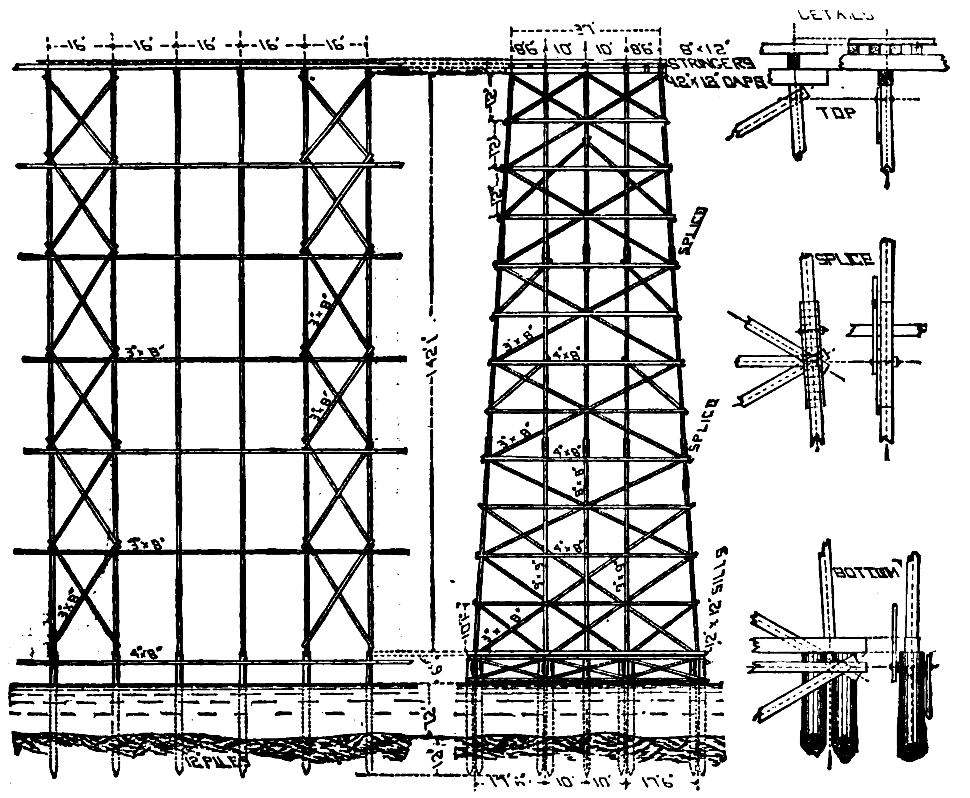
products of combustion, caused by perfect chemical combination.

The practical deduction to be made from the statements which I have had the honor of laying before you is that no very marked improvement is to be expected in boilers. All sorts and shapes have been tried, and the best of them do not surpass the duty obtained at Cardiff, where extreme skill in management was combined with a comparatively light demand on the powers of the boiler. When inventors come to you and propose to effect the usual saving of 50 per cent. in your fuel consumption, you will be able to fix them to something more definite, and then, if they understand the subject at all, you will find that their pretensions will be materially modified. You will also have noticed the important part that absolute temperature plays in all thermodynamic problems. I trust that the day is not far distant when all thermometers will be graduated from absolute zero. It will be but realizing Fahrenheit's idea, only with better information, and although it will at first sound strange to hear people talk, for example, of a very cold night with the thermometer at 460°, meaning the zero of Fahrenheit, still we shall soon get accustomed to that, and will have the advantage of abolishing negative readings and mistakes in calculations arising out of them. I have now completed the task assigned to me by the Council, and have shown how the potential energy of fuel is converted into the potential energy of steam at high pressure and temperature. It will be the duty of my successor at this table, Mr. E. A. Cowper, on the 17th of January next, to show by what mechanical contrivances the potential energy of steam is converted into the energy of motion, suited to the wants of man. My subject is by no means exhausted, but time will not permit me to touch on the important points relating to incrustation, corrosion, and some other matters of interest.

To the late Professor Rankine, I believe, is due the honor of having first pointed out the true principles on which the duty of a boiler should be estimated, namely, by comparing the work actually done with the potential energy of the fuel used, and I cannot conclude this lecture without paying a tribute of admiration to one who was a brilliant ornament to our profession, who combined in his own person the qualities of a profound mathematician, of an acute physicist, and of an excellent practical mechanic, and whose early death has deprived the profession of a member who has done so much for its advancement, and the science of thermo-dynamics of one of its most devoted and successful votaries. The very day on which I handed the MS. of this lecture to Mr. Forrest, one of the brightest stars in our firmament was hastening to his setting. I had intended sending a proof to Sir William Siemens, in the certain expectation that, with the kindliness and consideration which have marked every action of his life, he would have looked through my work, and given me, and this institution, the benefit of advice founded on his extensive and accurate knowledge. You must have noticed how often I have quoted his name, and the regrets I have expressed in the want of a high temperature pyrometer. In writing to me in October last about the melting point of steel, Sir William Siemens concludes by saying: "I am now following up a plan of getting reliable indications of temperature exceeding the limits of melting steel." In addition, therefore, to the already too numerous causes of regret we must add this, that the production of a trustworthy high-temperature pyrometer has been indefinitely postponed; for I know of no man living so competent to accomplish a task which will severely tax the most cultivated intellect, and require the command of exceptional facilities for experiment. I spoke of Sir William Siemens as a star which had set for ever; his influence, however, will not so soon fade away. Just as this generation is profiting by the solar radiation which fell on the earth countless ages ago, so will the labors of our late colleague form a store of knowledge, potential with respect to this and succeeding generations, destined to confer advantages, greater than we can now estimate, to the ever-advancing cause of science.

THE RONDOUT BRIDGE.

