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Hydraulic Construction of Large Embankments on the Chicago, Milwaukee & Puget Sound Ry.

The construction of the new line of the Chicago, Milwaukee & Puget Sound Ry. (which is the Pacific coast extension of the Chicago, Milwaukee & St. Paul Ry.) has included some heavy work in the Rocky Mountains, and among the special features of the work is the use of the hydraulic or sluicing system for building some very large embankments. This use of the hydraulic system in railway construction is not new, having been employed several years ago by the Canadian Pacific Ry. and the Northern Pacific Ry. (mainly, however, for the filling of high trestles). Some of the work on the new line, however, is not only of unusual extent, but involves interesting plant and methods. The pumping plant and the work on one of the banks were described in our issue of March 12, 1908.

The work described herewith was done under contract by the Smyth Contracting Co., and Mr. Sidney Smyth, President of the company, was in personal charge of the work. Mr. E. W. Cummings, consulting engineer for the company, designed the method of building the banks and also designed and constructed the hydraulic plant. Mr. E. J. Pearson is Chief Engineer of the Chicago, Milwaukee & Puget Sound Ry., and Mr. Geo. A. Kyle is Assistant Engineer. On the division which included the hydraulic embankments, Mr. James Wilson was Division Engineer; Mr. C. H. Byers, District Engineer; and Mr. H. J. Taylor, Resident Engineer. The offices of the contractors and the engineers are at Seattle, Wash. A general description of the work was furnished to us by Mr. Louis P. Zimmerman,* and we are indebted to Mr. Wilson and Mr. Cummings for additional information, together with drawings and photographs.

The work in question is on the west slope of the Cascade range, about 19 miles from the Snoqualmie Pass summit, and is in the canyon of the South Fork of the Snoqualmie River. It comprises four banks and four cuts aggregating 5,000 ft. in length (2,300 ft. for the banks and 2,700 ft. for the cuts). The largest bank (across Topographer's Gulch) is said to be the highest railway embankment in the world. The three large banks, which were built by sluicing, are as follows: Russian gulch (at the east end), Pearson's gulch, and Topographer's gulch. The fourth bank, at the west end, is 800 ft. long, but the grade was too low and the length too great for sluicing the material directly into place. The material was sluiced therefore into settling tanks or "sand bunkers." From these it was discharged into dump cars which hauled it out and dumped it on the fill.

*302 Pioneer Building, Seattle, Wash.

A general plan and profile of the work are given in Figs. 2 and 4. The plan shows the location of the center line, the limits of cuts and banks, and the positions of the flumes and pumping plant, etc. The dimensions and approximate quantities of the three large banks are as follows: the west bank contained about 25,000 cu. yds., making a total of 860,000 cu. yds.

HYDRAULIC EXCAVATION AND SLUICING FOR CUT AND BANK AT TOPOGRAPHER'S GULCH; C., M. & P. S. RY.

(At the top are the hydraulic jets in the east cut and below these are the main and lateral flumes. The fine sand is delivered at the center of the bank and the coarser gravel at the sides. To the left of the jets is the end of the 24-in. steel pressure main from the pump, connecting with 16-in. wood stave pipes to the cuts. In the foreground, at the bottom, is the gravel flume from the west cut. Note the size of the trees.)

Name of gulch.	Length at grade line, ft.	Max. height, ft.	Max width, ft.	Roadbed width, ft.	Quantities, cu. yds.
Russian	250	140	300	24	36,000
Pearson's	500	160	360	24	100,000
Topographer's..	800	282	706	30	700,000

All the banks were built up with the material from the cuts at either end, working from both ends towards the center. The amount of work on the cuts depended entirely upon the formation of the hill, and not upon the amount of material to be moved. In Topographer's Gulch, the cost of the east cut was approximately eight times as much as that on the west side, there being three nozzles in use for 10 months at the former and two nozzles for four months at the latter. Yet the amount of material removed at the east side exceeded that from the west side by only 25,000 to 50,000 cu. yds.

The canyon is very winding, and its wall is broken by a series of lateral ravines with intervening spurs of ridges. Very heavy work is required to keep the grade within the maximum of 1.75% (Fig. 2). The ordinary method of building a railway through a region of this character, is to tunnel the hills and bridge over the intervening gulches. On these mountains, the soil is mainly glacial drift with a large proportion of sand and loose gravel, which makes it almost impossible to secure good foundations for bridges without excessive excavation. The sides of the gulches have so steep a slope that great retaining walls and protection sheds would have been necessary at the portals of tunnels. The snowfall is not excessive, and no landslides occur in this district.

The ridges are mostly of this loose glacial drift with very steep sides (the slopes ranging from 35 to 45%), and water is available in unlimited quantity in the river only a short distance away. Hydraulic sluicing was decided upon therefore as the most satisfactory method of making the cuts and building up the banks between the ridges. The contract for the four cuts and for the four banks was let early in 1907. Work was begun on the installation of the pumping plant and pipe lines in February, 1907, and sluicing was commenced on Nov. 15, 1907. The work was finished in January, 1909.

