the wages of employees, which constitute 40 per cent. of the expense of operation.

"They have decided to increase some of the interstate rates, on an approximate average of 10 per cent. It means a difference of less than 10 cents on $40 suits of clothes shipped from St. Louis to Beaumont, to the shipper; but it may constitute the difference between life and death to the railroad companies of Texas.

"But a vigorous effort is being made to stop up this avenue of escape. The railroad commission obtained the consent of the Governor of Texas, and the aid of the Attorney-General, and the aid of one of our United States Senators, and proceeded to Washington to protest the proposed increase. All the powerful machinery of our state government was therefore brought to bear. According to the newspaper reports, the Chairman of the Commission filed with the Interstate Commerce Commission at Washington a statement contrasting the earnings and expenses of 1891, a period of depression, with the figures for the year ending June 30, 1907, which as above stated, was the best in the history of Texas railroads, when they earned almost 6 per cent. on the amount of their stocks and bonds. But it appears he was utterly silent as to the figures and circumstances for the year ending June 30, 1908, above referred to, which created the conditions which are forcing the raise of interstate rates.

"Suppose the interstate rates are not increased, will the Texas commission increase the purely intrastate rates? Every one knows it will not. Will the employees agree to accept less wages? Every one knows they will not. Any effort to reduce wages would probably bring on a general strike. Will the commission cancel the orders to buy more equipment or improve the tracks? They have declared they will not. Will the state remove some of the new burdens of taxation? Everyone knows it will not. Will our public functionaries persuade the lawful holders of our outstanding bonds to waive the payment of current interest? They cannot. Will they request the legislature to repeal the insolvent corporation law? Everyone knows they will not.

"Then, what can possibly be expected in regard to the fate of the Texas railroads? The situation is so acute and dangerous as to be almost laughable. At the beginning of the present period of depression the writer saw one of the oldest and most honored of the railroad officers in Texas sitting before the railroad commission of Texas, giving testimony, with tears in his eyes. The fears he expressed at that time did not cover the actual conditions obtaining now.

"We see statements in other periodicals condemning the proposition to increase the interstate rates, saying that everybody has suffered during the late depression, and that the railroads should stand their part of the general losses; also, predicting a recovery of business and the movement of a heavy traffic this fall. The reply is that a deficit may mean death to a railroad which has been compelled to do business year after year on rates so thin it has no surplus to keep it out of the red; not so with the shipper. He has no limitation on his prices except competition, and if a prudent man has charged such prices in good times that he has laid away a fund to carry him through hard times; and if necessary, can increase his prices when good times come again to make up for previous losses without let or hindrance.

"Moreover, if railroad rates are not compensatory, do not contain a sufficient margin of profit, what comfort can there be in the prospect of a big business? It is believed by good traffic men that some commodities in Texas are under existing rates, transported at an actual loss. On such traffic, the more business done, the greater is the loss. Since the passage of the law referred to by the last legislature in our judgment Texas railroad companies will not only be justified, but absolutely compelled to bring all of their rates up to a point where a margin of safety will at all times exist to remove the dread of deficits, and we believe the courts will sustain them."

PROGRESS ON THE ST. PAUL'S PACIFIC EXTENSION.

Construction work on the western end of the St. Paul's Pacific extension—that is, from Butte, Mont., to Seattle, Wash.—is nearly finished on some divisions, but the big tunnels and certain heavy fills will yet take some time. Rails are now laid in five different sections, but are not continuous for more than 120 miles. On the Seattle-Tacoma line, track has been finished from Black River Junction south 17 miles to Sumner, Wash., paralleling the Seattle-Tacoma Interurban through Kent and Auburn, and crossing the Puyallup river just above the Interurban bridge.

