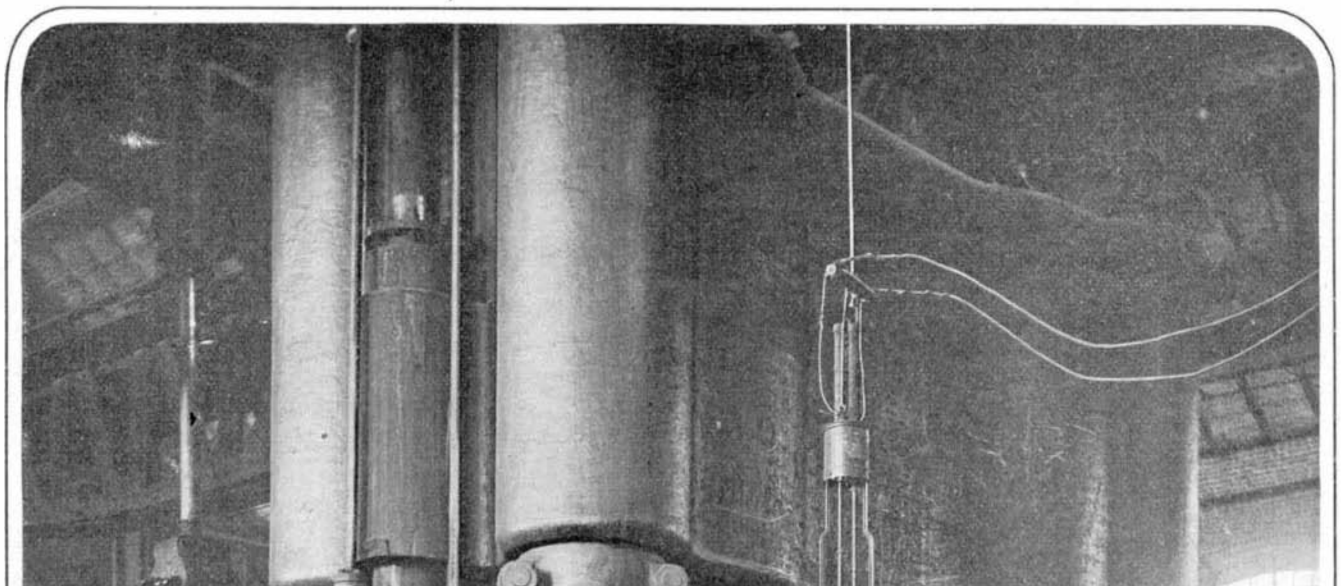
Manufacture of Armor Plate.—As already explained, the armor-plate ingots are cast with a large excess of metal, which serves both as a "sinking head" and also as a rude sort of handle, by which the enormous mass may be manipulated on the mandrel of the hydraulic press and transferred to and from the furnace. The excess of metal in an armor-plate ingot is greater than that of any other mass of metal casting, the finished plate representing on an average about 40 per cent only of the original casting. Some of these castings weigh as high as 275,000 pounds. When the ingot has been hauled to the forge, its "sinking head" is placed in one end of a massive cast-steel sleeve, from the other end of which projects a long steel bar about two feet in diameter, which is provided with sliding balance weights. The sleeve is supported in an endless chain sling from an overhead crane, by which it is transferred from the heating furnace to the hydraulic press. Here the total "squeeze" given to the plate when it is upon the anvil is the same as though a big battleship like the "Maine" were permitted to bear with its full weight upon it. The massive forging is lifted, turned over, flattened (kneaded as it were) and brought down to size with an ease which must be seen to be appreciated. At the first forging the ingot is roughed down to the approximate shape of the finished armor plate, but is considerably thicker. It is now ready for that most important process of hardening the face, technically known as cementation. This varies greatly in its details for Harvey and for Krupp armor, although its general principles are the same. In both processes the plate is placed in a furnace, and exposed for from three to four weeks to the action of highly carbonaceous material. In the case of the Harvey plate the carbonizing is effected by a layer of bone dust, charcoal, and other suitable materials. In the Krupp process the carbonizing agent is used in the form of a gas. After the plate has taken up an excess of carbon for the depth of an inch and a quarter to an inch and a half, it is returned to the forge, heated, and forged down to the finished thickness. Then it is transferred to the machine shop, where test specimens are removed and subjected to tensile tests in the presence of naval inspectors. Here the plate is sawn down to the correct size, and such machining as is necessary is done upon it. We present some illustrations of the remarkable collection of machinery in the armor-plate machine shop. It was all built specially for this work, and is framed on a colossal scale. In one place will be seen a circular saw that is capable of taking a cut through a steel plate 24 inches in thickness and 33 feet long. Elsewhere will be seen a huge rotary planer engaged in taking a 6-inch cut from the edge of a 10-inch plate faster than a saw will cut on a 6-inch strip from the same plate. Practically the whole of the machine work has to be done before the final hardening of the armor-plate by the water spray, for the steel tool does not exist that can touch the hardened face of a Harvey or Krupp plate. The plate then takes a journey to the forge again, where it is carefully straightened or bent, as the case may be, and brought to the desired form. Time and again the huge mass, weighing as much as a locomotive, will be lifted on to cars and transported from one building to another, undergoing operation after operation, until at last it is ready for the process of hardening, which consists of heating the plate to a temperature slightly above the recalescent point, and then case-spraying it with innumerable streams of water delivered under high pressure. Then follows the oil-tempering, to remove strains, and another heating for the final "rectification" to the proper shape. After the hardening, the plate is again taken to the machine shop, where additional tests are taken for the satisfaction of the navy inspectors, and it receives its finished machining by means of grinding machines. In the rough-machining already alluded to, the plate was brought practically to its finished shape and size, and now that its face has been hardened, it is only possible to act upon the inch and a half of extremely hard surface by means of the emery grinders. All the warped surfaces, such as those at the portholes, at the sighting hoods, etc., have to be chipped and finished by hand with files, the outer hardened portion being ground down. Then follows the drilling of the holes for the bolts by which the armor is fastened to the backing and framework of the ship, and the tapping of the bolt holes, after which the armor plates are assembled to make sure that the joints are true and close. One of our illustrations shows the barbettes for the battleship "Louisiana" in the erecting shop, and the workmen busy with the grinding wheels, finishing off the top edges and smoothing down irregularities in the vertical joints. Each grinder is operated by a rope drive from a portable motor standing on the floor of the shop. After the armor has been assembled and the bolts tried in the bolt holes, it is inspected carefully by government representatives. Then it is taken down, the bolt holes are filled with tallow and white lead, and the plates stamped with the name of the vessel and the part of the ship to which plate is assigned. The final operation is the weighing, which, in the case of such costly material, is carried out with the greatest care.



