tests were continued later upon an experimental high tension line at the Westinghouse Company's Works, East Pittsburg, when a long and careful series of measurements was made under varying conditions. The manufacture of high tension transformers has been going on continuously for several years, and on the whole so successful has been their operation and so marked have been the improvements in the design and construction of the higher voltage transformers, that to-day consulting engineers and prospective builders of transmission lines have become accustomed to the use of voltages of 40,000 and 50,000, and are seriously considering voltage as high as 60,000. No little confidence, of course, has been established by the successful operation of several high voltage systems in the West, notably the plant of the Missouri River Power Company, which transmits energy at 50,000 volts from Canyon Ferry to Helena and Butte, distances of 17 and 65 miles respectively. Mention is so frequently made to-day of transmission at voltages in the vicinity of 50,000, and so many projects are being planned which embody transmission lines of approximately this voltage, that the successful inauguration early this year of a 50,000 volt line almost one hundred miles in length did not attract the attention it would have done even twelve months ago. I refer to the transmission system of the Shawinigan Water and Power Co., extending from Shawinigan Falls on the St. Maurice River, P. Q., to Maissonneuve, a suburb of Montreal. Since the middle of February, this line has been delivering energy generated at Shawinigan Falls to Montreal, ninety miles distant, at a pressure of 50,000 volts. From the time this line was first thrown into service no shut downs whatever have occurred

The generating plant and the transmission line each merit detailed description. It is the purpose, however, of this paper to describe only the transformers as typical of the latest and best engineering practice in the design of high tension apparatus. The raising transformers are designed to step up from the generator pressure, 2,200 volts two-phase, to 50,000 volts three-phase. The lowering transformers step down from 44,000 volts three-phase (allowance being made for a line drop of 12 per cent.), to 2,400 volts three-phase, two transformers being connected in T. Taps for 86.7 per cent. are provided in both the high tension and the low tension windings; since two transformers connected in this way have a slightly higher efficiency and a better regulation than they would if connected either in V or in T, with the full windings of both transformers in use.

No reference has as yet been made to the capacity of either the raising or lowering transformers. In the rating of these units lies one of their special features, well worth mentioning at this time. The generating plant at Shawinigan Falls was designed with the idea of furnishing power at 2,200 volts to industrial establishments in the immediate vicinity. For the power service contemplated a frequency of 30 cycles was chosen. When the plans for the transmission lines to Montreal were made it was decided to use the 30 cycle generators already installed, transmitting at that frequency and changing at Montreal to the frequency in use there (60 cycles) by means of motor-generator outfits. Future contingencies were, however, kept in mind and it seemed advisable to have the high tension transformers so built that at a later date, if desired, 60 cycle generators could be installed at Shawinigan Falls and the company's Montreal customers supplied with 60 cycle current direct from the secondaries of the step-down transformers. In fine, the transformers were to be designed for operation at either 30 or 60 cycles. This was done in the following manner: A design was made for a 30 cycle transformer of the specified capacity (1,110-K.W. for the raising, and 1,000-K.W. for the lowering), the characteristics being such that high efficiency and good regulation would be obtained. Both high tension and low tension windings were made in two equal parts, with terminals arranged for either series or multiple connection. For 30 cycles the windings were designed to be connected in series. For 60 cycles, however, the two parts were to be connected in multiple, the same voltage being applied to but half the number of turns. The result of this is that while each part will carry the same amount of current as with the 30 cycle connection, the two parts together will deliver twice the amount of current with the same copper loss and at the same voltage as before, thereby doubling the capacity of the transformer. Thus, while the raising transformers have a capacity of 1,100-K.W. for 30 cycle operation, they are rated at 2,220-K.W. for 60 cycles, and the lowering transformers are likewise rated at 1,000-K.W. and 2,000-K.W for 30 and 60 cycles respectively. Operating at 60 cycles the transformers will deliver their rated output (2,200 K. W.), with an ohmic drop only one-half of that for full-load at 30 cycles. The inductive drop will be the same under either condition. The regulation, therefore, at 60 cycles is better than at 30 cycles, the exact figure in the case of the raising transformer being for loads having a power factor of 100 per cent., the extremely low value of 0.376 per cent. With the number of effective turns decreased by the same amount, the flux density in the magnetic circuit will be the same, the loss per cycle being slightly more at the higher frequency than at the lower. The iron loss is, therefore, a little more than double at 60 cycles. Its percentage value, however, is increased but very little.

In the preliminary consideration of these transformers, there was but little choice concerning the general type to be employed. With the construction used at present, in the air blast transformers, the limit of its voltage is in the neighborhood of 25,000 or 30,000. The oil-insulated transformer, however, has been built for voltages far in excess of those now in commercial use, so that the voltage of transmission lines of the future will not be determined by the limitations of the transformers. For voltages above 30,000, then, we are safe in saying that the feature of oil insulation is essential. For transformers of small capacity the cases may be designed with a surface of such an area that natural radiation will keep the temperature of the transformer at some conventional figure. The cost of this radiating surface increases, however, as a high power of the increase in capacity, so that for large transformers recourse must be had to artificial cooling of some kind. In the Shawinigan transformers the heat is removed from the oil by means of the conventional cooling coils, through which water is circulated. These coils are of brass tubing and have no joints nor connections of any kind inside the case, so that the danger of leaks is reduced to a minimum. The Shawinigan transformers are placed in an upright position in boiler iron cases. A more detailed description of these cases will be given later. Both high tension and low tension leads are brought out through the case iron tops, long specially made tubes of fullerboard and mica being used for the high tension conductors. The coils of these transformers are wound up in sections of only one turn per layer. The turns are well insulated from each other and the several coils and sections are protected by wrappings and washers of heavy insulation. A very generous provision is made for ventilating ducts between the sections and between the laminae of insulations. There has been a tendency in the design of some transformers to overlook the fact that there are losses generated in the insulation and that in high tension transformers some provision must be made to dispose of the resulting heat. Careful attention was given to this point in the transformers in question and the insulating material, as well as the copper itself, is kept at a temperature only slightly higher than that of the oil. This point was proved by careful exploration with thermometers during the tests. The ducts through the windings are vertical, so that when a transformer is operated a pronounced chimney effect is produced, the oil rising to the top with such a velocity that the surface of the oil is visibly distributed. The iron laminations are also separated at frequent intervals by ventilating ducts, which permit the oil to circulate to within less than an inch and a half of every part of the magnetic circuit. The low tension leads from the coils are brought direct to a heavy marble terminal board, so arranged with studs and connectors that the somewhat complicated combinations referred to earlier can be easily and quickly made. The terminal board for the high tension leads presented a more difficult problem; its solution was found, however, in the use of standard porcelain insulators mounted on pins and cross arms. Since the insulators are under oil, a compact arrangement was effected which has