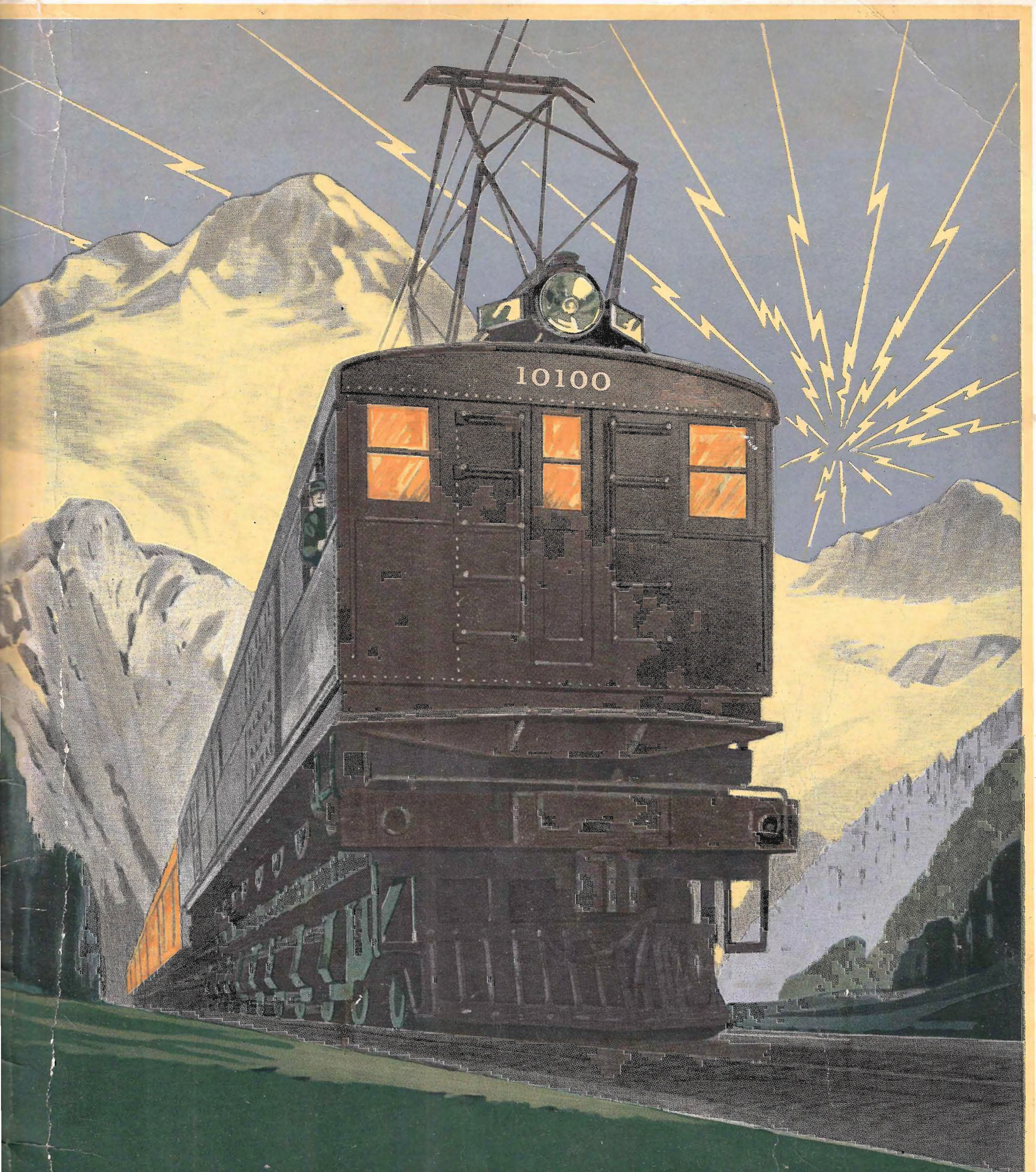
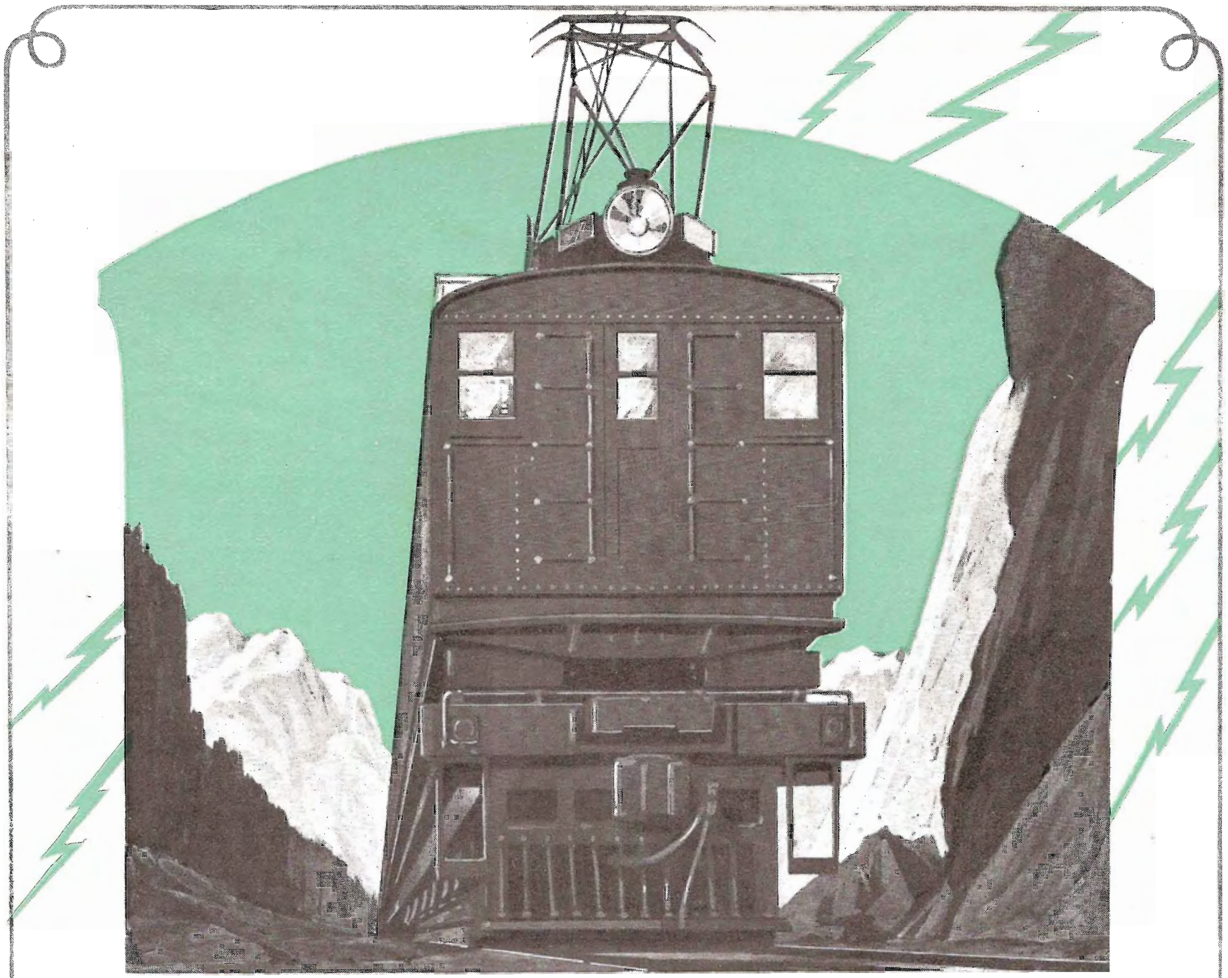


The King of the Rails

CHICAGO, MILWAUKEE & ST. PAUL RAILWAY



The KING of the RAILS

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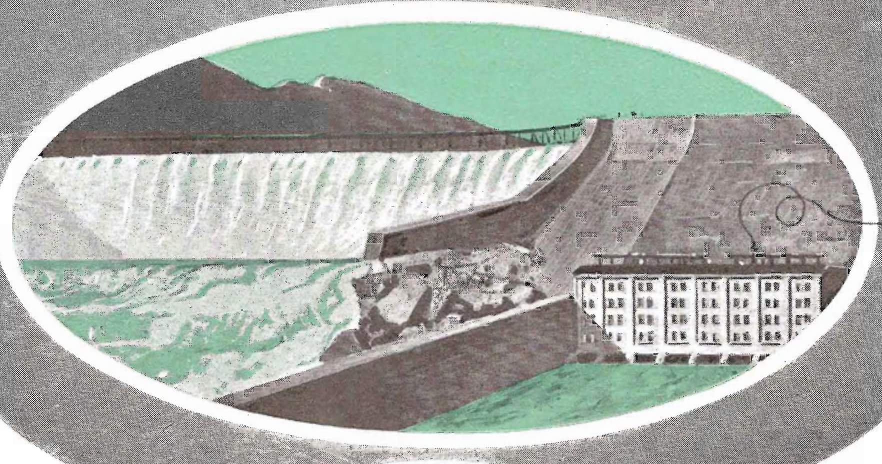


The MIGHTIEST LOCOMOTIVES IN THE WORLD

DRAW "THE OLYMPIAN" AND "THE COLUMBIAN" OVER THE ELECTRIFIED MOUNTAIN DISTRICT OF THE CHICAGO, MILWAUKEE & ST. PAUL RY.

The ELECTRICAL ERA IN RAILROADING-HAS DAWNED

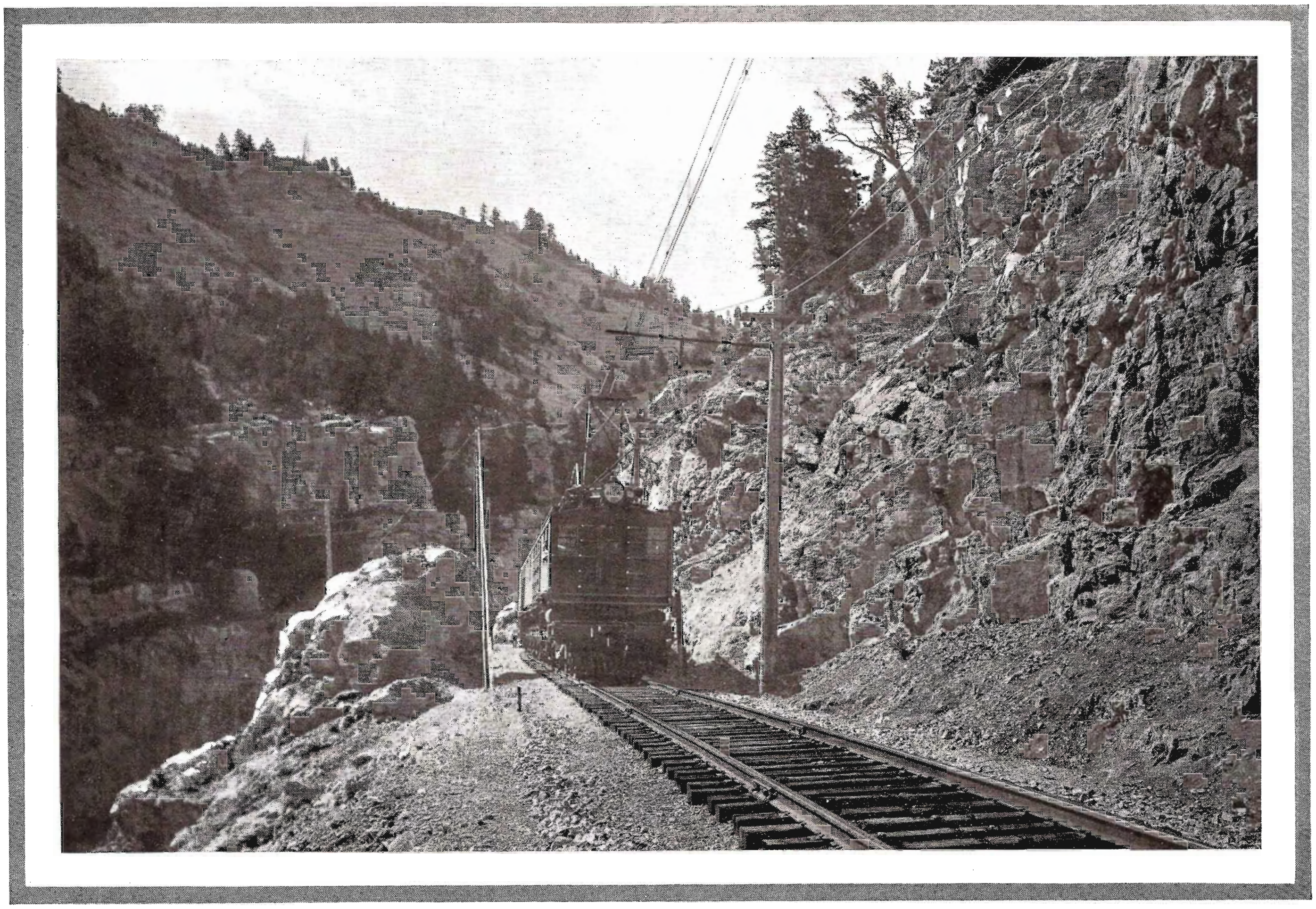
ONLY a little more than ninety years ago, on a rail line between Stockton and Darlington, England, the first steam locomotive, driven by Stephenson, made its maiden trip. Thirty-four vehicles, making a gross load of about ninety tons, composed the train, which attained the then marvelous speed of from five to ten and even fifteen miles an hour. And in advance rode a signalman on horseback!

So began the era of steam transportation. Only twenty-five years later, the first train on the line that formed the nucleus of the Chicago, Milwaukee & St. Paul Railway made its first trip between Milwaukee and Waukesha, a distance of twenty miles. Thus, almost from the beginning of railway history, The Pioneer Line has been identified with the progress of transportation in America. It blazed the first Northwest Trail—between Chicago and the Twin Cities. In 1911 it inaugurated the shortest and most direct transcontinental route between the Great Lakes and the cities of Puget Sound. All the time it led the van in the development of steam locomotion.

And then—

In 1915, on the Rocky Mountain Division of The Pioneer Line, another locomotive made its maiden trip, pressing westward from Harlowton, Montana, over the Continental Divide. This locomotive, by contrast with Stephenson's, and all locomotives used in regular traffic since his day, is electric. And it is mighty—the mightiest of any type in the world. Its huge bulk of 284 tons is three times greater than that of Stephenson's whole train. Its titanic hauling-power could draw thirty-five such trains as Stephenson's up a 1 per cent grade (52.8 feet rise to the mile) at sixteen miles an hour—or, on a level, nine such trains at a mile a minute.

Thus the Chicago, Milwaukee & St. Paul Railway has ushered in the Electrical Era in Railroading—the last word in scientific transportation.



THE HISTORIC MONTANA CANYON

SHOWING THE RAILWAY'S TROLLEY LINE AT THE RIGHT OF THE RIGHT-OF-WAY, CHARACTER OF OVERHEAD BRACKET CONSTRUCTION, AND THE CATENARY SUSPENSION OF THE TROLLEY WIRE FROM "MESSENGER"

What the traveler by "The Olympian" and "The Columbian" sees of this epoch-making feat of engineering as he passes through the mountains under electric traction, is sufficient to whet his desire to see more—or at least to know more—of the details of construction and operation than appears in swift passage through the district. And well may the casual layman be keenly interested in an achievement which has arrested the attention of electrical engineers and railway scientists the world over.

