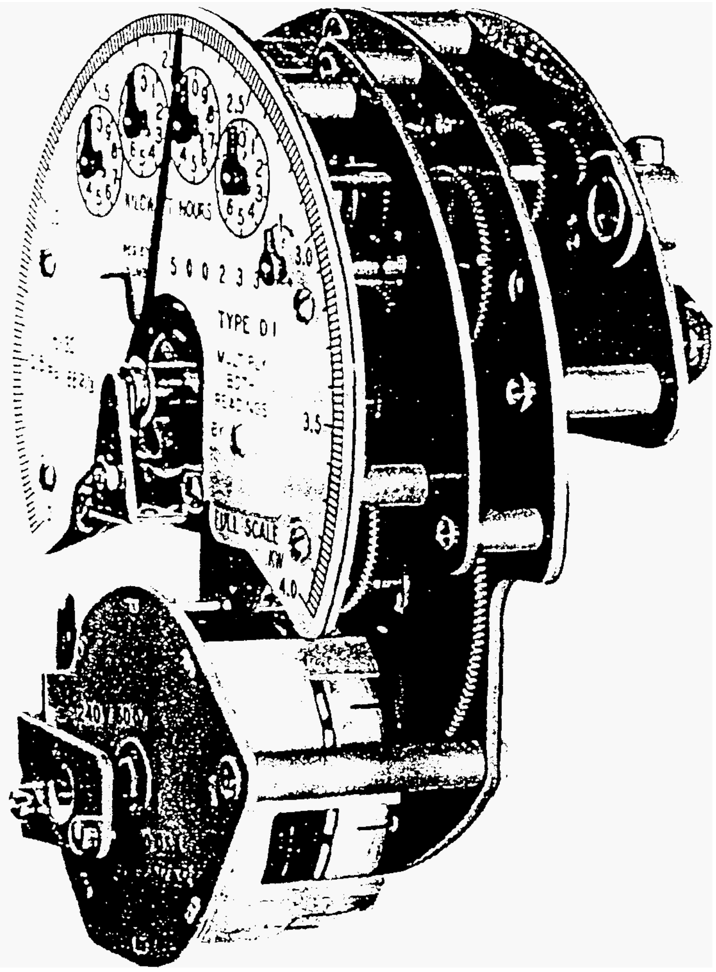


Figure B-1

Mechanical

The mechanical demand register is an instrument which is used in place of the standard kilowatthour register to measure kilowatt demand in addition to kilowatt-hours. As its name implies, the mechanical demand register obtains load information through mechanical gearing from the watthour meter disk.

The complete register is made up of the gearing associated with the kwh dials and three mechanisms that operate together to measure maximum average kw load in a demand interval. These three mechanisms are:

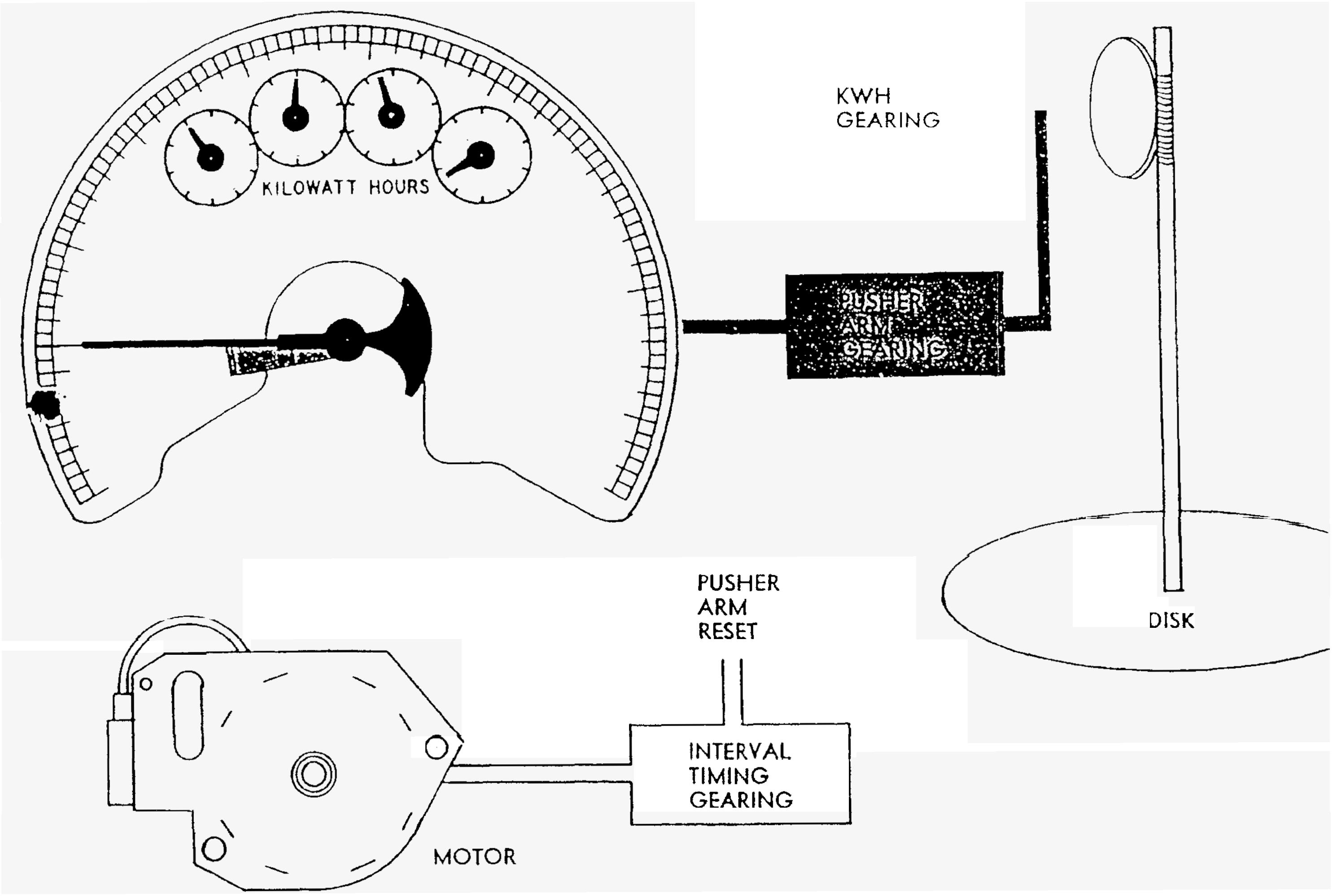
a. Pusher Arm
b. Interval Timing
c. Pusher Arm Reset

After explaining the basic function of the mechanical register, each of the three demand mechanisms will be explained in detail. They will then be combined to show the complete operation of a mechanical demand register.

Basic operation

The watthour meter disk turns at a speed proportional to the load. When a mechanical demand register is attached to a watthour meter, the kwh gear train (yellow—Figure B-2), similar to the gear train of a standard watthour meter register, records the revolutions of the disk on kwh dials. The same information is fed through the pusher arm gear train (red) to the pusher arm of the demand register and it accordingly moves the maximum demand pointer up scale in proportion to the speed of the disk.

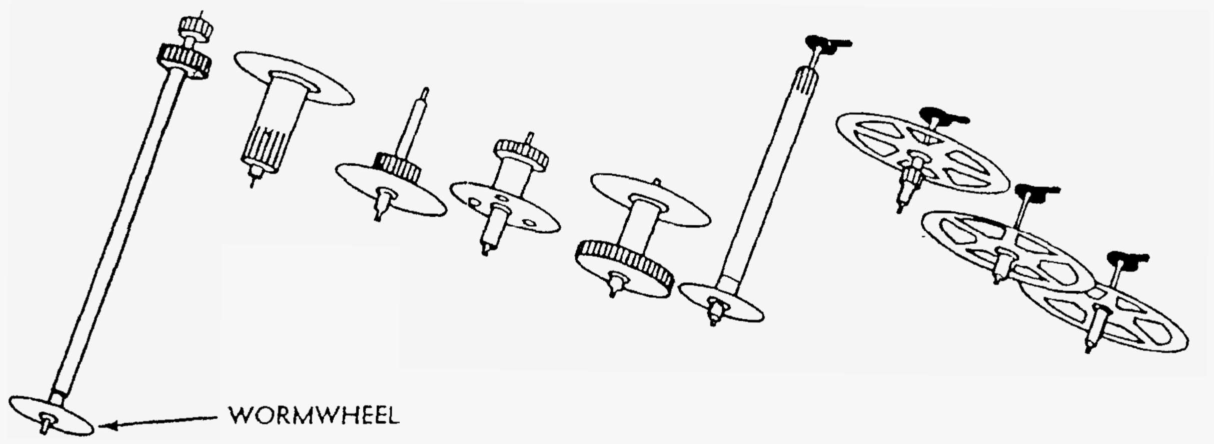
Figure B-2 **BASIC ELEMENTS OF A DEMAND REGISTER**



The pusher arm, because it is geared directly to the kwh train, would actually drive the maximum demand pointer to record kwh if the arm did not reset to zero at the end of each time interval. When the pusher arm resets, the maximum demand pointer remains at the maximum indication.

The motor driven timing gearing (white), at specified intervals, signals the pusher arm to stop recording kwh, reset to zero, and start over. This action is accomplished by the pusher arm reset mechanism (orange). Since the pusher arm is indicating kwh per time interval, the scale is marked in kw.

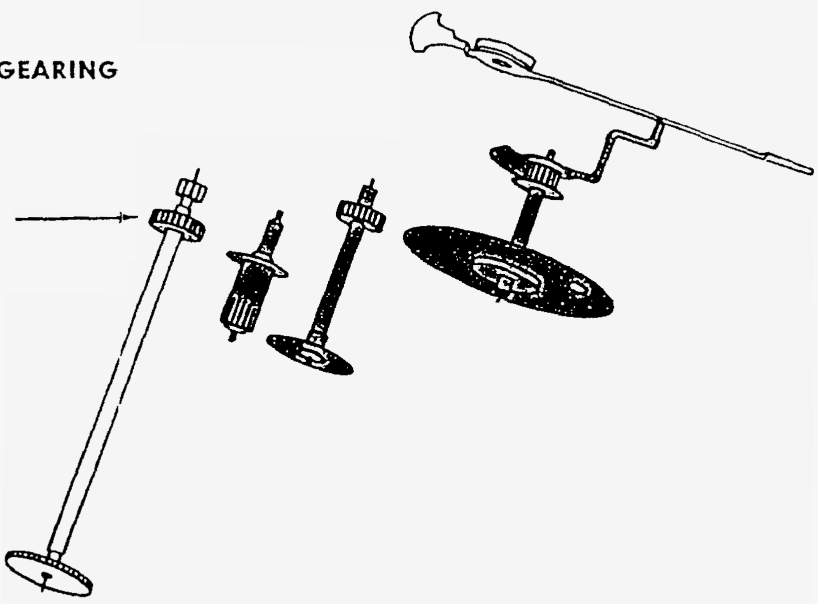
Figure B-3 | **KWH GEARING**



Pusher arm operation

As previously described, the pusher arm is geared to the watthour meter disk through the same wormwheel and shaft as the kwh dials (Figure B-3). Consequently, the pusher arm would be expected to record kwh if it were not for the reset action. The sequence of pusher arm gearing (red) is shown in Figure B-4.

Figure B-4 | **PUSHER ARM GEARING**



The relationship between the kwh dials and the pusher arm indication can be illustrated by the following example and table. Assume that a 15 minute interval demand register is measuring a steady load of 16 kw. After the first 15 minutes (1/4 hr), the kwh dials will indicate 4 kwh. Assuming the pusher arm does not have a reset action, it will also indicate 4 kwh in 15 minutes or 16 kwh in one hour. However, since the pusher arm is reset every 15 minutes, it is scaled to indicate kwh per hour or $\frac{\text{kwh}}{\text{hr}} = \frac{4}{1/4} = 16$ kw, which is the average load.

To further clarify the relationship between kwh and kw in a demand register, the following table shows pusher arm indication for 15, 30 and 60 minute interval registers measuring a 16 kw load.

Elapsed Time	Kw Load	Kwh	Pusher Arm Indication (kw)		
			15 Minute	30 Minute	60 Minute
15 min.	16	4	16	8	4
30 min.	16	8	16	16	8
45 min.	16	12	16	8	12
60 min.	16	16	16	16	16

In each register, the pusher arm will have pushed the maximum demand pointer to a scale indication of 16 kw.

Important characteristics of the pusher arm mechanism include:

—low friction gears and bearings,
—concentric location of the pusher arm and maximum demand pointer hubs with respect to the arc of the demand scale,
—constant friction for maintaining the up scale position of the maximum demand pointer,
—kw values precisely located on the demand scale.

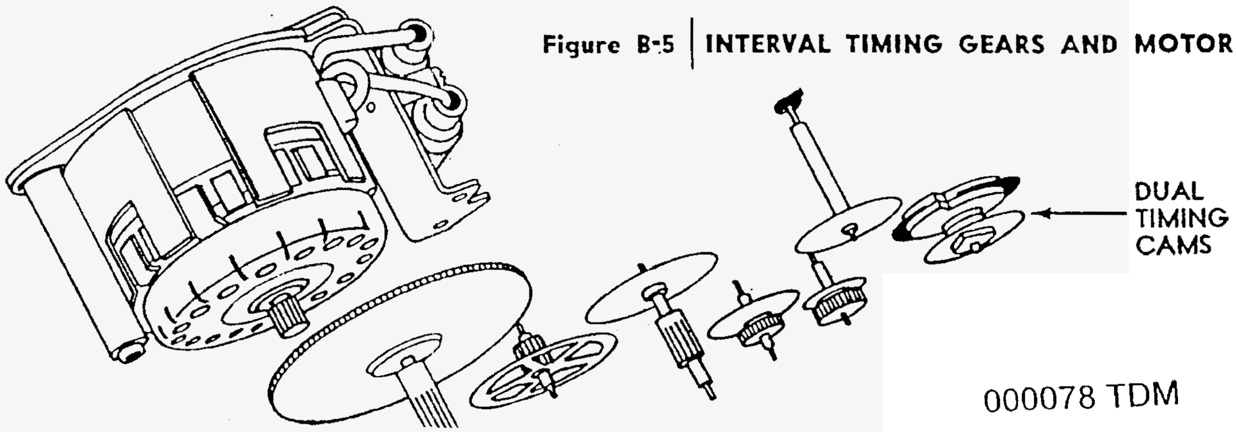
The gears in the Sangamo Type D register are machined to provide proper tooth form which assures consistent and dependable operation. All of the gears in this mechanism move very slowly with the exception of the pusher arm compound. The pusher arm compound moves up scale slowly and then resets rapidly. Because of this, special attention should be given to the design and material used in the pusher arm compound bearings. To insure long life for the compound, Sangamo uses two ring type sapphire jewels and hardened, polished stainless steel pivots.

Constant friction on the maximum demand pointer is obtained through the use of a pressure sensitive silk washer friction system.

Interval timing

The interval timing mechanism can be thought of as a clock which establishes the demand interval. This mechanism (Figure B-5) consists of the timing motor, reduction gearing and timing cams for triggering the reset operation. The timing cams make one revolution per interval. The length of the demand interval is determined by the reduction gearing between the motor rotor and the timing cams. This gearing can be designed to allow intervals of a few minutes to several hours.

Figure B-5 | INTERVAL TIMING GEARS AND MOTOR



The heart of the timing mechanism is the motor (Figure B-6). It assures that the resetting operation takes place precisely at the end of each time interval. The essential characteristics of a good demand register motor are high torque, stable operation over wide temperature ranges, maintenance of synchronous speed under all conditions, and high insulation level.

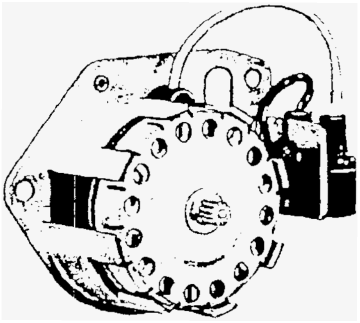


Figure B-6 | TYPE H MOTOR

The first Type H motors were used in demand registers in 1948. Since that time, approximately two million have been manufactured. This is the same dependable motor that is used for the precise time requirements of Sangamo time switches and graphic meters.

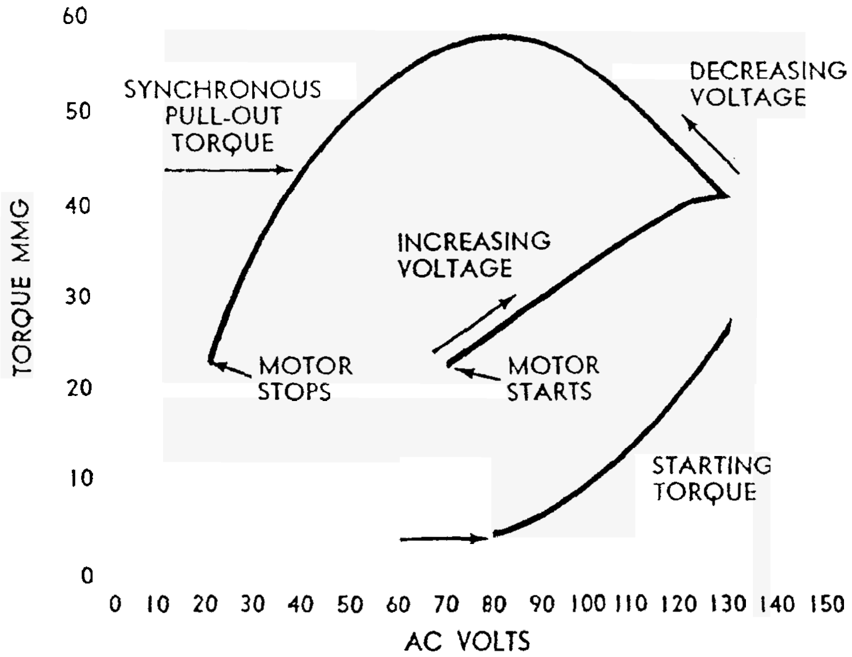
A polished stainless steel shaft mounted in permanently lubricated porous bronze bearings supports the rotor cup. Operation is not affected by temperatures as low as −50°F or as high as +250°F.

This motor runs at a synchronous speed of 450 rpm. The 120 volt motor will maintain synchronous speed when potential is reduced to as little as eight volts.

The motor coil is encapsulated in an epoxy resin and will withstand surges in excess of 10,000 volts. It is obvious that the motor speed, and thus the timing, will not be affected by voltage fluctuations or line surges.

The Type H is a high torque (40 mmg.) hysteresis motor. A curve representing the torque output with voltage increase and decrease is shown in Figure B-7. This curve illustrates why the motor stays in synchronism during low voltage conditions and has sufficient torque to overcome any friction that might develop.

Figure B-7 | TYPE H MOTOR-TORQUE/VOLTAGE



The motor is mounted below and in front of the demand register. This positioning, together with the inherent characteristics of the motor and the magnetic shield located on polyphase registers between the motor and the watthour meter, insures negligible interference between the motor and potential coil fluxes and makes it possible to calibrate the watthour meter with the demand register detached.

