# The Electric Power Supply for the Puget Sound Lines of the Chicago, Milwaukee & St. Paul Railroad

A. W. Copley

THE electrification of the Puget Sound lines of the Chicago, Milwaukee & St. Paul Railroad, which is now being put into operation, covers the Pacific and the Columbia River divisions and extends from Othello to Seattle and Tacoma, Washington. It does not connect with the electrification of the Missoula and Rocky Mountain divisions, as there is a gap of about 200 miles where steam operation is being continued. The power supply for the eastern lines (the Missoula and Rocky Mountain Divisions) is obtained from the Montana Power Company, with its large water power developments on the Missouri and Clark Fork Rivers. The power supply for the new electrification is obtained from the Intermountain Power Company, which buys power from the Washington Water Power Company and the Puget Sound Traction Light & Power Company. As these companies have large water power developments, the entire electrification can be said to be operated without the use of coal or oil fuel.

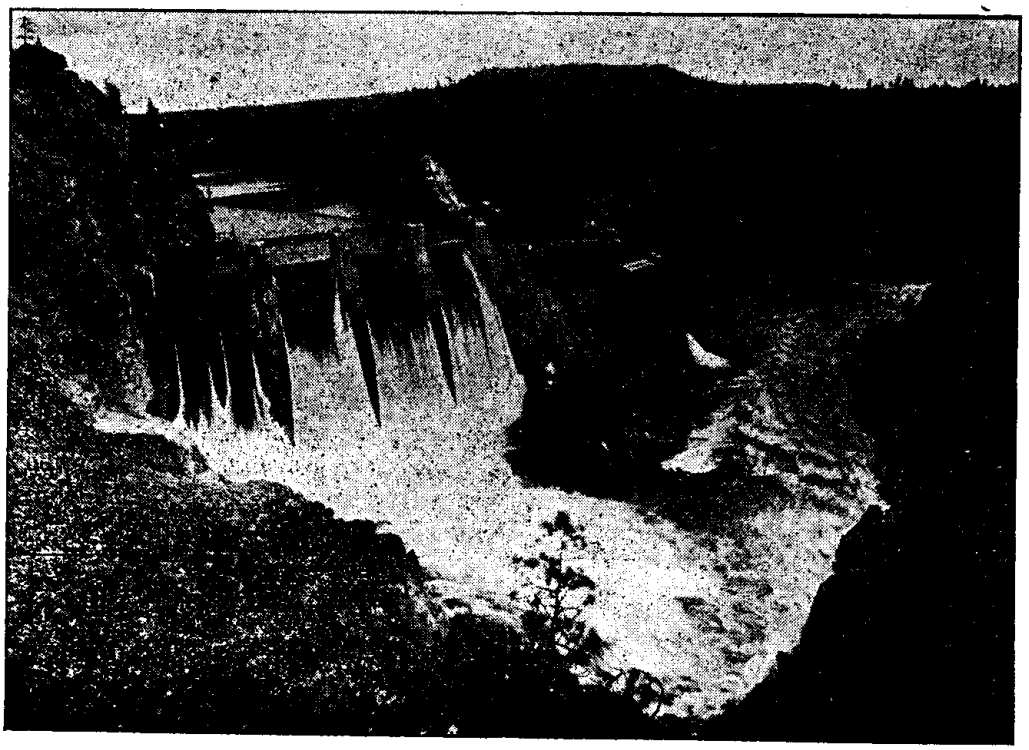

FIG. 1—LONG LAKE PLANT OF THE WASHINGTON WATER POWER COMPANY
Having a total capacity of 65 000 hp.*

Power for the Pacific and Columbia River Divisions is delivered to the railroad at three points (four ultimately) and in order to distribute the power to the eight substations, a transmission line has been built by the railroad on its right of way from Taunton to Cedar Falls, and another from Renton to Tacoma. Both of these lines are built with 110 000 volt construction. The eight substations are located at Taunton, Doris, Kittitas, Cle-Elum, Hyak, Cedar Falls, Renton, and Tacoma. At each of these the power is transformed to 2300 volts, which is applied to the motors of the motor-generator sets, 3000 volts, direct current being obtained from the generators. Power is supplied at this voltage to the trolley.

The railroad transmission line between Taunton and Cedar Falls is 141 miles long. It is similar in its construction to the line which has been in service on the Rocky Mountain and Missoula divisions, the principal modification being the fact that transpositions, coordinated with those of the neighboring telephone lines, have been introduced,. in order to reduce as far as possible inductive interference from this part of the system. Single poles with two cross-arms are used. The upper arm supports at one end a 3/8 inch steel ground wire and at the other end a 00 stranded copper

*Figs. 1, 2, 5, 9, 10 and 13 furnished through the courtesy of the *Stone & Webster Journal*, Boston, Mass.

conductor with hemp core. The other oo line conductors are suspended from the ends of the lower arm. This gives a spacing of the conductors in the form of a right-angle triangle with a base of 10 ft. 2 inches and an altitude of 9 ft. A diagram of the high-tension system showing the transpositions is shown in Fig. 8. There is one complete "barrel" between Tacoma and Renton (a distance of about 27 miles) and another between Renton and Snoqualmie (about 21 miles), the ground wire being changed from one end of the upper arm to the other at Renton. Between Snoqualmie and Taunton there are two transpositions, one at Cedar Falls and another at Kittitas. These two transpositions affect only the diagonally opposite conductors, which are interchanged at the transposition points.

