RATING UNKNOWN POWER TRANSFORMERS

How to find the current rating and operating characteristics of standard power transformers by using two simple graphs.

By
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POWER transformers are designed and built to do a certain job. Their ratings are clearly spelled out in the manufacturers' catalogues and this makes the selection of an appropriate transformer a relatively simple matter.

What should be done, however, when such catalogues are not available? This is often the situation when salvaged transformers are being considered for a project. A few simple measurements will permit the rating of a transformer with the aid of the curves given here. This makes it possible to avoid a power transformer that is too small for the job at hand.

The method to be discussed is useful for checking unknown power transformers to be used with a full-wave, center-tapped rectifier circuit, as shown in Fig. 1. The curves cover a size range of about 30 to 300 volt-amperes (va.).

Unenergized Testing

The first step in the rating process is to tighten the through bolts and check the leads. If the transformer is still mounted in a piece of equipment, it will be necessary to remove tubes or disconnect other loads before making the required measurements. Check the continuity of all windings and record the d.c. resistance values for these windings. If the leads are not properly color-coded, tag them. The winding(s) having the highest resistance will be the high-voltage winding for the rectifier. If only two high-voltage leads are found, check to see if the center-tap is grounded internally. The resistance to ground—core or case—will be about half that of the resistance between leads if this is so. If the high-voltage or other winding is tapped, this may be determined by the continuity and resistance checks.

Occasionally an extra lead is found which does not appear to connect to any winding. This lead may connect to a Faraday shield located between the primary and the several secondary windings. The other winding having appreciable resistance will be the primary. The d.c. resistance of most heater windings is usually too low to be measured conveniently. After identifying all windings by continuity check, make another check from winding to winding to make sure that there is no internal short between windings. This completes the unenergized testing on the transformer.

"Cooking" the Transformer

Hook the transformer primary to a source of power. The transformer should be allowed to "cook" for several hours to see how hot it gets under no-load. A transformer with a shorted turn will usually destroy itself very quickly. Most transformers will become warm at no-load—warm but not hot. The transformer must become warm even though not loaded electrically because the iron losses must be dissipated. Excessive heating or noise are warnings of trouble although the noise might be due to a loose lamination in the core.

While the transformer is "cooking," check and record the no-load voltage developed by the several windings. This check will further identify the various heater windings. *CAUTION*: Never connect more than one voltmeter lead to a winding before energizing the transformer. The transient voltage developed in the secondaries by current inrush into the primary can damage the voltmeter. Learn the one-hand technique—one hand in the pocket. Use insulated alligator clips on the meter leads and it will be easy to make all connections with one hand. If possible, measure the no-load primary current. This is a relative indicator of trouble.

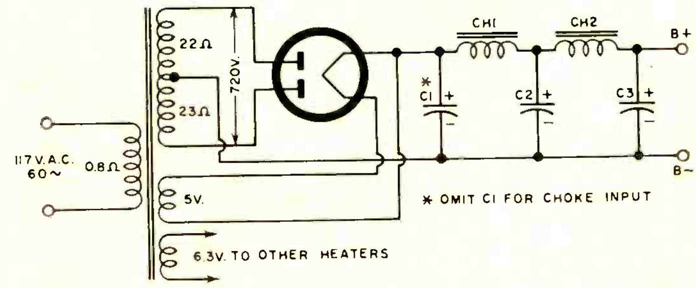
Current Ratings

The no-load primary current will range from about half of full-load current for very small transformers—particularly those operating at high magnetic flux density in the iron—to about one-eighth of full-load current for larger units of, say, 300-va. rating.

To determine the maximum current that can be drawn from the high-voltage secondary as d.c. current from the filter, it is necessary to calculate the unit resistance of the high-voltage winding. Divide the measured d.c. resistance in ohms by the open-circuit or no-load a.c. voltage to get ohms/volt. Since the two halves of the high-voltage winding may be slightly different, use the total voltage and the total ohms to get an averaged value. Read on the curves of Fig. 2 the permissible d.c. current (in ma.) that can be drawn from the filter for either choke or capacitor input filter.

The plate-to-plate a.c. voltage of the high-voltage winding under load can be approximated by subtracting from the measured no-load voltage the product of the d.c. load current (in amps.) and twice the measured d.c. resistance from plate-

Fig. 1. Transformers are to be used in full-wave circuit. Typical resistance values and voltages are indicated here.



to-plate. The resultant d.c. voltage into the filter can be found for a particular rectifier tube from curves in a tube handbook.

Practical Transformers

Practical transformers are built under restrictions imposed by economics, space, and required electrical characteristics. This often results in a design that is far from ideal. By one definition, an ideal transformer would have a core of square cross-section as for a given voltage per turn, the length of each turn would be least. This means less resistance and thus lower I^2R losses and better regulation. Transformers with cores having a square cross-section are uncommon—most transformers having a core thickness greater than the width of the center section. This construction reduces the weight slightly and may reduce mounting area. The reduction in iron losses is offset by increased copper loss because of the fact that the turn length is greater.

It is worthwhile to look at the changes that take place in transformer design as size is increased from about 30 to 300 va. The outside surface does not increase as rapidly as the volume. Since volume determines rating and surface determines cooling, it is necessary to improve the efficiency as size increases by reducing the iron and/or copper losses. The losses in the iron core can be reduced by lowering the magnetic flux density or by using a better grade of iron. As size is increased it is also desirable to reduce the permissible current density in the copper wire of the windings. This means larger wire of lower resistance and less I^2R loss. These factors may improve the voltage regulation of the transformer—generally speaking, the larger transformers will have the better voltage regulation.

