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a complete failure of the small triangular feet and allowed the falsework to settle clear of the arch, and yet be ready to prevent any accident which might occur by failure of the masonry span.

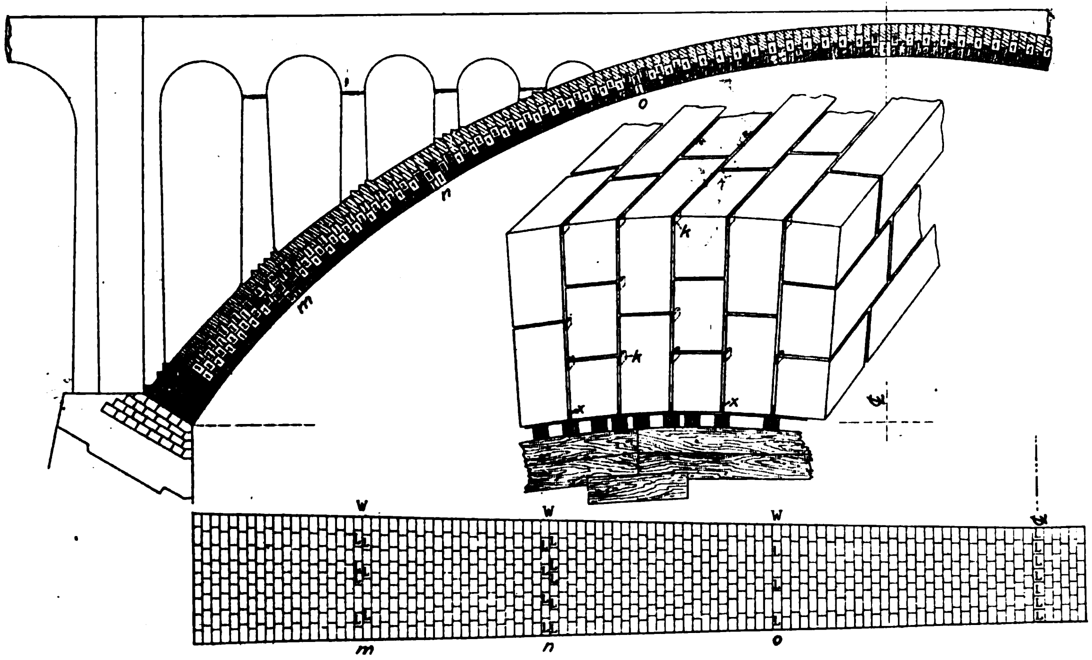
The construction work was assigned to two different companies. Redlich & Berger Brothers built the main arch, while the viaducts were built by Sard, Lenassi & Company.

In July, 1904, work on the foundation for the left abutment was begun. First, the cracks and pockets in the conglomerate were cleaned, enlarged and tamped full of concrete. In order to distribute the load over a large area a reinforced concrete mat, 7.2 ft. thick, 50.6 ft. long and 47.6 ft. wide, was built, upon which rested the main piers and the skewback of the arch. The concrete was mixed in proportions of 1:2:3 and the reinforcement consisted of a four-tier grid of steel I-beams.

The right abutment was laid in a bed of loamy crushed rock and was carried on a similar mat, which in both cases reduced the pressure to 56.8 lb. per square inch. By March, 1905, the foundations were ready to receive the skewbacks and main piers.

In October, 1904, the wood for the falsework was on the ground and the scaffolds were ready to begin sinking the caisson in the river. By the end of November, 1904, the caisson had been sunk through about 20 ft. of broken rock to a clay-slate bed, into which it was driven 1.6 ft. It was then filled with concrete.

Scarcely had the laying of the concrete been completed when a heavy rain caused a flood which destroyed part of the scaffolding around the caisson and carried away the air lock. The current striking the broadside of the pier caused a powerful eddy which wore a large hole about 26 ft. deep in the bed of the river. This hole was afterward filled with heavy riprap, which was placed all around the pier to protect it from the action of the stream. In February, 1905, the falsework was begun, and by the end of April it was finished. In June the masonry work was started.



Scheme of Laying the Voussoirs and Detail Showing the Use of the Wood Spacing Blocks.