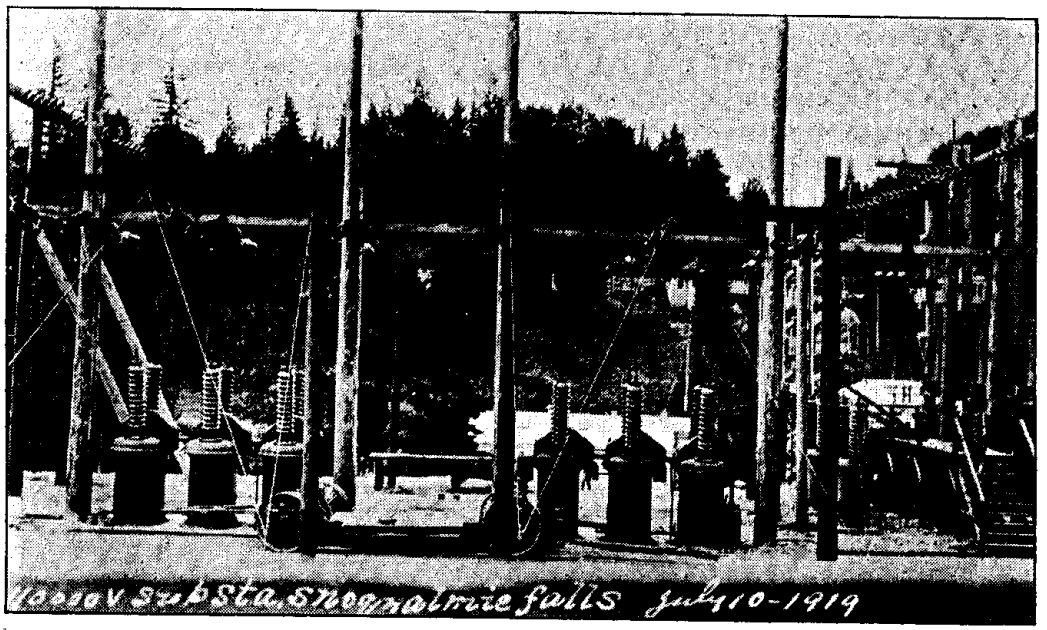


FIG. 2—OUTDOOR SUBSTATION AT SNOQUALMIE, SHOWING LINE SWITCHES

Traction Light & Power Company are entirely separated and must be synchronized before the sectionalizing circuit breakers may be closed again. Synchronizing is accomplished at the substation at which the line has been opened. The plant which will supply the power from the Washington Water Power Company is located at Long Lake on the Spokane River. This is connected to feed the railroad transmission circuit by a 110 000 volt, three-phase line, 113 miles long. This line uses the wood pole "H" frame construction, giving a horizontal spacing of the conductors of 10 ft. 6 in. Six suspension insulators are used for each string. A 3/8 inch steel ground wire is supported on the tops of the poles above the transmission wires for lightning protection. The line conductor is 115 500 circ. mil 7-strand copper. In the Long Lake plant there are three 19 500 kv-a. three-phase, 60 cycle, 4000 volt generators and three banks of 6500 kw, single-phase, step-up transformers. These are connected delta-delta for 63 000 volts high-tension or delta-star to give 110 000 volts. One spare transformer unit is installed. The tie lines between the other plants of the Washington Water Power Company are operated at 63 000 volts, but at Long Lake one generator and bank of transformers are connected to supply the 110 000 volt cir-

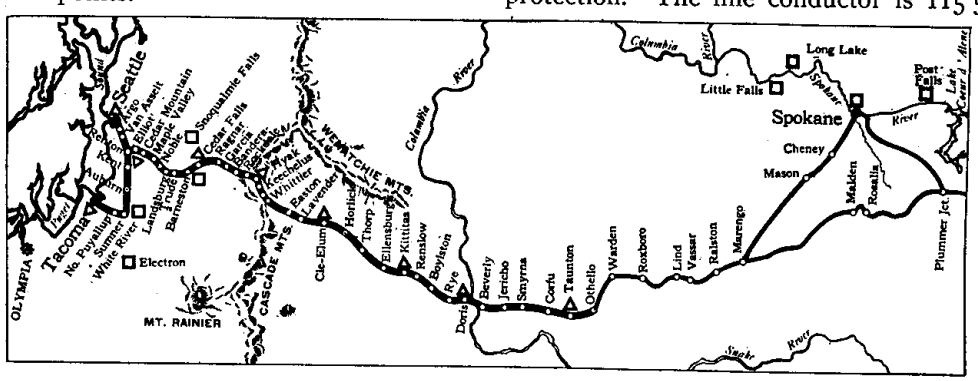


FIG. 3—MAP OF RECENTLY ELECTRIFIED SECTION OF THE CHICAGO, MILWAUKEE & ST. PAUL RAILROAD
Showing location of substations (triangle) and hydroelectric stations (square) supplying power.