The general arrangement of the water supply and distribution systems is shown in Fig. 4. The water for sluicing is taken from the south fork of the Snoqualmie River at a point about half a mile above the first bank, where a dam has been built at a narrow rocky gorge. The dam is of log crib construction, with rock filling, and is sheeted on the upstream side. It has a maximum height of 15 ft. and its crest is at an elevation of 1,128 ft. above sea level. From the dam, a flume extends for 5,300 ft. on a grade of 0.3% to a penstock box at the edge of Topographer's Gulch, the water level in the box being

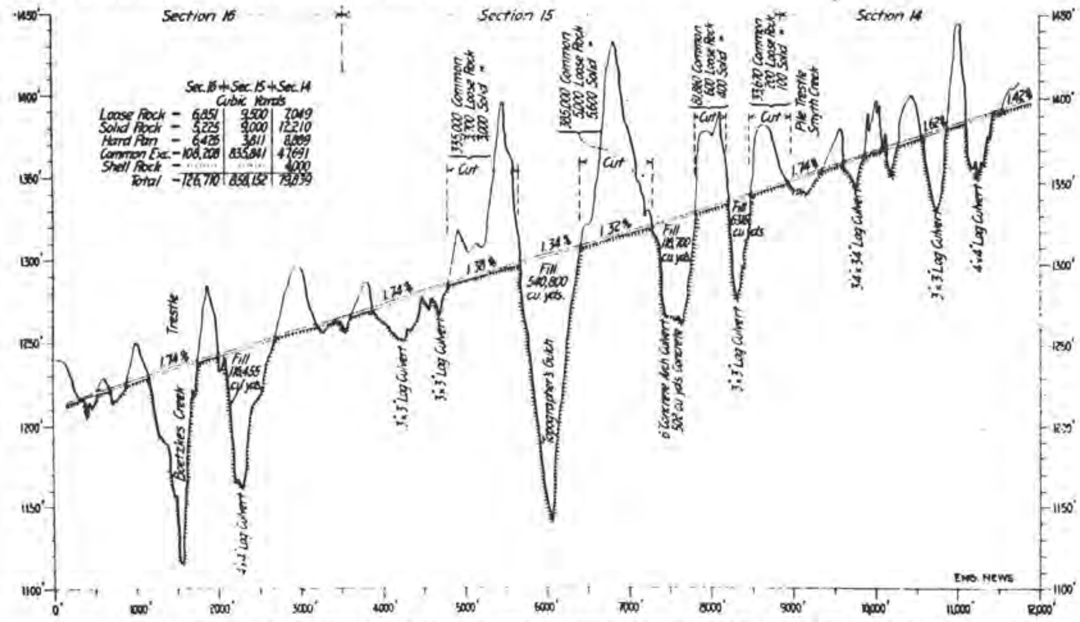

FIG. 2. PROFILE OF LINE HAVING HYDRAULIC BANKS AND CUTS.

at an elevation of 1,112 ft. The connection with the reservoir is made on the north bank of the river, and the flume is carried across the river (just below the dam) by a truss bridge of 60-ft. span (Fig. 4). The flume had one trestle 600 ft. long, and another 950 ft. long, the latter with a maximum height of 56 ft.

The flume was V-shaped, as shown in Fig. 3, its cross-section being formed by two sides of an equilateral triangle, each 6 ft. wide. The sides were made of two thicknesses of 1-in. fir lumber in widths of 8, 10 and 12 ins., laid so that the layers broke joints. The flume was supported on sills 4 ft. apart and was braced on both sides with 2 × 6-in. pieces. These also were spaced 4 ft. apart, and were toe-nailed to the sills and to the cross timbers on the sides of the flume. The flume of V-section was adopted as being more easily built, curved, and kept watertight than a rectangular flume.

From the penstock box, a pressure pipe was led to a pumping plant on the bank of the river. This was a 38-in. wood stave pipe having a fall of 398 ft. in about 800 ft. to the pump. An overflow flume was also led from the penstock box to the river, as shown. The pumping plant was set upon a concrete foundation and consisted of a 16-in. four-stage Worthington turbine pump, directly connected to four impulse water wheels in parallel on the same shaft. A steel branch or by-pass diverted part of the water from the penstock to the pump suction or intake. The water supply system, including the dams, flumes, pumping plant, etc., involved an expenditure of about $40,000.

From the delivery side of the pump, a 24-in. steel pipe about 1,450 ft. in length was carried up the slope to a three-way box or junction at an elevation of about 600 ft. above the pump. The gage pressure at the lower end of this pipe was 340 lbs. per sq. in. From the junction box, three lines of 16-in. wood stave pipe were led to the different cuts, to serve the excavating nozzles. The longest distributing branch was a 16-in. pipe half a mile in length. These branches were run as nearly level as possible in skirting them around the hills. For the excavating and sluicing jets, 6-in. and 4-in. rubber hose and plain nozzles with an effective diameter from 1½ ins. to 3½ ins. were used in all the work. The pressure at the nozzles varied from 40 to 80 lbs. per sq. in., depending on the kind and location of the material moved. A plain ring bushing was used in the nozzles to choke the size of the stream and regulate the pressure. There were 10 nozzles used in all; four of these were used in Topographer's Gulch, four on the east side and two on the west side.

All the material used on the work, including the Worthington turbine pump weighing 22½ tons, had to be hauled a distance of 2½ miles by wagon and team, from the end of the railway spur at the Weeks saw mill. Much material had to be taken up the hill from time to time from the wagon road, and it was impossible to haul it by teams. A 36-in. Risdon water wheel was installed at the top of the hill, about ¼-mile from the wagon road. This was connected to the 16-in. pipe line with a 16 × 16 × 6-in. T-connection and valve, and the wheel was directly connected to a 60-HP. hoisting engine. The drums and levers of the engine were used to control the movements in the usual way. A ⅞-in. and ⅝-in. steel cable were used to haul the material up the hill. At night, the water wheel was disconnected from the hoisting engine, and was belted to a direct-current dynamo used to supply the current for the arc lights distributed over the work for lighting the work at night.

