other deformed bars of a type satisfactory to the engineer. After the contract was let it was decided to use round corrugated rods throughout. The material for reinforcing bars is medium open hearth steel having an ultimate strength of from 60,000 to 68,000 lbs. per sq. in.; an elastic limit not less than one-half the ultimate strength; elongation of 22 per cent; the capacity to bend cold 180° to a diameter equal to the thickness of the piece tested without fracture on the outside of the bend.

Trinity River Span.—This span had four steel girders connected by steel cross girders. All metal work is to be encased in concrete. The steel girders carry in direct compression the horizontal thrust of the adjacent arch spans. This thrust is carried into the bottom flanges of the girders by means of special cast steel shoes, shown in Fig. 7. The upright portion of the shoe bears against the concrete of the pier on one side and against the cast steel wedge on the other, the wedge being driven between the cast steel shoe and the end of the bottom flange angles. The girders are otherwise of the ordinary type of construction and the material specified is medium steel except for rivets, which are to be of soft steel.

Lighting System.—At each pier on either side there will be a cement lamp standard on which are to be placed three 40-c. p., 50-watt series Tungsten lamps. Each lamp will be encased in a heavy 10-in. R. I. glass globe. The wiring system is to be so arranged that the center light on each post will be on one circuit and the two side lights on another circuit, so that either one, two, or three lights in each group can be used, as desired. At the Houston St. stairways the lamp standards will have a single lamp only.

The total cost of the structure, including engineering and all incidentals, will be about $570,000. The cost per square foot of floor is about $2.10, which is a remarkably low figure for a structure of this height. The contract was awarded to Corrigan, Lee & Halpin, of Kansas City, Mo. The concrete piles are being put in place by the Gulf Concrete Construction Co. of Houston, Texas. The field work is being carried out under the supervision of Hedrick & Cochrane, consulting engineers, Kansas City, Mo., and J. F. Witt, county engineer. E. N. Noyes is resident engineer, representing the consulting engineers. The work was begun in October, 1910, and is to be completed by Dec. 1, 1911.

EARTH AND ROCK SECTION

Methods and Some Costs of the Construction of the St. Paul Pass Tunnel.

BY K. C. WEEDIN, MEM. A. S. C. E.*

The St. Paul Pass tunnel is on the line of the Chicago, Milwaukee & Puget Sound Ry. where the latter crosses the Bitter Root range of mountains on the Montana-Idaho state line. It is 8,750 ft. long; 3,412 ft. being in Montana and 5,338 ft. in Idaho. The summit grade in tunnel is elevation 4,169 ft. at a distance of 3,520 ft. west of the east portal and this point is 1,020.7 ft. below the surface. The gradient is 0.2 per cent in both directions from the summit. The location lies in a zone of extremely great snow fall, possibly the greatest in the United States; the actual fall during the winter of 1907-08 being 33 ft. 4 ins. Fortunately there is little wind.

Construction was begun Jan. 18, 1907, and

Fig. 1—Looking East from Summit along Tangent, St. Paul Pass Tunnel.

was completed March 4, 1909. The writer assumed charge for the company on Dec. 6, 1907, or about one year after the work was started.

The C., M. & P. S. Ry. practically parallels and lies near the Northern Pacific from Missoula to Taft, Mont.; there they diverge, the former bearing to the southwest and crossing the range into the valley of the North Fork, a tributary of the St. Joe River.

Taft being the nearest point to the tunnel on an operated railroad, 2.5 miles distant, it was decided to locate the power house there, generate the electricity and transmit it to substations, one at each end of the tunnel. There were two alternate propositions, both having the main power station located near the east portal. One provided for the construction of a railroad, which would necessarily be on a steep grade, from Taft to the east portal. This would be difficult and expensive to operate on account of both grade and snow. The other was to team all machinery, fuel and supplies from Taft to the power house. The cost of either would have been greater and the probability of uninterrupted service less than that of the one adopted.

A wagon road was constructed from Taft across the range at great expense, over which all supplies, machinery, timber, etc., were transported both for the west end of the tunnel and for the grading and bridge work on the west slope.

