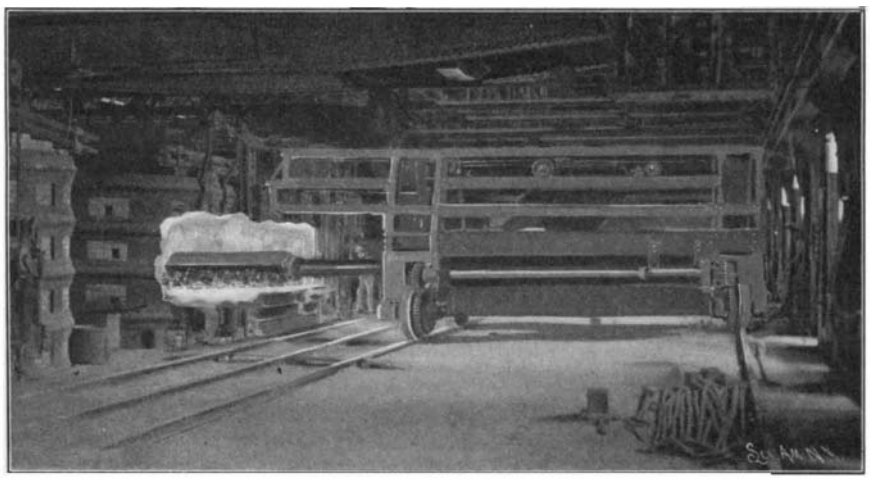
MANUFACTURE OF GUNS AND ARMOR AT THE BETHLEHEM STEEL WORKS.

I.—THE OPEN HEARTH PROCESS.

Among the industrial establishments in this country which will always be associated with the history of the modern United States Navy, none will merit more honorable mention than the vast assemblage of forges, furnaces and machine shops, many of them the largest of their kind in the world, which have given the historic town of Bethlehem a new lease of life and a world-wide reputation.

The relation between a country's navy and the establishments which provide its ships, guns, and armor is, or should be, one of mutual helpfulness. Without such institutions as the Carnegie and the Bethlehem Steel Works, and the shipyards at Philadelphia, Newport News, and San Francisco to produce ship plates and forgings and assemble this material in the completed and fully equipped fighting ship, the task of reconstructing our navy, commenced in 1883, would still be in its initial stages; on the other hand it is the needs of the navy and the expected recurrence of orders for material that are answerable for the lavish scale upon which some of these industrial establishments have been laid down, enlarged and furnished with costly equipment. They are mutually dependent. This is specially true of the Bethlehem Steel Works, which, in preparation for the needs of the future, has built what is probably the most complete plant devoted almost exclusively to the manufacture of guns and armor to be found in any country of the world. The Bethlehem Steel Works are located upon a strip of land which is about a quarter of a mile in width and extends for a mile and a quarter along the banks of the Lehigh River. The whole of the yard is served by some nineteen parallel railway tracks, which make up, including broad and narrow gage, a total of thirty-five miles. The various forges and armor plate and machine shops are located throughout the yard in such relation to each other and to the railways as conduces to economy in transportation and handling—a most serious consideration when we bear in mind that single masses of gun steel and armor plate that are being handled at this works will weigh as high as 137 tons, and that every one of these heavy forgings has to be handled and transported fully twenty times in the Harvey process, and no less than fifty times in the yet more costly Krupp process. The buildings themselves are truly colossal, as will be seen from the following list of the largest of them, which includes an open hearth building, 1,950 feet long by 111 feet wide, a machine shop, 1,375 feet by 116½ feet, an armor forge, 850 feet by 116½ feet, a carbonizing department in which the face-hardening of the armor is carried out, 700 by 63 feet, and an armor plate machine shop, 610 feet long by 124 feet wide. There are many other subordinate building which, while they would be mentioned for their size in a description of most establishments, are relatively insignificant compared with the huge structures above mentioned.

