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Lawrence Berkeley Laboratory
UNIVERSITY OF CALIFORNIA

ENERGY & ENVIRONMENT DIVISION

Presented as an On-Site Demonstration Procedure for Solid-State Fluorescent Ballast, Lawrence Berkeley Laboratory, Berkeley, CA, September 11, 1980

ON-SITE DEMONSTRATION PROCEDURE FOR SOLID-STATE FLUORESCENT BALLAST

Rudy Verderber and Oliver Morse

September 1980

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Rudy Verderber
Oliver Morse

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Lawrence Berkeley Laboratory
University of California
Berkeley, CA 94720

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Abstract

The following report was presented to plant engineers and managers who were involved in an on-site demonstration of EETech solid-state ballasts for two 40-watt T12 fluorescent lamps. The group was not aware of the current state-of-the-art solid-state ballasts and, thus, this report includes a brief review of the operating principles of solid-state fluorescent ballasts and the status of development achieved during the Lawrence Berkeley Laboratory program. The remainder of the text describes the techniques of managing and instrumenting a test area for assessing the performance of solid-state fluorescent ballasts at an occupied site.

1.1 INTRODUCTION

The EETech solid-state ballast for two 40-watt or two 35-watt T12 fluorescent lamps presently undergoing scrutiny by the demonstration participants is their most advanced design. It is the culmination of design improvements incorporated as modifications to the original units submitted to LBL more than three years ago. These design changes were made as a result of exhaustive life tests of both the ballasts and the lamps. The initial testing program identified potential problems that might become evident after many hours of operation. Therefore, we anticipate that the present electronic ballast design will operate lamps in the same safe and reliable manner as the core-coil ballasts used for the past forty years. Moreover, it will provide illumination more efficiently, and will reduce energy consumption by 20 to 25%.

2.1 PRINCIPLES OF BALLAST OPERATING

The solid-state fluorescent ballast functions essentially the same as the core-coil ballasts, i.e., it provides a high voltage to ignite the gas discharge and then limits the current through the lamp, keeping it operational. However, the solid-state ballast supplies electrical power to the lamp at a high frequency (20-30kHz). The 60Hz is converted to dc power by the use of a rectifying bridge. The dc power is then inverted to high frequency that is supplied to the lamps. Fluorescent lamps operated at high frequency convert the input electrical energy to visible light with better efficacy (at high frequency, the rate of change of the applied lamp voltage is more rapid than the recombination of the ionized gas; thus, there is virtually no ion or light decay during each cycle). In addition, the solid-state ballast can transform the input electrical power to the lamp more efficiently, since power control is accomplished with smaller high frequency components that dissipate less power than in magnetic core ballasts.

In addition to the intrinsic 20-25% energy savings, these new solid-state lighting systems offer other significant advantages:

i The flicker associated with fluorescent lamps is virtually eliminated.

ii There is no audible noise (humming).

iii The ballasts are light in weight (approximately 1 pound).

iv Less heat is generated from each fixture, reducing the building's air conditioning load.

v The lamps will have a lower lumen depreciation.

These features both contribute to the actual savings in energy and provide a more comfortable illumination that should improve productivity of the occupants.

3.1 HISTORY

The discovery that fluorescent lamps operated more efficiently at high frequency was made about 30 years ago. At that time, a small effort was made to develop centralized fluorescent lighting systems using motor-generator sets to provide higher frequency power (approximately 3000Hz). However, those systems were not cost-effective.

For the past 15 years, electronic circuits have been attempted which could provide satisfactory ballasting functions, but the component costs made these systems prohibitive for general use. In the early 1970s, two major events provided the basis for reconsidering the commercialization of electronic ballasts. First, the cost of energy increased, and it was presumed that it would continue to increase. The second factor was the adoption of electronic systems by the auto industry. This latter factor led to the price reduction of switching power transistors that are essential for solid-state ballasts.

The ballast industry had earlier concluded that the electronic ballast was still too expensive for widespread application, and little effort was expended by this group to modify their existing products. However, there were several small development organizations outside the lighting industry which believed that they could produce a cost-effective electronic ballast.

In 1976, the Department of Energy (DOE) initiated a lighting program to assist in the commercialization of energy-efficient products and concepts. Dr. Samuel Berman of the Lawrence Berkeley Laboratory became the Principal Investigator of this program. His first project was to determine the commercial viability of the solid-state fluorescent ballast.

After three years of testing and demonstrations with follow-up improvements, there was no doubt that the electronic fluorescent ballast was a viable, cost-effective, energy-efficient product ready for widespread application. Testing of the product's performance at the LBL lighting laboratory, by Independent Testing Laboratories, and by the ballast developers all confirmed the performance of the electronic ballast. The following facts summarize the present state-of-the-art of these ballasts:

- i Electronic ballasts are 20-25% more efficient than present ballasts.
- ii Electronic ballasts produce no audible noise.
- iii Electronic ballasts reduce fluorescent lamp flicker.
- iv Electronic ballasts present no safety hazard.

v Electronic ballasts have superior voltage-light regulation.

vi Electronic ballasts have excellent performance with a high line power factor.

vii Electronic ballasts are reliable.

viii Electronic ballasts do not adversely affect lamp life.

In addition to the above performance evaluation in the laboratory, the first EETech ballasts have been assessed in a real environment. In 1978, EETech ballasts were installed in an entire floor of the Pacific Gas and Electric Company (PG&E) office building in San Francisco. The floor was instrumented to carefully monitor the power consumption of the electrical lighting before and after installation of the electronic ballasts. The PG&E staff kept track of the ballast and lamp failures and were interested in determining if the new ballasts disturbed any of the office operations or occupants.

The results of this demonstration confirmed the laboratory measurements of improved efficiency (20-25%) for lamp systems operated with these electronic ballasts. The PG&E staff did not find any negative effects on office operations that included the use of communication systems, copying machines, data processors, and typewriters.

While some ballast failures did occur during the two and one-half years, it is interesting to note that none of the failures presented an electrical or fire hazard. The source of the ballast failures has been identified as being due to excess power dissipation with one lamp out of the socket. However, even with this known mode of failure, more than 300 ballasts are still in operation. The present EETech ballast has resolved this problem, making it unlikely that their ballasts will fail under this mode of operation. In concert with the PG&E demonstration, LBL ran standard lamp life tests in their lighting laboratory. Standard industrial procedures were followed, operating lamps for three hours and turning them off for 20 minutes. We had observed, early in the tests, that electrode sputtering occurred upon starting. However, we continued the life test to determine the lamp life with the initial EETech models. We have obtained lamp life as long as 12,000 hours even with the early ballast models.

The new EETech ballasts have been designed to start the fluorescent lamps by the rapid start mode (softly) in contrast to the instant start mode used by the initial ballasts. With these ballasts, we anticipate lamp life to be extended past the normal 18,000 hours; lamp life tests will be initiated soon at the LBL lighting laboratory with the latest EETech ballast to test this hypothesis. All previous tests and demonstrations have been conducted with noncommercial prototypical development ballasts. The present qualification tests are being made with EETech ballasts scheduled for production. These ballasts are presently being assessed by Underwriters Laboratory and are expected to have U/L certification. By performing as we expect (efficiently, safely, and reliably) in the 20-30 qualification sites that have been selected, the ballasts will be subjected to the first comprehensive measurements (in a variety of environments) needed to verify their commercial viability.

4.1 ON-SITE DEMONSTRATION

The evaluation of products tested in on-site demonstrations presents unique problems not present in laboratory measurements. In a laboratory, all the parameters that influence the performance of the product can be controlled or measured. The experiment can also be isolated and secured so that no unknown alterations will be introduced. An on-site demonstration must be designed and scheduled to include a large variety of operating conditions. By this flexibility, it will be possible to identify any field situation that will affect the new product being evaluated. An on-site demonstration also provides a means to observe the operation of a large number of units, allowing one to identify coherent or cooperative effects that would adversely influence the operation of the test area, including equipment and personnel.