This booklet is designed, stripping the subject of its technicalities, to explain how this Great Thing has been done.

The ELECTRIFIED ZONE

The electric zone extends from Harlowton, Montana, to Avery, Idaho, a distance of 440 miles. Including yards and sidings, the electrified trackage totals 590 miles. So successful has been electric operation in this first zone that already work has been begun on an additional 211 miles from Othello, Washington, to Seattle and Tacoma, on the Pacific Coast, over the Cascade Mountains.

To the tourist this is a region of the most enchanting mountain scenery on the continent. To the engineer it presents a different, but no less fascinating aspect, for hitherto it has been a region opposing to his utmost ingenuity and profoundest scientific skill—difficulties almost insuperable.

There are many short stretches of main line in the United States, formerly operated by steam, where trains are now successfully driven by electricity; but nowhere else in the world has electrification of a trunk line of railway been carried through on a scale even approaching in magnitude—as regards both length of line, tonnage per train, and physical difficulties overcome—this successful accomplishment of the Chicago, Milwaukee & St. Paul Railway.

The most casual inspection of a profile map of the Cordillera region in the northern United States is sufficient to indicate the complexity of these physical difficulties. The Chicago, Milwaukee & St. Paul line at the summit of the Belt Mountains (the easternmost range) reaches an elevation of 5,788 feet; at the crest of the Rockies, 6,322 feet, and at the summit of the Bitter Roots, 4,170 feet above sea level. To haul freight trains of from 2,000 to 3,200 tons, and the heavy all-steel passenger trains—"The Olympian" and "The Columbian"—by electric locomotive across this ragged continental midrib was an undertaking no less than stupendous.

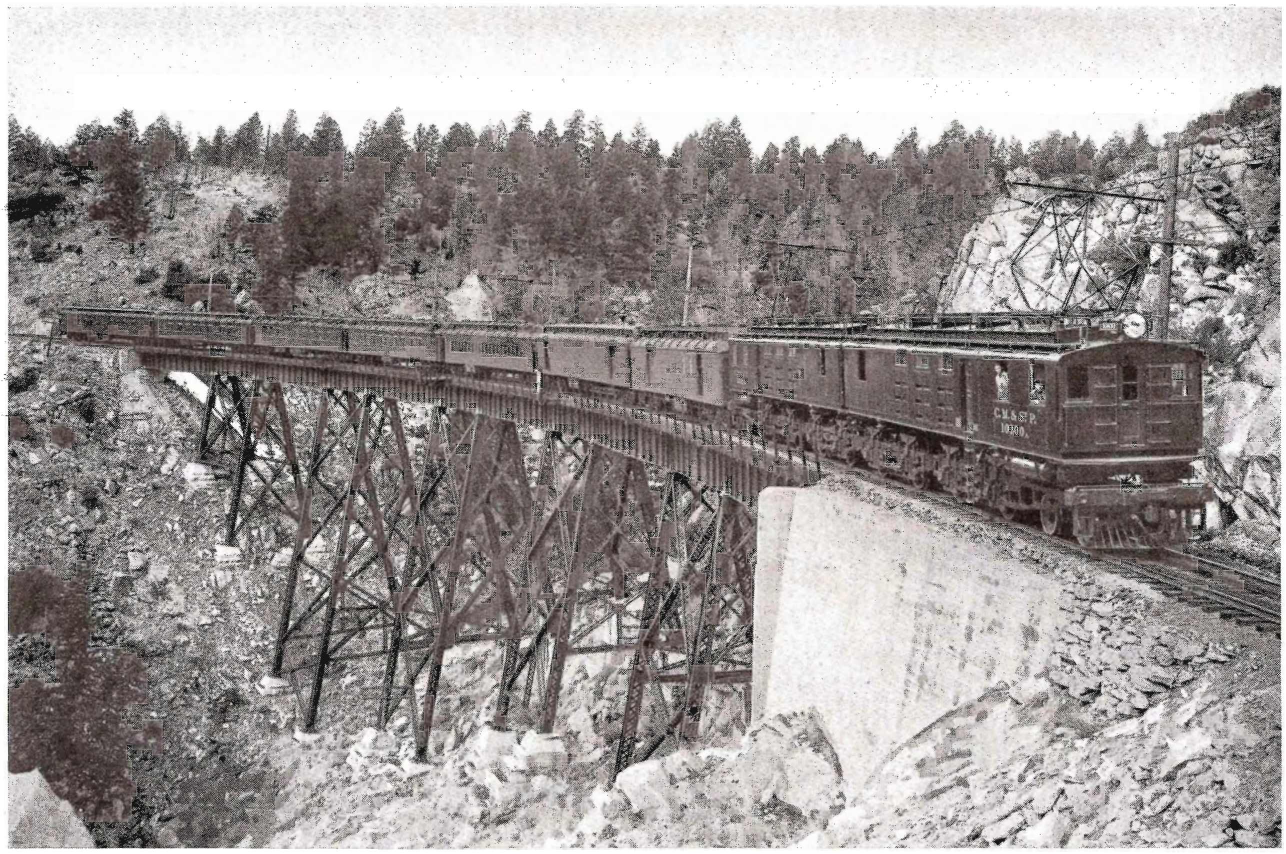
Yet difficulties as great, if not greater, are to be overcome by the westward extension of electrification now under way. This will cross the backbone of the Cascade Mountains in Washington, fourth and last of the great ranges rising across the railway's path. Although not attaining so great an altitude as the Rockies, the rise is more abrupt, while the excessively mountainous topography created obstacles to railway operation which have been overcome only by the most consummate engineering skill.

The ELECTRIC LOCOMOTIVE

In appearance, the Electric Locomotive is as modest as it is mighty. Its trim lines, however, suggest eloquently its latent power. How great is this power may be judged from inspection of its driving equipment—eight massive 430-horsepower motors, each geared to a driving axle, thus giving 3,440 horsepower to each locomotive. Although the locomotive body is divided in the center for greater flexibility in handling, the engine is a unit, with four of its motors at each end.

THE ELECTRIC "OLYMPIAN" ASCENDING THE CONTINENTAL DIVIDE

Just as a trolley car is controlled from either end at will, so is this locomotive, which, accordingly, requires no turntable at division points. Between the leading trucks at each end are four 4-wheel driving trucks, each with a wheel base of 10 feet 6 inches. The length over all is 112 feet. That means that the forty-two electric locomotives which are required for the Harlowton-Avery electrified unit, if placed end-to-end, would reach nearly a mile! The total weight of 284 tons is more than six tons heavier than the Mallet compound engine (with tender)—the mammoth steam locomotive of the most modern type elsewhere in use on the Chicago, Milwaukee & St. Paul Railway.



REGENERATIVE BRAKING AND ELECTRIC SPEED CONTROL

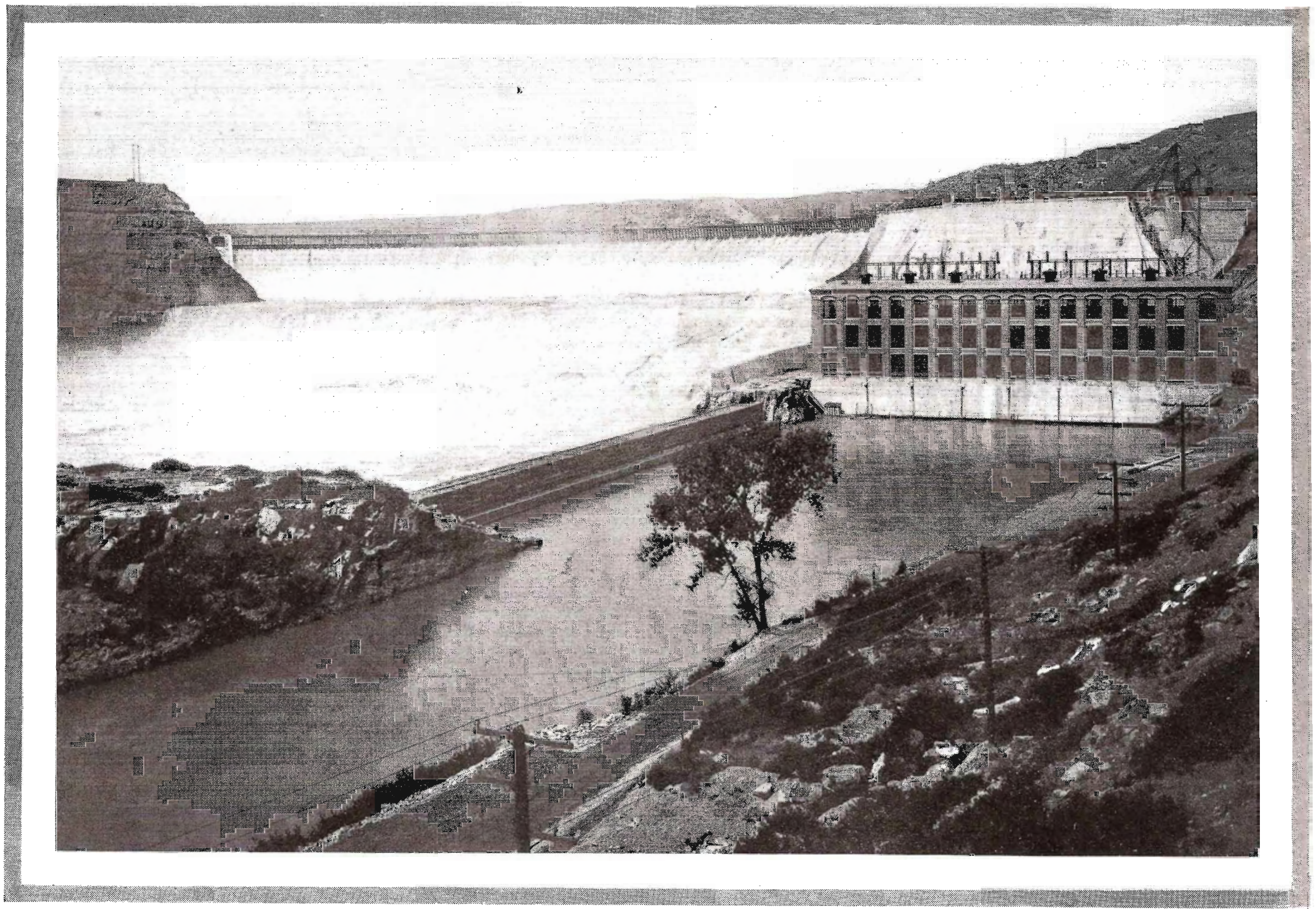
HERE THE ALL-STEEL "COLUMBIAN" IS SEEN DESCENDING A 2 PER CENT GRADE IN THE ROCKIES, RETURNING CURRENT TO THE LINE AS IT COASTS DOWN THE MOUNTAIN SIDE

The electric locomotive takes the place of four ordinary steam locomotives. Also, it is capable of handling its full tonnage on a heavy grade at 15 to 16 miles an hour, as against 8 to 10 miles an hour for the steam locomotive. On a 1 per cent grade (52.8 feet rise to the mile) the electric engine will haul an 800-ton passenger train at 25 miles an hour, or, on level track, at 60 miles an hour—a very considerable gain over speeds obtainable under like conditions with steam traction.

How essential is this element of power—hauling capacity—possessed by this great electric engine, may be judged from the fact that the controlling grades (engineers call them "gradients") in the ascent of the mountains crossed vary from 52.8 feet to the mile (1 per cent) to 106 feet (2 per cent).

Each of these electric locomotives is entirely independent, naturally, of fuel trains, for it uses neither coal nor water, and requires no tender. Furthermore, as it can run 1,000 miles or more without overhauling, one locomotive operates over several steam railway divisions. It has no ashes to dump—no flues to clean—no boilers to inspect.

Winter, above all, demonstrates the efficiency of the Electric Locomotive. Its greater driving power gives it a marked advantage over the steam locomotive in pushing through heavy snowdrifts. Of even more importance, however, is the fact that, whereas the steam locomotive experiences most



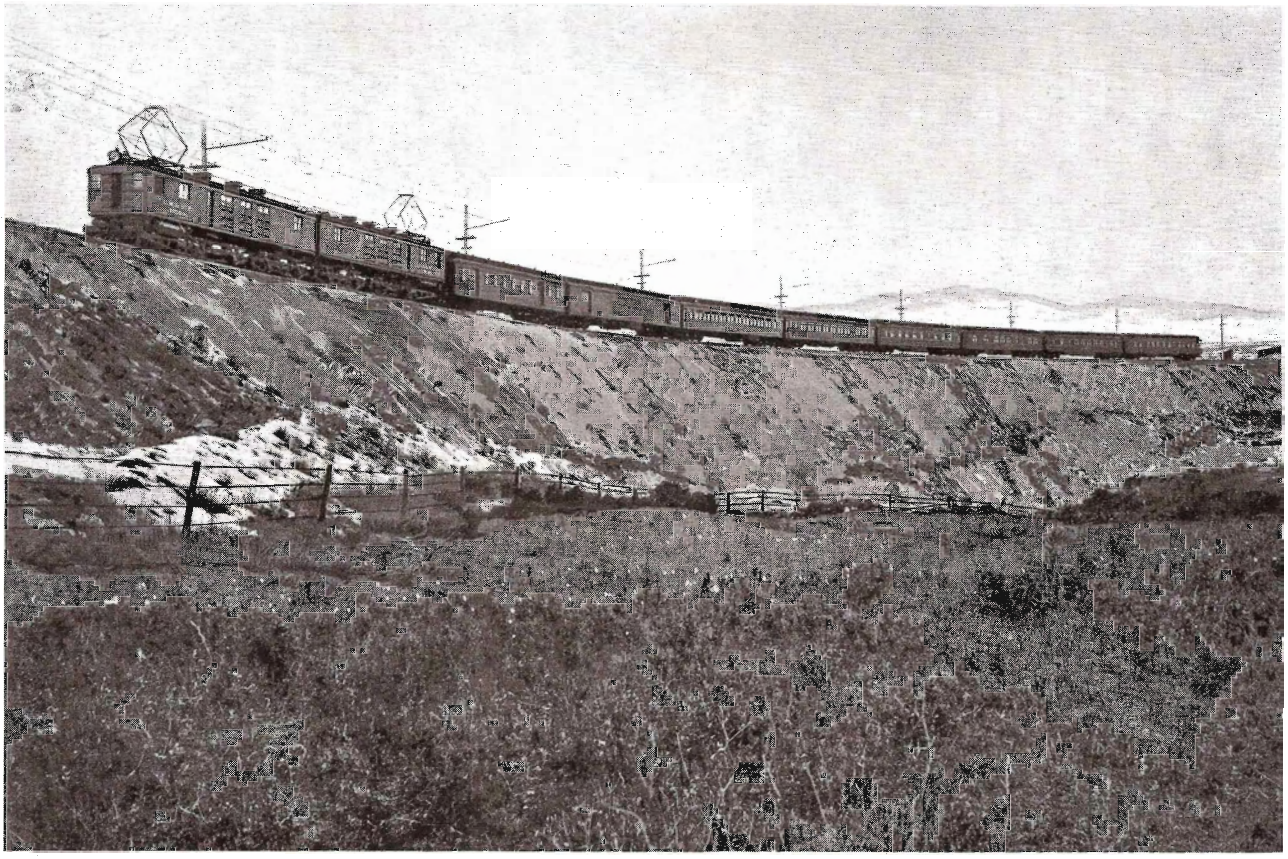
DAM, POWER PLANT AND SPILLWAY AT GREAT FALLS, MONTANA

ONE OF THE PRINCIPAL NATURAL SOURCES OF THE ELECTRIC ENERGY WHICH HAULS "THE OLYMPIAN" AND "THE COLUMBIAN" OVER THE CONTINENTAL DIVIDE

trouble in bitter cold weather, through slow fires, loss of heat by radiation, and frozen pipes, the Electric Locomotive is at its best under such conditions. Not only are electrical conditions most favorable in the dry, cold air of winter, but since the heating of the wires in the electric motor, and therefore the amount of work it can do without over-heating is to a considerable extent dependent on the weather temperature, it follows that the colder the weather the less the coils will heat.