Starting from Seattle, the main line is completed to a point five miles east of Maple river, 75 miles. The heaviest work of the entire extension is through the Cascade mountains from the Black river to Easton, which includes the big tunnel under Snoqualmie Pass. Work on this tunnel is very slow, but progress is satisfactory, and every effort will be made to get it finished on time. Between the Black river and the tunnel is one of the least advanced sections. This division has many heavy 60 to 70 ft. cuts and fills, on which work is only fairly started. The cost of this section will easily average $75,000 a mile.

From a point three miles east of the Cascade summit at Snoqualmie Pass to a point 13 miles east of Ellensburg, in Kittitas county, Wash., is a 67-mile stretch of completed line. Then follows a gap of about 20 miles of uncompleted line extending to Beverly, on the Columbia river. Beyond Beverly, east to Rock lake, Whitman county, Wash., 119 miles of road is finished. On this section, between Snoqualmie Pass and Rock lake, except for the part between Beverly and Ellensburg, the bridges are in place, tracks and side tracks are laid, and some surfacing has been done. The 15-span bridge over the Columbia river is being built. The piers and approaches are in place, the steel for the superstructure is on the ground, and erection will begin by October 15. It is expected that the bridge will be ready for traffic by March, 1909.

Between Rock lake and Plummer, about 50 miles, is the second long stretch of uncompleted line. Grading in this district is now in progress and is being pushed with all possible speed. The line from Plummer, just across the line in Idaho, to within 15 miles of St. Paul Pass tunnel in the Bitter Root mountains, has 75 miles of track laid. On this division, commonly called the St. Joe division, the grading is all done and the bridges are completed. A majority of the side tracks are laid, while work on the stations, freight warehouses and switch yards is being pushed rapidly. Nearly all of the ballasting will be finished this fall. A number of small streams are spanned by temporary wooden bridges. Permanent steel bridges are being erected as fast as the steel can be brought from the East. At present, the St. Paul crosses a branch of the Spokane river at Tekoa on the 900-ft. bridge of the Oregon Railroad & Navigation Co. On this division about 90 per cent. of the work is done.

The last of the completed sections extends from St. Paul Pass tunnel to Butte. However, about 100 miles of this grade in Hell Gate canyon, between Butte and Missoula, was washed out last June and has not been rebuilt. From Missoula to St. Paul Pass tunnel, 85 miles, grading is finished and the track laid. On the eastern end of the line, passenger service through to Butte has just been begun. Freight service to Butte has been in operation for some time.

Terminal work at Seattle is barely started, a great deal of filling being necessary before work on building foundations or switch yards can be begun. This will have to be pushed vigorously to be ready for the opening of the line. At Tacoma, work on extensive terminals on the tide flats in Commencement bay is under way. The piling for the docks is about all in place and work on the bulkheads has begun. Two siphon dredges are working on the channel, which is to be deep enough to accommodate the largest ocean vessels.

Several branch lines have been located, this being about all that has been done in this direction. One branch that will be very essential is located from St. Maries, Idaho, southward up the St. Mary's river into the rich Palouse wheat country of southeastern Washington and northwestern Idaho. It is not expected that the construction of this branch will be commenced before next spring. Extensive surveys have been made in the Clallam county peninsula, and a line is projected around Olympia to Port Angeles, on the strait of Juan de Fuca. Nothing has been done on this branch, and it is doubtful if it will be built for several years.

Electricity will probably be used in the near future on the 800-mile stretch through the mountains, where water power is abundant and tunnels frequent. The consulting engineer having charge of the extensive electrification projected on the St. Joe river is now in Chicago arranging for the commencement of actual work on this project.