The assimilation of all the data from laboratory testing and on-site demonstrations will permit a complete assessment of the product to be introduced into the marketplace.

4.2 SOLID-STATE BALLAST DEMONSTRATION

4.2.1 Objectives

i To compare the relative power consumption and light output of a fluorescent lighting system operated with core-coil ballasts and with EETech's electronic ballasts.

ii To keep a record of the number of ballast and lamp failures. This includes recording the time of the failure and the fixture at which it occurred.

iii To determine if the electronic ballast operation affects any of the test areas or the building operations.

4.2.2 Site Selection

The selection of the best test area should be determined by the degree of isolation and control that can be obtained, the ease of making measurements, and the attitude of the management and personnel in the test area.

4.2.2.1 Isolation and Control

We have found it best to confine the test to one area of the building--one floor; one-half of the floor; one room; a group of adjoining rooms, etc. This permits the test area to be better isolated and easier to control.

4.2.2.2 Electrical Measurements

Most buildings use 120 volts or 277 volts for lighting. Each lighting panel is subdivided into several branch circuits that can be independently switched on or off at the panel. These branch circuits are fused and, for three-phase systems, each branch is on a particular phase. A branch generally supplies power to a group of adjoining fixtures. Thus, it eases the measurement of electrical power, voltage, and current if the test areas include all the fixtures in a branch. By selecting an area that includes all the fixtures in a branch, the electrical measurement can be made at the power panel (usually in an electric closet). This minimizes any disturbance to the area occupants and permits test equipment to be permanently attached if one desires to use chart recorders for continuous monitoring.

4.2.2.3 Personnel Awareness

It is our opinion that all the area's occupants should be advised of the demonstration and its purpose and be given a general description of the events. Each occupant should be assured that this test does not pose any hazard to his or her well-being. If the test is run in secrecy and the area's occupants discover that a test is being conducted there may very well be a negative response affecting the morale of the people in the test area. We have found that informed people generally respond positively and are helpful in reporting ballast failure and the manner of failure immediately. The program should also be supported by corporate management as well as the management personnel in the test areas. We believe that, if the personnel in the test areas are unionized, the test objectives and schedule should be discussed with relevant union representatives.

If the test area's occupants or management appear hostile, we strongly suggest selecting another site.

4.2.3 <u>Preparation of the Test Site</u>

Regardless of the preparation of the selected test site, once the demonstration starts (i.e., baseline data are collected), no changes should be made in the test area.

The SITE DESCRIPTION FORM (Appendix II) should be completed as a guide to site preparation. Several choices are available for site preparation. Relamping and cleaning the fixtures and walls are the major choices (which are optional). However, if one relamps prior to the test, no measurements should be made until the new lamps have been operated for at least 100 hours. If one does elect not to clean the fixtures, care should be exercised when the electronic ballasts are installed so as not to disturb the dust, etc. If too much dust is removed during installation of the new ballasts, changes in the coefficient of utilization may occur. This could introduce errors into the interpretation of the light measurement before and after the installation.

4.2.4 Maintaining and Controlling Test Site

While there are options in the preparation of the test site, the most crucial part of the test is to control and maintain the area. Lamp failures should be recorded and replaced within a reasonably short period of time. The same type of lamp from the same manufacturer should be stocked. Note the lamp wattage, type, manufacturer, and color (cool white, warm white, etc.). We have found that the fixtures in the test can be marked with a small (1" to 2") colored tab to indicate that it is a special test fixture. A tab can also be placed in each room in the test area. These markers alert the maintenance staff that general building maintenance procedures may not be appropriate in these areas.

4.3 MEASUREMENTS

The two essential measurements in this experiment concern power and light levels. Electrical measurements should also include line voltage and current. A data report form, designed for the convenience of the demonstration staff, is shown in Appendix III. The essential data can be collected in a few minutes and the results listed on this form. A photocopy of the results should be mailed to LBL for their information.

A sample layout is also included in Appendix III. This layout represents a LBL demonstration site. Note that each fixture in the test area is indicated, showing the position at which the illumination level will be measured. We find simple schematics are very helpful to assure control of the experiment.

5.1 INSTRUMENTATION

The two essential measurements in this experiment concern power and light levels. Electrical measurements should also include line voltage and current.

5.1.1 Watt Meters; Watt Transducers

A watt meter measures the rate of flow of energy (power) by instantaneously multiplying the voltage by the current. All watt meters and transducers are very expensive. Clarke-Hess, Weston, and Yokogawa watt meters are connected as shown in Fig. 5.1.

Please note that the current terminals are connected to the neutral (white wire) side of the line for safety reasons. Also remember that the load side of an open neutral conductor can present a lethal shock hazard. The advantage of these watt meters is their 1% accuracy. The disadvantage is that only one branch can be measured at a time.

It is very important not to exceed the voltage or current ratio of a watt meter. For instance, if the current is 10x full scale and the voltage is only 5% of full scale, then the meter will read mid-scale while the current coil is being destroyed.

Watt transducers do not read out wattage directly, but convert wattage to a dc voltage or current. Fig. 5.2 shows four different types of single-phase watt transducers, labeled a through d. The transducer in Fig. 5.2(a) can measure only one branch. The other two types of transducers can measure more than one branch; however, all branches must be on the same phase.

If it is necessary to measure branches of different phases, then the watt transducer shown in Fig. 5.2(d) must be used.

The following precautions must be taken when selecting power transducers:

1. Select the correct power range. To estimate the power, multiply the number of two-lamp fixtures by 100 watts and the number of four-lamp fixtures by 200 watts.

2. Select the correct voltage range. 240-volt models usually work satisfactorily on 277 volts. Check the manufacturer's specifications carefully to see if a given 240-volt model can operate on 277 volts.

3. Once the power and voltage ranges are selected, the current range is simply P/V. Watt meters and transducers also have current ratings that must be adhered to.

4. Select the desired output. Full scale outputs of 0.1 volt, 10 volts, and 1 m.a. dc are typically available. Note the

calibration constant. Some models require an external load resistor across the output. Check carefully for this.

5. Be sure that the aperture is physically large enough for the number of conductors intended to be passed through it.

6. Some transducers require an external power source to operate the instrument. Others operate from the line voltage being measured. External power is needed only if the measured line voltage drops to very low values. Since this will not be the case during these demonstrations, select the transducer that does not need the external power source. Watt transducers are manufactured by Ohio Semitronics, American Aerospace Controls, FW Bell, and others.

PROBLEM:

A test area has been chosen which has 25 two-lamp fixtures and 25 four-lamp fixtures, and is served by two branches on the same phase of a 277-volt service. Determine the correct power transducer to be used. An Ohio Semitronics Brochure will be used for the solution. (See Appendix IV.)

SOLUTION:

1. A rough estimate of wattage can be made by multiplying 25 two-lamp fixtures by 100 watts (2500 watts) and 25 four-lamp fixtures by 200 watts (5000 watts), a total of 7500 watts. The brochure shows that the next higher rating is 12kw.

2. Since the supply voltage is 277 volts, check to see if 240-volt models can be used. The brochure states that the device can be used up to 125% of rated voltage, or 300 volts.

3. The rated current will be P/V = 12000/240 = 50 amps. Model PC5-29 is the correct model.

4. If no output option is stated, the full-scale output voltage will be 50 millivolts dc. If option "C" is selected, the full-scale output will be 10 volts dc with no external power required. The output calibration will be 10 volts out for 10kw in, or a conversion factor of 1 volt per kw. A check of output loading shows that it must only be greater than 2k. Most voltmeters' input resistances exceed this easily.