The 110 000 volt line may be sectionalized at any substation. At Taunton, Kittitas, Hyak and Cedar Falls, sectionalization is accomplished by the use of oil circuit breakers provided with power directional relays, so set as to cut out only the affected section in case of a short-circuit or ground. At Doris and Cle-Elum, horn-gap disconnecting switches are used for sectionalization and these are non-automatic. When the line is opened at any of these stations, the power plants of the Washington Water Power Company and the Puget Sound

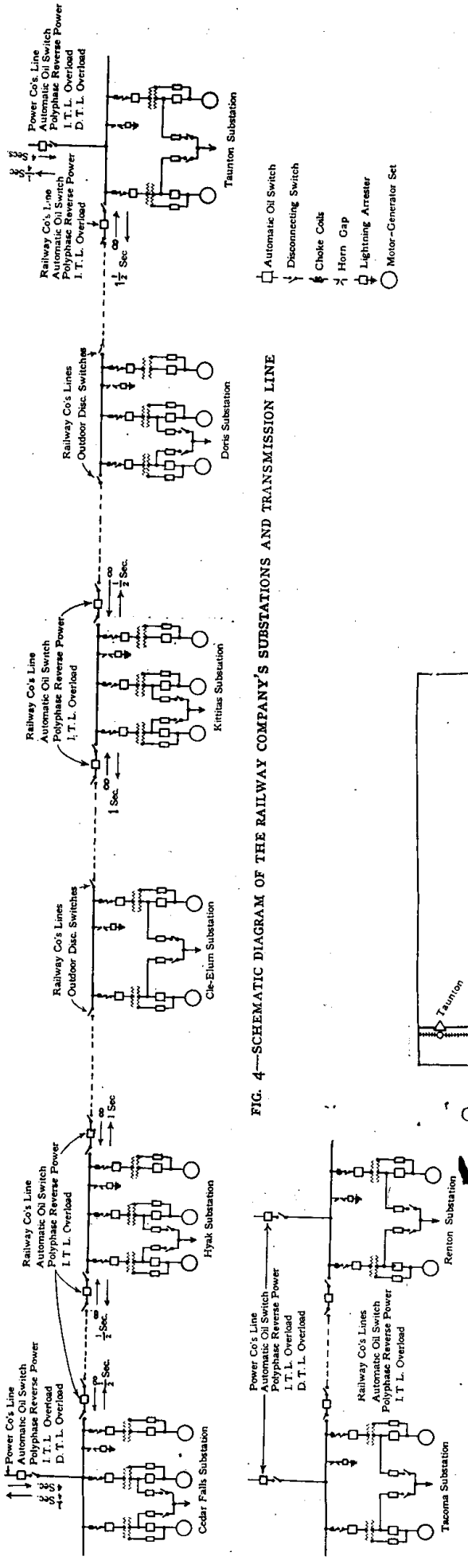


FIG. 4—SCHEMATIC DIAGRAM OF THE RAILWAY COMPANY'S SUBSTATIONS AND TRANSMISSION LINE

FIG. 5—GATE HOUSE, PENSTOCK AND TRANSMISSION LINE AT LONG LAKE PLANT

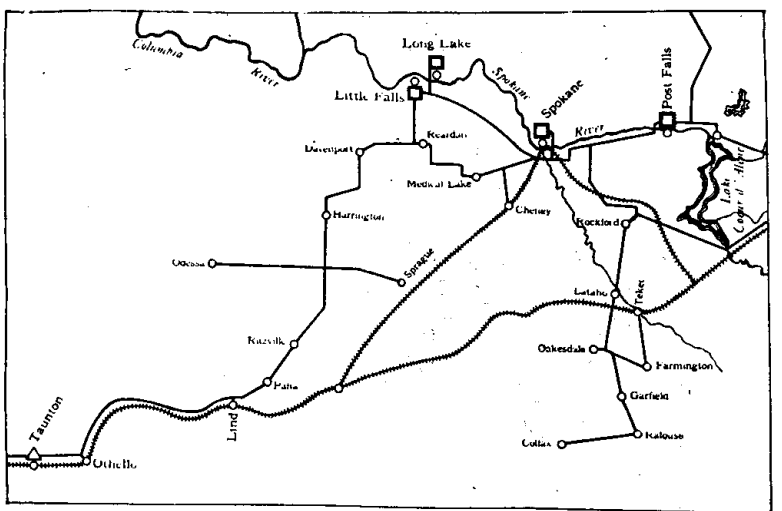


FIG. 6—LOCATION OF HYDRO-ELECTRIC SUBSTATIONS AND HIGH TENSION TRANSMISSION LINE

Of the Washington Water Power Company and of the Intermountain Power Company, connecting with the Railway Company's transmission line at Taunton.