STRAIGHTENING A 14-INCH ARMOR PLATE UNDER A HYDRAULIC PRESS.

Why Armor Plate is Costly.—The general public has always been mystified at the extremely high price paid for armor plate. We have endeavored to indicate in the course of this article some of the causes of this high cost, the most important of which is the great length of time required for the successful manufacture of a plate; for, on an average, every plate is being constantly worked upon, either in furnace, forge, machine shop, or annealing and tempering department, for a continuous period of nine months. Other causes of high cost are: the large number of separate operations, the frequency with which the great masses must be transported, and the distances over which they must be carried in their journey from one department to another. To illustrate the vast scale on which the works are laid out and the distances to be covered from shop to shop, we may mention that the whole establishment extends in one direction continuously for a length of a mile and a quarter, and that the forty or fifty handlings and transshipments, which occur in making a single Krupp plate, take place in and between such buildings as the open-hearth structure, which is 111 feet wide by 1,950 feet in length; the machine shop, 116½ feet in width by 1,375 feet in length; the armor forge, 850 feet in length; and a face hardening department and an armor-plate machine shop, both of which are but little less in size. Further elements of expense are the large percentage of losses which is liable to occur, the high first cost of the extensive plants that must be laid down, and the fact that new and improved methods of manufacture may at any time render the plant more or less obsolete. The greater cost of the Krupp armor is largely compensated for by its much greater resisting qualities, which make it possible to give equal defensive qualities for 20 to 25 per cent less weight of armor.

STATISTICS OF OUR IRON AND STEEL PRODUCTION.

The statement that last year forty per cent of the pig iron in the world was produced in the United States gives one no very definite realization of the quantity of that product, though he be reminded on every hand by iron and steel ships, bridges, railroads, buildings, machinery, tools, nails, tacks, etc., *ad nauseam*, that this is the iron age. Even the statement that the United States last year mined over thirty million long tons of iron ore, gives one no adequate impression of the vastness of this amount. On the other hand, if one should see the entire iron ore production of the year piled up in a single heap, he would readily comprehend this quantity by a comparison of the pile with familiar objects in the landscape. This shows us that it is large numbers instead of large quantities which confuse the mind; for example, the statement that a wagon holds over 30,000,000 grains of coal would give a person a very hazy idea of the actual quantity specified, but he would immediately comprehend the quantity if told that it represented two tons; for a larger unit of weight would be used, thereby reducing the count to a figure well within the mental grasp. Thus in trying to represent to our readers just how large are the quantities of materials used in the iron and steel industry, we have endeavored to choose larger units of measurement; and finding that our standard measures are far too small for the purpose, we have resorted to the use of familiar landmarks as bases of comparison.