This road required a great deal of attention. The average traffic over it was about 100 four-horse teams per day and the maximum about 160 four-horse teams. About 60 men were required in summer to keep the road open, and about twice that number were required in winter and spring. These men were stationed in three camps along the road, one at each portal and one at the summit. The road was about 4½ miles long and the summit was about 1,000 ft. above the portals. Fresh snow was attacked with a steel logging plow pulled by 24 horses, then a 30-horse wooden wedge plow was used and the work was finally finished with shovels. In spite of this work the road bed was steadily elevated during the winter until it was well up to the roofs of the camp houses.

During the winter of 1907-08 a cableway one mile long was built from the east portal to the summit. This cableway was driven by a 30-hp. motor. Supplies, fuel, timber, etc., were teamed from Taft to the lower terminal near east portal, carried on the cableway to the summit, there transferred to wagons and hauled down the west slope. This method obviated the long, heavy team haul up the mountain and greatly lessened the time.

The main power station equipment consisted of the following items:

6 150-hp. Atlas high pressure tubular boilers, set up in batteries of two.
2 Blake 8x5x10-in. boiler feed pumps.
2 Fairbanks-Morse 5½x3½x5-in. boiler feed pump.
1 Blake 14x7½x12-in. underwriters fire pump, normal capacity 500 gals. per minute.
1 Blake 14x22x24-in. air pump and jet condenser.
2 20x48-in. Corliss engines.
1 14x28x20-in. tandem compound McEwen engine direct connected to a 200-kw. 3-phase, 60-cycle, 2,200-volt generator.
1 17x22-in. Atlas engine.
1 10x16-in. Atlas engine, driving exciters.
2 200-kw. 3-phase, 2,200-volt, 60-cycle, G. E. generators belted to the Corliss engines.
1 200-kw. 3-phase, 2,200-volt, 60-cycle, engine type, Westinghouse generator, direct connected to McEwen engine. A 17½-kw. 125-volt Westinghouse exciter was belted to this generator.
1 35-kw. 125-volt G. E. direct connected generator, used for exciter.
3 250-kw. 2,200 to 6,600-volt, 60-cycle transformers—oil cooled.
3 Sets of 6,600-volt multigap lightning arresters with choke coils and all necessary switch board panels, connections, volt meters, circuit breakers, etc.

The machine shop equipment was as follows:

1 24-in. x 14-ft. New Haven heavy duty engine lathe.
1 Four-jaw chuck, 16-in. diameter.
1 20-in. Hoefer back geared drill press fitted for No. 3 drill socket.
1 30-in. Wallcott & Wood geared shaper, extended base and counter shaft.
1 No. 96 Forbes belt and hand driven pipe machine with dies from 1 in. to 6 ins. with cutting off attachment.
1 Blacksmith outfit complete.

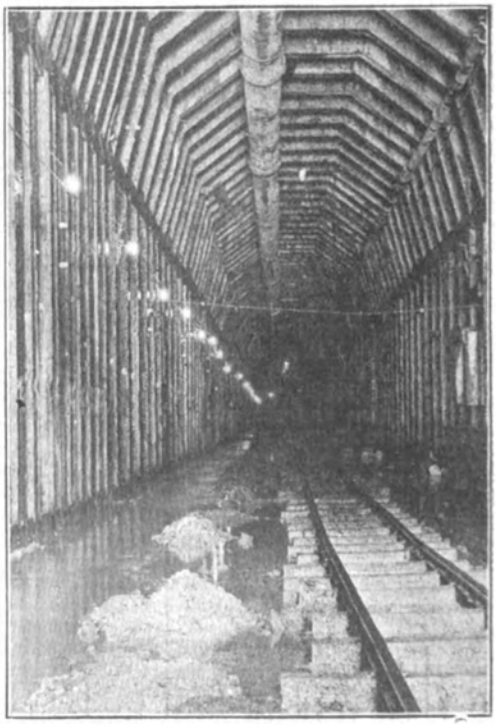

Fig. 2—View Showing Completed Timber Lining of St. Paul Pass Tunnel.

(Large Pipe in Roof is Ventilating Pipe. Small Pipe is High Pressure Line.)