5. The area is served by two 20-amp branches. The brochure states that current sensor "C" must be used. It turns out that "C" has a current window 3/4" in diameter, which is more than adequate for two No.12 conductors. Therefore, the correct transducer is Model PC5-29A. The June, 1977 price sheet shows the cost to be $250.70. Now that the transducer has been chosen, a 0-10 dc voltmeter is necessary. Weston's

and Yokogawa's are very accurate (±1%) but are bulky and expensive. Small multimeters may or may not be accurate. There are many different sizes and shapes at various costs. Regardless of the model selected, it is advisable to calibrate it against a laboratory standard. There are probably hundreds of different brands of multimeters on the market. Radio Shack, Simpson, Heathkit, and Eico each have a dozen or so models.

5.1.2 AC Volt Meters

As is the case with dc volt meters, Weston and Yokogawa ac volt meters have ±1% accuracy, but are bulky and expensive. If one of the many readily available smaller, less expensive units is used, then it is advisable to have it calibrated. Since the line voltage is usually very nearly sinusoidal, frequency response is not a problem.

5.1.3 AC Ammeters and Transducers

The current waveform for solid-state ballasts is likely to be very non-sinusoidal. Therefore, a suitable ammeter should have a frequency response which includes the first dozen or so harmonics of the 60Hz fundamental frequency. A true r.m.s. device should be used. Again, the Weston or Yokogawa meter is excellent, but only one branch can be measured at a time. Current transducers are available, and they must be chosen carefully for true r.m.s. reading. To select a current transducer, estimate the total power consumed in the test area and divide by the line voltage. In the previous example of 7500 watts of lighting served by a 277-volt source, the total current would be 7500/277 = 27 amps. A 50-ampere current transducer will suffice. Current transducers are available from Ohio Semitronics, American Aerospace Controls, FW Bell, and others. AC ammeters are available from Radio Shack, Simpson, Heathkit, and many others.

Do not use the clamp-on ammeters for measuring non-sinusoidal currents. While clamp-ons are handy and can measure more than one branch at a time, they are all peak-sensing (only calibrated for r.m.s.) devices. For example, a 10-ampere r.m.s. sine wave has a peak value of 14.1 amperes. The clamp-on ammeter senses the 14.1 ampere peaks, and its internal circuitry divides the peak by $\sqrt{2}$ to indicate 10 amperes. If a 10-ampere r.m.s. square wave is read, the ammeter will sense the 10-ampere peak, divide by $\sqrt{2}$, and indicate only 7.07 amperes.

5.1.4 Light Meters

It is important to choose a light meter that is stable and linear. Absolute accuracy of light flux is very difficult to obtain, particularly in these types of field measurements. Although there are several different types of light detectors, we suggest the use of selenium cells or silicon photodiodes. Selenium cells are inexpensive and fairly good. Their main disadvantage is that they experience fatigue at high light levels over a long period of time. Since the light levels likely to occur in these demonstrations will not be very high, this should not be a problem. The G.E. Model 214 costs $35.00, and should do the job satisfactorily.

There seems to be no intermediate grade of light meter. The next step up is to the very best photometers, which usually are silicon photodiodes. These are very stable and very linear. In this class are the Spectra FC-200 at $600, and the Tektronix at $1200.

Whatever grade of light meter is used, it should be color-corrected, i.e., it should be corrected to account for the response of the human eye to different wavelengths of light. Also, it should be cosine-corrected if measuring footcandles or lux (metric). All the above-mentioned instruments are color-corrected and cosine-corrected.

5.1.5 Energy Measurement; Watt-hour Meters

If it is known how long the lights are on every day, it will be possible to calculate the total energy consumption from the watt meter (or watt transducer) readings. Wattage is rate of energy consumption, and watt-hours are a measure of energy.

If it is known how long the lights are on, it is advisable to measure the total energy consumption. This may be done two different ways. The first is to connect a strip chart recorder to the output of the watt transducer. The total energy can be calculated from the recording by multiplying watts times "on" hours on the chart. The other way is to install a watt-hour meter, just as the utility company does in a residence. Digital laboratory versions of watt-hour meters are also available, Ohio Semitronics manufactures a digital watt-hour meter, and residential types are made by G.E. and Westinghouse.

6.1 MEASUREMENT TECHNIQUE

The most essential thing to remember is that a scientific experiment is being conducted. One is trying to measure the change in energy consumption when a conventional ballast is replaced by a solid-state ballast. For this comparison to be valid, all other factors must be held constant when "before" and "after" measurements are made. The "before" data are called baseline data; the "after" data are called experimental data. The same instruments must be used in the same manner for both sets of data. Any replacement, recalibration, or change of conditions between baseline and experimental measurements will compromise the validity of the experiment.

6.1.1 Electrical Measurements

The same watt transducers, voltmeters, and ammeters must be used before and after the installation of the new ballasts. The instruments can be checked any time during the course of the experiment, but cannot be altered or adjusted between baseline and experimental measurements.

6.1.2 Light Measurements

The same light meter must be used in the same manner in both sets of measurements. This means that the observer must write down the exact location of the light meter, which affects the measurement. Also, all light measurements should be done at night so that daylight will not alter the readings. Of course, if an interior room with no daylight is being measured, it can be done at any time. The observer's clothes can affect meter readings by virtue of their reflectance and the observer's position.

7.1 INSTALLATION OF INSTRUMENTATION

7.1.1 Electrical

First, the test area must be chosen. Complete, accurate electrical plans of the site should be obtained. The easiest area to instrument is one that is served exclusively by one electrical branch. In such a case, one needs only to install a watt meter or a watt transducer so that only one branch conductor passes through it.

If such an area is not available, more than one branch must be monitored. If these branches all happen to be on the same phase, they can all be passed through the same transducer. The current through the transducer must be in the same direction for each branch.

If the branches are not all on the same phase, a three-phase transducer must be used (see Fig. 5.2(d)). Be careful to pass the conductors through the current transformers in the direction shown in Fig. 5.2(d). Verify the connections by switching on one branch at a time, then all the branches at once. The total reading should equal the sum of the individual readings. Do not interchange any branch or circuit breaker connections, as this may overload the branch neutral conductors. Be sure to verify the branch circuiting for <u>every</u> light fixture.

7.1.2 Light Measurements

Choose repeatable measuring positions to make the light measurements. Choose a position on someone's desk directly under the center of a light fixture. Record the exact location on the electrical plans, and write down the height of the surface being metered. This is necessary because someone could move the furniture sometime between baseline and experimental measurements. The measurements must be done at night so that daylight will not alter the light measurements.

7.1.3 Preparing for Baseline Measurements

Once the test area has been selected and branch circuitry verified for every light fixture therein, preparations for baseline measurements can be made. Since it is best to have as little change as possible between baseline and experimental measurements, clean the light fixtures and put in new lamps. After the lamps have been seasoned with 100 hours of operation, make the baseline measurements. Lamps and fixtures so seasoned are least likely to burn out or lose significant light output between baseline and experimental measurements.

7.1.4 Making Baseline Measurements

Do the measurements at night. Turn on the lights in the test area. Be sure that they are all working, and let them warm up for at least 20 minutes. Measure the branch voltage, current, and power at the panel. Then measure the light levels at the selected spots in the test area. Recheck the readings to be sure they are reasonable.

7.1.5 Changing the Ballasts

This should be done as soon as possible after the baseline measurements so that the lamps will age as little as possible, and the test area will be less likely to be altered. The installers should shut off the power when changing the ballasts. Many installers don't mind working "hot". Although it's unlikely (but not impossible) for someone to be electrocuted under these conditions, a shock could startle a man into falling from his ladder and being injured.

7.1.6 Making Experimental Measurements

Do the experimental measurements as soon as possible after the new ballasts have been installed. Failures of defective ballasts usually occur in the first few hours of operation, so be sure all lights are working when making the measurements. Make the measurements in the same manner and with the same instruments as in baseline measurements.