At the points *m*, *n* and *o*, as indicated in the drawing of the voussoirs, wooden blocks were fastened, thus dividing the arch into eight sections, and work was begun simultaneously in all sections. The first ring was laid dry, wooden spacing strips, *x*, and wedges, *k*, being laid between the stones. When the ring was completed the joints were tamped full with 1:3 cement mortar, and the tamping compressed the mortar to such an extent that the spacing wedges were easily removed.

The first ring, which was completed June 14, caused the falsework to sink 1 in. On June 15 the second ring was begun, the stones being laid in the order indicated by the Arabic numerals on the voussoir drawing, the mortar being tamped in as the work progressed. The next step consisted in laying the stones labeled with Roman numerals and in the order indicated, thereafter completing the second ring. The last ring was finished July 1, and on August 8 the lowering of the falsework was begun.

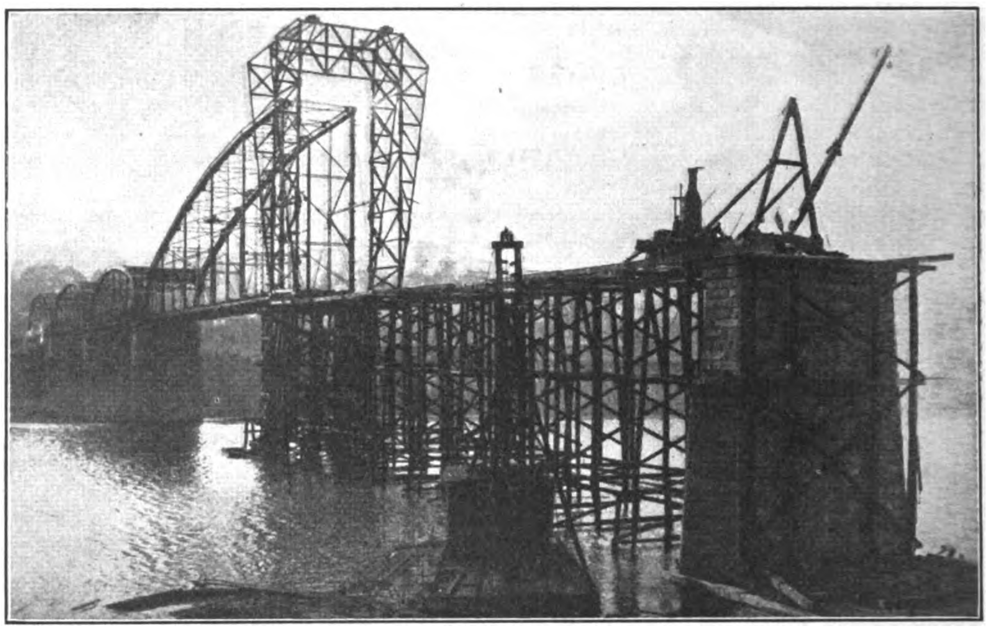
Up to the time when the arch was completed the crown had sunk 1.57 in., and when the falsework was removed it sunk 0.236 in. more. The work of tearing down the falsework and completing the rest of the masonry work was carried through without delay and the bridge was ready for service by the middle of November, 1908.

The following quantities of materials were involved in the construction of the main arch and spandrels, including the main piers, but not the viaduct approaches.

The total amount of stone masonry and concrete in the main span, including the two main piers above the skewback, excluding, in other words, both approach viaducts, is 14,200 cu. yd. The main falsework included 492,000 ft. b. m. of timber, and the auxiliary falsework, 280,000 ft.

THE ERECTION OF THE WEBSTER-DONORA BRIDGE.