The power station was protected by a good gravity water system in addition to that afforded by fire pump. The capacity of plant was 750 kw. and the alternating current was carried to the sub-station at each end of the tunnel—2½ miles to the east end and 4½ to the west end—over a transmission line of

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three No. 4 copper wires supported on cross arms bolted to tree trunks about 35 ft. high. The cross arms were covered by 1x12-in. boards nailed together in the shape of an A to protect the wires from snow, and prevent short circuiting. They are shown by Fig 1.

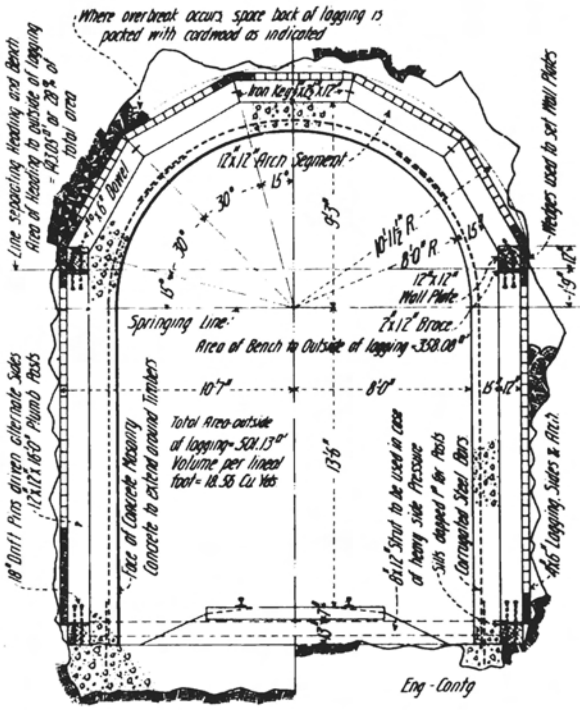

Fig. 3—Cross Section of St. Paul Pass Tunnel.

At each sub-station the current is stepped down from 6,600 volts to 440 volts through three 100 kw., oil cooled transformers.

The east end sub-station equipment comprised the following items:

2 220-hp. 60-cycle, 3-phase, 440-volt, G. E. induction motors, driving compressors.
1 100-hp., 60-cycle, 3-phase, 440-volt, G. E. induction motor.
1 100-kw. 575-volt, G. E., D. C. generator.
1 50 hp. 2-pole Thompson-Houston 500-volt D. C. generator.
1 50-hp. 500-volt Westinghouse D. C. motor.
1 30-hp. 4-pole, 500-volt Westinghouse motor.
2 Westinghouse-Baldwin electric locomotives fitted with 2 No. 64, 500-volt, D. C. motors, 24-in. gage.
2 7½-kw. 500 volt motors.
3 100-kw. 6,600 to 440-volt, 60-cycle, G. E., oil cooled transformers.
3 7½-kw. 440 to 110/220-volt Westinghouse oil cooled transformers.
2 1,205 cu. ft. of free air per minute each, running at 135 r. p. m. Ingersoll-Sargeant, belt driven, air compressors, type J-2.
1 Size K Exeter fan with 2,000 ft. 16-in. galvanized iron air pipe.
1 No. 2 Root blower with 5,000 ft. 8-in. galvanized iron air pipe.
1 16-in. swing saw.
1 Numa drill sharpener.
1 No. 1, 20-in. self feed drill press.
1 Walcott engine lathe, 18-in. swing, 12-ft. bed.
1 Model 20 Marion shovel.
25 Ingersoll-Rand 3½-in. air drills.

The equipment at the west end was practically a duplicate of that at the east end except that the air drills used were Wood drills made by the Wood Drill Works, Paterson, N. J.

The compressors at each end furnished power to 13 drills (8 in heading and 5 on bench), the Marion, model 20 shovel, the drill sharpening machine, a welding hammer and two forges. The Marion shovels were constructed especially for this character of work, the booms being short to permit swinging between the lining timbers and were equipped with 1¾ cu. yd. dippers. Drill bits were upset, reshaped and sharpened on a Numa, air driven, drill sharpening machine that proved to be a great factor in making rapid progress.

The ventilation of the tunnel was accomplished by the use of an Exeter fan operated as an exhauster, exhausting through a 24-in. galvanized iron pipe made up in 30-ft. lengths with flanged joints and paper gaskets. The end of this pipe was maintained at a distance behind the bench sufficient to prevent the pipe from being dented and perforated by shooting. A No. 2 Root blower was also operated to pump fresh air into the tunnel through an 8-in. galvanized iron pipe. The latter pipe was carried close to the heading face.