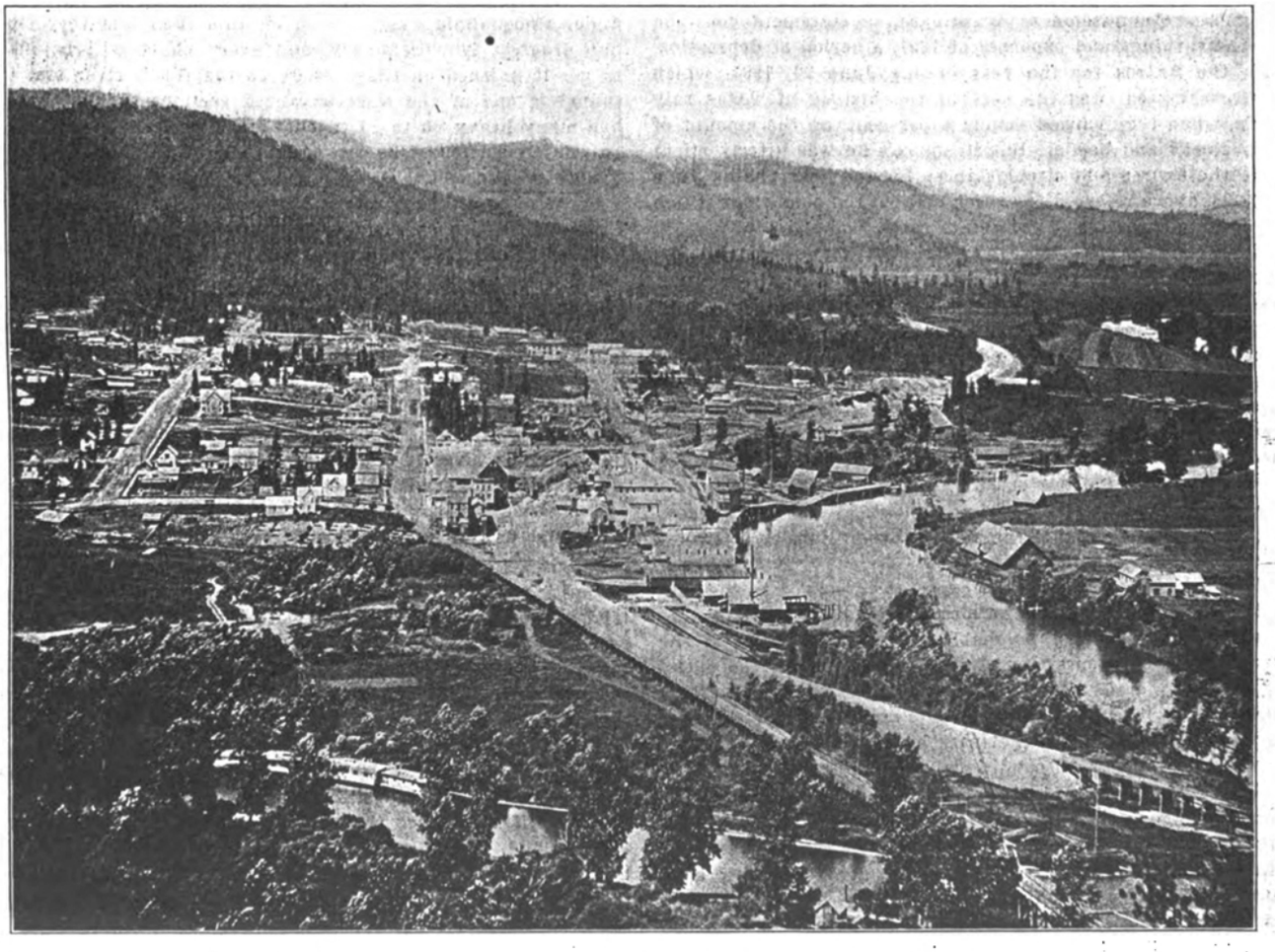
The Chicago, Milwaukee & St. Paul has leased a floor of the White building on Fourth avenue and Union street, Seattle, and will move its offices there soon.

The Parisian subways had an average length of 27 miles in 1907, which was 2½ miles more than the year before. They carried 194,800,000 passengers, which is 18 per cent. more than in 1906, and the gross earnings increased 14½ per cent., and were $64,232 per mile of road. The working expenses were 43⅛ per cent. of the earnings and have varied little from that proportion since 1903. The number of employees was 3,630 at the end of 1907; the number of cars in service was 780. Of the tickets sold during the year, 17½ per cent. were first class, 56 per cent. second class and 26 per cent. were return tickets.