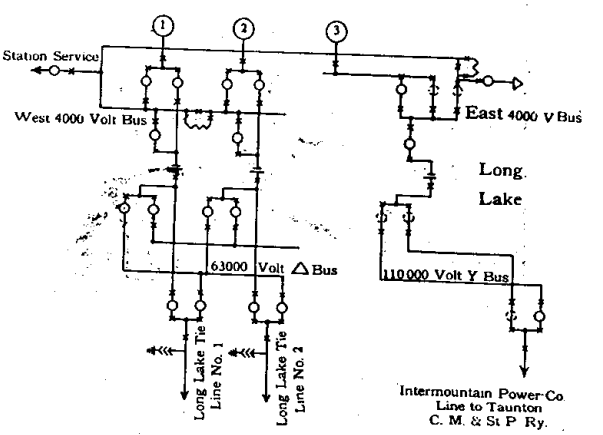


FIG. 7—CONNECTIONS BETWEEN 63 000 VOLT SYSTEM OF WASHINGTON WATER POWER COMPANY AND THE 110 000 VOLT FEEDERS AT LONG LAKE

cuit to the railroad. There is a 4000 volt transfer bus in the station so that any generator can be connected to any transformer bank as an insurance of continuous service. When the generators are all operated on the six three-phase transformers (with one spare) are installed. In addition to these plants a steam plant in Spokane can be connected to the 63 000 volt system, but ordinarily it is not so connected.

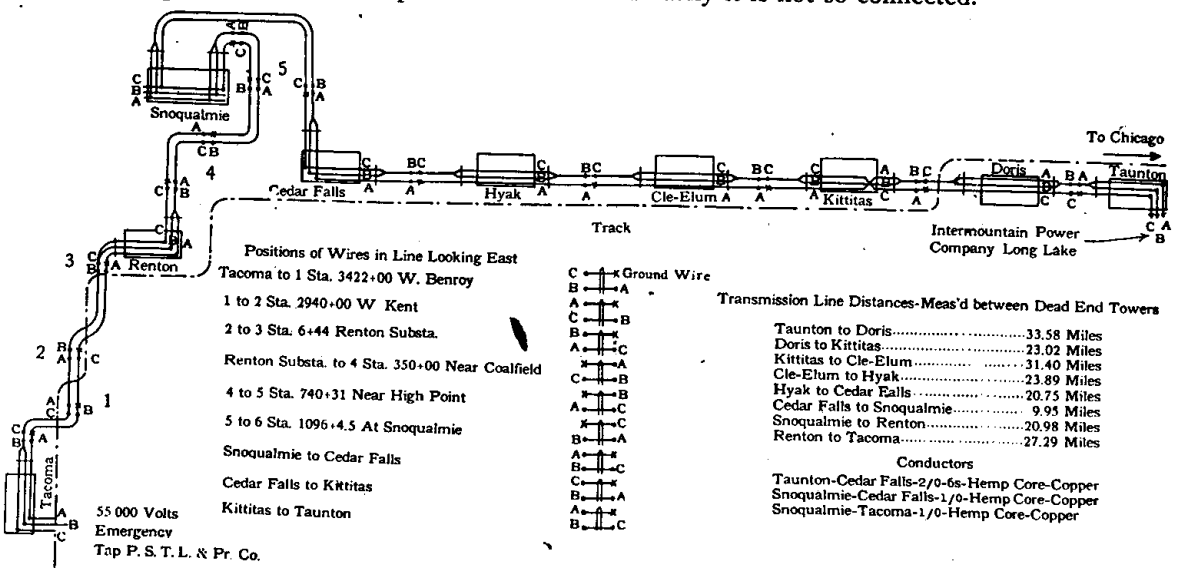


FIG. 8—TRANSPOSITION SCHEME OF THE RAILWAY COMPANY'S 110 000 VOLT SYSTEM

bus, ten percent reactors are connected between the bus sections.

It is also possible to supply the railroad transmission line with power from Little Falls or Post Falls by stepping down from 63 000 volts at Long Lake to the 4000 volt bus and then up to 110 000 volts through the regular generator transformers. At Little Falls there are four generators, three of them being rated at 6250 kv-a. and one at 6900 kv-a. These connect to three-phase transformers, stepping up from 4000 volts to 63 000 volts with grounded neutral on the high-tension side. At Post Falls, five 2250 kv-a. generators and