The foundation and setting for the water wheel and pumps, the intake, discharge and tail race were all built of concrete. Just above the concrete bed of the pumping plant, the penstock made an angle of about 30° in coming into the vertical intake of the turbine pump. To strengthen this portion of the pipe, a frame 6 ft. high (of fir planks 2 × 12 ins.) was built around it and filled with gravel. This added additional weight and stability to the wheel foundation and supported the lower end of the penstock.

The lower end of the 38-in. stave pipe of the penstock was subjected to what is said to have been probably the greatest pressure ever used on wood pipe work, 175 lbs. per sq. in. This pipe was made of staves cut to the radius of the pipe from 2 × 6-in. planks, 12 to 20 ft. long. The staves were bound with ½-in. steel bands of about 60,000 lbs. tensile strength. The distance between the bands varied with the pressure to which the pipe was subjected. At the lower end of the penstock the bands were spaced as close together as it was possible to put them, and the staves carried the pressure without any signs of deterioration. The wood pipe was laid upon the ground and not covered. It followed the contour of the surface, and was anchored as securely as possible by means of steel cables passed around the pipe and fastened to trees and stumps.

The general plan in the hydraulic sluicing work for the bank across Topographer's Gulch, provided for segregation of the materials. This was in view of the large amount of sand and fine glacial drift in this section of the mountains. Three principal constituents were found in the soil: gravel, sand and rock, with a very small amount of glacial loam. The soft, loose condition of the glacial drift in Topographer's Gulch, the large percentage of sand and loose gravel, and the steep grade of the bottom of the gulch (about 35%), made it necessary to segregate the materials for the fill, and this was done by the use of settling tanks or bunkers. The coarse gravel and rock were thrown on the down-hill side of the slope, the sand was run inside the outer wall of gravel, and the sluicing water was drawn off and discharged outside the fill. This method of working necessitated the use of settling tanks or sand bunkers, for the character of the soil is such that if a large amount of water were run over it a large amount of the loose gravel would wash down the gulch. While this method of segregating the material was used at the start, later on in the work all grades of material were deposited together in the bank.

The view on the front page shows the work at Topographer's Gulch. At the top (in the cut) are the excavating jets, with the main and lateral flumes extending along the site of the bank. At the middle, near the bottom, may be noticed the finer material which was washed into place to form the center or core of the bank. The general plan employed was as follows: Starting at the point where the sluiced material was cut out by the water jets, flash boards were placed to direct the material into a wooden flume. This flume led to the sand settling tanks, from which three flumes led out; one carried water outside the work (so as not to erode the bank), one carried gravel, and one carried sand to the bank. The grade of the flumes at first was 45%; as the cut increased and the bank was built up, the grade gradually lowered to 10%, which was the lowest grade used. A short section was laid with a grade of 5%, but the only way in which material could be carried through it was by placing streams under heavy pressure 50 ft. apart to drive the material along. In starting the cut,

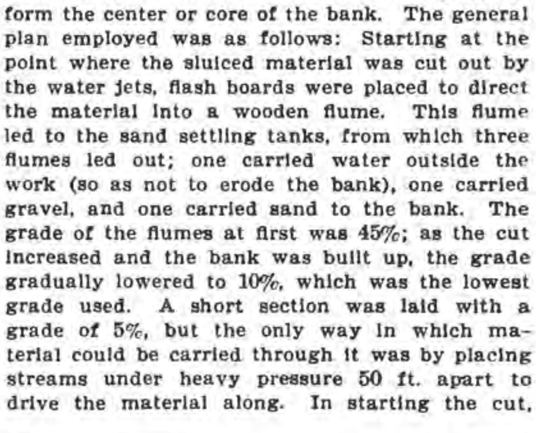

Fig. 3. V-Shaped Flume for Supplying Water-Power Pumping Plant for Hydraulic Excavation (Section 6 x 6 Ft.).

the flume was built out half way across the gulch and the material taken from the lowest part of the cut just above the grade line. As the fill was built up the grade was decreased, the material being dumped closer in and being taken from the higher elevations of the cut. A small amount of excavating in the center of the cuts was done with a steam shovel.

Various grades for the flumes were used during the work (as noted above), and a grade of 15% was found to be the most economical. At this grade the rock (of which there was a large proportion) would slide from the flume continually; with a flatter grade, the flow was slower and more water was needed to carry the material along. With a steeper grade, the rocky materials gained such momentum that they rolled and bounded down the flume in a manner extremely dangerous to the men, and very hard on the sides and bottom of the flume itself.

The flume construction is shown in Fig. 5. The flumes were 24 ins. wide inside and 24 ins. high, built of 2 × 12-in. plank, set edge to edge, with the sides nailed on the outside of the bottom. Braces 2 × 6 ins., 4 ft. apart, at an angle of 45°, were toe-nailed to the 2 × 6-in. plank sills. Upright pieces 2 × 6 ins., 4 ft. apart, were used to hold the sides of the flume in place. The flume had a walkway on one side for the use of the men. The flumes were carried on ordinary timber trestles, some of which were 50 ft. in height. These were all built of green timber cut on the mountains. As the flume carried a large percentage of rock and coarse gravel, the bottom was paved with 6 × 12-in. wood blocks 4 ins. thick, set on end and toe-nailed. The blocks were from butt cuts of live, green, yellow fir of a uniform texture, and packed closely together to get an even wear. They eliminated uneven spots almost entirely. Fir planks 2 × 6 ins. were nailed on both sides of the flume just above the blocks to prevent wear on the sides of the flume, and to hold the paving blocks in place on the bottom.

