MEASURING CURRENT ON THE POWER SYSTEM

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For many years, iron-cored current transformers have been used on the power system for both metering and relaying applications. In spite of many new developments in the current measuring field, current transformers will continue to be used in the future because of their simplicity, ease of application, high accuracy, and reliability.

This paper discusses the important shortcomings of metering and relaying current transformers. These shortcomings are usually related to the burden, the remanence, and the current transformer's finite dynamic range.

Metering Current Transformers

Two important factors that affect the accuracy of a metering current transformer are the burden and the residual magnetism in the core. Large burdens cause a loss of accuracy because of overloading, while residual magnetism causes a loss of accuracy by allowing the iron to operate in a region of relatively low permeability. The two phenomena are discussed below.

Usually, the burden on a metering current transformer can be readily determined, and if necessary, maintained within prescribed limits. There are circumstances, however, where the burden is difficult to determine, such as in current summation circuits. Some technical personnel do not realize that the physical burden should be multiplied by the number of current transformers used in a current summation circuit (Figure 1) to obtain the "effective burden". Similarly, some forget that an auxiliary transformer, when connected between a primary transformer and load, adds additional burden to the circuit. On occasion the burden of such an auxiliary alone can exceed the rated burden of the primary transformer.

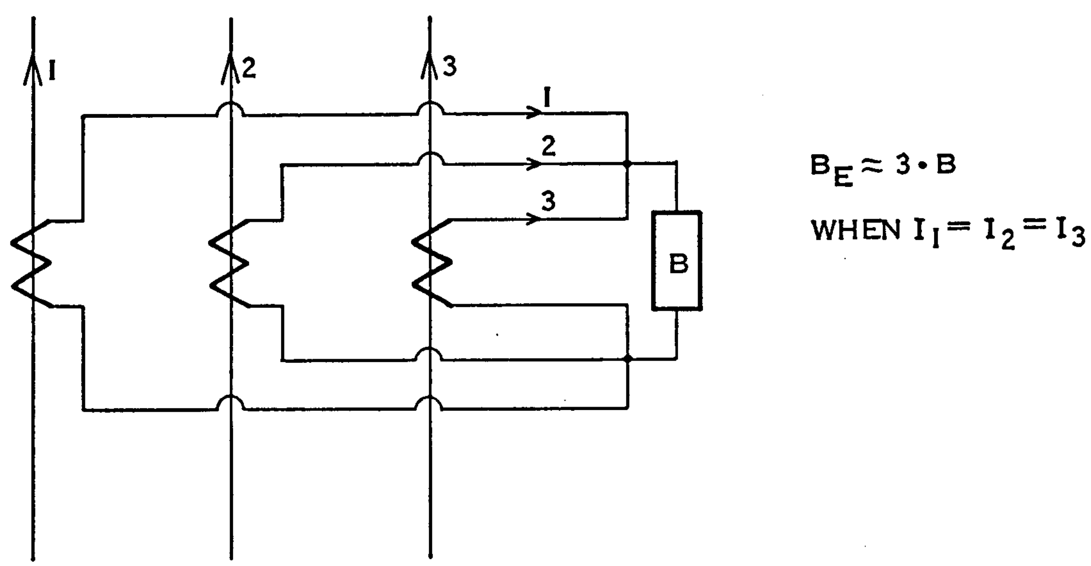

FIGURE 1

EFFECTIVE BURDEN ON CURRENT TRANSFORMERS IN CURRENT SUMMATION CIRCUITS

It is important, therefore, to compute the "effective burden" for each transformer in an installation. This burden is equal to the voltage across the terminals of the transformer divided by the current supplied by the transformer. It can be readily seen that the effective burden changes, and therefore the accuracy of an installation changes, as the load is shared differently by the transformers in an installation. It is also apparent that under certain load conditions, the "effective burden" may assume a very large, or even a negative value.

In an effort to reduce the burdens on metering current transformers in a station, where transformers are located in a bus, the circuit in Figure 3 was developed. This circuit provides all the necessary line currents without the use of previously used auxiliaries as shown in Figure 2. This results in a saving on equipment, a reduction of burden, and an increase in accuracy. Figure 4 shows the connections for a relatively large station.