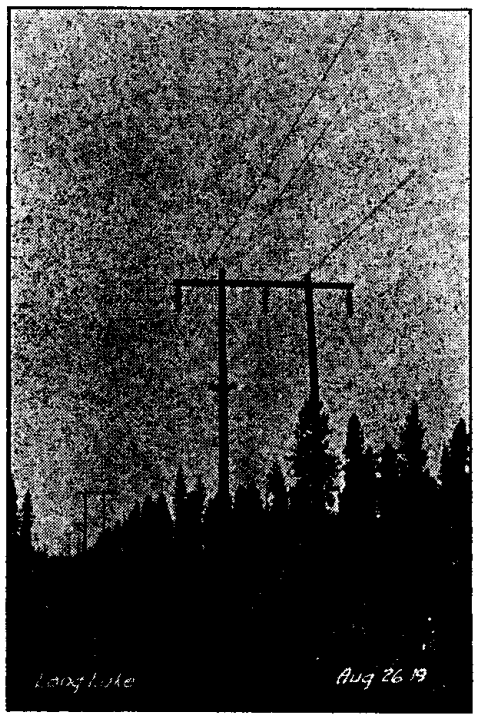


FIG. 9—TYPICAL LINE CONSTRUCTION OF THE INTERMOUNTAIN POWER COMPANY

Telephone wires are carried on the lower cross arms.

At the western end of the electrification, power is supplied from the plants of the Puget Sound Traction Light & Power Company, connections being made through a bank of 4500 kv-a. transformers at the Intermountain Power Company's substation, located at Snoqualmie. One transmission line at 110 000 volts runs from here to Cedar Falls and another from here to Renton. These lines are built with the same construction as used on the railroad transmission lines, except that the conductor is No. 0 stranded copper, with hemp core. Eventually power will also be supplied directly to the Tacoma substation but, at present, power for this station comes from Renton over the railroad transmission line.

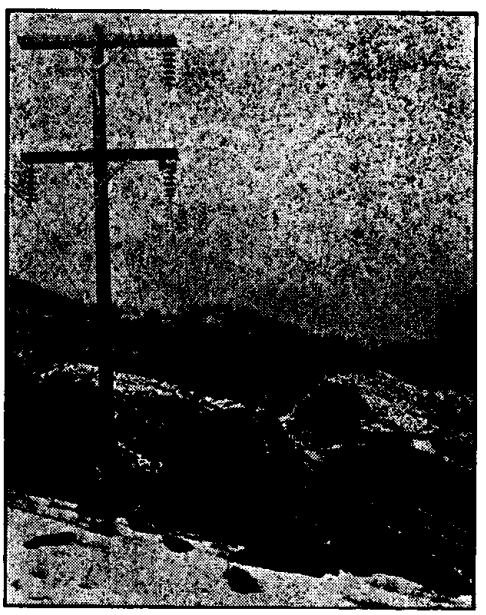

FIG. 10—110 000 VOLT RAILWAY COMPANY TRANSMISSION LINE

At a high point on the line. This shows the double arm construction and the stranded steel ground wire on the left end of the upper cross arm.

The power which can be supplied to the feeders at Snoqualmie consists of the Snoqualmie plant, with 18 000 kw capacity, the White River plant with 52 000 kw, the Electron plant with 14 000 kw, together with the steam plants in the City of Seattle. At times, however, it is expected that power will be fed in the reverse direction over the Cedar Falls feeder, with the Washington Water Power Company supplying some of the Puget Sound Traction Light & Power Company's load over the Railroad company's transmission line.

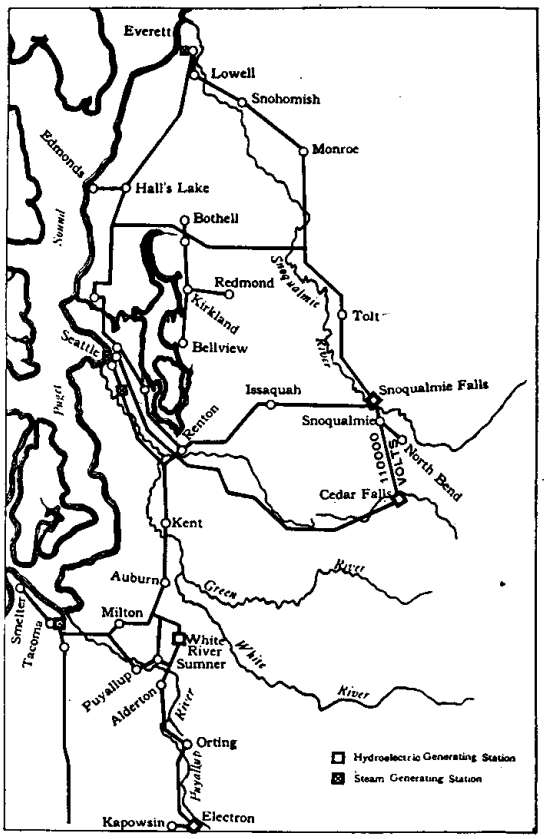


FIG. 11—LOCATION OF HYDRO-ELECTRIC SUBSTATIONS AND HIGH-TENSION TRANSMISSION LINES OF THE PUGET SOUND TRACTION, LIGHT AND POWER COMPANY'S SYSTEM