CONSTRUCTION OF THE ST. PAUL PASS TUNNEL; CHICAGO, MILWAUKEE & ST. PAUL.

The Pacific extension of the Chicago, Milwaukee & St. Paul crosses the main range of the Bitter Root mountains by a new and hitherto almost unknown pass, now named St. Paul pass. The tunnel now being built under the summit of this pass is 8,750 ft. long, one end of it being in Montana and the other in Idaho. The summit grade of the line, which is 3,518 ft. from the east portal, has an elevation of 4,169 ft. and is 1020.7 ft. below the surface. The tunnel grade is 0.2 per cent. each way from the summit. Electric power is being used exclusively in the excavation of this tunnel, due to physical and climatic conditions.

The map of the location of the line across the Bitter Roots shows the C. M. & St. P. and the Northern Pacific to be quite close together until the former swings west for the mountain crossing. Opposite Taft the St. Paul line is located on the mountain slope high above the Northern Pacific. In the Bitter Roots the winters are severe and long and the snow deep. The east portal of the tunnel is 2½ miles from Taft and it would have been extremely difficult and costly to haul fuel and heavy equipment from Taft to the tunnel. It was therefore decided to locate the power station at Taft and transmit the power electrically to the tunnel.

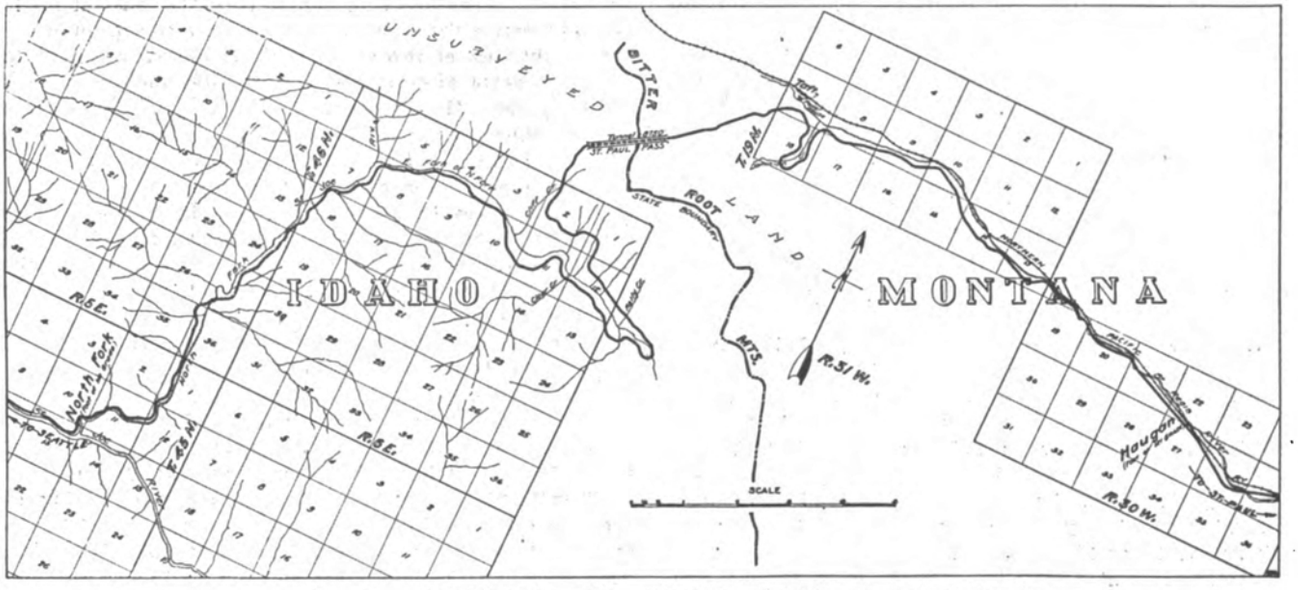


Grade Through St. Maries, Idaho; Pacific Extension of the St. Paul.