The settling tanks or sand bunkers were arranged as shown in Fig. 6. Those located at the end of the first flume and connecting to the distributing lines out on the work, were 14 ft. square and 12 ft. high, built of 3 × 12-in. fir planks set edge to edge and calked with oakum to be practically watertight. These bunkers were used to precipitate the sand and run off the clear water down the outside of the bank. A sand flume 2 ft. square was attached to the tank, having a steel gate and lever operating handle. Only enough water was admitted to the sand flume to carry the sand out readily. The sand flume was paved with 2-in. blocks, toe-nailed as in the two other flumes. Two guard rails 2 × 6 ins. were placed just above the blocks to hold them in place and take the wear from the sides of the flume. About 1 ft. from the top of the tank a 12 × 12-in. water waste flume led down over the side of the bank with a slope of about 40%. In Fig. 8 may be seen some of these waste flumes extending down the face of the new bank.

Above the bunkers a screen or grizzly was built in the bottom of the main flume. Through this the water and sand drained into the settling tanks, while the coarser gravel and rock passed over and down the gravel flume. The grizzly was 12 ft. long with 6-in. openings lengthwise of the flume.

The bank at Topographer's Gulch was built up on a slope of 1 on 1¾ (Fig. 1), varying somewhat with the nature of the material and the amount of water used to move it. Starting at the lower bottom side of the fill, brush dikes were built up as shown in Fig. 7. Posts 3 to 5 ft. long were driven so as to leave about 2 ft. of the post above the surface in a line where the dike was to be built. The posts were spaced about 8 ft. apart. Behind this framework some gravel and sand was washed up with a hose to get the required backing. Back of and on top of this, green brush with the butt ends resting on the upper part of the framework was piled to a sufficient depth to hold the material behind it.

The amount of brush used depended, of course, upon the fluidity of the material behind it. It was found that by placing the tops or ends of the limbs and trees pointing towards the inside of the dike, a much better and more effective dike was obtainable with the same amount of material. This was due to the fact that when pointed in and down, the mud would bend the branches back and so make a firm solid mat of twigs. Turned the other way, the mud would slide over the brush very easily. On an average the dikes were built about 2 ft. high and spaced about 3½ ft. apart, giving a slope of 1 on 1¾. This is shown in Figs. 8 and 9.

In building up the material behind the dikes, due to the excessive looseness of the earth, it was impossible to allow the sluiced water to run to waste over the slope of the bank, as it would have washed away the filling. In the hydraulic regrading work at Seattle, Wash.,* the material is run on the mud lines and allowed to pile up and flow off, which sluiced material will do with a slope of about 1 on 4. Spillways are provided and the water escaping carries with it a considerable amount of material in suspension which is deposited farther out on the tide flats. This is permissible in that work as it is not wasted, and the fill on the tide flats covers a large area to a depth of only a few feet.

On the railway work, however, in filling up behind the dikes, the material was washed toward the outer edge of the fill with a hose, and as high as possible over it, usually a foot or two. This method left the water standing on the top of the fill usually from 20 to 30 ft. back from the outer edge. To dispose of this, "chimneys" and box drains were used to carry the water down through and out below the bank. These "chimneys" are shown in Fig. 7. They are vertical flumes 16 × 28 ins. in section, made of 2 × 12-in. fir planks. A connection with a slope of about 2% is built from the outside of the embankment, in and up as far as possible, and then another vertical connection is put in and led through the fill to the surface. When by stepping back, the outer edge of the bank comes to the top of the vertical chimney, another 2% connection drain is built in and back. The upper side of this drain is built of 2 × 6-in. planks placed crosswise for greater strength to support the bank above it. Above the surface, one side of the "chimney" is left open and as the bank fills, cross timbers are nailed on so that the water flows over and into the chimney. A screen of ordinary wire netting was used to keep out refuse from the flume. Fig. 10 shows one of these chimneys with screen in place. When this system was used, the bunkers were omitted and all the water went upon the bank.

Where the top surface of the bank is mud or clay, the water will flow over the top and collect around the drain chimneys and run away through them. Where there happen to be pockets of gravel or rock, the water will sink in and flow along these strata until it comes to the outside

*Engineering News, Nov. 12, 1908.

