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ELECTRICAL COMMUNICATIONS TECHNIQUE AND ITS APPLICATIONS IN ALLIED FIELDS

POWER FACTOR MEASUREMENTS IN OIL ANALYSIS

"SAY YES" became a familiar method of determining the end of the useful life of automobile lubricating oils as a result of an intensive advertising campaign some months ago. However satisfactory this test may have been to oil companies, public-service corporations using large quantities of insulating oils in transformers and cables require a more specific test.

Insulating oils may gradually deteriorate due either to continued operation at too high voltages or to fouling. If such a condition is neglected, breakdown with loss of service will eventually occur. In order to avoid failures of this type, some companies have adopted the "Say Yes" policy—that is, have simply changed their oil at intervals which they considered sufficient. This has resulted in a reduction in failures as well as a considerable waste of oil.

It has been determined that the deterioration of the oil is accompanied by an increase in power factor. Pure oils have power factors so closely approaching zero as to suggest that were all the impurities removed the power factor would be zero. Progressive power companies are, therefore, inaugurating routine testing of transformer and cable oils so that all oils may be removed from service before the danger point is reached, while insuring the maximum safe use of the oil. Such servicing is resulting in savings for those companies which have inaugurated them sufficient to more than pay for the service.

While it is not likely that the corner service station will install a power-factor bridge to determine the state of the lubricating oil in your crankcase in the immediate future, it is true that impurities in lubricating oil can also be detected by the power-factor method. This method of study is viewed with increasing interest by all oil technicians, and there is a growing probability that electrical tests of oil purity will become a standard part of refinery technique for all types of oils.

Measurements of this sort are among the more difficult to make because of the very low power factors which must be measured. This has resulted in a considerable study of power-factor measurements and the development of a standard measuring cell for low-power factor liquids by Professor J. C. Balsbaugh of the Massachusetts Institute of Technology. This work was carried on under the sponsorship of the National Electric Light Association.

To so fine a degree have the measurements of power factor been carried in this work that not only the effect of slight dust deposits on the condenser plates but also that of occluded gas in the plates themselves have been detected.

The General Radio Company has instituted the manufacture of cells for the measurement of dielectric constant of oils after Professor Balsbaugh's design and under his direction. There is now available the cell described in the following article. —EDITOR.

The measurement of dielectric constant and power factor of a liquid such as an oil requires the use of a test cell, an air condenser which may be filled with the liquid and whose capacitance and power factor may be measured, first when it is empty and second when it is filled with the liquid.

The ratio of the "filled" capacitance to the "empty" capacitance is the dielectric constant of the liquid. The power factor of the liquid may be determined from the values of power factor observed for the two sets of capacitance measurements.

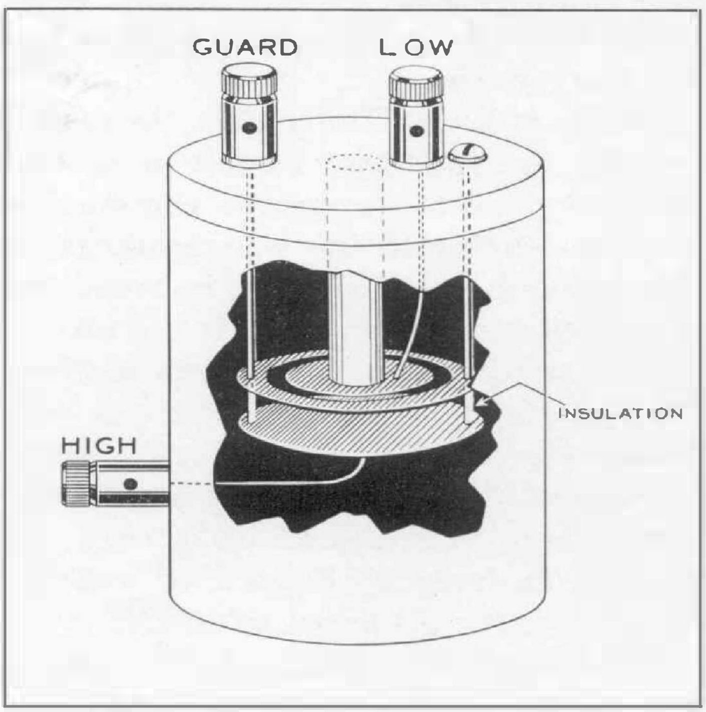


FIGURE 1. Schematic representation of a shielded 3-terminal oil cell which eliminates errors due to fringing and to losses in the dielectric supports