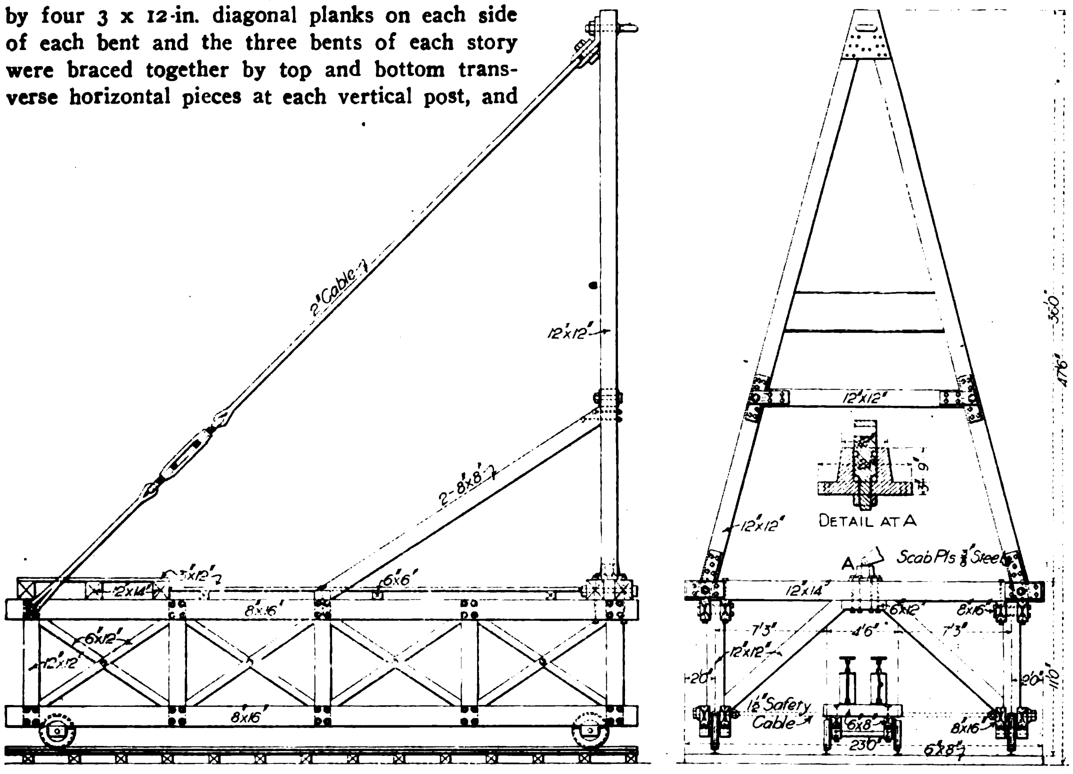
The Webster-Donora Bridge across the Monongahela River a few miles above Clairton, Pa., is designed for vehicles, pedestrians and two electric car tracks, and its 515-ft. channel span is one of the longest and heaviest highway truss spans in this country. The contract price of the bridge was $189,500, and it was put in service last January, and was illustrated in The Engineering Record of June 12. The channel span steel weighs about 1,400,000 lb. and has two pin-connected trusses 70 ft. deep and 26 ft. 8 in. apart with subdivided panels. The plate girder floor beams are field-riveted to the vertical posts above and below the lower chord bars and are web-connected to the plate-girder stringers. Above the roadway the trusses are braced by the top lateral system and by transverse sway-bracing.



Falsework in Position for Second Half of Webster-Donora Bridge.