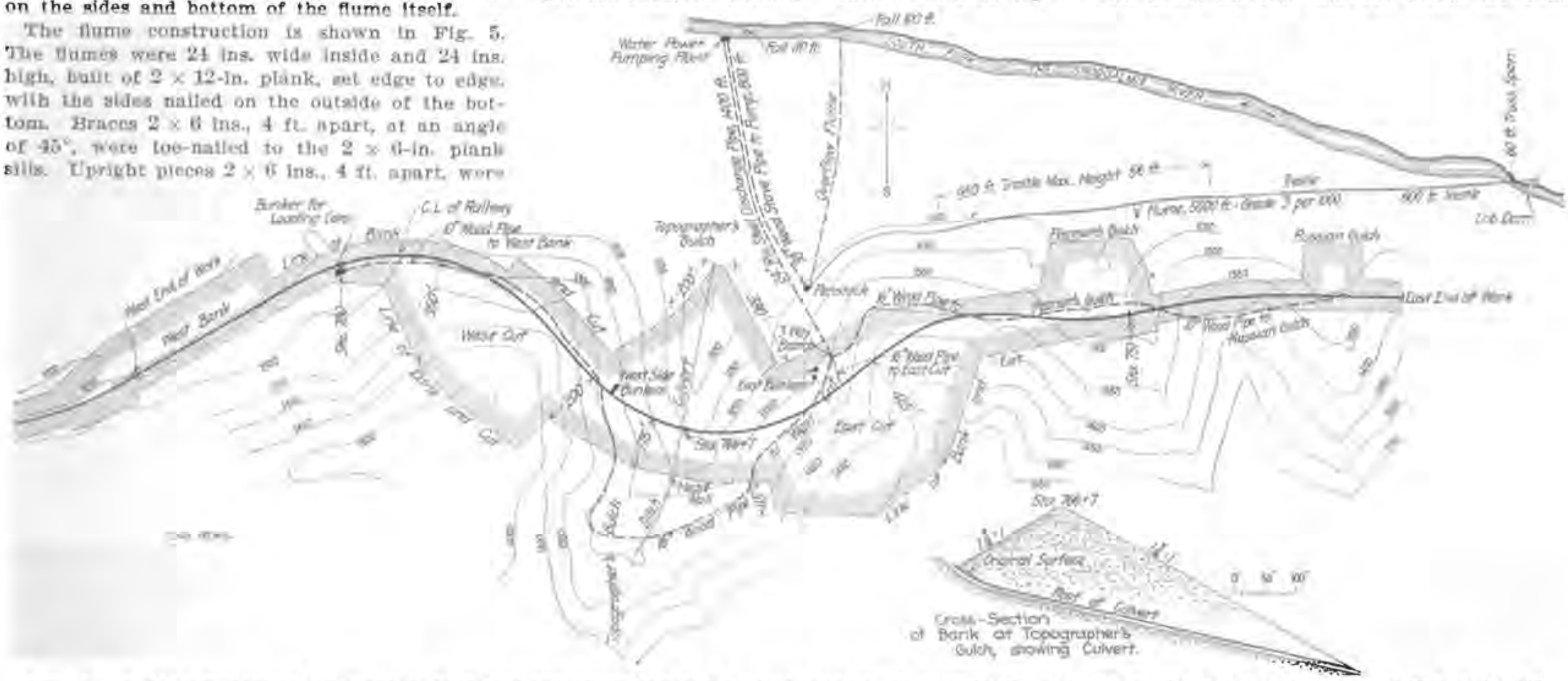

FIG. 4. PLAN OF BANKS AND CUTS FORMED BY HYDRAULIC EXCAVATION AND SLUICING, AND ARRANGEMENT OF THE WATER SUPPLY SYSTEM FOR THE HYDRAULIC WORK; CHICAGO, MILWAUKEE & PUGET SOUND RY.

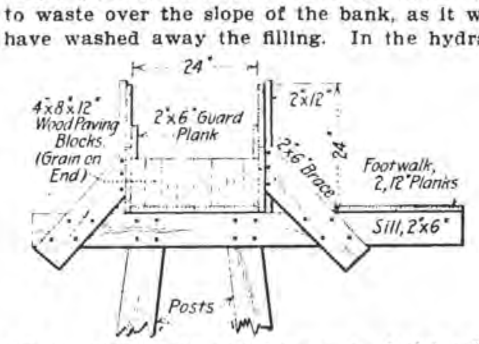

Fig. 5. Construction of Flumes for Sluicing Material to the Bank.

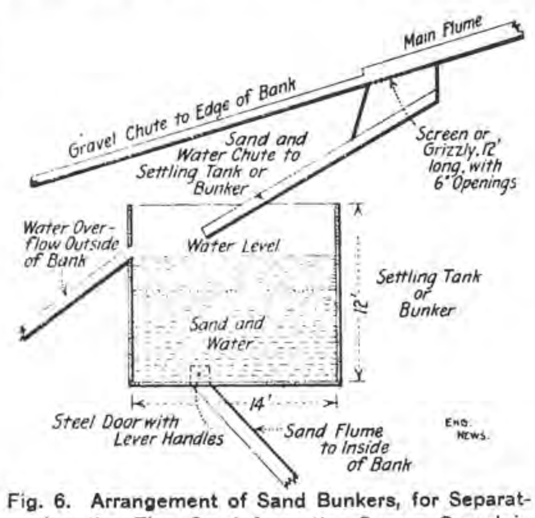

Fig. 6. Arrangement of Sand Bunkers, for Separating the Fine Sand from the Coarse Gravel in the Sluiced Material.

of the embankment, where it breaks out sometimes 150 ft. below the surface of the fill. To prevent these breaks from enlarging and washing away the side of the fill, a drain or lead-

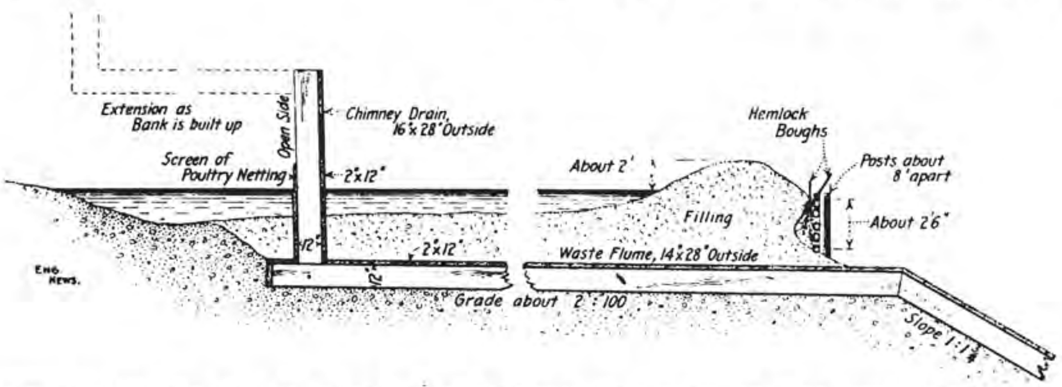

FIG. 7. ARRANGEMENT OF BOX DRAINS AND "CHIMNEYS" FOR CARRYING OFF WATER FROM SETTLING POOL ON TOP OF HYDRAULIC-FILL BANK.

off pipe was put in. This was done by making a bed of fir boughs and tops close up against the bank where the break occurred, and then driving a pipe into the bank at the point of the break. This pipe was dammed up with clay on both sides and covered with brush and poles. The pipe was carried down and the water allowed to escape. In this way the bank was kept from sloughing off and the water was disposed of in the natural drainage channel.