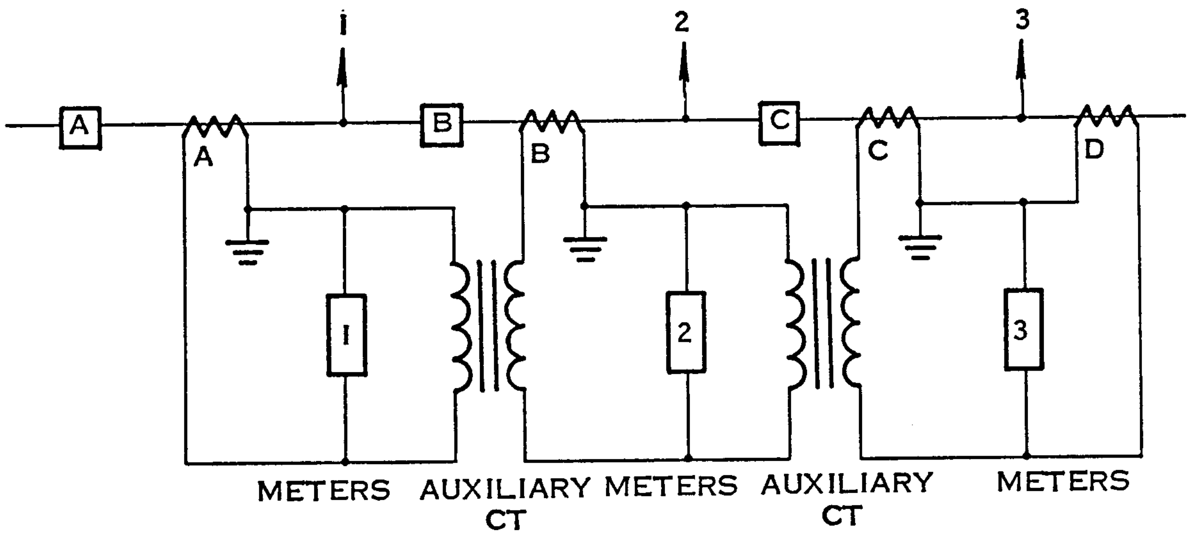

FIGURE 2

METERING OF LINES WITH METERING CT'S AND AUXILIARY CT'S

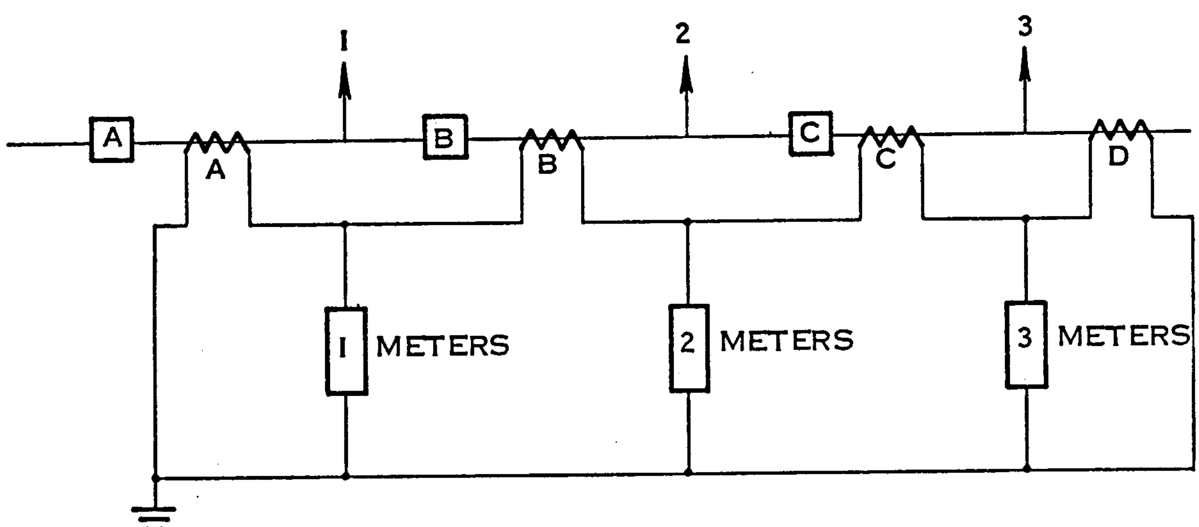

FIGURE 3

METERING OF LINES WITHOUT THE USE OF AUXILIARY CT'S

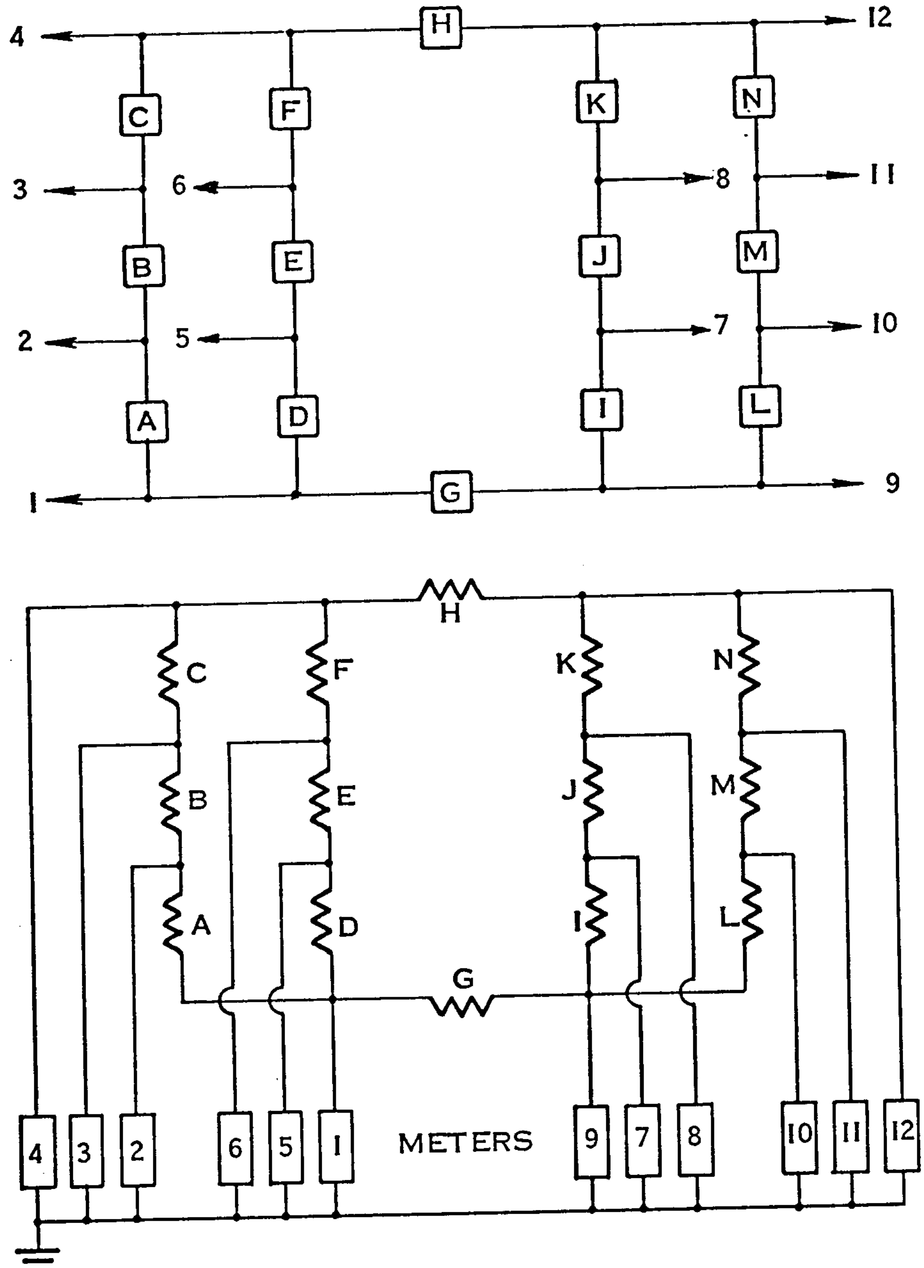

FIGURE 4

METERING OF LINES IN A LARGE STATION
WITHOUT THE USE OF AUXILIARY CT'S

The other shortcoming, not realized too often, is that of reduced accuracy due to residual magnetism or remanence. This phenomenon is largest in transformers exhibiting high metering and relaying accuracies. Figure 5 shows that a current transformer with 0.3 B1.8 accuracy may not meet the 0.6 B1.8 accuracy when in the magnetized condition. Transformers can be easily magnetized with a multimeter or buzzer continuity test. They may operate magnetized with reduced accuracy for a long period of time unless they are demagnetized. A voltage of at least 50% of saturating voltage is required for proper demagnetization.