The timing gears are all mounted on stainless steel pivots riding in lifetime lubricated porous bronze bearings. This insures low friction and long life for the register.

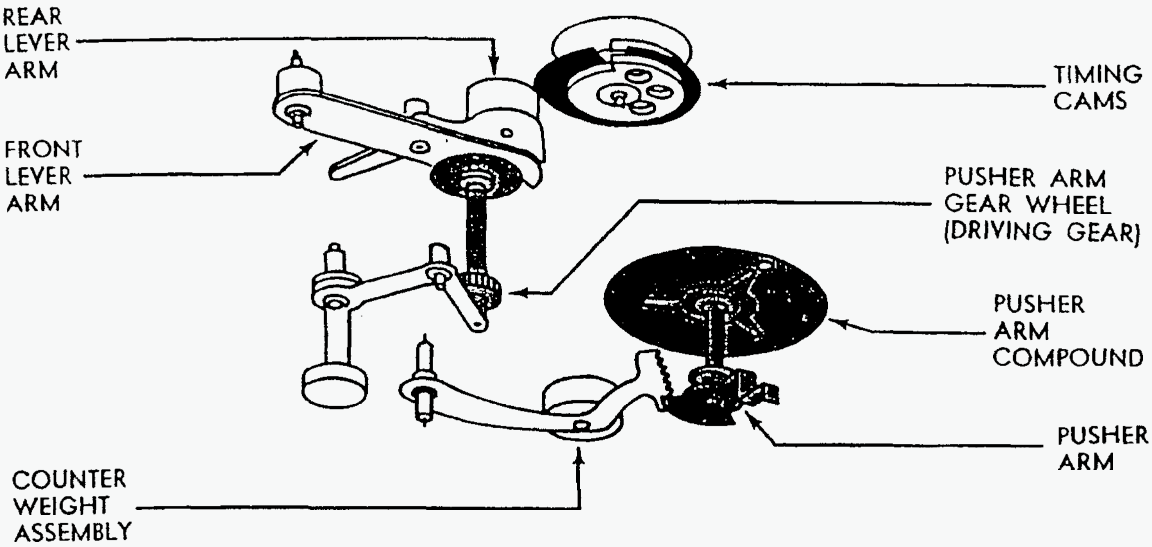
The dual timing cams (white, Figure B-5) are gear-driven from the motor, assuring accurate interval timing. The drop-off of each of the cams is slightly displaced so that the resetting action is properly triggered. The cams are driven through a non-adjustable, lifetime, metal to metal friction clutch in order to allow manual operation. A time indicator disk separates the dual timing cams.

Reset operation

A good reset mechanism in a mechanical register is an absolute necessity as it must perform exactly the same reset operation at the end of every interval, year after year. A 15 minute interval register will reset approximately 280,000 times in an 8 year service period. It must complete the resetting operation in a minimum length of time and have a minimum number of adjustments.

The operation of the reset mechanism (Figure B-8) is triggered by the timing cams. The pusher arm compound is momentarily disengaged from the pusher arm gear wheel, during which time the pusher arm is returned to zero. Immediate reengagement occurs, and the pusher arm begins its up scale movement for the next interval.

Figure B-8 | **RESET MECHANISM**



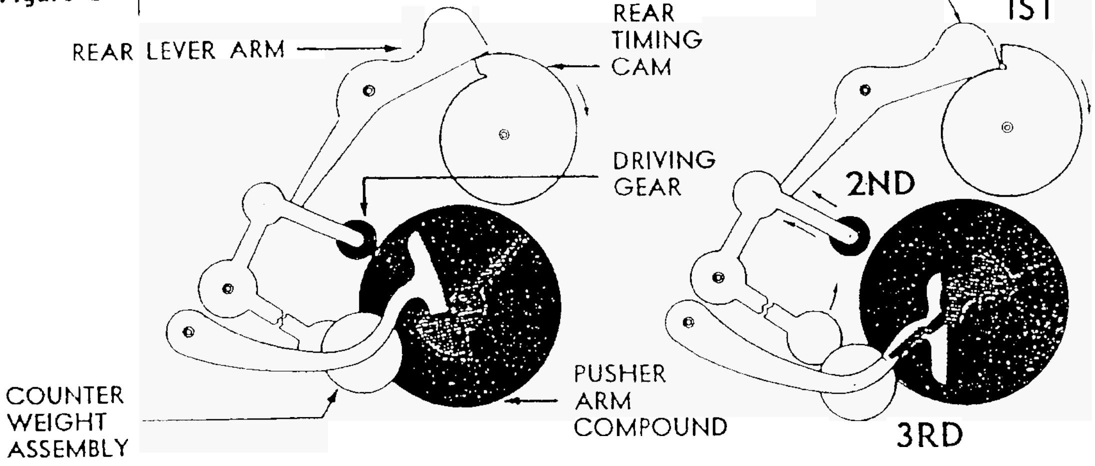
The energy for the positive reset operation in the D register is provided by a weight and pivot assembly geared to the pusher arm shaft. The resetting operation consists of the following actions (Figure B-9):

(1st) The rear weighted lever arm drops off the rear timing cam in a downward motion.

(2nd) This causes the lever assembly to pivot and momentarily lift the driving gear away from the pusher arm compound.

(3rd) When the pusher arm compound is freed from the driving gear, the counterweight assembly pulls the pusher arm down to the zero position.

Figure B-9 | **RESET ACTION**

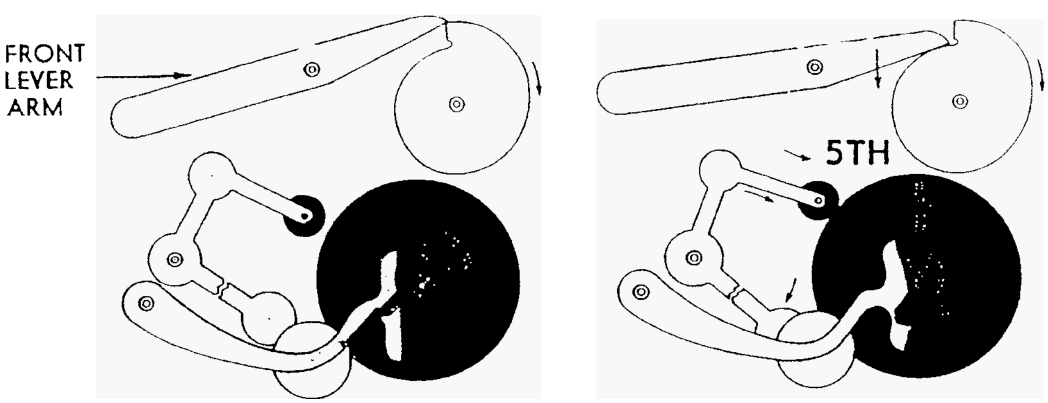


Immediately following this action (Figure B-10):

(4th) The front counterweight lever arm falls off the front timing cam.

(5th) The resulting gravity action re-engages the pusher arm driving gear with the pusher arm compound.

Figure B-10 | **RE-ENGAGEMENT ACTION**



This completes the reset operation and the pusher arm again moves up scale, counting disk revolutions. Since the pull of gravity on the weights is always the same, the resulting reset action is always the same. There are no springs or clutches that must be adjusted to insure proper resetting.

The original HM register incorporated another mechanical approach that is used today. In this approach, the timing train took control of the pusher arm and performed the periodic reset. In Figure B-11, note that in this device, the timing motor released a spring which drove the pusher arm to zero. The objection to this arrangement was the fact that a clutch was necessary which was strong enough to carry the pusher arm up scale and yet freely permit the down scale drive by the reset spring at the end of each interval. This introduced the mechanical problem of a clutch assembly that had to be adjusted between minimum and maximum weak limits, and minimum and maximum strong limits. This was a very difficult adjustment to maintain over a number of years.

Where such an arrangement is used, the serviceman must have a gage to measure this friction and adjust it between these limits. To eliminate such adjustments, Sangamo adopted the gravity reset mechanism which completely disengages gears, resulting in trouble-free dependable operation.

Figure B-11 | **SPRING TYPE RESET**

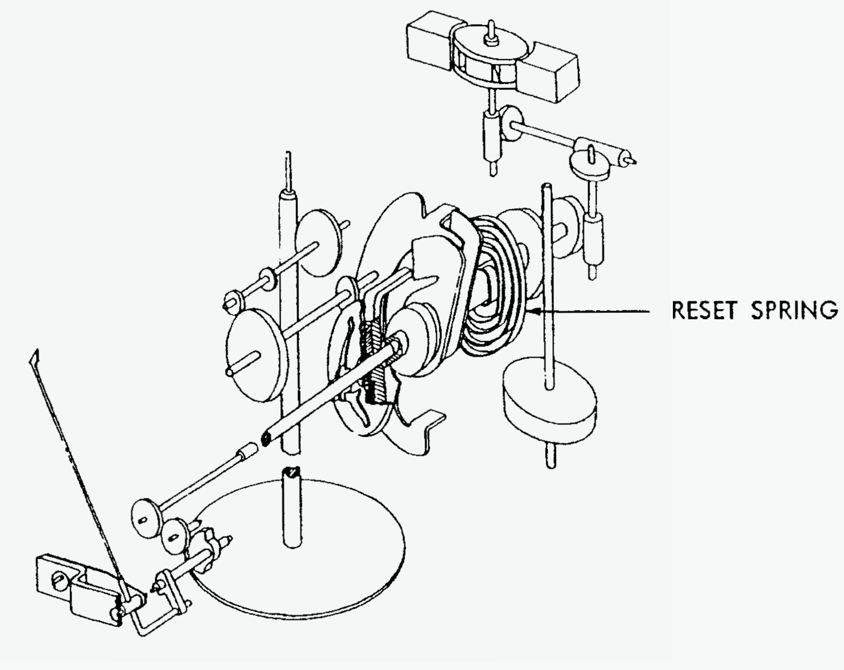
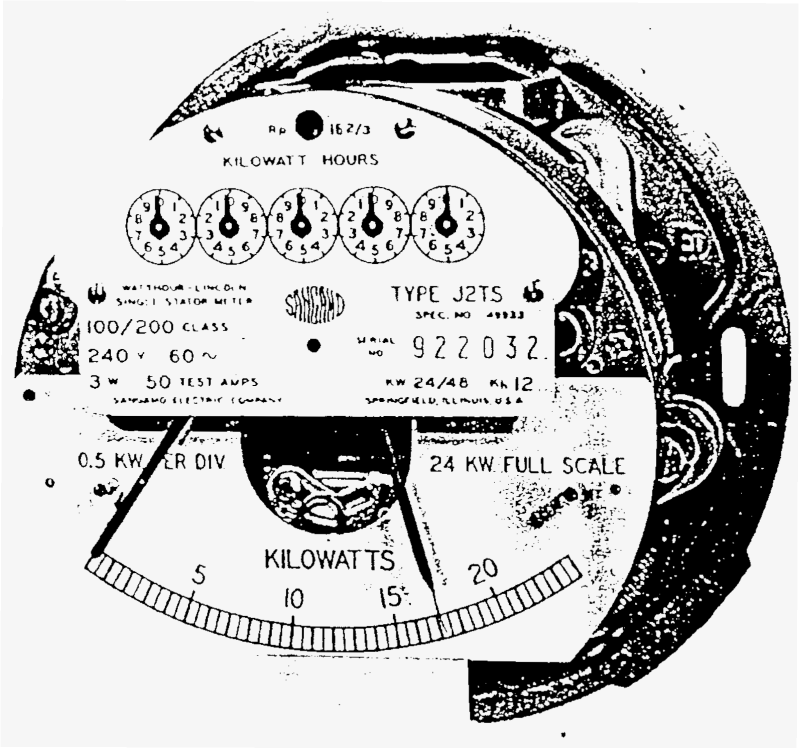
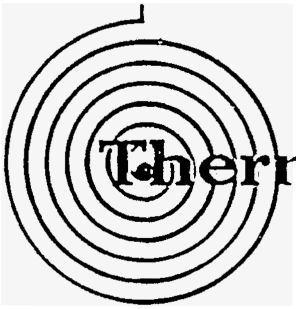


Figure C-1



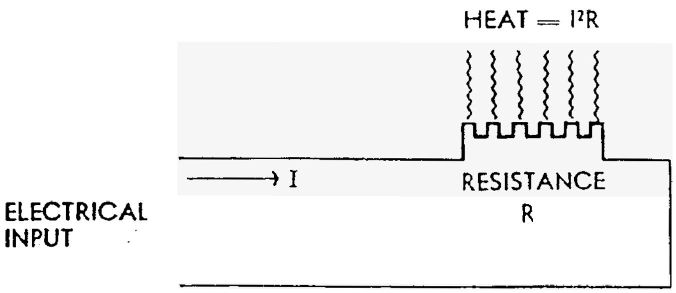


Thermal

The thermal meter measures average load with an inherent time interval and a response curve which is based on the heating effect of the load rather than on counting disk revolutions during a mechanically-timed interval. While the method of obtaining the maximum average load is entirely different from that of the mechanical demand register, the end result is the same.

The principle upon which the thermal meter operates is the conversion of electrical energy into heat. The heat developed in an electrical circuit of given resistance is proportional to the square of the current (Figure C-2).

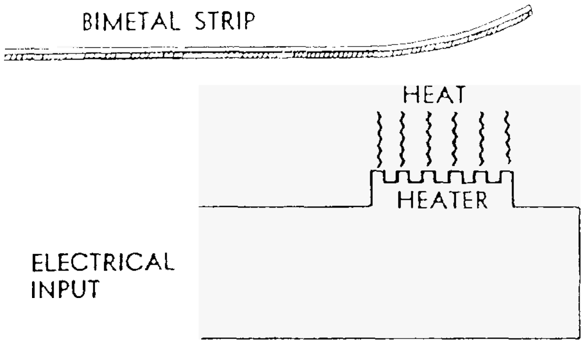
Figure C-2



Basic operation

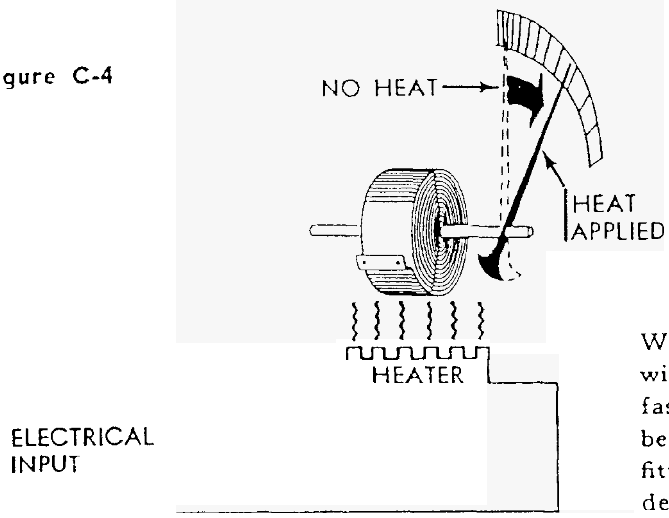
A simple analysis of the components in a thermal meter can be shown by the following illustrations:

Figure C-3



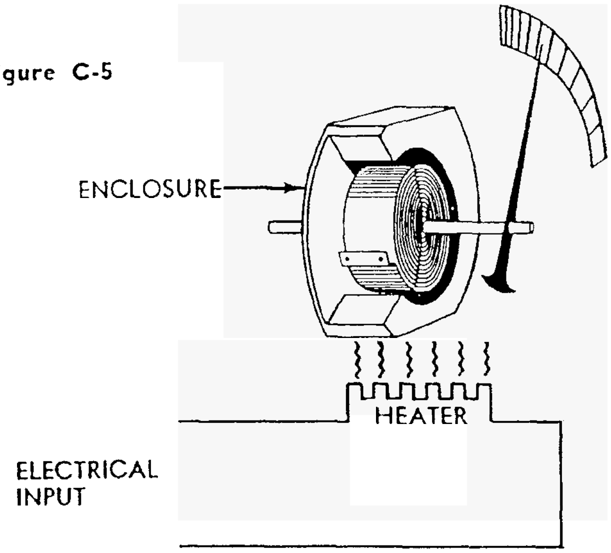
By fusing together two metal strips with different temperature coefficients of expansion, a bimetal is formed. These metals will expand at a different rate when heat is applied, and since they are attached to one another, the strip will bend.

Figure C-4



When a bimetal strip is wound into a coil with the outer end fixed, the inner end can be fastened to a shaft which will rotate with the bending of the bimetal. A pointer can be fitted to the end of the shaft to produce a deflection.

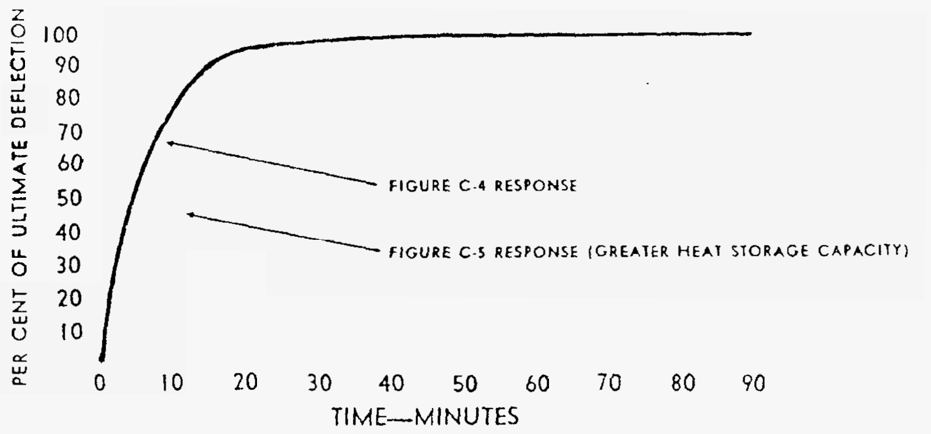
Figure C-5



If the coil were enclosed in a housing with heat storage capacity and the same heat applied, the response of the pointer would have been slower. However, it would have ultimately reached the same indication as the coil in Figure C-4.

The response variation of the bimetal coils in Figures C-4 and C-5 can be shown graphically in Figure C-6. An increase in heat storage capacity lengthens the time that it takes the bimetal coil to reach ultimate deflection, however the response curve is also affected by heat flow rate, which will be explained later.

Figure C-6



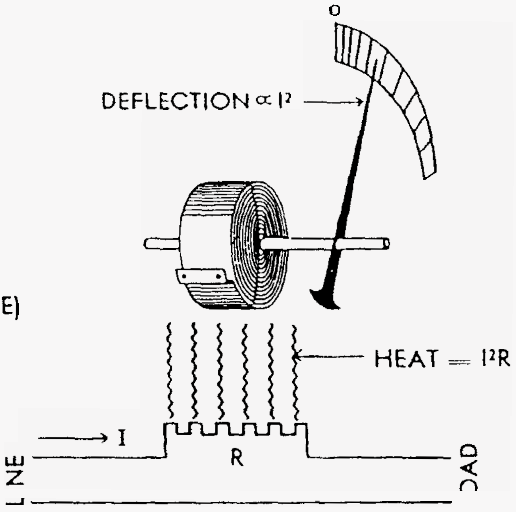
These basic components and principles are utilized in a thermal meter to measure demand by:

1. Converting heat into a heat difference.
2. Converting a heat difference into a temperature difference.
3. Converting a temperature difference into a pointer deflection.