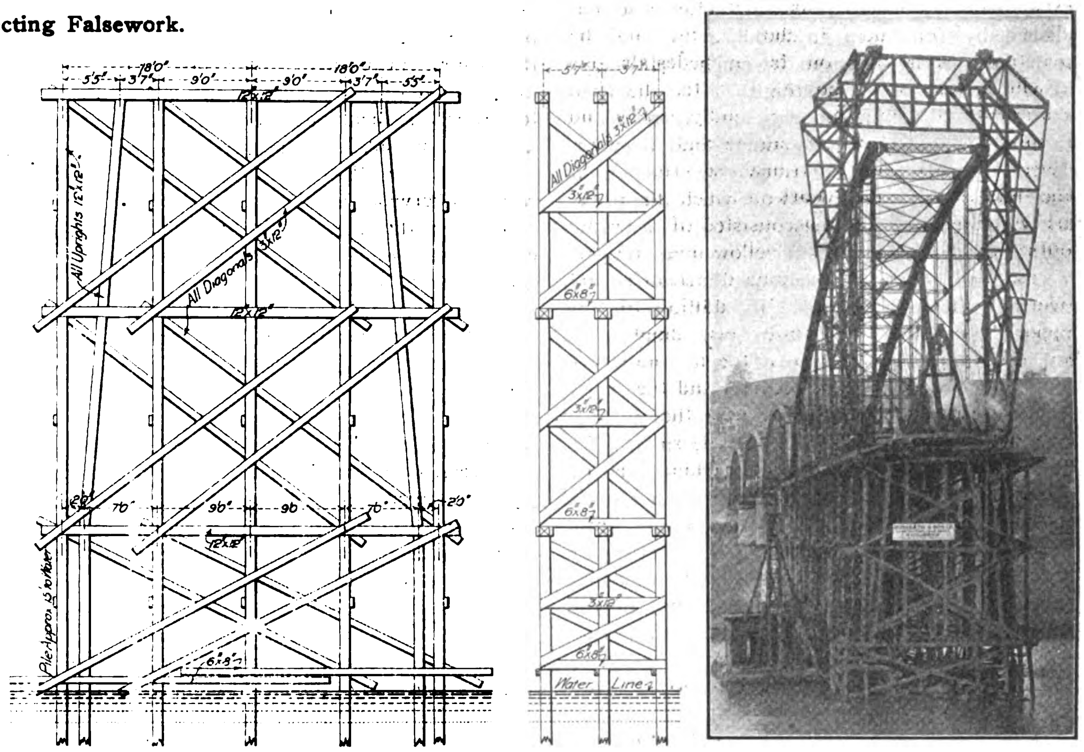
On account of the important navigation in the river at this point one-half of the channel under the main span was maintained entirely free from obstruction during the entire time of the erection of the bridge, thus involving a considerable greater time and expense for the work and more difficult operations than would have been necessary without this restriction. The wide channel was secured, as in the erection of other important spans across Monongahela River, mentioned in the previous article, by erecting the span in successive halves supported on falsework, that of the first half being removed before that for the second half was erected. This system, of course, concentrated more than one-half of the weight of the semi-span on the falsework bent supporting the center panel after the intermediate falsework for the first half of the span had been removed and that portion of the superstructure temporarily acted as a complete span of one-half the final length and supported at both ends only. This, of course, concentrated excessive load on this part of the falsework which was accordingly constructed as a tower, equivalent to a temporary pier. It also involved much greater probability of difficulty from settlement and trouble in making the final connections and swinging the span. In providing for these contingencies considerable skill and ability were shown and very simple and efficient expedients were devised, some of them novel and ingenious, which proved satisfactory and economical.

The falsework under the center vertical post of the span had to support a load of nearly 600,000 lb., including the weight of the traveler, and was carried on three transverse rows of piles 100 ft. long and 6 ft. apart. In each row there were ten 70-ft. heavy piles driven through 18 ft. of water to a refusal of ¼ in. under a 30-ft. blow of a 3,000-lb. hammer. The piles were cut off about 16 ft. above low-water level and their tops were X-braced, both longitudinally and transversely, and were capped with both longitudinal and transverse 12 x 12-in. timbers which formed sills for the 2-story bents of framed falsework above. Each bent was made in three 20-ft. stories with 12 x 12-in. caps and sills, eight vertical and two inclined 12 x 12-in. posts. It was X-braced by four 3 x 12-in. diagonal planks on each side of each bent and the three bents of each story were braced together by top and bottom transverse horizontal pieces at each vertical post, and by X-braces, all connections being made with wooden side pieces thoroughly bolted, so that each of the two stories forms a rigid parallelopiped, weighing about 22,000 lb., which was framed and completely bolted together on shore, floated to position, and handled as a unit by the mule traveler which was installed on top of the falsework and erected the latter panel by panel in advance. The falsework was of ordinary construction and was supported on a transverse row of five piles at each panel point. The piles were spaced 9 ft., 16 ft. and 18 ft. from the center line of the bridge and were cut off about 16 ft. above low water level, capped with 10 x 10-in. timbers and X-braced with 3 x 8-in. 30-ft. pieces reaching to horizontal struts at water level, each of the latter being made with two 6 x 8-in. 30-ft. pieces overlapping across the 18-ft. center space. The two-story frame bents seated on the pile caps had four 10 x 10-in. vertical posts and two battered posts of the same size, spaced 16 ft. apart at the bottom and 12 ft. 7 in. apart at the top. All caps were 10 x 10 in. timbers spliced in the center by a pair of 5 x 10-in. side pieces 8 ft. long. Both stories were X-braced like the pile bents and the bents were connected longitudinally by the stringers and by four 6 x 8-in. rangers at the water level, at the first story and at the second story caps. The bents were X-braced in pairs longitudinally to make alternate open panels and towers.