For rough measurements an ordinary two-terminal shielded condenser will yield satisfactory results, but there are two sources of error which make this simple cell useless for precision work. The first error is that due to fringing effects at the edges of the condenser plates. The second error is that due to the capacitance and losses introduced by the solid dielectric supports, the losses entering into both measurements. When both the power factor and capacitance of these supports are small as compared with the power factor and capacitance due to the liquid, the accuracy of the power factor determination as calculated from formulae will be satisfactory. On the other hand, for liquids with small power factors, errors due to losses in the solid dielectric supports will be relatively large and the accuracy of the final result will be unsatisfactory. Both sources of error can be eliminated by suitable design of the cell.

Except for special purposes, the two electrodes of the cell can be either parallel circular plates or concentric cylinders. In order to eliminate the effect of fringing, a guard ring can be placed around one plate, insulated from it but kept at the same potential. The second electrode is then allowed to extend for some distance past the gap between the guard ring and the guarded electrode. In this way the lines of force between the two principal electrodes of the cell are uniform over the whole surface of the smaller one.

Such an arrangement of electrodes is shown in Figure 1 but before discussing the constructional details it will be necessary to consider the capacitance network it represents.

There are three distinct capacitances involved, the direct capacitance C_{LH} between the two main electrodes and the direct capacitances C_{LG} and C_{GH} between the guard ring and each of the two main electrodes. These are related electrically as shown in Figure 2. Each of the three capacitances is called a "direct" capacitance to distinguish it from the "total" capacitance between the two corresponding terminals. The total capacitance is composed of one direct capacitance and the capacitance of the other two direct capacitances in series.*

The direct capacitance C_{LH} between the two main electrodes may be measured with a suitable bridge circuit. This usually involves the use of a Wagner ground, in which the guard ring is grounded and the low-potential electrode brought to the same potential. The magnitude of C_{LG} and C_{GH}, although entering into the preliminary adjustments of the bridge, will have no effect on the measurement of the direct capacitance C_{LH}.

*"Direct Capacitance and its Measurement," Robert F. Field, General Radio *Experimenter*, VIII, November, 1933.

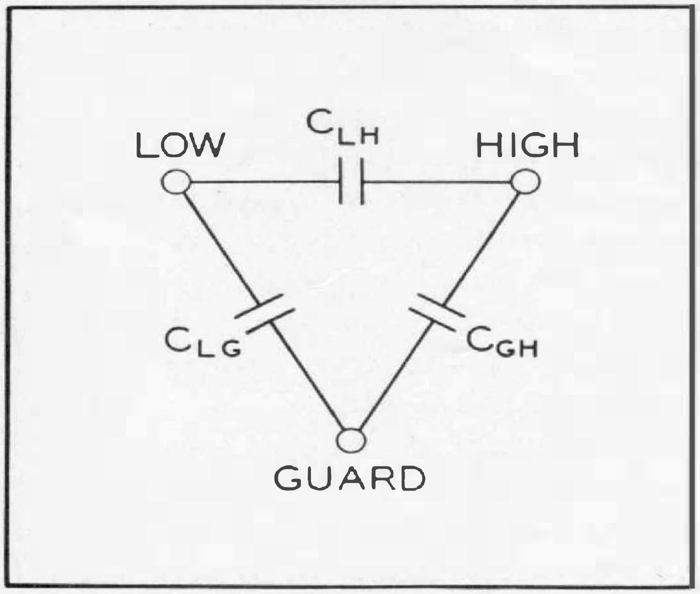


FIGURE 2. Capacitance network for a 3-terminal oil cell like the ones shown in Figures 1, 3, and 4

In a cell constructed like the one shown in Figure 1 the effect on the direct capacitance C_{LH} of the solid dielectric supports which serve to hold the electrodes in position can be eliminated by so placing these supports that they do not extend into the electric field between the main electrodes. In Figure 1, the low-potential electrode is suspended by a dielectric support, the high-potential electrode being attached by insulating spacers to the guard ring which in turn is suspended from and directly connected to the shield.

Cells using cylindrical electrodes like the one shown in Figures 3 and 4 can also be built, and in these the electrodes are most easily mounted on an axial insulating rod. Both the high-potential electrode and the guard rings are mounted on this rod and the low-potential electrode supported on insulators bridging the two guard rings.