The tunnel was driven by the top heading method. The material in general was a laminated quartzite with talc between the strata, but the character changed often, which necessitated changes in the method of conducting the work.

The heading was, when the material permitted, driven with a full face following it as closely as practicable, usually from 50 ft. to 60 ft. with the timber lining, but often it became necessary to drive small side drifts for the wall plates and carry the arch timbers within 2 ft. of the face. Usually 6 drills were operated abreast, driving the full heading face, two on one column about 3 ft. each side of the center line and one on a column in each corner. These were followed by a "trimmer" taking off all points to obtain the correct section. This work was followed by a special timber crew erecting the timber lining.

Fig. 4—View of the West Portal.

The packing back of lagging on side walls from the sills to the height a man could shovel is the natural material excavated from the bench; from this elevation to the wall plates and over the arch the packing is cord wood driven tight and wedged. Wood packing was not particularly objectionable here as the tunnel was very wet. The heading material was shoveled into 1 cu. yd. end dump cars, pushed by hand to a chute back of the bench and dumped into a car on a side track on the bench level. The heading track w... supported over the bench by timbers ...

TABLE I.—PROGRESS REPORT OF ST. PAUL PASS TUNNEL.

Date.	Feet Driven, East End. Heading. This month.	Total.	Bench. This month.	Total.	Tunnel. This month.	Total.	Feet Driven, West End. Heading. This month.	Total.	Bench. This month.	Total.	Tunnel. This month.	Total.	Total Feet Driven, Tunnel. This month.	Total.
1907.														
Jan.	15	.....	...	.....	7.5	....	...	.....	...	.....	.....	....	7.5	7.5
Feb.	23	38	...	.....	11.5	19.0	...	.....	...	.....	.....	....	11.5	19.5
Mar.	72	110	...	.....	36.0	55.0	...	.....	...	.....	.....	....	36.0	55.0
April	68	178	...	.....	34.0	89.0	...	.....	...	.....	.....	....	34.0	89.0
May	74	252	...	.....	37.0	126.0	...	.....	...	.....	.....	....	37.0	126.0
June	93	345	...	.....	46.5	172.5	...	.....	...	.....	.....	....	46.5	172.5
July	121	466	...	.....	60.5	233.0	...	.....	...	.....	.....	....	60.5	233.0
Aug.	94	560	...	.....	47.0	280.0	26	.....	...	.....	13.0	....	60.0	293.0
Sept.	64	624	123	.....	93.5	373.5	38	64	...	.....	19.0	32.0	112.5	405.5
Oct.	126	750	172	295	149.0	522.5	88	152	...	.....	44.0	76.0	193.0	598.5
Nov.	100	850	139	434	119.5	642.0	91	243	...	.....	45.5	121.5	165.0	763.5
Dec.	54	904	196	630	125.0	767.0	150	393	...	.....	75.0	196.5	200.0	963.5
1908.														
Jan.	200	1,104	246	876	223.0	990.0	159	552	50	.....	104.5	301.0	327.5	1.291.0
Feb.	247	1,351	229	1,105	238.0	1,228.0	285	837	192	242	238.5	539.5	476.5	1,767.5
Mar.	218	1,569	205	1.310	211.5	1,439.5	286	1,123	218	460	252.0	791.5	463.5	2,231.0
April	259	1,828	217	1,527	238.0	1,677.5	275	1,398	193	653	234.0	1,025.5	472.0	2,703.0
May	241	2,069	298	1.825	269.5	1,947.0	329	1,727	263	916	296.0	1.321.5	565.5	3.268.5
June	203	2,272	325	2.150	264.0	2,211.0	333	2,060	309	1,225	321.0	1,642.5	585.0	3,833.5
July	249	2,521	207	2.357	228.0	2,439.0	295	2,355	319	1,544	307.0	1,949.5	535.0	4.388.5
Aug.	318	2,839	200	2.557	259.0	2,698.0	310	2.665	415	1,959	362.5	2,312.0	621.5	5,010.0
Sept.	306	3,145	218	2,775	262.0	2,960.0	254	2,919	333	2,292	293.5	2,605.5	555.5	5,565.5
Oct.	320	3,465	272	3,047	296.0	3,256.0	227	3,146	342	2,634	284.5	2,890.0	580.5	6,146.0
Nov.	340	3,805	328	3,375	334.0	3,590.0	268	3,414	527	3,161	397.5	3,287.5	731.5	6,877.5
Dec.	357	4,162	284	3,659	320.5	4,211.5	298	3,712	304	3,465	301.0	3,588.5	621.5	7,499.0
1909.														
Jan.	341	4,503	333	3,992	337.0	4,548.5	385	4,097	448	3,913	416.5	4,005.0	753.5	8,252.5
Feb.	46	4.549	350	4,342	198.0	4,746.5	104	4,201	408	4,321	256.0	4,261.0	454.0	8,706.5
Mar.	..	.....	47	4.389	23.5	4,770.0	...	.....	40	4,361	20.0	4,281.0	43.5	8,750.0