Each of these principles will be discussed in detail on the following pages.

Converting heat into a heat difference

Figure C-7 SINGLE BIMETAL COIL (THERMOMETER PRINCIPLE) AFFECTED BY AMBIENT TEMPERATURE CHANGES



Suppose that the bimetal coil in Figure C-7 is heated by a resistor that has line current passing through it. As previously explained, the heat developed is proportional to I^2R and the pointer deflection would be proportional to I^2.

The pointer deflection in Figure C-7 would be a function not only of I^2R but also of ambient temperature. In effect, a single bimetal coil would act as a thermometer. To eliminate the effect of ambient temperature, a second coil that has been carefully matched with the first is put on the shaft so as to turn in the opposite direction (Figure C-8). Now, with a change in ambient temperature, one coil tends to move the pointer up scale and the second tends to move the pointer down scale. The result is that the pointer does not move with ambient temperature changes.

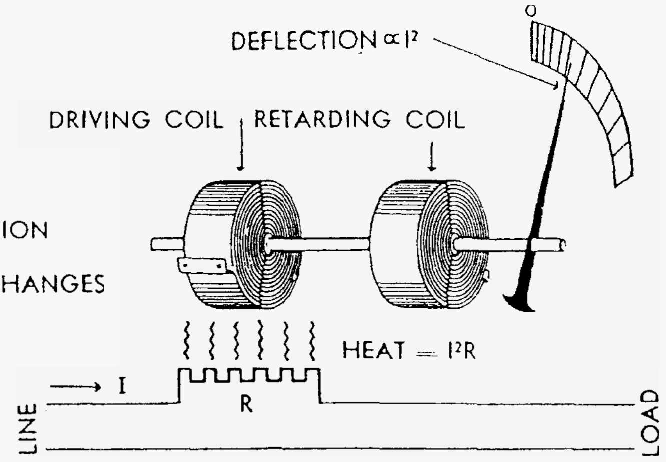


Figure C-8 AMMETER CIRCUIT—DEFLECTION NOT AFFECTED BY AMBIENT TEMPERATURE CHANGES

Each of these bimetal coils is contained in an enclosure, and one or both of these enclosures may be heated. If only one of the enclosures is heated, the shaft attached to the two coils will turn in proportion to the heat applied.

Utilizing the opposing bimetal coils, which are essential in all thermal meters, the circuit in Figure C-8 constitutes a thermal ammeter.

When current is passed through this meter, heat (I^2R) is developed in one enclosure causing the temperature to rise above that of the other enclosure. Responding to this difference in temperature, the bimetal coils produce a deflection of the pointer which is proportional to the heat developed and, hence, to the square of the current.

The watt demand meter has a basic circuit as shown in Figure C-9. A small potential transformer in the meter has its primary connected across the line and its secondary connected in series with two non-inductive heaters of equal resistance, one of which is associated with each enclosure.

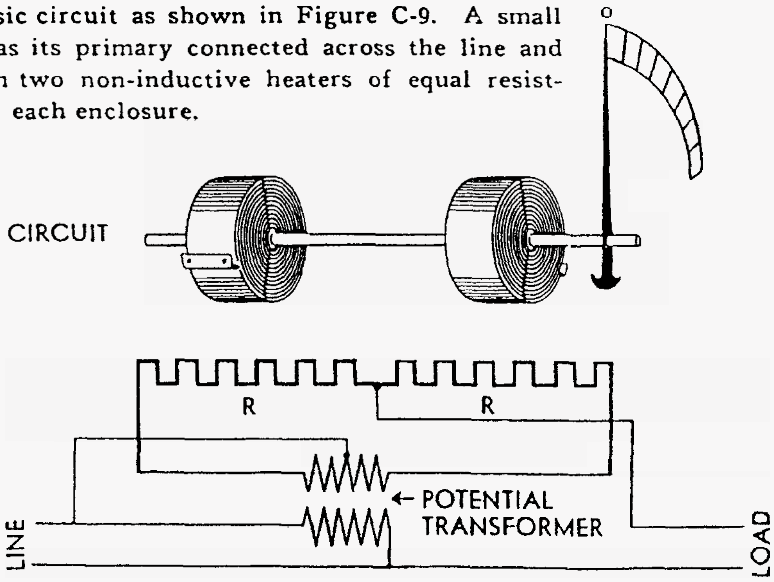
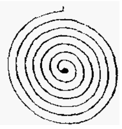


Figure C-9 BASIC WATT DEMAND CIRCUIT



With *potential only* applied to the meter, a current $\frac{E}{2R}$ circulates through the heaters as shown in Figure C-10. This circulating current is directly proportional to the line voltage and passes through each one of the heaters. With the potential circuit only energized, heat is developed at the following rates:

In the rear heater:

$$W_1 = \left(\frac{E}{2R}\right)^2 R = \frac{E^2}{4R}$$

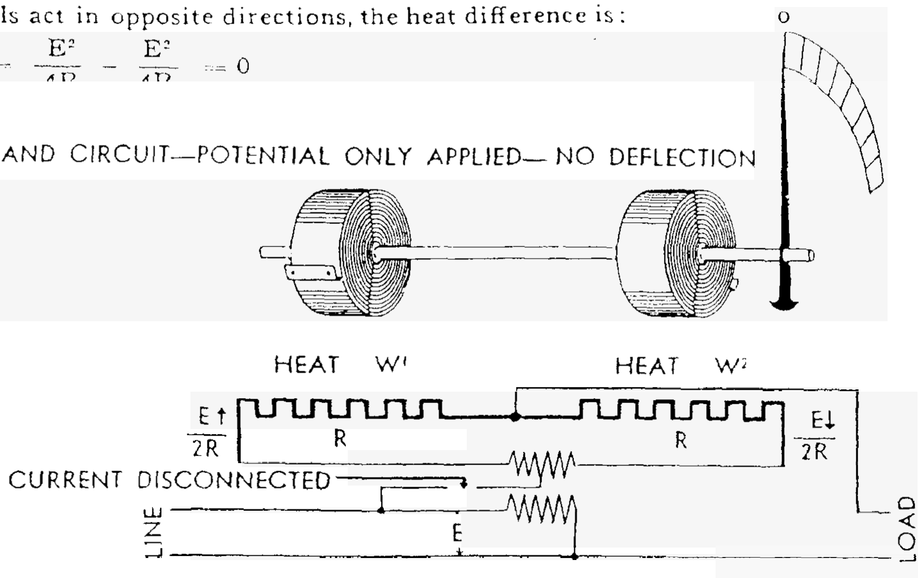
In the front heater:

$$W_2 = \left(\frac{E}{2R}\right)^2 R = \frac{E^2}{4R}$$

subtracting, since the coils act in opposite directions, the heat difference is:

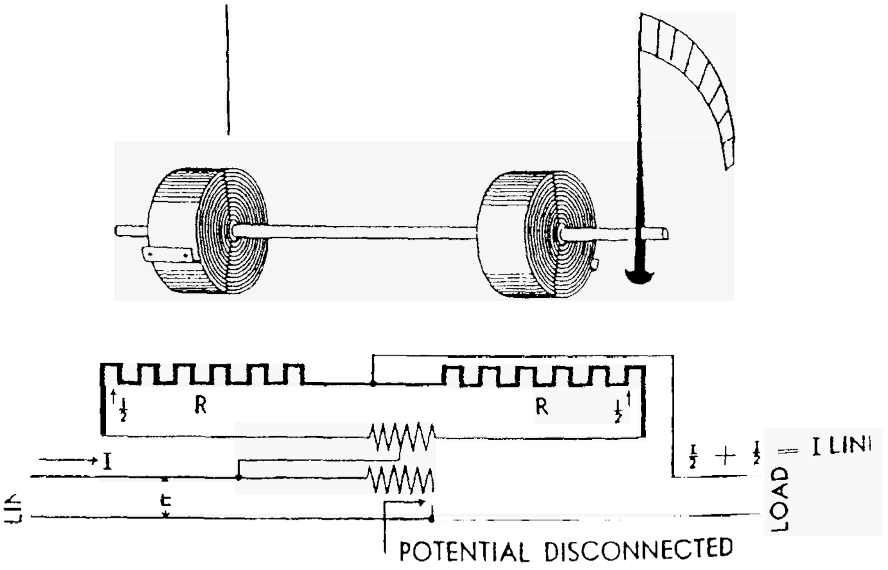
$$W_1 - W_2 = \frac{E^2}{4R} - \frac{E^2}{4R} = 0$$

Figure C-10 | WATT DEMAND CIRCUIT—POTENTIAL ONLY APPLIED— NO DEFLECTION



Thus, with only the potential circuit energized, the heat difference is zero, both bimetal coils are at the same temperature, and the pointer does not move.

Now analyze this same circuit with the primary of the potential transformer disconnected and the current section of the circuit completely energized with line current I (Figure C-11). This line current enters the mid-tap of the potential transformer secondary and divides equally. One-half of I now passes through each of the two balanced heater elements connected in parallel. With only the current circuit of the meter energized, heat is developed at the following rate:



Thus with only the current circuit energized, the heat difference is zero, both bimetal coils are at the same temperature, and the pointer does not move.

With both the current and voltage applied, a current $\frac{E}{2R}$ that is proportional to the line voltage circulates through the heaters as shown in Figure C-12. Current is introduced through the mid-tap in the potential transformer secondary and divides equally. Note that the currents $\frac{E}{2R}$ and $\frac{I}{2}$ add in the rear heater but subtract in the front heater. Heat is developed in the rear heater at a rate:

$$W_1 = \left(\frac{E}{2R} + \frac{I}{2}\right)^2 R = \frac{E^2}{4R} + \frac{EI}{2} + \frac{I^2R}{4}$$

and in the front heater: $W_2 = \left(\frac{E}{2R} - \frac{I}{2}\right)^2 R = \frac{E^2}{4R} - \frac{EI}{2} + \frac{I^2R}{4}$

Subtracting, the heat difference between the enclosures (and hence the deflection) is:

$$W_1 - W_2 = \left(\frac{E^2}{4R} + \frac{EI}{2} + \frac{I^2R}{4}\right) - \left(\frac{E^2}{4R} - \frac{EI}{2} - \frac{I^2R}{4}\right) = \frac{EI}{2} + \frac{EI}{2} = EI$$

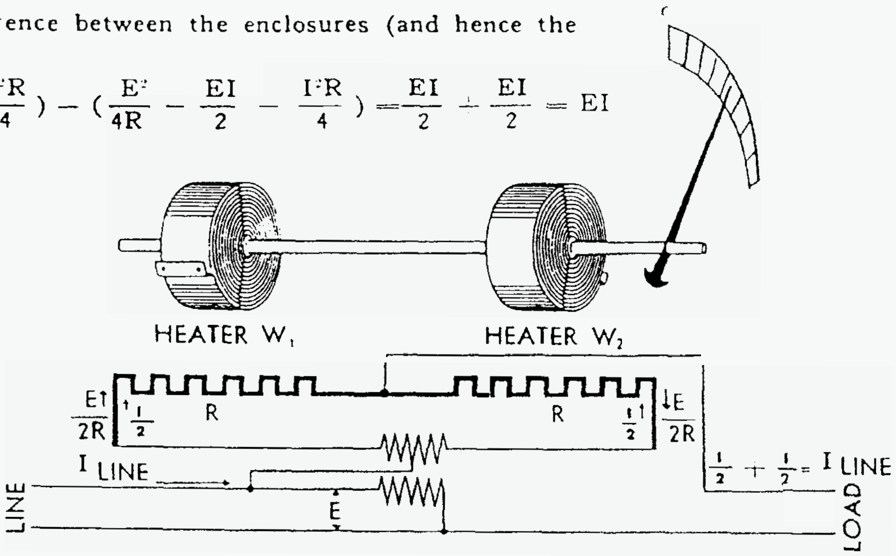


Figure C-12

WATT DEMAND CIRCUIT,
CURRENT AND
POTENTIAL CONNECTED—
DEFLECTION = EI

Because temperature rise in each enclosure is proportional to the heat input, the temperature difference between the two enclosures will correspond to the difference between these two values, or simply EI (watts).

The current and voltage in the above example were assumed to be instantaneous values, or at unity power factor. To illustrate how this meter measures watts at other than unity power factor, consider the following example:

Figure C-13

WATT DEMAND CIRCUIT

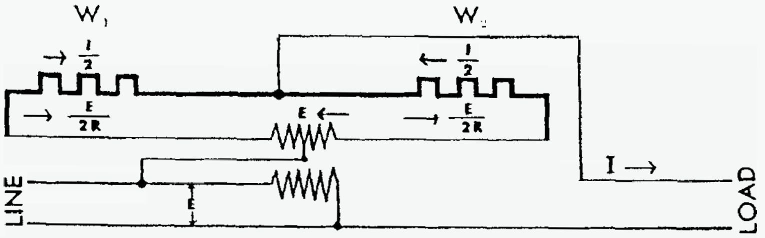
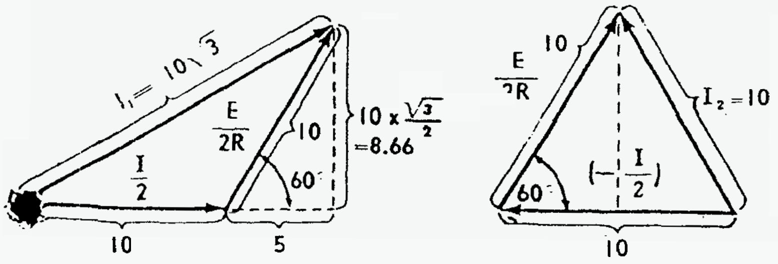


Figure C-14

WATT DEMAND CIRCUIT
VECTOR SOLUTION



Assume: E = 20 volts, I = 20 amps, p.f. = .5

(1) Then, Load = EI x p.f. = 20 x 20 x .5 = 200 watts and the thermal circuit quantities are: R = 1 ohm, $\frac{E}{2R}$ = 10 amps, $\frac{I}{2}$ = 10 amps

From the vector solution (Figure C-14):

$W_1 = (15^2 + 8.66^2) \times 1 = 225 + 75 = 300$ Watts

$W_2 = 10^2 \times 1 = 100$ Watts

(2) Then heat difference $W_1 - W_2 = 200$ Watts

The fact that the resistance, R, does not enter into the final equation, EI cos θ, indicates that R may have any value, provided the two resistances are equal. In practice, it is desirable to choose a value for R that will give minimum operating temperatures over the range of operation of the meter. Accordingly, a value for R is usually chosen so that $\frac{E}{2R}$ equals half the full load line current. This causes the circulating current to balance half the line current at rated load, unity P.F., and to cause one enclosure to be "cold" under these conditions.

The heaters are made of Nichrome, a nickel chromium alloy, because it has a very high specific resistance. Exact matching of resistance is accomplished by die punching the heater strips at adjacent positions from the same piece of material and pairing off. The resistance values are further checked by actual measurements. To eliminate variations in circuit resistance, the leads are positively attached by solder connections.

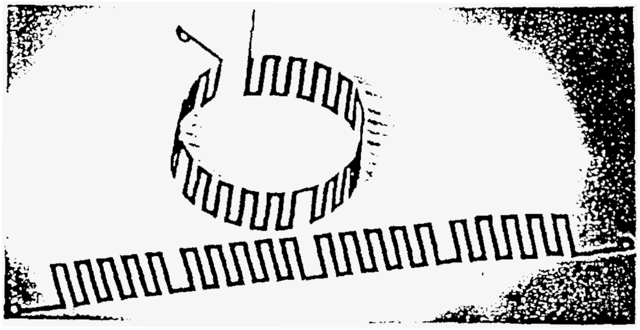


Figure C-15 | NICHROME HEATERS

The principle of the two-wire thermal meter can be applied to the thermal demand measurement of all singlephase and polyphase services. While the circuit of the two-wire watt demand meter shows only one heater associated with each bimetal coil, 2, 3, 4 or 6 of these heaters are utilized in polyphase meters. Since any polyphase circuit consists of two or more two-wire singlephase circuits, the heat inputs of the two-wire circuits can be added together and the resultant temperature difference measured with one pair of bimetal coils (Figure C-16).

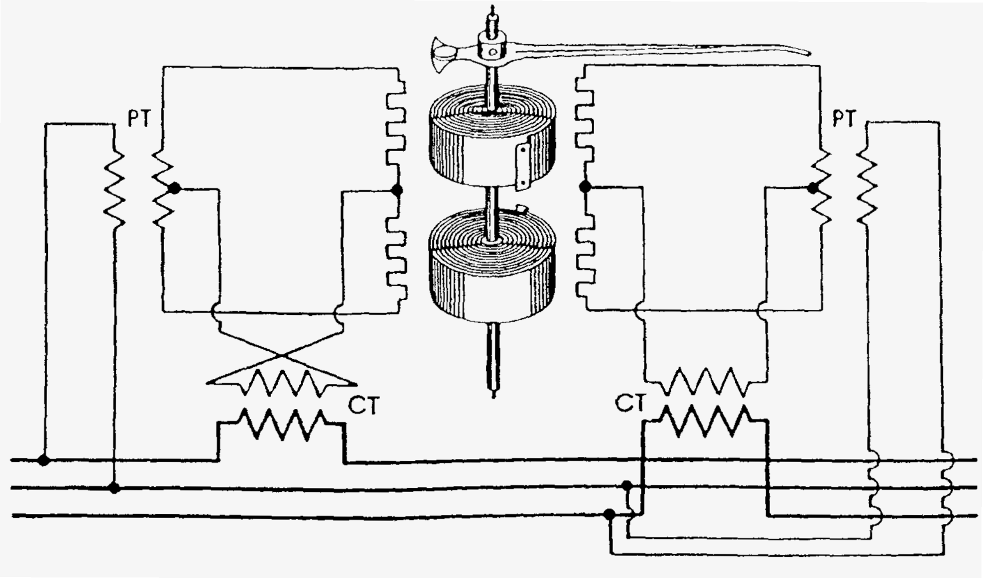


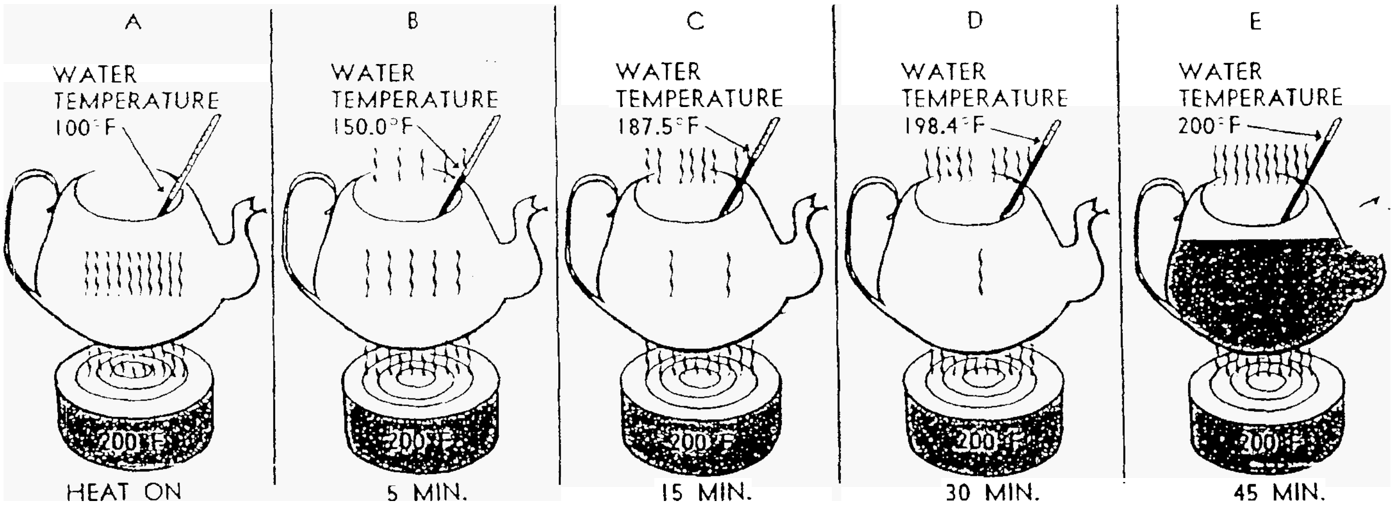
Figure C-16

POLYPHASE WATT DEMAND CIRCUIT

To reduce space requirements and installation costs, on demand billing applications, electric utilities generally specify combination thermal watt demand and kilowatthour meters. When the meters are so combined, the potential transformer of the thermal watt demand meter can take the form of a secondary winding on the potential electromagnet of the watthour meter. However, Sangamo Lincoln combination meters use separate potential and current transformers to obtain complete independence of the kilowatthour and demand meters. By this method, no sacrifice is made in the excellent operating characteristics of either the kwh or demand meter. With separate transformers in all Lincoln watt demand meters, current and voltage values are stepped down to permit compact design and minimum operating temperature.