As a unit of bulk, no larger single monument has man produced than the old pyramid of Cheops, and large though it be, it is all too small when used as a unit by which to measure the stupendous volume of material used in our pig-iron production of a single year. In the accompanying illustration, the huge blast furnace shown at the left represents a furnace which would receive at a single charge all our iron ore production during the year 1902, together with the fuel and limestone used. The charge measures approximately two billion cubic feet, or to use our proposed unit of bulk, this would be equivalent to twenty-four pyramids. As many individuals may have formed no adequate conception of the size of the Great Pyramid, we have used as an additional basis of comparison the tallest building in the world, namely, the Park Row Building in New York. This building measures 390 feet in height, and it would require thirteen such buildings, placed one above the other, to equal the height of our hypothetical blast furnace.

FUEL.

Of the contents of the blast furnace, by far the larger bulk is fuel, though the weight of the iron ore is almost twice that of the fuel. The square columns in our illustration will serve to give one some idea of the amount of fuel consumed last year by the blast furnaces of the United States. No exact figures are available for 1902, but a fair estimate would be about 16,000,000 tons of coke, 1,600,000 tons of coal, and 300,000 tons of charcoal. Coke is so light that if the 16,000,000 tons were built up in a column 400 feet square, the column would reach an altitude of 6,500 feet. No human monument is large enough to give us, by comparison with this column, any idea of such a height. If the base of the column were situated at sea level, a person at the top could look down on the summit of Mount Washington, N. H., and it would overtop every mountain in this country east of the Rockies.

Our column of coal includes both anthracite and bituminous. In the last two years there has been a considerable falling off in the use of anthracite while bituminous coal mixed with coke has shown a great increase over former years, so that our column would probably be made up of two parts bituminous to one anthracite coal. Their combined bulk would form a column 200 feet square by 1,300 feet high—a midget in comparison to the coke column, but not so small after all when compared with the Park Row Building.

Charcoal, which is the smallest item in the fuel statistics for 1902, or about one-fifth of the number of tons of coal, yet forms a column nearly two-thirds the height of the coal column, or twice that of the Park Row Building.

FLUX.

The amount of limestone used for fluxing purposes last year amounted to 9,490,090 tons. This would make a column 5,500 feet high, with a cross section 200 feet square. It may be interesting to note here that oyster shells are used in one of the furnaces in Maryland in place of limestone.

IRON ORE.

The next column, which is of a height equal to that of the coke column is composed of 34,636,121 tons of iron ore. However, this represents in bulk only one-quarter that of the coke.

PIG IRON.

All the above-mentioned materials were used last year to produce 17,821,307 tons of pig iron. This makes a column twice the height of the Eiffel Tower, the tallest monument to human skill in the world.

STEEL.

