sinking fund not commencing until 10 years from date of issue and then being payable in 30 annual installments. This plan was followed for two reasons: (1) Because it gives opportunity for the construction of the work and the provision for making it pay its own way, and (2) (and of equal importance) the payments are made proportional to the value received. In the east end of the valley, being nearer to Los Angeles and under partial irrigation from pumpage, the land has reached a fairly high state of cultivation with an equivalently high assessment. It is true that this more improved section must pay more than its proportional share of interest charges for the first decade, but by the end of that period the entire valley should be under irrigation, and the northern and western portions now thinly populated and under dry farming will have reached a condition of prosperity where the burden of payments of the principal will be much more equitably adjusted than is now possible.

Cost of Irrigation and Water Rights

The city has set a rate for irrigation of 1c. per miner's inch per hour, which, on the basis of 1 in. to 7½ acres for a period of 240 days, amounts to $11.68 per annum—a cost believed to be cheaper than for pumpage in the valley.

The most troublesome subject before the California courts is the question of water rights and in the present instance it is disposed of once for all in this way. The city has provided as the first requisite for the use of the water incorporation within its own limits. No water rights *per se* are given to the land. The irrigation user upon application and payment for the use of the water, to all intents and purposes stands in the position of a Los Angeles property owner who has paid for a tap from the city system and the water cannot be taken from the land so long as the rules of the Bureau of Water-Works and Supply are complied with. The water right is therefore one in fact and it has been accepted as such by the prospective water users of the district.

Immediate Market

Los Angeles during the past summer has stood in the unusual position of a city which has long been threatened with a water famine but which now has a supply amounting to a large surplus, yet because of political conditions and lack of distribution facilities is unable to dispose of it.

The proscription of a year ago that only territory within the city limits could use the water cut off an immediate market along the City Trunk Line, but effectively guarded the city against the plans of corporate interests who were prepared to contest the city in the possession of her water rights. With annexation accomplished within the next few months, the City Trunk Line should be available for the irrigation of a strip of several miles on each side of it during the summer of 1915. In addition, a temporary open, unlined ditch, taking its supply from the Lower San Fernando Reservoir, ready for storage about Jan. 1, will be carried for 7 mi. southwesterly toward the Chatsworth Reservoir. Beginning at an elevation of 950 ft., and with a capacity of 7500 miner's inches, it is anticipated by this means that 10,000 acres can be placed under the water during the coming irrigation season. Upon completion of the permanent system, this ditch will be abandoned.

The Snoqualmie Tunnel; C., M. & St. P. Ry.

The Puget Sound extension of the Chicago, Milwaukee & St. Paul Ry. crosses the summit of the Cascade Range about 60 miles east of Seattle, Wash., and the original plans called for a summit tunnel. In order to expedite the completion of the line through to the Pacific Coast, however, it was constructed with an open high-level line through the Snoqualmie Pass, and with this the road was ready for traffic in 1908. The operating troubles over this summit were serious, due to the heavy grades and the open high-level line over the Cascades (where snow conditions are exceptionally severe). Consequently, surveys for the tunnel were soon started.

The high-grade or open-pass line extends north and northwest from Keechelus, Wash., to the summit at Laconia (4.75 miles) with a grade of 2.2% and then southwest on a descending grade of 2.75% to Rockdale (4.4 miles). Its maximum curves are of 8°, and its summit is 3005.7 ft. above sea level.

The low-grade tunnel line or cutoff runs north from Keechelus to the east portal, and then due west to Rockdale, at the west end of the tunnel, 4.5 miles. This line saves 3.75 miles in distance (or about 40% of the distance between Keechelus and Rockdale), 444 ft. in rise and fall, and 1240° in curvature. It will enable westbound trains to dispense with the present helper service. Heavy eastbound trains will require only one instead of two helper engines, this helper service being necessitated by a 20-mile grade of 1.75% from Cedar Falls to Rockdale

The tunnel is 11,886 ft. long, with a summit elevation of 2556 ft. at 2000 ft. from the east portal. From the east end it has an ascending grade of 0.1%, followed by a descending grade of 0.4%. The tunnel is on tangent, but a 6° curve begins just inside the east end and a 3° curve inside the west end.

Work on the tunnel was commenced early in 1912, with the idea of extending the construction over several years. The severe snow troubles on the open line during the winter of 1912-13 made it evident that the low-grade tunnel line would have to be completed as soon as possible, and steps were taken to push the work vigorously.