Instead of employing the simple one-contact trolley of the ordinary street car, the Electric Locomotive takes its current from the trolley wire by means of an ingenious double trolley called a "pantagraph," after the draftsman's enlarging instrument of the same name. The use of this double-contact trolley, traveling on a double trolley wire, insures perfect contact at all times and eliminates danger of wasteful sparking. If a single trolley "jumps" over an unevenness in the wire (as, for instance, where the trolley wire is clamped at intervals), the circuit is momentarily broken and a flashing "arc" is produced; but in the case of the pantagraph there is but an infinitesimal likelihood of this occurring at two points of trolley contact simultaneously.

Because of the high voltages employed (for the higher the potential of the current—measured in volts—the farther the electric spark will leap through the air), it was found necessary in all overhead



"THE OLYMPIAN" CROSSING THE CONTINENTAL DIVIDE
SMOOTHLY AND SILENTLY, WITHOUT SMOKE, FUMES OR CINDERS

construction to pay unusual attention to insulation. Moreover, in order to obviate the possibility of the trolley wire breaking, falling to earth, producing a "short circuit" and thus interrupting traffic on the circuit affected, the trolley wire is suspended at short intervals from a strong steel cable, called a "catenary." In a word, every possibility of mishap, seemingly, has been foreseen, every contingency provided against.

INTERIOR OF *The* ELECTRIC LOCOMOTIVE

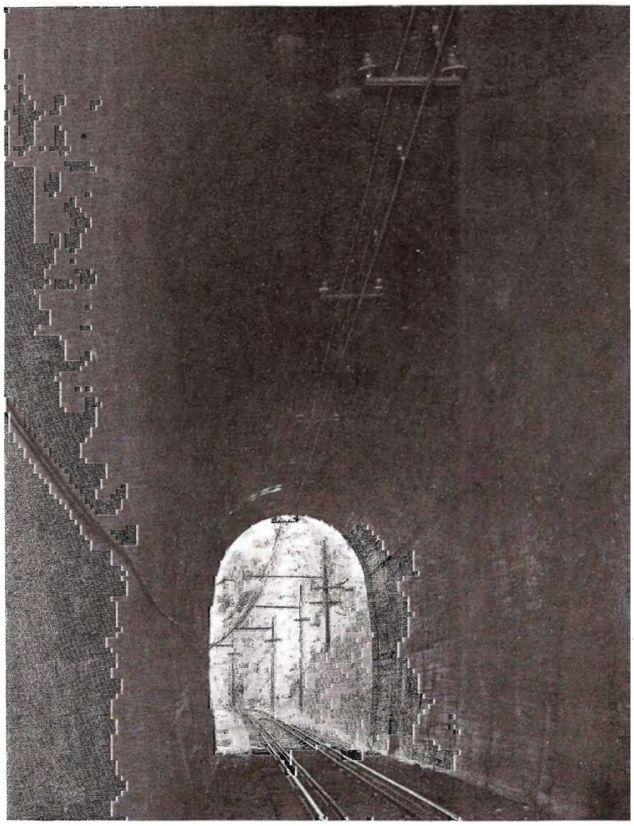
From the pantagraph the electric current passes to the engineer's control in the interior of the Electric Locomotive, and to the uninitiated a glimpse of this interior would be altogether bewildering, with its ammeters and gauges and speed indicators, its oil-fired steam boiler for heating the train, its air compressors for operating the auxiliary air brakes, and its small, motor-driven dynamos ("exciter units"), for use in the unique system of "regenerative braking" employed.

Thus it is seen that it is not simply to give necessary weight that the locomotive is made so long. Room is required for this maze of intricate electrical machinery, as well as for the compartment of the engineer and fireman at each end.

Compared with the devices requisite to convey a 3,000-volt direct current to these immense motors, the "controller" of an ordinary trolley car is as a safety pin to a watch, for complexity. Yet to the engineer who presides over the "solenoid switches" through which the current is relayed to the motors, all is as plain as the reading of a thermometer.

UNUSUAL PERFORMANCE-UNUSUAL PROBLEMS

To the superficial observer, familiar with the simplicity of electric traction as it appears to him in his daily travels on street cars, it might seem that the application of electricity to heavy traction, replacing steam as a motive force, involved merely questions of heavier current and more powerful motors. Nothing could be further from the truth. The problems and the difficulties of heavy railroading are peculiar to itself, and to apply electricity to the mastering of these difficulties immediately brings to the fore a vast complexity of new electrical problems.

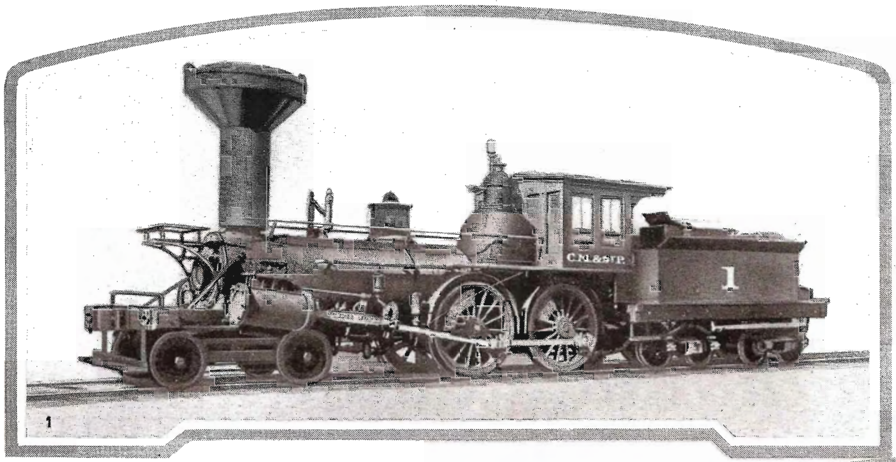


FORM OF CONSTRUCTION USED IN TUNNEL WORK
EVERYWHERE THIS ELECTRIFIED MOUNTAIN ROUTE FOLLOWS THE LINE OF SHORTEST PRACTICABLE DISTANCE, THOUGH OFTEN ENOUGH THE LINE OF GREATEST RESISTANCE

When, for instance, one considers what is the momentum of a 1,000-ton train, to say nothing of 3,200-ton freight, trailing after a 284-ton locomotive—when one bears in mind the increase in that momentum due to gravity in the descent of mountain grades—and when one stops to think that the engineer at all times must have absolute control of the last fractional kilowatt of his power in order infallibly to regulate train speed—then one begins to realize that the Electric Locomotive is not simply a big trolley car.

Again, it must be remembered that these locomotives are driven by a current of 3,000 volts' potential—the highest direct-current voltage employed in railway work anywhere in the world—and that this is more than five times the electrical tension used in ordinary street-railway work.

In lighter traction work, the low-tension currents employed may be handled directly in the "controller" by means of comparatively few resistance coils and a few hand-operated switches. In the case of this 3,000-volt current, however, such control is impossible. In order to distribute the energy taken from the wires, the "controller" in the engineer's compartment of the Electric Locomotive merely operates certain "banks" of electro-magnetic switches (the "solenoid switches" already mentioned), and these, in turn, apply the heavier current to the motors in exactly the amperage required.

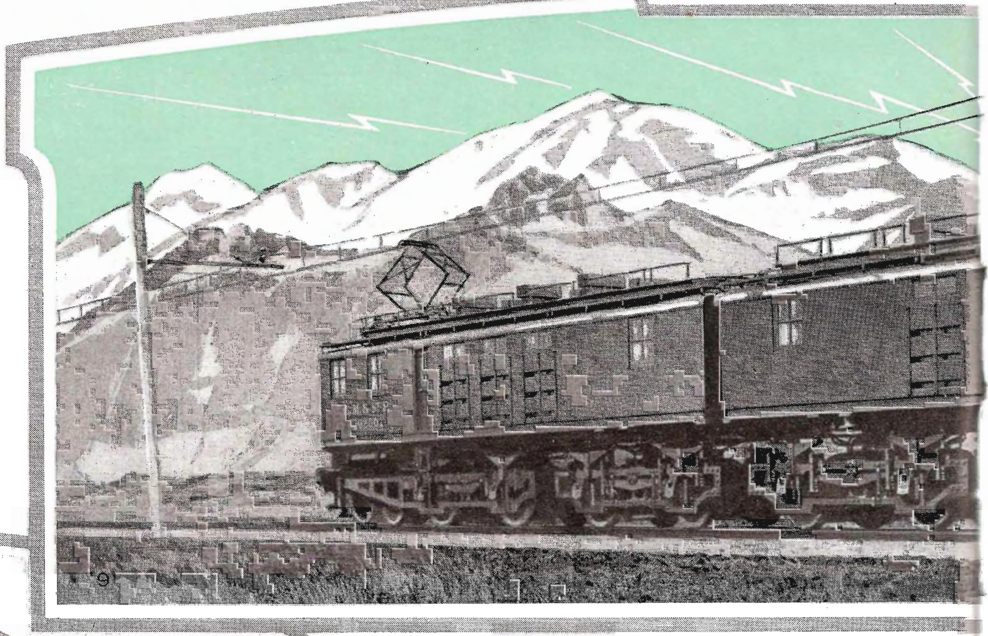


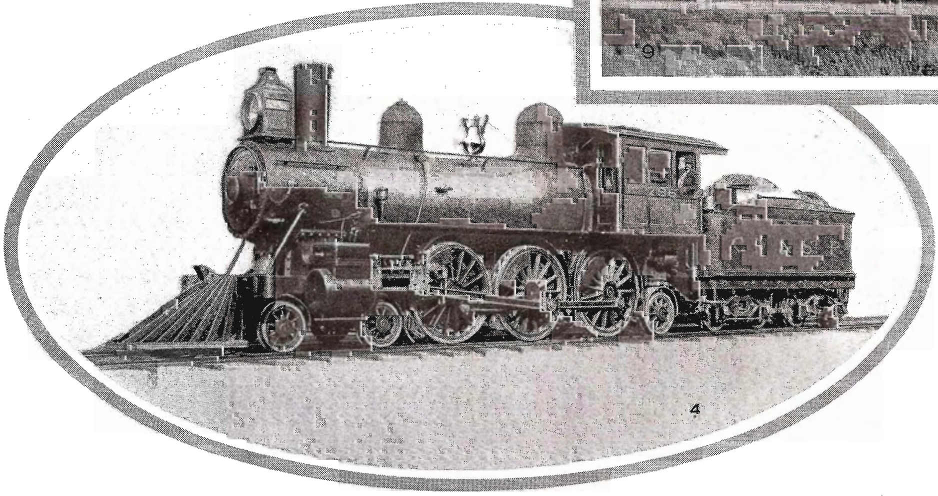
1—1848—"The First Engine that Ever Turned a Wheel in Wisconsin." Weight, 46,000 lbs.

2—1870—"The Fred F. Merrill."

3—1882—Standard Switch Engine of the Early '80s. For Many Years Shop Train Engine. Weight, 113,-000 lbs.

4—1889—"Old 796." Weight, 200,700 lbs. Crack Passenger Locomotive of its Day.





