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Nickel and Nickel-Steel.

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(Florida Meeting, March, 1895.)

UP to within a few years, the consumption of nickel has been more directly dependent upon the available supply than that of any of the other useful metals.

The Gap mine, in Lancaster county, Pennsylvania,* has been, for the last quarter of a century, the only property in this country furnishing nickel in paying quantities. Its yearly output was about 300,000 pounds of metallic nickel, or nearly half the amount used annually in the United States. Foreign nickel from mines on the New Caledonia islands, in the South Pacific, found entrance into our markets as the production of the Gap mine fell off. The price of nickel was constantly maintained, and no special effort was made to extend its use. Over-production was cautiously guarded against, and all surplus metal was held by the banking-houses of the Rothschilds, who assumed the bonded indebtedness of the *Société le Nickel.* The opening of the Ontario nickel-mines has, however, brought about a radical change; and nickel from the Sudbury district can be delivered in New York within four days, and in European markets within two weeks, as against two months consumed in transporting South Pacific ores. Former prices have been irretrievably smashed, and European trade-journals comment favorably on the influence which Canadian nickel has had in making lower prices, and breaking the backbone of the "nickel trust."

PRODUCTION AND COSTS.

The quantity of nickel produced and the prices which it commanded may be briefly summarized as follows:

The total production of the world from 1840 to 1860 was about 100 to 250 tons yearly of metallic nickel; from 1860 to

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* See *Trans.*, xxiv., 620, 883.

1870, 600 to 700 tons yearly; from 1870 to 1889, about 1500 tons yearly; in 1890, 2000 tons; and a fair estimate for 1894 is about 5000 tons. The metal sold for $2.25 per pound in 1860; in 1873 to 1875, for $6 to $7 per pound. From that time the price of nickel gradually declined, being $0.65 per pound in 1892, and less than $0.40 at the present time. The exceedingly high prices in 1873 to 1875 were caused by the adoption of a nickel coinage by Germany and some other European nations, causing a sudden demand which exceeded the supply.*

Properties of Nickel.

Nickel has physical properties similar to those of iron and copper. It is less malleable and ductile than iron, and less malleable and more ductile than copper. It alloys with these metals in all proportions. It has nearly the same specific gravity as copper, and is slightly heavier than iron. It melts at a temperature of about 2900° to 3200° Fahr. A small percentage of carbon in metallic nickel lowers its melting-point perceptibly. Nickel is harder than either iron or copper; is magnetic, but will not take a temper. It has a grayish-white color, takes a fine polish, and may be rolled easily into thin plates or drawn into wire. It is unappreciably affected by atmospheric action, or by salt water. Commercial nickel is from 98 to 99 per cent. pure. The impurities are iron, copper, silica, sulphur, arsenic, carbon, and (in some nickel) a kernel of unreduced oxide. It is not difficult to cast, and acts like some iron in being cold-short. Cast bars are likely to be porous or spongy, but, after hammering or rolling, are compact and tough. A piece of pure nickel rolled plate (A) and an untreated cast bar of nickel (B) were submitted to physical test by the writer, at the works of the Carbon Iron Co., Pittsburgh, Pa., with the following results:

Cross-section. Inches.	Length between fillets. Inches.	Ultimate strength per sq. in. Pounds.	Reduction of area. Per cent.	Ultimate elongation. Per cent.
A—3.11 by .045	8	69,390	31.5	31.4
B—0.623	2	30,985	6.5	6.5

The following table shows the properties of the metal.

* J. H. L. Vogt, *Nikkel-forekomster og Nikkel-produktion*, Kristiania, 1891.

Test of Strength of Malleable Nickel.

Material.	Tensile Strength. Pounds per square inch.	Elongation. Per cent.	Remarks.
Casting	85,000	12	
Wrought nickel	96,000	14	Wrought from 2 by 4 inches to ½ inch square.
Wrought nickel, annealed	95,000	23	Wrought from 2 by 4 inches to ½ inch square.
Rolled nickel	78,000	10	Very hard, because not annealed after rolling; rolled from 2 to ⅛ inch.

These figures are an average of a number of tests. As there were flaws in several of the specimens, the results are lower than they otherwise would have been.

Nickel readily takes up carbon, and the porous nature of the metal is undoubtedly due to occluded gases. According to Dr. Wedding,* nickel may take up as much as 9 per cent. of carbon, which may exist either as amorphous or as graphitic carbon, or in both conditions. The affinity which nickel shows for carbon is manifested in a striking manner in the Mond process of refining nickel.