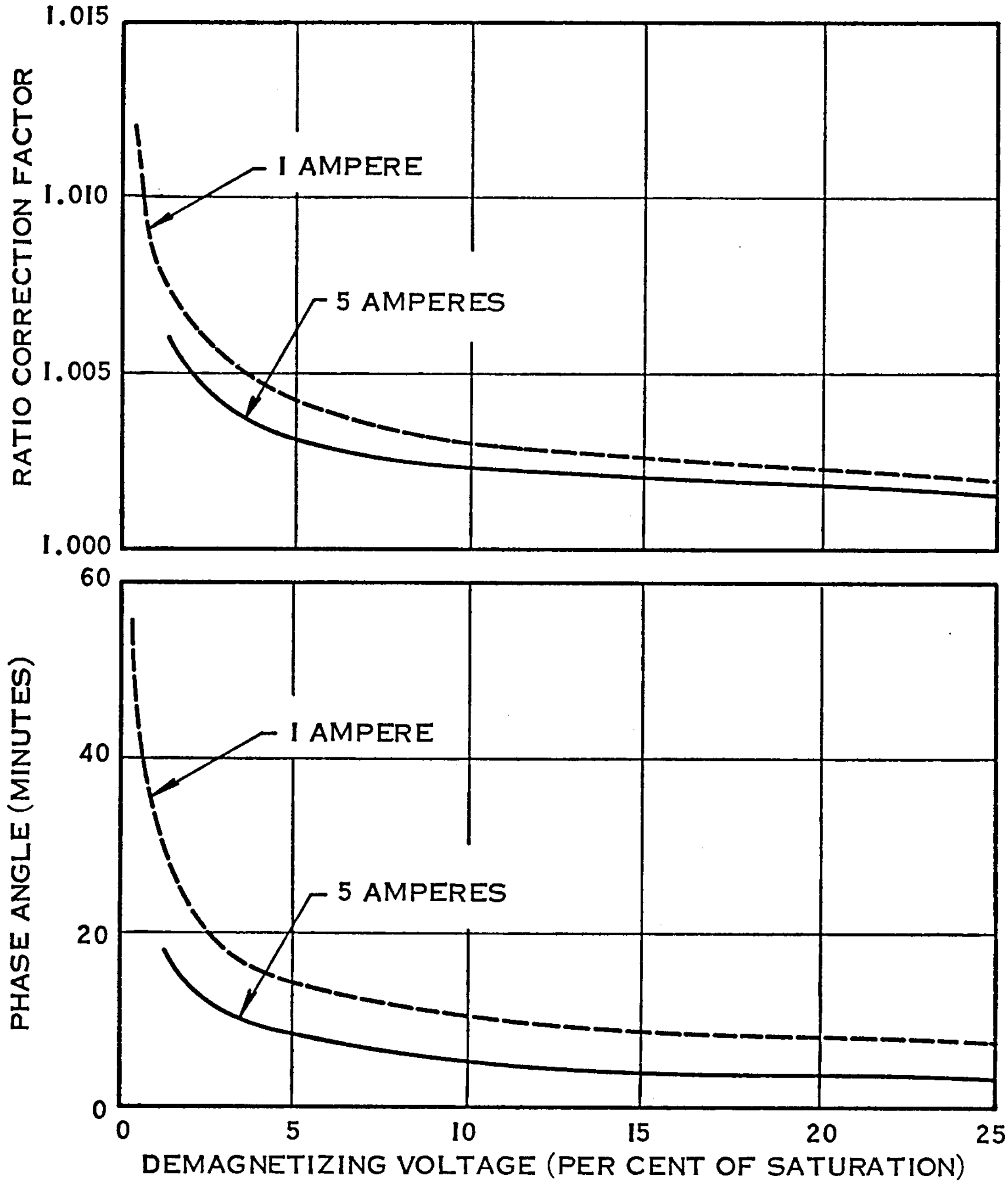

FIGURE 5

EFFECT OF REMANENCE ON
CURRENT TRANSFORMER ACCURACY

Relaying Current Transformers

The three important factors that affect the performance of a relaying current transformer are residual magnetism, saturation of the core due to the transient component of fault current, and the saturation of the core due to stray magnetic field. In all of these cases errors are caused by driving the core material into the saturation, or low permeability, region, which results in the clipping of the output current waveforms. They are discussed below.

In an era when fault clearing times are being pushed to the limit, there is not sufficient attention being paid to the errors of current transformers under fault conditions. Very few people realize that the accuracy of relaying transformers is specified and measured under "steady state" condition and that this accuracy must then be translated for fault conditions. The effect of remanence, saturation due to the transient component of fault current, and stray magnetic fields, must be accounted for.

Since remanence in a typical grain-oriented silicon-steel core of a transformer can exceed 75%, the performance of such a transformer can be reduced by a factor of 4 if the polarity of the fault current is unfavourable. To maintain accuracy, the core of the transformer can be increased by 4, or the burden reduced by 4. Alternatively, remanence can be reduced to about 10%, without severely affecting the relaying accuracy of the transformer, by introducing small air gaps in the core. Figure 6 shows the effects of air gaps on the error of a current transformer. Another alternative is to use a biased-core transformer such as shown in Figure 7. This arrangement provides high accuracy and low remanence, but increases the complexity of the transformer.