8.1 CALCULATIONS

8.1.1 Energy Savings

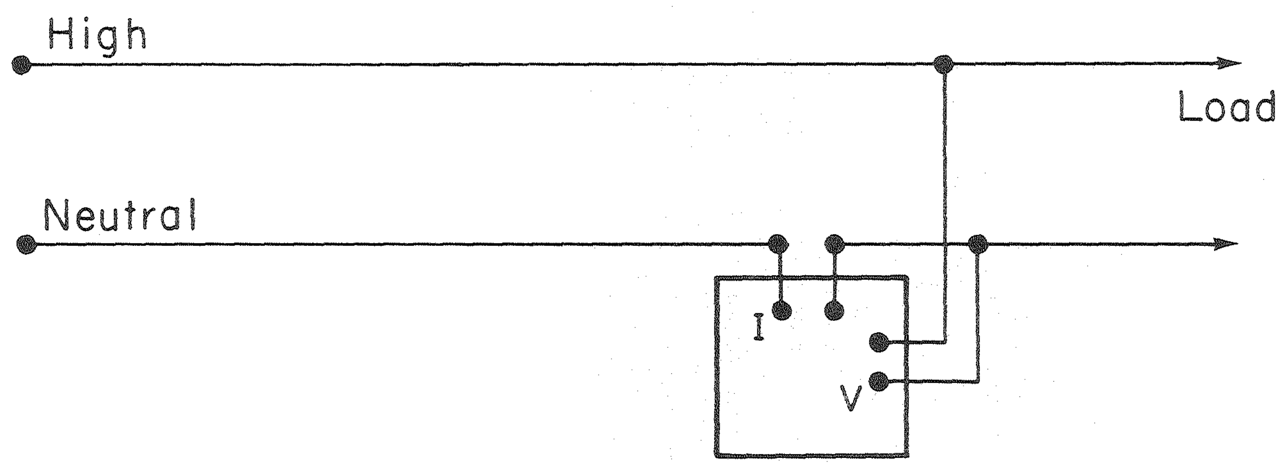
The watt transducer will give the rate of energy consumption in watts. Multiply it by the amount of time the lights are on; this will give the energy in watt-hours. The difference between experimental and baseline wattage times the number of hours per month the lights are on will give the monthly energy savings for the test area.
For instance, if the test area drew 10.0kw with conventional ballasts, and 8.0kw with solid-state ballasts, the difference would be 2kw.
If the lights are on for 14 hours daily (10 working hours and 4 for cleaning crews at night), and there are 20 working days in a month, the test area is saving 560kwh per month at $0.05 per kwh; this amounts to a monthly savings of $28.00 in the utility bill.

8.1.2 Efficacy

Efficacy of the system is light output divided by power input. The solid-state ballast can save energy by operating the lamp system more efficiently. If the original light level is maintained after the ballasts are changed, the difference in connected power reflects the improvement in system efficacy. If the light levels change after installing the new ballast, the different power measurement must be normalized in order to estimate the energy savings.

8.1.3 Power Factor

Power Factor is defined as $\frac{P}{\text{rms } V \times \text{rms } I}$. What causes the non-sinusoidal waveform? Most solid-state ballasts have a bridge rectifier followed by a filter capacitor to smooth out the rectified voltage. However, the capacitor is charged by input current spikes which have a very short duration. Some 240-watt solid-state ballasts draw 1.3 amperes versus the 0.85 ampere drawn by the conventional core ballast. The EETech ballast has special provisions to avoid this problem. The reason for excessive neutral current is that in three-phase systems the current spikes will add, and there is no cancellation. Generally, if the power factor is 0.9 or greater, there should be no problems; the EETech ballasts are designed to meet the above power factor criteria. For non-sinusoidal current or voltage waveforms, one must use the generalized expression above to determine the correct value of the power factor. In special cases, indicated by sinusoidal wave shapes, the phase angle between the current and voltage is a measure of power factor.



XBL 8010-2152

FIGURE 5.1

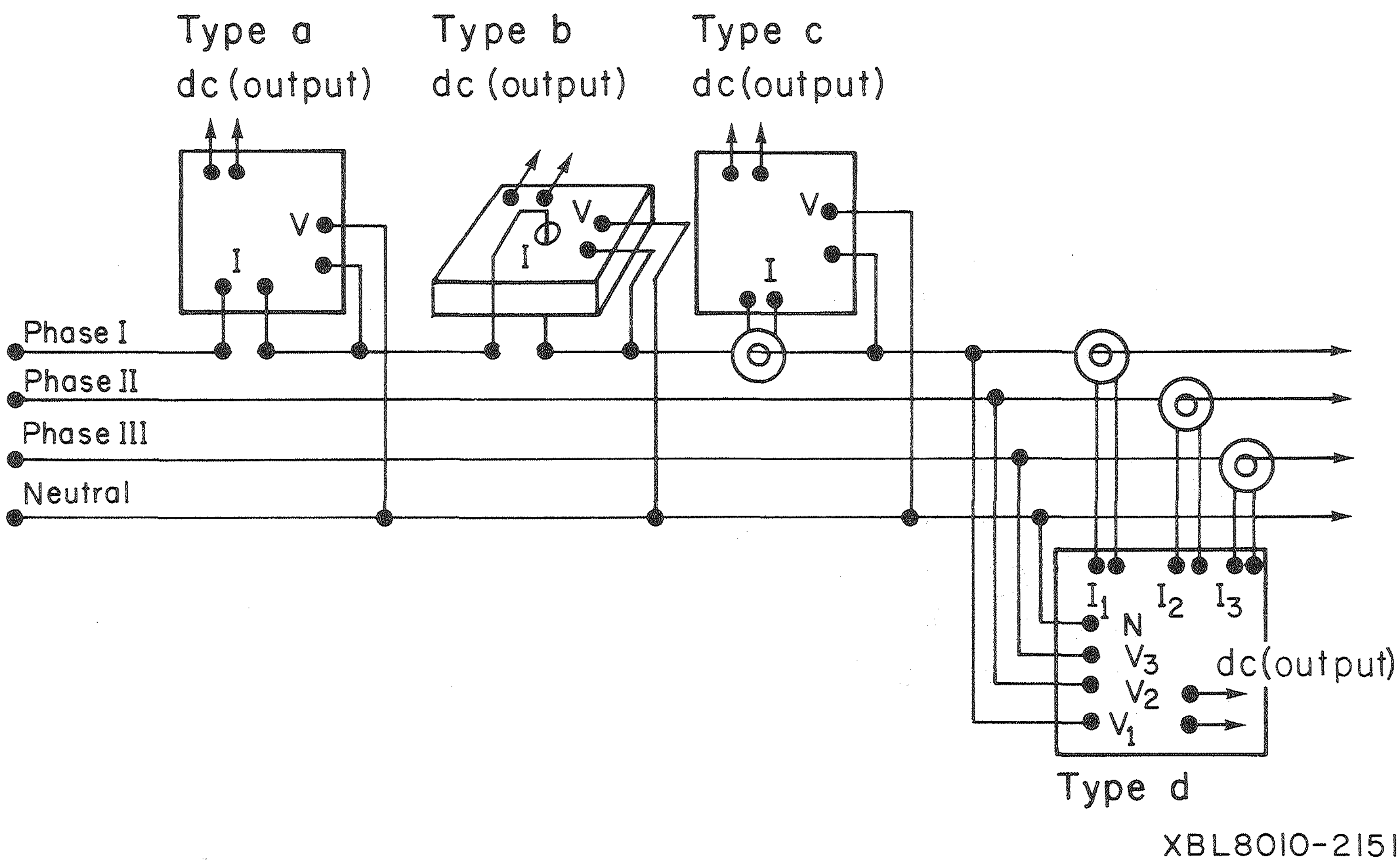

Type a
dc (output)
V
I
Type b
dc (output)
V
I
Type c
dc(output)
V
I
Phase I
Phase II
Phase III
Neutral
I1
I2
I3
N
V3
V2
V1
dc(output)
Type d
XBL8010-2151

FIGURE 5.2

APPENDIX I

General Essential Qualification Procedures

1. With regard to the lighting system, once the qualification has begun, the test area must be unchanged.

2. Reliable measurements must be made of the power supplied to the entire portion of the test area, or as large a portion as possible.