Dr. Fleitmann, of Germany, first discovered that the use of a small quantity of pure magnesium would free nickel from occluded gases and give a metal capable of being drawn or rolled perfectly free from blow-holes. Magnesium in nickel, like manganese in steel, acts as a purifying agent, and it improves the ductility and malleability of nickel to such an extent that the metal may be rolled into thin sheets 3 feet in width. Aluminum or manganese may be used equally as well as a purifying agent; but either, if used in excess, serves to make the nickel very much harder.

Nickel-Alloys.

Nickel will alloy with most of the useful metals, and generally adds the qualities of hardness, toughness, and ductility. It is commonly alloyed with copper and zinc in making the composi-

* *Stahl u. Eisen*, No. 8, 1893, p. 328.

tion known to the trade as German silver, white metal, British plate, Packfong or Chinese metal, Argentan, Electrum, and Maillechort, the hardness and whiteness of this alloy depending upon the percentage of nickel it contains. Nickel coins current in Germany, Belgium, Italy, the United States, and Latin American countries, contain 25 per cent. of nickel and 75 of copper. German silver has a considerable use in electrical fixtures and appliances, having a very high specific resistance.

The alloy known as "Christofle" is composed of 50 parts nickel and 50 parts copper. As yet comparatively little use is made of this alloy in the United States; abroad, it is largely employed in the manufacture of coachmakers' and saddlers' supplies, as well as for surgical instruments.

Analyses of nickel-alloys of various countries do not show very great difference in the percentage of nickel.

Analyses of Nickel-Alloys.

	Copper. Per cent.	Nickel. Per cent.	Zinc. Per cent.	Iron. Per cent.	Cobalt. Per cent.
Berlin Alloys.					
Richest,	52.00	22.00	26.00	......	......
Medium,	59.00	11.00	30.00	......	......
Poorest,	63.00	6.00	31.00	......	......
French Alloys.					
Tableware,	50.00	18.70	31.30	......	......
"	50.00	20.00	30.00	......	......
Maillechort,	65.40	16.80	13.40	3.40	......
Austrian Alloys.					
Tableware,	50.00	25.00	25.00	......	......
"	55.60	22.20	22.20	......	......
"	60.00	20.00	20.00	......	......
Sheffield, England, Alloys.					
Silver white,	55.20	20.70	24.10	......	......
Electrum,	51.60	25.80	22.60	......	......
Hard alloy,*	45.70	31.30	20.00	......	......
English,	60.00	18.80	17.80	......	3.40
" elastic,	57.00	15.00	25.00	......	3.00
Chinese packfong,	40.40	31.60	25.40	2.60	......
American Alloys.					
Alloy for castings,	52.50	17.70	28.80	......	......
" " bearings,	50.00	25.00	25.00	......	......
Bullet-shell,	75.50	24.10	......	0.40	......
One-cent coin,	88.00	12.00	......	......	......

* Can be worked cold.

		Per cent.
Vivian & Co., Swansea, copper-nickel alloy, . . .	Si,	.303
	Fe,	.826
	Cu,	48.49
	Ni,	50.09
Société le Nickel, Paris, copper-nickel alloy, . .	Si,	.186
	S,	.089
	Cu,	48.740
	Ni,	49.26
	Fe,	.610
Wiggins & Co., Birmingham, England, copper-nickel alloy, ...	Si,	.136
	S,	.041
	Cu,	47.68
	Ni,	49.87
	Fe,	1.228

Steel and Nickel-Steel.

It will hardly be questioned that scientific research is directed most energetically at the present time upon the art of uniting elements in such proportions that they may be more serviceable than in their pure state. The limit of ultimate strength in the practical application of pure metals has about been reached. The practical introduction of steel into general use has made a new era in manufactures, and "steel is only modified iron; the difference in its state from a condition as soft as copper to one as hard as glass being due to the modifications of carbon." Up to recent times the distrust of steel was so great that marine and civil engineers were afraid to use it. In the early days of the Pennsylvania railroad, its steel rails were imported from England, bent to the curves of the roadbed. As a superior metal for cutlery and tools it brought a fancy price of 36 cents per pound. To-day our battle-ships are sheathed with thousands of tons of the best steel, and 800 tons are used yearly in the manufacture of steel pens. Carbon-steel was a great improvement over iron, and the use of nickel in steel is found, in all cases in which careful investigation has been made, to mark a further improvement in the manufacture of steel. A German authority has recently observed that, considering the mutual affinity of nickel and iron, as shown by the presence of nickel in meteoric iron, it is remarkable that the example of the handiwork of Nature had not been copied before this.