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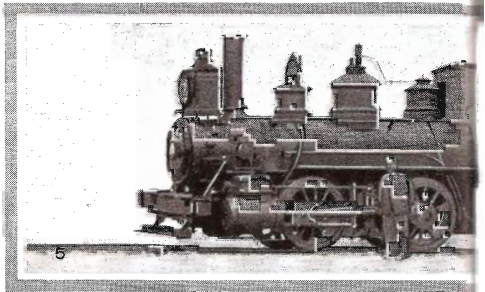
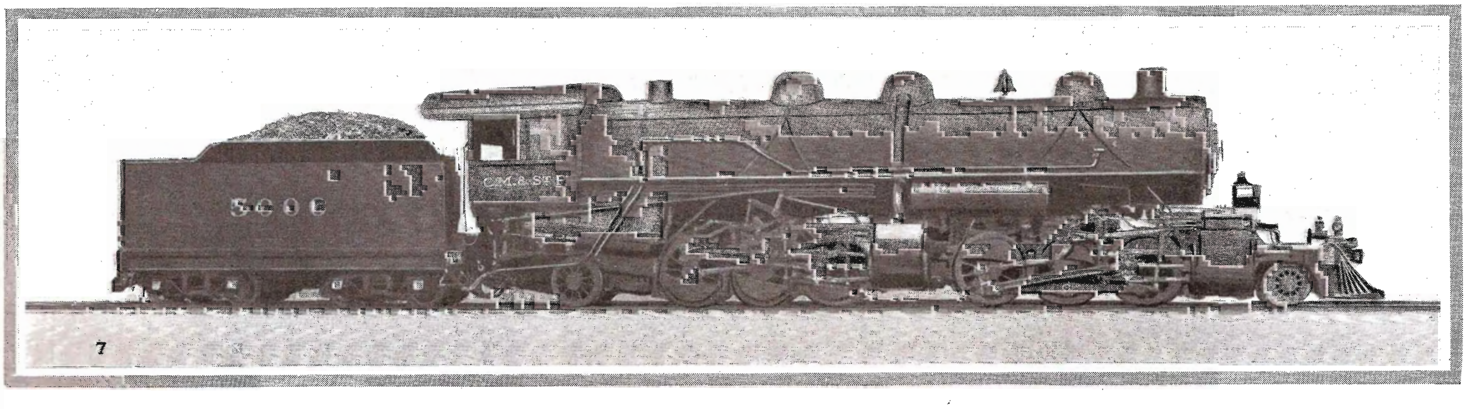
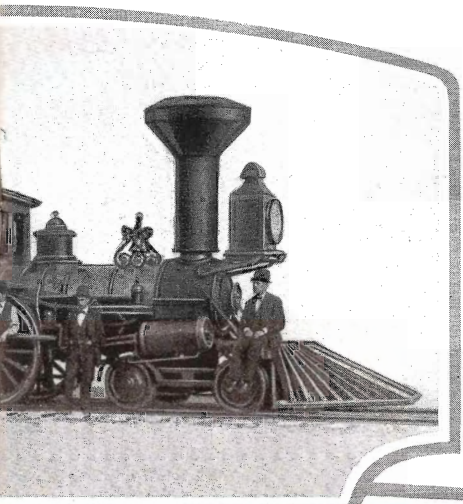
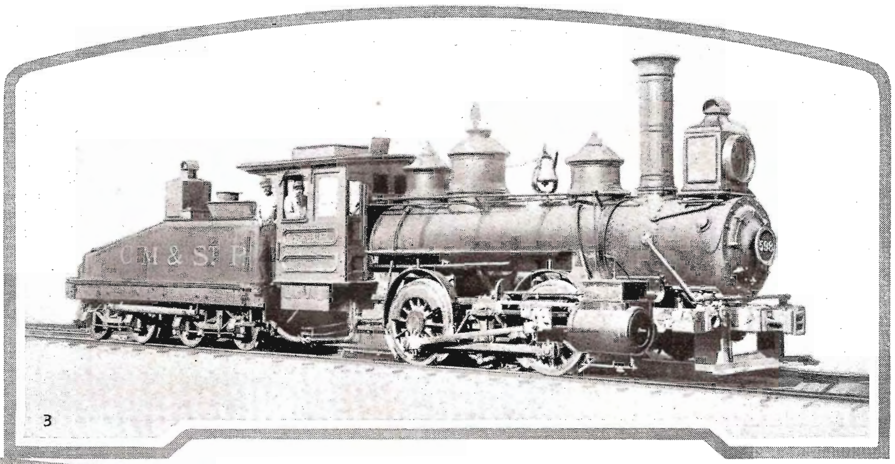
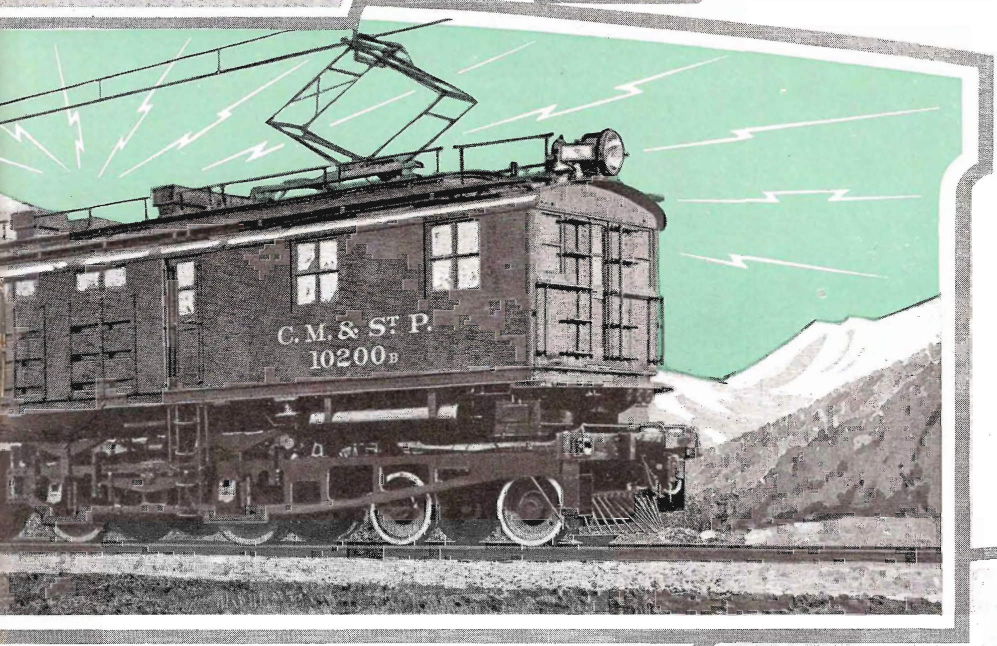










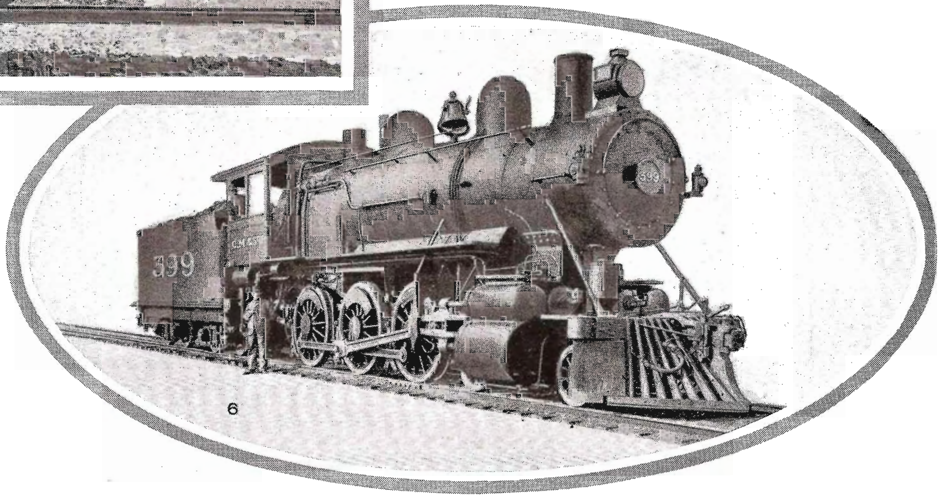
5–1892–"Old 1087." Weight, 115,000 lbs.

6–1901–"Old 399." Weight, 303,900 lbs.

7–1910–New Mallet Compound Locomotive. Weight, 561,700 lbs.

8–1910–New Pacific Type Locomotive. Weight, 409,700 lbs.

9–1915–The World's Mightiest Locomotive. Weight, 568,000 lbs.



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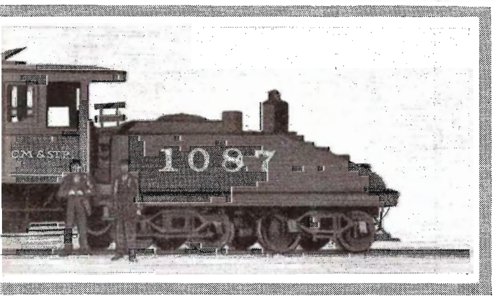
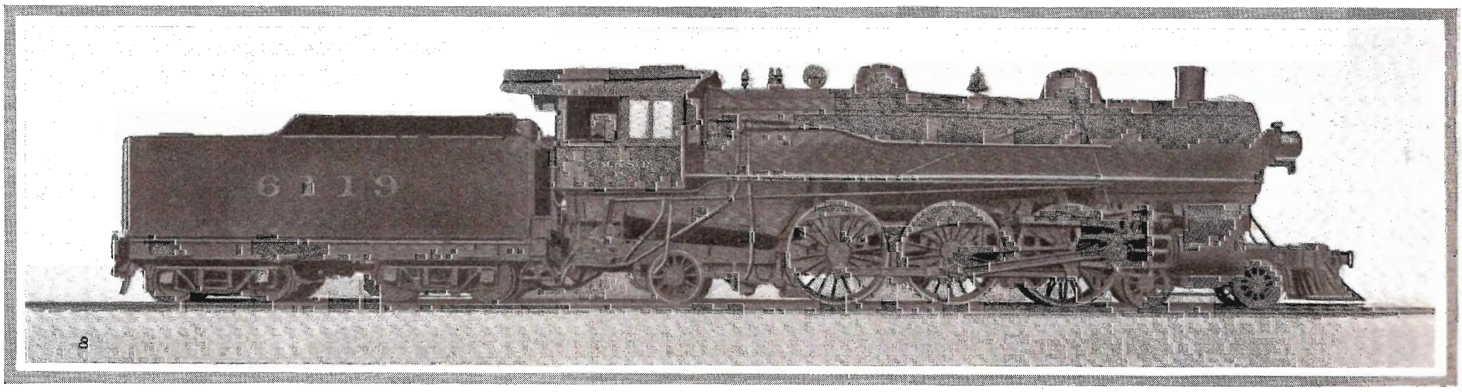
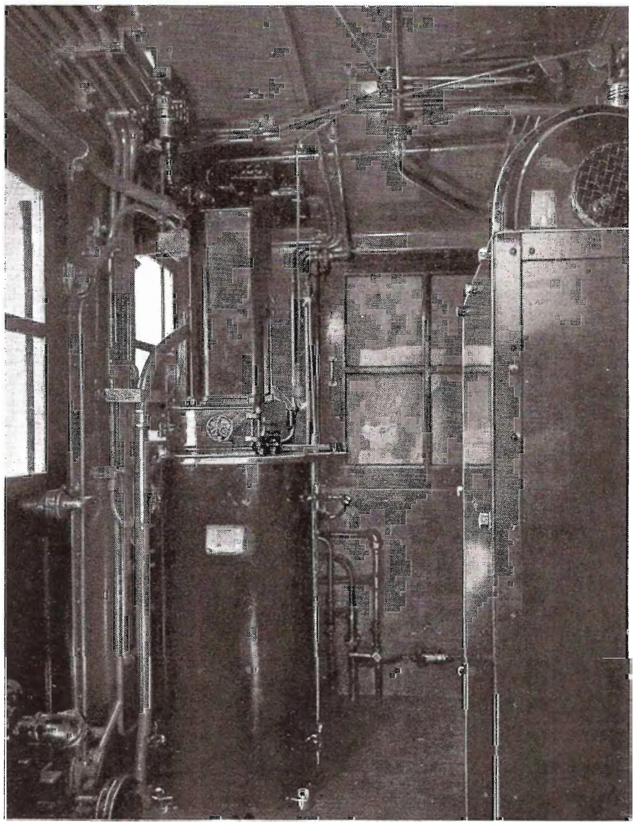
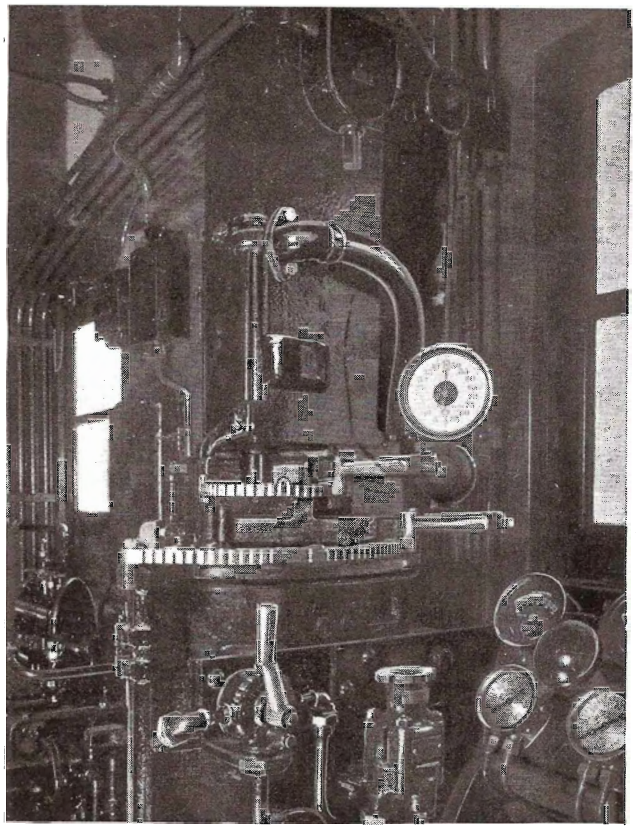






INTERIOR OF THE ELECTRIC LOCOMOTIVE

THIS VIEW OF THE ENGINEER'S CAB SHOWS ONLY A FRACTION OF THE INTRICATE MAZE OF MACHINERY THAT CONTROLS THE OPERATION OF "THE OLYMPIAN" AND "THE COLUMBIAN" THROUGH THE ELECTRIFIED MOUNTAIN DIVISIONS



INTERIOR OF THE ELECTRIC LOCOMOTIVE

HERE ARE SHOWN THE MASTER CONTROLLERS AND THE VARIOUS METERS AND GAUGES WHICH INDICATE SPEED, CONSUMPTION OF CURRENT AND QUANTITY OF ELECTRICITY REGENERATED

The SOURCE OF ELECTRIC POWER

The electrification of the Rocky Mountain divisions of the Chicago, Milwauke & St. Paul Railway marks a "high spot" in the conservation of the natural resources of the United States, no less than in the history of American railroading, for never before have the harnessed energies of such stupendous water powers been applied to the transportation of passengers and freight.

The Railway Company obtains from the Montana Power Company the electrical energy necessary. This current is delivered at seven points between Avery and Harlowton to the transmission system of the Railway Company. The power plants of the Great Falls hydro-electric system, the greatest natural power site in Montana, and one of the greatest in the country, are located on the Missouri River, near the city of Great Falls. At this point development is particularly easy, as in the space of eight miles the river drops 400 feet, about one-half of this descent being in abrupt falls. The Great Falls development, consisting of the Black Eagle, Rainbow and Big Falls plants, produces a total of 139,000 horsepower, making these the largest and most modern hydro-electric plants in the West.

A network of high-voltage transmission lines, covering a great portion of Montana, carries the electrical energy to nearly every part of the State.

Near the headwaters of the Madison River a storage reservoir covering an area of many square miles impounds enough water to supply the power plants at Madison Canyon, Helena and Great Falls during the dry months of late summer and during the winter months, when the usual flow is at a minimum. Similarly, Thompson Falls, on Clarks' Fork, is protected by a very large natural reservoir—Flathead Lake. By these arrangements for the conservation of the water flow, the power plants, and, by the same token, the Railway, are safeguarded against interruption of service. Each of the Chicago, Milwaukee & St. Paul Railway's fourteen electrical sub-stations is fed from two sources of supply, as a further insurance against accidental tie-up of its lines.

Remembering that 1.34 horsepower is the mechanical equivalent of an electrical kilowatt, the stupendousness of the Montana Power Company's great conservation enterprise may be appreciated from the statement that the company already operates to a capacity of 68,690 kilowatts and has upwards of 175,000 kilowatts under development.

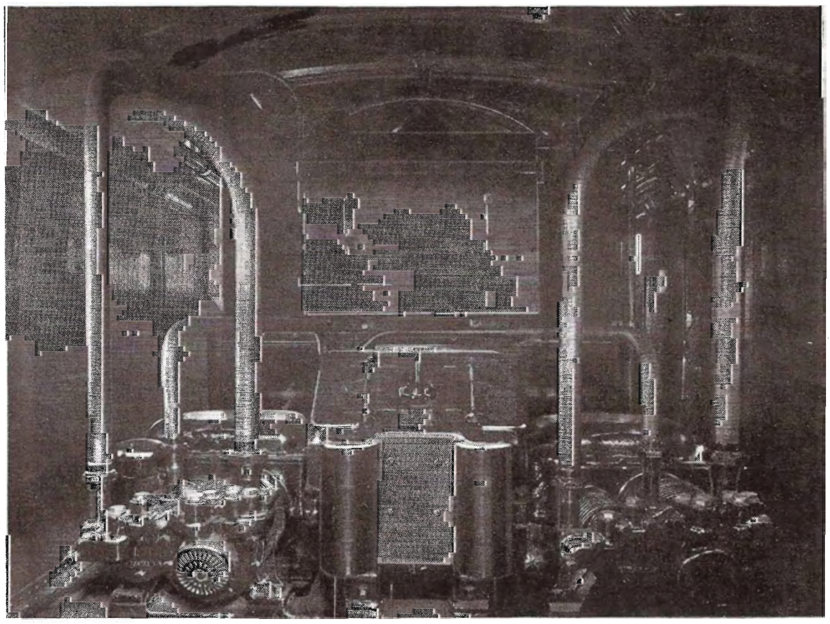
Power for the Cascade zone will be furnished by the Inter-Mountain Power Company from two sources of supply: on the east from Long Lake, 15 miles west of Spokane on the Spokane River; and on the west from Snoqualmie Falls. Transmission lines aggregating 170 miles will connect the two sources.