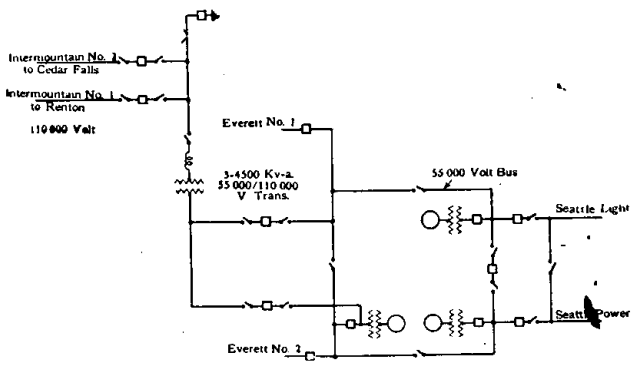


FIG. 12—CONNECTIONS BETWEEN THE 55 000 VOLT SYSTEM OF THE PUGET SOUND TRACTION, LIGHT & POWER COMPANY AND THE 110 000 VOLT FEEDERS AT SNOQUALMIE

At Tacoma and Renton substations the transformers are arranged for operation at either 55 000 or 110 000 volts. A power tap is provided at Tacoma which can, for emergency service, be connected to the 55 000 volt system of the Puget Sound Traction Light & Power Company at that point. This provides for power in an emergency, if the 110 000 volt transmission from Snoqualmie should be out of commission.

While this transmission line is nominally rated at 110 000 volts, and the Long Lake transformer is connected for 110 000 volts, the transformers at Snoqualmie are connected for 95 000 volts. This holds up the power-factor at Long Lake at times when no load is taken by the Snoqualmie plant. When only the transmission line is connected to the Long Lake plant, the high-tension voltage there is 115 000, and at the Snoqualmie end of the line it is 128 000, the potential rise being caused by the line charging current. Closing the switch to connect the transmission line to the

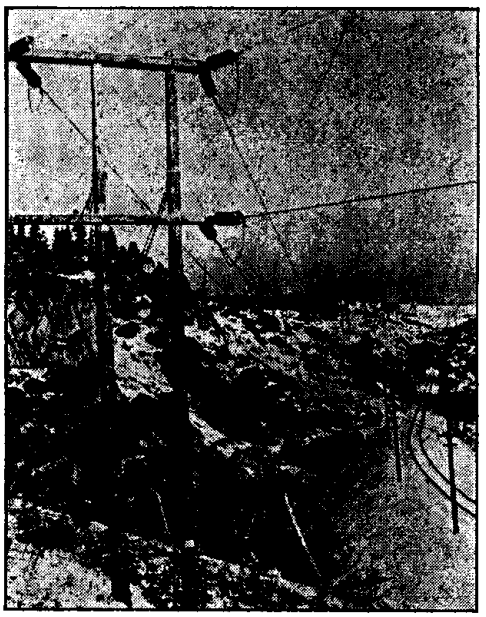

FIG. 13—SPECIAL CONSTRUCTION OF THE 110 000 VOLT RAILWAY COMPANY TRANSMISSION LINE
At an angle point, having a span of 675 feet.

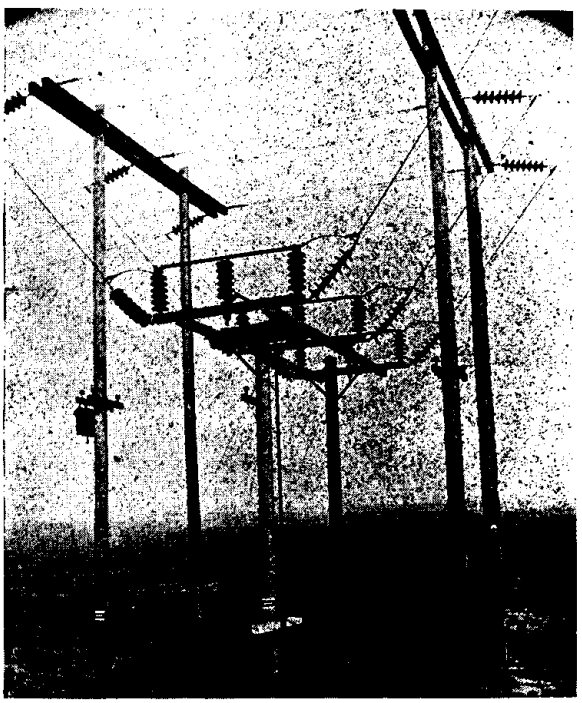

FIG. 14—110 000 VOLT POLE TOP SWITCH AT TAUNTON

95 000 volt taps on the Snoqualmie transformers, gives 101 000 volts at Snoqualmie. If Snoqualmie takes 10 000 kw from Long Lake, the voltage at Snoqualmie drops to 99 000 volts.