In a paper read before the Iron and Steel Institute, Mr. James Riley, manager of the Steel Works of Scotland,* says:

* "Alloys of Nickel and Steel," *Journ. I. and S. Inst.*, No. 1, 1889, p. 54.

"If the engineers of those stupendous structures (the Forth Bridge and the Eiffel Tower) had had at their disposal a metal of 40 tons (ultimate) strength and 28 tons elastic limit, instead of 30 tons strength and 17 tons elastic limit in the one case, and say 22 tons strength and 14 to 16 tons elastic limit in the other, how many difficulties would have been reduced in magnitude as the weight of material was reduced!"

Mr. Riley's paper was the first to present publicly the merits of nickel-steel, and attracted much attention.

Just about that time the Ordnance Bureau of the United States Navy Department was seeking the best type of armor-plate for the new battle-ships, and the superior qualities of nickel-steel were brought to the attention of the department. Secretary Tracy authorized a comparative trial of three armor-plates forged at the largest steel-works in France and England, and representing the best types of simple steel, nickel-steel and compound (hard and soft) steel armor-plates. The result of this trial, in September, 1890, indicated so strongly the superior merits of nickel-steel that Congress was justified in granting an appropriation for the purpose of purchasing the necessary quantity of nickel to continue experiments. These experiments were uniformly successful, and the Navy Department adopted nickel-steel for armor-plate, and, wherever possible, in the work of the Ordnance Bureau. Nickel-steel armor of the best quality is now regularly produced by two of the large steel-works of Pennsylvania, the Bethlehem Iron Co. and the Carnegie Steel Co., which have special facilities for handling this class of work. The former concern forges all its plates, while the latter employs rolls.

The Harvey process of hardening the face of nickel-steel armor by cementation to the depth of several inches, with subsequent water-hardening, is an important advance in making nickel-steel armor still more effective.

The type of armor-plate used by the British Admiralty is a compound plate made up of a hard steel face and soft steel backing. They considered the question of the best armor for their battle-ships as settled in 1878, when they adopted this type of armor-plate. Comparing the relative depth of penetration in the Harveyized nickel-steel, all-steel, compound and soft-steel armor-plates, the ratio of superiority in favor of the Harveyized nickel-steel plate is as follows, in the order named:

Relative penetration.	Kind of armor plate.	Relative resistance.
1.	Nickel-steel, Harveyized.	1.
1.64	All steel.	0.609
1.75	Compound.	0.572
2.2	Soft steel.	0.455

so that for equal power of resistance there can be a saving of 43.8 per cent. in weight, in favor of the Harveyized plate over the compound plate.* The ordnance trials at the Indian Head proving-grounds are as severe as any in the world; and it is with pardonable pride that the Bureau of Ordnance of the Navy regards the placing of an order for nickel-steel armor-plate by the Russian government with the Bethlehem Iron Company as an acknowledgment that we have, to-day, the material and facilities, and are forging in this country armor and projectiles that have no superior in the world.†

Krupp, of Essen, is furnishing, for vessels of the "Brandenburg" class in the German navy, nickel-steel armor made on a new system. The plates are 5½ inches thick, and show a resistance equal to plates of 9¾ inches made by the old system.

The French government uses an armor-plate containing 0.4 per cent. carbon, 1 per cent. chromium and 2 per cent. nickel.

Nickel furnishes toughness; and chromium, hardness. It is in the highly desirable qualities of extreme toughness and elasticity that nickel imparts valuable properties to steel, increasing its resistance to shocks and hindering crystallization.

The Bureau of Steam Engineering, United States Navy, has had the two intermediate line-shafts of the "Iowa" and the two propeller-shafts of the "Brooklyn" made of nickel-steel by the Bethlehem Iron Company. The line-shafts are 15¾ inches outside and 9¾ inches inside diameter, while the propeller-shafts are 17 inches outside and 11 inches inside diameter; the walls being in both cases 3 inches thick. The government specifications require a tensile strength of 85,000 pounds and 50,000 pounds elastic limit. Six test-pieces from one of the propeller-shafts of the "Brooklyn" gave the following results:

Nickel-Steel Propeller-Shaft for U. S. Ship "Brooklyn."