Traveler for Erecting Falsework.

The falsework bents and falsework tower at the center of the span were framed and assembled on shore and were erected by a mule traveler running on top of the completed falsework and setting each bent one panel in advance with a 60-ft. heavy wooden boom. This traveler had a floor platform with a center clearance of nearly 10 ft. above the base of rail which carried the hoisting engine and was supported by transverse beams seated on the top chords of two longitudinal trusses 40 ft. long and 19 ft. apart on centers, mounted on single double-flange wheels at each end, and provided clearance between them for the material track and cars. At the forward end of the traveler the double transverse beam forms the sill for the base of an A-frame, 36 ft. high, made with two 12 x 12-in. inclined posts with pin connections to the ends of the sill and to the ends of an intermediate transverse strut, and with bolted connection plates at the top for the back stays and for the topping lift. The back stays were made with loop-end sections of 2-in. cables adjusted by turn-buckles, and engaging pins in the longitudinal trusses and a shackle at the upper end.



Detail of Center Falsework Tower and End View of the Traveler.

The boom was seated in a patented foot block with a horizontal flange bolted to the sill of the A-frame. The foot block received a vertical pivot casting with roller bearings at the battom and near the top of the foot block. The lower end of this pivot projected through the base of the foot block to which it was secured by a nut of 3¼ in. in diameter. The upper end was bored for a horizontal 2-in. pin through the foot of the boom. When the traveler lifted very heavy loads it was reinforced by a 1½-in. transverse horizontal safety cable engaging eyes through the feet of the vertical posts under the sill of the A-frame.

The traveler used for erecting the steel work was of the ordinary wooden gantry construction about 95 ft. high over all, with vertical and horizontal inside clearances of 78 ft. 6 in. and 35 ft. 2 in. respectively. It had two bents 24 ft. 2 in. apart in the clear which were connected by four 8 x 16-in. jigger beams, by the bottom longitudinal sills and by intermediate longitudinal X-bracing of 3 x 8-in. planks. The vertical posts were 10 x 10-in. timbers, spliced, the inclined posts were 6 x 10-in. timbers and the bracing between them was of double 3 x 8-in. pieces. The tops of the vertical posts were connected by a truss about 12 ft. deep and 60 ft. long over all. The traveler moved on a 30-ft. gauge track concentric with the material track, and when in service was stiffened by two horizontal safety braces between the vertical posts, about 30 and 60 ft. above the track and by intersecting diagonal transverse safety tackles.

In order to provide for possible settlement under the heavy concentrated load on the center tower, the blocking and cambre wedges were adjusted to give the horizontal bottom chord a continuous uniform grade of about ½ per cent., the abutment end of the first half span erected being started at the required height with the pedestals seated in their final position on the bridge seat and the pedestals at the opposite ends, being erected 26 in. above their required level. This brought the elevation of the center bottom chord pins 13 in. above their required height, and the bottoms of the vertical posts at this point were seated on special pairs of oak wedges 10 ft. long, 12 in. wide and tapered from 2 to 10 in. Staggered ½-in. holes 2 in. deep were bored in the faces of the wedges which engaged each other and were filled with axle grease which, under the compression of about 300 tons from each vertical post, was forced out on to the contact surfaces and thus formed an efficient automatic lubrication. The angle of the wedges was less than that of their frictional resistance so that they had sufficient stability to carry their loads, but were comparatively easily displaced when the bridge was swung.

After the first half span was erected careful levels showed that a settlement of only ½ in. had occurred on the center pier. The cambre wedges between that point and the abutment was then carefully slacked and the semi-trusses were swung as a complete span, concentrating the load on the center pier which settled under it only ½ in. more. The falsework was then removed and redriven on the opposite side of the center pier and the remainder of the span was erected from the center to the opposite abutment, completing the superstructure. The end pedestals, and the center vertical post were supported on 12 x 12-in. yellow pine cribbing and were required to be lowered 26 in. and 13 in., respectively. In previous cases extensive sand boxes or numerous powerful hydraulic jacks had been provided for lowering such spans weighing hundreds of tons, but in this case the lowering was rapidly and safely accomplished without them and without any other special apparatus.