For the natural drainage of Topographer's Gulch an egg-shaped concrete culvert was built across the site of the bank, as shown in Fig. 1. This has a grade of about 3½%. It is lined with vitrified paving brick on the bottom. At each end is a paving of rip-rap to provide against scour. The area of the culvert gives sufficient waterway to take care of the maximum drainage and flood waters without endangering the bank by pressure on the upper side. The culvert was braced on the inside by temporary timber supports during the construction of the lower part of the bank. These timbers were not allowed to be removed from any part of the culvert until that part had a covering of sluiced material (well compacted and free from water) to a depth of at least 2 ft. over the crown of the culvert.

The details of this culvert are shown in Fig. 11, together with the aprons, the end cut-off walls, the forms, and the temporary interior bracing above mentioned. A similar culvert was built in Pearson's Gulch. The approximate quantities are as follows: concrete per lin. ft., 1.36 cu. yds.; concrete in end walls, 26.4 cu. yds.; rip-rap at ends, 18 cu. yds. The general specifications for culverts are as follows:

The bed under the culvert must be finished to proper level and grade and thoroughly rammed in order to prevent (as far as possible) settlement under weight of embankment. A slight camber will be given to guard against formation of pockets by settlement. Generally the fall of the culvert will be as steep as the difference in elevation of inlet and outlet will admit. In no case should the fall average less than 1 in. in 6 ft. In places where the nature of the ground is such that any settlement is liable to occur, the culvert should be built in sections 8 or 10 ft long, separated with a heavy layer of tarred felt; the joints to be vertical.

The filling shall not be done before the concrete has set, the minimum time allowed being two weeks. Tamp the earth thoroughly on sides of culvert, using water, when practicable. Where the culvert crosses the track at an angle, the end walls should be built parallel to the track, if possible. The ingredients for concrete, except for inverts, will consist of 1 part Portland cement, 3 parts of clean sharp sand, and 6 parts of broken stone or gravel, by bulk. The ingredients for concrete for inverts will consist of 1:3:5 parts.

The quantity and arrangement of riprap of ends may be modified by the division engineer to suit the varying conditions of the ground. The depth of foundation walls shall be changed wherever necessary to meet conditions as they are found.

A special feature of the culvert at Topographer's Gulch is that from its upper end a wooden flume is carried up the bed of the gulch for about 500 ft. This is shown in Fig. 12. It has grades of 17% and 20% at the upper end, and then falls on a grade of 90%, entering the culvert by a grade of 50%. The changes in grade are made by vertical curves, as shown. The bottom consists of three layers of 2-in. plank laid on mud sills. The sides are of 3 x 6-in. planks (6 x 6 at the upper end), laid flat, and spiked to 8 x 12-in. posts placed at the ends of each sill. To prevent excessive wear, the floor is paved with wooden blocks.

The upper end of the flume is widened out, as shown in the plan, and is fitted with a grizzly or screen made of 60-lb. rails; this is to prevent rocks and debris from being carried into the culvert, which might become damaged or choked. The rails are 18 ft. long, spaced with their flanges 4 ins. apart. Above the screen is an apron or paving of boulders weighing about 150 lbs. each. These were laid on a bed of concrete, and the voids were filled with a 2:1 grout of cement and sand.

FIG. 8. HYDRAULIC EMBANKMENT AT TOPOGRAPHER'S GULCH; C., M. & ST. P. RY.

(This shows the settling pool and the pole and brush dams for building up the face of the slope. The flume at the right, on the far side of the bank, comes from the sand bunker or separating tank.)

FIG. 9. BRUSH AND POLE DIKES FOR BUILDING UP THE SLOPE OF THE BANK.

Fig. 10. Vertical Drain or "Chimney" for Draining Water from the Settling Pool Through the Bank.

The general character of the work at the other two hydraulic-filled banks was similar to that above described in regard to the bank at Topographer's Gulch. In each of these two cases, however (at Pearson's and Russian gulches), the bottom of the gulch was of hardpan, the slope was flat, and the glacial drift was very much harder than in Topographer's Gulch. This made it unnecessary to use sand settling or separating tanks for the work on these two banks. At the West or fourth bank (as already noted), the sluiced material was delivered to dump cars and not sluiced directly into place. The work at the four gulches was carried on more or less simultaneously, as conditions warranted. About 12,000,000 gals. of water per 24 hours were used throughout the year.

STEAM PROPULSION BY TUGS has been adopted by the German Government for the Rhine-Weser canal. The decision is said to have been influenced by experience with electric traction on the Furow canal, where electric traction was introduced in 1898, and the Teltour canal, where electricity was introduced three years ago. The objections to electricity are the heavy cost of installation and operation, and the obstruction of the canal banks by the rail tracks and trolley lines.