The genesis of the open hearth process which forms the subject of the present article is to be found in the stock yard, in which the material that is to be melted down in the open hearth furnaces is stored, and the "mixture," as it is called, made up in its proper proportions for charging the furnaces. In the open hearth process wrought iron or steel scrap are melted with cast iron in such proportions as to reduce the percentage of carbon to that required for the particular grade of steel which is being manufactured. Hence, it is necessary that the composition of every pile of pig iron and iron and steel scrap in the stock yard should be accurately known; and to this end the scrap which is brought from the various forges and machine shops throughout the works is stacked in separate piles and its composition carefully recorded. The stock yard is, in itself, a most interesting study. In one pile will be seen the massive ends which have been cut from steel ingots at various stages of the forging process. In another pile may be seen the turnings from the heavy lathes and milling machines in the gun and armor plate shops. Elsewhere may be seen a train of charging boxes full of "skull scrap" from the casting pits, while adjacent to the scrap piles are located the bins from which the ores, of which a certain amount is used in the bath for decarbonizing, are taken to add their quota to the mixture. In our engraving of the stock yard will be seen a train of cars upon which are loaded the "charging-machine boxes," open rectangular boxes which are loaded with the mixture, and hauled up an inclined plane onto the charging platform in front of the open hearth furnaces. Here they are picked up, one at a time, by an electrical charging machine, which is provided with a massive extensible arm that hooks into the charging box, raises it from its car, thrusts it into the furnace, turns it completely around, thereby discharging its contents, and afterward withdraws it and places it empty on the truck. The charging machine is a most powerful affair, as will be seen from the fact that it can lift a dead weight of 7,000 pounds at the end of its 20-foot arm, and hold the weight out literally at "arm's length," handling it apparently with the same ease with which one handles a cupful of water.



ELECTRICAL CHARGING-MACHINE EMPTYING A 7,000-POUND BOX OF MIXTURE INTO THE FURNACE.

Before proceeding to a detailed description of the furnaces, it will be well to state that the open hearth process is used exclusively at the Bethlehem Steel Works, and no Bessemer steel whatever is made. While Bessemer steel is admirably suited for steel rails and structural material for buildings and bridges and for shipbuilding, it has not hitherto been possible to secure by this process the high qualities which are demanded in all specifications of gun steel and armor plate. The superior results obtained with this process are due to several causes, but chiefly to the fact that the process of decarbonizing in the open hearth process being greatly protracted, it is possible to make a large number of successive tests and stop the process at the moment when the steel in the furnace has reached the exact composition required. In the Bessemer process the decarbonizing is accomplished by pouring the molten metal into a converter and blowing air through it until the whole of the carbon and most of the sulphur, phosphorus and silicon have been burnt out, when a certain amount of spiegeleisen is added to bring up the percentage of carbon to the desired point. The Bessemer "blow," as it is called, occupies twenty minutes only, and should the blowing be extended beyond the moment at which decarbonizing is complete, the metal will be burnt, with subsequent injurious effects to the steel. The open hearth process, on the other hand, occupies from eight to twelve hours; and it is possible to know at any time just exactly what are the conditions of the heat and what chemical changes are taking place. Moreover, the temperature can be most carefully regulated.

The distinctive qualities which are sought in the manufacture of gun steel and armor plate are obtained by varying the composition of the mixture, by the method of treatment in the furnace, and by subsequent treatment of the cast ingot by fluid compression, forging, tempering and annealing. The requisite properties for the gun steel furnished to the government are hardness, to enable the guns to resist the wearing action of the projectiles and the erosion from the powder gases; toughness, to enable it to undergo change of form without fracture; elasticity, to enable it to give under enormous pressures, and yet return to its original dimension, and a high, though not an excessive, ultimate breaking strength. For armor plate the desirable qualities are extreme hardness, particularly at the face, combined with great thoughness throughout the whole body of the plate. The latter quality is secured in the Harveyized armor by the introduction of a certain amount of nickel, and in the Krupp armor of other elements during the furnace treatment; while in both types of armor the hardness and the toughness are enhanced by a most elaborate system of forging, tempering and annealing, which in the case of the Krupp plate, has no parallel in the whole range of the industrial arts. The open hearth furnace, with its regenerators, is a most elaborate and costly construction. The furnace proper consists of a large dish-shaped structure, lined with refractory sand, into which the mixture is loaded by the charging machine already referred to. The furnace is heated with producer gas, manufactured by burning coal in air-tight ovens, which are fed with air under pressure in an insufficient amount for complete combustion. The resulting carbon-monoxide gas passes through large regulating valves, located below the charging platform, then through a mass of firebrick checkerwork, and finally enters the side of the furnace through the lower flue, shown in the engraving. Air is admitted by way of the valves, and passes through