Since, in both designs, the direct capacitance C_{LH} contains no solid dielectric, the ratio between C_{LH} when the cell is filled to C_{LH} when it is empty gives directly the dielectric constant of the liquid. For the same reason there is no dielectric loss associated with C_{LH}, and its power factor is zero when the cell is empty, hence the power factor of C_{LH}, as measured when the cell is filled, is the true power factor of the liquid.

This is strictly true at low voltages only. At voltage gradients sufficiently high to produce ionization, there are appreciable losses in the air between the plates as well as in the gas occluded in the electrodes themselves. Professor J. C. Balsbaugh* of the Massachusetts Institute of Technology has shown that the power factor due to occluded gas may be as great as 0.001% at room temperature for a potential difference across the cell of 800 volts. This power factor increases rapidly with temperature and may amount to 0.02% at 100°C. By degassing the electrodes, the power factor may be reduced to much less than 0.001% and made practically constant with temperature. The small losses in the air may be eliminated by making the cell air tight and removing the air.

The cell shown in Figures 3 and 4 is the General Radio Type 683-A Oil Cell, the arrangement of parts being due to Professor Balsbaugh. The electrodes and all the metal used for mounting them are of polished nickel and the stem, supporting rods, and container are pyrex glass. The high-potential electrode and the two guard rings are welded to nickel discs which fit tightly over the glass tubing at the center. Holes are punched in these discs to allow circulation of the liquid.