Holes through the thick ends of the wedges under the central vertical posts enabled steamboat ratchets to be shackled to them, and the opposite ends of the ratchets being attached to the lower chord pins at adjacent panel points afforded sufficient resistance for the wedges to be easily pulled out by four men at each panel point as their points were carefully tapped with sledges. Preventer lines were also attached to the shackles and being led opposite to the ratchets were snubbed around the foot of the vertical post and gradually slacked off and paid out to prevent any possibility of the wedges flying apart and allowing the truss to settle too rapidly.

Great care was taken to slack the cambre wedges between the vertical post and the second or highest pedestal a little more rapidly than the wedges under the center post were slacked so as to avoid all danger of throwing the bearing off from the main pier and developing cantilever stresses in the truss which was not designed to resist them. The work was satisfactorily accomplished by four men in about 4 hr. and the span then swung clear on its end pedestals, one of which was 26 in. too high. After the span was swung, the high end was rapidly, safely and cheaply lowered by a very simple and ingenious device dependent on the transverse crushing of pine timbers. The crib work on which the pedestals were supported at first consisted of a bottom course of three 12 x 12-in. yellow-pine timbers, a cross top course of the same dimensions, and covered with 2-in. planks. In addition to this support a vertical 12 x 12-in. post about 4 ft. long was seated on the top of the masonry pier as close as possible to the pedestal and the upper end beveled to full bearing against the inclined lower flange of each end post of the span. The top of the timber was securely clamped to the end post and was braced by a nearly horizontal strut to the second lower chord-panel point. This post, although not capable of carrying the estimated 300-ton load on the pedestal, was sufficient for a considerable part of it and proved, as was intended, adequate to take its proportion and gradually adjust itself by a slight lateral displacement to permit the descent of the end post.

Hydraulic jacks were inserted under the pedestals and operated to release the upper course of cribbing timbers, and one timber was removed under each pedestal. The jacks were then slacked off, transferring the pressure to the two remaining timbers in the course, which were thus subjected to stresses 30 per cent greater than previously imposed. These stresses were sufficient to crush the fibers transversely and compress the thickness of the timber from 12 in. to about 10 in., thus lowering the end of the span 2 in. The jacks were then replaced, the crushed timbers removed, new timbers of their diminished thickness put in their place and the bridge weight transferred to them. This again compressed the timbers and lowered the bridge another 2 in. and the operations were repeated until the bridge was finally lowered to the required elevation in about 2 hr., care being taken always to maintain the blocking-up to the full height so that no accident could possibly occur through failure of the jacks.

After the completion of the erection the main traveler was taken down in a very expeditious and economical manner without the use of derricks or shear legs. Single runner lines were attached to the tops of the four vertical posts and were led, away from the traveler, to snatch blocks, from which they were taken to spools of the special extra-heavy Mundy hoisting engine by which the span had been erected. The tops of the vertical posts were also connected in the planes of the runner lines by horizontal six-part longitudinal tackles with the lead lines snubbed at the foot of the traveler and the becket line carried zigzag four times across the face of the traveler and rove through gate blocks attached to the vertical post and thence rove through the blocks of the tackle, thus affording a long extension to the tackle which served to take up or pay out slack as required.

Horizontal 12 x 12-in. longitudinal struts were inserted as kicking pieces between the feet of the vertical posts with 5-ft. pieces of vertical sliding planks at the ends to afford bearing for the feet of the posts. A light vertical transverse bent 20 ft. high was erected midway between the traveler bents and thoroughly guyed in position. The longitudinal bracing, caps, sills and jigger beams were removed from the traveler leaving the naked bents which were maintained in their vertical position by the horizontal tackles and by the runner lines. The tackles were gradually slacked off and the runner line operated by the hoisting engine thus steadily revolving the bents away from each other from vertical to horizontal position as the lower ends of the vertical posts were displaced against the vertical slipping planks. As the bents approached a horizontal position the longitudinal tackles engaged the cap of the center transverse bent and were thus maintained at an elevation sufficient to give an efficient angle for controlling the final positions of the bents which otherwise would have imposed too great a stress on the tackles. In this manner the traveler bents were successfully lowered to the ground in 20 min.