The scrap from the various forges and machine shops is brought to this yard, and stacked according to its chemical composition. Here the "mixture" is made up in boxes and carried on cars to the open hearth furnaces.

THE STOCK YARD AT THE BETHLEHEM STEEL WORKS.

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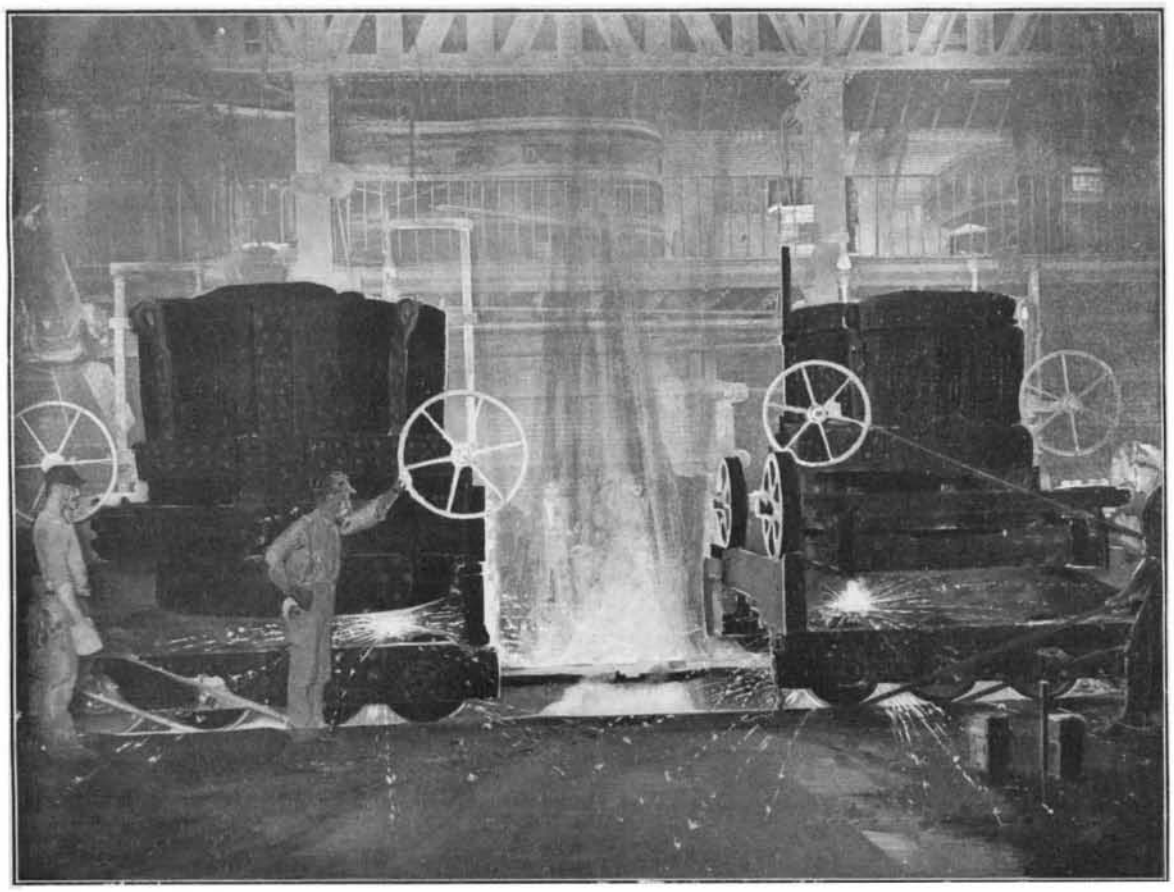
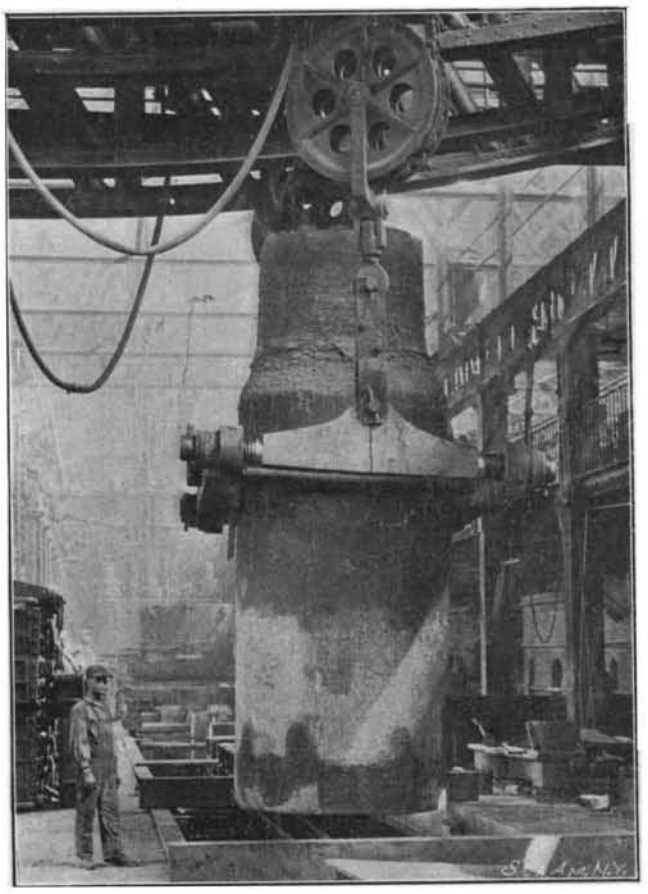