ning the tunnel and resting on the wall plates.

The bench was driven by 4, and at times, 5 drills working on the floor level; occasionally it was necessary to drill "down" holes and also at some places where the material was particularly hard it was necessary to take out a sub bench. In fact, many different tunneling methods were resorted to, as circumstances dictated. The timber lining on the bench was done by the regular bench crew. The completed lining is shown by Fig. 2.

The air shovels loaded all bench material into 1½ cu. yd. Peteler cars which were spotted by horses, but hauled out of and into the tunnel by two 15-hp. electric locomotives at each end—from 8 to 11 cars to the train.

The heading muck cars were run out on a platform over the bench workings a distance of 150 ft. to a muck chute leading to the tunnel trains on a track below. This platform was built ahead as the bench progressed and new chutes were added as required. In front of the bench were two narrow gage tracks on the sides of the tunnel with a cross-over beyond the chute for the heading muck.

The electric locomotive hauled the cars to the crossover and the cars were hauled by a horse from here to be loaded and returned to the outgoing track. At the east portal the dump began just outside the approach. Here a 60-ft. fill had to be made for the main line. At the west portal there was a haul of about 2,500 ft. to a 70-ft. fill about 600 ft. long. Snow gave trouble on the dumps and 10 or 12 men were required in winter to keep the track open on the west side and on the east side a temporary snow shed was erected over the dinky track.

The overbreak was carefully measured every 8 ft.—oftener when necessary—and averaged 2.94 cu. yds. per lin. ft. of tunnel. The total quantity removed was 21.5 cu. yds. per lin. ft.

A track incline connecting the heading and bench tracks was utilized for transporting timber and tools to the heading. This incline was so arranged that, as the bench advanced, it could easily be moved forward, and the timbers supporting the heading track could be taken down and used ahead. The incline kept all heading operations away from the bench, and as the work was conducted on the bonus system the bench operations were not interfered with by the carrying of tools, machines and timber into the heading, and consequently the bench operatives could not complain of being discriminated against.

The bonus system consisted in giving $2 to the foreman and $12.50 for distribution among the men for both heading and bench above 3½ ft. per shift based on the monthly average.

The progress record is shown in Table I, a study of which will quickly impress the reader with the fact that the progress was phenomenal and that the effort to maintain this record was splendidly sustained; the monthly average for the twelve-month 1908, being 544.6 ft. As will be seen the average monthly progress for 1907 was 80.3 ft. and for 1908, 544.6 ft. The highest records of daily progress were Nov. 17, 18 and 19, 1908, and were, respectively, 23.5 ft., 32.5 ft., and 28.5 ft.

Fig. 5—View from West End of St. Paul Pass Tunnel.

The view, Fig. 2, and the drawing, Fig. 3, clearly show the type and design of timber lining. The timbers are 12x12-in. Oregon fir; posts 16 ft.; wall plates are 18 ft. long and have a lap joint of 12 ins. fastened together with two ¾-in. bolts. The sills were 4 ft. long, and the arch is made up of five segments with joints slotted for a ½x2½x12-in. key. The usual spacing of the ribs was 4 ft. c. to c., but this was reduced as the pressure became greater. In some places the timbering was placed without spacing between the ribs. The lagging over the arch is 4 ins. thick, but that on the walls, where any at all was used, varied from 4 ins. to 2 ins. in thickness according to the caving propensities of the material. The concrete lining and floor indicated in Fig. 4 was placed at those sections of the tunnel where the pressure was greatest and a year after the driving was completed.