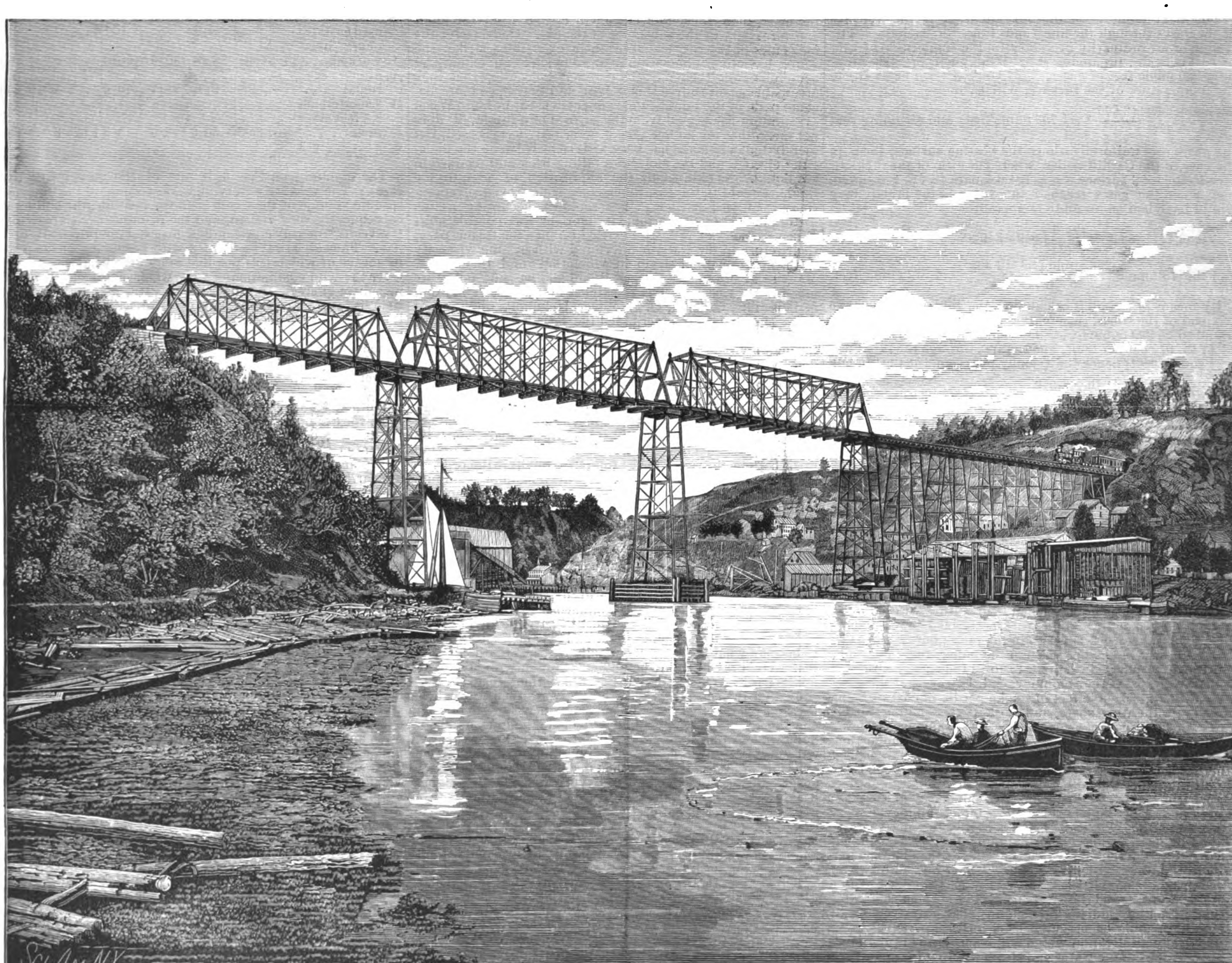
THE New York, West Shore, and Buffalo Railway crosses Rondout Creek at an elevation of 150 feet above water, in order to permit the passage of large schooners and barges. There is a large amount of coal, cement, and flag stone that annually passes this point, and a drawbridge, which the height of the present structure makes unnecessary, would have seriously interfered with the operation of the road.



FRAMEWORK FOR ERECTING THE SPANS.

The line of the road leaves the top of a hill of the same elevation as the bridge, crosses the three spans, then a long viaduct, and thence through a tunnel in the opposite hill. The spans are of the following lengths, beginning at the south (left of the engraving):

One of 168 feet, one of 24 feet, and one of 264 feet. They rest upon three iron piers of 15 by 30 feet section. The via-



RONDOUT BRIDGE, NEW YORK, WEST SHORE, AND BUFFALO RAILROAD.

duct is 531 feet long, supported on piers—thus making a total length of 1,244 feet. The weight of the iron entering into the construction is 2,000 tons. The work of erection was begun November 8, 1882, and the first train crossed May 8, 1883. The total cost of the bridge was about $350,000.

The iron work was designed and constructed by Clarke, Reeves & Company, of Phœnixville, Pa., in accordance with specifications and detailed directions of Col. Walter Katte, chief engineer of the North River Construction Company, and E. L. Corthell, chief engineer, and A. Lucius, engineer in charge of bridges, of the New York, West Shore, and Buffalo Railway.

The bridge is 29 feet wide from center to center of trusses, the viaduct being the same from center to center of column caps. The first span has a height of 32 feet, and the other two a height of 45 feet It is a pin connected, wrought iron bridge, the iron having a minimum ultimate tensile strength of 50,000 pounds per square inch of original sectional area before fracture. The end and intermediate posts and top chords, as well as the columns in the piers, are of the pattern known as Phœnix columns. The wooden floor consists of transverse floor timbers, extending the full width of the bridge, supporting rails and guard beams. According to the specifications for bridges of this size, they must carry the dead load consisting of the iron in the structure and a floor weighing 400 pounds per lineal foot of track consisting of rails, ties, and guard timbers only, and a moving load for each track—supposed to be moving in either direction—consisting of two consolidation engines, coupled, followed by a train weighing 2,240 pounds per running foot. In order to provide for vibrations and wind pressure, the bottom lateral bracing in through bridges is proportioned to resist a lateral strain of 450 pounds for each foot of span.

The viaduct is composed of lattice girders supported upon six iron piers, the distance between facing columns of the piers being 50 feet in all except that next the bridge, which is 60 feet. Much trouble was experienced in obtaining a suitable material upon which to build the piers, and in some instances excavations to the depth of 60 and 80 feet had to be made before finding a good foundation. The bridge piers rest on masonry, built on piles driven to refusal.

The placing in position of a structure of this magnitude at so great a height involves great care and much labor, and its rapid and successful completion makes it a subject well worth studying No false work was used in erecting the viaduct. The piers consist, practically, of four iron columns resting on beds of masonry, and firmly held in position by struts and ties. After the foundations had been completed the columns were raised in place, when a gin pole (a wooden mast having a pulley at its upper end, through which a hoisting rope passes) is fastened to them by iron bands. A rope passes from a hoisting engine through a block at the base, thence through the pulley in the gin pole. By this means the several parts were raised into position and secured. The work was completed, section by section, to the full height, and the track laid. As soon as the first section had been finished a traveler, operating on top, assisted in the work of raising the balance.

Very different and much more difficult was the task of erecting the spans. In this case it was necessary, in order to support the great weight of iron, to build a framework of heavy timber of strength sufficient to bear the load and resist the wind which sometimes sweeps through the gorge with great violence. Our drawings show a side and transverse elevation, with details of the top, bottom, and splice. All bolts were three-quarter inch, all diagonal transverse braces were 3 inches by 8 inches, all horizontal transverse braces were 4 by 8 inches, all longitudinal braces 3 by 8 inches, with X bracing between outside and center legs. This framework was supported on piles; the distance from the top of the piles to the caps was 142 feet. Three hundred thousand feet of timber were used and 416 piles. Putting the span together after this had been finished was comparatively easy. About two-thirds of the total cost of erection was for the false work, engines, blocks, tackle, and other appliances. The total cost of erection was about 1¼ cents per pound. The cost was from one-third to one-half a cent per pound greater than it would have been in summer, owing to last winter being an unusually inclement one. Much of the time the ropes, stagings, etc., were covered with ice.

THE FRENCH IRON CLADS L'INDOMPTABLE AND LE MARCEAU.

EVER since the appearance of La Gloire—the first iron-clad built by Mr. Dupuy de Lome—France and England have been striving to rival one another in the creation of more and more formidable types. The fact must be recognized that these two countries have, in a manner, proceeded side by side, although the ideas of engineers as to the role of the apparatus with which iron-clads are armed and the general aspect of their vessels are quite different.

On the present occasion we shall describe to our readers two of the most recent iron-clads that have been added to our navy—L'Indomptable and Le Marceau. Owing to the distribution of her artillery, which sweeps the entire horizon, and to the possibility of the large turret guns being able to cross their fire, the Indomptable possesses undoubted merits. Every ship that makes an attack upon her will have to expose herself to the fire of at least one of the turret guns.

The Indomptable, which was launched at Lorient, September 19, 1883, was built after plans made by Mr. Sabattier, Director of Naval Constructions. She is 278 feet in length, 59 feet in breadth, and 24·75 feet in depth. Her draught is 23 feet forward, and 24·5 feet aft. Her displacement, when completely equipped, will be more than 7,000 tons Her estimated speed is 14 knots

The entire hull, including the frame, is of steel. Her hold is constructed after the cellular system, and is divided into a large number of water-tight compartments by 9 transverse bulkheads that rise to the iron-clad deck and are intersected by partial longitudinal ones.