3. Reliable measurements must be made of the illumination levels in the entire test area.

4. Any change of burned out lamps must employ the same type of lamp.

5. The maintenance or change of lamps or ballasts must be monitored.

APPENDIX I

Prescribed Qualification Task Schedule

I. IDENTIFICATION OF DEMONSTRATION AREA

1. Present area layout

2. Number of fixtures and ballasts

3. Input voltage supply (120V or 277V)

II. COMPLETE SITE DESCRIPTION FORM (see Appendix II)

III. PREPARE DEMONSTRATION SITE

1. Leave area as is /clean area/ celan area, relamp.

2. Identify all measuring equipment, watt meter, light meter, energy monitoring.

3. Prepare plan to determine how data will be collected.

   a. Power
   b. Light level
   c. Energy consumption
   d. Lamp count (replacement, date)
   e. Ballast count (replacement, date)

IV. BASELINE DATA (Collection of Data Before Installation)

1. After preparation of demonstration site

2. Before installation of new EETech ballasts

V. SOLID-STATE BALLAST DATA

1. After installation is complete

2. Energy every one, two, or three months

3. At completion, six months of solid-state installation

TIMING SCHEDULE

START:	I	II	III	IV	V
TIME:	0	0	1 Month	2 Months	2½ - 8½ Months

APPENDIX II

Site Description

DATE ____________ CORPORATION ____________________

ADDRESS ____________________

____

A. DEMONSTRATION SITE

1. Project Leader __________ Telephone ____________

   Site Address ____________________

   ____

2. Type of Building ____________________

3. Work done in test area ____________________

4. Approximate dimension of test area ______ ______ ______
   (length) (width) (height)

5. Number of Fixtures ______

6. Number of Ballasts ______

7. Lamp types (35- or 40-watt)

8. Lighting Supply Voltage (120V or 277V)

B. RESPONSE TO DEMONSTRATION SCHEDULE

1. I can start qualification on ____________.
   (date)

2. Prepare Demonstration (Refer to 111 of the Prescribed Qualification Task Schedule)

   a. We will ______ ______ ______
      (leave as is) (clean) (relamp)

   b. Can measure ______ ______ ______
      (power) (light level) (energy use)

   c. Meter types ______ ______ ______
      (power) (light) (energy)

B. RESPONSE TO DEMONSTRATION SCHEDULE

3. Measurement Schedule

a. I can measure baseline date

________________ __________________________
(after preparation) (before refitting new ballasts)

b. I can measure solid state ballasts

_________________ ____________________
(after installation) (every 1, 2, 3 months)

____
(at the 6th month)

c. I can measure energy consumption ___ ___
Yes No

4. Other remarks

APPENDIX III

DATA REPORT FORM

1. Date ____________

2. Site ____________

3. ____________________ Project Manager
   Signature

4. Date of measurement ______ Time ______

5. Power ____ watts

6. Light Level Positions

1____	foot candle	6_____	foot candle
2____	foot candle	7_____	foot candle
3____	foot candle	8_____	foot candle
4____	foot candle	9_____	foot candle
5____	foot candle	10____	foot candle

7. Energy used from ____________ to _________ (dates)

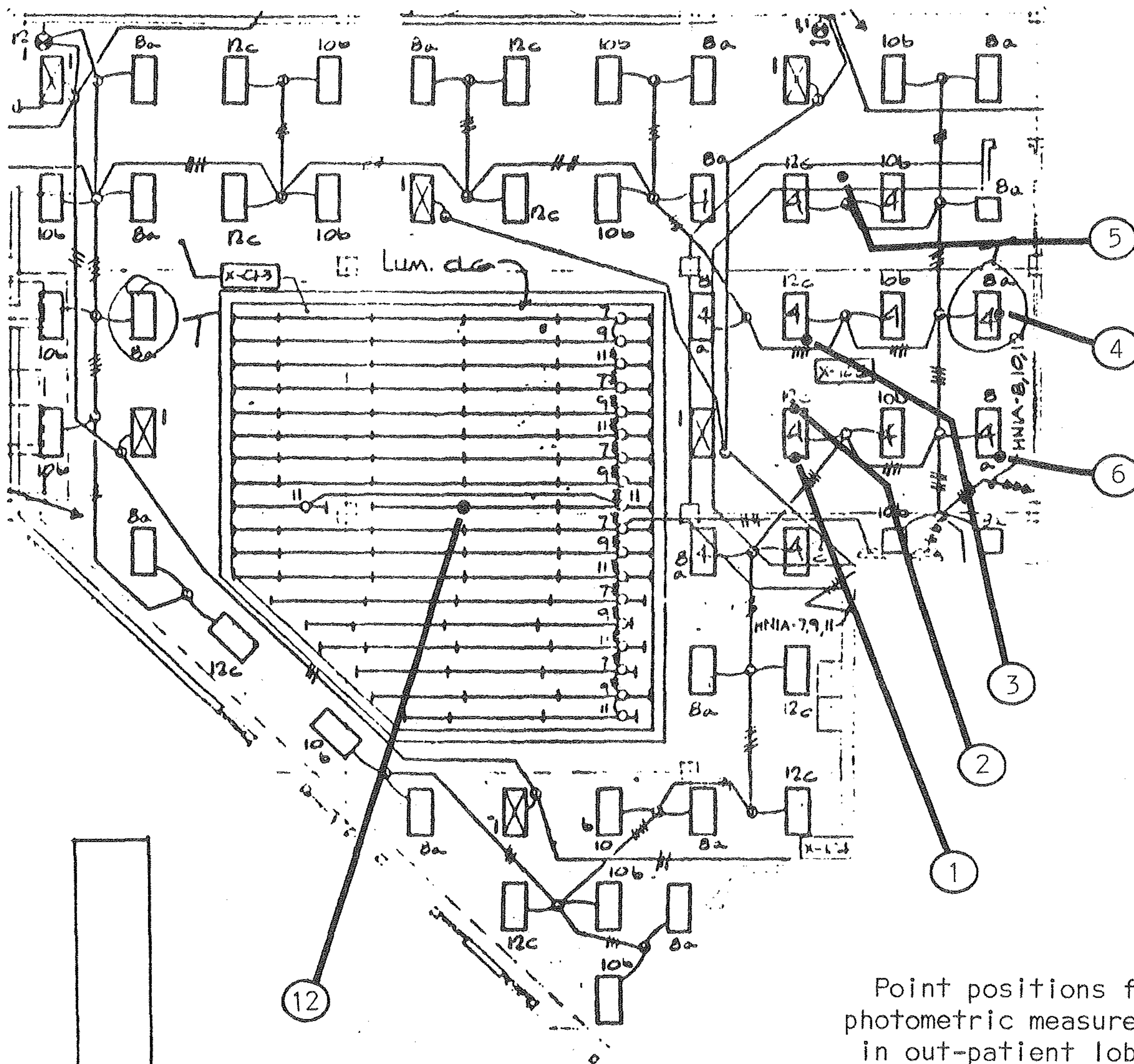
8. Number of lamps replaced: ______________ ______________
   date position