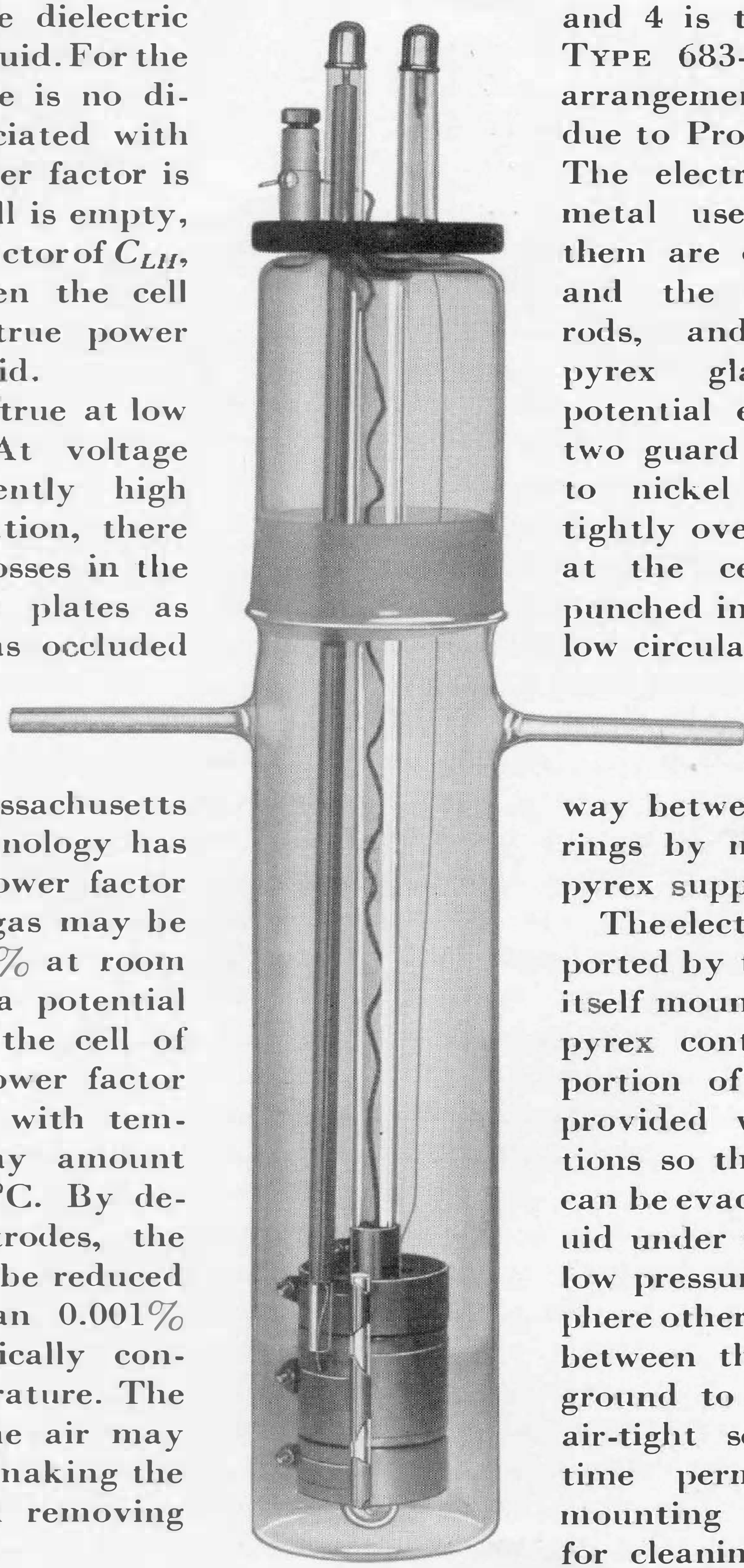


Figure 3. General Radio Type 683-A Oil Cell, a sealed glass container in which the electrode structure shown in Fig. 4 is suspended

The low-potential electrode is supported midway between the two guard rings by means of the two pyrex supporting rods.

The electrode structure supported by the axial tubing is itself mounted in a two-piece pyrex container. The lower portion of the container is provided with two tubulations so that the whole cell can be evacuated and the liquid under test introduced at low pressure or in an atmosphere other than air. The joint between the two sections is ground to help maintain an air-tight seal, at the same time permitting the dismounting of the assembly for cleaning. Both the container and the electrodes can be cleaned satisfactorily by several flushings with carbon tetrachloride.

The lead wire for the high-

*J. C. Balsbaugh and A. Herzenberg, "Comprehensive Theory of a Power-Factor Bridge," *Journal* of the Franklin Institute, Vol. 218, No. 1, July, 1934, pp. 49–97.

potential electrode is brought out through the central tubing in which a thermometer or a thermo-couple may be placed for measuring the temperature of the liquid. Connections to the low-potential electrode and the guard ring are brought out by nickel wires through seals in the upper section of the container. The low-potential electrode lead is shielded for its entire length. This method of bringing out the terminals increases the guard-electrode capacitances as shown in Table I.

All the nickel parts are heated in a vacuum to remove occluded gases and are then given a treatment in which the occluded gas is replaced by hydrogen. This markedly decreases the energy losses in the cell due to occluded gas.

An important feature of the General Radio oil cell is its ability to operate with a very small sample of oil. The external container has a volumetric capacity of only 200 cc. This not only provides economy of samples but it also means that the temperature-controlled water bath usually used need not be large. The over-all length of the cell is 17 inches, and the over-all width across the tabulations is approximately 8 inches. The outside diameter of the glass container is 2½ inches.

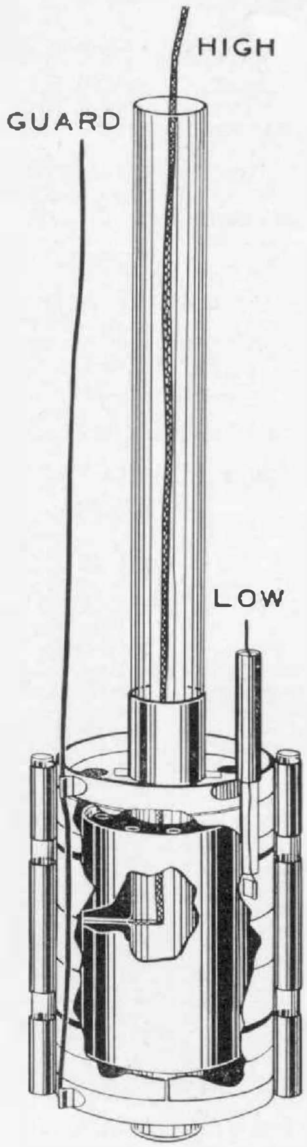


FIGURE 4. Electrode structure of the TYPE 683-A Oil Cell with the high potential electrode inside the low potential electrode and the two guard rings

The spacing between the electrodes is 5/32 of an inch, a knowledge of which enables one to calculate the voltage gradient in the sample under the test conditions employed. The direct capacitance of the measuring electrodes in air is 7 μμf. Values for the other capacitances are given in Table I together with values for the electrode structure only, as shown in Figure 4.

TABLE I

Direct Capacitances for TYPE 683-A Oil Cell

	C_{LH}	C_{GH}	C_{LG}
Cell complete . .	7 μμf	12 μμf	23 μμf
Electrodes only	7 μμf	8 μμf	7 μμf

In use the oil cell should be surrounded by a grounded shield. The metal container for the water bath may serve, or, if a water bath is not used, tin-foil can be wrapped around the lower portion of the container and grounded so that the slight leakage over the surface of the glass will not introduce a loss in the capacitance of the measuring electrodes.