The headings met on Aug. 4, 1914, but a slide about 1800 ft. from the east portal made it necessary to hole through from the west heading, and as the east and west ends had top and bottom headings respectively, the lines could not be checked until Aug. 18. The final checking showed that the west line came 0.15 ft. north of the east line; the elevations checked to 0.13 ft., and the actual tunnel distance was 6 ft. longer than that calculated from the survey lines which had been run across the summit. The meeting of line and grade was considered very satisfactory. The 6-ft. variation in distance seems considerable, but it is explained that no special effort at great refinement was made in the surface measurement, as each time this was made in 12 to 15 ft. of snow.

The excavation was mainly in hard black shale rock, with some conglomerate, etc., the strata being inclined but slightly from the vertical, as shown by the geological section, Fig. 1. A considerable amount of water was struck in the conglomerate, due largely to small lakes (formed by the melting snow) on the east slope. There was water also in the loose material encountered near the west portal.

The tunnel was built by the railway company in accordance with its practice of doing practically all construction work with its own forces. J. I. Horrocks was Engineer and Superintendent under E. O. Reeder, Assistant Chief Engineer. All the work was under the direction of C. F. Loweth, Chief Engineer of the Chicago, Milwaukee & St. Paul Ry. The tunnel was completed and ready for traffic in January, 1915.

Design of Tunnel

The standard cross-section of the tunnel is 24 ft. high and 16 ft. wide, with a flat floor and a semi-circular roof chambers for the conduits, as shown. The refuge chamber is about 2 ft. deep and 6 ft. wide, with a total height of 9 ft. 6 in., but at the top is placed the conduit box, so that the clear height is 6 ft. 6 in.

On account of the amount of water met with at various points, which must be provided for in the completed tunnel, concrete gutters have been constructed as shown in Fig. 2. The gutters are 12 in. wide and 10 in. deep, and at the refuge chambers they are covered with planks. One side is formed by the footing of the tunnel wall. The other side is a curb wall to retain the ballast.

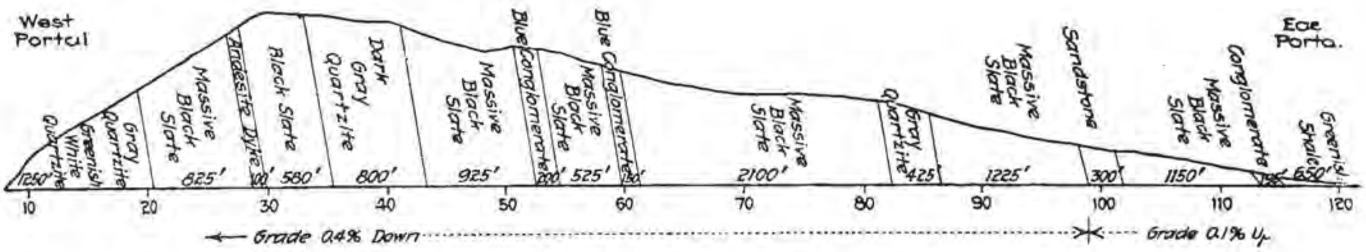


Fig. 1. Typical Geological Section Along the Snoqualmie Tunnel; C., M. & St. P. Ry.

arch, as shown in Fig. 2 The sides have a batter of 4 in. in 6 ft. above the top of the footing course. The tunnel is lined throughout with 12-in. of concrete, this being made necessary by the stratified condition of the rock (Fig. 1).

Embedded in the lining on one side are two 3-in. fiber conduits for telegraph wires and electric cables. On the same side of the tunnel are refuge chambers about 300 ft. apart, which serve also as inspection or splicing

To allow the water to flow from the tunnel into the gutters, 6x6-in. concrete baffles are placed diagonally across the tunnel floor at intervals varying from 150 to 300 ft. At each baffle the water passes through a grating in the curb wall and enters a 4-in. pipe which discharges into the gutter some distance further along. The object of this is to avoid having the gutter open directly to the tunnel floor. The baffles discharge the water on alternate sides, as shown.

