of this periodic flux, linked with the secondary circuit, originates in this last a periodic electromotive force. The whole of the flux linked with the primary circuit is not interlinked with the secondary circuit. The difference is called the *magnetic leakage* of the transformer. This leakage is increased with the secondary output of the transformer and with any disposition of the primary and secondary coils which tends to separate them. The leakage exhibits itself by increasing the *secondary drop.* If a transformer is worked at a constant primary potential difference, the secondary terminal potential difference at no load or on open secondary circuit is greater than it is when the secondary is closed and the transformer giving its full output. The difference between these last two differences of potential is called the secondary drop. This secondary drop should not exceed 2 % of the open secondary circuit potential difference.

The facts required to be known about an alternating current transformer to appraise its value are (1) its full load secondary output or the numerical value of the power it is designed to transform, on the assumption that it will not rise in temperature more than about 60° C. above the atmosphere when in normal use; (2) the primary and secondary terminal voltages and currents, accompanied by a statement whether the transformer is intended for producing a constant secondary voltage or a constant secondary current; (3) the efficiency at various fractions on secondary load from one-tenth to full load taken at a stated frequency; (4) the power factor at one-tenth of full load and at full load; (5) the secondary drop between full load and no load; (6) the iron core loss, also the magnetizing current, at the normal frequency; (7) the total copper losses at full load and at one-tenth of full load; (8) the final temperature of the transformer after being left on open secondary circuit but normal primary potential for twenty-four hours, and at full load for three hours.

The matters of most practical importance in connexion with an alternating current transformer are (1) the iron core loss, which affects the efficiency chiefly, and must be considered (*a*) as to its initial value, and (*b*) as affected by “ ageing ” or use ; (2) the secondary drop or difference of secondary voltage between full and no load, primary voltage being constant, since this affects the service and power of the transformer to work in parallel with others;.and (3) the temperature rise when in normal use, which affects the insulation and life of the transformer. The shellacked cotton, oil and other materials with which the transformer circuits are insulated suffer a deterioration in insulating power if continuously maintained at any temperature much above 80° C. to 100° C. In taking the tests for core loss and drop, the temperature of the transformer should therefore be stated. The iron losses are reduced in value as temperature rises and the copper losses are increased. The former may be 10 to 15% less and the latter 20% greater than when the transformer is cold. For the purpose of calculations we require to know the number of turns on the primary and secondary circuits, repre- sented by N1 and N2 ; the resistances of the primary and secondary circuits, represented by R1 and R2; the volume (V) and weight (W) of the iron core ; and the mean length (L) and section (S) of the magnetic section. The hysteresis loss of the iron reckoned in watts per lb per 100 cycles of magnetization per second and at a maximum flux density of 2500 C.G.S. units should also be determined.

The experimental examination of a transformer involves the measurement of the efficiency, the iron core loss, and the secondary drop; also certain tests as to insulation and heating, and finally an examination of the relative phase position and graphic form of the various periodic quanti- ties, currents and electromotive forces taking place in the trans- former. The efficiency is best determined by the employment of a properly constructed wattmeter (see Wattmeter). The transformer T (fig. 5) should be so arranged that, if a constant potential trans­former, it is supplied with its normal working pressure at the primary side and with a load which can be varied, and which is obtained either by incandescent lamps, L, or resistances in the secondary circuit. A wattmeter, W, should be placed with its series coil, Se, in the primary circuit of the transformer, and its shunt coil, Sh, either across the primary mains in series, with a suitable non-inductive resistance, or connected to the secondary circuit of another transformer, T1, called an *auxiliary transformer,* having its primary terminals connected to those of the transformer under test. In the latter case one or more incandescent lamps, L, may be connected in series with the shunt coil of the wattmeter so as to regulate the current passing through it. The current through the series coil of the wattmeter is then the same as the current through the primary circuit of the transformer under test, and the current through the shunt coil of the wattmeter is in step with, and proportional to, the primary voltage of the transformer. Hence the wattmeter reading is proportional to the mean power given up to the transformer. The wattmeter can be standardized and its scale reading interpreted by replacing the transformer under test by a non-inductive resistance or series of lamps, the power absorption of which is measured by the product of the amperes and volts supplied to it. In the secondary circuit of the transformer is placed another wattmeter of a similar kind, or, if the load on the secondary circuit is non-inductive, the secondary voltage and the secondary current can be measured with a proper alternating current ammeter, A2, and voltmeter, V2, and the product of these readings taken as a measure of the power given out by the transformer. The ratio of the powers, namely, that given out in the external secondary circuit and that taken in by the primary circuit, is the efficiency of the transformer.

In testing large transformers, when it is inconvenient to load up the secondary circuit to the full load, a close approximation to the power taken up at any assumed secondary load can be obtained by adding to the value of this secondary load, measured in watts, the iron core loss of the transformer, measured at no load, and the copper losses calculated from the measured copper resistances when the transformer is hot. Thus, if C is the iron core loss in watts, measured on open secondary circuit, that is to say, is the power given to the transformer at normal frequency and primary voltage, and if R1 and R2 are the primary and secondary circuit resistances when the transformer has the temperature it would have after running at full load for two or three hours, then the efficiency can be calculated as follows : Let O be the nominal value of the full secondary output of the transformer in watts, V1 and V2 the terminal voltages on the primary and secondary side, N11 and N2 the number of turns, and A1 and A2 the currents for the two circuits; then O/V2 is the full load secondary current measured in amperes, and N2N1 multiplied by O/V2 is to a sufficient approximation the value of the corresponding primary current. Hence O2R2/V22 is the watts lost in the secondary circuit due to copper resistance, and O2R1N22/V22N12 is the corre­sponding loss in the primary circuit. Hence the total power loss in the transformer ( = L) is such that

\*\*\*\*O2 ∕NΛ 2 O2

L = C +y^∙R2 + ÇjjJ y^Rι = C + (R2 + R1α2)O2∕V22.

Therefore the power given up to the transformer is O+L, and the efficiency is the fraction O/(O+L) expressed as a percentage. In this manner the efficiency can be determined with a considerable degree of accuracy in the case of large transformers without actually loading up the secondary circuit. The secondary drop, however, can only be measured by loading the transformer up to full load, and, while the primary voltage is kept constant, measuring the potential difference of the secondary terminals, and comparing it with the same difference when the transformer is not loaded. Another method of testing large transformers at full load without supplying the actual power is by W. E. Sumpner’s differential method, which can be done when two equal transformers are available (see Fleming, *Handbook for the Electrical Laboratory and Testing Room,* ii. 602).

No test of a transformer is complete which does not comprise some investigation of the “ ageing ” of the core. The slow changes which take place in the hysteretic quality of iron when heated, in the case of certain brands, give rise to a time-increase in iron core loss. Hence a trans- former which has a core loss, say, of 300 watts when new, may, unless the iron is well chosen, have its core loss increased from 50 to 300% by a few months’ use. In some cases specifications for transformers include fines and deductions from price for any such increase; but there has in this respect been great improvement in the manufacture of iron for magnetic purposes, and makers are now able to obtain supplies of good magnetic iron or steel with non-ageing qualities. It is always desirable, how­ever, that in the case of large sub-station transformers tests should be made at intervals to discover whether the core loss