9. Number of ballasts replaced: ____________ ______________
   date position

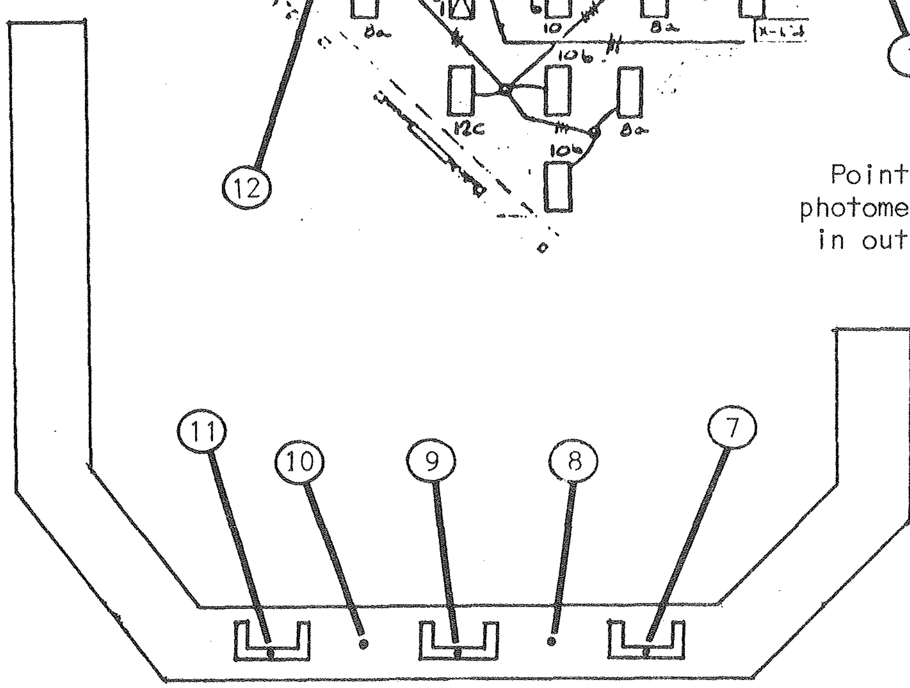
10. Remarks:

APPENDIX III

SAMPLE TEST LAYOUT



Point positions for photometric measurements in out-patient lobby



All measurements at desk height

Reception Counter

A 2x enlargement of the upper right-hand corner of the above figure.

APPENDIX IV

SPECIALISTS IN MEASUREMENT MONITORING, AND CONTROL OF CURRENT, POWER AND ENERGY

OSI

PC 5 SERIES

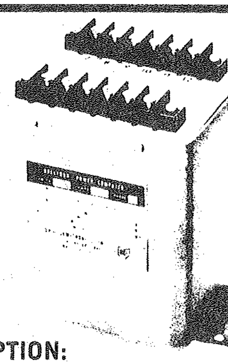
AC WATT TRANSDUCER

SINGLE PHASE 60 Hz MODELS

MODEL NUMBER PC5-	FULL SCALE INPUTS VOLTS	AMPS	WATTS	OUTPUT CALIB. 50MVDC	*CURRENT SENSOR DIMENSIONS
1	120	5	600	500W	—
2	240	5	1.2K	1KW	—
3	480	5	2.4K	2KW	—
10	120	10	1.2K	1KW	—
11	240	10	2.4K	2KW	—
12	480	10	4.8K	4KW	—
19	120	15	1.8K	1.5KW	—
20	240	15	3.6K	3KW	—
21	480	15	7.2K	6KW	—
28	120	50	6K	5KW	†C
29	240	50	12K	10KW	†C
30	480	50	24K	20KW	†C
31	120	100	12K	10KW	C
32	240	100	24K	20KW	C
33	480	100	48K	40KW	C
34	120	200	24K	20KW	D
35	240	200	48K	40KW	D
36	480	200	96K	80KW	D
37	120	400	48K	40KW	D
38	240	400	96K	80KW	D
39	480	400	192K	160KW	D
40	120	600	72K	60KW	E
41	240	600	144K	120KW	E
42	480	600	288K	240KW	E
43	120	1000	120K	100KW	E
44	240	1000	240K	200KW	E
45	480	1000	480K	400KW	E
46	120	2000	240K	200KW	E
47	240	2000	480K	400KW	E
48	480	2000	960K	800KW	E
49	120	50	6K	5KW	†W
50	240	50	12K	10KW	†W
51	480	50	24K	20KW	†W
58	120	100	12K	10KW	W
59	240	100	24K	20KW	W
60	480	100	48K	40K	W
67	120	200	24K	20KW	W
68	240	200	48K	40KW	W
69	480	200	96K	80KW	W
76	120	400	48K	40KW	X
77	240	400	96K	80KW	X
78	480	400	192K	160KW	X
85	120	600	72K	60KW	X
86	240	600	144K	120KW	X
87	480	600	288K	240KW	X
94	120	1000	120K	100KW	Y
95	240	1000	240K	200KW	Y
96	480	1000	480K	400KW	Y
103	120	1	120	100W	—
104	240	1	240	200W	—
105	480	1	480	500W	—
106	120	2.5	300	300W	—
107	240	2.5	600	600W	—
108	480	2.5	1200	1200W	—

CASE SIZE DRAWING H, See Page 11

*50 AMPS and ABOVE, 1 EXTERNAL SENSOR IS SUPPLIED, See Page 11.
Standard units have millivolt outputs as indicated. Units having 0 to + 1 milliampere or 0 to + 10 volts are available as options and are ordered by adding the option letter as a suffix to the standard model number. For example PC5-1A has an output of 0 to + 1 milliampere for 500 watt input.



MODEL PC5-4

DESCRIPTION:

OSI Watt Transducers utilize Hall Effect multipliers in order to provide an output which is proportional to the electrical power consumed in single phase or three phase loads or equipment. The multipliers provide instantaneous multiplication of the voltage times the current on a continuous basis.

The Watt Transducers are especially useful in monitoring, control, protection and regulation circuits. Their fast response results in accurate power measurement even when distorted or chopped waveforms are present.

Various output filtering and signal conditioning features are provided in watt transducer models to permit easy interface with circuits where amplified voltage output or current output is desirable. In all units the output signal is electrically isolated from the power lines to provide maximum flexibility in interfacing with other electrical or electronic circuits.

The unique, four-quadrant, high-accuracy multiplying properties of Hall Effect devices coupled with their demonstrated reliability provides a low-cost approach to power measurement where linearity, repeatability, and long life are important considerations.

ADJUSTMENTS:

All PC5 series watt transducers have been calibrated at the factory to give the correct output at the specified power rating.

Each unit has an overall "CAL" and an optional "ZERO" adjustment located on the lid. The "CAL" adjustment is set at the factory and should not be adjusted unless recalibration is required. The optional "ZERO" adjustment is provided to correct for an output offset, "at no load condition", without effecting the calibration of the unit.

OUTPUT OPTIONS:

A: 0 to + 1 milliampere DC output. No external amplifier power required. Output load 0 to 10K ohms.

B: 0 to +1 milliampere DC output. External amplifier power required. 85—135 VAC at 2 watts. Output load 0 to 10K ohms.

C: 0 to + 10 volt DC output. No external amplifier power required. Output load greater than 2K ohms.

D: 0 to + 10 volt DC output. External amplifier power required. 85—135 VAC at 2 watt. Output load greater than 2K ohms.

E: 4 to 20 milliampere DC output. External amplifier power required. 85—135 VAC at 2 watt. Output load less than 1500 ohms.

F: Filtered output. Ripple reduced to <1%. Load on output should be >1 megohm.

NOTE 1: For chopped waveforms select only models that use current transducers C, D or E, in Sensor Dimension column.

NOTE 2: † Indicates 2 turns thru the external transducer or transformer window.