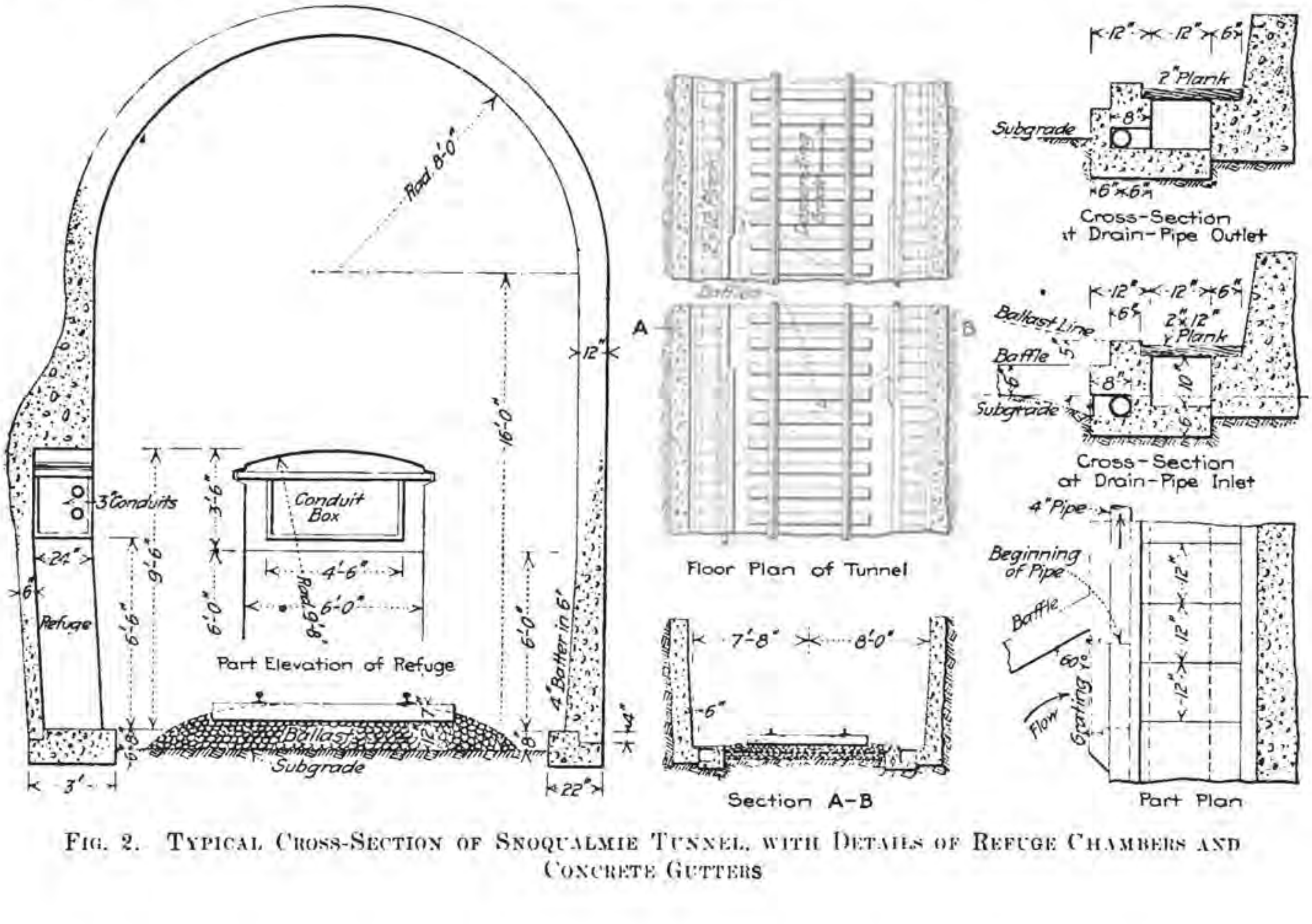


Fig. 2. Typical Cross-Section of Snoqualmie Tunnel, with Details of Refuge Chambers and Concrete Gutters

Methods of Driving the Tunnel

The construction of the Snoqualmie tunnel is of special interest on account of the use of the bottom-heading system (common in European practice) for the greater part of the work. This was adopted as giving greater speed and economy for the conditions under which this long tunnel had to be driven.

At the east end of the tunnel, however, there is a long and deep approach cut, and as this could not be completed until after the actual driving of the tunnel was in progress, it was decided to drive a top center heading at this end. This heading was widened to full arch section, and, to avoid placing temporary timbering, about 3000 ft. of the arch was concreted in advance of the removal of the bench.