Where the pressure was very great, a built up arch rib was substituted for the solid timber segmental rib. It sustained greater weight without distortion, was more quickly erected and did not collapse when an unusually heavy shot in the bench lowered a wall plate. It also more closely approached the true circular arc.

Both substations were equipped with a complete blacksmithing outfit. The framing sheds were equipped with motor driven swing saws for cutting wedges and lagging.

Two shifts of 10 hours each were worked until about six months prior to the date of completion, when the time was changed to 11 hours per shift. Shifts changed from day to night and vice versa every two weeks. The wage rates were as follows:

	For 10 hrs.
Shift bosses	$4.75
Machine runners	3.75
Machine helpers	3.25
Inside laborers	2.75
Outside laborers	2.25
Carpenters	4.00

No complete records are available of the cost of the work but the following figures are averages taken on the work when it was proceeding at the usual rate. They do not include interest and general office expenses.

Driving.	Per lin. ft.
Labor	$ 84.50
Power house labor	7.00
Engineering and superintendence	3.00
Coal, 25 tons per 24 hrs. at $2.50	4.16
Freight on coal	3.20
Plant, 50% of cost chgd. against the work	15.00
Power house repairs	8.75
Dynamite heading, 27 lbs. 60% at 16½c	4.45
Dynamite bench, 23 lbs., 40% at 12c	2.76
Caps and fuse	2.10
Rubber clothes	4.62
Drill repairs, small tools, etc.	13.65
Water system	.35
Camps	1.10
Total	$154.64

Timbering.	Per M. ft. B. M.	Per lin. ft.
Timber delivered at Taft	$18.50	$ 9.25
Timber teaming from Taft, 2½ miles	4.00	2.00
Timber framing	4.50	2.25
Cord wood: cutting $2, teaming $2	4.00	.40
Iron		.40
Erecting on bench		2.00
Erecting in heading		2.35
Total		$ 18.65
Grand total cost of timber lined tunnel		$173.29

The tunnel is on tangent, but there is a curve to the right at the east end and a curve to the left at the west end (stationing increasing toward Seattle) and the spirals extend 20 ft. into the tunnel. The east approach cut is approximately 50 ft. deep and the west cut about 75 ft. deep; these conditions necessitated very short sights for producing the line into the tunnel. Fig. 4 shows the natural conditions.

Owing to the profile of the surface and depth of snow it was necessary to locate all the transit points on towers.

Fig. 6—West End Camp Buildings, St. Paul Pass Tunnel.

The frame work of these towers was made of round timbers and had a spread at the base of 15 ft. at the top 6 ft. and braced well in both directions. A platform was built on the top of the towers to which access was had by means of ladders. Immediately after the transit points were established on the towers they were carefully referenced so they could be accurately reset if the towers should shift, which they did. This flimsy method of monumenting the alinement of a tunnel nearly two miles long is justly open to criticism, and it is greatly to the credit of the resident engineer, Mr. A. E. Hammond, and his assistants, that they succeeded in transferring the line into the tunnel with such accuracy and precision that the closure was almost perfect.

The greatest difficulty of this work was establishing accurately the first points inside the tunnel owing to the refraction occasioned by the meeting of the warm air currents inside the tunnel and the cooler air at the portals. It was necessary to repeat these observations many times, and when the degree of temperature inside and outside was approximately the same. The points inside the tunnel were fine scratches on the heads of tacks driven into a wood block embedded in a concrete monument from which all temporary points were set. Permanent monuments were approximately 500 ft. apart. The levels were run with a 22-in. Gurley instrument, and the alinement with an ordinary Buff & Buff transit. The final result of the instrument work was as follows: Alinement checked to 0.03 ft. Levels checked to 0.01 ft. Measurement checked to 0.13 ft.

The tunnel, shops and camp buildings were lighted by electricity, and a splendid gravity water system with a 150-ft. head provided an ample supply for all purposes including efficient fire protection. Hydrants were conveniently located about shops and camp and 100 ft. of 2-in. hose was attached to each hydrant—all protected from the weather. The camp had shower baths for the use of all employes.