The price of the TYPE 683-A Oil Cell is $150.00, complete as shown in Figure 3. For those who wish to adapt the cell for use with existing equipment, the electrode structure itself can be obtained separately, price $125.00.

—ROBERT F. FIELD.

POWER SUPPLIES

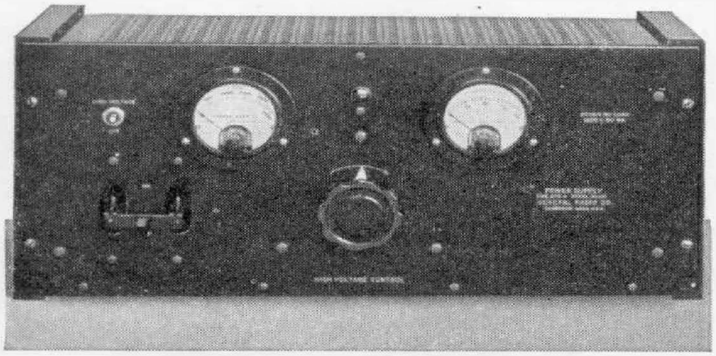
THE problem of obtaining d-c power in amounts necessary to supply ordinary vacuum tube installations has received much attention in the last decade. At the present writing, two methods of obtaining this power are generally used, namely, rectifier-filter equipment operating from the a-c line, and wet or dry batteries. Making a choice between a power supply or a battery installation requires a careful consideration of the particular circumstances involved. In general, rectifier-filter equipment is used whenever possible to eliminate the inconvenience and expense of maintenance and replacements required in all battery installations.

There are two general types of power supplies, depending on the particular use for which they are designed. The first type consists essentially of transformer, rectifiers, and filter, with no means of changing the d-c output voltage level. The second type necessarily involves the same equipment, but in addition embodies a means of independently controlling the output level of the d-c voltage. The first type of power supply is designed usually for commercial installations where the unit is to be permanently installed to supply, say, Class A or Class B modulators. The second type, which includes the first as a special case, is a general purpose instrument, such as would be used for manifold purposes in the experimental laboratory.

TYPE 672-A Power Supply. This is one of two new power-supply units in which the output voltage is adjustable

It is not difficult to design a power supply that will yield a good regulation at a given voltage level. When a variable voltage level instrument is designed, however, care must be taken that the regulation and efficiency hold up at all voltage levels. The most obvious way to vary the voltage level of a power supply is to place a resistance in series with or a potentiometer across the output. Either one of these methods very seriously impairs the regulation and the efficiency of the power supply, and the method is of little practical use unless the power supply is to be operated at a fixed load. Placing the resistance arrangement in the primary of the plate transformer avails nothing as it is merely reflected into the secondary or high-voltage circuit. A tapped transformer may be used to secure various voltage levels, but such devices besides being inconvenient are limited in their range and afford no *continuous* voltage control.

The General Radio Company has accordingly brought forth two power supply units that incorporate the use of the Variac, a *continuously variable* auto transformer, in the primary of the plate transformer. The Variac is described in the June-July, 1933, and the January-February, 1934, issues of the *Experimenter*. The Variac operates as a linearly variable voltage device that is independent of load current. Unlike



TYPE 673-A Power Supply. Practically any voltage from zero up to the rated maximum can be obtained from the high-voltage supply circuit of this unit

the potentiometer control, there is no appreciable series or parallel resistance introduced into the line to impair efficiency and regulation. Consequently *any* voltage and current up to full load may be obtained without sacrifice in regulation or efficiency by merely manipulating the variable tap of the Variac mounted on the panel. Accomplishing the same ends with resistances would entail a great deal of bother in order to locate at the correct point in the output current and voltage region.

The filters are of the choke input type, and are carefully designed to yield a low ripple voltage and a good regulation at any particular setting of the Variac. The characteristics of the two power supply units are briefly given below.

The TYPE 672-A Power Supply Unit will deliver 45 watts at 300 volts, full load. It may be used to supply vacuum-tube circuits of any description whatsoever as long as the voltage and current ratings are not exceeded. A variable bias voltage up to 100 volts is also provided. The hum is less than 0.1% of full load voltage on either the anode or bias supplies, expressing hum as the ratio (in per cent) between the r.m.s. ripple and the d-c voltage. Hums of this order of magnitude are not objectionable in any type of circuit.