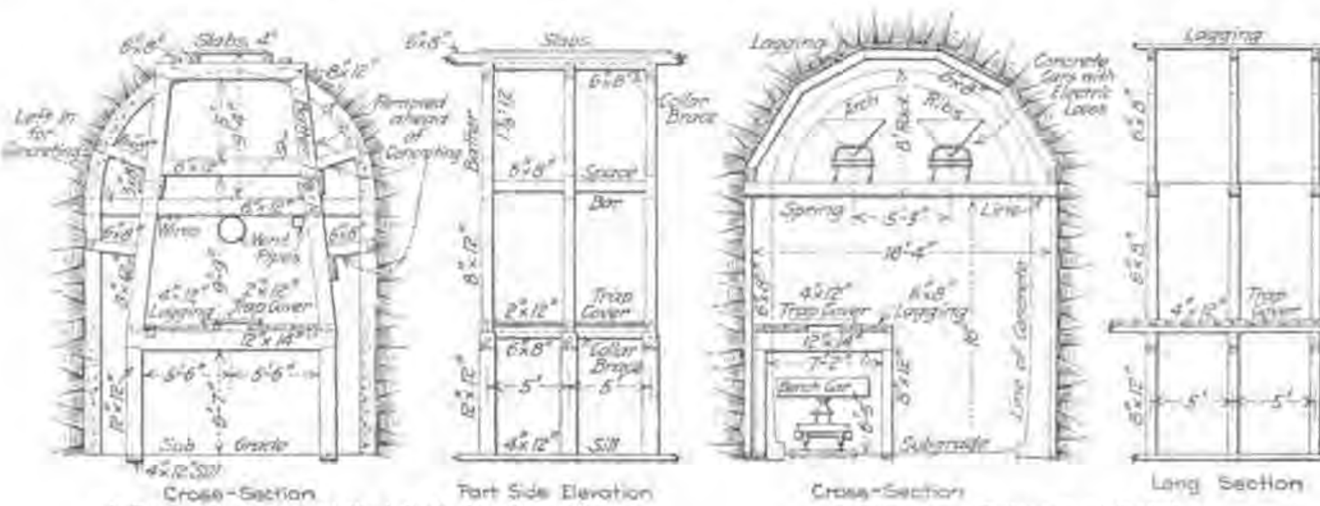
The greater part of the tunnel was driven from the west end, using the bottom-heading system. A bottom drift 8 ft. high and 13 ft. wide was driven first along one side of the tunnel, and was then widened out on its other side to the full normal width of 18 ft. This full heading was timbered. The sets were spaced 5 ft. c. to c., and consisted of posts 12x12 in. with caps 12x14 in., upon which stringers and flooring were placed. The timbers were so arranged that the bench rock could be dropped directly to the 1½-yd. side-dump cars on the mucking tracks below.

At intervals of 150 ft., openings were driven upward to full tunnel section, and from these the bench was worked in both directions. The entire face was shot at one time. This gave both muckers and drillers continuous work in each bench stope and permitted the working of any number of stopes, depending on labor conditions.

A double-track narrow-gage line was laid as far as this bench work, a single track extending beyond to the face of the bottom heading. Horses operated the cars on this track, while at the bench the cars were made up into trains to be handled by gasoline locomotives. As the 1½-yd. cars were too high for hand shoveling, 1-yd. steel rocker dump cars were used for work at the face.

Four drills were used in the heading and were mounted upon a cross bar instead of upon tripods. For each round these drilled from 16 to 30 holes 9 ft. deep, depending upon the rock encountered. Usually there were 12 holes above the bar and four below, the latter acting as lifters in blasting. Steel plates laid on the floor facilitated the shoveling of the muck into the cars.

For ventilation, a 24-in. exhaust pipe was carried to the end of the completed bench and a 10-in. blower pipe was extended to the heading, this pipe within 100 ft. of the heading face being of canvas. As the distance from the portal increased, booster fans were installed at the blower line.



A-Frame Timbering at West End; Sta. 10 to 26 Temporary Timbering at East End

Fig. 3. Timbering of the Snoqualmie Tunnel; C., M. & St. P. Ry.