The curves of Fig. 2 show the relationship between the unit resistance (Ω/v.) of the high-voltage winding and the permissible current that may be drawn from the filter. The curves were developed by plotting data taken from transformers of several manufacturers, covering the size range of about 30 to 300 va. rating. The data plotted very well with little spread. Although permissible d.c. load current for choke input is about one-third greater than for capacitor input, the transformer load is not increased as the r.m.s. current from the transformer is less for a given d.c. load when operating into a choke input filter.

The ratings of heater windings are more difficult to determine unless the wire of the winding is brought out as a lead. In this latter case, the permissible current is easily calculated after the wire size is measured—allowing one ampere for each 700 circular mils of wire cross-section. Standard copper-wire tables can be used to relate measured wire size to cross-section area in circular mils. (For example, No. 22 wire will carry about 0.9 a.; No. 20, about 1.5 a.; No. 18, about 2.3 a.; No. 16, about 3.7 a.; and No. 14, about 5.9 a.)

In service, the heater winding voltage should be checked. If the voltage under load is less than the nominal rating, *e.g.* 6.3 volts, the winding is probably overloaded. The method used for rating the high-voltage winding could also be used to rate the heater windings—with different curves. The method would not be too practical as few experimenters have the necessary equipment to measure such low resistances.

Final Check

One final check which can be made with the transformer under full-load is to check the primary current. The primary current must not exceed the value shown on the curve of Fig. 3, which relates the permissible primary current to the primary d.c. resistance in ohms. The values on the plot are for 117-volt primaries. For the occasional 220-volt primary, enter the curve with one-quarter of the measured resistance. The winding of a 220-volt primary is approximately twice as long as a 117-volt primary and is wound with wire having about half of the cross-sectional area, which doubles the resistance per unit of length.

For example, take a power transformer having the d.c. resistances and high-voltage secondary open-circuit voltage shown in Fig. 1. Calculate *ohms/volt* = (22+23)/720 = 45/720 = 0.0625. From the curves of Fig. 2, read 245 ma. for a capacitor-input type filter and 325 ma. for a choke-input type filter.

The plate-to-plate a.c. voltage into the rectifier under load will be approximately 720 − (2 × 45 × .245) = 720 − 22 = 698 volts. The actual voltage will vary with the total transformer load but, for design purposes, this value is more useful than the open-circuit voltage. This transformer will be fully loaded when the primary current reaches 2.3 amperes, which is the value corresponding to a resistance of 0.8 ohm on the curve of Fig. 3.

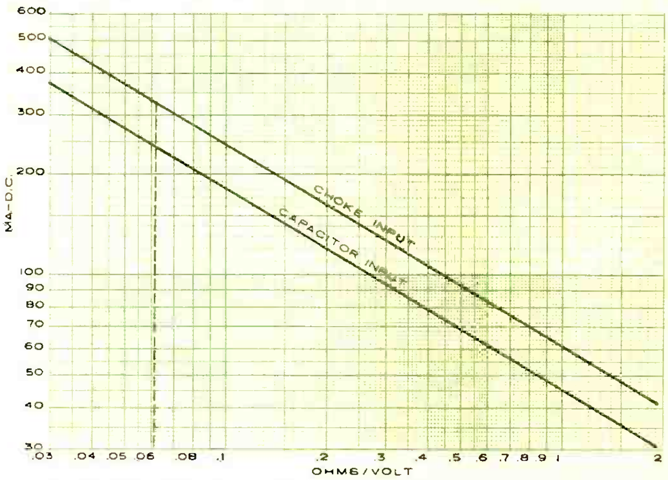


Fig. 2. Unit resistance of h.v. winding vs permissible current.

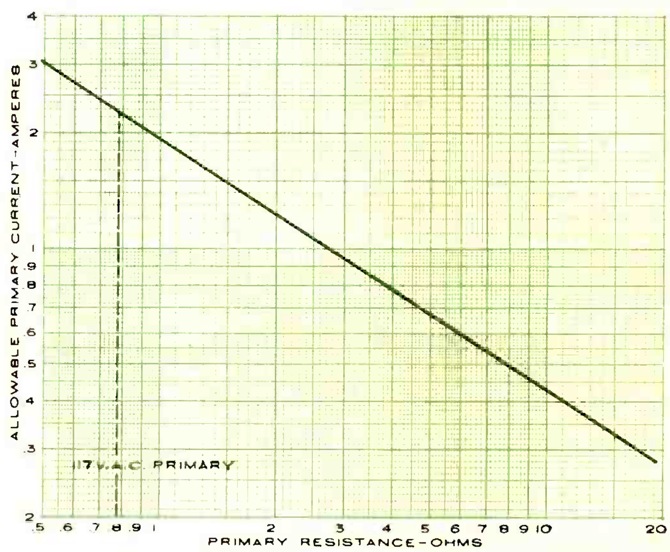


Fig. 3. Primary current plotted for various primary resistances.

The curves given in this article are for standard radio and TV type transformers—not hermetically sealed but equipped with standard end shells. Transformers with special heat radiating fins inserted into the core are capable of somewhat higher loads—the increased surface makes it possible to dissipate more heat. Standard-type transformers will run hot at full-load as the copper losses as well as the iron losses must be dissipated. The method detailed in this article may be extended to hermetically sealed transformers but this will require collection of data to prepare additional curves. Generally speaking, ratings for hermetically sealed units will be lower because of the increased difficulty in dissipating the heat. ▲