Substations, power house and headquarters building were connected by telephone. There was a hospital service under efficient management and the railroad division of the Y. M. C. A. had a large and commodious building, under the direction of a regular secretary, devoted to the comfort and amusement of the workmen.

The work was done under Mr. E. J. Pearson, Chief Engineer of the Chicago, Milwaukee & Puget Sound Ry. Co. Winston Bros. Co. were the contractors, while the writer was tunnel engineer for the railway company.

Methods of Constructing and Sinking The Steel Tubes for the Traction Tunnel at La Salle St., Chicago.

The La Salle St. tunnel, the last of the three tunnels under the Chicago River which were required by the U. S. government engineers to be lowered to conform with the regulations of the War Department, was sunk to its place in the bed of the Chicago River on April 2, 1911. The steel tubes lined with concrete are 278 ft. long, 24 ft. in height and 41 ft. wide over all. They are built symmetrically about a center longitudinal axis. The center longitudinal wall is 3 ft. thick, 17 ft. high and forms a heavy reinforced concrete girder the entire length of the tubes. The tubes were erected in a dry dock, floated to the site which had been dredged to receive them, and sunk to a depth giving 27 ft. of water above them.

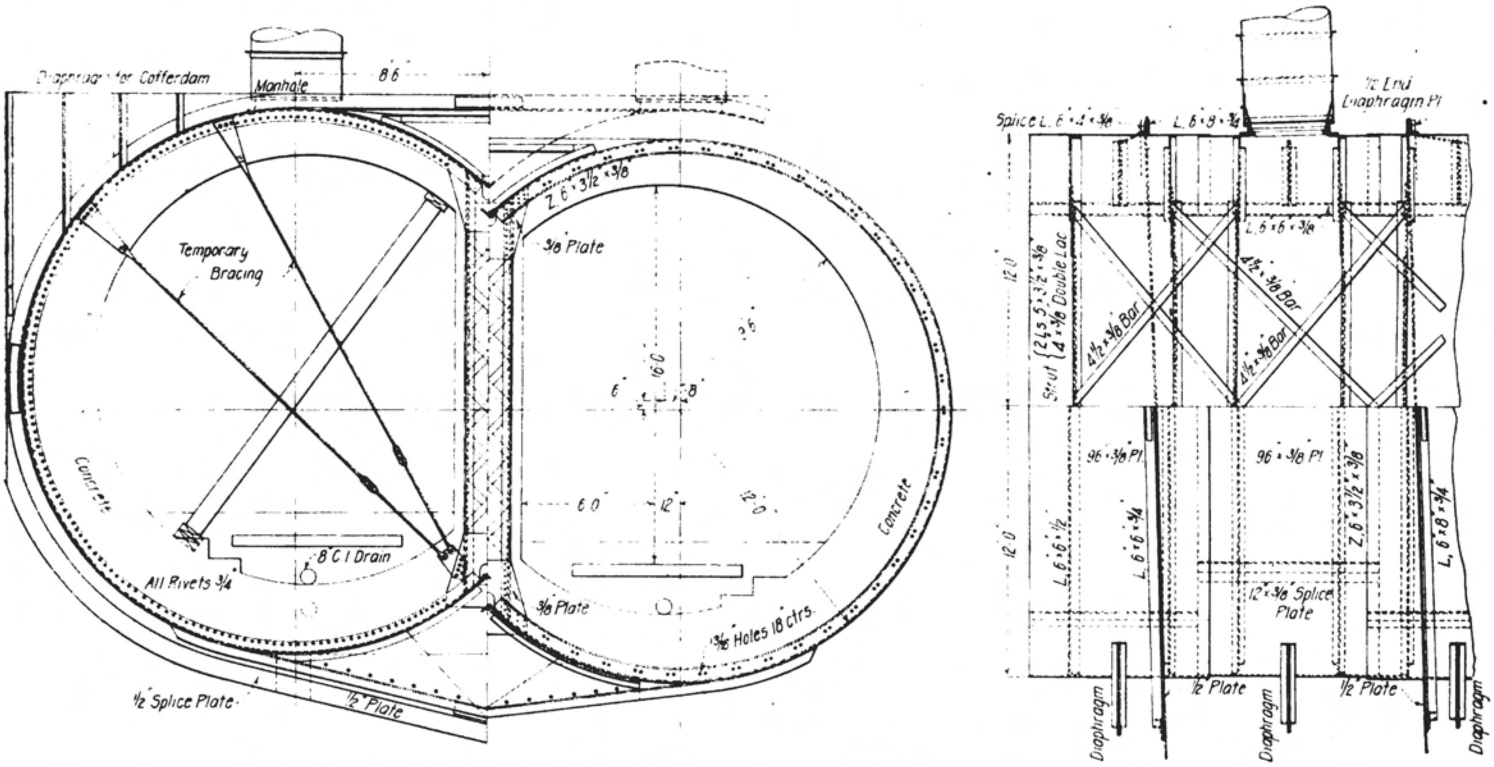

Fig. 1—Showing Details of La Salle St. Tunnel Tubes in Transverse and Longitudinal Sections.

History.—In 1904 an act was passed by the Congress of the United States declaring each of the three tunnels under the Chicago River to be an unreasonable obstruction to navigation. The War Department, acting under obedience to the act notified the city of Chicago and the City Council passed an ordinance requiring the tunnels to be lowered so as to cease to be an obstruction to navigation. Work was begun on the Van Buren, the Washington* and the La Salle St. tunnels, but during the work on the latter such serious leaks occurred that the tunnel was filled with water and all work on it was abandoned. In 1908 the Board of Supervising Engineers was organized, which assumed charge of all reconstruction for the Chicago Railways Co. This board immediately set to work upon plans for the reconstruction of the La Salle St. tunnel. Plans were prepared for six types of tunnel, consisting of (1) a single-bore brick of 26-ft. span, (2) a single-bore reinforced concrete tunnel of 26-ft. span, (3) a twin-bore brick tunnel (each bore of 14-ft. span), (4) a twin-bore reinforced concrete tunnel (each bore of 14-ft. span), (5) a combined twin and triple bore reinforced concrete tunnel and (6) a triple-bore steel shell for use in the river section in combination with a triple-bore land tunnel.