The armor, which extends from stem to stern, is 11·8 inches thick fore and aft and 19·7 inches amidship. It is of compound metal, that is, iron faced with steel. The turrets are armored with this same metal 16·7 inches in thickness. The breech of the turret guns is further protected by a small steel cupola. The total weight of the armor, including that of the turrets, is 1,744 tons. The deck itself is armored with steel plates 3¼ inches thick. The engines are expected to yield a power of 6,000 horses, with 85 revolutions for an ordinary run, and 90 for the greatest speed. They are of the vertical three-cylinder type, and actuate two screws that have a pitch of 18·7 feet. Steam will be furnished them by 12 cylindrical two-furnace boilers placed in two water-tight compartments. The coal bunkers form at the two sides 4 compartments that protect the engines and boilers.

The cabins, which are upon the armored deck, are protected by a second deck of steel, and above this there is a spardeck.

The armament of the Indomptable will consist of 2 sixteen and one-half inch guns, weighing 77 tons, throwing 1,540 lb. projectile, and placed in the *barbette* turrets; 4 four-inch guns placed upon the upper deck; and Hotchkiss guns placed both upon deck and in the tops. The large guns are to be maneuvered by hydraulic apparatus. Their field range is 135° on each side, starting from the axis of the vessel. The vessel will be provided with two tripod masts for signals, with tops armed with Hotchkiss guns. This ship will probably not be finished until the end of 1885, when her construction will have lasted nearly eight years Her total cost will be $2,068,000, say $1,397,000 for the hull and accessories, $106,600 for her armament, $213,200 for the engines, and $304,000 for the artillery equipment.

Figs. 1, 2, and 3 show the principal arrangements of the vessel.

The second vessel, Le Marceau, is a squadron iron-clad that was launched at La Seyne on the 16th of January, 1884, and built by the Société des Forges at Chautiers de la Mediterrance after plans by Mr Huin, an engineer of the navy. This vessel is 330 feet in length, 65 feet in width, and

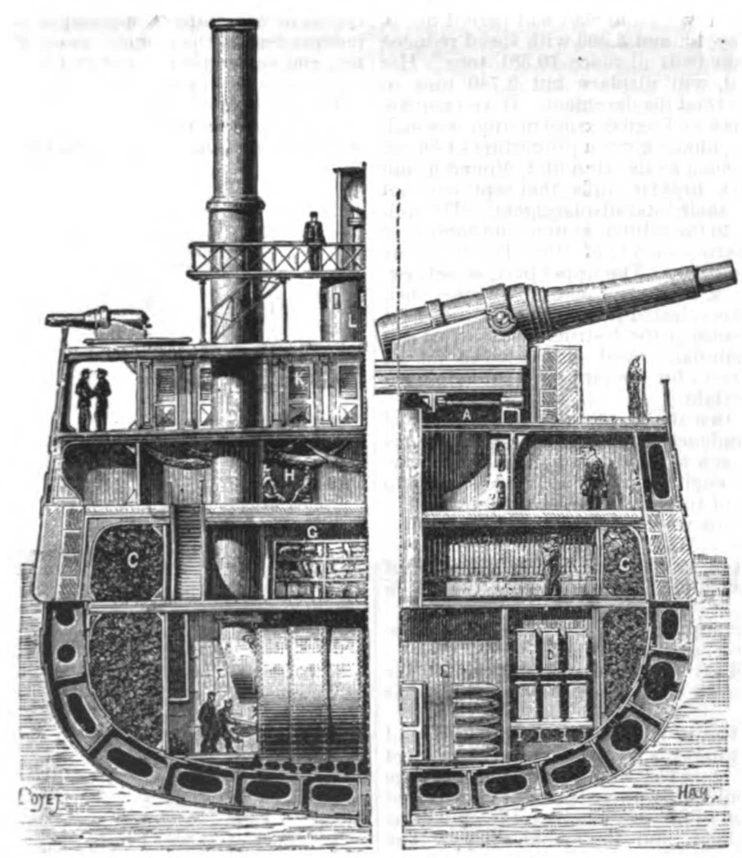


FIG. 1.—THE FRENCH IRONCLAD L'INDOMPTABLE. (Transverse Sections.)

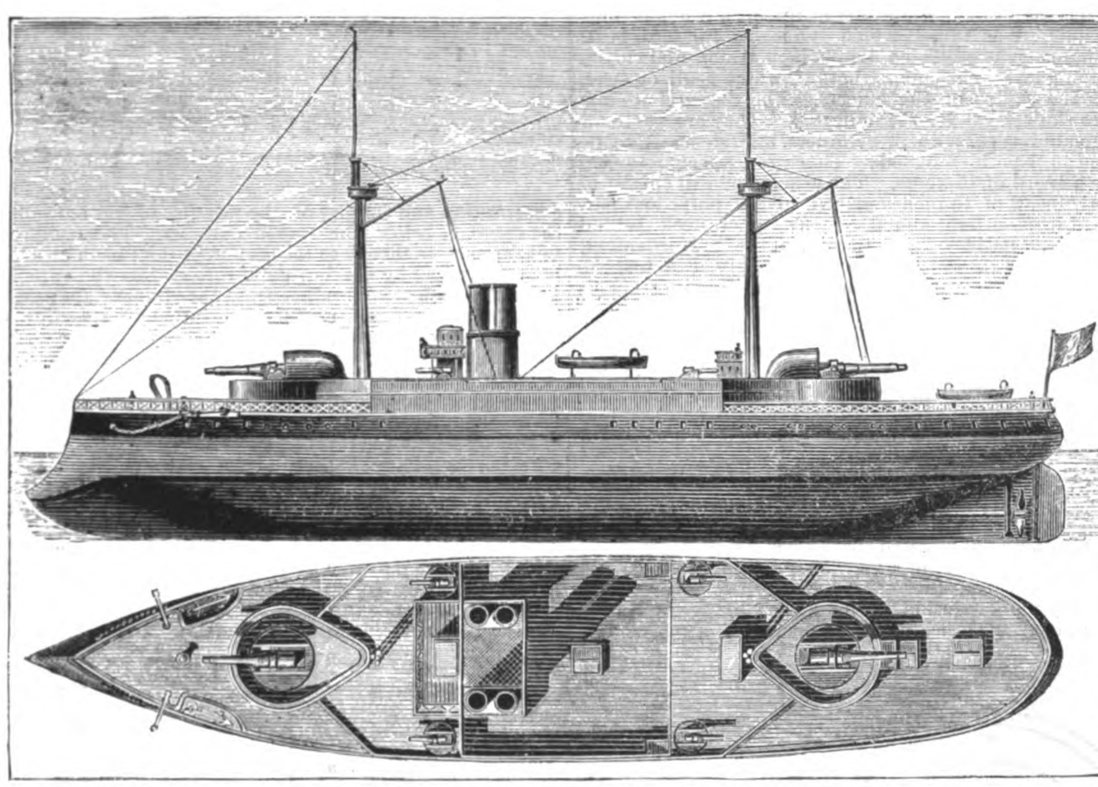


FIG. 2.—GENERAL VIEW OF L'INDOMPTABLE.