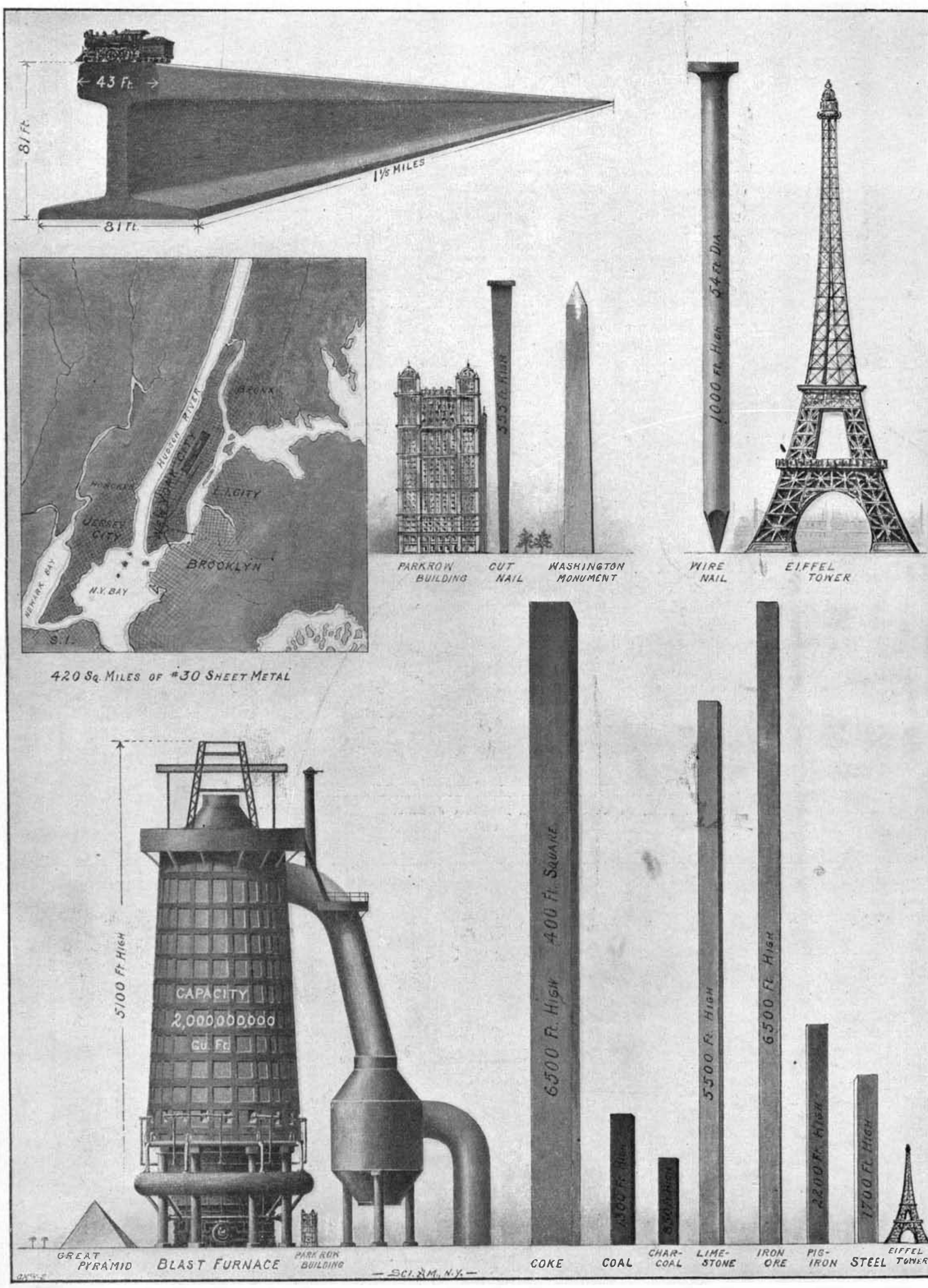
The larger part of the pig-iron production of this country is converted into steel; 14,947,250 tons represent the total output for last year. Of this, 9,138,363 tons was made by the Bessemer process, 5,687,729 by the open-hearth process, and 121,158 tons was crucible steel.

FINISHED PRODUCTS.

Of the finished products for the year, 2,947,933 tons represent the amount of iron and steel formed into rails. If all this metal were rolled into a single rail of standard proportions, it would measure approximately 81 feet high, and would be about a mile and one-fifth long. The base would, of course, equal the height, and the tread would have a width of 43 feet. In our illustration we have shown the relative proportions of a locomotive of average size, placed on this rail.

Next in quantity to the iron and steel rail production is last year's output of plates and sheets; 2,665,409 tons of metal were thus converted. This amount, if rolled into a single sheet of No. 30 standard gage, which is the thinnest sheet steel commercially used, would cover 420 square miles, or nearly twenty times the area of the island of Manhattan. The extent of this area is illustrated in the accompanying map of New York city and its vicinity.

The production of nails forms no small part of the finished products for the year. Wire nails represent, of course, a much larger part of the output. The totals are 10,982,246 100-pound kegs of wire nails and 1,633,762 100-pound kegs of cut nails. Following the method in our two previous comparisons, we have represented each amount by a single nail of standard proportions. The cut nail would tower far above the Park Row Building, measuring almost exactly the height of the Washington Monument, while the wire nail would rise to nearly double this height, overtopping the Eiffel Tower, and forming a solid column of metal 54 feet in diameter and 1,000 feet high.



COMPARATIVE DIAGRAM SHOWING THE TOTAL ANNUAL AMOUNT OF RAW AND FINISHED MATERIALS OF THE IRON AND STEEL INDUSTRY IN THE UNITED STATES.