Flexible Staybolts for Locomotive Boilers.*

We have to consider the cost of applying flexible bolts in comparison with the cost of applying rigid or solid staybolts. I find in computing the cost of both the flex-

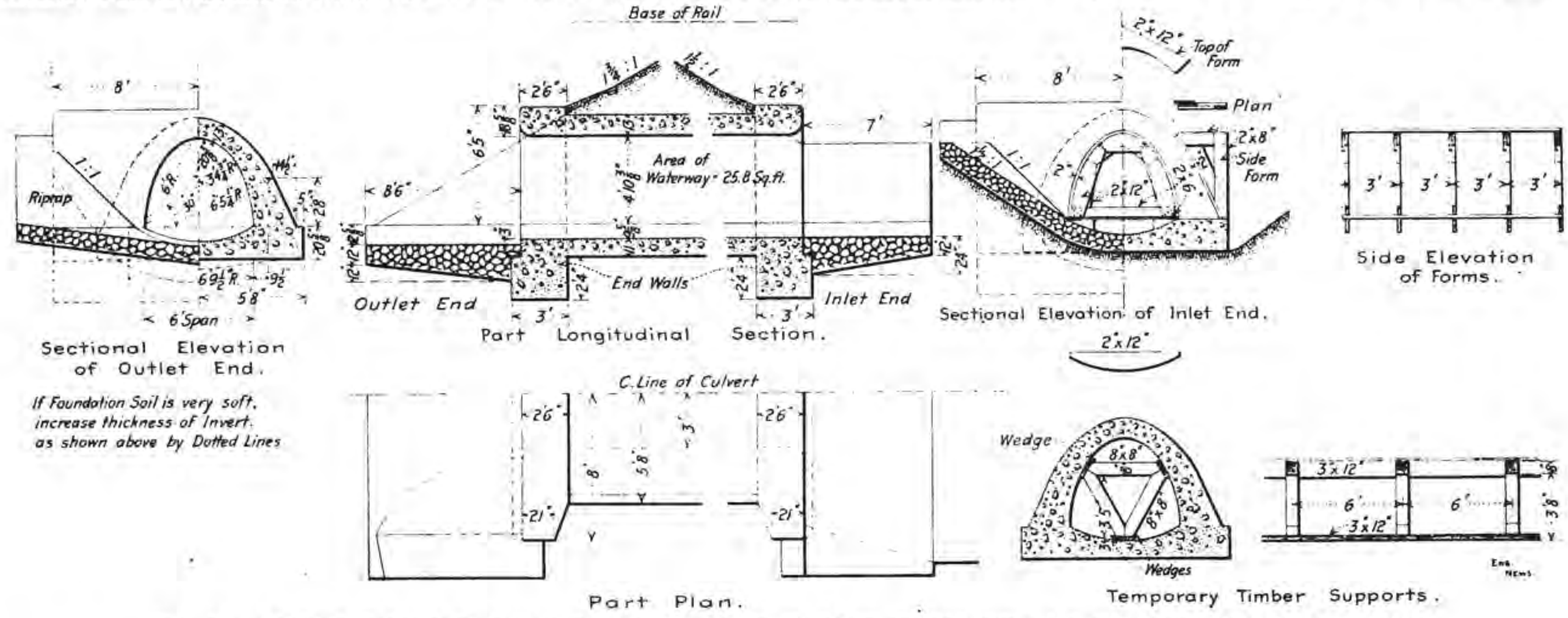

FIG. 11. CONCRETE CULVERTS UNDER HYDRAULIC EMBANKMENTS; CHICAGO, MILWAUKEE & PUGET SOUND RY.

ible staybolts and rigid staybolts, a difference of something like 50%, which cost has to be credited to the applying of the flexible staybolts. Is the cost commensurate with the service and excess cost of this bolt over the rigid or solid staybolt? I maintain that it is.

Now let us consider the flexible staybolt at a cost of 50% more for application to a locomotive boiler. We shipped one of our engines for overhauling. The boiler was sent to the boiler shop for a new firebox, with instructions to make a full installation of flexible staybolts; that is, back head, throat sheet, and both side sheets up to the seams of wagon top. This engine has been in service now for over 2 years and has not had one broken staybolt removed. This looks pretty good for the flexible staybolts, as engines of this same type only run from 60 to 90 days before more or less of the solid staybolts have to be renewed.

When we figure the cost of maintenance of locomotive boilers in service and compare the general cost of the solid staybolt against the first cost of the flexible staybolt, we can readily see, from a cost standpoint, that the excess cost of the application of the flexible staybolts, everything considered, has the best of the rigid staybolts.

In the application of flexible staybolts, I would suggest always a full installation of these bolts. When these bolts are applied spasmodically, or in what is considered the breaking zones, the rigid bolts next to the flexible bolts later on break or fracture. For this reason I believe it would be wise to always make a full installation, keeping before us always the loss to the company of from $600 to $700 per day for every day the engine is out of service.

From causes such as bad water, or possibly a poor sheet of steel, it was necessary to remove a firebox from one of our engines to which I applied a new firebox about 2½ years ago. This engine had a full installation of flexible staybolts, and the man who removed this firebox advised me that he failed to find a broken flexible staybolt in this engine.

When the firebox is placed in the boiler, mud ring fitted, firebox sheet faired up, the first thing I do is to map out the zones for solid staybolts, then I have these holes tapped out and staybolts run in. Thus I secure the firebox sheets from the danger of pulling in as each successive flexible staybolt is applied. It only requires a very little strain on each bolt put in to draw the side sheets of a firebox until in the center of the side sheet, you will (by using a straight edge) find your sheet drawn in from ½ to ¾-in. Where your bolts are cut to length, this becomes a serious feature in the application of flexible staybolts.

Having had this trouble, I have instituted the above method to overcome this difficulty and it works very nicely. When all flexible staybolts are in the several zones, I remove the solid bolts that I have put in to stay the firebox sheets. Then drill, ream and tap out and apply the balance of the flexible bolts, this completing the full installation of flexible staybolts in this engine.