Each heading shift was composed of a foreman, 4 drill runners, 4 helpers, 10 muckers or shovelers, and a nipper. They worked 6-hr. shifts, with 12-hr. rest between shifts, except that the foreman and nipper worked 12 hr. These shifts were paid on a bonus system. The basis of this was 100-ft. advance for a 10-day period, and for each additional foot of advance each man on the shifts received one hour's extra pay. The average progress was 9.5 ft. of heading per day, with a maximum of 25 ft.

For work at the east end, under the top heading system, a center drift 9x6 ft. was driven first, with its floor at the springing line, and this was winged out to the full arch section. Shafts at intervals of 1000 ft. were sunk to the floor level, and stoping drifts were run from these at one side of the tunnel, from which the bench was taken out to the full section.

Concreting

The permanent concrete lining was put in while the tunnel was under construction, its purpose being largely to prevent fall of the roof. Where the excavation was in loose material at the west end, and was far in advance of the concreting, an A-frame timbering was put in to support the roof temporarily. This is shown at the left in Fig. 3. It was removed in advance of the arch concrete work, cross timbers being placed at the springing line to carry the track for the concrete cars. At the east end, some temporary timbering was required, as shown at the right in Fig. 3.

The concrete walls were built in lengths of 50 to 100

TABLE I. FORMS OF DAILY PROGRESS REPORTS ON THE EXCAVATION OF THE SNOQUALMIE TUNNEL; C., M. & ST. P. RY.

Daily Progress Report on Tunnel
West End (Bottom Heading System)

June 1914	Bottom Heading Lin.Ft. Driven Per Day	Total 6816	Station 74 + 74	Per Day	Total	Station	Top Bench Lin.Ft. Driven Per Day	Total 5696	Station 63 + 54	Per Day	Total	Station
1	6	6822	74 + 80	....	....	....	0	5696	63 + 54	....	....	....
2	10	6832	74 + 90	....	....	....	0	5696	63 + 54	....	....	....
3	6	6838	74 + 96	....	....	....	8	5704	63 + 62	....	....	....

Daily Progress Report on Tunnel
East End (Top-Heading System)

June 1914	Top Heading, Center Drift Lin.Ft. Driven Per Day	Total 3853	Station 86 + 89	Top Heading, Enlarged Lin.Ft. Driven Per Day	Total	Station	Bench Lin.Ft. Driven Per Day	Total 1472	Station 110 + 70	Remarks Cars of Tunnel Muck Bench	Heading
1	16	3869	86 + 73	....	....	....	4	1476	110 + 66	79	97
2	18	3887	86 + 55	....	....	....	4	1480	110 + 62	95	126
3	16	3903	86 + 39	....	....	....	4	1484	110 + 58	118	103

TABLE II. FORM FOR DAILY REPORT OF CONCRETING IN THE SNOQUALMIE TUNNEL; C., M. & ST. P. RY.

Daily Concrete Report, June, 1914
West End

	Right Footing			Left Footing			Right Sidewall			Left Sidewall			Arch					
Date	Sta.	Lin. Ft.	Total Lin. Ft.	Sta.	Lin. Ft.	Total Lin. Ft.	Sta.	Lin. Ft.	Total Lin. Ft.	Sta.	Lin. Ft.	Total Lin. Ft.	Sta.	Lin. Ft.	Total Lin. Ft.	Cu. Yds.	Total Cu. Yds.	Actual Time of Plant in Operation
	53 + 53	..	4689	53 + 81	..	4691	51 + 83	..	4493	51 + 93	..	4503	51 + 50	..	4437	..	23,747.0	..
1	54 + 33	80	4769	54 + 78	97	4788	51 + 99	16	4509	......	..	..	......	..	..	29.5	23,776.5	11
2	55 + 00	67	4836	55 + 13	35	4823	52 + 47	48	4557	......	..	..	......	..	..	79.5	23,856.0	11

ft., and the roof arch in 12-ft. lengths. A concrete mixing plant was installed near each portal, and the concrete was transported in ½-yd. steel dump cars on narrow-gage tracks. These tracks were carried by cross timbers placed at the springing line and supported on posts until the side walls were concreted, as shown in Fig. 4. This arrangement enabled the concrete cars to be operated independently of the mucking cars, and it also enabled the concrete to be dumped directly into the forms for the sidewalls. That for the arch was shoveled into place. The cross timbers extended to the rock face and were left embedded in the concrete of the side walls, being sawed off level with the face of the walls after the completion of the work.

At the west end, the concrete cars were operated on an endless cable haulage system as shown in Fig. 4. At the east end (Fig. 3) they were operated by electric locomotives.