Converting heat difference into a temperature difference

Figure C-17 | PRINCIPLE OF HEAT STORAGE



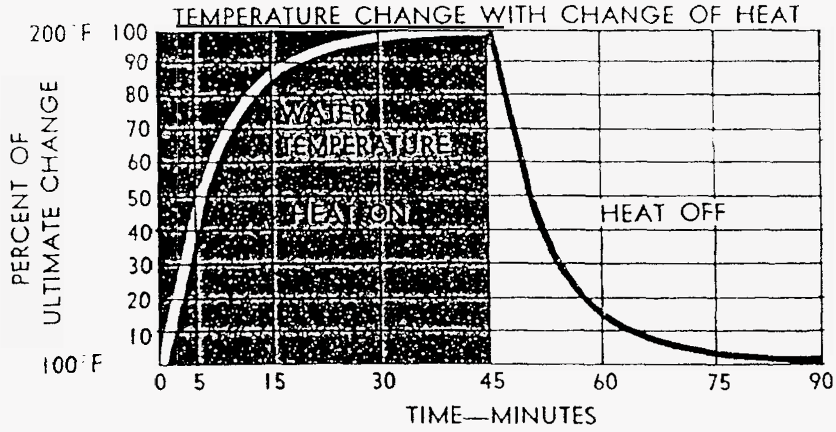
ATMOSPHERE TEMPERATURE 100° F

When a constant heat is applied to a body which is at the same temperature as its surrounding (Figure C-17a), all the initial heat input is used in raising the temperature of the body. As the temperature of the body rises above its original temperature, a portion of the heat is lost to the surroundings due to this temperature difference (Figure C-17b). As the temperature of the body becomes higher, a greater proportion of the total heat applied is given off, and less heat is available for raising the temperature of the body (Figure C-17c); until, ultimately, a temperature is reached at which all of the heat applied is given off and no further temperature rise takes place (Figure C-17e). This is the "ultimate temperature". The body will remain at this temperature until the heat applied is changed.

If, now, the heat input to the body is stopped, heat continues momentarily to flow out of the body at the same rate as before since the temperature difference between it and the surroundings is the same. However, since heat is no longer being applied, the heat which flows out is that which was stored in the body, and accordingly, the temperature of the body drops rapidly. As the temperature drops, the rate of heat loss decreases but the temperature continues to drop until the temperature of the body returns to the temperature of the surroundings.

The temperature rise of the water in the example (Figure C-17) can be graphically shown in Figure C-18.

Figure C-18



If a greater volume of water were heated in the kettle of Figure C-17, or if the water had been replaced with a liquid of greater heat storage capacity, the time required to reach ultimate temperature would have been longer, as shown in Figure C-19. The heat storage capacity depends upon the mass and specific heat of the materials present, and also to some extent, on their arrangement.

The time required to reach ultimate temperature is also determined by factors that determine the rate of heat flow. Some of these factors are; size, configuration, nature of surfaces, and material. In summary the greater the heat storage capacity, the slower the temperature response (Figure C-19); and the greater the heat flow rate, the faster the temperature response (Figure C-20).

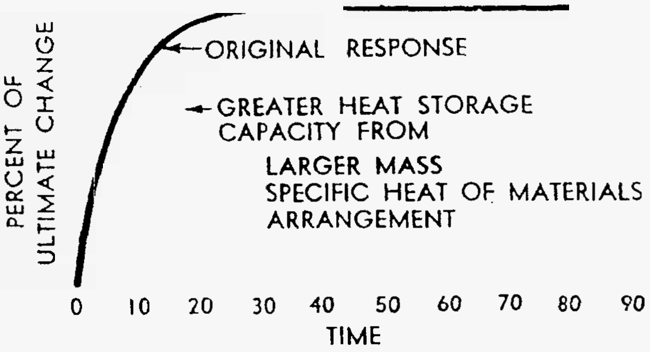
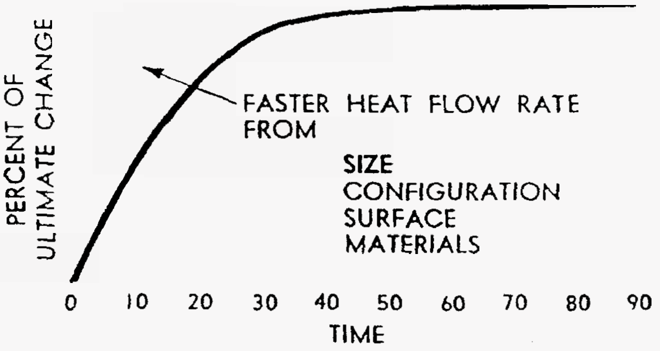
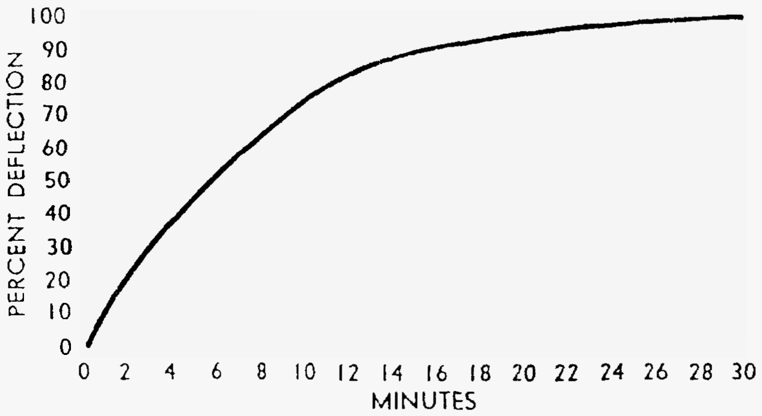


Figure C-20



The curves of heating or cooling of a body under certain ideal conditions are closely approximated by the response curves of thermal demand meters. Theoretically, fifteen minute interval Lincoln meters indicate 90% of a steady load fifteen minutes after the load is applied. Further, in the next 15 minutes they respond to 90% of the remainder of the total load. The deflection reached in any subsequent 15 minute interval will always be 90% of the difference between the indication at the beginning of the interval and the steady load (Figure C-21).

Figure C-21 ACTUAL RESPONSE CURVE OF 15 MINUTE KW DEMAND METER



The above response is in accordance with the definition of a 15 minute thermal demand interval as established by the "Code for Electricity Meters."

The following indications closely approximate the actual response curves of 15 and 30 minute interval Lincoln kw demand meters measuring a steady 100 kw load.

15 Minute Interval Lincoln Meter

Load On

Elapsed Time	Pusher Pointer Indication
0 min.	0 kw
15 min.	90 kw
30 min.	99 kw
45 min.	99.9 kw
60 min.	99.99 kw

Load Off

Elapsed Time	Pusher Pointer Indication
0 min.	100 kw
15 min.	10 kw
30 min.	1 kw
45 min.	0.1 kw
60 min.	0.01 kw

30 Minute Interval Lincoln Meter

Load On

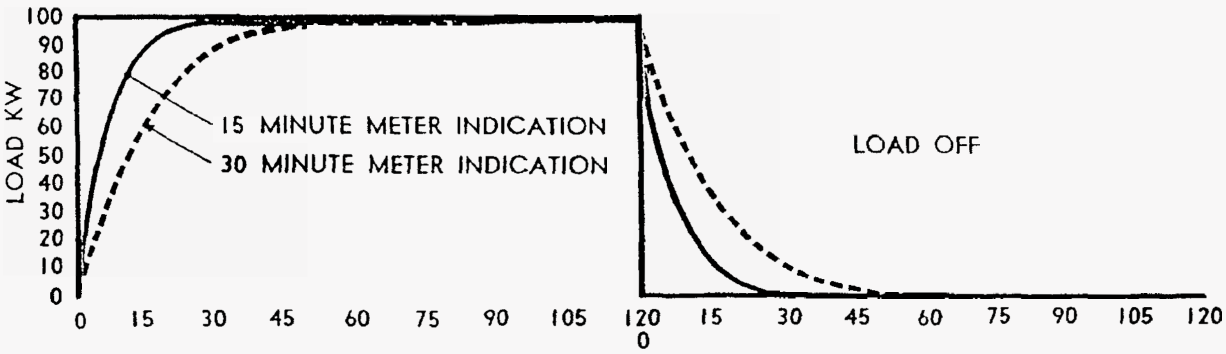
Elapsed Time	Pusher Pointer Indication
0 min.	0 kw
30 min.	90 kw
60 min.	99 kw
90 min.	99.9 kw
120 min.	99.99 kw

Load Off

Elapsed Time	Pusher Pointer Indication
0 min.	100 kw
30 min.	10 kw
60 min.	1 kw
90 min.	0.1 kw
120 min.	0.01 kw

By plotting the data from the tables of elapsed time and pusher pointer indication, the following response curves are obtained (Figure C-22).

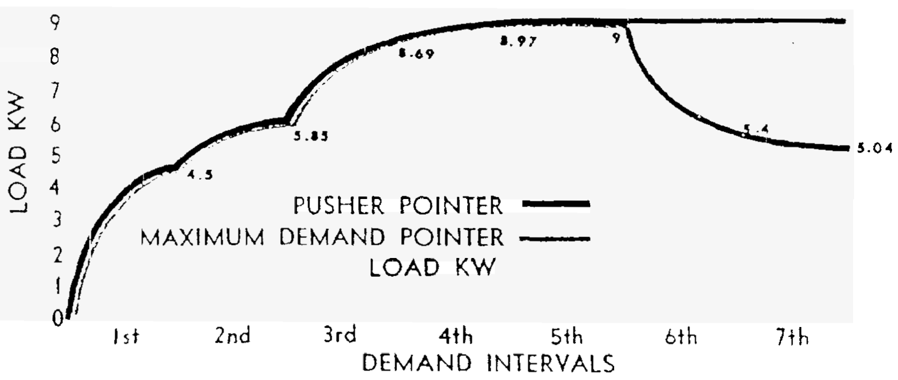
Figure C-22 LINCOLN THERMAL METER RESPONSE CURVES



Thus far, the response of Lincoln meters has been explained in reference to 90% indication of a steady load in the time interval of the meter. When extended to changing loads, the basic principle of thermal demand measurement is that the Lincoln meter responds to 90% of an increment of load change within a time interval (Figure C-23).

Figure C-23

CONTINUOUS AVERAGING OF LOAD



Interval 1: Load: steady 5 kw
Pusher pointer: moves from 0 to 90% of 5 = 4.5 kw
Maximum Demand pointer: moves from 0 to 4.5 kw

Interval 2: Load: increases from 5 to 6 kw
Pusher pointer: moves from 4.5 to 4.5 plus 90% of (6-4.5) = 5.85 kw
Maximum demand pointer: moves from 4.5 to 5.85 kw

Interval 3: Load: increases from 6 to 9 kw
Pusher pointer: moves from 5.85 to 5.85 plus 90% of (9-5.85) = 8.69 kw
Maximum demand pointer: moves from 5.85 to 8.69 kw

Interval 4: Load: steady 9 kw
Pusher pointer: moves from 8.69 kw to 8.69 plus 90% of (9-8.69) = 8.97 kw
Maximum demand pointer: moves from 8.69 to 8.97 kw

Interval 5: Load: steady 9 kw
Pusher pointer: moves from 8.97 to 8.97 plus 90% of (9-8.97) = 9 kw
Maximum demand pointer: moves from 8.97 to 9 kw

Interval 6: Load: drops to 5 kw
Pusher pointer: moves from 9 kw to 9 minus 90% of (9-5) = 5.4 kw
Maximum demand pointer: remains at maximum demand of 9 kw

Interval 7: Load: steady 5 kw
Pusher pointer: moves from 5.4 kw to 5.4 minus 90% of (5.4-5) = 5.04 kw
Maximum demand pointer: remains at maximum demand of 9 kw

A common misconception of the maximum demand indication for thermal demand meters is that only 90% of the maximum demand is indicated during the interval. Note that at the end of the third interval, after the maximum load had been on for only one interval, the maximum demand indication is 8.69 kw or 96.4% of the actual load (9 kw). After the load had been on for two intervals, the maximum demand indication is 99.7% of the actual load. This is, again, because the thermal meter responds to 90% of a change of load during each interval.

The maximum demand established in Figure C-23 is typical of obtaining maximum demand under service conditions. In actual practice, maximum demands are created by the load increasing from one level to a higher level and usually remaining on the line longer than the duration of a single time interval.

A mechanical type demand meter measures demand by averaging the load over a period of time, and equal weight is given to each value of load during that period. With a thermal demand meter, the average is logarithmic and continuous, which means that the more recent the load, the more it is weighted in this average (Figure C-23). As time passes, the importance of an instantaneous load value becomes less and less in its effect on the meter indication. The indication of a thermal demand meter at any instant depends not only upon the load being measured at that instant but also on the previous values of the load. Because of the inherent time interval, the pointer slowly approaches its ultimate indication.

The first principle dealt with the development of a heat difference through an electrical circuit. This heat difference has now been converted into a temperature difference between the two enclosures to produce a response proportional to the load. This response represents a continuous averaging of the load during an inherent interval and so constitutes a measure of demand.

To complete the thermal method of demand measurement, the temperature difference must be converted into pointer deflection.

Converting temperature difference into a pointer deflection

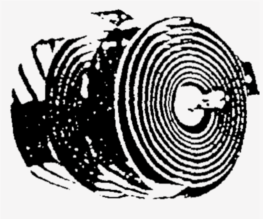
When the two electrical heaters of a thermal kw demand meter create a heat input difference, the two enclosures develop a temperature difference proportional to the load. This temperature difference can be measured with bimetal coils which convert the temperature difference into pointer deflection.

The bimetal coils are frequently made of nickel invar and manganese alloy which have a substantial difference in temperature coefficients of expansion. The invar is the low expansive metal and manganese is the high. Bimetal strips of correct length (Figure C-24) are spot welded to a hardened steel hub and wound into a spiral with the high expansive metal on the inside of the spiral which causes the coil to expand under a rising temperature. The bimetal is carefully wound by a winding machine designed to maintain perfect concentricity and equal spacing of each spiral. After winding, the bimetal spiral is heat-treated to set it into a permanent coil. Proper aging of the coil assures permanence and stability of its characteristics, providing accurate and reliable performance when in service.

Figure C-24 BIMETAL STRIPS AND COIL

WOUND COIL
HIGH EXPANSIVE
METAL ON INSIDE

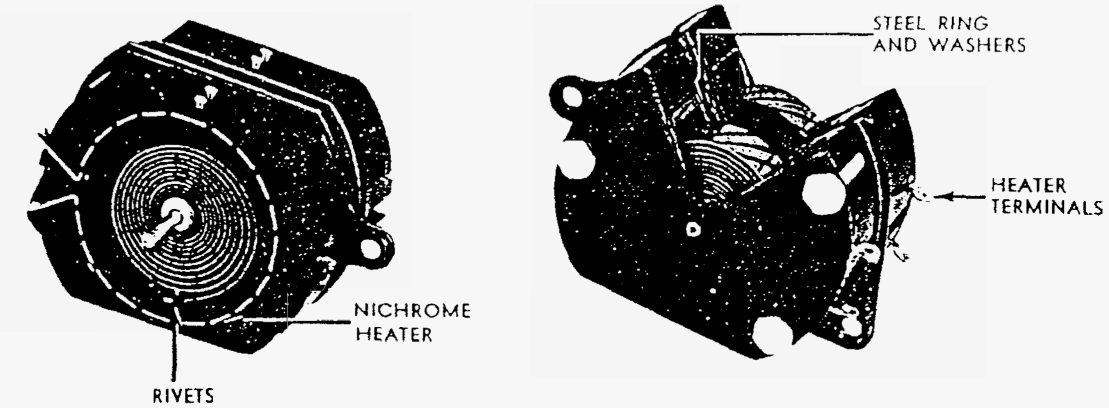
COIL IN CUT AWAY
ENCLOSURE



BIMETAL COILS ON SHAFT

Figure C-25

Before the coils are placed on a shaft, they are carefully matched. This matching process assures that coils which have identical expansion characteristics are placed on the same shaft. If they were not exactly matched, a change in ambient temperature would cause a slight pointer deflection. The coils are placed on a steel shaft in opposition to each other (Figure C-25). The hub in the center of the spiral coils is firmly positioned on a knurled portion of the shaft.



INTERNAL VIEWS OF ENCLOSURES

Figure C-26

The heater strips and bimetal coils are exactly positioned in the center of enclosures (Figure C-26). The outer end of the coil is riveted to a retaining ring so that when a temperature difference occurs, the shaft will rotate due to the expansion or contraction of the coil. These enclosures are small and compact, and are mainly composed of a thermal insulating material, bakelite. Nichrome heaters are located on the inside periphery of the enclosures and are held in place by a retaining ring. A steel ring and washers assure uniform distribution of heat to the bimetal coils and add heat storage capacity. The complete assembly is the thermal measuring element.