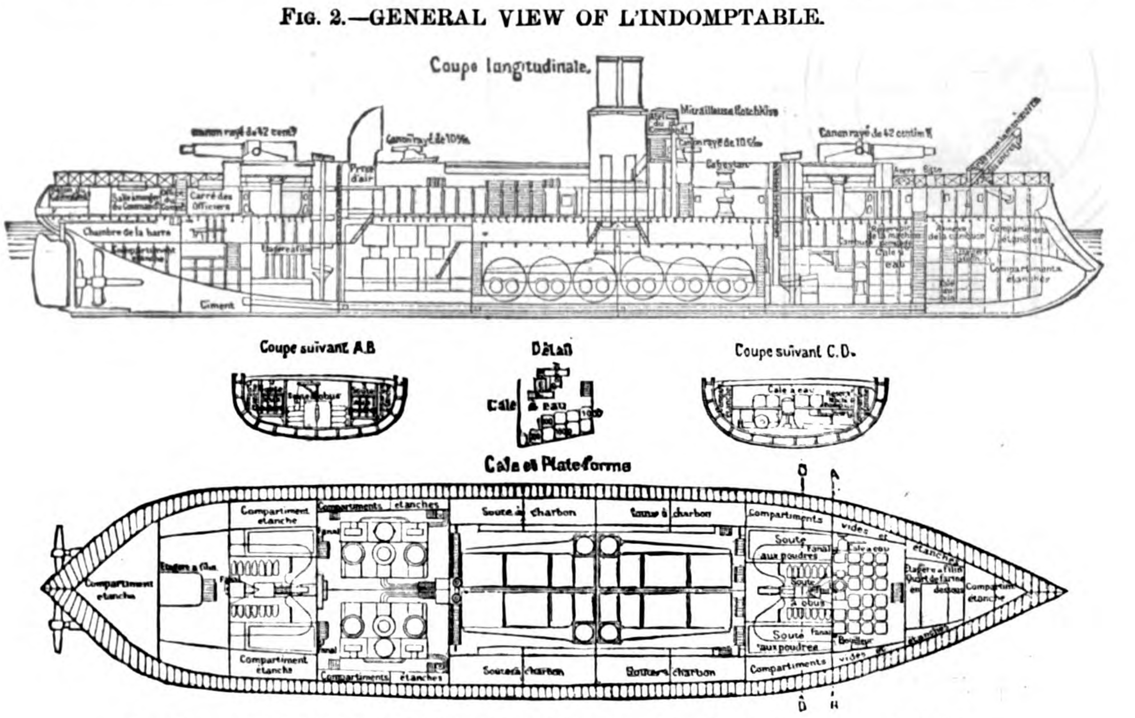
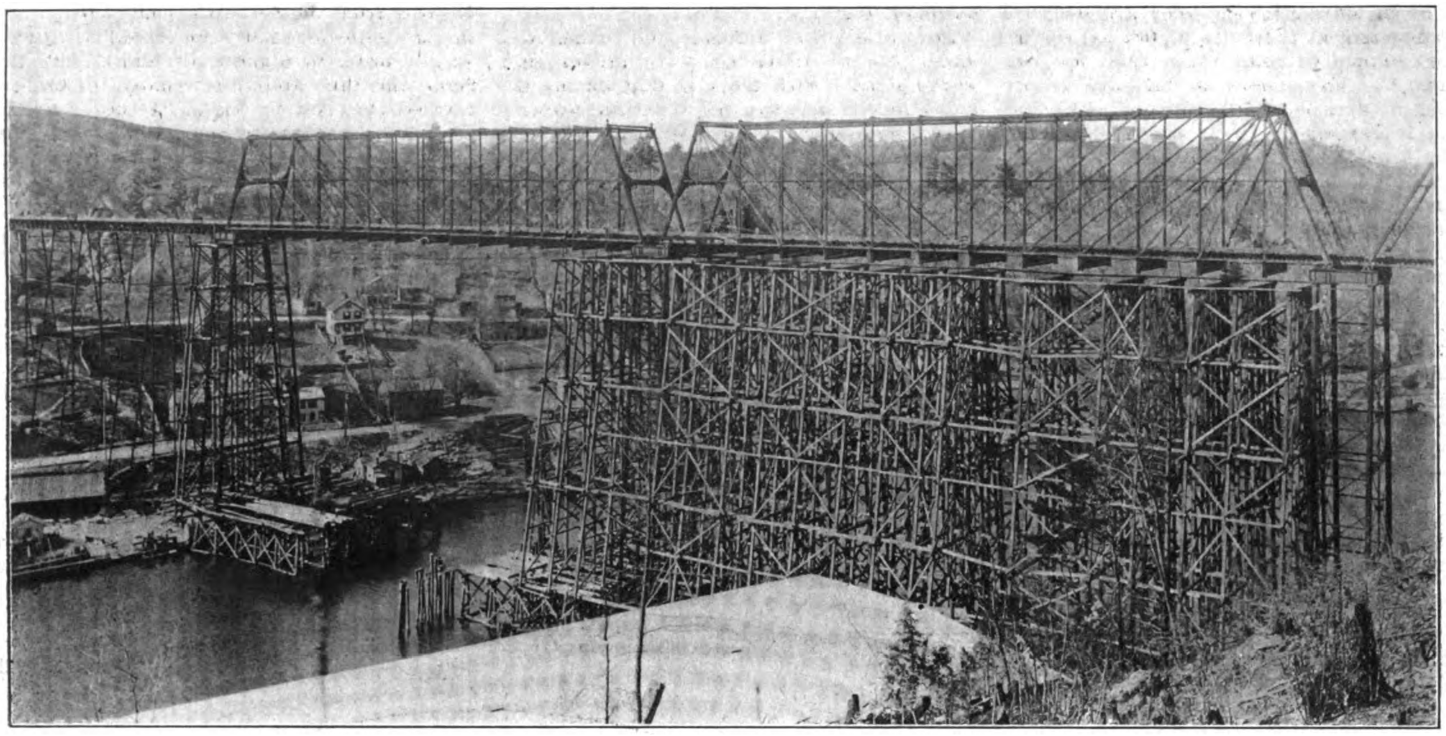


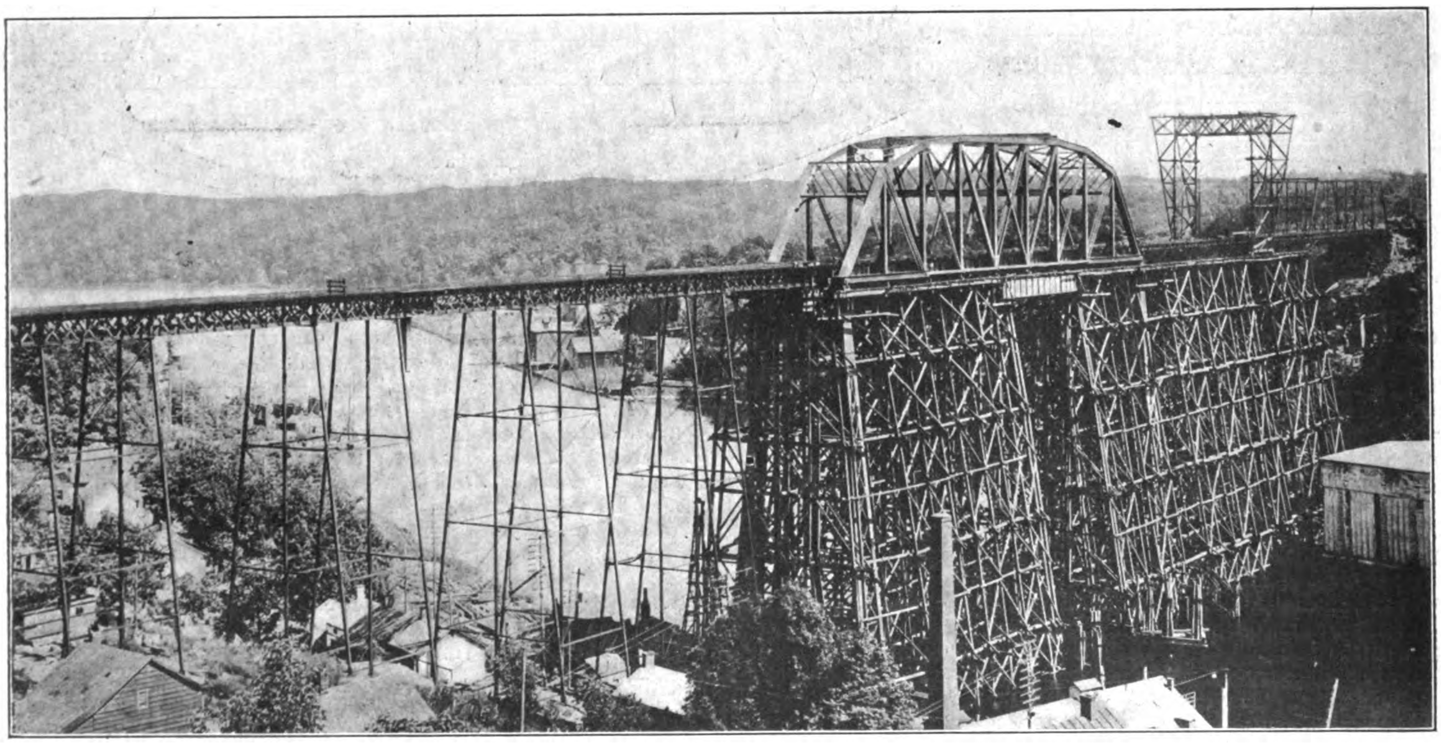
FIG. 3.—THE IRONCLAD L'INDOMPTABLE. (Longitudinal Section and Plan.)