This great work of conservation is typical of what is going on throughout the vast Pacific Northwest traversed by the Chicago, Milwaukee & St. Paul Line, with incalculable horsepower remaining to be made available. And in thus applying to its traction needs so inexhaustible a source of electric energy lying ready to its hand, The Pioneer Line is the first railway in the country, on any scale so immense, to "make Nature drive the wheels."

DISTRIBUTION OF CURRENT—*The* SUB-STATIONS

In a comparison of electric and steam traction systems, it will be observed that whereas the steam locomotive, in and of itself, is a complete generator of power, the electric locomotive is simply a motor, depending upon an outside source of power to energize it.

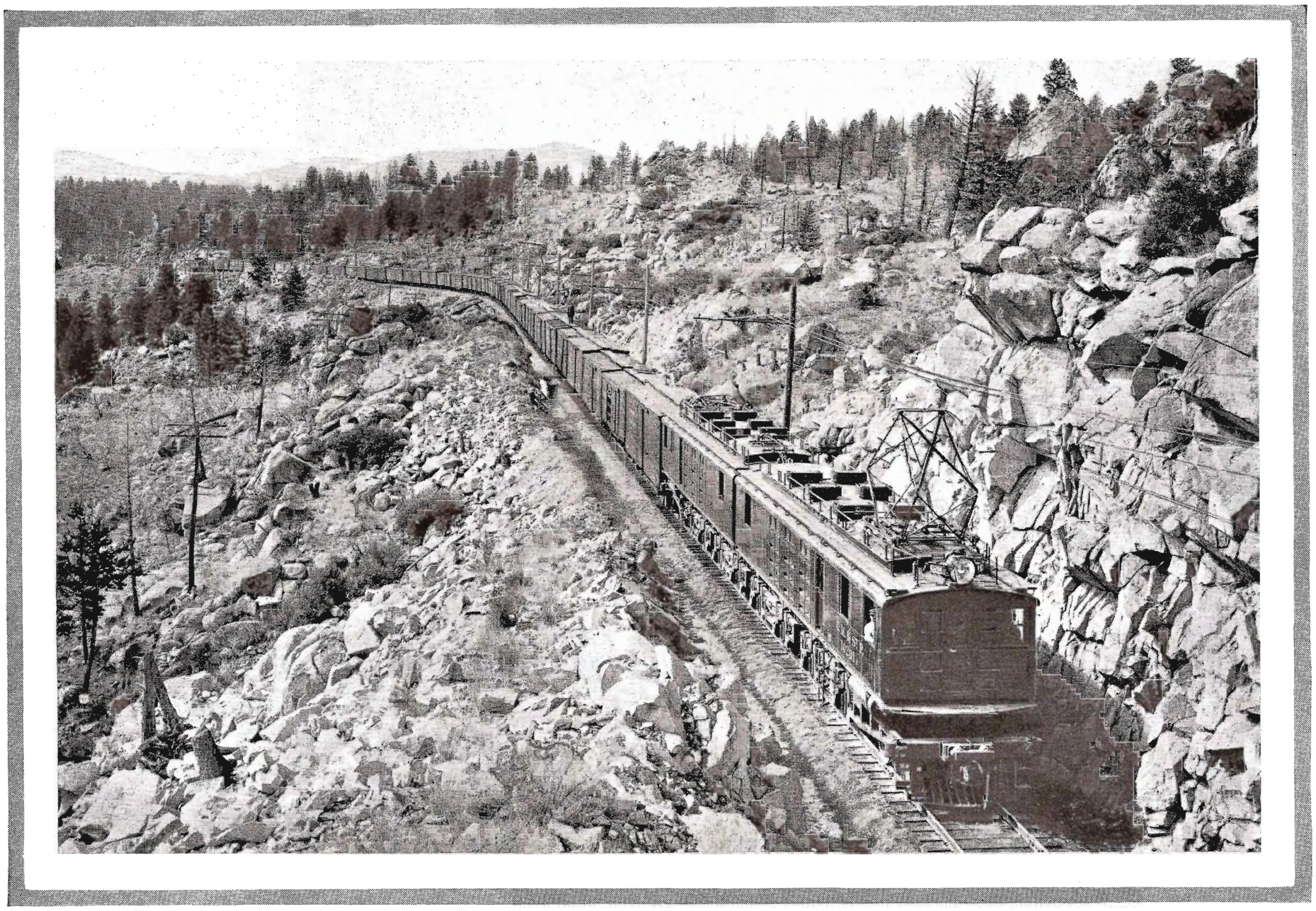
From the transmission system of the Montana Power Company, a definite contract quantity of current is fed to the Railway Company's transmission line, which parallels the track in the electrified area. However, this current is alternating, which is not so satisfactory for the Railway's purposes as direct current. (A direct current, it may be explained, is a steady flow, comparable to that of water in a pipe, from a point of high electrical potential to one of low potential. An alternating current, on the other hand, changes its direction at inconceivably minute intervals—an effect that may be likened to the reciprocating motion of a shuttle in a loom.)



INTERIOR OF ELECTRIC LOCOMOTIVE

SOME IDEA OF THE COMPLEXITY OF THIS REMARKABLE ENGINE MAY BE GAINED FROM THIS GLIMPSE OF THE AIR COMPRESSOR AND PIPING

This current, moreover, is delivered to the Railway at the extremely high voltage (corresponding to steam pressure or water pressure) of 100,000 volts. Hence the need of sub-stations, in which the current as received may be converted into exactly the form desired.



HANDLING FREIGHT AS FREIGHT NEVER BEFORE WAS HANDLED

A 3,000-TON TRAIN IS EASILY CONTROLLED BY REGENERATIVE BRAKING IN THE DESCENT OF A 2 PER CENT GRADE ON THE EASTERN SLOPES OF THE ROCKIES

Why, it may be asked, is not the current transmitted from power plant to railway in exactly the form and at exactly the voltage in which it is to be used? The answer is technical, but in simplest terms, the reason is that because of certain electrical considerations tremendous economy in the size of the copper conductors required is made possible by transmitting the current at a very high voltage; and, further, for this purpose, alternating current must be employed. On the other hand, for the flexible operation of the Electric Locomotive, direct current of a much lower voltage must be used. Therefore the current as received is turned into direct current and "stepped down" to a lower voltage.

In the sub-stations, the 100,000-volt current passes through oil switches to transformers, which reduce it to a voltage of 2,300, but still alternating. (Because of the high intensity of the current, the switches are arranged to be opened and closed in oil, to exclude the air and prevent "arcing," or flashing, which is wasteful of current and fuses the contacts.) This 2,300-volt current is then used to drive alternating-current motors, which in turn operate dynamos, generating direct current at the 3,000 volts' pressure desired.

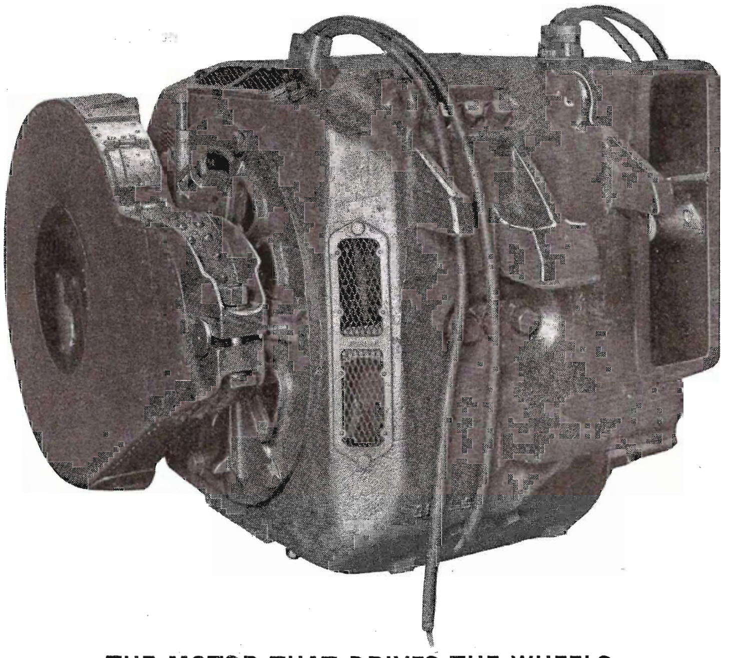
In this connection one may absorb a very beautiful lesson in the operation of the universal natural law of the Conservation and Correlation of Energy. In the Great Falls water power appear millions of foot-pounds of energy—gravity pulling the water from higher to lower levels. For ages this force did no useful work, until man introduced turbine water-wheels, and compelled the hurrying waters to turn them. This produced motion, which, transmitted to dynamos, reappears in another form—electrical energy. In the coils of the transformers in the sub-stations this 100,000-volt current "induces" a separate and distinct "secondary" current at 2,300 volts. This current produces motion again, in the armatures of the alternating-current motors, which in turn drive generators that produce electricity again—this time direct. In the motors of the Electric Locomotive this current again produces rotary motion, and in the train as a whole, horizontal motion. In the incandescent bulbs that illuminate the train, the selfsame current, or its equivalent, produces light and a modicum of heat.

At the reduced pressure of 3,000 volts, the direct current passes from the sub-stations to the feeder wires, thence to the trolley wires, and by pantagraph contact to the engineer's control; then through the motors, and, through the wheels and rails, to earth.

This brief outline of the course followed by the electric current from waterfall to railway and of the functions of the sub-station necessarily gives no adequate idea of the intricacy, bulk and costliness of the equipment. Of the generator sets which produce the current that actually drives the Electric Locomotive, each sub-station has two, and some, where the traffic and grades are heaviest, three. Thence the current passes to the switchboard, and thence to the two feeders, one running east, the other west. Each of the "feeder panels" in the switchboard is protected by an automatic circuit-breaker, which instantly opens in case of an overload or other trouble on either circuit. Just as trying to run too heavy a quilt through the wringer on an electric washer will burn out a fuse, so the circuit-breaker guards the sub-station equipment against an injuriously heavy current.

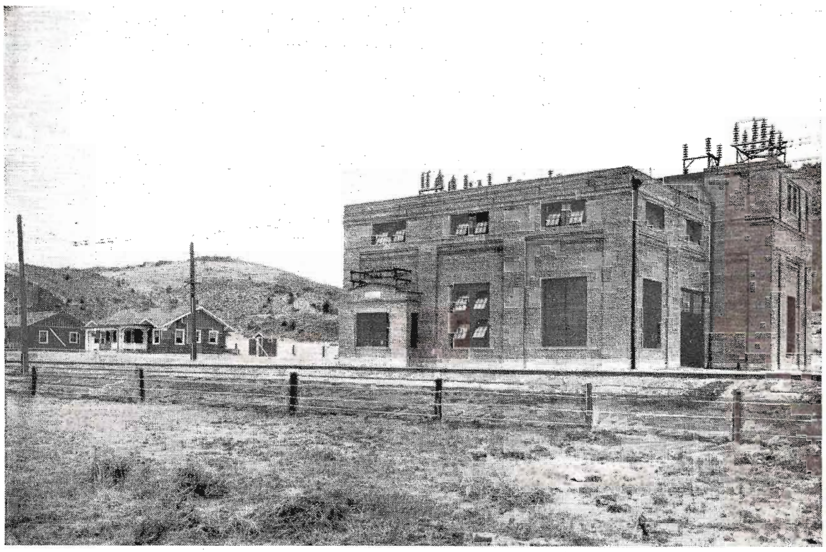
On every circuit are delicate registering instruments, some of which "keep the books" of the Railway with the Power Company, while others merely serve to inform the sub-station operators of the state of the voltage on various circuits. The former are called "ammeters," recording amperage, or electrical volume; the latter "voltmeters," registering voltage, or electrical pressure. The ammeters, as will be seen further on, not only indicate to the operators the quantity of current flowing in any particular circuit, but also measure the current for which the Railway must pay the Power Company, credit the Railway with the electric current restored through the process of "re-generative braking," and even keep a graphic pen-and-ink record of the momentary fluctuations of current volume consumed throughout every twenty-four hours.

From the sub-stations, also, is controlled the new type of automatic electric block safety signal system now employed on the Rocky Mountain divisions. The "Power Indicating and Limiting System," which, as will be seen, guides the dispatcher in his expeditious and economical movement of trains, also has its registering instruments whereby it may be determined, day by day, if trains are being so handled as to keep the maximum consumption and the minimum consumption of electricity as close as possible to the average electrical requirements of the system. More than that, whenever the dispatcher observes that too much power is being used, all he has to do is to introduce "resistance" into the power-limiting circuit. Instantly the amperage over the entire system is reduced, and the speed



THE MOTOR THAT DRIVES THE WHEELS

EACH OF THESE EIGHT POWERFUL ELECTRIC ENGINES, TWIN-GEARED TO THE DRIVING WHEELS, IS CAPABLE OF DEVELOPING 430 HORSEPOWER, GIVING A TOTAL OF 3,440 HORSEPOWER TO THE LOCOMOTIVE



ONE OF THE MOUNTAIN SUB-STATIONS

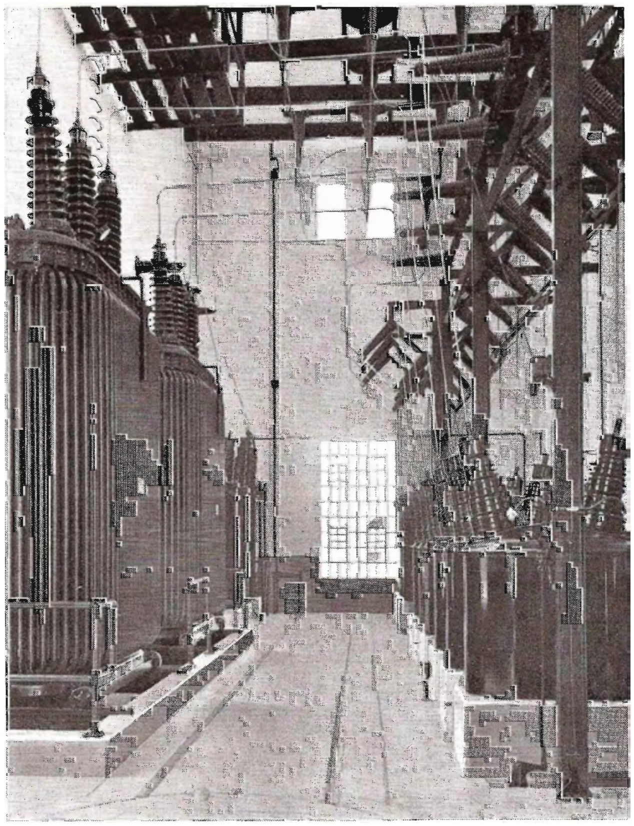
IN THIS PHOTOGRAPH ARE SHOWN THE TRANSMISSION LINE ENTRANCES ON THE ROOF, THE TROLLEY WIRES, AND AT THE LEFT THE EMPLOYES' BUNGALOWS

of all trains under his control is reduced in proportion.