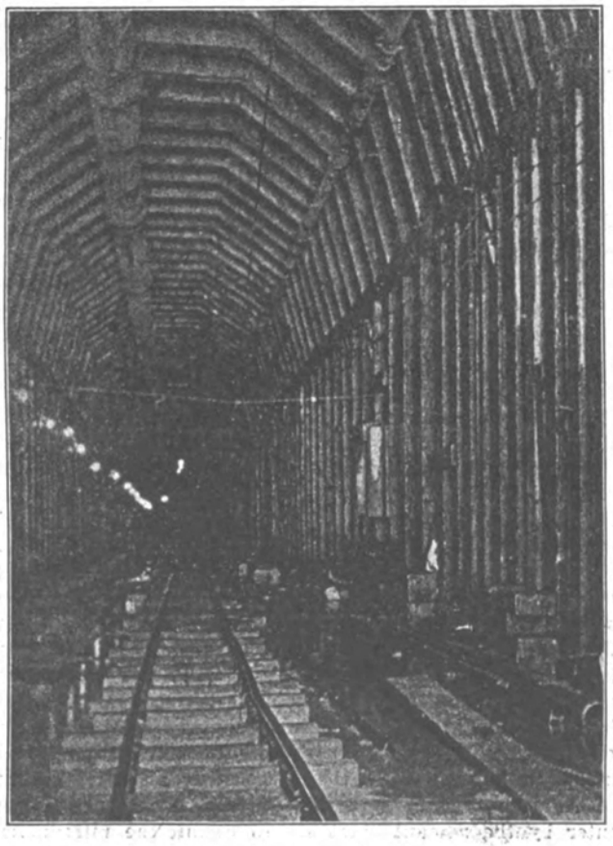
The power plant equipment consists of six 150-h.p. Atlas return flue boilers; two Blake boiler feed pumps; an Underwriters' fire pump, having a capacity of 500 gals. per minute; a Blake air pump and jet condenser; three Corliss engines, and three General Electric three-phase 60-cycle generators, with exciters. The capacity of the plant is 750-k.w. and the voltage is raised to 6,600 through three 250-k.w. step-up transformers. The current is carried a total distance of 4½ miles to the sub-

stations at each end of the tunnel. The transmission line consists of three No. 4 copper wires strung on trees sawed off 35 ft. above the ground, each cross-arm being covered with a 12-in. board to protect it from snow and short-circuiting.

At each sub-station the voltage is reduced to 440 through three 100-k.w. transformers. Each sub-station contains two Ingersoll-Rand duplex, compound air compressors with a capacity each of 1,205 cu. ft. of free air per minute at 135 revolutions. They are driven by 200 h.p. General Electric motors. Each of these compressor outfits furnishes air for eight drills in the heading and five on the bench, for an air shovel, a drill-sharpening machine, an air hammer and the blacksmith forges. The air drills are 3½ in., Ingersoll-Rand being used in the east end and Wood in the west end. The shovels are the Marion, Model 20, type, worked by compressed air. They have a special short boom to enable them to work in the limited space, and have 1¼-yd. dippers. All drill steel is sharpened on a Numa drill-sharpening machine, the result being a great improvement over hand sharpening both in quantity and quality of work. The tunnel is ventilated by an Exeter fan at each end, drawing through a 24-in. galvanized iron pipe, each fan being driven by a 30-h.p. motor.



Location of St. Paul Pass Tunnel; Chicago, Milwaukee & St. Paul.



Timber Lining of St. Paul Pass Tunnel.

The general method of excavation is to drive a full face heading, follow within 60 ft. with the timber lining and then remove the bench. Owing to the changeable character of the material encountered, which is a laminated quartzite, having in many places a layer of talc between the strata, it is often necessary to change this method and take the heading out in a very small opening, then enlarge the section and follow up immediately with the timbering.