gates were set up, which dammed the water at that place and made it possible to continue the work of enlarging the tunnel and revetting it with masonry where necessary up to that point, awaiting the excavation from the south, which was behind hand because of difficulties encountered at earlier stages of the work. The hot spring is formidable not on account of the quantity discharged, which is much less than some other springs which have been cut; but because it makes it too hot to work. The south heading was advanced only 81 ft. in September, leaving 798 ft. between it and the north face.

After Sept. 6 the work was almost exclusively in cutting a drainage channel to the side tunnel (which hereafter is to be excavated for a second track) in walling out the hot spring, and getting in order the cooling apparatus which alone will make it possible to work in rock which has a temperature of 109 deg. The rock is so broken up that it is necessary to arch the side tunnel at the bottom in many places near the present south face. When work was resumed on the south face of the main tunnel (which was to be done in October), machine drills could not be used until it had advanced some yards past the hot spring, and the operators with the hand drills have an exceedingly uncomfortable task, in spite of the streams of cold water forced in to keep down the temperature. If no more hot springs be encountered it will probably be possible to cut the main tunnel through by the end of this year; but the character of the strata at both faces is very unpromising—limestone, much fractured, which according to the geologists was not likely to be found at this depth.



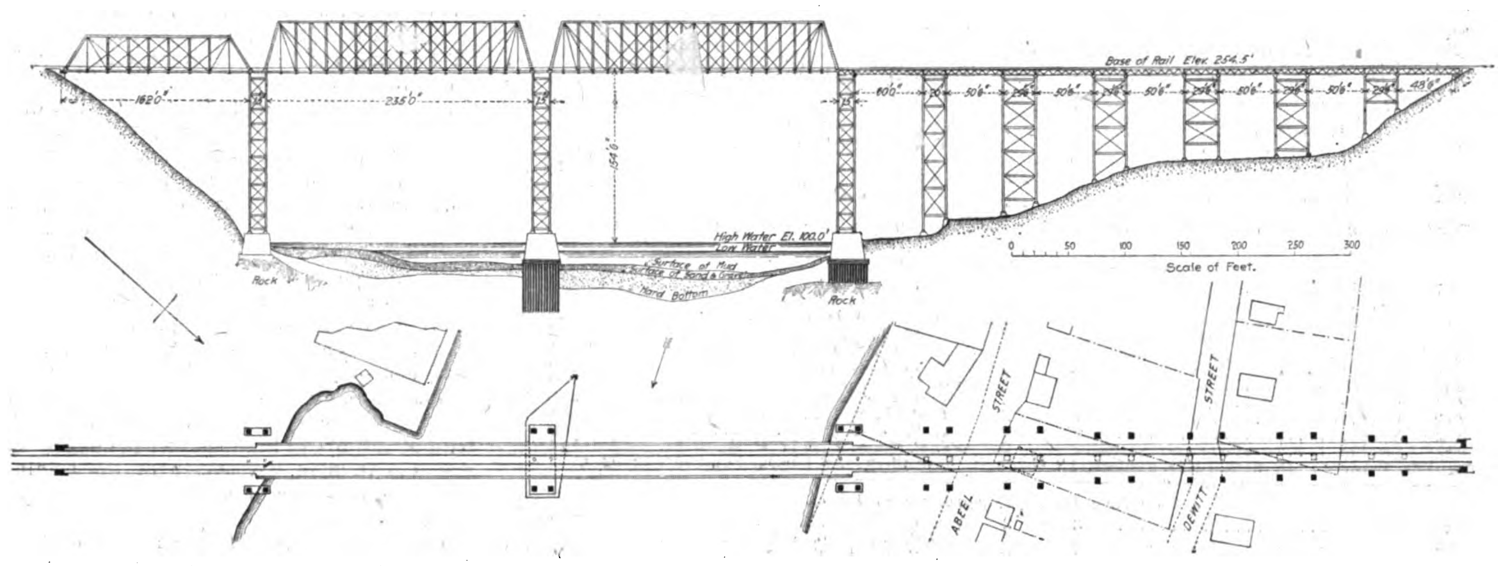
Old Rondout Viaduct Showing Falsework Partially Completed.



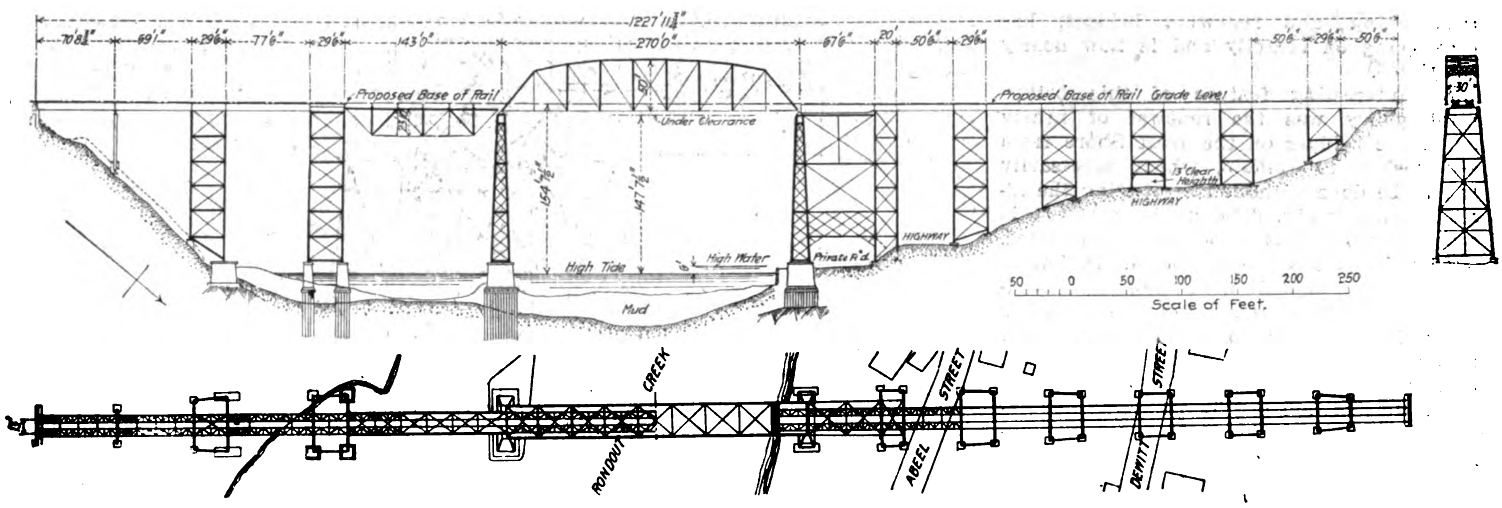
New Rondout Viaduct Showing Completed Falsework and Traveler.