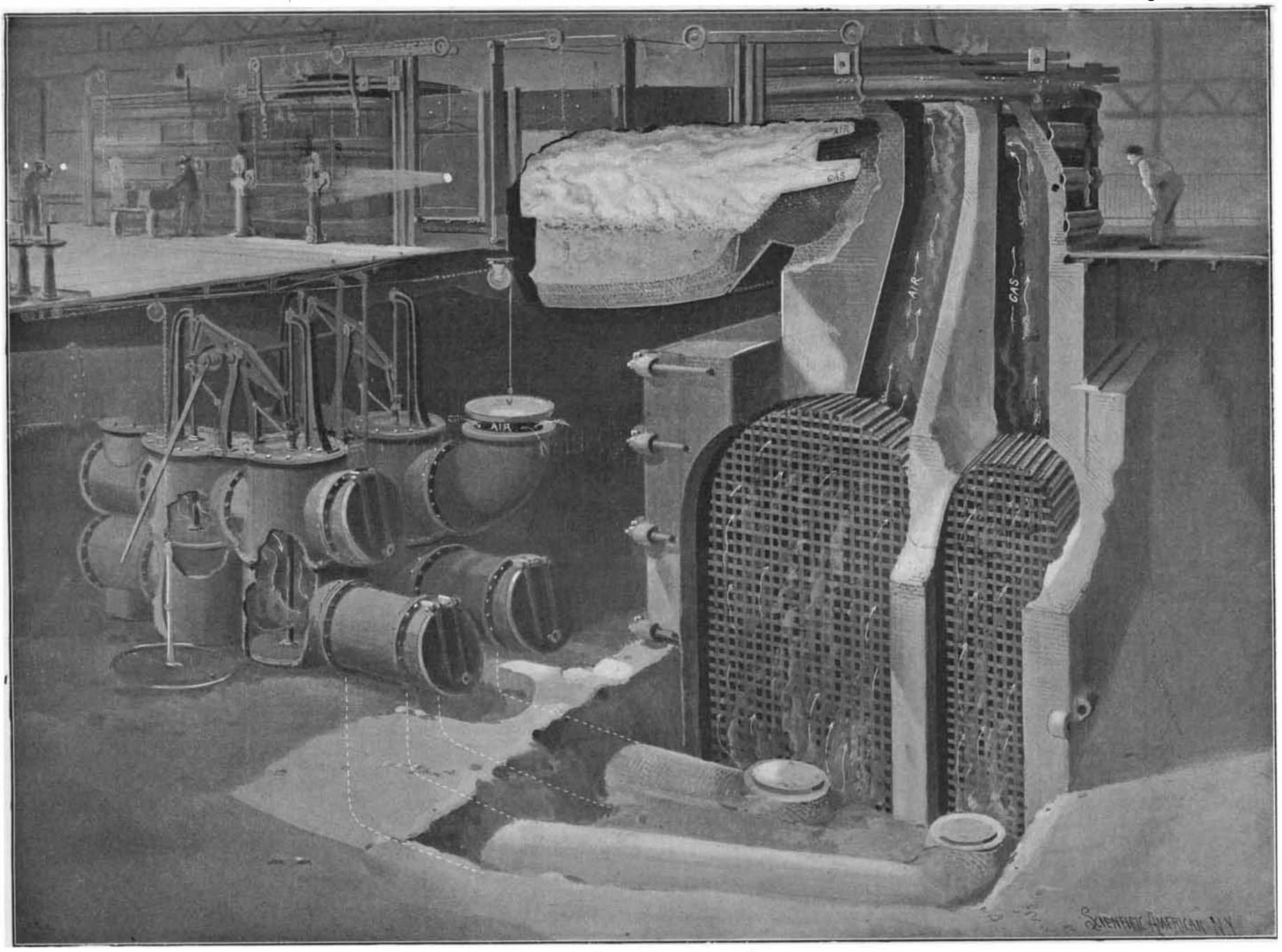
The metal is being run into the mold from the two ladles above the casting pit.