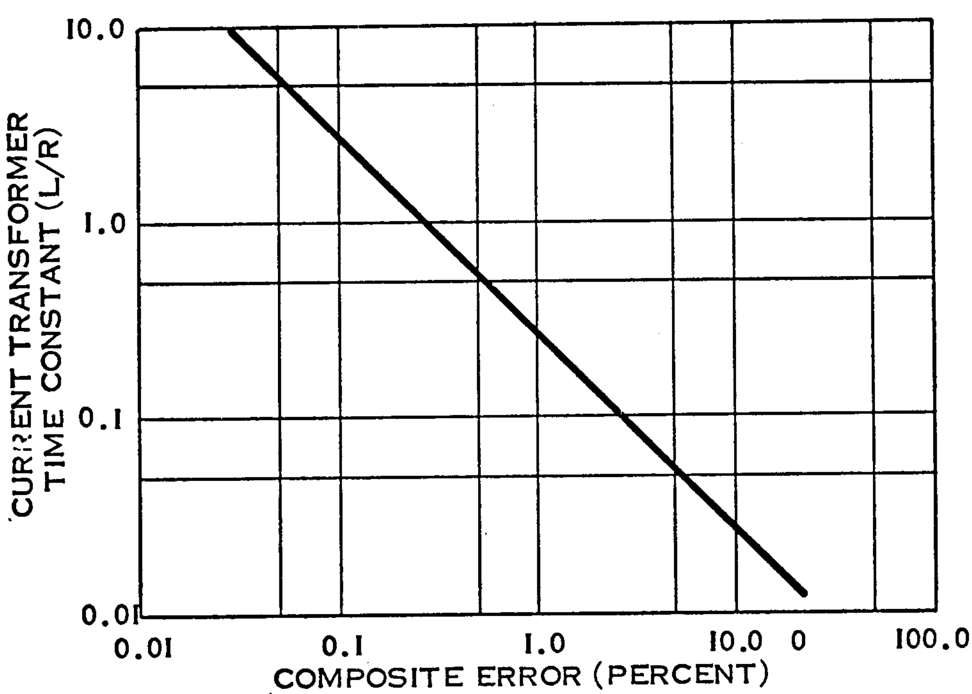

FIGURE 6

COMPOSITE ERROR OF AIR-GAPPED CURRENT TRANSFORMERS

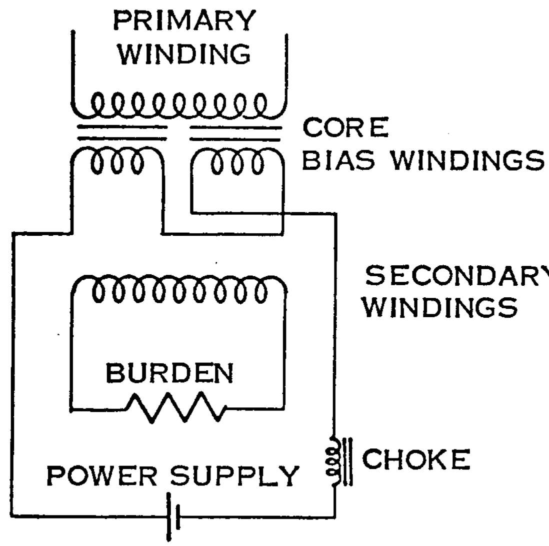

FIGURE 7

BIASED CORE CURRENT TRANSFORMER

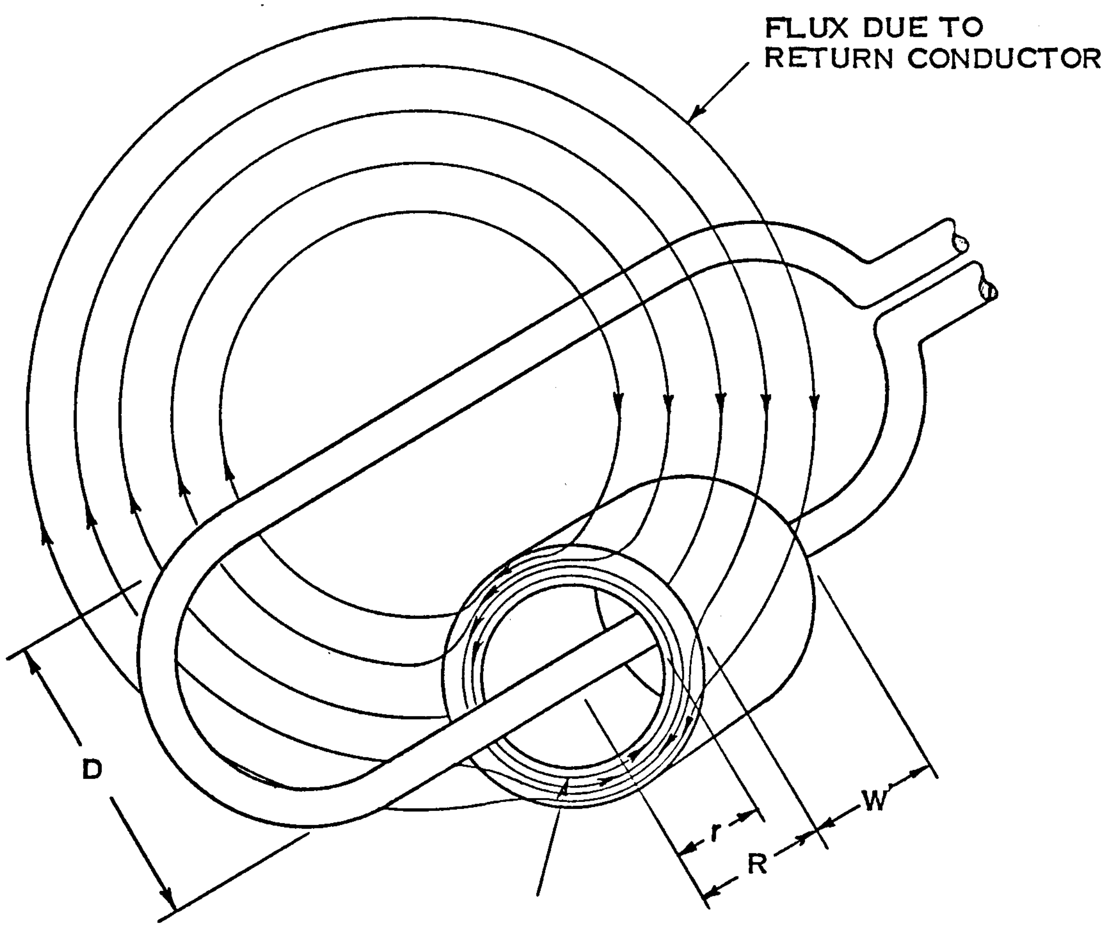

FIGURE 8

STRAY FLUX DUE TO CURRENT IN THE RETURN CONDUCTOR

The second important cause of transformer inaccuracy is core saturation caused by the transient component. Even without any transient component, and assuming no remanence, a transformer can cope with only one-half the fault current in the first half cycle. This is due to the "doubling effect" - the same effect that is responsible for the inrush currents on power and potential transformers. To cope with the transient component, the transformer core must be increased. The required increase is approximately 377 times the transient's time constant. Since transients on the power system range up to 0.05 seconds or so, the multipliers for the core will therefore range up to 20 or so.

The third important cause of transformer inaccuracy is caused by the stray magnetic field from the return conductor or from nearby current carrying conductors (Figure 8). This phenomenon, although of highest importance for large ratio transformers, such as generator current transformers, is also important for current transformers of medium ratios. To avoid the pick-up of the stray magnetic field, shield windings are indicated. A typical shield winding consists of a number of windings on the core, all paralleled together on a common bus (Figure 9). In the presence of stray (external to the core) magnetic field, a circulating current is set up between the windings. Under ideal conditions, the magnetic field due to this circulating current is equal and opposite to the stray field. The effect of such a winding is shown in Figure 10 where the operating range of the current transformer has been extended tenfold.