Hollow-forged, oil-tempered, rough-machined. Outside diameter, 17⅛ inches; inside diameter, 11 inches; length, 38 feet 11⅜ inches; weight, 19,112 pounds.

* See *Stahl u. Eisen*, No. 4, 1893, p. 143.

† See article "British Armor and Ordnance," *London Engineer*, March, 23, 1894.

Test bars cut from this tube gave the following results :

Dimensions of specimens. Inches.	Tensile strength. Lbs. per sq. in.	Elastic limit. Lbs. per sq. in.	Elongation. Per cent.	Contraction. Per cent.	Fracture.
0.496 by 2	94,185	58,995	26.4	60.83	Dense gray lipped.
0.497 by 2	94,245	60,770	25.55	60.58	" " "
"	93,215	58,740	25.8	61.33	" " "
"	93,730	60,770	25.8	59.81	" " "
0.498 by 2	92,410	59,550	28.0	60.74	" " "
"	90,350	56,470	28.0	60.74	" " "

It is to be noted that the elastic limit of this shaft is about equal to the tensile strength of a shaft made of ordinary mild steel, while the elongation and contraction of area are nearly the same.

A comparison of the strength of the nickel-steel shafts of the U. S. vessels "Brooklyn" and "Iowa," within their elastic limits, with that of solid shafts of the same sectional area made of soft, simple steel, having an elastic limit of 30,000 pounds per square inch, and also a comparison of their weights per linear unit with that of solid soft steel shafts of equal strength, may be of interest. The following table gives the results of calculations made by Prof. Mansfield Merriman, Lehigh University, Pa.:

Case I. Comparison of three steel shafts.	Propeller shaft U. S. S. Brooklyn. Hollow. Outs. diam. 17 inches; ins. diam. 11 inches. Nickel steel, E. L. 50,000 lbs. per sq. in.	Solid shaft, same (approximate) sectional area. Diameter 13 inches. Simple steel, E. L. 30,000 lbs. per sq. in.	Solid shaft, same strength under applied loads or horse-powers. Diameter 18.9) inches. Simple steel, E. L. 30,000 lbs. per sq. in.
Area of section, square inches, ...	131.95	132.73	280.55
Weight per yard, pounds, .	1,346	1,354	2,861
Comparative strength under applied loads in flexure, or under applied horse-power in torsion, . .	307	100	307
Load, in pounds, at middle of a span of 12 feet on two supports, which strains to one-half elastic limit, .	276,200	89,900	276,200
Length of beam on two supports, which is strained by its own weight to one-half elastic limits, . .	121 ft. 6 in.	77 ft. 6 in.	83 ft. 4 in.
Horse-power transmitted at 50 revolutions per minute when strained to one-half elastic limit, . . .	15,780	6,130	15,780

Case II. Comparison of three steel shafts.	Intermediate Line shaft U. S. S. Iowa. Hollow. Outs. diam. 15¾ inches; ins. diam. 9¾ inches. Nickel Steel, E. L. 50,000 lbs. per sq. in.	Solid shaft, same (approximate) sectional area. Diameter 12⅜ inches. Simple steel, E. L. 30,000 lbs. per sq. in.	Solid shaft of same strength under applied loads or horse-powers. Diameter 17.71 inches. Simple steel, E. L. 30,000 lbs per sq. in.
Area of section, square inches, ...	120.17	120.28	246.34
Weight per yard, pounds, .	1,225	1,227	2,513
Comparative strength under applied loads in flexure, or under applied horse-power in torsion, . .	293	100	293
Load which, at middle of a beam 12 feet in span on two supports, causes strains equal to one-half elastic limit, pounds, . . .	227,200	77,500	227,200
Length of beam on two supports which is strained by its own weight to one-half elastic limit, . . .	115 ft. 6 in.	75 ft. 9 in.	80 ft. 8 in.
Horse-power transmitted at 50 revolutions per minute when strained to one-half elastic limit, . . .	12,980	4,430	12,980

The hole in a hollow forged simple steel shaft of 15½ inches outside diameter is 7 inches. Nickel-steel hollow forged shafts having the same outside diameter may have a hole of 11¾ inches diameter. But for fear of any possible chance of buckling, the hole is made 9¾ inches in diameter. The propeller-shafts of the American Line steamers "St. Louis" and "St. Paul" are of nickel-steel; they will stand 42½ tons breaking-strain per square inch, and show 28 per cent. elongation and 50 per cent. reduction of area per square inch. The shaft of the "Iowa" will stand 45 tons breaking-strain per square inch, while 33½ tons is the limit in ordinary steel shafts.