Casting a Large Armor-Plate Ingot.



Cast for tube of 16-inch, 126-ton army gun.

A 100-Ton Nickel-Steel Ingot.



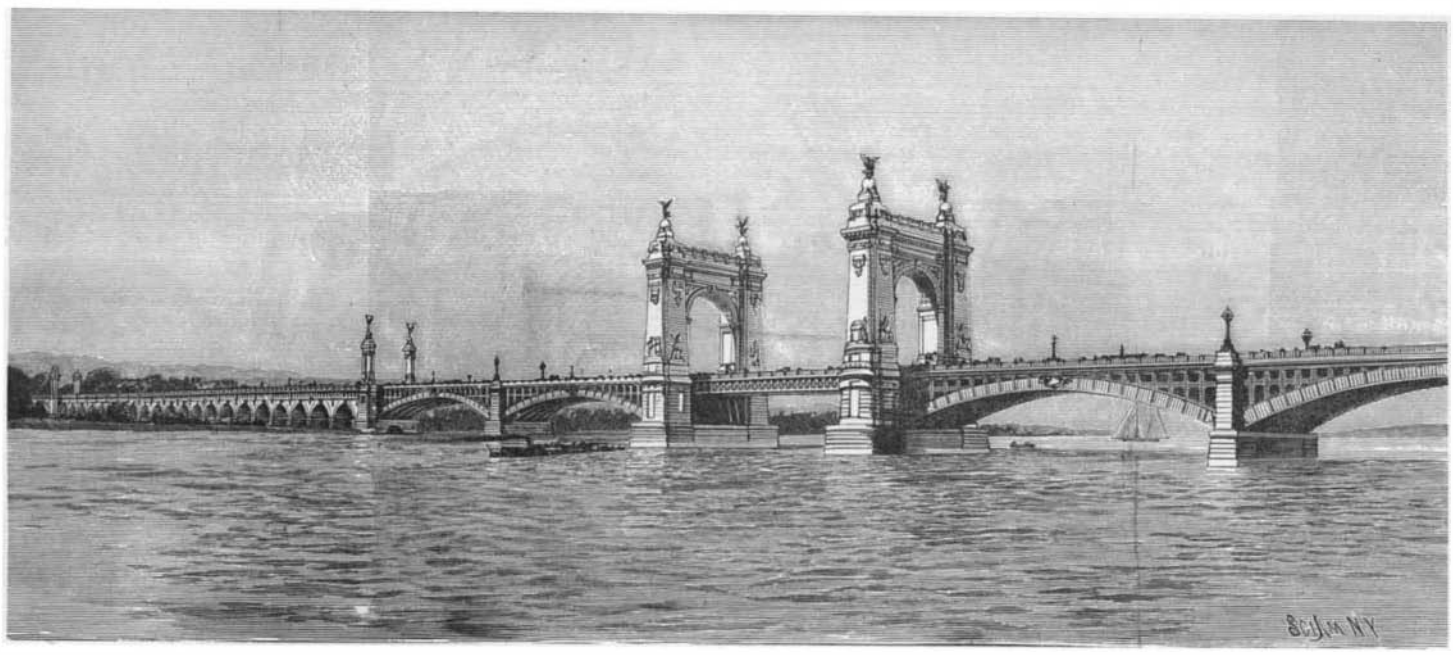
Part Sectional View through an Open Hearth Furnace, Showing Regulating Valves, Checkerwork and Air and Gas Flues.

MANUFACTURE OF GUNS AND ARMOR AT THE BETHLEHEM STEEL WORKS—I. THE OPEN HEARTH PROCESS.—[See page 312.]

another mass of checkerwork built up alongside the first-named mass, and is conducted to the furnace by two flues, which are located on each side of and above the gas flue. Here the gas and air mingle and combustion takes place at extremely high temperatures, ranging from 2,700° to 3,000° F. The products of combustion pass over the charge and out at the opposite side of the furnace, and through a set of flues and checkerwork exactly similar to those through which the gas and air entered, raising the checkerwork to a high temperature. About every twenty minutes the lever controlling the regulating valves is thrown over and the gas and air are directed through the now heated checkerwork and flues on the left-hand side of the furnace. Here they are regenerated to from 1,500° to 1,800° F. The flow of gas is reversed every twenty minutes during the ten to twelve hours occupied by the process.