For testing flexible staybolts, I recommend a hammer test under air pressure, when it is possible to get a pressure of air from 125 to 150 lbs. Where the bolt is broken, this, in a measure, separates the parts and the broken bolts are easily detected. However, it will be somewhat more difficult to detect a fractured bolt, but where the inspector is a careful, painstaking man, this will soon be overcome as he will, in connection with this method, learn to detect the difference in sound of the broken and fractured bolts.

MOTOR LIFEBOATS are being introduced in England by the National Lifeboat Institution. No steam lifeboats have been built by the Institution since 1901, owing to the promising development of the internal-combustion engine for marine work. The motor must be enclosed in a perfectly watertight casing, the engine must require practically no attention when running, and the carbureter must be so designed as to give a regular and proper mixture even when the boat has a heavy list to one side. In case of a self-righting boat capsizing, the engine must be stopped automatically, so that the boat will not run away or its screws be a danger to the men in the water. It is also necessary that the engine and apparatus must not reduce the rowing and sailing qualities or interfere with the balance of a self-righting boat. Two-cylinder engines were first used, but are being replaced with four-cylinder engines. A boat 43 ft. long and 12½ ft. beam has a Blake engine developing 40 brake-HP. at 550 r. p. m. A boat 42 x 11 ft. has a Tylor engine of 30 HP. at 900 r. p. m., and a boat 37 x 9¼ft. has a Thornycroft engine of 24 HP. at 1,000 r. p. m. All these are four-cylinder engines. The engines are of special advantage to assist when sailing, enabling the boats to work against the wind.

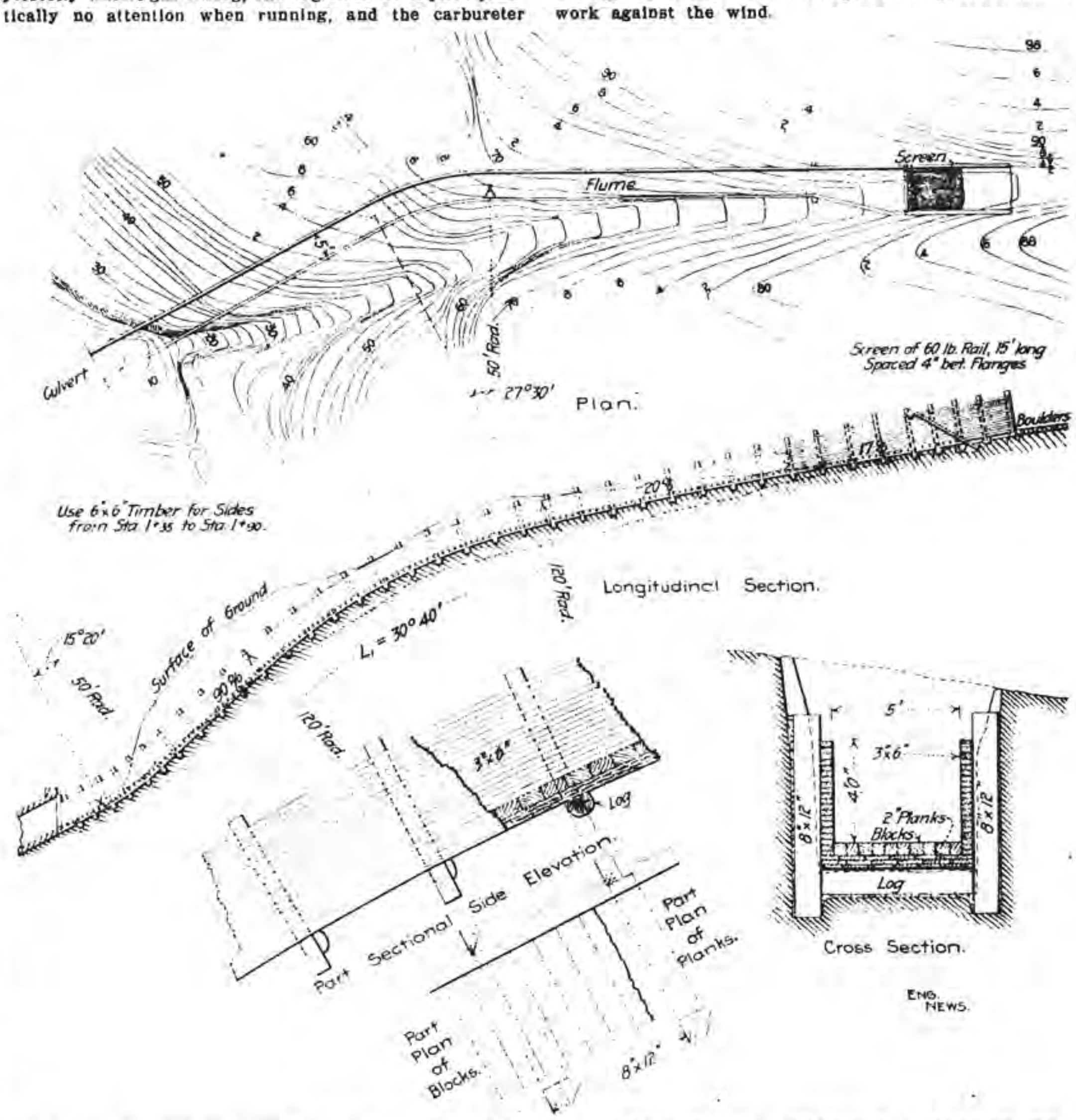

FIG. 12. FLUME ALONG THE BOTTOM OF TOPOGRAPHER'S GULCH, FORMING A FEEDER TO THE CONCRETE CULVERT THROUGH THE BANK.

*Abstract of a committee report presented at the annual meeting of the International Master Boiler Makers' Association, held at Louisville, Ky., in April, 1909.