The substation equipments include 2500 kv-a. step-down transformers, and 2000 kw motor-generator sets, each set consisting of a 2300 volt, three-phase, 60 cycle synchronous motor driving two 1500 volt, direct-current generators, which are connected in series to obtain 3000 volts. Initially each substation contains two transformer and motor-generator set units, except at Cle-Elum and Renton, where only one set is installed at present. Provision is made for additional units at these stations and also at Doris, Kittitas, Hyak and Cedar Falls.

Equipment for the substations is being supplied by the Westinghouse Electric & Mfg. Company and the General Electric Company. Each of these companies has taken special precautions to guard against the occurrence of flash-overs on the direct-current generators at times of short-circuit on the 3000 volt system. The substations whose equipment is supplied by the General Electric Company are provided with high-speed circuit breakers with a view to opening the circuit before the current has had opportunity to build up. The machines furnished by the Westinghouse Company are protected by the "flash suppressor", a device developed especially for this electrification. It has been proven in service and has been found to meet fully the requirements.

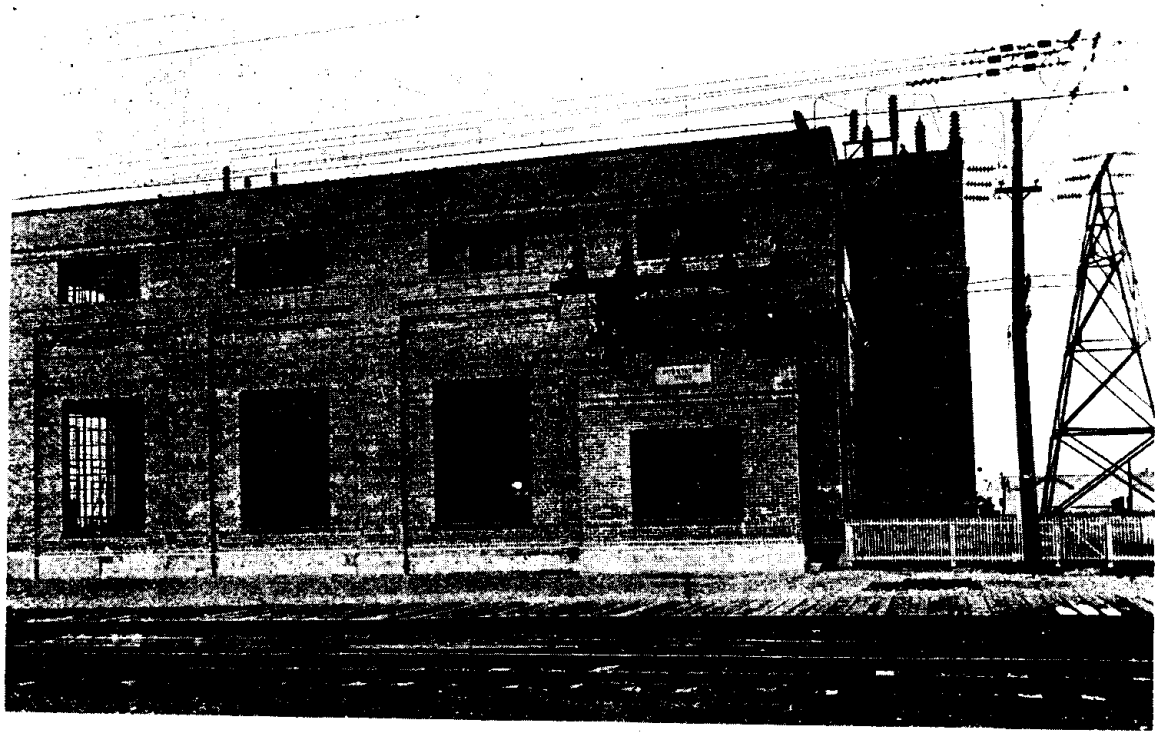

FIG. 15—SUBSTATION NO. 23

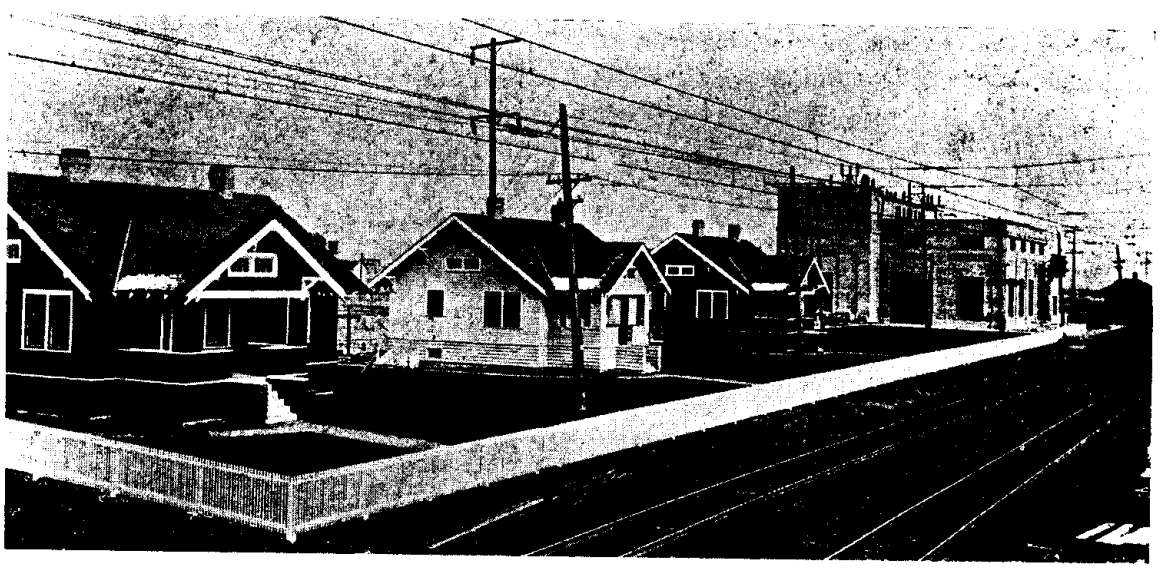

FIG. 16—VIEW OF KITTITAS SUBSTATION, TROLLEY CONSTRUCTION, TRANSMISSION LINE AND COMPANY RESIDENCES

The contract between the Intermountain Power Company and the Chicago, Milwaukee & St. Paul Railroad specifies that the total demand of the Railway Company must not exceed a stated amount when integrated over a period of five minutes, and that the power payment be based upon this amount, with a maximum load factor of 60 percent. For instance, if the denominated maximum is 10 000 kw, the Railway Company will pay for 6000 kw integrated over the month, whether this amount is used or not, and for amounts in excess of 6000 kw will pay at the same rate per kw-hr. This requirement gives the Railway Company the benefits in cost of power generation that accrue because of high load factor. In order to meet the conditions of the contract it becomes necessary to totalize at every instant the whole load being taken into