MEASURING ELEMENT AND POINTERS

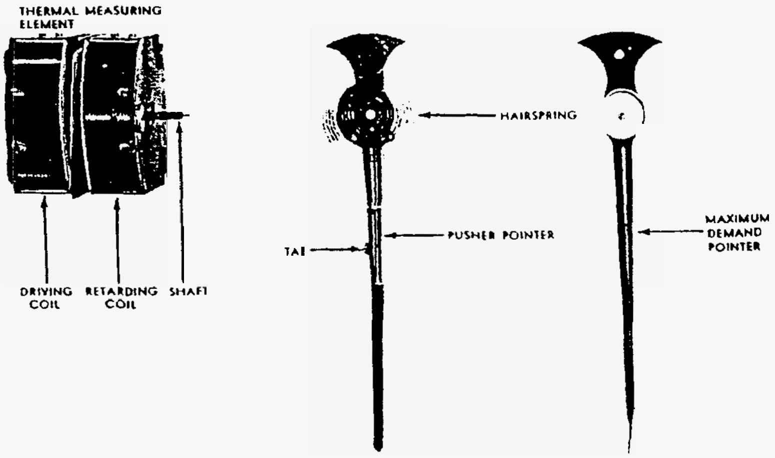
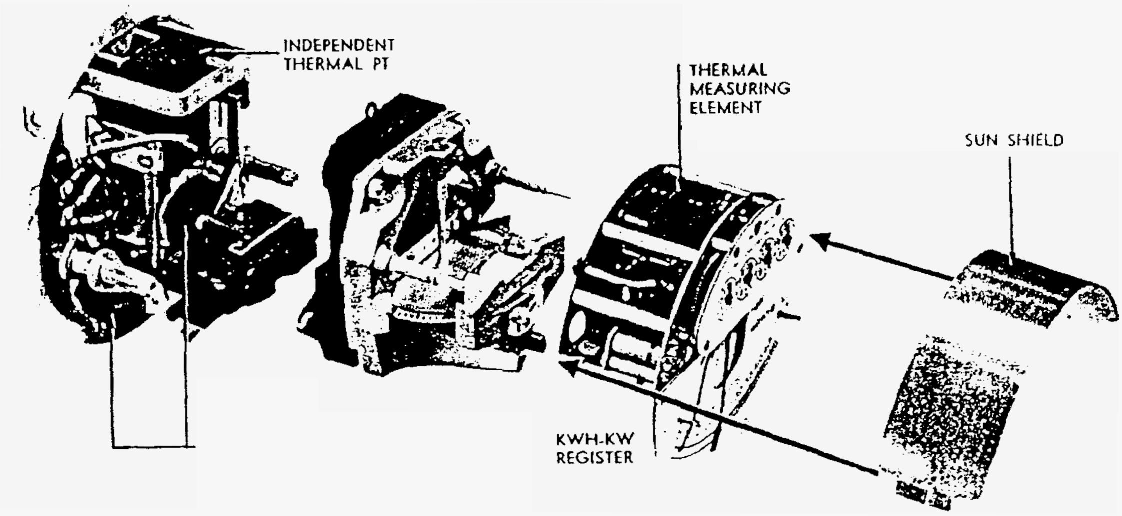


Figure C-27

When the thermal measuring element is placed in a meter, the shaft with a pusher pointer attached, turns on polished stainless steel pivots. Advancing torque is developed by the rear (driving) coil and opposing torque by the front (retarding) coil, so that the rotation of the shaft, and hence the deflection of the pointer, is proportional to the load being measured. A sun shield placed over the measuring element (Figure C-28) assures that direct rays of the sun will not produce an ambient temperature difference between the coils.

Figure C-28 EXPLODED VIEW OF COMPLETE SINGLEPHASE THERMAL METER



Pusher pointer deflection, which fluctuates according to the magnitude of the kw load, is read on a linear scale.

To indicate the maximum up scale deflection, the maximum demand pointer is advanced by the pusher pointer. The pusher pointer has a small tab which contacts the maximum demand pointer during up scale movement. The tab is twisted so that only an edge surface contacts the maximum demand pointer to prevent a friction band between the two pointers.

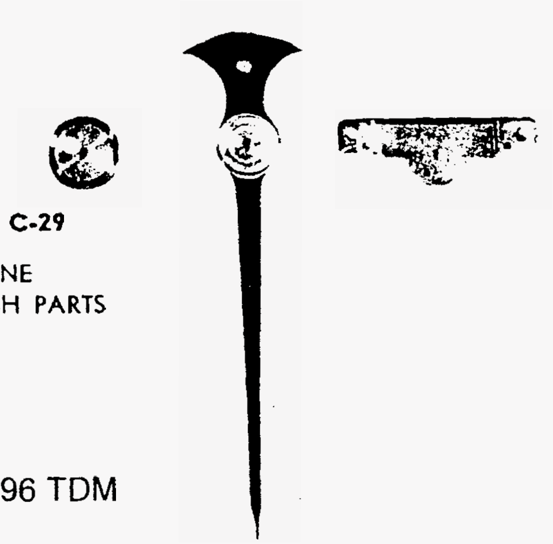


Figure C-29

SILICONE CLUTCH PARTS

The maximum demand pointer remains at the highest up scale, or kw value, reached by the pusher pointer until manually reset at the end of the billing period. It is carefully balanced and held in place with a silicone-controlled clutch (Figure C-29) when not being advanced up scale by the pusher pointer. The specially prepared silicone compound provides high holding torque for the maximum demand pointer against vibration or rapid motion. However, the clutch exerts negligible restraining torque to the slow steady movement of the pusher pointer.

The scale

The thermal demand scale covers an arc of 70 degrees. It is over 4 inches in length and is nearly horizontal for easy reading. Lincoln combination meters are designed so that demand pointers do not obstruct reading of the kilowatthour dials.

Full scale values and the number of divisions for a given full scale value are determined by industry standards as listed below.

Full Scale Value	No. of Divisions	Value per Division	Full Scale Value	No. of Divisions	Value per Division
0.5	100	0.005	18.0	90	0.2
1.0	100	0.01	24.0	48	0.5
1.0	100	*	36.0	72	0.5
1.5	75	0.02	48.0	96	0.5
2.0	100	0.02	72.0	72	1.0
3.0	60	0.05	96.0	96	1.0
4.0	80	0.05	100.0	100	*
6.0	60	0.10	144.0	72	2.0
8.0	80	0.1	192.0	96	2.0
12.0	60	0.2			

*Values per division for 100 division scales will depend on the capacity of the demand meter to which the scale is applied. Multiplying constants for demand meters having 100 division scales will be based on the full scale values listed above, $\left(\frac{\text{full scale value}}{100}\right)$, in addition to the ratio of instrument transformers when applicable.

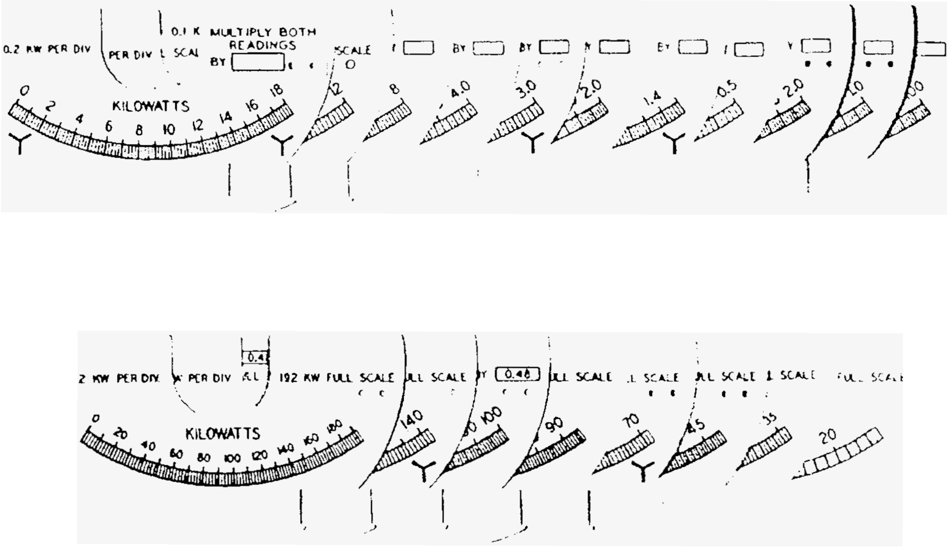


Figure C-30 ASSORTED THERMAL DEMAND SCALES

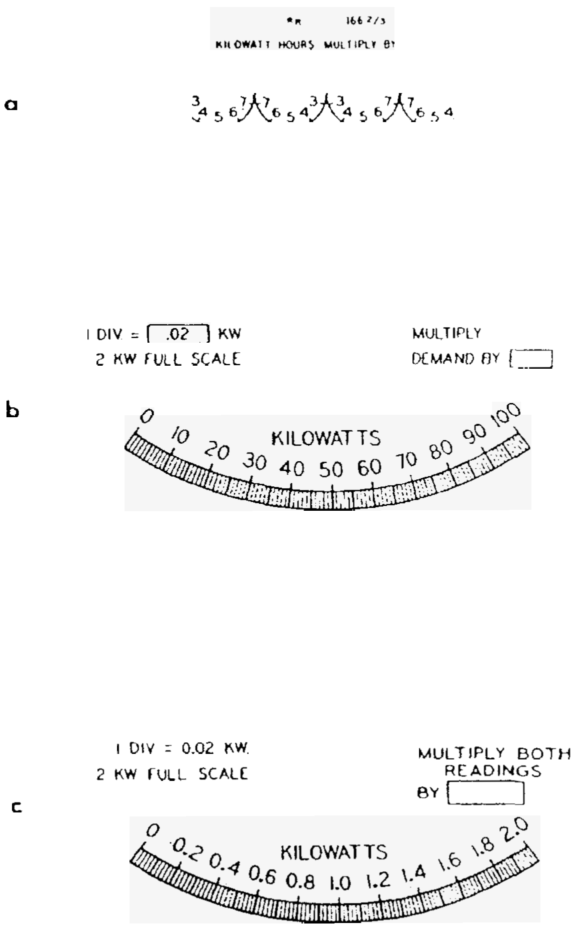
The above full scale values when applied to one and two stator meters are expressed as "class" on the meter nameplate. "Class" denotes the maximum load range in amperes of the demand meter.

Standard full scale values for various classes of one and two stator watthour-thermal watt demand meters are listed on the following page.

CLASS DESIGNATIONS—FULL SCALE VALUE

	Thermal Demand Class	Meter Test Amps.	Full Scale Kw 1ϕ 3W	 ϕ 4WΔ	 3ϕ 4W Y		 3ϕ 3W			 3W Network		
			240V	240V	120V	240V	120V	240V	480V	120V	240V	480V
Transformer	5	2.5	1	2	1.5	3	1	2	4	—	—	—
Type	10	2.5	2	4	3	6	2	4	8	—	—	—
	50	15	12	24	18	36	12	24	48	12	24	48
	50/100	15	12/24	24/48	18/36	36/72	12/24	24/48	48/96	12/24	24/48	48/96
Self-Contained	100	15	24	48	36	72	24	48	96	24	48	96
	100/200	30	24/48	48/96	36/72	72/144	24/48	48/96	96/192	24/48	48/96	96/192
	200	30	48	96	72	144	48	96	192	48	96	192

Figure C-31 | MULITIPLIER DESIGNATIONS



Multiplying constant

When a multiplying constant is applicable to the kwh reading only, it is adjacent to the kwh dials and is preceded by the words "Kilowatt Hours —Multiply By" as in Figure C-31a.

When a multiplying constant is applicable to the thermal demand reading only, it is adjacent to the kw scale and is preceded by the words "Multiply Demand By" as in Figure C-31b

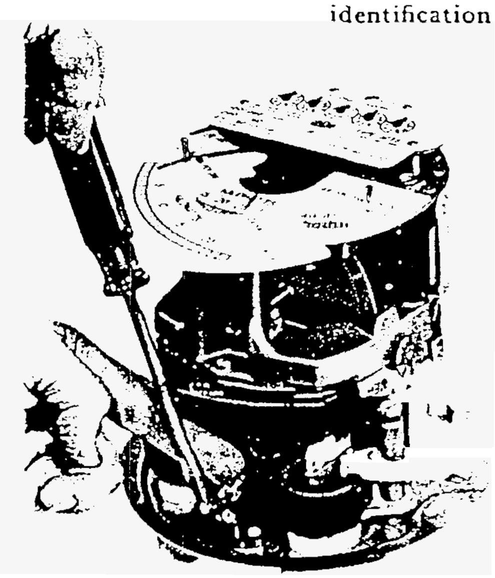
When the same multiplying constant is applicable to both the demand reading and the kwh dials and is determined by the ratio of the instrument transformers with which the meter is used, a removable plate having the words "Multiply Both Readings By______" is attached to the demand scale as in Figure C-31c.

Dual range

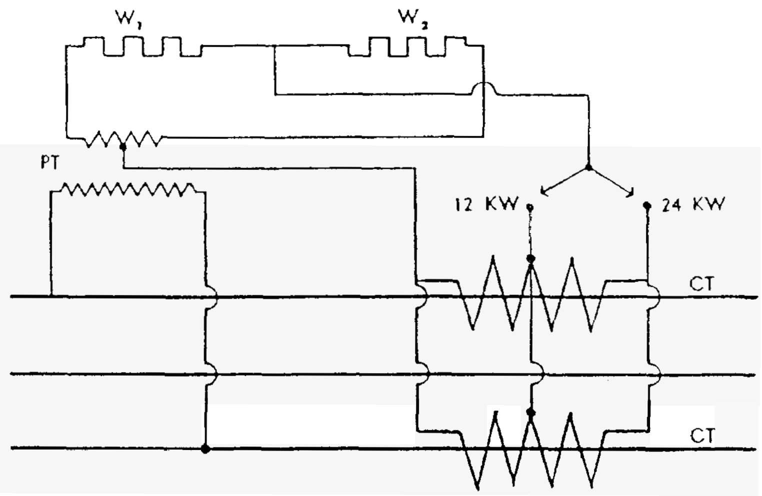
Because thermal meters are also rated in per cent of full scale, the full scale rating of the demand meter should be matched as closely to the load as possible. Since it is frequently necessary to increase the meter capacity with load growth, a dual range feature is advantageous.

Lincoln singlephase and polyphase thermal combination meters are available in dual range construction. This makes it possible to use the meter on a low range initially and to double the range later. Full scale values are determined by the connection of the mid-tapped current transformer secondary (Figure C-32). On a singlephase meter (Figure C-33) the range is changed by transferring a single lead on the terminal block of the base plate. On polyphase meters (Figure C-34), the change consists of moving the transformer secondary links at the top of the meter. The terminal blocks are marked to indicate the range on which the demand meter is connected.

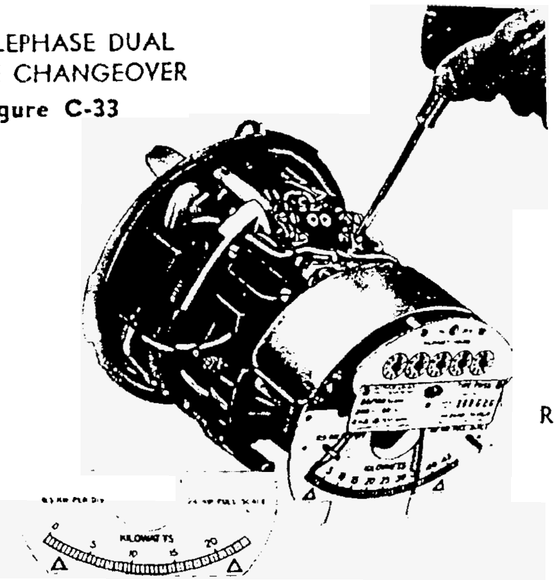
The demand scales must also be changed to correspond with the selected range. By merely removing the two screws holding them in place, the two scales may be interchanged. When a two range meter is supplied, the demand scales are located one above the other with the low range on top. The utility company identification tag is not disturbed by this operation.



SINGLEPHASE DUAL
RANGE CHANGEOVER
Figure C-33



SINGLEPHASE DUAL RANGE
CIRCUIT DIAGRAM
Figure C-32



POLYPHASE DUAL
RANGE CHANGEOVER
Figure C-34

Accuracy

Lincoln thermal demand meters are calibrated for 1% full scale accuracy at all points on the demand scale. As in any indicating instrument, per cent of accuracy is expressed in relation to full scale or full load value.

For example, a Lincoln meter with 96 kw full scale capacity would have ±0.96 maximum error limits. At one-half scale, this meter would still have ±0.96 maximum error limits but, because the load value is then 48 kw, the accuracy would be ±2% of load.

At lower scale points, the error in percentage of load will increase inversely with the load (Figure C-35). Consequently, it is advisable to use demand meters as well as any other indicating meter in the upper one-half of their scales.

SCALE ACCURACY

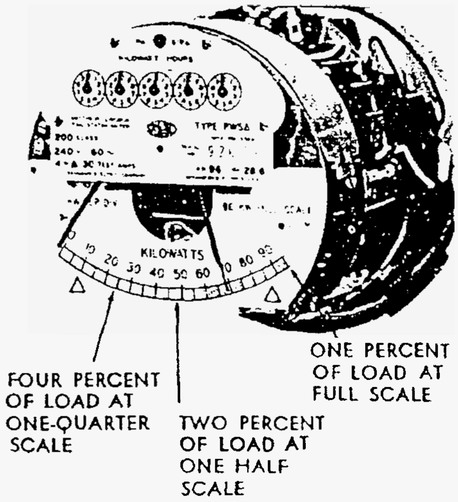
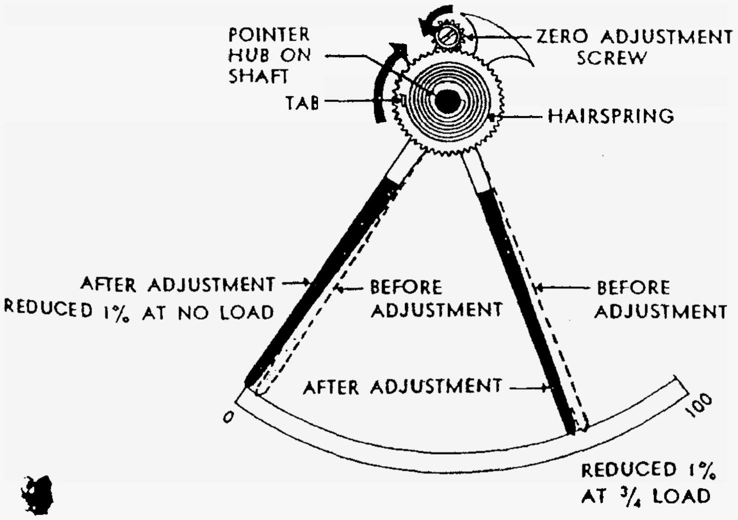


Figure C-35

The excellent field accuracy of thermal meters is, in part, a result of the simplicity of design (only one moving part). Careful selection, matching, and aging of the bimetal coils are other factors of prime importance. Compensation for fluctuations of ambient temperatures (sun shield, enclosure design, deflection adjustment) give stable accuracy in all installations.