The general plan for reconstruction of this tunnel provides for a permanent double-bore tunnel extending from Randolph St. on the south to Michigan St. on the north, a distance of 2,000 ft.† Each bore will accommodate a single track with ample room along the outside walls for cables and conduits. The design is such that a connection can be made at either end with a subway without interfering with traffic through the tunnel; and entrances are also provided at either end for the temporary use of the surface cars pending the construction of the Chicago subways. The tunnel will be the main artery connecting territory north of the Chicago River with the subway in the business district.

The plans prepared by the engineers contemplated the execution of the work by the open-cut method, but owing to the fact that the U. S. government engineers objected to obstructing the river with cofferdams the twin-bore steel tunnel was designed. The government engineers permitted the construction of cofferdams for a distance of 60 ft. inside the dock lines, thus leaving 180 ft. free for navigation at all times.

An addenda to the original contract states that the M. H. McGovern Co., contractor for the work, agreed to build the river section of the tunnel by the steel-tube method, "the cost of the same not to exceed the amount originally estimated for doing the work by the open-cut method." Representatives of the contractor presented sketches for the design of a twin-bore steel tube which was similar to that previously developed by the chief engineer of the board, Mr. Bion J. Arnold. These sketches were later developed by the consulting engineers for the contractor, E. C. and R. M. Shankland, and the plans were approved by the board.

Design.—In designing the twin-bore steel shell the scheme of the French engineers for carrying the Metropolitan railway tunnel under the Seine at Paris was considered. A description of this is given in another column in this issue. This method, however, would have involved the use of the open-cut method in the river and was therefore out of the question. The method used by the Michigan Central Ry. in sinking its tunnel under the river at Detroit was more closely followed, but the design of the La Salle tubes accomplished a large saving in material over that employed in the Detroit tunnel (ENGINEERING-CONTRACTING, March 2, 1910). The Detroit steel cylin-

*See Engineering-Contracting, April 20, 1910.

†See Engineering-Contracting, Jan. 11, 1911. Methods of Constructing the Land Sections of the LaSalle Street Tunnel.