the railway system at the substations located at Taunton, Cedar Falls, Renton and eventually Tacoma. This load must be totalized in such manner that it can be measured by a maximum demand meter with a five minute interval, as well as indicated and recorded. Also, in order to prevent the peaks of load usual to railway service from penalizing the road in additional power cost, the voltage generated at the substations is reduced automatically when the total load reaches such proportions that the nominated maximum demand is in danger of being exceeded. The result is a smoothing out of the load curve of the system by slowing down trains during the peak and spreading some of this load over the valleys of the curve.

# Transformer Equipment

## For the Chicago, Milwaukee & St. Paul Installation

WALTER M. DANN

THE motor-generator sets that supply direct-current to the Chicago, Milwaukee & St. Paul locomotives are connected to the 100 000 volt alternating-current lines through three-phase substation transformers, having a rating of 2500 kv-a. Each motor-generator set, with its motor rated at 2420 kv-a., is fed by its own three-phase transformer, making a complete transforming unit from the high-voltage alternating-current lines to the 3000 volt direct-current circuits.

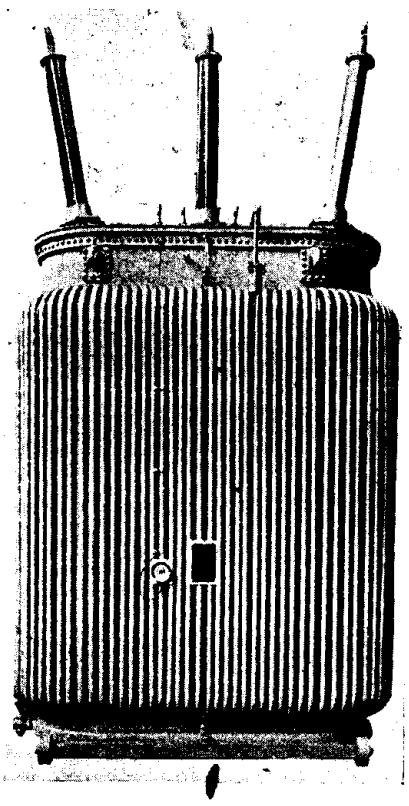

FIG. 1—25 000 KV-A. OIL INSULATED SELF-COOLING TRANSFORMER

These substation transformers are self-cooling, i.e., they dissipate the heat due to their losses without depending upon circulated water or forced air. One of the features that marks the installation as being different from many recent installations is the form of the case. Instead of being provided with external radiators, as most large self-cooling transformers now are, the oil circulates and is cooled through a large number of external tubes, extending from the top to the bottom of the case. This form of self-cooling case is very rugged and substantial, and quite efficient in its heat dissipating qualities. It is more expensive than the radiator type case but it is compact, and requires considerably less floor space. In these substations, the use of the tubular tanks resulted in savings in the cost of the buildings which offset the extra cost of the transformers.

FIG. 2—GROUP OF TRANSFORMERS INSTALLED IN THE DORIS SUBSTATION