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ALLOY STEEL

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mesne assignments, to U. S. Rustless Steel &
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This invention relates to alloy steels, and more particularly to chrome steels containing less than 2% of chromium, together with copper, silicon and phosphorus. In the term "steels" I include the low carbon steels commonly referred to as ingot irons, which, because of their process of manufacture, are steels of the low carbon variety.

This application is a continuation in part of my application Serial No. 701,537, filed December 8, 1933.

Chromium steels containing less chromium than the stainless steels are commonly divided into two classes; (1) those containing less than 2% chromium, and (2) those containing from 2 to 8% chromium. The first class of such steels have good mechanical and fabricating properties, such as the capacity for ready hot working, ductility, and very low air hardening capacity, particularly when the carbon content is low, and the capacity for manufacture easily in open hearth furnaces in large tonnage to give a clean steel in ingots of good surfaces and free from seams. The resistance to corrosion by the atmosphere and other corrosive media of the steels in the first class is not as good as those in the second class. However, as the chromium is increased above about 2%, the steel becomes not only more costly to make, but difficulties are encountered in making and fabricating, such as greater difficulty in hot working, greater air hardening, less ductility, and greater tendency for inclusions and seams. These difficulties increase progressively as the chromium content increases in this higher range. Steels of this second class which lie between the readily workable steels of the first class and the stainless steels, have not found wide application because their resistance to corrosion, which is greatly inferior to that of the stainless steels, has not been sufficient to compensate for their increased cost in manufacture and fabrication over the steels of the first class.

The present invention relates to the first class of steels, and to their improvement, particularly in corrosion resistance, by the addition thereto of phosphorus in conjunction with copper and silicon, all in the ranges and proportions hereinafter pointed out.

The effect of phosphorus on carbon steels and many alloy steels is well known and its influence is regarded as a detrimental one, so that in most steel specifications an upper limit for the phosphorus content is set at .020% or .030% or .040% or .050%, depending upon the remainder of the composition of the steel and the purpose for

which it is to be used. Bessemer steels with their high phosphorus content have been regarded as inferior in many respects to lower phosphorus steels made by the open hearth, crucible or electric furnace processes. Among the detrimental influences of phosphorus have been (1) the hardening of steels which makes them objectionable for cold-forming and cold-drawing operations; (2) the development of "cold-shortness" or ease of rupture when mechanically worked at atmospheric or slightly elevated temperatures, to a degree all out of proportion to the higher hardness, which "cold-shortness" makes them still more objectionable for cold-forming and cold-drawing operations; and (3) the segregation of phosphorus in the ingots into which the steels are cast prior to hot working, or in other cast forms, resulting in great non-uniformity of properties throughout the cast or wrought body of steel.

I have found that the addition of phosphorus to chromium-copper-silicon steels of the first class greatly improves their resistance to corrosion by the atmosphere and other corrosive media, without impairing their workability and mechanical properties. In some cases their workability may be actually improved by the increased phosphorus. While, as above noted, phosphorus is highly detrimental in its effect upon most steels, I have found that steels containing the chromium-copper-silicon combination within the ranges hereinafter specified are an exception, and that the phosphorus does not have its usual deleterious effects in either the cast or wrought condition. I have found that a very small amount of phosphorus has a remarkably large effect upon corrosion resistance. For example, a steel containing approximately .06% carbon, .90% chromium, .45% copper, .75% silicon, and .12% phosphorus possesses resistance to atmospheric corrosion about equal to that of a steel containing the same carbon, copper and silicon contents, but with 1.85% chromium and .03% phosphorus. The addition of a small amount of phosphorus produces a steel having the same resistance to corrosion as a low phosphorus steel of higher chromium content and one which is therefore cheaper and is moreover more readily workable, or produces one with increased resistance to corrosion with the same chromium content.

I have found that low carbon chromium-copper-silicon steels containing less than 2% chromium and up to about .75% phosphorus are extremely ductile and readily workable hot and

cold. This is contrary to previous experience with other steels of high phosphorus content. Moreover, in such steels the phosphorus content appears to segregate to a much smaller degree than in carbon steels of like carbon content. As illustrative of the good ductility of such steels, a steel containing .02% carbon, .94% chromium, .31% copper, .63% silicon and .54% phosphorus was bent flat upon itself without fracture and the test pieces, the tensile strength, the yield point, the elongation and the reduction in area. It is to be noted that not only do these steels exhibit a resistance to atmospheric corrosion at least three times that of a plain carbon steel of like carbon content, but in addition they are remarkably strong and ductile. Ordinarily in steels of low alloy content, it is difficult to obtain these three qualities simultaneously.