Adjustments

Figure C-36 | ZERO ADJUSTMENT DIAGRAM



On Lincoln combination demand meters, there are only two adjustments affecting the demand meter. Both are easily accessible from the front of the meter and are made with a screwdriver.

The zero adjustment consists of a light, spiral hairspring attached to the shaft of the pusher pointer (Figure C-36). Rotating the zero adjustment screw adds to or subtracts from the deflection position of the pusher pointer. It affects the pointer deflection equally all along the scale and its action is independent of the pusher pointer position. For example, if it is adjusted to reduce the no load (zero) position by one per cent, it also reduces the full load indication by one per cent. For this reason, the zero adjustment should always be made before the deflection adjustment.

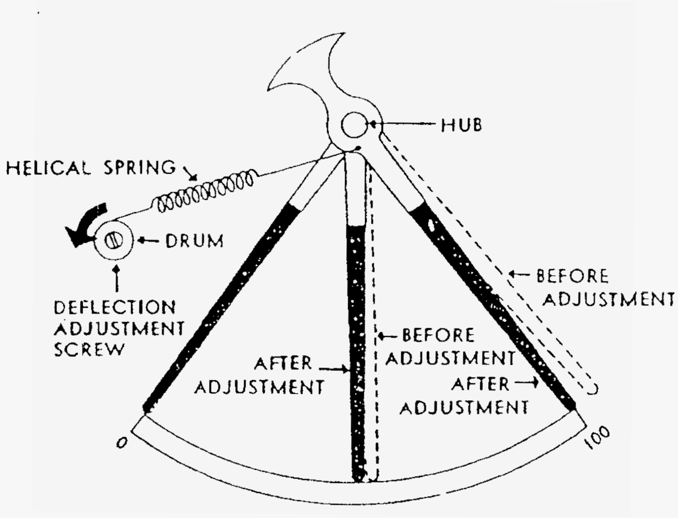


Figure C-37 | DEFLECTION ADJUSTMENT DRAWING

The deflection adjustment consists of a spring attached to the pusher pointer (Figure C-37). The amount of torque exerted on the pusher pointer is proportional to the scale position of the pointer. At zero indication no torque is exerted; but as the load increases, torque is exerted approximately proportional to the deflection position. For example, if the deflection adjustment is operated to reduce full scale indication by two per cent, then the indication at half load is reduced by two per cent of the reading, or one per cent of full scale.

Testing and maintenance

Periodic tests of Lincoln demand meters can coincide with the normal test periods of kilowatthour meters. This sustained accuracy is the result of the inherent design and the fact that thermal meters have only one moving part.

Thermal meters can be tested in either the shop or the field. However, for economical reasons the most practical method is to gang-test them at a central location. This is because of the time involved in producing actual loading conditions for pusher pointer deflection. Deflection of the pusher pointer cannot be checked by mechanical means.

When gang-testing is employed (Figure C-38), the meters should be left in the test room and on potential for a minimum of two hours. The current circuit is disconnected and the meter covers should be in place, simulating no load conditions. After this warming period on potential only, the zero adjustment of the pusher pointer can be made (Figure C-39).

Full scale indication can be checked during gang-testing by two different methods. One is to use a graphic or indicating meter which has been carefully calibrated as the standard meter. The meters to be tested are connected in series with the standard meter and a load of 3/4 scale or higher applied. After three intervals, the maximum indications are compared. A second method is to control the load at the above level by means of an automatic load holder. Here again adjustment is made after three intervals (Figure C-40).

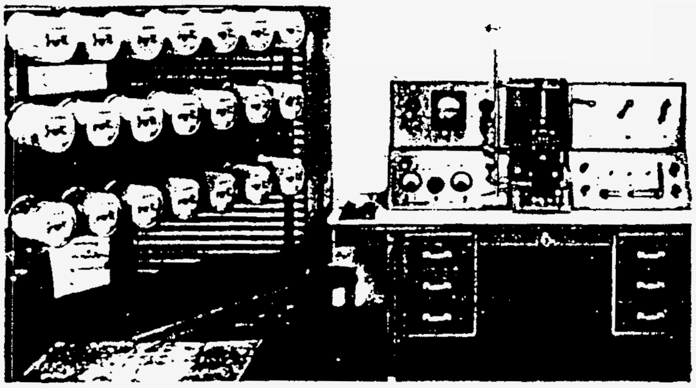


Figure C-38 | THERMAL METERS ON GANG-TEST BOARD

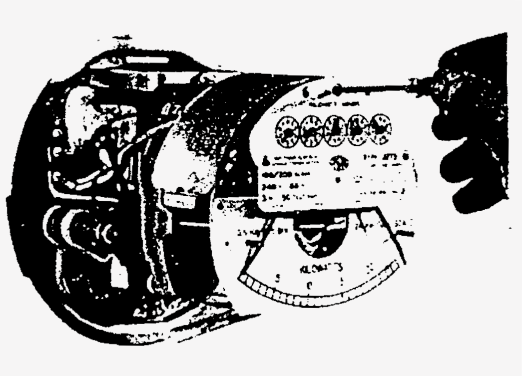


Figure C-39 | ZERO ADJUSTMENT

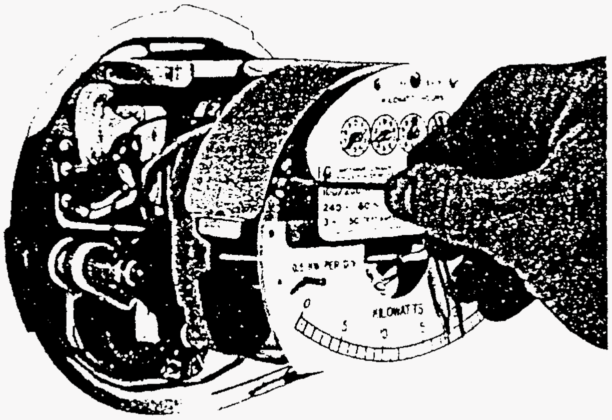


Figure C-40 | DEFLECTION ADJUSTMENT

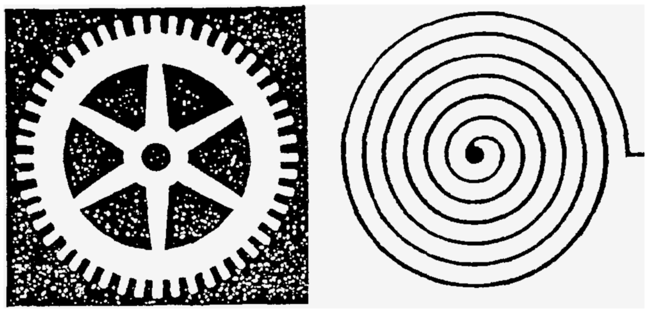
Other methods can be used to field test thermal meters. These methods can also be used in shop testing, but the testing cost per meter is not as economical as when large groups are gang-tested. These field tests can be accomplished as follows:

1. Put a specially-calibrated meter of the same capacity in series with the meter under test and allow it to remain long enough to compare the maximum demand readings.
2. Use an indicating wattmeter and controlled phantom or resistance load. The load must be held steady during the third time interval.
3. With a stop watch, time the speed of the kwh meter disk or a rotating standard at frequent intervals. The average load can then be calculated and it should closely correspond to the indication of the pusher pointer.

When testing from a no load condition, it is recommended that more than one interval should be used before accuracy is checked. For example, with a 15 minute interval meter, the pusher pointer indication 15 minutes after a steady load has been applied, should not be multiplied by $\frac{10}{9}$ and checked with the value of the steady load.

Since the only moving part, the bimetal shaft, moves slowly on polished stainless steel pivots, no lubrication is required on any part of the thermal meter. The bimetal coils will remain stable indefinitely because of the aging processes performed before they are assembled in the meter. The heating elements are precisely matched during manufacture and do not require further attention.

The maximum demand pointer clutch is the only component that requires inspection during the life of the meter. The action of the clutch should be checked during periodic tests. Clutch action can be checked by moving the maximum demand pointer to one or more positions on the scale. Balance of the maximum demand pointer is correct when the pointer remains stationary at all check points. Sufficient holding torque is present if the pointer will not move when the meter is subjected to external vibration or shock (tapping the cover). If the clutch does not have a sufficient amount of silicone compound, it should be cleaned and renewed according to factory instructions with compound specified by the manufacturer.



Questions and answers

The previous sections have explained the theory of operation and the construction of mechanical demand registers and thermal demand meters. There are a number of questions that arise regarding a direct comparison of the two instruments. This section is intended to give frank answers to some of the most frequently encountered questions.

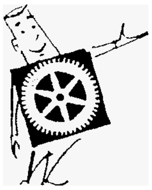
1. HOW CAN THE POPULARITY OF SINGLEPHASE THERMAL DEMAND METERS BE EXPLAINED?

ANSWER: Sales of singlephase thermal demand meters are approximately 3 to 1 over mechanical demand registers because there is little or no price differential, and the thermal demand meter offers:

1. Service reliability and minimum maintenance (only one moving part).
2. Sustained accuracy to permit the demand portion to be tested only when the watthour meter would normally be tested.
3. Dual Range feature for load growth.

2. HOW CAN THE POPULARITY OF POLYPHASE MECHANICAL DEMAND REGISTERS BE EXPLAINED?

ANSWER: Sales of polyphase mechanical demand registers are approximately 3 to 1 over thermal demand meters because there is a slight price advantage in favor of the mechanical demand registers, and because:



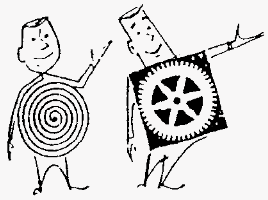
1. The "theoretical" accuracy advantage is considered worthwhile by some utilities for large loads.

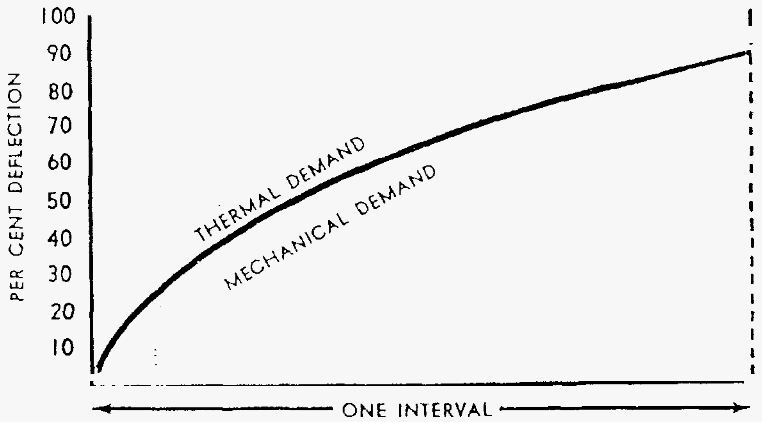
2. Periodic installation tests are required on polyphase services more frequently than on singlephase services and the mechanical demand register easier to test in the field.

3. **IS THERE A DIFFERENCE IN INDICATION OF THE TWO INSTRUMENTS FOR SHORT DURATION LOADS?**

ANSWER: Yes, as shown in the response curves of Figure D-1, the thermal meter will read higher for loads of a duration less than approximately 80% of the rated time interval. Some utilities feel that the higher reading for short interval loads is justified. This *special case* would rarely occur at the time of maximum demand.

Figure D-1 | MECHANICAL AND THERMAL RESPONSE CURVES

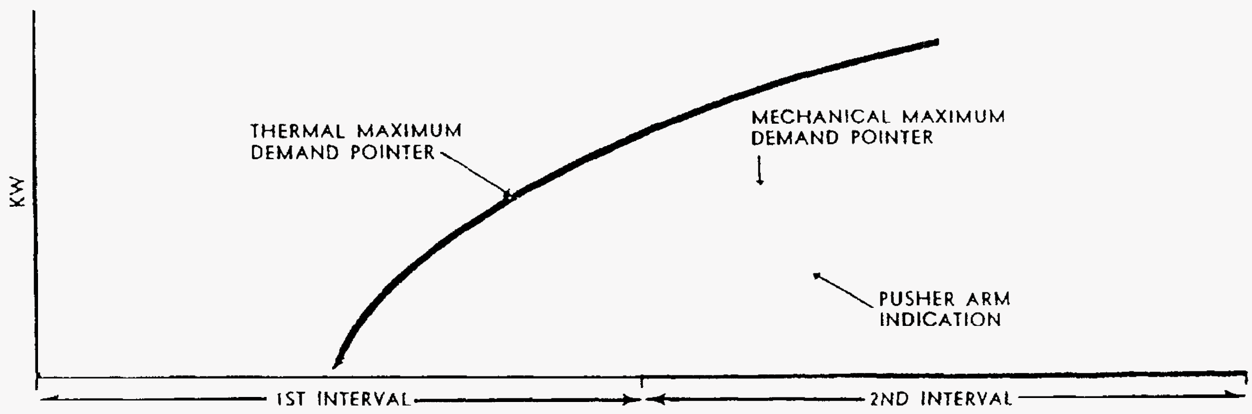


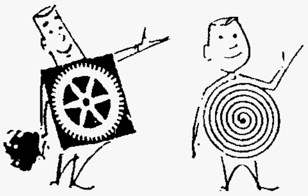


4. **WHAT IS PEAK SPLITTING AND HOW DOES IT AFFECT THE INDICATION OF THERMAL AND MECHANICAL DEMAND INSTRUMENTS?**

ANSWER: Peak splitting may best be defined by the following illustration (Figure D-2):

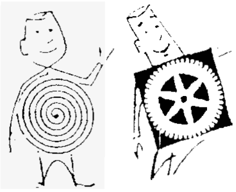
Figure D-2 | PEAK SPLITTING





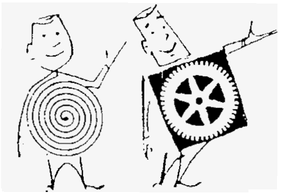
It can be seen from the above drawing that the load was applied when the mechanical demand register was half way through the reset cycle of the first interval. The load was then removed at the middle of the second interval and as a result, the demand indicated was only one half of the maximum load. The thermal demand meter is not affected by peak splitting because its interval starts when a change of load is applied. Therefore, in the above example, the thermal demand meter indicates 90% of the load, while the mechanical demand register indicates 50% due to peak splitting.

5. DOES PEAK SPLITTING INTRODUCE AN ERROR IN THE CUSTOMER'S MAXIMUM DEMAND?



ANSWER: No, it does not. During the average billing period of one month there are 2,880 fifteen minute demand intervals. The likelihood that all the load changes will occur in the middle of an interval or that the maximum load will remain on for less than 15 minutes is extremely improbable. Extensive field tests by utilities verify the fact that both thermal and mechanical demand meters indicate the average maximum load during the billing period.

6. ARE SPECIAL DEMAND METERING PRACTICES USED ON CUSTOMERS WHO VARY THEIR LOADS TO TAKE ADVANTAGE OF PEAK SPLITTING?



ANSWER: There are two schools of thought on this question. Some utilities feel that the customer can control his load in any manner and that he shouldn't be billed for any more than the demand meter indicates. Those utilities who want to bill on the actual maximum demand during any billing period can try altering the reset time of a mechanical demand register at the beginning of each billing period and also remove the interval pointer. One foolproof method of preventing a customer from taking advantage of peak splitting is to use a thermal demand meter, since it continuously averages the load and does not reset.

7. RECENT ADVERTISEMENTS HAVE SUGGESTED THAT THERMAL DEMAND METERS ARE LESS ACCURATE THAN MECHANICAL DEMAND REGISTERS SINCE THEY ONLY INDICATE 90% OF THE AVERAGE DEMAND DURING THE TIME INTERVAL. IS THIS TRUE?

ANSWER: No! The inherent response has little or nothing to do with the accuracy of demand billing. In order to make the mechanical demand register accuracy look better than the thermal demand meter accuracy, the following curves have been shown (Figure D-3):

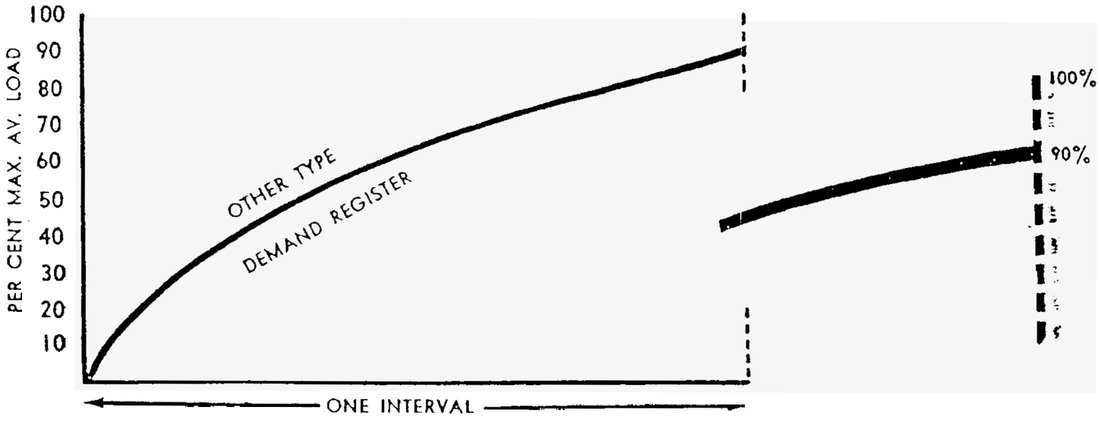


Figure D-3 | A SPECIAL CASE TO FAVOR MECHANICAL DEMAND REGISTERS

Obviously, the "other type" is the thermal demand meter. This is a *very special case* and does not present a factual comparison of the two meters. Those who use the above illustration certainly must realize that the mathematical possibility of such a condition occurring is as remote as the possibility of having the reset operation occur in the middle of the interval. (**Figure** D-4).