Progress Records and Reports

The greatest advance per month was 455 ft. in the west heading (March, 1913) and 433 ft. in the east heading (September, 1913). The maximum total advance for both headings was 785 ft. (May, 1914). The average daily heading advance was about 9.5 ft., with a maximum of 25 ft. for the west (bottom) heading and 24 ft. for the top center drift of the east heading. The progress diagram, Fig. 5, shows what a steadily uniform progress was made, the light straight lines indicating the average estimated progress. The heading work kept pretty closely to these lines. The bench work at the west end was slow, due to small force under labor conditions. On Dec. 31, 1914, the excavation of both benches had been completed, and the concrete lining was completed early in January, 1915.

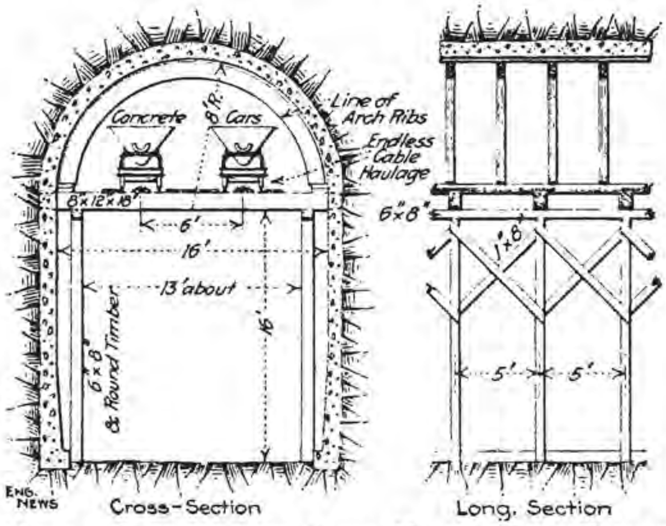


Fig. 4. Timbering to Carry Narrow-Gage Tracks for Concreting the Tunnel (Endless-Cable Haulage System)

The two forms of daily progress report of tunnel excavation are shown in Table I. The sheets are 8½ in. wide and 11 in. high. The report for the west end shows the bottom heading and top bench. That for the east end shows the center drift of the top-heading, the enlarged top heading and the bench; it has also a column for remarks, which in the example given is used to record the number of muck cars. The form for daily progress of concreting is shown in Table II, and is the same for work at both ends. This gives the progress on the different parts of the work, with the total advance, yardage and hours per day.

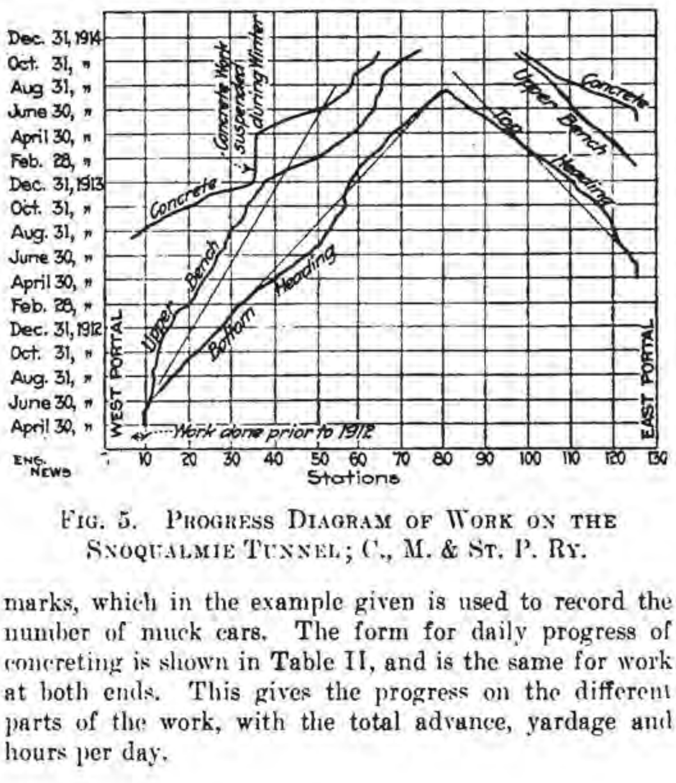


Fig. 5. Progress Diagram of Work on the Snoqualmie Tunnel; C., M. & St. P. Ry.