"Here, then, is a material admirably suited to the shafting and engine-forging required by the marine engineer of modern high-service engines, and it is believed that as its merits become known its use will be widely extended. In the highest development of the modern marine engines, reduction of weight of all parts is of prime importance. This can only be accomplished by reducing sectional area. On the other hand, outside dimensions cannot be usually reduced without sacrificing necessary stiffness. We are, therefore, led to removing the metal along neutral axes, or, in other words, to the use of hollow forging. It is evident that to farther reduce weight, as well as to increase the absolute strength of parts, the designer of marine engines needs a stronger material than that now employed; that is, a material having a greater elastic limit, but at the same time possessing such a degree of toughness as to insure resistance to sudden strain and shock. Simple steel strengthened and toughened by tempering and annealing will show, in specimens cut from the center of sections, say 3 inches to 6 inches thick, an elastic limit of about 45,000 pounds per square inch, an elongation of about 23 per cent., and a contraction of area of from 50 to 55 per cent. A farther and very pronounced improvement in strength and toughness can be obtained by the use of nickel-steel, tempered and annealed as above described. The use of nickel allows a reduction of carbon, makes the steel more sensitive to temper, and facilitates the tempering of irregular shapes. Specimens from nickel-steel forgings, tempered and annealed, will show uniformly an elastic limit of from 50,000 to 55,000 pounds per square inch, an elongation of 23 per cent. and above, in specimens 2 inches long by ½-inch diameter, and a contraction of area of from 55 to 60 per cent. In cases where, owing to thickness of sections and irregular shape, tempering is not advisable, nickel-steel will still show a higher combination of elasticity and toughness than any other material known, under the same conditions."*

Ordnance.

A complete set of nickel-steel forgings for an 8-inch gun has been made by the Bethlehem Iron Company for the Bureau of Ordnance, United States Navy, and is now being assembled at the Washington navy-yard. The average physical qualities obtained in these forgings in transverse specimens were:

	Tensile st. lbs. per sq. in.	Elastic limit lbs. per sq. in.	Elongation per cent.	Contraction of area per cent.
Tube, ...	93,200	58,300	21.2	42.0
Jacket, . . .	99,900	60,000	20.4	45.9
Hoops, . . .	109,100	68,200	20.5	46.9

Test specimens were 2 inches long by ½-inch diameter. Comparing with the average of qualities usually obtained in corresponding navy gun-forgings made of simple steel, the tensile strength shows an increase of about 10 per cent., with an increase in elastic limit from 22 to 28 per cent., while the contraction of area and elongation are but slightly reduced.

The Bureau of Ordnance found, while experimenting, that two small-arm barrels showed greater endurance than others. They were respectively of a very high-carbon steel and a steel containing about 4½ per cent. of nickel. The latter was fairly easy to machine, while the high-carbon steel was almost in-

* R. W. Davenport, Vice-President Bethlehem Iron Company, *Trans. Nav. and Marine Engrs.*, vol. i., 1893.

tractable. Consequently the Bureau decided to adopt nickel-steel for its small-arm barrels.* The great excellence attained by the Greener gun is attributed to the use of nickel-steel barrels containing 2.75 per cent. of nickel and 0.2 per cent. of carbon.

Other Uses.

It is evident that, besides the application to which nickel-steel is being put in armor-plate, gun-forgings and marine shafting, there is a still wider field open to its use for structural steel, heavy castings, car-couplers, car-wheels, boiler-plates, small pinions and knuckles, shear-knives, bicycle-spokes, gears for motors, and all varieties of work demanding hardness, toughness and malleability.

Plates of iron or steel and nickel, when laid together and heated to welding-temperature, may be rolled out into thin plates with a continuous nickel surface on both sides, or nickel on one side and iron or steel on the other. The union of the two metals is not merely a welding, but is of the nature of cementation, an actual alloy being formed to some depth below the surface of contact. There is a steam-vessel in New York harbor sheathed in part, as an experiment, with this material, fastened with iron nails. After eight months' constant service, the iron nails have corroded away, and all of the bottom, except the nickel sheathing, is corroded and foul, while the latter is as clean as when first put on. If nickel nails were used, it would seem as if nickel sheathing, or sheet-nickel, would make an ideal sheathing for all salt-water craft. This material is also used for lagging steam-cylinders, feed-water heaters, etc. It takes a beautiful polish, and is stronger than brass or copper.