The TYPE 673-A Power Supply Unit is designed to deliver power up to 225 watts at a voltage of 1500 volts. Tube installations of any description may be supplied by this unit as long as the current and voltage ratings are not exceeded. The hum is less than 0.2% of full load voltage.

Both power supplies have panel meters that read the output current and voltage. Any ground connections may be employed and each unit is suitable for table or relay rack mounting. The ratings are given below.

	Voltage-Current Ratings				
Type	*High Voltage*	*Bias*	*Heater*	*Code Word*	*Price*
672-A	300 v at 150 ma 400 v at no load	100 v, 2 ma	45 w at 2.5 v and 6.3 v	AFOOT	**$130.00**
673-A	1500 v at 150 ma 2000 v at no load	. . . .	65 w at 10 v (center-tapped)	AGONY	**180.00**

A VARIAC FOR HIGH POWER

THE many applications which the Variac continuously adjustable transformer has found in industry have resulted in a demand for units capable of handling higher powers. The TYPE 100 Variac with a 2-kva rating is now available. This instrument is suitable for reducing voltage on devices requiring considerable power, and it is especially well adapted to problems of theater-light control.

The new Variac follows the same toroidal core construction as those earlier announced. It is supplied in an open iron frame which serves as protection against casual contact with current-carrying parts, but is not totally enclosed.

The rating of this type of device

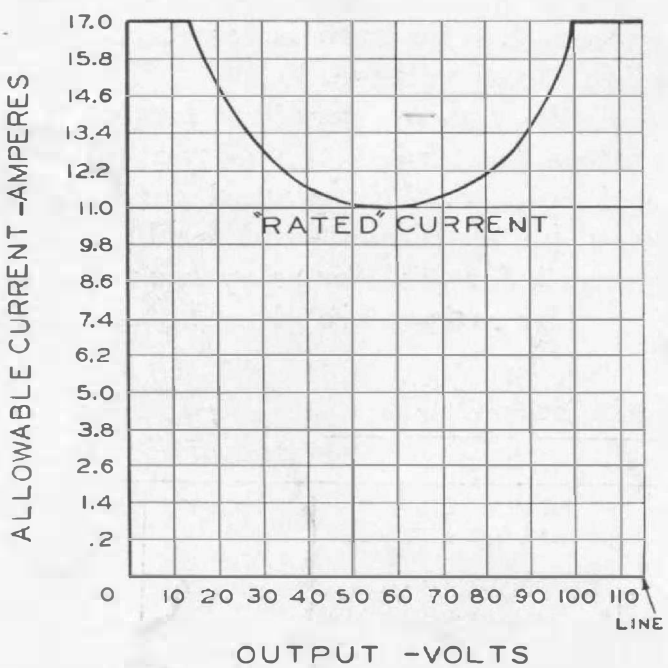


FIGURE 1. Maximum allowable current that can be drawn from a TYPE 100-K Variac plotted as a function of output voltage

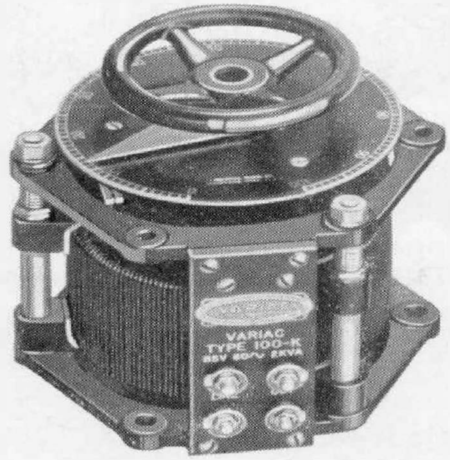


FIGURE 2. The TYPE 100-L Variac is identical with the TYPE 100-K Variac, shown above, except that the former is designed for operation on 230-volt circuits

presents somewhat of a problem, since both the maximum current and maximum kva that it can handle safely are functions of the output voltage. The TYPE 100 Variac has been rated at the volt-ampere rating of the resistive load which it can carry at full (line) voltage. That is, the instrument will control at any setting a load which draws 2 kva at the rated line voltage. It should be pointed out that the Variac will not deliver 2 kva at reduced voltage settings.

The current-carrying capacity of the unit is a minimum at approximately half-voltage setting. The curve of Figure 1 shows current-carrying capacity as a function of the output voltage of the Variac. The TYPE 100 Variac is available in 115-volt and 230-volt models. Complete specifications are available on request. Price, both models, $40.00.