The sub-stations, of which fourteen are required to serve the electrified district in the Rockies, and eight will be needed to serve the Cascade zone, are spaced at intervals of about thirty miles. Each has its pair of artistic bungalows for the comfort of the operators, and each, with all equipment, costs about $165,000.

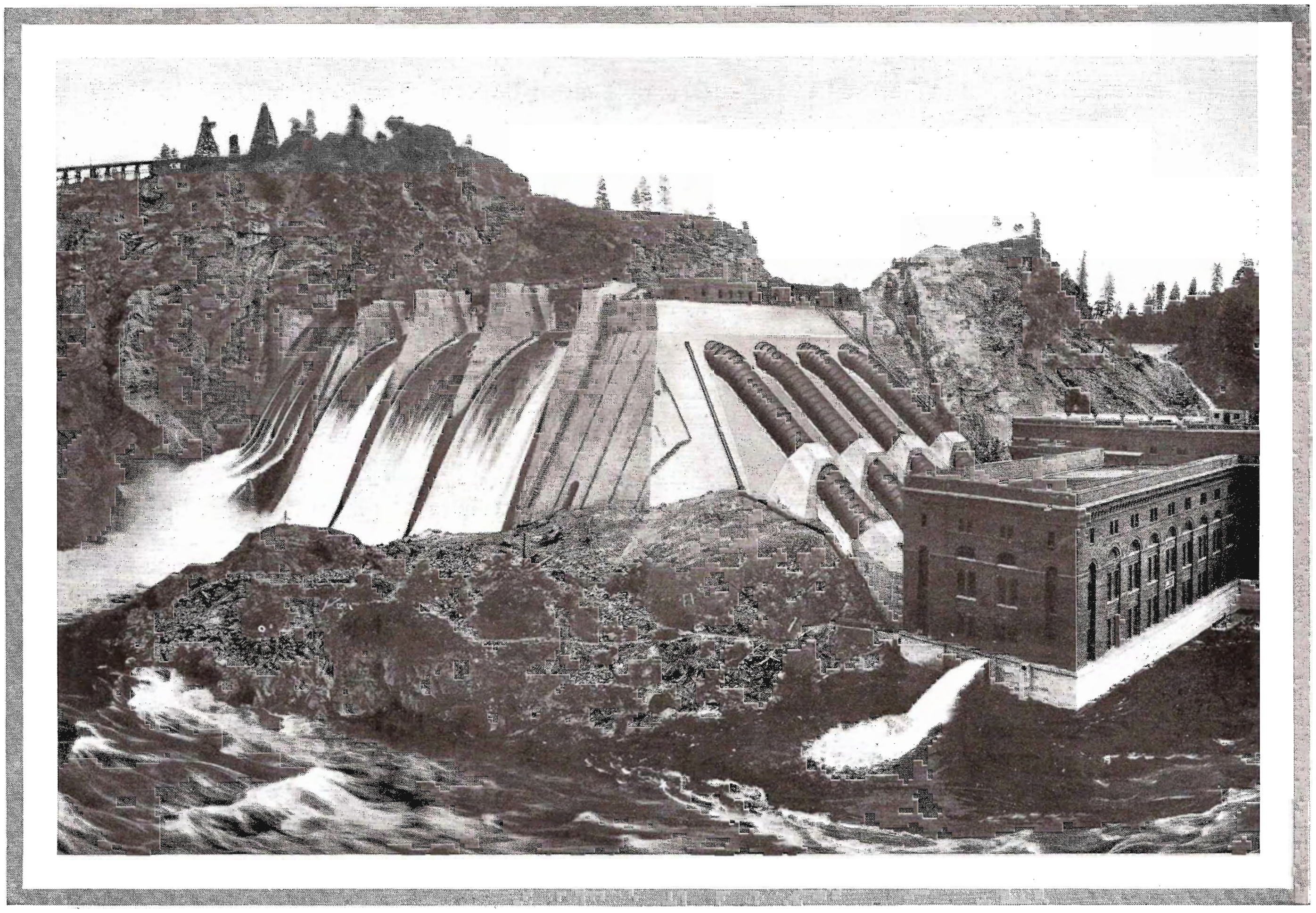
Not so spectacular, doubtless, as many other features of the electrification enterprise—but vital in its importance—is the trolley-wire system. Any proper discussion of the difficulties encountered, because of the high voltage employed and the peculiarities of mountain construction, would transcend the limits of space at command. Moreover, it would be too technical to be of general interest. It is enough to say that from the selection and rigorous inspection of the Idaho cedar poles that support the lines, down to the last detail of adapting brackets and insulators to specific requirements, calculating sags due to span and temperature variations, and inspecting the copper conductors for defects of every sort—the work of engineering and construction has conformed to the highest standards of this most exacting age.

The matter of conveying track signals to enginemen—ordinarily accomplished by the raising and lowering of semaphore arms by day, and of colored lights at night—is yet another problem which required special treatment under electrification. Semaphores of the type used on a steam line would not answer, because the trolley-supporting structures along the track would obscure the engineer's clear vision. Accordingly a system of light signals so bright as to be infallibly visible by day or by night, has been devised and installed. Thus brilliant electric lights, their rays concentrated by powerful compound lenses, throw a compact beam of white or colored light to indicate at all times the condition of the track ahead. White shows the track is clear; green indicates "Caution," while red is for "Stop!" Only one of these signals is displayed at any one time.



INTERIOR OF A SUB-STATION

TO THE RIGHT ARE SHOWN THE OIL SWITCHES IN SUB-STATION, IN WHICH THE HIGH-VOLTAGE CURRENT IS TURNED ON AND OFF WITHOUT SPARKING. TO THE LEFT ARE THE MAMMOTH TRANSFORMERS, WHICH STEP DOWN THE CURRENT AS RECEIVED FROM 100,000 TO 2,300 VOLTS

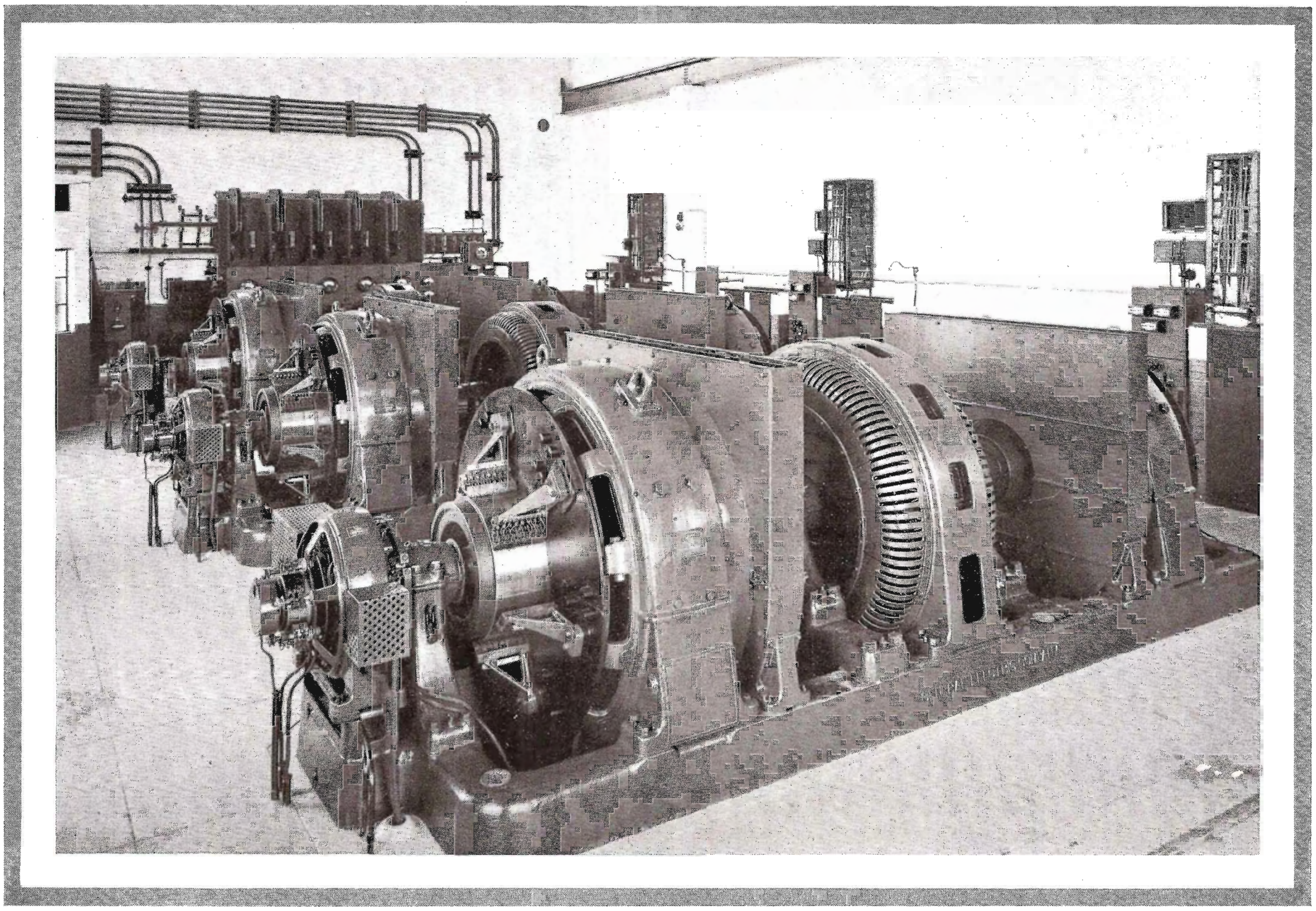


HYDRO-ELECTRIC POWER PLANT AT LONG LAKE, NEAR SPOKANE, WASHINGTON
THIS PLANT WILL FURNISH A LARGE PART OF THE POWER FOR THE CASCADE ELECTRIFICATION

REGENERATIVE BRAKING

Rarely, perhaps, has a revolutionizing achievement in applied science reached its climax of success under more dramatic circumstances than attended the operation of the first electric locomotive over the mountain divisions of the Chicago, Milwaukee & St. Paul Railway. Let one picture to one's imagination the thrill of the moment when laboriously worked-out engineering plans receive their first test in practice. The engineers responsible for the work of electrification *knew* that it was possible so to handle an electric locomotive that a portion of the electric energy consumed in climbing an up-grade should be regained—*regenerated by means of gravity*—while descending the down-grade. Yet, although the possibilities of "regenerative braking" has been recognized for some time, never had the principle been applied to direct-current locomotives under the most severe conditions of actual, heavy service. Step by step the Railway's engineers worked out the plans for making this new and most ambitious application of a recognized principle.

The new machinery required has been built and installed. The Electric Locomotive, on its maiden trip, climbs the first gradient—passes the summit—begins the descent. By the controller stand their engineers responsible for the achievement, their eyes fixed on the quivering needle of the ammeter, which indicates the quantity of current that is being consumed. The train gathers momentum as it "coasts" down the incline.

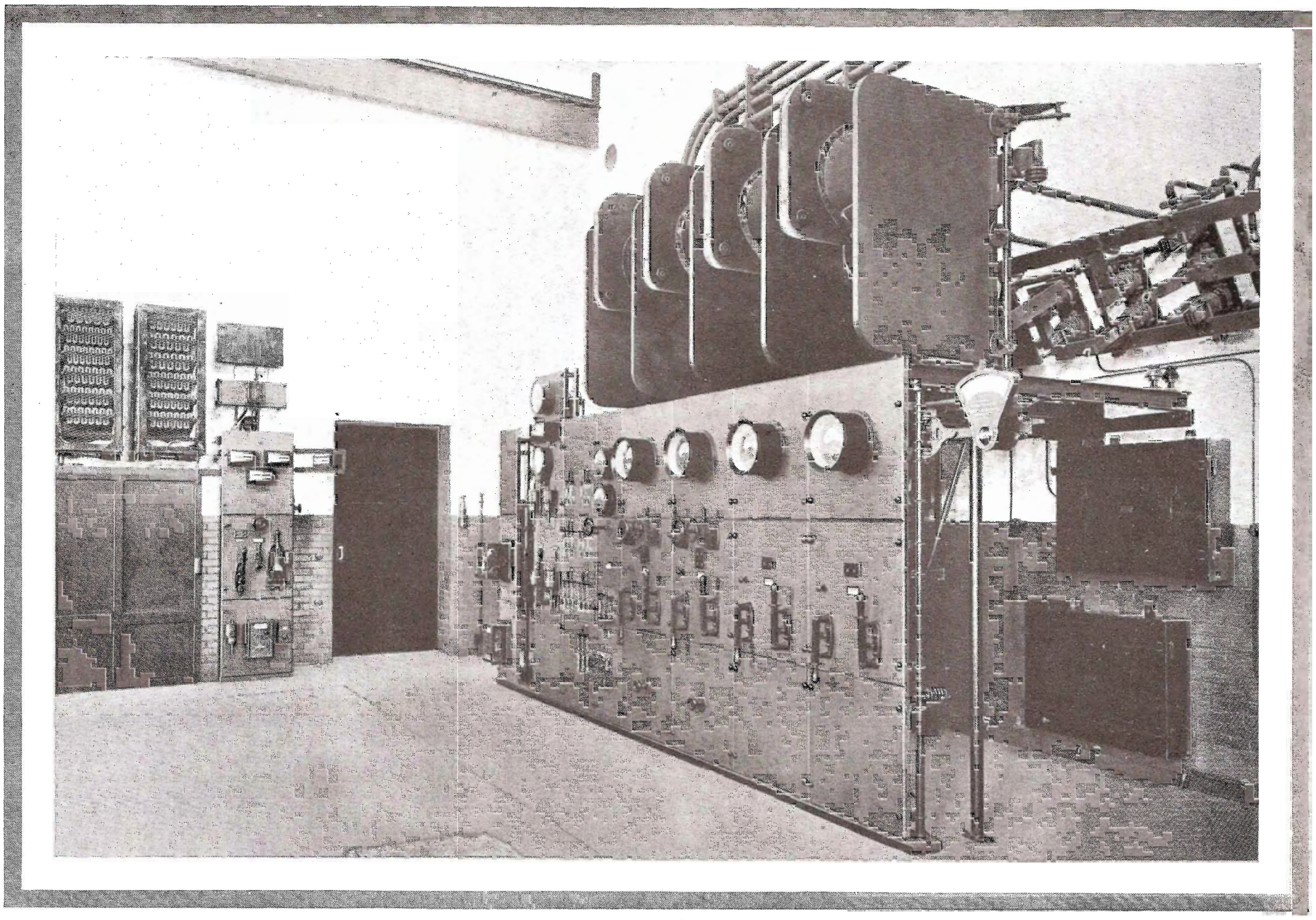


INTERIOR OF A SUB-STATION

THIS PHOTOGRAPH, TAKEN IN PIEDMONT (MONTANA) SUB-STATION, SHOWS THE IMMENSE TRIPLE MOTOR-GENERATOR SETS, WHICH CONSIST OF ALTERNATING-CURRENT MOTORS, 2,300 VOLTS, DRIVING DIRECT-CURRENT DYNAMOS, WHICH PRODUCE A 3,000-VOLT CURRENT AVAILABLE FOR USE IN THE ELECTRIC LOCOMOTIVE

Gently the speed slackens; the motors (not the brakes—for they are not needed) are asserting their perfect control of this mighty bulk. The gradient becomes sharper; but speed is not accelerated. Instead, as the engineer scans the dial, he sees the trembling pointer slowly reverse its motion—creep, point by point, in the opposite direction. The motors, turned generators, are giving back current to the power line! Regenerative braking, on a mammoth mountain train, is a success—just as they knew it would be!

