

purpose very well. An opening should be made near the bottom and another at the top of the box to permit a circulation of air and also to serve as a means of controlling the temperature of the air inside the box. The heat may be applied by circulating current through resistances, the iron grid form is frequently most suitable, placed at the bottom of the box. It should be applied at such a rate that the transformer coils will be maintained at approximately 90 C. (194 F). Care should be taken to protect the transformer from direct radiation from the heaters. Care must be taken also to see that there is no inflammable material near the heaters which may catch fire. This method of drying out has an advantage over the method outlined in (a) in that direct current may be used for heating.

Instead of placing the heater inside the box containing the transformer, it may be placed outside and the heat carried into the box through a suitable pipe. Where this plan is used the heat may be generated by the direct combustion of gas, coal or wood, but none of the products of combustion should be allowed to enter the box containing the transformer. Heating by direct combustion is not advised except in case where electric current is not available.

(c) Internal and external heat.

The transformer should be placed in a wooden box as in (b) and external heat applied, while at the same time a small amount of current is circulated through the transformer windings. The method of circulating the current should be the same as given in (a), and the method of applying the external heat the same as given in (b). The current should, of course, be considerably less than when no external heat is used, the value being determined, to a certain extent, by the amount of external heat applied. This method is used occasionally where direct current only is available, a certain amount of current being passed through the high-tension winding only, as the low-tension winding is ordinarily wound for so heavy a current that it cannot be obtained economically from a direct-current circuit.

The length of time the drying-out should be continued will depend largely upon the condition in which the transformer is received, and unless in very bad shape, a week's run should be sufficient to put the transformer in good condition. In certain cases, however, it has been found necessary to continue the run for a somewhat longer time.

It will be found that when the current is first applied and the transformer heats up the insulation resistance will drop very rapidly, until the desired temperature is reached; then, as this temperature is maintained constant, the resistance will gradually increase. It will also be found that variations from a constant temperature will cause wide changes in resistance. Resistance readings should be made every few hours and the drying continued until the resistance no longer increases, or increases at a very slow rate.

PRECAUTIONS TO BE OBSERVED.

In order to dry out the transformer, it is necessary to maintain it at a temperature which approaches the point where fibrous materials deteriorate. Great care must, therefore, be observed during the whole period of drying out to see that the tempera-

ture does not reach a value much in excess of 90 degrees C.

For measuring the temperature of the transformer coils, several thermometers should be used. These should be placed well in between the coils, near the top of the transformer, and screened from air currents, so that they will indicate the maximum temperature of the windings. As the temperature will rise quite rapidly at first, it is necessary to watch the thermometers carefully to see that the maximum allowable temperature is not exceeded.

As the transformer is soaked with oil, on account of the test which it receives in the works, the material is in an inflammable condition, and while hot it may be ignited very easily by a very small arc or from a blaze of any kind. Before beginning the drying-out, it is well to have some chemical extinguisher, or at least a supply of sand, at hand, which may be used in case of necessity. In general, it is not safe to attempt the drying out of transformers unless constant attention can be given to them.

Cooling of Transformers.

When an alternating current is passed through a coil having an iron core, such as a transformer, besides the copper loss we always have hysteresis and eddy current losses also. However, by proper designing and the use of good material and the exercise of some care in the process of manufacture these losses may be reduced to a minimum, but they are a constant quantity, however small, as long as the transformer is connected to the primary mains.

The copper loss is a variable quantity depending on the square of the load carried. At full load the copper loss is generally made as nearly equal to the iron losses as possible. The energy expended in supplying these losses has no choice but to appear as heat in the iron and coils, and therefore some method has to be adopted to carry off this heat so as to keep the temperature down to a point where it will not be injurious to the insulation. This is accomplished by the use of oil (oil in conjunction with water) and air under pressure.

SELF-COOLING.

The oil-insulated self-cooling transformer is wound for voltages as high as desired and for capacities as great as 5 k.w. This transformer depends for its cooling upon radiation from the surface of the case in which it is mounted. The only satisfactory case yet devised for a self-cooling transformer of large size is one made of heavy sheet iron, corrugated in such a manner as to give a very large surface. The corrugated cases are mounted either in an angle-iron framework or with the sides set into a cast-iron base. A cast-iron top is usually provided and in this are placed suitable bushings for the primary and secondary leads. The self-cooling transformer has one great advantage over all other types, in that no extraneous devices are required for cooling, so that when once installed it will operate indefinitely with practically no attention.

The capacity of the self-cooling transformer is limited to approximately 500 k.w. For greater capacities than this, the cost and dimensions of the case become excessive.

For many classes of service where no attention can be given to the apparatus, the self-

cooling transformer is the only satisfactory type. This promises to be the case in single-phase railway work, where one or two transformers will be installed in out-of-way substations, or perhaps in certain cases on poles where inspection can be made at rare intervals only.

ARTIFICIALLY-COOLED.

System 1. Then we have the oil-insulated artificially cooled type. This transformer can be wound for any desired capacity or voltage. Its construction differs from that of the oil-insulated self-cooled transformer principally in the form of case and in the cooling devices. A number of different methods have been proposed and tried for carrying off the heat, but one method is now almost always used. This consists in forcing or siphoning water through coils of brass or copper tubing placed inside the transformer case below the surface of the oil. This method of cooling is the most simple and direct of any of the artificial-cooling systems.

The case for containing the oil is usually made of boiler-plates riveted and caulked. A cast-iron case and cover are provided and the terminals of the water cooling coils and the leads from the primary and secondary windings are carried through this cover. This form of cooling is used on all the large stepping up transformers of the various Niagara Power companies, and is the only type which would give entire satisfaction where break downs are strictly prohibited.

System 2. Then again we have another type of oil-insulated artificially-cooled transformer. This system is only used to a limited extent and consists in drawing the hot oil away from the transformer tanks, circulating it through a cooling coil which is immersed in running water, and then returning the cooled oil to the transformer case. The circulation is maintained by means of a small motor-driven pump. The advantage of this system over the first one mentioned is that in case of a leak in the cooling system the oil will escape into the water instead of the water into the oil; but as there are very few cases on record where trouble has resulted from leaky water-coils, this advantage does not seem to be of great moment. To effect this single advantage, a pump, a motor, a cooling tank and a system of oil piping are required for the cooling system, and there is the possibility that should a deposit form in the oil it will gather on the inside of the tubes and prevent the circulation and cooling of the oil.

AIR-COOLED.

The air-blast transformer, as its name implies, is one in which the heating is accomplished by means of a forced draught of air. It may be wound for pressures not exceeding approximately 33,000 volts, in units of any desired quantity.

The transformer proper is mounted in a cast-iron housing, so arranged that air, which is admitted at the base, may pass through the cooling ducts between the coils and through those in the iron. Two separate air-passages are provided, one for cooling the coils and the other for cooling the iron. The transformers are usually placed above an air-chamber in which a pressure usually less than one ounce per square inch, above the surrounding air, is maintained. The air is supplied from large steel-plate fans, which