The bridge was built in accordance with the plans and specifications of the engineers of the joint boards of Washington and Westmoreland Counties, Pa., Mr. W. E. Wylie and Mr. John Grundy. The steel superstructure was fabricated by the Toledo-Massillon Bridge Company and was erected by Mr. Robert Dunseath, now president and manager of the Dunseath Engineering Company, New York. The erection was completed without any accident whatever either to men, plant or structure, excepting a very slight injury to one man's finger and the loss of a small hand-rail brace in the river, a record which is believed to be unprecedented in the history of bridges across the Ohio, Monongahela and Allegheny Rivers.

Glass-Lined Concrete Tanks are used at Bordeaux, France, according to a recent U. S. Consular Report, for storing wines. It was found that when unlined tanks were used the acids in the liquid often decomposed the cement and that the walls absorbed the freshness and "bouquet" of the wine. Acid-proof coatings were applied to the concrete walls but did not prevent absorption. However, a lining consisting of small squares of glass, joined with cement mortar, is said to have given satisfaction, as a tartar forms on the thin surface of cement and resists acid attacks. The lined tanks are made in sizes which contain from 530 to 66,000 gal., and are recommended not only for storing wines but also for storing cotton seed and other oils.

POWER COSTS FOR FACTORIES.

Presidential address by F. W. Ballard, before the Ohio Society of Mechanical, Electrical and Steam Engineers.

Power plant economies in steam plants are now pretty well established and standardized, and it is quite generally understood just what might be expected in the way of cost for production of a unit of power in a steam plant. On the other hand, however, the question of the economical distribution and use of power seems to have been largely neglected, or at least this seems to be the case with the great majority. Many people who generate power for use in factories seem to be contented with the idea that they are running their power plant in an economical manner, while at the same time half of the power they generate may be wasted in a poor system of power distribution. Be the power plant large or small, it is a great mistake to devote all of one's attention to lessening the amount of coal necessary to evaporate a pound of water or produce a kilowatt of power, when at the same time it might be possible to operate the factory and produce the same results with a consumption of only one-half the amount of power being used.

There are hundreds of ways in which power may be wasted in transmission, and it should not be necessary to remind engineers of such obvious economies as that power-driven pumps are more economical to operate than those driven by steam, or that it is more economical to heat buildings with exhaust steam than it is to run engines condensing, and use live steam for heating, and yet it is surprising to find in how many places these very things are being done in the wrong way at a heavy loss. Again, it is surprising to find in how few factories there is a record kept of the proportion which the shafting load in any department bears to the whole load, and there are very few factory superintendents who actually know anything about the amount of power consumed by the individual machines in their plants.

There is a great deal being said at the present time about the possibility of using gas engine power for running factories by way of a substitute for the present steam power plants. It is generally conceded that when the power alone can be used, and the latent heat from the steam engine or gas engine cannot be utilized, that the gas engine is a more economical power producer. This is no doubt true under the usual conditions, for the gas engine has the advantage of being the most economical prime mover we have as far as fuel consumed is concerned. It has also been shown that in a modern well-designed gas engine plant the cost of maintenance need not be more than half what the cost of repairs would be in a steam power plant of the same capacity. The cost of labor also would probably not run much over half of what the service account would total in the steam plant. However, it is not always possible to use as cheap fuel in the gas engine as can be found available for consumption under the boilers of the steam plant. We can use the cheapest grades of coal to advantage for the generation of steam, but we must manufacture gas for the gas engine when natural gas is not available. The best result we can get with the highest type of steam plant is a horsepower hour for about 20,000 heat units. We can get the same power from the ordinary gas engine with a consumption of only 9000 or 10,000 heat units, yet this vast difference in economy may easily be offset by the difference in the cost of the coal and the cost of gas. It costs us about 20 cents per thousand to manufacture artificial gas, and 30 cents per thousand must be paid in this locality for natural gas, and these prices are not far from the same value per heat unit, as natural gas has a thermal value of 1000 B.t.u. per cubic foot and coal gas about 650. However, in