Under this new system, instead of having constantly to apply the air brakes on descending grades and rounding curves, the air brakes are but auxiliary to the regenerative system. Only to stop the train at stations, or in emergency, are the air brakes employed. When in motion, as has been indicated above, the speed of the train on descending grades is momentarily regulated by this remarkable invention. This is not "electric braking," as the term is commonly used. Electric speed control would be a more accurate expression. Instead of retarding or locking the wheels by means of brake-shoes (resulting in friction, heat, sometimes a broken wheel and frequently a flat wheel), the same end is attained by means of the motors, with the additional advantage of regenerating a considerable portion of the total power demand.



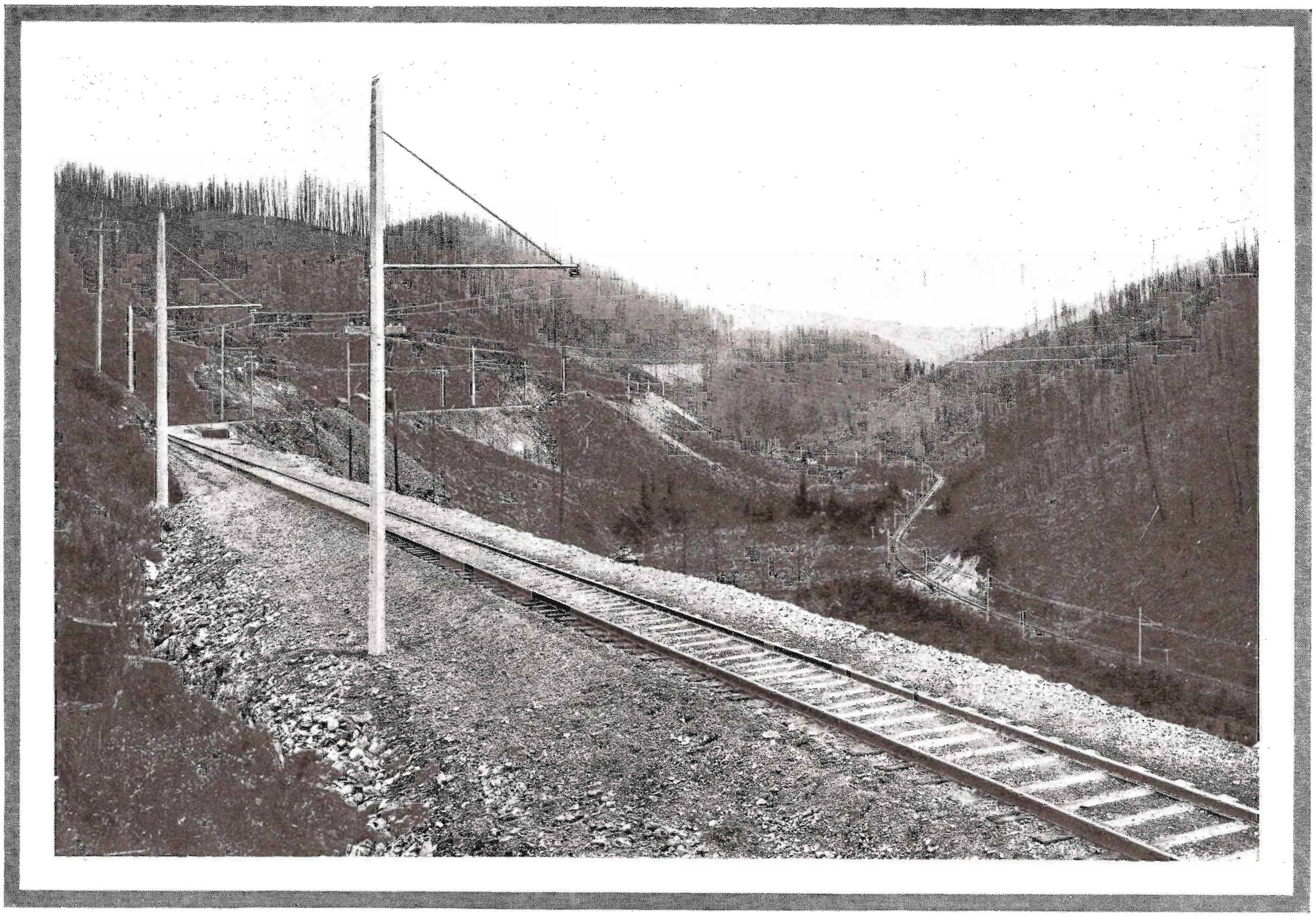
INTERIOR OF A SUB-STATION

THE SWITCHBOARD SHOWN CONTROLS TWO 3,000-VOLT DIRECT-CURRENT GENERATOR SETS AND THE OUTGOING FEEDERS. EACH CIRCUIT IS PROTECTED BY AN AUTOMATIC CIRCUIT-BREAKER, SEEN AT THE TOP OF THE SEVERAL FEEDER PANELS

The same motor, therefore, which, energized by the electric current, enables "The Olympian" and "The Columbian" to climb a mountain, will *produce* an electric current when its armature is revolved, as when coasting downhill. By ingenious devices, this recovered current is either restored to the Railway's power line as direct current, or, if it is not needed on the circuit where it is generated, to the power company's transmission line as alternating current.

In the latter case, the restored current automatically sets back the power company's meters and credits the Railway with the amount of the regenerated current. Electricity keeping its own books, forsooth!

But one may ask how this current-saving process controls the speed on descending gradients. Simply by giving the train—and gravity—useful work to do. According to physical law, work is the overcoming of resistance. When gravity pulls a train downhill gravity is overcoming the resistance of inertia *plus* friction. The train cannot be running downhill at excessive speed and rotating the motors at the same time; for rotating the motors is *work*, which consumes a portion of the gravitational force, leaving the friction of the wheels on the rails to take care of the rest. The steeper the incline, the stronger the pull of gravity *tending* to greater speed; but, the greater the



THE BITTER ROOTS OF IDAHO

THE STEEP, FORESTED SLOPES OF THIS RANGE ARE GAINED BY SOME OF THE MOST REMARKABLE FEATS OF RAILROAD CONSTRUCTION

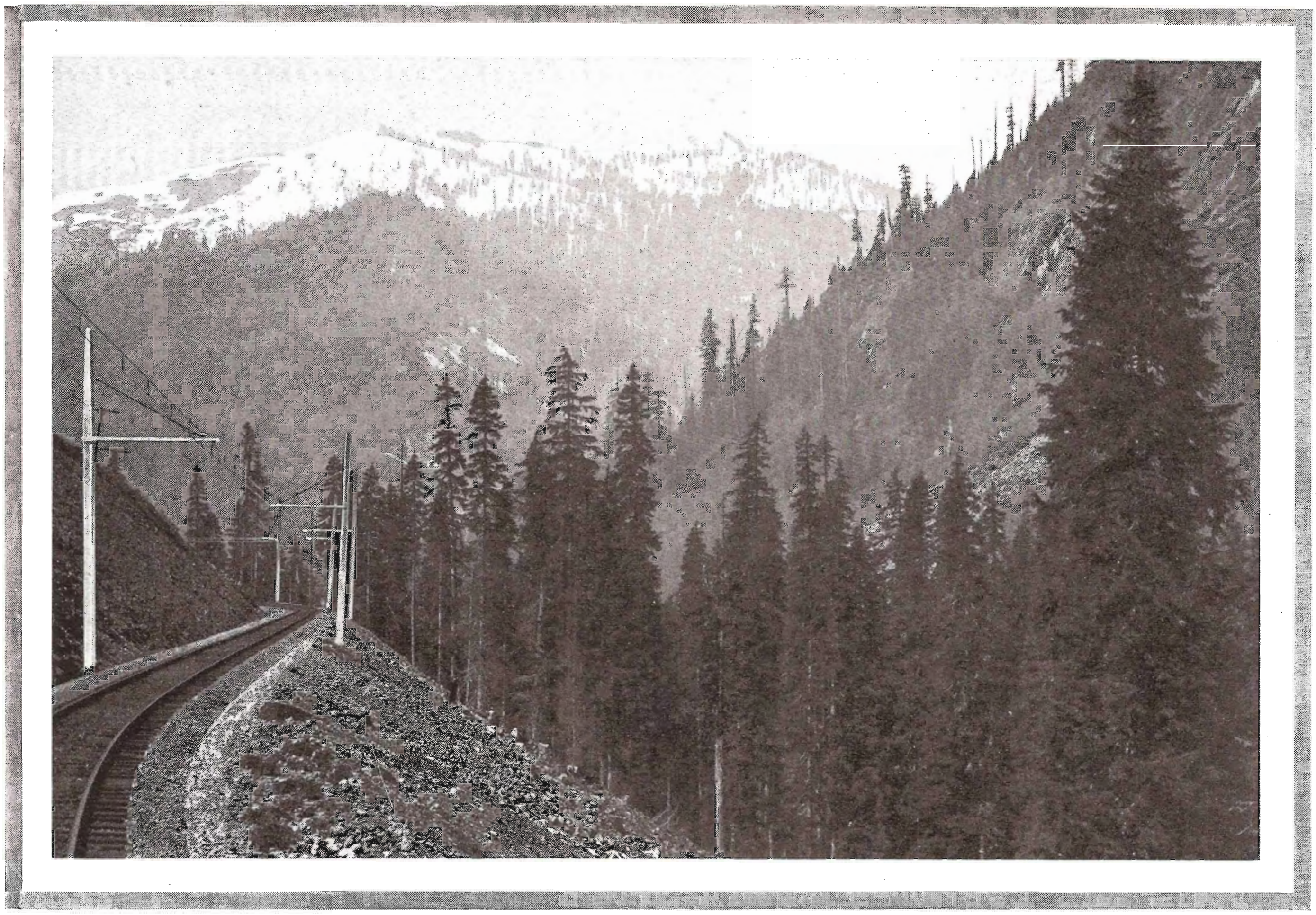
speed, the more electricity generated, the greater the resistance of the electric "field" to the rotation of the armature, and the stronger the pull-back of the motors, which, for the time being, are dynamos. Thus train speed on the down-grades is made uniform.

SIGNIFICANCE OF *The* NEW ERA

The electrification of these mountain divisions is more than the achievement of a single railway—far more than simply a boon to the travelers who are so wise as to select that particular railway's lines. Marking, as it does, the inauguration of a new era; signalizing, as it does, man's conquest and conservation of vast natural resources, this enterprise is of real, deep, abiding significance to society—just as was Stephenson's invention less than a century ago. The interests of one are the interests of all.

And as for the traveler—

One who rides by "The Olympian" or "The Columbian" between Chicago and the Puget Sound cities needs none to tell him of the pre-eminent desirability of the short, direct, comfortable electrified



CROSSING THE SNOW-CROWNED CASCADES, WASHINGTON

THESE MIGHTY MOUNTAINS WILL SOON BOW THEIR LOFTY HEADS TO THE CONQUEROR, ELECTRICITY, AS HAVE THE BELTS, ROCKIES AND BITTER ROOTS

mountain route thus offered—needs none to tell him of the peculiar advantages afforded him by electrification.

Passing the Great Continental Divide, the traveler enjoys a marvelous vision, unobscured by smoke—a quiet, restful comfort, unbroken by the grinding of air brakes on descending grades, unimpaired by dust, or fumes or cinders. Thus smoothly, silently, in all luxury of travel, he is drawn by one of the world's mightiest locomotives through this wonderland of western grandeur.

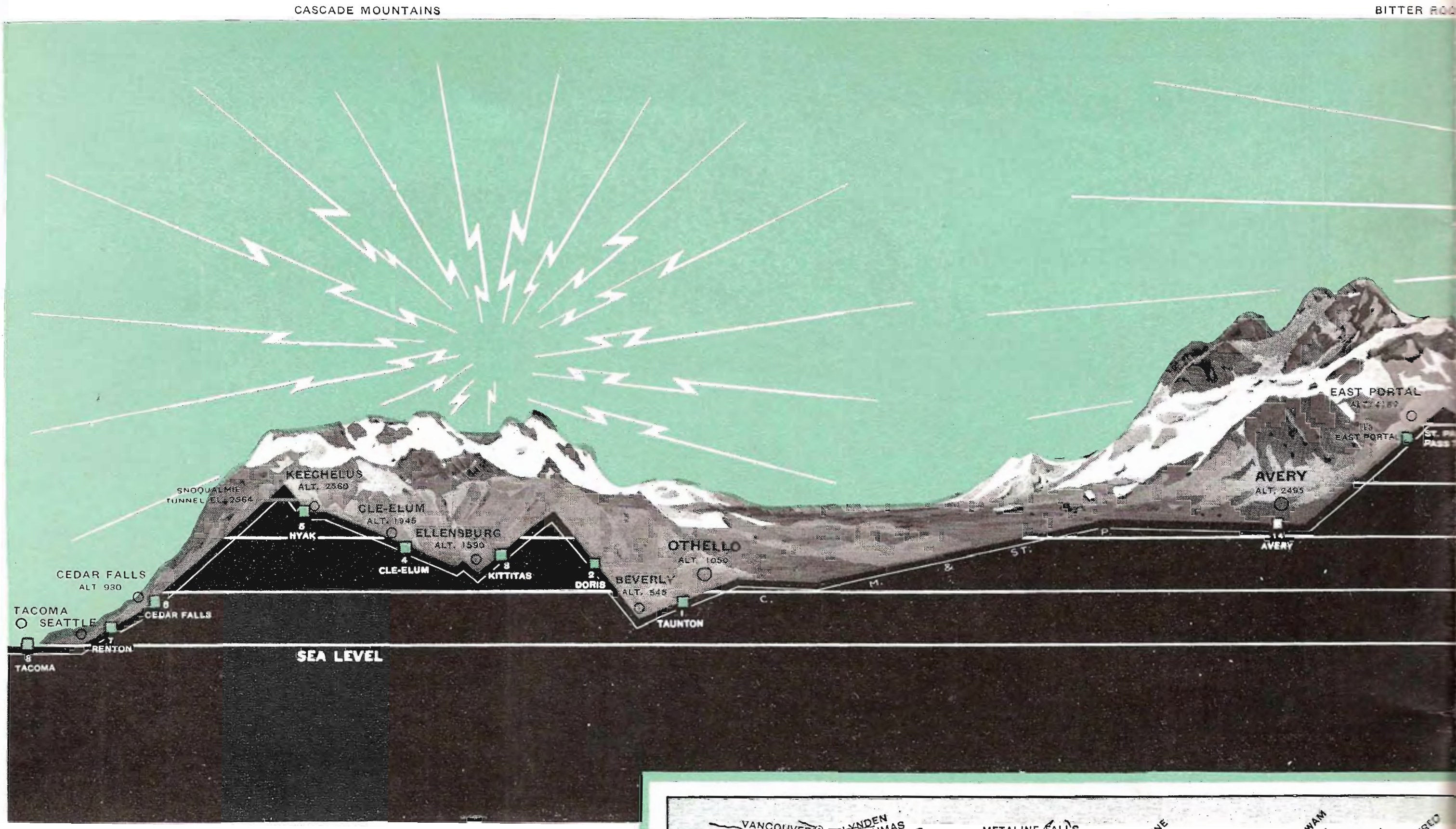
He knows that by no other route can the entrancing scenery of the mighty Rockies, the forested Bitter Roots and the snow-crowned Cascades be enjoyed so completely.