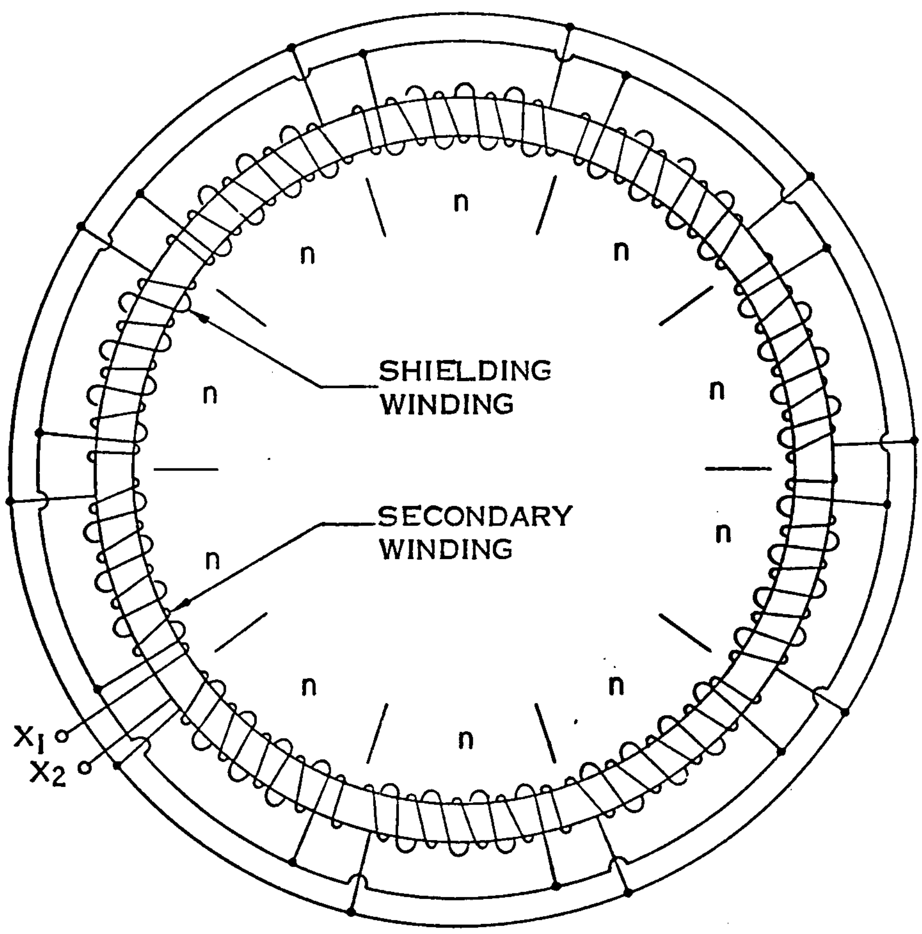

FIGURE 9

DIAGRAM OF A CURRENT TRANSFORMER WITH A SHIELD WINDING

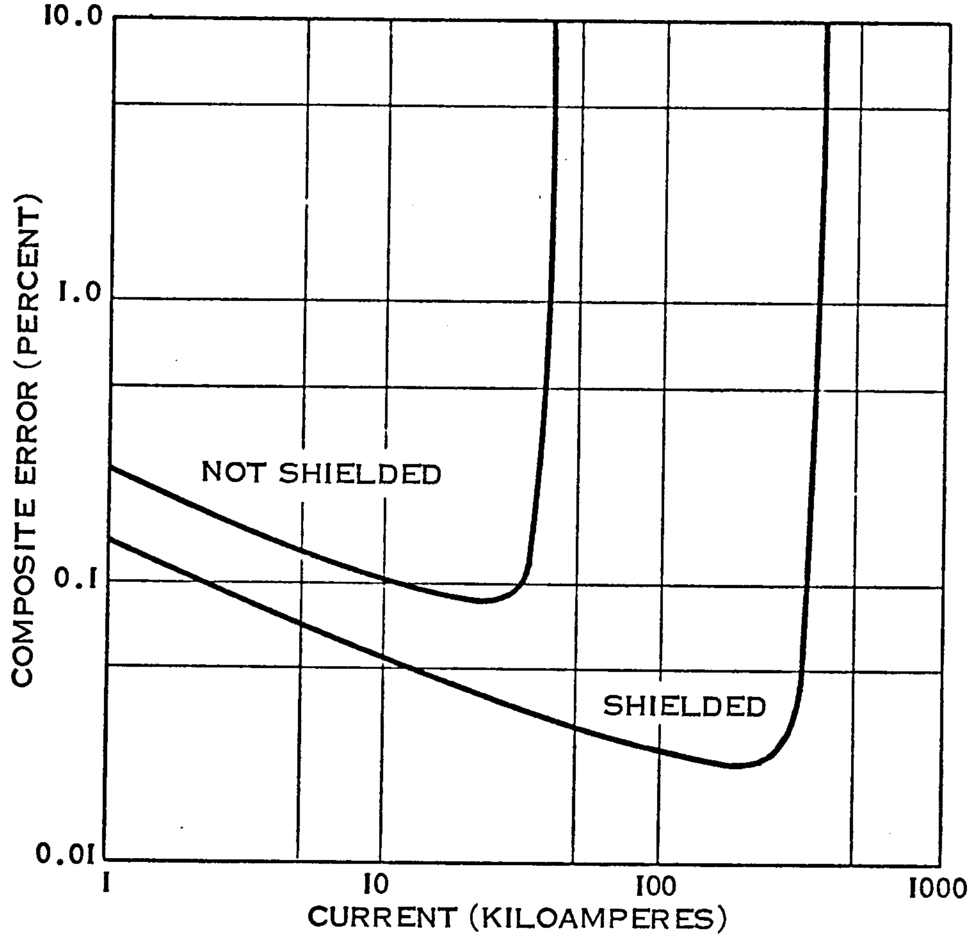

FIGURE 10

PERFORMANCE OF SHIELDED AND NOT SHIELDED TOROIDAL CURRENT TRANSFORMER

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