It takes about six and a half hours to melt the charge, and four to six hours are consumed in boiling down to get rid of the carbon and various impurities. As soon as the heat is melted, samples are taken from the furnace and carefully analyzed, and these tests are repeated at frequent intervals until the heat is ready for casting. One of the views shown on our front page is taken at the back of the open hearth furnace above the casting pit and shows the process of casting. As soon as the steel has reached its proper composition, a tap hole is opened and the steel is run off into the large ladles, which are shown in the engraving, from which it is run into the molds by opening a tap hole in the bottom, which is ordinarily closed with a plug of fireclay. In all of these castings a considerable excess of metal, known as the "sinking head," is formed at the top of the mold, which serves the double purpose of compressing the lower portion of the ingot, increasing its density, and closing any cracks or holes which might form during cooling. It also serves to collect the impurities in the metal, which rise by their lesser gravity to the surface. The metal which is to be worked up as gun steel, is subjected to hydraulic pressure in what is known as the fluid compression process, a description of which will be given in a succeeding article; but a few of the largest castings for gun steel and all of the armor plate castings, on account of their great size, are cast direct in the form of massive ingots. One of our illustrations represents the great 100-ton ingot which was cast for the manufacture of the 16-inch army gun, which is now nearing completion at the Watervliet Arsenal.