	C	Mn	Si	Cu	Cr	P	Dimensions and conditions	Tensile strength	Yield point	Elongation	Reduction in area
15								#/sq. in.	#/sq. in.	Per cent in.	Per cent
1	0.03	0.30	0.84	2.73	1.42	0.19	14" plate as rolled	86950	70050	30.0	65.3
2	0.04	0.28	1.22	0.49	1.00	0.20	14" plate as rolled	73600	56100	35.5	65.5
3	0.04	1.24	1.16	0.83		0.21	14" plate as rolled	77250	61900	34.5	60.4
4	0.16	0.28	0.62	0.45	1.00	0.09	14" plate as rolled	81100	53500	34.5	65.4
5	0.06	0.30	0.70	0.87	1.00	0.18	0.025" sheet annealed	62250	46750	19.0	
6	0.07	0.22	0.68	0.87		0.24	0.025" sheet annealed	63800	48500	19.5	
7	0.05	0.28	0.71	0.51	0.95	0.25	0.025" sheet annealed	57900	39550	24.0	
20	8	0.05	0.28	0.58	0.30	0.93	0.025" sheet annealed	74650	54500	21.5	
9	0.06	0.25	0.75	0.45	0.74	0.12	54" plate as rolled	71500	59200	36.5	63.7
10	0.06	0.25	0.75	0.45	0.74	0.12	54" plate annealed	69600	56400	40.0	74.4
11	0.10	0.29	0.89	0.50	1.14	0.21	54" plate as rolled	86300	66800	35.0	68.4
12	0.10	0.29	0.89	0.50	1.14	0.21	54" plate annealed	83200	65200	34.2	66.1
13	0.06	0.25	0.75	0.45	0.74	0.12	.025" sheet as rolled	81600	70700	16.5	
14	0.06	0.25	0.75	0.45	0.74	0.12	.025" sheet normalized	70300	50200	27.5	
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then the double thickness was bent again at right angles to the first bend also without any fracture even at the corner of the double bend.

While I find that chromium-copper-silicon steels of the first class above referred to are greatly improved if they contain from .07% to .75% phosphorus, I prefer to use from .09% to .30%, and more particularly from .09% to .20% phosphorus. For best resistance to corrosion, the carbon content should be less than about .30%, preferably not in excess of .15%, the lower limit being about .01%. Carbon up to about .60% may be used for some applications of the steel in which hardness combined with resistance to corrosion is desired. The chromium is less than 2%, preferably not over 1.5%, the lower limit being about .3% or .4%. The preferred range of chromium is about .50% to 1.50%. The copper is from .15% to 3%, the upper limit of the copper being preferably .60%. The preferred range of copper is about .30% to .50%. The silicon may vary between .25% and 3%, usually between .25% and 2%, the preferred range being between .50% and 1.50%. The manganese and sulphur are maintained low, the manganese not exceeding .50% and the sulphur not exceeding .10%. The manganese may vary between .02% and .50%, preferably from .10% to .35%. The sulphur preferably is not over .06%. The balance of the steel is substantially all iron, by which I mean that other alloying elements are not employed in amounts to deleteriously affect the desired corrosion resistance and/or mechanical properties, although small amounts of, say, a fraction of a per cent of one or more of the usual steel making alloying elements may be present, such as nickel, molybdenum, vanadium, etc.

Although excellent results are obtained from steel within the broadest ranges which have been given, the best results, taking into consideration all of the various factors such as resistance to corrosion, tensile strength, ductility and ease of fabrication, are obtained when the elements chromium, silicon, copper and phosphorus are present, respectively, in the proportions of about 6:6:3:1.

The following table illustrates examples of steels made in accordance with the present invention. The table gives the composition of the various steels, the dimensions and conditions of

The sulphur in each of these steels does not exceed .10%.

A steel containing—

Carbon	.01% to .30%
Chromium	.3% to less than 2%
Copper	.15% to 3%
Silicon	.25% to 2%
Phosphorus	.07% to .30%
Manganese	.02% to .50%
Sulphur	not over .06%
Balance	substantially all iron,

is characterized by a tensile strength in a rolled and normalized condition of about 50,000 to 90,000 pounds per sq. in., a resistance to atmospheric corrosion of about two to seven times that of a plain carbon steel of like carbon content, and a deformability at room temperatures at least equal to that of plain carbon steel of equal tensile strength.

A steel containing—

Carbon	.03% to .15%
Chromium	.50% to 1.5%
Copper	.30% to .6%
Silicon	.50% to 1.50%
Phosphorus	.10% to .20%
Manganese	.10% to .35%
Sulphur	not over .06%
Balance	substantially all iron,

is characterized by having a tensile strength in a rolled and normalized condition greater than 65,000 pounds per sq. in., a resistance to atmospheric corrosion at least three times that of a plain carbon steel of like carbon content, and a deformability at room temperatures at least equal to that of plain carbon steel of equal tensile strength, and further characterized by high resistance to impact at temperatures as low as -40° F. and by low hardening capacity on air cooling.