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AC WATT TRANSDUCER

PC 5 SERIES

SPECIFICATIONS:

INPUT:

VOLTAGE: 0 to 110% FS

CURRENT: 0 to FS

OVERLOAD (Continuous):
- —Voltage 1.25 X Rating
- —Current:
  - —2 X Rating: 1 Ampere thru 15 Ampere Models and All Current Transformers Model W, X, Y
  - —50 X Rating: Current Transducer Models C, D & E

BURDEN (Full scale input):
- —Voltage 1.25 VA
- —Current 1.25 VA
- —Option Amplifier 2 Watts

POWER FACTOR RANGE: Unity to lead, lag 0.

FREQUENCY RANGE: 50 to 70 Hz

DIELECTRIC TEST:
(Input/Output/Case): 1500 VAC

RESPONSE: (Transient—90%)
100 microseconds with models using transducers.
1 millisecond with models using current transformers.

OUTPUT:

OUTPUT LOADING:
- —Base Unit: > 100K ohms
- —Options A & B: 0-10K ohms
- —Options C & D: > 2K ohms
- —Option F > 1 meg ohms

ADJUSTMENT RANGE: (See Adj. Note Page 8)
- —Base Unit: 0 to 110%
- —With Options: ±10% Min.

RESPONSE TIME:
- —Base Unit: 1 millisecond
- With Options: 250 milliseconds

TEMPERATURE EFFECT: (−10° to +60° C)
± 1% of Reading
With Options: ± 1% of Reading
± 0.1% FS

AC COMPONENT AT UNITY P.F.:
- —Base Unit: DC with an AC Component of 200% p to p
- —With Option: DC with an AC Component of < 1% FS

ACCURACY:

Including power factor, linearity, repeatability and initial set point:
±0.5% F.S.: PC5-1 thru PC5-48, PC5-31-2 thru PC5-33-2, PC5-103 thru PC5-108
±0.75% F.S.: PC5-49 thru PC5-102

SPECIALISTS IN MEASUREMENT MONITORING, AND CONTROL OF CURRENT, POWER AND ENERGY

OSI

3 PHASE 3 WIRE 60 Hz MODELS

MODEL NUMBER PC5-	FULL SCALE INPUTS			OUTPUT CALIB. 100MVDC	*CURRENT SENSOR DIMENSIONS	NUMBER OF SENSORS SUPPLIED
	VOLTS	AMPS	WATTS			
4	120	5	1.04K	1KW	—	—
5	240	5	2.08K	2KW	—	—
6	480	5	4.16K	4KW	—	—
13	120	10	2.08K	2KW	—	—
14	240	10	4.16K	4KW	—	—
15	480	10	8.31K	8KW	—	—
22	120	15	3.12K	3KW	—	—
23	240	15	6.24K	6KW	—	—
24	480	15	12.5K	12KW	—	—
31-2	120	100	20.8K	20KW	C	2
32-2	240	100	41.6K	40KW	C	2
33-2	480	100	83.1K	80KW	C	2
52	120	50	10.4K	10KW	W	†2
53	240	50	20.8K	20KW	W	†2
54	480	50	41.6K	40KW	W	†2
61	120	100	20.8K	20KW	W	2
62	240	100	41.6K	40KW	W	2
63	480	100	83.1K	80KW	W	2
70	120	200	41.6K	40KW	W	2
71	240	200	83.1K	80KW	W	2
72	480	200	166K	160KW	W	2
79	120	400	83.1K	80KW	X	2
80	240	400	166K	160KW	X	2
81	480	400	332K	320KW	X	2
88	120	600	125K	120KW	X	2
89	240	600	249K	240KW	X	2
90	480	600	499K	480KW	X	2
97	120	1000	208K	200KW	Y	2
98	240	1000	416K	400KW	Y	2
99	480	1000	831K	800KW	Y	2

CASE SIZE DRAWING H OR DRAWING K WITH OPTION E, Page 11

3 PHASE 4 WIRE 60 Hz MODELS

MODEL NUMBER PC5-	FULL SCALE INPUTS			OUTPUT CALIB. 150MVDC	*CURRENT SENSOR DIMENSIONS	NUMBER OF SENSORS SUPPLIED
	VOLTS	AMPS	WATTS			
7	120	5	1.80K	1.5KW	—	—
8	240	5	3.60K	3KW	—	—
9	480	5	7.2K	6KW	—	—
16	120	10	3.6K	3KW	—	—
17	240	10	7.2K	6KW	—	—
18	480	10	14.4K	12KW	—	—
25	120	15	5.4K	4.5KW	—	—
26	240	15	10.8K	9KW	—	—
27	480	15	21.6K	18KW	—	—
55	120	50	18K	15KW	W	†3
56	240	50	36K	30KW	W	†3
57	480	50	72K	60KW	W	†3
64	120	100	36K	30KW	W	3
65	240	100	72K	60KW	W	3
66	480	100	144K	120KW	W	3
73	120	200	72K	60KW	W	3
74	240	200	144K	120KW	W	3
75	480	200	288K	240KW	W	3
82	120	400	144K	120KW	X	3
83	240	400	288K	240KW	X	3
84	480	400	576K	480KW	X	3
91	120	600	216K	180KW	X	3
92	240	600	432K	360KW	X	3
93	480	600	864K	720KW	X	3
100	120	1000	360K	300KW	Y	3
101	240	1000	720K	600KW	Y	3
102	480	1000	1.44M	1.2MW	Y	3

CASE SIZE DRAWING H (BASE UNIT AND OPTION F), Page 11
CASE SIZE DRAWING K (WITH OPTION A, B, C, D, OR E), Page 11
*See Page 11 for all external sensor dimensions.

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BULLETIN PC79-1
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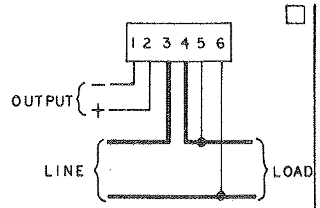
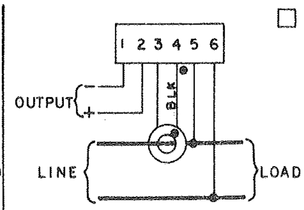
DWG
PC 77-1

DIRECT CONNECTIONS FOR 1 PHASE—2 WIRE

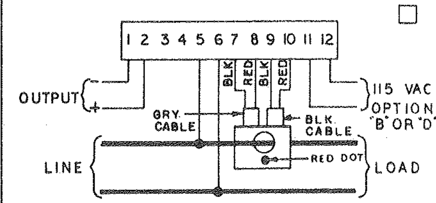


Circuit showing current directly connected through terminals 3 and 4. The voltage input is applied to terminals 5 and 6 with the output appearing on terminals 1 and 2. *Used with Options B and D only. Connect 115 vac power to terminals 11 and 12.