Renewing Bridges on the West Shore.

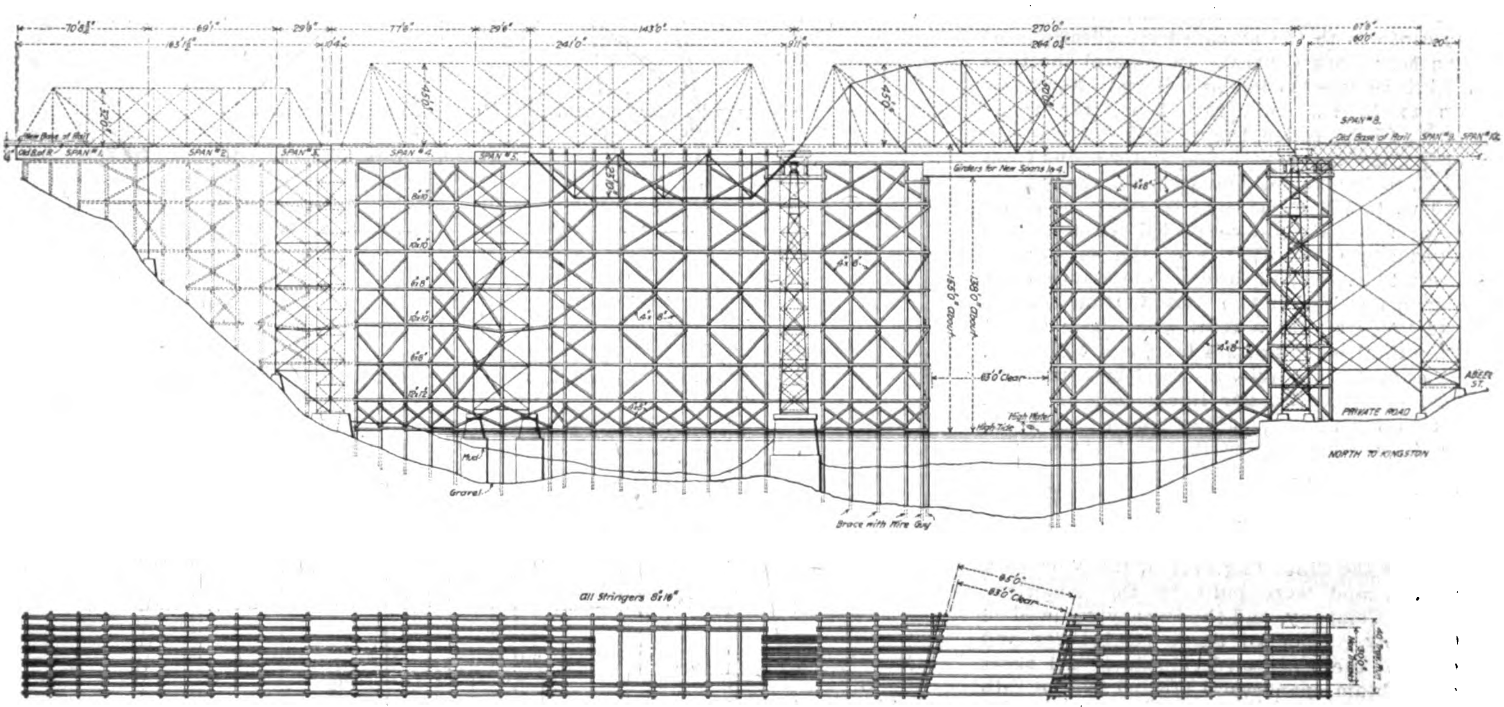
It has long been the aim of the New York Central to utilize the West Shore Railroad which it owns and operates, for hauling all of the heavy through freight between New York and Buffalo and to use its main line, which is four-tracked for most of the distance, for fast freight and passenger trains. The West Shore between Albany and Buffalo parallels the Erie Canal and the New York Central. It is a double-tracked road, but never since it was first built in the early eighties has it been up to the standard of a first class road. Some six years ago the New York Central began a systematic scheme of improvements designed to ultimately put this road in shape for handling heavy traffic. This work, which included laying heavy rails,



Plan and Side Elevation of Old Bridge over Rondout Creek, West Shore Railroad.



Plan and Elevation of New Bridge over Rondout Creek, West Shore Railroad.



Plan and Elevation of Falsework Used in Erecting the New Rondout Viaduct.

New Bridges on the West Shore Railroad.

River Division, Weehawken to Ravena, Bridges over 75 Ft. in Length.

Bridge No.	Location.	No. of Spans.	No. of Tracks.	Type.	Total length of bridge.
4	Granton	1	2	T. P. G., F. B. & S.	121 ft. 6 in.
8	Little Ferry	1	2	T. P. G., F. B. & S. draw	102 ft. 8 in.
17	West Nyack	1	2	D. P. G.	86 ft.
64	Cornwall	1	2	T. P. G., F. B. & S.	87 "
25	West Haverstraw	1	2	D. P. G.	84 "
96	Marlborough	1	2	T. P. G., F. B. & S.	82 "
141	Kingston	20	2	Viaduct	1,228 "
152	Mt. Marion	5	2	D. P. G.	448 "
172	Catskill	18	2	D. P. G. & D. L., viaduct	1,222 "
185	North Baltimore	4	2	D. P. G.	221 "

Smaller Bridges: 13 deck plate girders, 14 through plate girders, 15 I-beam and plate bridges.

Mohawk Division, Ravena to Syracuse.

Bridge No.	Location.	No. of Spans.	No. of Tracks.	Type.	Total length of bridge.
197	Bethlehem	4	2	D. P. G. & T. P. G. viaduct	186 ft.
199	Bethlehem	1	2	T. R. T., F. B. & S.	103 "
213	Fullers	3	1	D. R. T. & D. P. G.	347 "
337	Harbor over Erie Canal	1	2	T. R. T., F. B. & S.	172 "
340	Utica	4	2	T. P. G., S. F. on columns	184 "
346	New York Mills	2	2	D. P. G.	104 "
356	Clark's Mills	2	2	D. P. G.	104 "
404	Canaserago	2	2	T. R. T. & S. F. & T. P. G., S. F.	236 "
412	Chittenango	2	2	T. P. G., S. F.	88 "
372	Vernon	2	2	T. P. G., S. F.	90 "
383	Oneida	2	2	T. P. G., S. F. & D. P. G., S. F.	114 "

Smaller Bridges: 10 deck plate girders, 18 through plate girders, 6 I-beam and plate bridges.

Western Division, Syracuse to Lyons.

Bridge No.	Location.	No. of Spans.	No. of Tracks.	Type.	Total length of bridge.
448	Amboy	8	2	D. P. G.	139 ft.
453	Jordan	1	2	T. R. T., F. B. & S.	129 "
454	Jordan, over Erie Canal	1	2	T. P. G., F. B. & S.	116 "
457	Weedsport, over Erie Canal	1	2	T. P. C. T., F. B. & S.	207 "
461	Port Byron	3	2	T. P. G., F. B. & S.	181 "
470	Clyde, over Erie Canal	1	2	T. R. T., F. B. & S.	168 "
471	Clyde	2	2	T. P. G., F. B. & S.	109 "
473	Clyde	2	2	T. P. G., F. B. & S.	121 "
474	Clyde	2	2	T. P. G., F. B. & S.	188 "

Smaller Bridges: 4 deck plate girders, 3 through plate girders, 1 I-beam and plate bridge.

re-ballasting, and renewing bridges, has been going on steadily and is now nearly completed.