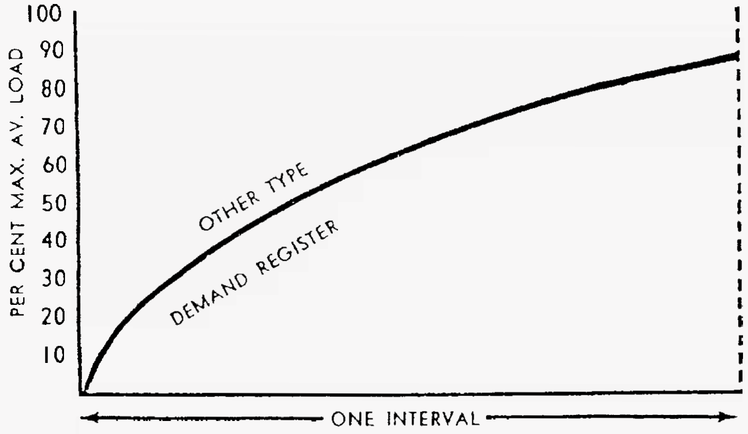
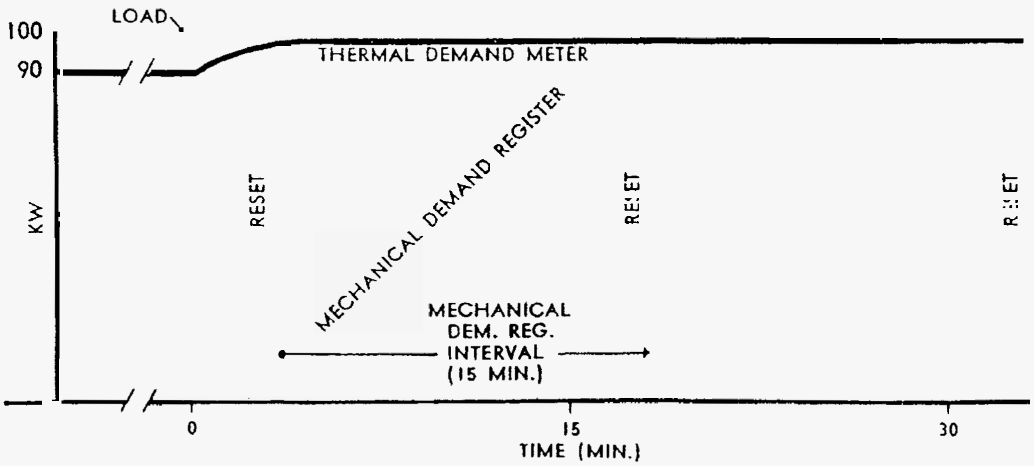


Figure D-4 A SPECIAL CASE TO FAVOR THERMAL DEMAND REGISTERS

This second *very special case* would show the thermal demand meter indicating 90% at the end of the first interval, while the mechanical demand register is indicating only 50%. This is also an unfair comparison. In actual practice neither of these special cases occurs continually during the billing period. For an objective comparison of the two meters, the following *actual* conditions must be considered:

1. The maximum load is nearly always on the line longer than the duration of a single demand interval.
2. The maximum load is reached a number of times during the billing period.
3. The maximum load is not suddenly thrown on the line. Maximum demands are created by the load increasing from one level to a higher level. The two instruments can be more objectively compared by the following example (Figure D-5) where the load increases from 90 to 100 kw and remains at that level for more than one interval.

Figure D-5 RESPONSE TO ACTUAL LOAD CONDITIONS

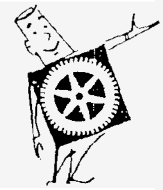


During the first 15 miuntes the maximum demand pointer of the mechanical demand register could be indicating any value from 90 to 100 kw. The value would depend on when the pusher arm reset. However, since the load was applied for at least 30 minutes (two intervals), the maximum demand pointer would indicate 100 kw at the end of the second interval.

The thermal demand meter pusher pointer and maximum demand pointer were indicating 90 kw when the load was increased to 100 kw. Since the thermal demand meter inherently responds to 90% of the change in load during an interval, the pusher pointer would be indicating 99 kw at the end of the first 15 minutes. During the next 15 minutes the thermal demand meter would respond to 90% of the difference between the indication and the maximum load. Consequently, the thermal demand meter would be indicating 99.9 kw at the end of 30 minutes.

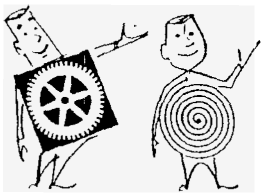
Since it is impossible to read an indicating instrument of this type any closer than 1/10 of 1%, the mechanical demand register and thermal demand meter are indicating the same value or the average maximum load. From this example, it can be seen that either instrument will accurately measure the maximum average load during a billing period.

8. IT HAS BEEN FREQUENTLY STATED THAT THE ACCURACY OF THE MECHANICAL DEMAND REGISTER IS COMPARABLE WITH THE WATTHOUR METER ITSELF SINCE THE DEMAND INDICATION IS OBTAINED BY DIRECT GEAR DRIVE FROM THE METER DISK SPINDLE. IS THIS TRUE?



ANSWER: Not altogether. As previously explained the accuracy of these instruments is expressed in percent of full scale. Even if the watthour meter is in perfect calibration, the error of a mechanical demand register which has 1% full scale accuracy can be ±4% of the load at quarter scale. Although the mechanical demand register does count disk revolutions, it is not correct to state that the accuracy is due to this direct gearing. The rated accuracy of a mechanical demand register is determined by the eccentricity of the pointer hub with respect to the arc of the scale, the time required for resetting, and possible backlash in the gearing. Sangamo's precisely manufactured D registers are rated at ±1% of full scale.

9. HOW DO THE TWO INSTRUMENTS COMPARE WITH REGARD TO READING ERRORS?

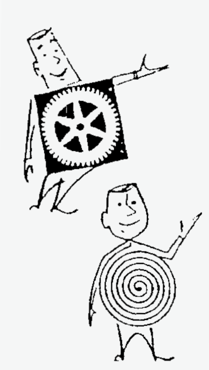


ANSWER: The mechanical demand register has a scale length approximately twice that of a thermal demand meter, and accordingly may be read more closely. As an example, a 24 kw mechanical demand register would have 120 divisions of 0.2 kw per division, whereas a 24 kw thermal demand meter would have 48 divisions of 0.5 kw per division.

On the other hand, the thermal demand scale covers a smaller arc and is nearly horizontal for easy reading. Lincoln combination meters have the demand scale so located that the demand pointers do not interfere with the reading of the kilowatthour dials.

10. IS THE MECHANICAL DEMAND REGISTER MORE ACCURATE THAN THE THERMAL DEMAND METER?

ANSWER: This question can be more easily answered by considering both the "theoretical accuracy" and the "field accuracy" of mechanical demand registers and thermal demand meters. The Sangamo Type D register and the Lincoln thermal meter are factory calibrated to 1% of full scale. However, there is a slight advantage in favor of the mechanical demand register in considering the theoretical accuracy of the instruments when both have been carefully designed and are functioning properly. When the watthour meter is correctly calibrated, it is easier to maintain the accuracy of the mechanical demand register under laboratory conditions. The difference in the theoretical accuracy of the two types of demand meters is a matter of a few tenths of a percent. The human elements involved in reading make it very difficult to verify this slight difference in theoretical accuracy.



Field accuracy on the other hand concerns the overall accuracy in billing the customer. This billing, of course, must be accomplished under all climatic conditions for extended periods of time. Each of these instruments has its advantages and disadvantages for producing long range accuracy. Some of these advantages and disadvantages are pointed out elsewhere, but the net result is that *the all important "field accuracy" of the two instruments is comparable.*

11. WHAT ARE THE FACTORS THAT AFFECT THE LONG RANGE "FIELD ACCURACY" OF MECHANICAL DEMAND REGISTERS AND THERMAL DEMAND METERS?

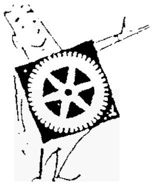
ANSWER:

1. The failure rate (see question 17) has a great effect on the average accuracy of demand billing.
2. Too little holding torque in the maximum demand pointer of either instrument would result in the possibility of errors from vibration.
3. Power outages can affect the timing of polyphase mechanical demand registers. If there is a temporary failure of one of the three phases serving a customer, and the timing motor is connected across that phase, the timing motor stops and the pusher arm continues up scale until the motor is reenergized and calls for resetting. With an outage of this type, the demand indication will be high or off scale. This cannot happen with a thermal demand meter since it continually averages the load and is independent of the watthour meter.
4. Direct sun and temperature changes can cause an error in a thermal demand meter if the bimetal coils are not carefully matched. They must also be shielded so that there is no ambient temperature gradient between the two bimetals. Lincoln combination demand meters are designed with a metal shield as a part of the register. For this reason the Lincoln meter can utilize a clear glass cover and avoid the possibility of paint flaking from a painted cover.

   A considerable amount of error can be introduced into the demand register if the timing motor has not been designed to withstand extremes in temperature without slowing down (and giving a high demand).
5. Reading errors limit the "field accuracy" of both instruments.
6. The maximum demand indication of both instruments must be above half scale to take advantage of the accuracy ratings.

Long range performance and sustained accuracy of both mechanical demand registers and thermal demand meters depend upon the quality built into them through design, engineering, and care in the manufacture.

2. IS THERE AN ERROR INTRODUCED BY THE TIME REQUIRED FOR RESETTING OF THE MECHANICAL DEMAND REGISTER?

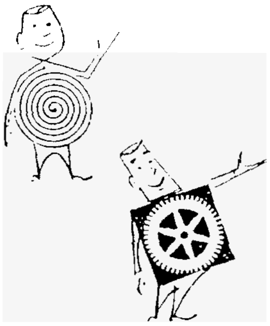


ANSWER: The time required to reset the D register is only 1.5 to 4.5 seconds for a 15 minute interval register and this minor error is included in the overall rating of ±1.0% full scale for the instrument.

HOW DOES TESTING TIME COMPARE FOR THE TWO TYPES OF INSTRUMENTS?

ANSWER: This question should be answered on the basis of field testing and shop testing, and will depend to a great extent on the methods employed by the tester.

In general, less time is required to test a mechanical demand register in the field. It is usually only necessary to utilize a register checker, or to run the register up scale knowing the pusher arm ratio, and then to observe the resetting operation after the meter has been reinstalled. It is also advisable to check the speed of the timing motor.



The time required for field test of the thermal demand meter varies greatly because of the different approaches to testing of these meters. One possible scheme where a customer's load is steady or where a steady phantom load can be used is to count the disk revolutions of the watthour meter (or to observe a portable wattmeter). This observation of the load should be continued for approximately 15 minutes (or the interval of the meter). The scale reading can then be checked. A comparison method utilizing a standard thermal demand meter would require more time since the meters must reach full load indication.

Shop testing is usually accomplished through gang-testing because it is more economical than testing either type of instrument individually. When tested individually, the mechanical demand register does require less time for calibration; however, when gang-testing is employed there is relatively little difference in the time required for the two instruments. The test equipment and procedures can vary in complexity with different companies and therefore it is difficult to compare testing time. If the two instruments are to be gang-tested, the cost of the equipment required is approximately the same.

14. CAN DEMAND METERS BE SAMPLE TESTED AS RECEIVED FROM THE MANUFACTURER?

ANSWER: Yes. One large utility with approximately 50,000 demand meters in service has found that it can rely on sampling 10% of the singlephase and polyphase Lincoln demand meters received.

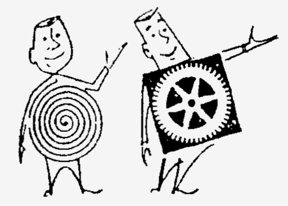
15. DOES THE TYPE OF DEMAND INSTRUMENT AFFECT THE DETERMINATION OF PERIODIC TEST INTERVALS?

ANSWER: Periodic test intervals for demand instruments are determined primarily by utility commissions and individual utility practices. The type of customer and size of load are more important considerations in determining periodic test intervals than the type of demand instrument.

Thermal demand meters are sometimes assigned longer periodic test intervals, but this may be due, in part, to the fact that they are more frequently used on singlephase services.

Either demand instrument can fit into the trend toward longer periodic test intervals—especially if an inspection is scheduled between tests.

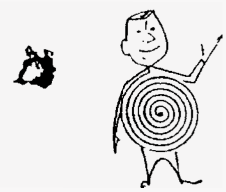
16. HOW FREQUENTLY SHOULD MECHANICAL AND THERMAL GRAPHIC DEMAND METERS BE TESTED?



ANSWER: As explained in #15, the test interval depends on type of service, size of load, and regulations. Because they are employed on larger loads, graphic demand meters are usually tested more frequently than indicating demand meters. Checks can be made on these meters in between periodic test as follows: The mechanical graphic demand meters can employ a counter as a check against the kwhr register on the number of contacts received during the billing period.

The chart of a thermal graphic demand meter can be integrated with a radial planimeter and the calculated kwhr value compared with the kwhrs indicated on the integrating meter. This can be done quite accurately (within ±2%) when the load has not rapidly fluctuated.

17. WHAT FAILURE RATE AND MAINTENANCE COST HAS BEEN EXPERIENCED ON THERMAL AND MECHANICAL DEMAND INSTRUMENTS?



ANSWER: Utility experience indicates that maintenance costs will be much lower on thermal demand meters. One company with over 30,000 demand meters in service, including both demand registers and thermal demand meters, reported that the failure rate of Lincoln demand meters was only 0.3% per year compared with 1.3%, 4.0% and 12.5% per year on various makes and models of demand registers. Obviously, a failure of either demand meter results in an error of many times the accuracy ratings of the instruments.

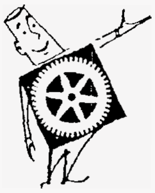
Cost of a complete overhaul and test of the two instruments is approximately the same, but experience indicates that because of the inherent design there is less likelihood of a thermal demand meter requiring a complete overhaul.

18. IT HAS BEEN STATED THAT THE MECHANICAL DEMAND REGISTER HAS AN ADVANTAGE OVER THE THERMAL DEMAND METER IN THAT IT "FAILS SAFE". IS THIS TRUE?

ANSWER: It is true that in many instances a failure of the motor in a mechanical demand register will result in a "zero" or "off scale" reading. However, failure of other components, such as reset mechanism, gearing and maximum demand pointer, to operate properly does not necessarily cause the demand register to "fail safe." It is also possible for some timing motors to lose synchronism and run slower than synchronous speed (older types could run faster), causing a higher reading because of the longer interval. This slowdown is highly improbable with the H motor because of its inherent high torque.

A thermal meter could also be described as failing safe, in that if lightning were to knock out a potential or current transformer, a very large error would result. This would enable the billing department to recognize the discrepancy between the total kilowatthours consumed and the erroneous demand indicated. On the other hand, with the mechanical demand register, if potential element of the meter fails, both kilowatthours and the demand indication will be off and the billing department might interpret this as a change in customer load.

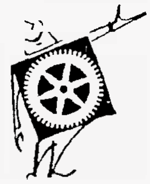
19. WHAT IS THE EXPECTED LIFE OF A DEMAND REGISTER MOTOR?



ANSWER: One manufacturer recently answered this question in the following way: "Experience indicates that the expected life of the timing motor is usually about ten years. The motor is easily removed by loosening two mounting screws and disconnecting two leads."

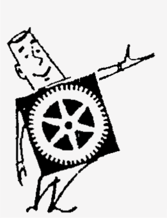
On the other hand, the Type H motor, which is the heart of Sangamo's Type D register, doesn't even require relubrication for a period of at least ten years, and its life expectancy is comparable to that of the watthour meter.

20. ARE THERE ANY SAVINGS IN INVENTORY THROUGH THE USE OF MECHANICAL DEMAND REGISTERS?



ANSWER: Yes, but this depends to a great extent on the standards of individual utilities. Universal demand registers which offer interchangeability between meters of different service ratings would reduce inventory needs. Universal registers would be more popular except for the problem of handling odd multipliers in the meter and billing departments.

21. WHAT BURDEN IS IMPOSED ON INSTRUMENT TRANSFORMERS BY THESE TWO INSTRUMENTS?

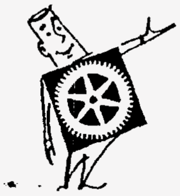


ANSWER: Obviously, the demand register itself imposes no extra burden on a current transformer. The additional burden on one phase of a potential transformer from the Type H Demand Register motor is 4.2 V.A. and 2.3 watts for all voltage ratings.

Because Lincoln combination meters include independent thermal meter elements and transformers, an additional burden is imposed on the instrument transformer. On a class 10, 2.5 amps, 120 V 2-wire singlephase kwh meter, at rated load, burden in the current coil circuit is 0.70 V.A. and 0.26 watt, while potential burden is 7.5 V.A. and 1.0 watt. On the same rated combination kwh-kw Lincoln meter current burden is 0.86 V.A. and 0.60 watt, while potential burden is 8.9 V.A. and 3.1 watts. The small additional burden in a combination meter is well within the burden characteristics of miniature current and potential transformers. Combination thermal meters can be used along with other measuring instruments without overtaxing the instrument transformer.

22. CAN BOTH MECHANICAL AND THERMAL INSTRUMENTS BE UTILIZED FOR MEASUREMENT OF KVAR AND KVA DEMAND?

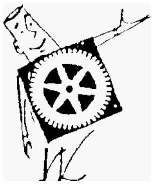
ANSWER: Thermal demand meters have been utilized for direct measurement of kvar and kva demand for many years. The meters are completely self-contained for both singlephase and polyphase measurement of these values. Lincoln meters of this type offer independent measurement of demand and energy in one package.



Kva and kvar demand measurement can also be obtained through mechanical demand registers, although many manufacturers' watthour meters require an external phase shifting transformer. However, Sangamo has designed self-contained polyphase kva-hour and kvar-hour meters which eliminate external phase shift transformers. Type D mechanical demand registers or contact operated instruments can be used with these meters to measure kva and kvar demand.

When a mechanical demand register installation requires either kva or kvar demand *and kwh measurement*, a separate meter must be used to obtain the kwh. The same installation can be metered with one combination thermal meter, which provides both kva or kvar demand *and* kwh measurement.

23. WHAT FEATURES OF BOTH INSTRUMENTS PERMIT MEASUREMENT OF GROWING LOADS WITHOUT CHANGING OUT THE COMPLETE METER?



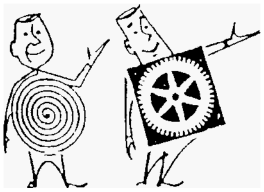
ANSWER: The mechanical demand register offers the flexibility of field removal and replacement with a register of higher kw rating. In addition to providing extra capacity, this change-out feature of registers enables the maximum demand to be maintained in the upper one-half of the scale. No recalibration is needed with this register change.

Thermal demand meters are available with a dual range feature that is easily changed in the field. This feature provides extra demand measurement capacity and better accuracy by keeping the demand reading in the upper half of the scale as loads increase. Again, recalibration is not necessary on Lincoln meters with a range change.

The time to make the change for either type of instrument is approximately the same.

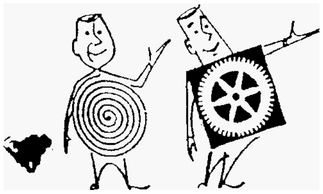
24. IT HAS BEEN STATED THAT THE DRIVING TORQUE IS HIGHEST AT TIME OF MAXIMUM LOAD FOR A MECHANICAL DEMAND REGISTER, AND THAT IT IS LOWEST AT TIME OF MAXIMUM LOAD FOR A THERMAL DEMAND METER. IS THIS TRUE?

ANSWER: **No.** This statement is apparently the result of confusing the driving torque of a meter with the torque required to move the demand pointer system. The driving torque of *either* type of demand meter is maximum at the time of maximum demand; and, in a properly designed meter of *either* type, is many times greater than the torque required to move the demand pointer.