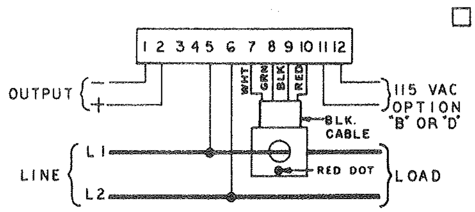


USING CURRENT TRANSFORMERS
(HIGH CURRENT)

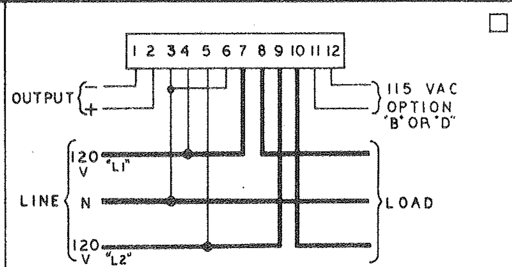
115 vac Option B or D to terminal 11 & 12



USING CURRENT TRANSDUCERS
(HIGH CURRENT)



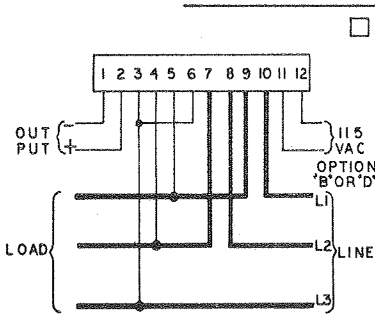
USING CURRENT TRANSDUCER
(SPLIT CORE)



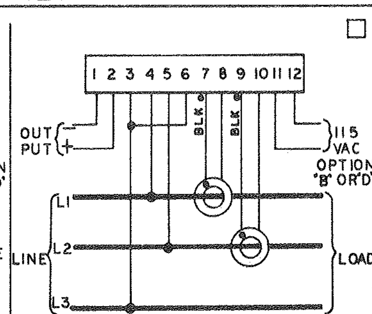
EDISON SYSTEM
(120/240 3 WIRE)

For currents above 15 amperes use 3Ø 3W Current Transformer connection diagram with L3, shown in drawing, used as neutral

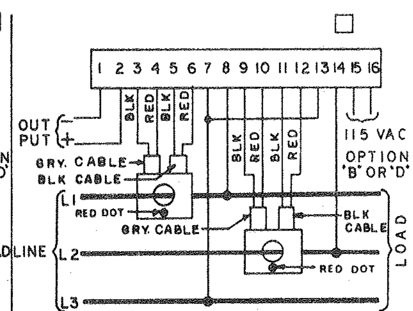
DIRECT CONNECTIONS FOR 3 PHASE—3 WIRE



Circuit used for balanced or unbalanced networks by algebraically summing the EI Cos Ø product from two phases.
*Used with Options B and D only. Connect 115 vac power to terminals 11 and 12.

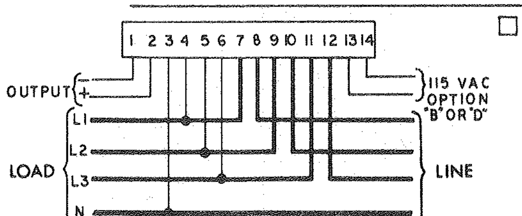


USING CURRENT TRANSFORMERS
(HIGH CURRENT)

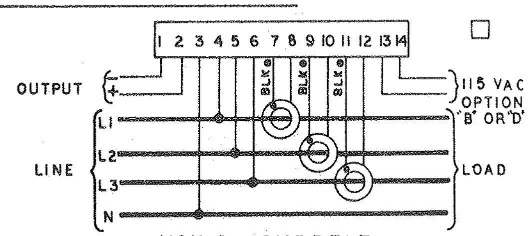


USING CURRENT TRANSDUCERS
(HIGH CURRENT)

DIRECT CONNECTIONS FOR 3 PHASE—4 WIRE



Circuit for balanced or unbalanced 4 wire networks. The output from all three phases are algebraically summed to obtain the total true power. Used with Options B and D only. Connect 115 vac power to terminals 13 and 14.



USING CURRENT TRANSFORMERS
(HIGH CURRENT)

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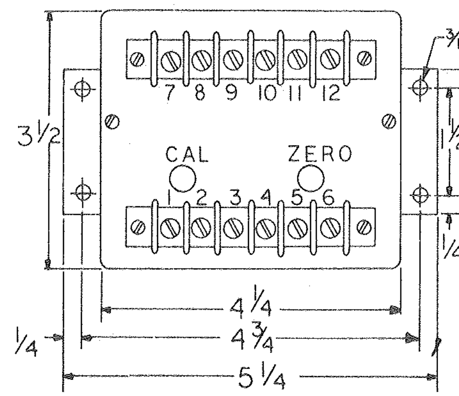
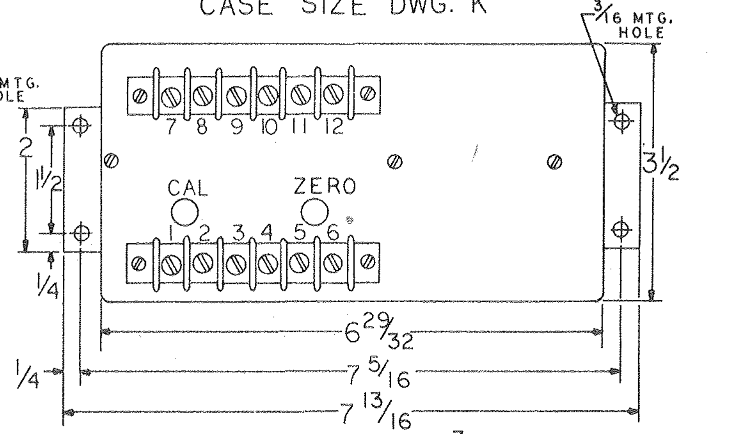
PC 77-1

CASE SIZE DWG. H

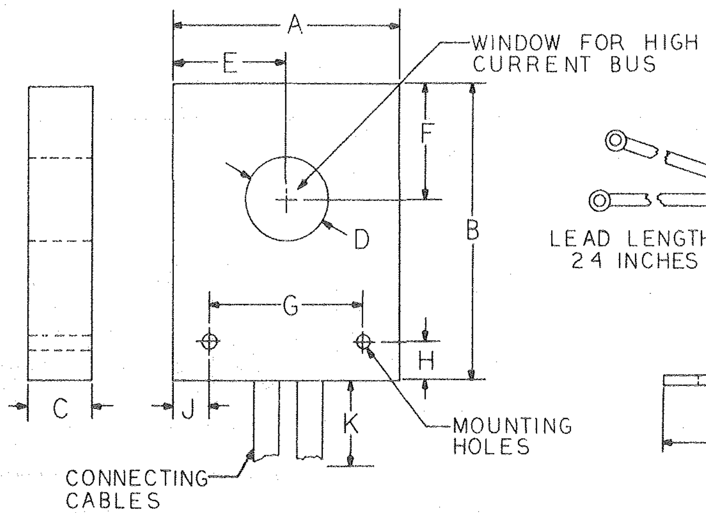


OVERALL HEIGHT 5 1/8

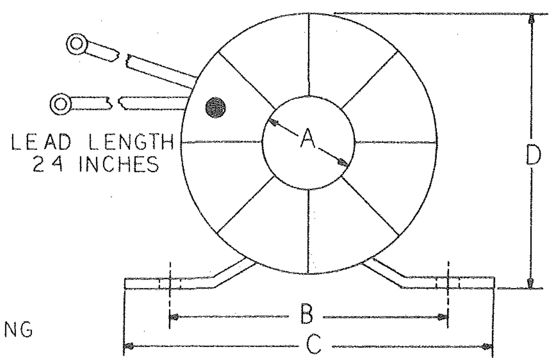
CASE SIZE DWG. K



OVERALL HEIGHT 4 7/8



OUTLINE DIMENSIONS FOR C, D & E



OUTLINE DIMENSIONS FOR W, X & Y

OUTLINE DIM	A	B	C	D	E	F	G	H	J	K	THICKNESS	WT. LB.	MTG. HOLE
C	2	2	3/4	3/4	1	7/8	1 1/2	1/4	1/4	15		1/4	9/64
D	3 1/8	4	7/8	1 1/8	1 9/16	1 9/16	2 1/8	1/2	1/2	15		3/4	11/64
E	4 1/8	5	1 1/4	2	2 1/16	2	3 1/4	7/16	7/16	15		2 1/8	17/64
W	1 1/4	3 7/8	5 1/8	3 7/8							1 5/8	2	9/32
X	2 1/4	5 3/4	7 1/8	5 1/8							1 1/2	3	9/32
Y	2 3/4	5 3/4	7 1/8	5 1/4							1 1/2	2 1/4	9/32

*ALL DIMENSIONS ARE IN INCHES

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