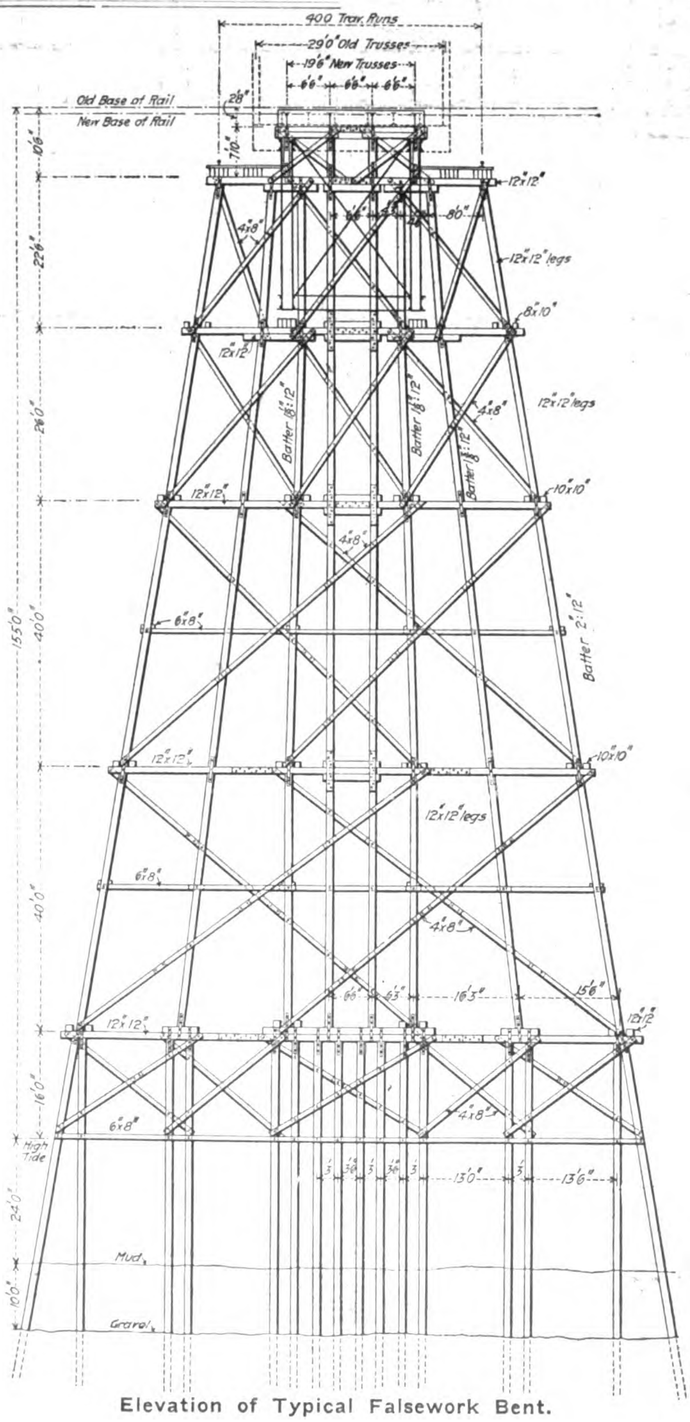
An interesting feature of this betterment policy was the renewal of nearly all of the bridges on the West Shore from Weehawken to Buffalo, which necessarily had to be done without interrupting the already heavy traffic. The greater part of this renewal work has now been completed. Thirty bridges of over 75 ft. in length have been renewed with new and modern steel structures and 84 smaller spans have also been renewed. The old bridges taken out were mostly built of iron, having been put in when the road was first built. In addition to this all of the remaining bridges have been thoroughly overhauled, repaired and strengthened. The accompanying table shows the location, type and span of the important bridge renewals on each division from Weehawken to Buffalo. About 9,000 tons of steel were required in all for the renewals on the River Division and as much more for new bridges between Ravena and Buffalo.

All of the new bridges have been built to conform to the standard specifications of the New York Central. In general the type of bridge selected was as follows: For spans up to 13 ft., solid rail floor; for spans up to 25 ft., rolled beams with cover plates or longitudinal trough floors; for spans from 25 ft. to 100 ft., plate girders; for spans from 100 ft. to 180 ft., riveted trusses; for spans of over 180 ft., pin connected trusses. The truss spans are usually of the sub-trussed Pratt type. For all bridges the standard assumed live load is two consolidation engines and tenders with a total wheel base of 101 ft., a total weight of 284 tons, and 40,000 lbs. on each driving axle, followed by a uniform load of 4,500 lbs. per lineal foot of track. An alternative loading also used is 60 tons equally distributed between two axles spaced 7 ft. apart followed by a uniform load of 4,500 lbs. per lineal foot of track beginning 5 ft. behind the rear axle.

The new bridges were all designed in the office of the Chief Engineer of the New York Central and were built by the American Bridge Company, and the Pennsylvania Steel Company. Some of the truss bridges and most of the plate girder bridges and short rolled beam spans were erected by the railroad company's own forces. All other spans were erected by the contractors.

The two most important bridge renewals made were the viaduct over Rondout creek, a mile south of Kingston on the River Division, and the Catskill viaduct at Catskill. The Rondout viaduct is the longest bridge on the line being 1,228 ft. long, and the Catskill viaduct, which is the next longest, is 1,222 ft. long. The old bridge at Rondout, built in 1882, consisted of three iron, Whipple, through truss spans at the south end, 162 ft., 235 ft. and 255 ft. long respectively, supported on iron latticed towers and seven deck latticed girders for the north approach, resting on light iron towers with short connecting girders over the tops of the towers. It was a light structure throughout, being designed only for loads of two 80½-ton consolidation engines followed by a moving load of 2,240 lbs. on each track. The level of the base of rail above high tide on the old bridge was 154 ft. 6 in. A sketch of the original structure is shown in one of the accompanying drawings.

The new bridge put in consists of three deck plate girder approach spans at the south end, one deck truss 143 ft. long, one through truss 270 ft. long over the channel, and seven deck plate girder approach spans at the north end. New steel towers were



Elevation of Typical Falsework Bent.

built to support the structure and the bridge as renewed will now carry the heaviest traffic on both tracks simultaneously at high speeds. A comparison of the accompanying drawings of the old bridge and the new bridge shows the changes in the substructure made necessary by the renewal. At the south end the old abutment was allowed to remain as before but a new coping course and back wall were put in. About halfway down the bank, two pier foundations were put in for the rocker bent supporting the plate girder approach spans, Nos. 1 and 2. The foundation piers for the old tower at the foot of the south bank were used for supporting the outer legs of the new tower and two new piers were built higher up the bank to support the in-shore legs. Tower 3 is entirely new and the four piers resting on piles were sunk before the tearing down of the old bridge had begun. The piers for all of the other towers are the original masonry with new coping courses. The towers under all of the approach spans consist of four legs battered 1 to 8 toward the center line of track but vertical in a longitudinal plane. They are 29 ft. 6 in. between bents and the tracks are carried over them on short plate girders. All of the towers are stiffened longitudinally and laterally with diagonal and cross-braces, and towers Nos. 5 and 6 are also connected together top and bottom with stiffening trusses.