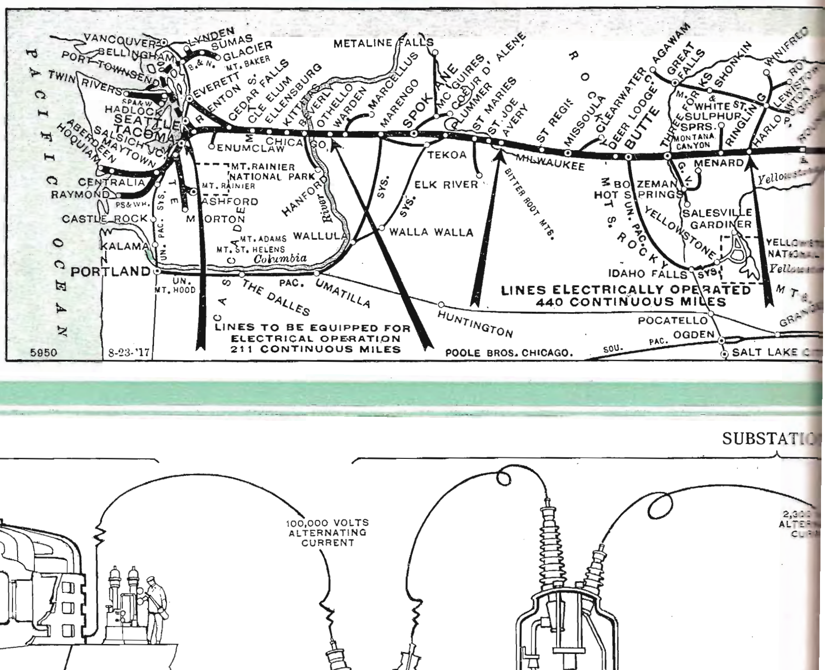
He knows of the perfect control in which the engineer holds that giant of steel up ahead.

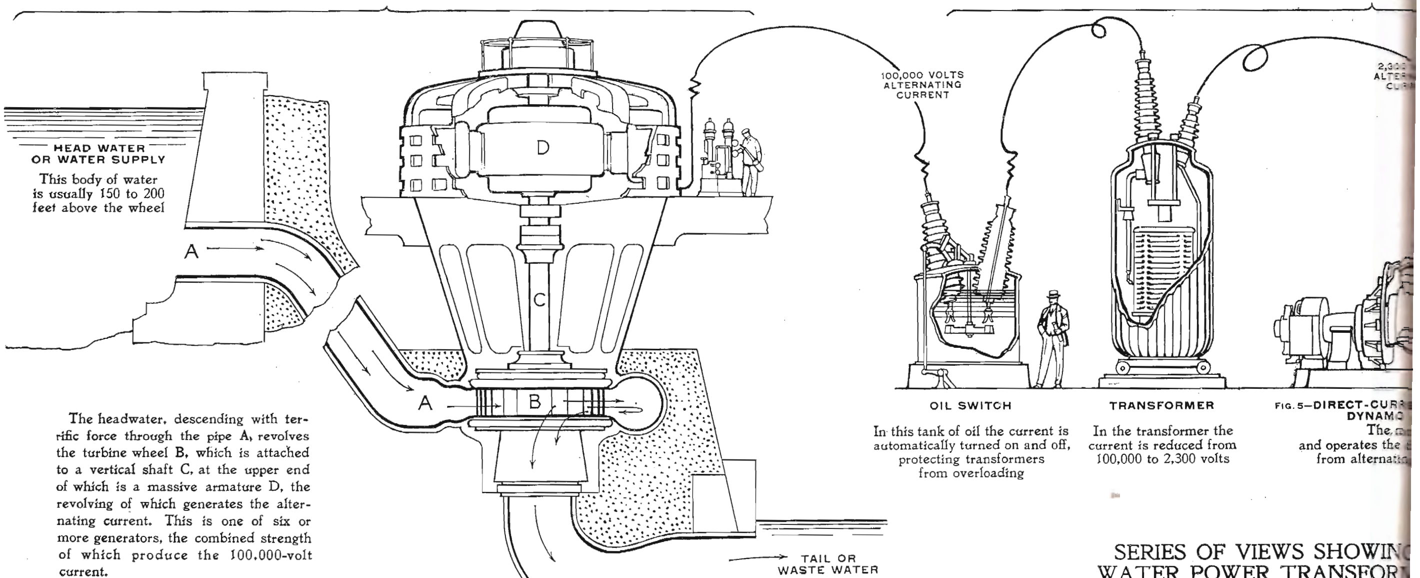
He knows that back of the engineer stands an alert dispatcher, with all the resources of electrical science at his command, his very finger on the source of the power that drives each train.

He knows, in a word, that he is participating in the most revolutionary achievement in the history of railroading.

And, with it all, he enjoys the world-renowned service of "The Olympian" and "The Columbian," of which travelers, returning home, make all haste to tell their friends!







SERIES OF VIEWS SHOWIN
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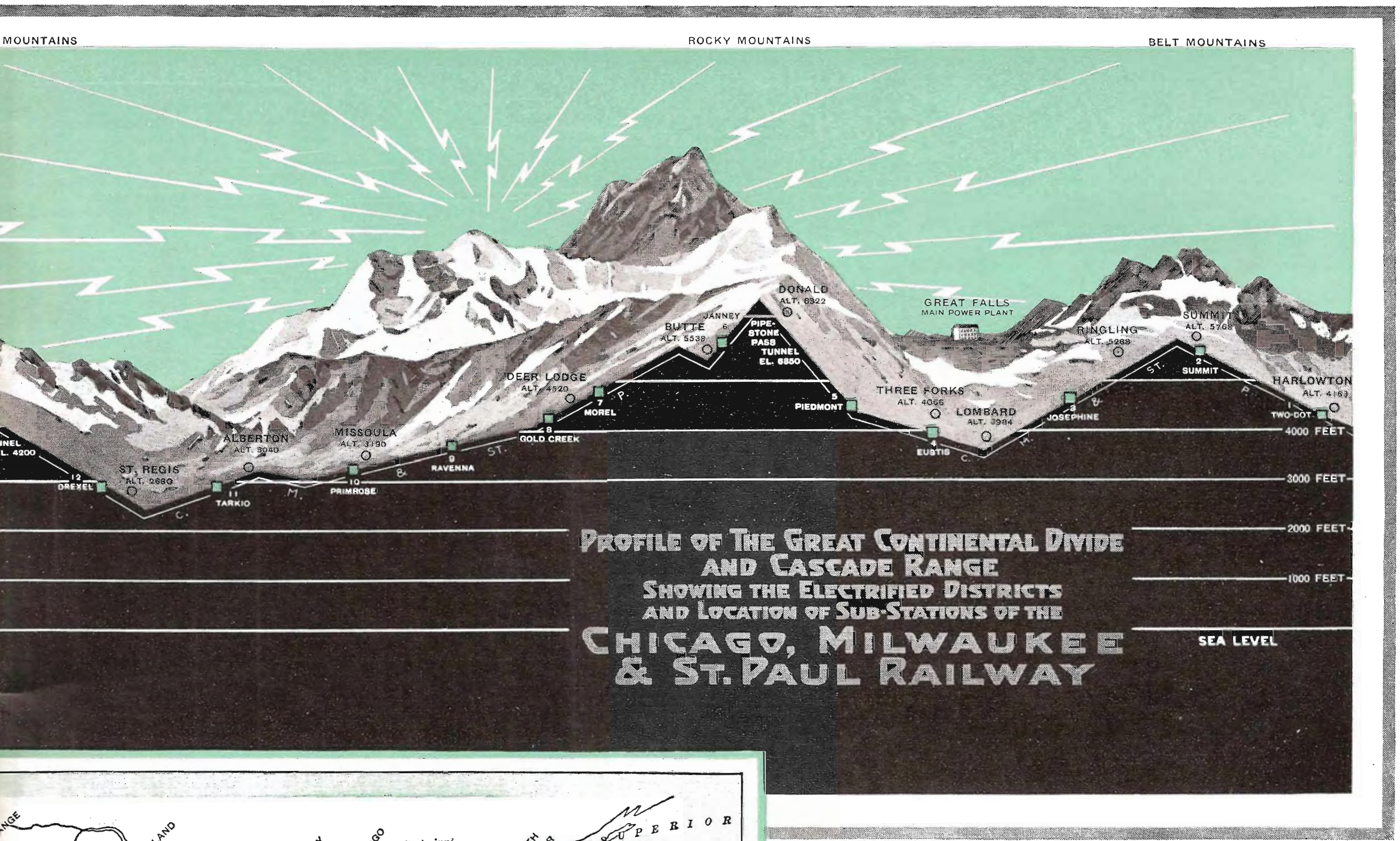
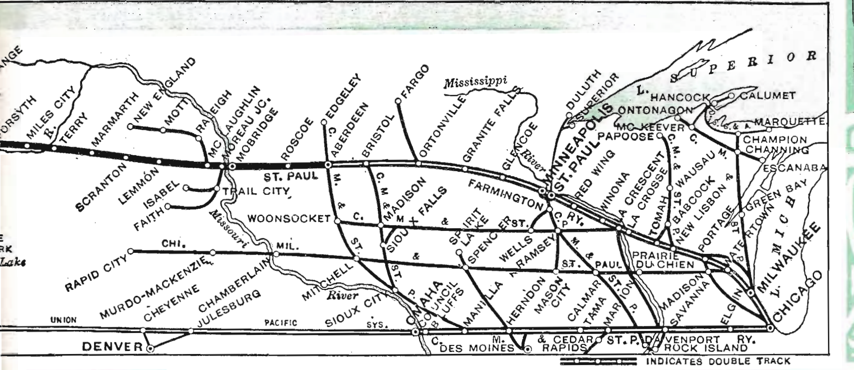




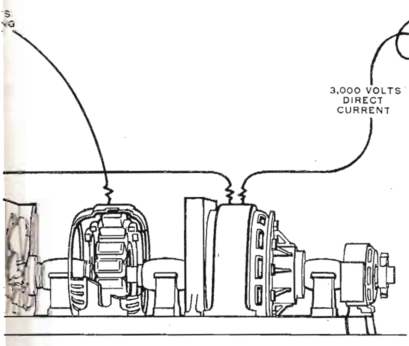
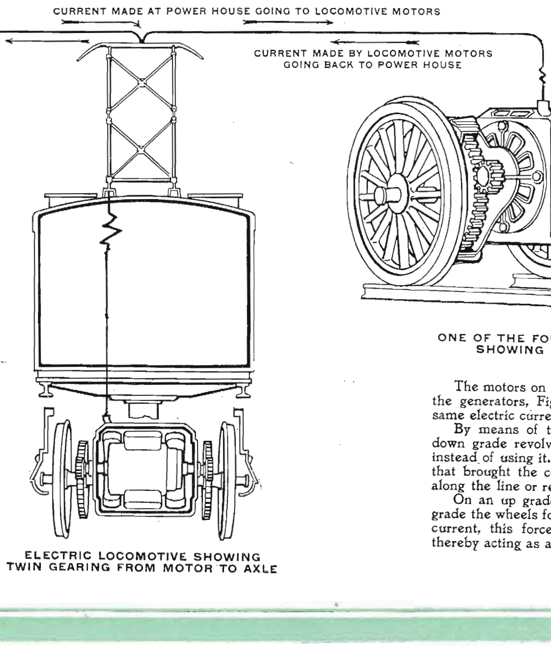


FIG. 6—ALTERNATING-CURRENT MOTOR FIG 7—DIRECT-CURRENT DYNAMO

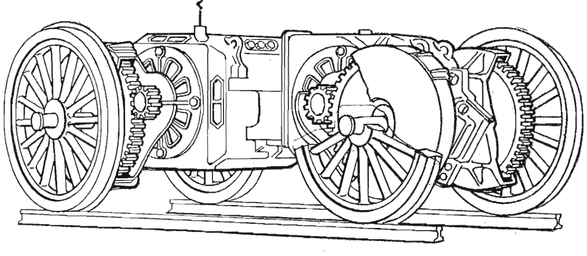
... the center is driven by the alternating current, ...es, or generators, on either side, which change the current ...ent, direct current being used to operate the locomotives

"...HE MANNER IN WHICH ...) INTO ELECTRIC POWER ... OF THE RAILS"

ELECTRIC LOCOMOTIVE



ELECTRIC LOCOMOTIVE SHOWING TWIN GEARING FROM MOTOR TO AXLE



ONE OF THE FOUR MOTOR TRUCKS ON EACH LOCOMOTIVE SHOWING METHOD OF REGENERATIVE BRAKING

The motors on these trucks are practically the same as those in the generators, Figs. 5, 6 and 7, and if revolved will create the same electric current.

By means of the gearing shown above, a locomotive coasting down grade revolves the motors, thereby making electric current instead of using it. This current travels back over the same wires that brought the current on the up grade, and is used elsewhere along the line or returned to the Power Company.

On an up grade the motor forces the wheels, but on the down grade the wheels force the motor. As well as generating an electric current, this force necessarily retards the motion of the train, thereby acting as a brake.

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Aberdeen, Wash. .... E. A. Lalk, Commercial Agent
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Bellingham, Wash. .... A. W. Nase, Commercial Agent
Boston, Mass., 260 Washington Street .... F. N. Hicks, New England Passenger Agent
Buffalo, N.Y., 303 Main Street .... A. Mallum, Commercial Agent
Butte, Mont., 127 North Main Street .... C. H. Mitchell, Assistant General Passenger Agent
Cedar Rapids, Iowa .... J. F. Kane, Division Passenger Agent
Chicago, Ill. {Railway Exchange .... Geo. B. Haynes, General Passenger Agent
Chicago, Ill. {52 W. Adams Street .... C. N. Souther, General Agent Passenger Department
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Cleveland, Ohio, 27 Taylor Arcade .... E. G. Hayden, District Passenger Agent
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Passenger Traffic Manager
CHICAGO

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