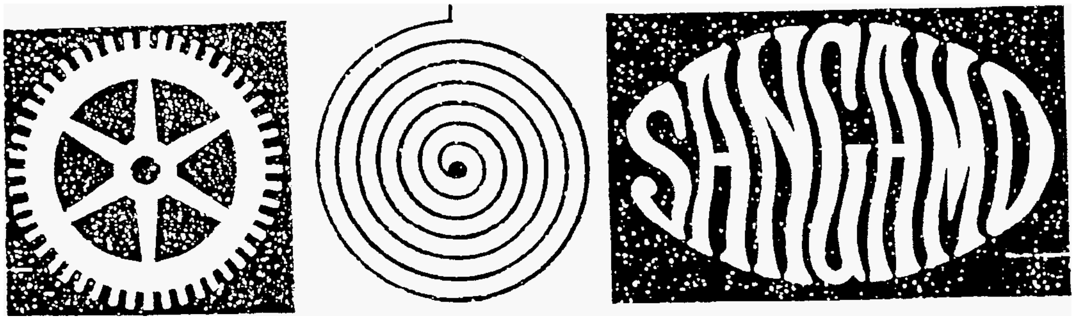
25. HOW CAN A METER DEPARTMENT DETERMINE THE MOST DESIRABLE DEMAND INSTRUMENT FOR THESE PARTICULAR APPLICATIONS?

ANSWER: Consideration should be given to the applicable rate, test schedules, operating problems, and operating practices which all affect the economics of meter selection.



Although these questions and answers have dealt primarily with the comparison between mechanical and thermal demand instruments, an evaluation of two makes of the same basic type of instrument might reveal as many variations as a comparison of two basic types of instruments (thermal and mechanical).

SANGAMO
ELECTRIC
COMPANY



SPRINGFIELD, ILLINOIS

Jim DeMars
09/24/02 04:43 PM

To: Magda Rothman/CS/FPL@FPL, Cathy Carpenter/CS/FPL@FPL
cc:
Subject: kWh vs. kWd Billing

Okay! After much research and discussion here is the "official" Meter Engineering response to the question:
"Can a demand meter register zero kWh but register kWd?"

If the meter is a thermal demand meter (first character "1" or "4"), the customer should not be billed on kWd if the kWh is zero.

The reasons are:

- The meter could just be off-zero.
- If potential is applied to the meter and there is no current flow, thermal meters have demonstrated the ability to register a little demand due to thermal heating from direct sunlight.

If the meter is electronic (first character "6", "D",), the customer should be billed on the kWd even though there does not appear to be kWh.

The reason is:

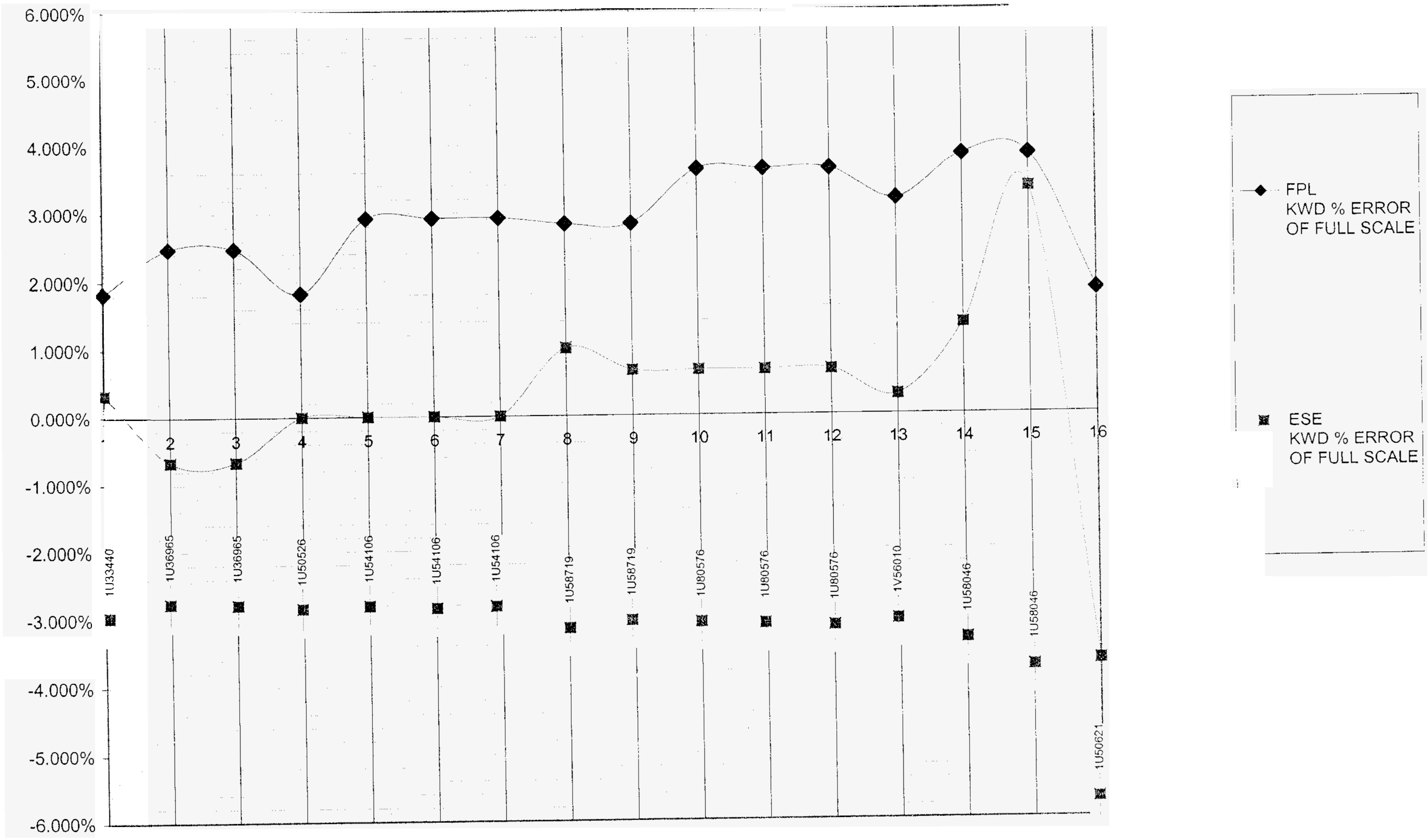
- Transformer-rated meters can have large multiplier. The smallest kWh value that can be recorded is the value of the transformer constant. Say the multiplier is 240, when the kWh reading indicated 00001, this would correspond to a billed value of 240 kWh. But the demand register has the resolution of two decimal places and it would show some value long before the kWh reached the value of "1".

We are in the process of retiring the thermal demand meters but with a population of 91,000, it is going to take a few years. When we do, then one rule will fit all applications.

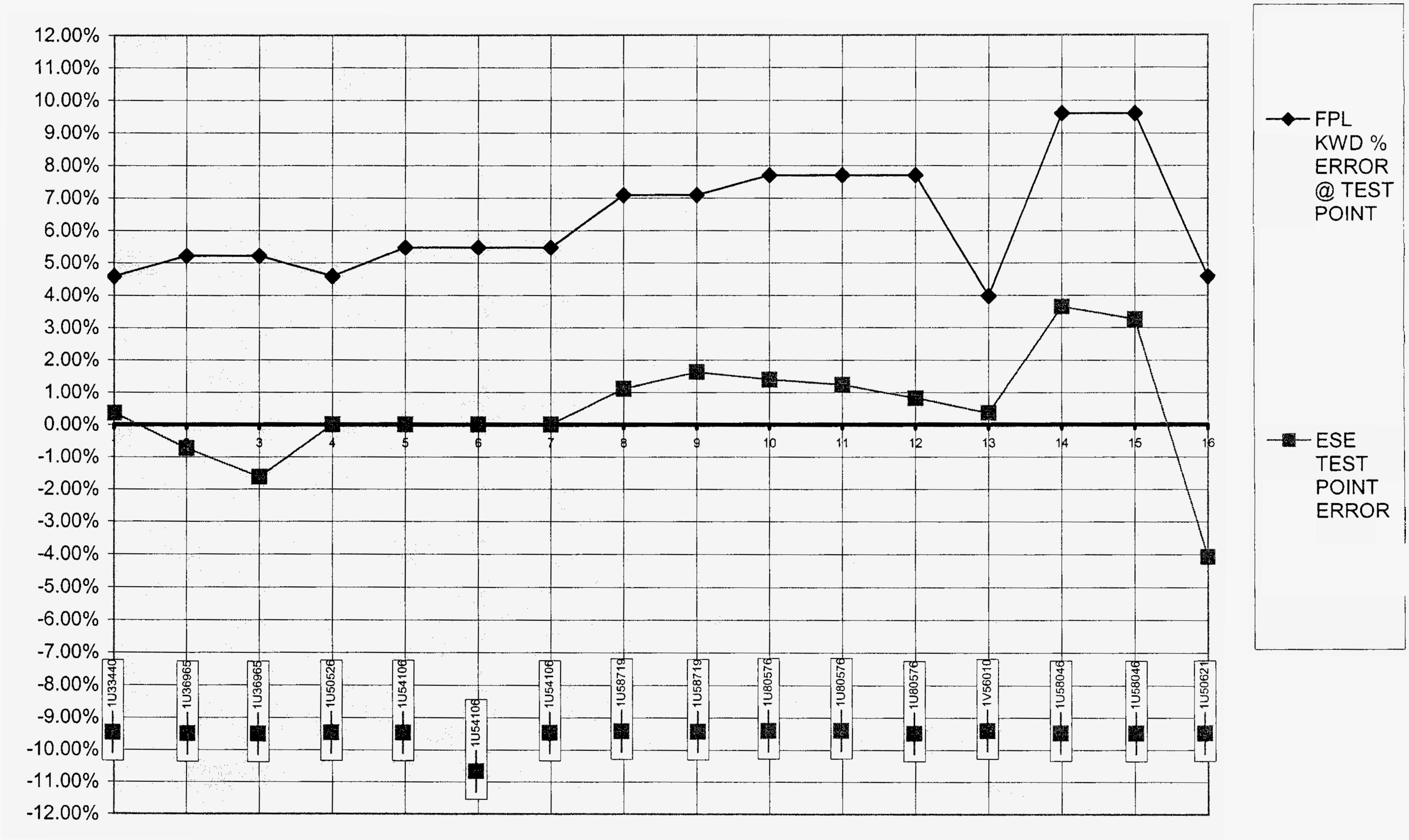
FPL--ESE TEST REPORT SUMMARY

						METER TESTING RESULTS 12-9 THRU 12-11 2003												ESE TEST REPORTING 3-29-04 THRU 3-30-04				
CUSTOMER NAME	TEST DATE	prior test date	METER #	BOARD # OF PRIOR TEST 12-2003	Full scale	STANDARD READING	standard conversion factor	AMPS	STANDARD CONVERSION X .0288	KWD READING	% OF FULL SCALE	KWD % ERROR OF FULL SCALE	FPL KWD % ERROR @ TEST POINT	24 MO AVG CUST KWD RDG	KWH-% WA		APPLIED TEST AMPS APPX.	Standard Reading Mar 29-30 2004	% OF FULL SCALE	MUT Mar 29-30 2004 KWD Reading	KWD % ERROR OF FULL SCALE	Change
CHATEAULEAU INN ONE INC	12/10/2003	6/8/1989	1U80576	4	1.5	24.5	0.0288	1.48	0.7056	0.76	47.04%	3.627%	7.710%	0.73	100.65	TEST ONE	1.58	0.72	48.0%	0.73	0.667%	-2.96%
	8:23:27		1U80576													TEST TWO	1.80	0.81	54.0%	0.82	0.667%	-2.96%
			1U80576													TEST THREE	2.50	1.21	80.7%	1.22	0.667%	-2.96%
WALGREEN	12/10/2003	5/7/1998	1U54106	3	1.5	27.75	0.0288	1.67	0.7992	0.843	53.28%	2.920%	5.480%	0.79	99.73	TEST ONE	1.58	0.72	48.0%	0.72	0.000%	-2.92%
	10:10:37		1U54106													TEST TWO	1.80	0.81	54.0%	0.81	0.000%	-2.92%
			1U54106													TEST THREE	2.50	1.21	80.7%	1.21	0.000%	-2.92%
PEP BOYS	12/11/2003	10/19/94	1U58046	3	3	41.5	0.0288	2.50	1.1952	1.31	39.84%	3.827%	9.605%	1.01	100.22	TEST ONE	5.80	2.74	91.3%	2.84	3.333%	-0.49%
	6:39:18		1U58046													TEST TWO	2.50	1.23	41.0%	1.27	1.333%	-2.49%
WALGREEN	12/11/2003	2/1/1993	1U58719	3	3	41.5	0.0288	2.50	1.1952	1.28	39.84%	2.827%	7.095%	0.83	100.47	TEST ONE	5.80	2.7	90.0%	2.73	1.000%	-1.83%
	9:29:51		1U58719													TEST TWO	2.50	1.23	41.0%	1.25	0.667%	-2.16%
WALGREEN	12/11/2003	1/2/1996	1U36965	4	3	49.5	0.0288	2.98	1.4256	1.5	47.52%	2.480%	5.219%	1.5	99.92	TEST ONE	5.80	2.74	91.3%	2.72	-0.667%	-3.15%
	6:37:06		1U36965													TEST TWO	2.50	1.23	41.0%	1.21	-0.667%	-3.15%
WALGREEN	12/11/2003	2/28/1995	1U50526	3	3	41.5	0.0288	2.50	1.1952	1.25	39.84%	1.827%	4.585%	0.95	99.78	TEST ONE	5.80	2.7	90.0%	2.7	0.000%	-1.83%
	9:29:51																					
WALGREEN	12/11/2003	4/29/1997	1U50621	3	3	41.5	0.0288	2.50	1.1952	1.25	39.84%	1.827%	4.585%	0.98	100.20	TEST ONE	5.75	2.7	90.0%	2.59	-3.667%	-5.49%
	9:29:51																					
WALGREEN	12/11/2003	1/1/1985	1U33440	3	3	41.5	0.0288	2.50	1.1952	1.25	39.84%	1.827%	4.585%	1.12	99.83	TEST ONE	5.80	2.74	91.3%	2.75	0.333%	-1.49%
	6:39:19																					
JC PENNEY	2/26/2003		1V56010		3.5	42	0.0664	2.5	2.7888	2.9	79.68%	3.177%	3.9874%	N/A	N/A	TEST ONE	2.50	2.79	79.7%	2.8	0.286%	-2.89%
												2.704%									0.25%	-2.66%

FPL-ESE TEST REPORTS KWD FULL SCALE % ERROR COMPARISON



FPL-ESE TEST REPORTS KWD <u>TEST POINT</u> % ERROR COMPARISON



okay?

MR. MOYLE: Well, what time is your bedtime?

I mean that's fine. Go.

We're going to be here -- well, every time I got a question you've got to go talk about whether it's privileged, it's going to be a long evening.

MR. HOFFMAN: That's an unfortunate mischaracterization of what's happened so far.

(Whereupon a recess was taken at 4:40 p.m. to 4:45 p.m., after which the following occurred:)

AFTER RECESS.

MR. MOYLE: Back on.

MR. HOFFMAN: I think we're asking about bedtimes before we broke.

MR. MOYLE: And mine is not to the wee hours.

I was asking you -- read back the last question.

(Whereupon the last question was read

by the Reporter.)

DIRECT EXAMINATION CONTINUED

BY MR. MOYLE:

Q Do you understand the question that was posed?

Do you have an answer for it?

MR. HOFFMAN: I'm going to instruct him not to answer on the basis it's attorney/client and work product privilege.

I asked him, at my request, in anticipation of some potential future litigation, to investigate what problems there might be, if any, with the standard meter, and that's what he was referring to.

My understanding is that the meters that were independently tested are not the meters that are at issue in this docket, but I still had a concern, and it was at my request that they undertake this investigation, and that's why he was reluctant to answer.

So I'm instructing him not to answer.

MR. MOYLE: You asked him to do a test with respect to the standard meter board?

MR. HOFFMAN: Uh huh, yes.

MR. MOYLE: To do what?

MR. HOFFMAN: To investigate the standard meter board, to see if there was any problems with the standard meter board.

MR. MOYLE: And you're of the belief that that's something I can't get into as it relates to our claim for refunds for meters?

MR. HOFFMAN: Yes. I'm of the belief that I'm entitled to prepare for hearing.

MR. MOYLE: Hey, Cochran, I'm sorry.

MR. HOFFMAN: And that I'm entitled to ask my client, under the context of attorney/client and work product privilege, to investigate an issue, and that is what I did here.

MR. MOYLE: Cochran.

MR. MATLOCK: Cochran still hasn't returned.

MR. MOYLE: Is the pre-hearing officer available?

MR. MATLOCK: I don't know.

MR. MOYLE: Well, how about if you try to find Cochran.

MR. MATLOCK: Okay, sir.

MR. MOYLE: Let's take a break.

I need to get this resolved.

I'm not going to be able to move my case, Ken, if you throw a cloak over the whole meter board.

MR. HOFFMAN: I understand.

My position, my first position, Jon, is, I don't even think these meters are in the docket, so I don't know why you can't move your case forward?

MR. MOYLE: The standard meter board is in the docket.

MR. HOFFMAN: Yes. I mean there can be an issue on the standard meter board, but we're talking about meters.

MR. MOYLE: I understand, but if you're telling him to investigate the standard meter board, and there's a problem with the standard meter board, and I don't get to know about that problem, then I don't know.

(Whereupon a recess was taken at 4:50 p.m. to 5:00 p.m., after which the following occurred:)

AFTER RECESS.

MR. MOYLE: Cochran, let me give you sort of a little synopsis of why we felt the need to have you here, and what Ken and I think we've managed to work out, but you're aware, I believe, about the independent test issue that occurred over in Bradenton, and then the disparity between some numbers, in an effort to have additional testing performed in Miami, right?

MR. KEATING: As I understand, just to make sure I got this right, the disparity is between some independent test results done in Bradenton, versus test results done at FPL's facility in Miami?

MR. MOYLE: Right. And anyway, I was asking some questions, and the one question I asked was, if FP&L had taken additional steps to investigate why the disparity in numbers between the Miami facility and the Bradenton facility, and what those steps were, that sort of line of questioning.

Mr. Bromley thought it might be impinging upon privilege.

He asked for a break, I gave him a

break.

He and his attorneys discussed it, and then came back in and privilege of attorney/client communication and work product was asserted with respect to that line of questioning, and at that moment, I wanted to talk to you and try to get the pre-hearing officer, because it's, from my perspective, it's a pretty critical line of questioning with respect to the integrity of the meter test board center here in Miami, and I think I have the right to ask that.

Ken interposed the objection and whatnot.

We've taken some time, and we were going to go late tonight. I think we're going to try to wrap up at about six thirty, and Ken has agreed to get with me next week with respect to exploring a way in which -- let me let him sort of take it over from there and not put words in his mouth as to what will be explored.

MR. HOFFMAN: The issue arose, Cochran, when the independent meter testing was done in Bradenton, and the results tended to show, and I don't have the sheet in front of me, that the overregistration was lower than whatever the results had shown when these meters were tested in Miami at our meter test center

Then, of course, there was some communications that Jon had with you at that time, and I think George put something in writing to the staff, reflecting concerns they had about the fact that the level of underregistration had actually diminished.

In response to that, I asked FPL to conduct an independent evaluation of our standard meter at the meter test center.

I had not specifically recalled that request, when Jon asked his question some probably twenty-five minutes ago, but it was a request that I made in early April, that FPL conduct this independent evaluation, which remains ongoing, and what I've committed to do is, to get with Jon after the deposition, next week, if possible, to see if we can work out sort of