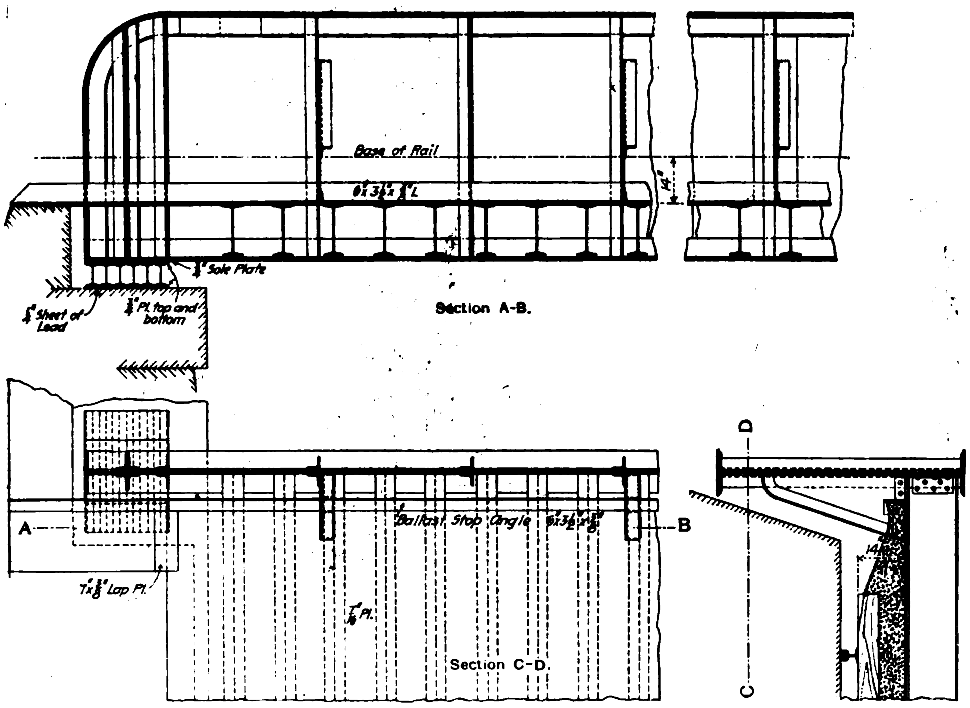
After the new masonry was completed and before the dismantling of the old bridge was begun, falsework was built up from the ground and the bottom of the creek to support the track while the bridge was being renewed and to form a runway for the traveler used in erecting. This falsework consisted of 41 bents supported on piles and tied together with 4-in. x 8-in. diagonal braces and longitudinal struts. The two outside posts on each side of the bents were battered and the four middle posts were vertical. The bottom sill rested on the tops of the piles which were driven in pairs under each post and the number of stories in each bent was varied according to the rise of the bank. As far as possible all the braces, sills and caps were made of uniform sizes to save cost in getting out the timbers in the mill. A general plan and elevation of the falsework and an elevation of a typical bent under the deck span are shown in the drawings.

The stringers, laid on the caps of the bents, were all 8 in. x 16 in. and were grouped in banks of three under each rail and in banks of two under the traveler runway on the outside. The bents were spaced, in general, 15 ft. apart and the stringers were made 32 ft. long to rest on three bents. Where the towers interfered with the regular spacing of the bents, 18-in. I-beams, three under each rail, were substituted for the wooden stringers. Rondout creek is navigable for canal boats and small steamers and it was necessary to preserve a clear waterway in the channel. Two bents close together were built on each side of the 63-ft. clear channel opening which was left, and the eight new plate girders intended for spans Nos. 1 and 4 were laid on the caps of these bents. One girder was placed under each rail and one under the traveler runway on each side. All of the falsework was designed in accordance with Cooper's E-35 loading.

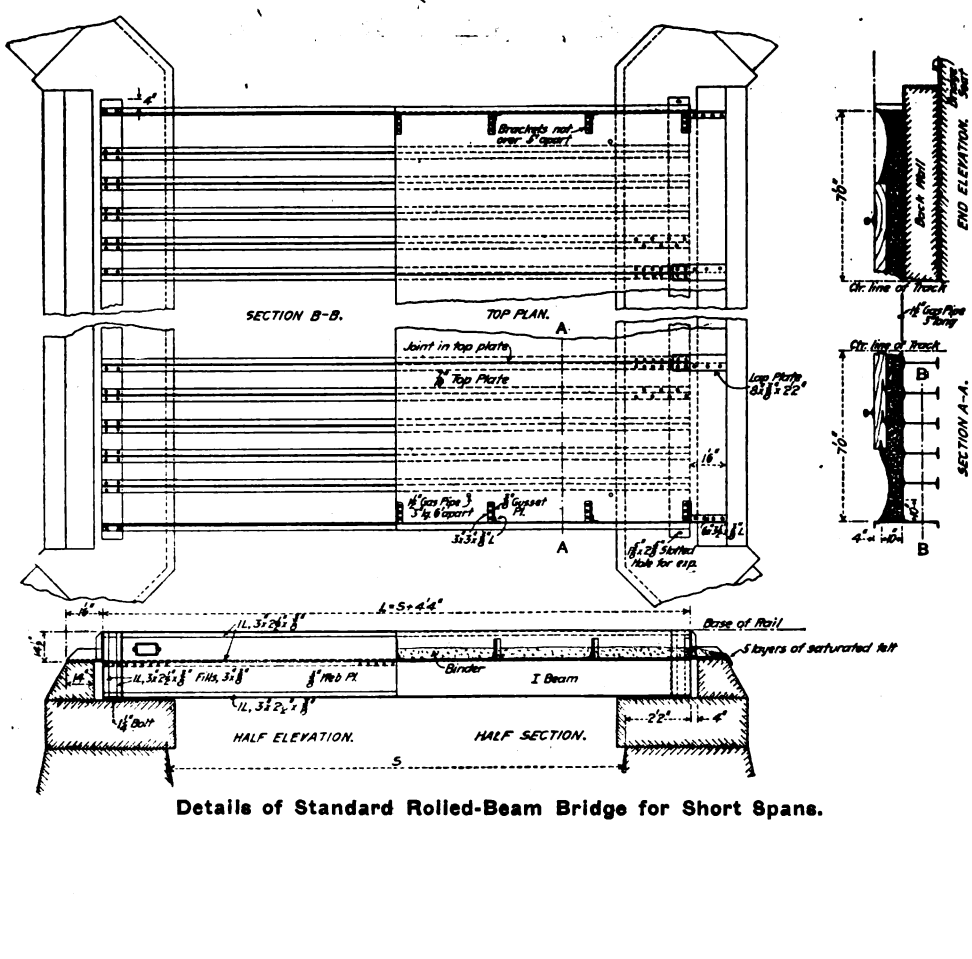
After the falsework was all up, the traveler used for dismantling and erecting was assembled on the runway and the work of taking down the old through spans was begun from the north end. The traveler used is shown in one of the illustrations from a photograph. It was of the ordinary form, having two legs or towers of four posts each with a bridge across the top having sufficient clearance to move over any of the old or new spans. The old through truss span at the north end over the channel was taken down first and the new 270-ft. truss was erected on the new towers already built up from below. The second through truss was then taken down and as the work progressed the iron stringers over the channel tower were fleeted ahead to rest on the pony bents of the falsework, no wooden stringers being put in under that part of the old span above the new deck truss. After the deck truss had been erected, the remaining through truss was replaced with the plate girders used in the temporary span over the channel and finally the latticed girders in the north approach were replaced with plate girders resting on the new towers. The whole work was done with little interruption of traffic and with no accidents. The American Bridge Company, which built the superstructure at its Pencoyd, Edgemoor and Athens plants, designed and built all of the falsework and erected the bridge on the site. About 3,000 tons of steel were used in the superstructure.

We are indebted to Mr. Olaf Hoff, Engineer of Structures, New York Central, for the illustrations and information.

The Prussian authorities are reported to have become satisfied that further experiments with fast trains hauled by steam locomotives on the Military Railroad are unnecessary. Based on the results attained, they will aim to increase gradually the speed of express trains, not expecting to exceed a maximum of 120 kilometers (74½ miles) an hour. The authorities now are turning their attention to improved brakes. A mechanical engineer has been investigating the subject in America.



Details of Standard Through Plate Girder Bridge with Solid Plate Floor.



Details of Standard Rolled-Beam Bridge for Short Spans.