When driving a full section, six drills, working on four-columns, are used in the face. The heading material is shoveled into 1 yd. cars and pushed by men, over a track supported by beams spanning the tunnel and resting on the wall plates, to a point behind the shovel working on the bench, where it is dumped through a chute into a car below. All the excavated material is hauled out of the tunnel by two 30-h.p. electric locomotives at each end.

In the east end a track incline is used to transfer cars of heading timber direct into the heading, which greatly facilitates the work and is quicker and cheaper than the old method of raising the timber with block and tackle.

The timber lining is made up of 12 in. x 12 in. longitudinal sills and wall plates, with 16-ft. posts and a five-segment arch rib, spaced according to the character of the material to be supported, usually 4 ft. center to center; but in many places the material necessitated putting the timbers closer together. Two-inch lagging is used on the sides and 4 in. on the arch. A special timber crew does the erection in the heading, but the regular mucking crew does it on the bench.

Two shifts of 11 hours each are worked, and shifts change from day to night work bi-weekly. Unusually rapid progress has been made with the work during the past four months, the amount of completed tunnel driven being

May	563 ft.
June	590 "
July	534 "
August	616 "
Total	2,303 ft.

The theoretical excavated cross-section contains 18.5 cu. yds. per lineal foot of tunnel.

The power plant and sub-stations are equipped with lathes,

shapers, drill presses, emery wheels, pipe cutting and threading devices and the usual blacksmithing tools, and the framing shed with a motor-driven swing saw for cutting lagging and wedges.

The tunnel, shops and camp are lighted throughout by electricity, and each camp has shower baths for the workmen. The power plant and each sub-station is provided with a splendid gravity water supply and fire protection system, which has demonstrated its efficiency on several occasions.

All important points on the work at each end of the tunnel and at Taft are connected by both private and long distance telephones. The company also has a hospital service well conducted, and the Y. M. C. A. has a reading and recreation room at the east end camp under the direction of a regularly appointed secretary.

The work is in charge of W. E. Dauchy, Division Engineer. K. C. Weedin is Tunnel Engineer and Winston Brothers Co. the contractor. We are indebted to E. J. Pearson, Chief Engineer, for the data for the foregoing.

RECENT TYPES OF EXPRESS LOCOMOTIVES.*

The four-coupled locomotive is still deemed suitable for express service on many railroad systems, either because the conditions of traffic allow the weight of the train to be kept under a certain average, or because the stops are far apart and the grades light. Nevertheless, it seems that its hours are numbered, not only in countries where the load per axle is limited to 15 or 16 tons, but even on lines where an adhesive weight as high as 40 tons on two axles is permitted.

The four-coupled locomotive in its most recent form, the Atlantic type, is perfectly adapted for the fastest train services, and when fitted with a wide firebox its grate area per unit of adhesive weight may attain a very high proportion, which is, as is well known, a characteristic of engines suited for fast trains.

The Atlantic type is compact, can be very well proportioned, is adapted for the use of a wide firebox, and constitutes probably the last word in four-coupled engine design. Its only disadvantage is the limitation of the adhesive weight to some 30 to 40 tons, according to the limits laid down by the permanent-way staff, save in America, where a weight of as much as 50 tons is permissible. It is a recognized fact that the locomotives do not use all or even the greatest part of their adhesive weight, except on starting, on severe gradients, or in passing through tunnels, so that where the stops are fairly far apart and the road easy four-coupled engines may be sufficient with trains which at first sight would appear to be beyond their power. But this type is confined to a well-defined kind of service, and hence might be considered on certain systems as too highly specialized. The Atlantic engine, having a large proportion of its weight concentrated on the center—where are the coupled axles—has some tendency, when running at high speeds, to a pitching motion; much more so, indeed, than engines having a coupled or heavily loaded trailing axle.