The Niagara Falls Power Company has recently installed four 5000 horse-power electric generators coupled to turbine water-wheels. In this type of generator the periphery of the large rotating field travels at the rate of nearly two miles per minute. The bobbins are secured within a ring of nickel-steel that is forged without a weld, having an outside diameter of 139⅜ inches; inside diameter, 130 inches; width, 50¾ inches; weight, 28,840 pounds. This ring of nickel-steel is extremely light for its strength, and resists the centrifugal forces of this large field, while adding but little to its weight.

* Private letter.

The Bureau of Steam Engineering, United States Navy, has decided to put nickel-steel boilers in the cruiser "Chicago," which is shortly to undergo repairs.

Nickel-Steel Wire.

Nickel-steel containing as much as 30 per cent. of nickel may be drawn into wire as easily as ordinary steel. Wire of this class, containing sufficient nickel to make the non-corroding qualities of the metal prominent, is especially adapted for hawsers and cable-service in salt water. A sample of nickel-steel wire, containing 27.8 per cent. nickel and 0.40 per cent. carbon, used as torpedo-defense netting by the United States Navy, gives the following physical test:

Diam. cross sec. Inch.	Area of cross sec. Sq. inch.	Reduced diameter. Inch.	Reduced area. Sq. inch.	Con. area. Per cent.	Elong. in 2 in. Per cent.	Load in pounds.	Breaking strain per sq. in. in pounds.
0.116	0.01057	0.106	0.0088	16.5	6.25	2100	198,700

The high tensile strength of this wire, with the comparatively small reduction in elongation and contraction of area, indicates extreme toughness; and at the same time it is not acted upon by salt water, so that it admirably answers the requirements of marine service.

Flange-Steel.

The Cleveland Rolling Mill made some flange-steel for the Canadian Copper Company, with and without nickel, for the purpose of making comparative tests of their physical qualities. The results are given in the table on the next page.

This nickel-steel shows an average increase of 11,400 pounds per square inch, or about 31 per cent. in elastic limit, and an average increase of 10,400 pounds per square inch, or about 20 per cent. in ultimate strength, without any perceptible effect upon the ductility, as evidenced by the percentage of elongation and contraction of area.

The Canadian Copper Company, at its works at Brooklyn, near Cleveland, Ohio, made a series of experiments on nickel-steel with varying percentages of nickel and carbon in an improvised acid-bottom open-hearth furnace. The heats amounted to about 1000 pounds of metal, made out of washed low-phosphorus pig and high-grade Bessemer ore. Nickel in metallic form was charged into the bath about one and one-half hours before

Comparative Tests of Nickel-Steel and Best Soft Flange-Steel.

(Specimens cut from plates.)

	Charge. Pounds.	Reduction of Area. Per cent.	Elongation in 8 inches. Per cent.	Elastic Limit. Pounds per square inch.	Ultimate Strength. Pounds per square inch.
		53.	23.25	....	64,080
I. Nickel-Steel.	Basic scrap, 9000.	53.3	26.	47,100	66,370
Containing C, 0.08;	Low-phosphorus pig, 9000.	56.3	25.	44,700	66,000
Mn, 0.36; P, 0.045;	80-per cent. ferro, 165.	45.1	24.5	47,400	67,100
S, 0.038; Ni, 2.69.	97-per cent. nickel, 540.	54.4	26.	47,300	64,800
		49.7	23.75	48,900	66,200
		45.6	26.	35,700	55,500
II. Soft Steel.		45.8	26.	35,500	54,600
Containing C, 0.10;	Basic scrap, 9000.	52.9	27.5	32,800	53,900
Mn, 0.27; P, 0.048;	Low-phosphorus pig, 9000.	61.8	32.	34,060	52,500
S, 0.039.	80-per cent. ferro, 160.	63.	27.	35,500	53,700
		63.	26.	37,900	56,500

tapping. Difficulty was experienced in controlling the heat, and other adverse conditions were encountered on account of the limited scale and lack of facilities in managing such a small furnace, which rendered it impossible to make steel of a uniform grade and show the degree to which a definite percentage of nickel in steel would be influenced by varying percentages of carbon, and *vice versa*. Still, the results of the physical tests of this steel may be of interest. The test-pieces were all taken from the center of the ingot, hammered to one and one-half inches square, and then turned down to a diameter of ⅝-inch, with two inches between fillets, which were ⅞-inch in diameter and threaded:

No. of Specimen.	Carbon. Per cent.	Nickel. Per cent.	Ultimate Strength. Pounds per square inch.	Reduction of Area. Per cent.	Elongation. Per cent.	Length. Inches.	Fracture.	Hardness in Lathe.
14	0.16	3.35	102,800	29.1	15.0	2	Silky.	Soft, UnA.
14	0.16	3.35	100,650	48.1	27.0	2	Silky.	Soft, A.
19	0.19	2.62	141,100	24.8	11.9	8	Gray.	Hard, Drawn.
13	0.22	2.05	88,880	34.6	20.5	2	Gray.	Easy, UnA.
13	0.22	2.05	84,650	55.4	31.5	2	Gray.	Easy, A.
13	0.22	2.05	83,040	58.2	25.1	8	Gray.	Easy, Drawn.
15	0.31	3.40	109,100	24.4	17.0	2	Gray.	Easy, UnA.
15	0.31	3.40	100,800	49.2	26.0	2	Gray.	Easy, A.
15	0.31	3.40	98,120	44.4	20.0	8	Silky.	Easy, Drawn.
41	0.51	4.93	127,075	27.10	16.0	2	Crystallized.	Hard, A.
24	0.54	3.20	131,200	12.7	10.5	2	Gray.	Hard, A.
24	0.54	3.20	134,400	36.7	14.3	8	Gray.	Hard, Drawn.
29	0.96	3.10	151,880	12.9	8.0	8	Gray.	Hard, Round.
34	0.91	3.10	138,000	22.3	9.88	8	Gray.	Hard, Round.

This steel was quiet in the moulds after tapping, set quickly without piping, and the ingots were smooth and clean. They were submitted to the same treatment in the hammer-shop and rod-mill as is given to ordinary steel. Through a mistake in getting numbers changed, the bars drawn through the rolls of the rod-mill received an extra annealing-heat. The conditions of the tests were as near alike as possible; the only exception being that the rods were pulled in the testing-machine* as they came from the 1⅛-inch rolls, in 8-inch lengths, while the other test-specimens were 2 inches long and ⅝-inch diameter.

The specifications of the Baltimore and Ohio R. R. for steel

* Otis Steel Company's Olsen machine.

tires, and the U. S. Navy Bureau of Steam-Engineering for crank- and propeller- shafts, connecting- and piston-rods and ordnance, are as follows:

Specifications of Baltimore and Ohio Railroad.

Grade.	Carbon, per cent.	Tensile strength, pounds per square inch.	Elongation in 4 inches, per cent.
I.	0.50 to 0.60	105,000	16
II.	0.60 to 0.70	115,000	14
III.	0.68 to 0.78	125,000	10

Grade I. is for passenger-engine tires, outside diameter, 60 inches; Grade II., for Consolidation, Mogul, etc., outside diameter, 45 to 60 inches; Grade III., for switching-engines, car-wheels, and all tires less than 46 inches in outside diameter.

A variation of 10,000 pounds in tensile strength above or below the above figures is permitted.

Specifications of the Bureau of Steam-Engineering, U. S. Navy.

	Tensile strength, pounds per square inch.	Elongation in 2 inches, per cent.	Contraction of area, per cent.
Propeller-shafts, ...	85,000	23	....
Crank-shafts, ...	58,000	28	....
Connecting-rods, ...	65,000	25	....
Piston-rods, ...	65,000	25	....
Ordnance, ...	85,000	18	35

It goes without saying, that, where other conditions are equal, soft or low-carbon steel possesses advantages over hard or high-carbon steel, as it is easier to machine, and (what is of greater importance) may be submitted to much rougher treatment, because it is not subject to the dangerous internal strains of hard steel. It is in this respect, especially, that nickel-steel, having the superior qualities of soft steel, fulfils the requirements of service sought for in hard steel, and offers to engineers the advantages of a material which will give greater strength with same weight, or equal strength with less weight, than any other at their disposal. Comparing the accepted standard of mild steel with nickel-steel having approximately the same carbon-contents, we have:

	Tensile strength, pounds per square inch.	Elongation, per cent.	Contraction of area, per cent.
Ordinary steel, ...	65,000	23 in 8 in.	48.0
No. 13 nickel-steel (2.05 pr cent. nickel), ...	84,650	31.5 in 2 in.	55.4
No. 14 nickel-steel (3.35 pr cent. nickel), ...	100,650	27.0 in 2 in.	48.1

We have here nickel-steel, containing less than 0.2 per cent. carbon, and 3.35 per cent. of nickel (annealed), that more than meets the specifications of the Navy Department for ordnance, shafting, etc., and of Grade I. for steel tires on the Baltimore and Ohio R. R.