MOLYBDENITE is proving to be of value in the manufacture of steel. The present market valve in Pittsburg is $200



PROPOSED NATIONAL MEMORIAL BRIDGE ACROSS THE POTOMAC AT WASHINGTON.

PROPOSED NATIONAL MEMORIAL BRIDGE ACROSS THE POTOMAC AT WASHINGTON.

The Secretary of War has just accepted the final plans for the proposed Memorial Bridge to be built across the Potomac to Arlington. The successful winner of the competition is the well-known bridge engineer, Prof. W. H. Burr, of the Department of Civil Engineering of Columbia College, New York. Four prominent bridge constructors, namely, Prof. W. H. Burr, George S. Morrison, Leffert L. Buck and William H. Hutton, all of New York city, were especially invited by the Secretary of War to compete for the honor of designing the Memorial Bridge. The designs and drawings were to be paid for in their order of merit as recommended by the Board of Engineers, as follows: For No. 1, $1,200; No. 2, $1,100; No. 3, $1,000; No. 4, $900. The designs and drawings were then to become the property of the United States.

The selection of the design marks an important step in this commendable project, which contemplates the spanning of the Potomac River between the government reservations at Washington and Arlington with a monumental structure which shall form a fitting national monument to American patriotism in its highest and broadest sense.

The specifications called for the presentation of two designs, one for a bridge with a draw opening and to provide for street cars as well as for ordinary vehicles and pedestrians; the other for a bridge with draw opening, but without provision for street cars, etc. After full consideration of the various plans for the bridge and approaches, including the architectural features, ornamentations, cost, etc., the board concluded that the general design of Mr. Burr should be designated as first in the order of merit and should be adopted, subject to a few modifications, such as width, slope of roadway, towers, provisions for tramcars, and such other minor modifications as might develop during the progress of the work.

The main features of Prof. Burr's design No. 1 are as follows: The whole structure, with the exception of the bascule over the main channel, will be of arched construction, and will consist of the bridge proper over the river channel, and a long approach at either end; the four main arches and bascule which constitute the former being constructed of steel and the approaches of masonry.

The design is for a double deck bridge, 60 feet in width between railings, providing for two sidewalks, each 10 feet wide, and a roadway 40 feet wide. A double-track street railway is provided for upon the lower deck. The total length of the openwork of the bridge proper and approaches will be 3,440 feet. The bridge is to consist of two 283-foot steel arches, one steel draw span having a clear width of 213 feet, and two more 283-foot steel arches. The draw-span has two bascule arms supported on trunnions, balanced by rear extensions and counter-weights. The clear opening is about 167 feet, and the span from center to center of trunnions, 235 feet. The floor is to be of asphalt cork block. It is proposed to operate the draw by electric motors. The bascule and the adjacent piers are to be built on bed rock by the pneumatic process, the caissons to be filled with concrete; the other piers are also to be founded upon bed rock and built up within cofferdams. The 283-foot steel arches are segments of a circle, the springing line being 24 feet above mean low water. The Washington approach is to consist of fifteen 46-foot spans, masonry arches, back of which is an earthen embankment, 500 feet long. The Arlington approach will consist of twenty-one 46 foot masonry arches, approached by an earthen embankment 1,500 feet long. The principal divisions of the bridge are marked by massive masonry arches and towers, decorated with emblematic groups of statuary, etc., commemorating men distinguished in the foundation and development of the Republic. The cost of the structure is estimated at $4,083,850.

ALEXANDRE III. MEMORIAL BRIDGE, PARIS.

ALEXANDRE III. MEMORIAL BRIDGE, PARIS.

The Pont Alexandre III., though completed, was not relieved of unsightly superstructures until a day or two prior to the official opening of the Paris Exposition. As it stands today, this superb bridge, with its four lofty towers, each surmounted by a golden Pegasus that glitters in the sunlight, forms the connecting link between two new sections of the city and the Fair, the fame of which will soon be world-wide. The new