Six-coupled engines mounted on large driving wheels behave as well at the high speeds actually attained as four-coupled engines, while they are able to start heavier trains and to accelerate them more quickly. They have, in fact, a reserve of tractive power which proves very valuable upon occasion. At the same time, being less specialized, they are available for a greater variety of service, and may be employed for heavy slow trains with frequent stops, or even, in case of necessity, for goods trains.

Adhesion is only one factor in the power of locomotives, and is, indeed, as we have said, only fully utilized for a comparatively short time. But while it determines the maximum tractive effort actually obtainable, the grate area is the principal factor in deciding the tractive effort which any given engine can exert at the highest speed it may be called upon to attain, or, inversely, the maximum realizable speed for a given tractive effort. To put it in another way, the maximum *static* effort is settled by the adhesion, while the work which any locomotive can develop is decided by the area of the grate. Thus the latter may be, in some sort and within certain limits, independent of the weight available for adhesion; the work, proportional to the product of the two factors, speed and tractive effort, can be constant for important relative variations of each of these two factors.

Take the case of two engines having the same boilers and the same grate area, one of the Atlantic and the other of the 4-6-0 type. They will both be able to maintain the same tractive effort at the same speed—say, 50 miles per hour—but the second will possess as its sole advantage the power of making a quicker start or of developing its maximum power with a heavier train at lower speeds. If, on the other hand, the increase of adhesion ought to correspond with the traction, at the same given maximum speed, of heavier trains, it ought of necessity to be accompanied by a proportional increase of the grate area. But the provision of a large and deep firebox is much more difficult on an engine with six-coupled wheels of large diameter than on a four-coupled Atlantic engine.

As a matter of fact, if the narrow firebox is retained in the latter type, as the trailing wheels are of a comparatively small diameter, it is possible to give the firebox a sufficient depth without raising the boiler too much, or giving the grate an excessive inclination. Typical examples of this arrangement may be seen in the Atlantic engines of the P. O., Nord, and P. L. M. in France, and the North-Eastern, Great Central and Lancashire & Yorkshire in England.

If, on the other hand, the wide firebox is adopted, it is not necessary to give to the boiler the excessive length which it attains in the Pacific type, and it is possible to obtain the same grate area with much less total weight, but the adhesive weight is, of course, smaller too. Most of the great American railroads, the Great Northern &. Brighton in England, and the Prussian State Railways, have Atlantic engines with wide fireboxes in service, but though such engines are compact and powerful, their adhesive weight on account of the continual increase in the weight of trains, is growing more and more insufficient on some systems, or at least on difficult and hilly sections of such systems. The type appears to be principally suitable for lines on which axle weights of 20 tons and over are allowed. In the United States some Atlantic engines take 50 tons on the four-coupled wheels, while in Germany and Italy such a weight cannot be carried on less than three axles; but as the weight of trains in America is greater than in Europe, the situation is about the same, and the Atlantic type is there also becoming insufficient.

The combination of the wide firebox and six-coupled wheels of more than, say, 5 ft. 6 in. diameter, has led to the introduction of the Prairie and Pacific types. The obvious difference between the two designs, namely, the use of a leading pony-truck in the former, and of a leading bogie in the latter, appears at first sight to be of small importance, but it carries with it a factor of more account, for while the cylinders of the Prairie type are placed between the leading and the coupled wheels, in the Pacific type they are brought more to the front between the wheels of the bogie. The result is a notable lengthening in the Pacific engine, not only of the frame, but of the boiler. As far, however, as the latter is concerned, the whole length available for the tubes is not used, either to avoid a surplus of weight or to obviate the troubles that might result from the use of very long tubes. In fact, the Prairie type is really a mogul engine, but it has a wide firebox over a fifth axle, trailing and non-coupled. The Pacific, on the other hand, results from a similar transformation of the 4-6-0 engine, or better still, of the Atlantic type, with a wide firebox, lengthened in the center by the amount necessary to permit the introduction of a third pair of coupled wheels between the cylinders and

*From a paper in *The Engineer*, London, by Maurice Demoulin.