For Grade III., requiring high-grade steel, we make the following comparison with nickel-steel, annealed, containing 0.20 per cent. less carbon than the required carbon in plain steel:

	Tensile strength, pounds per square inch.	Elongation, per cent.
B. & O. R. R. steel tires, Grade III., . .	125,000	10 in 4 in.
No. 24 nickel-steel, ...	134,000	14 in 2 in.

By 2.0 per cent. of nickel (No. 13) the tensile strength of mild steel is raised 30 per cent., and by 3.35 nickel (No. 14) 41 per cent., without any appreciable change of elongation or reduction of area. "The presence of 4.7 per cent. of nickel increases the tensile strength 35 per cent., and the elastic limit 75 per cent., while the elongation and contraction of area is practically the same."*

In reviewing the results of these experiments, corroborated by the experience of others, it is found that better results are obtained by using more rather than less than 3 per cent. of nickel. The tensile strength and elastic limit of steel increases with the percentage of nickel, up to the point of extreme hardness in machining, and the percentage of carbon has everything to do in raising or lowering this property of nickel-steel, as much as in ordinary steel.

Torsion-tests of these specimens were made by the Standard Tool Co., Cleveland, Ohio, as follows:

No. of specimen.	Carbon, per cent.	Nickel, per cent.	Torsion breaking-point, in pounds per square inch.	Degrees of twist in 3 inches before breaking. 360 degrees = 1 full twist.	
14,	. 0.16	3.35	2325	360	....
19,	. 0.19	2.62	2150	130	Split.
13,	. 0.22	2.05	2434	240	Twisted off.
15,	. 0.31	3.40	1807	355	....
41,	. 0.51	4.93	2200	120	....
24,	. 0.54	3.00	1200	60	Split.
29,	. 0.96	3.10	1700	60	Split.

* Riley's Experiments.

The specimens in these torsion-tests were 1¼ inches square. A number of the specimens were found to be checked and laminated in structure.

In a cold-bending test of a specimen 2½ by 2¼ inches (full thickness of wall of forging), 18 inches long, under hydraulic press through 180°, the ends met within ¼ inch; the greatest distance between sides was ⅞ inch. There was only one slight crack, in one corner on the inside of the bend.*

The percentage of nickel in all the government work herein referred to is 3.25 per cent., with carbon at about 0.2 per cent. It is not improbable that familiarity with working and cheapening the cost in manufacture will permit the percentage of nickel to be considerably increased above this figure to good advantage. It has been the practice in this country to charge the nickel into the furnace in the form of nickel oxide enclosed in sheet-iron boxes. In other countries, pig- or ferro-nickel is used. Some steel-plants use metallic nickel, which offers this advantage over the oxide, that less nickel slags off. The best results are obtained in the basic open-hearth furnace. Several of the Pittsburgh steel-works use nickel as an alloy for steel, but are not yet prepared to make a special feature of nickel-steel castings outside of government work. The Bethlehem Iron Company, having enlarged its plant, has special facilities for making nickel-steel in any desired form or size for the general trade, besides taking large government contracts.

It is obvious from the foregoing data, which briefly summarize the present status of the metallurgy of nickel, that the field for the use of nickel is one of magnitude, and that the era of its development has only just commenced.

The results herein given are accompanied with authorities, so that they may be followed more in detail by those desiring to study the subject further and to discuss the statements offered in this paper.

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Cinnabar in Texas.

BY WILLIAM P. BLAKE, MILL ROCK, NEW HAVEN, CONN.

(Florida Meeting, March, 1895.)

THE literature of the occurrence of quicksilver-ore in the United States does not contain, so far as the writer is aware, any mention of the locality herein described.

In the preliminary report * upon the resources of the trans-Pecos region of Texas, von Streerwitz gives a long list of minerals observed as occurring there, but cinnabar is not mentioned. In the second report upon the same region † mention is made of the reported existence of cinnabarite in one of the mountain ranges north of the Sierra Carrizo and the Bofecillos, but the author adds: "In spite of my careful examination of the float, I have not yet found any traces of this metal (quicksilver) up to the present time." Prof. Dumble, also, in

* *Geol. Surv. of Texas*, E. T. Dumble, 1889, p. 225 (first report).

† *Geol. Surv. of Texas*, E. T. Dumble, 1890, p. 713 (second report).