Alloy steels having high physical properties, as well as high resistance to corrosion, may be made in either cast or wrought form in accordance with the present invention. If any element which is used for the purpose of bringing about resistance to corrosion tends to deleteriously affect the mechanical properties of the steel, it is offset by other elements which impart

corrosion resistance and which also tend to counteract these undesirable mechanical properties. For instance, the deleterious properties due to a high content of phosphorus are entirely counteracted by the presence with the high phosphorus content of a definite combination of chromium, copper and silicon in the ranges herein specified. By the simultaneous use of all these elements, non-corrodibility and high physical properties are brought about without the presence or manifestation of any of the deleterious properties. For instance, the ability of phosphorus to impart corrosion resistance and machinability to steel is utilized without any manifestation of cold-shortness or brittleness. As the high physical properties, machinability, ductility, and ease of fabrication are obtained by the elements as specified above, the presence of any other elements in appreciable percentages becomes entirely superfluous. It is known that manganese in high percentages is used for imparting strength, and sulphur for imparting free machinability to steel. In the balanced composition of my invention, it is not necessary to use any appreciable percentage of manganese or sulphur to obtain these desired properties. In fact, the presence of manganese and sulphur above the limits set forth above would upset the balance established by the elements chromium, copper, silicon and phosphorus, and would tend to impart undesirable properties to the steel when chromium, copper and silicon are within the limits set forth above. If, for instance, higher percentages of manganese and sulphur were present than given above, it would become necessary to increase the percentages of the non-corrosive elements to counteract any deleterious properties that would be brought forth by the manganese and sulphur contents.

The steel of the present invention has high strength and ductility, high resistance to impact, effective resistance to mild corroding media, and, in addition, low air-hardening capacity so that it may be subjected to the usual operations incident to hot forming and welding without sufficient hardening and consequent loss of ductility to require heat treatment prior to structural application. The particular combination of non-corrosive elements in the definite limits set forth above, therefore, produces a steel which is of a comparatively low alloying content with the attendant advantages of cheapness and ease of manufacture, and possessing the necessary desirable qualities of non-corrodibility and high physical strength produced by the non-corrosive elements themselves.

Wrought alloy steel articles made in accordance with my invention are resistant to atmospheric and other mild corrosive media such as weak acids and alkalis, chemicals with mild acid or alkaline reactions, natural waters including sea

water and mine water, etc. The alloy can be made into castings or fabricated into wrought articles such as plates, sheets, structural shapes, tubing, wire, which are to be used where corrosion resistance is desired, as, for example, in ship building, railroad car making, transmission towers, bridges, etc.

The present invention is not limited to the proportions set forth in the illustrative embodiments, but may be otherwise embodied within the scope of the following claims.

I claim:

1. An alloy steel containing .01% to .60% carbon, .3% to less than 2% chromium, .15% to 3% copper, .25% to 3% silicon, .07% to .75% phosphorus, .02% to .50% manganese, and not over .10% sulphur, the balance being substantially all iron.

2. An alloy steel containing .01% to .30% carbon, .3% to less than 2% chromium, .15% to .60% copper, .25% to 2.0% silicon, .09% to .30% phosphorus, .02% to .50% manganese, and not over .06% sulphur, the balance being substantially all iron.

3. An alloy steel containing .01% to .15% carbon, .50% to 1.50% chromium, .30% to .50% copper, .50% to 1.50% silicon, .09% to .20% phosphorus, .10% to .35% manganese, and not over .06% sulphur, the balance being substantially all iron.

4. An alloy steel containing .01% to .30% carbon, .3% to less than 2% chromium, .15% to 3.0% copper, .25% to 2.0% silicon, .07% to .30% phosphorus, .02% to .50% manganese, and not over .06% sulphur, the balance being substantially all iron, the alloy steel being characterized by a tensile strength in a rolled and normalized condition of about 50,000 to 90,000 pounds per sq. in., a resistance to atmospheric corrosion of about two to seven times that of a plain carbon steel of like carbon content, and a deformability at room temperatures at least equal to that of plain carbon steel of equal tensile strength.

5. An alloy steel containing .03% to .15% carbon, .50% to 1.50% chromium, .30% to .60% copper, .50% to 1.50% silicon, .10% to .20% phosphorus, .10% to .35% manganese, and not over .06% sulphur, the balance being substantially all iron, the alloy steel being characterized by having a tensile strength in a rolled and normalized condition greater than 65,000 pounds per sq. in., a resistance to atmospheric corrosion at least three times that of a plain carbon steel of like carbon content, and a deformability at room temperatures at least equal to that of plain carbon steel of equal tensile strength, and further characterized by high resistance to impact at temperatures as low as -40° F. and by low hardening capacity on air cooling.

JEROME STRAUSS.

CERTIFICATE OF CORRECTION.**Patent No. 2,006,304.****June 25, 1935.****JEROME STRAUSS.**

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 2, second column, line 15, in the boxed table under the heading "Elongation" for "Per cent in." read Per cent in 2 in.; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 13th day of August, A. D. 1935.

(Seal)

Leslie Frazer
Acting Commissioner of Patents.