

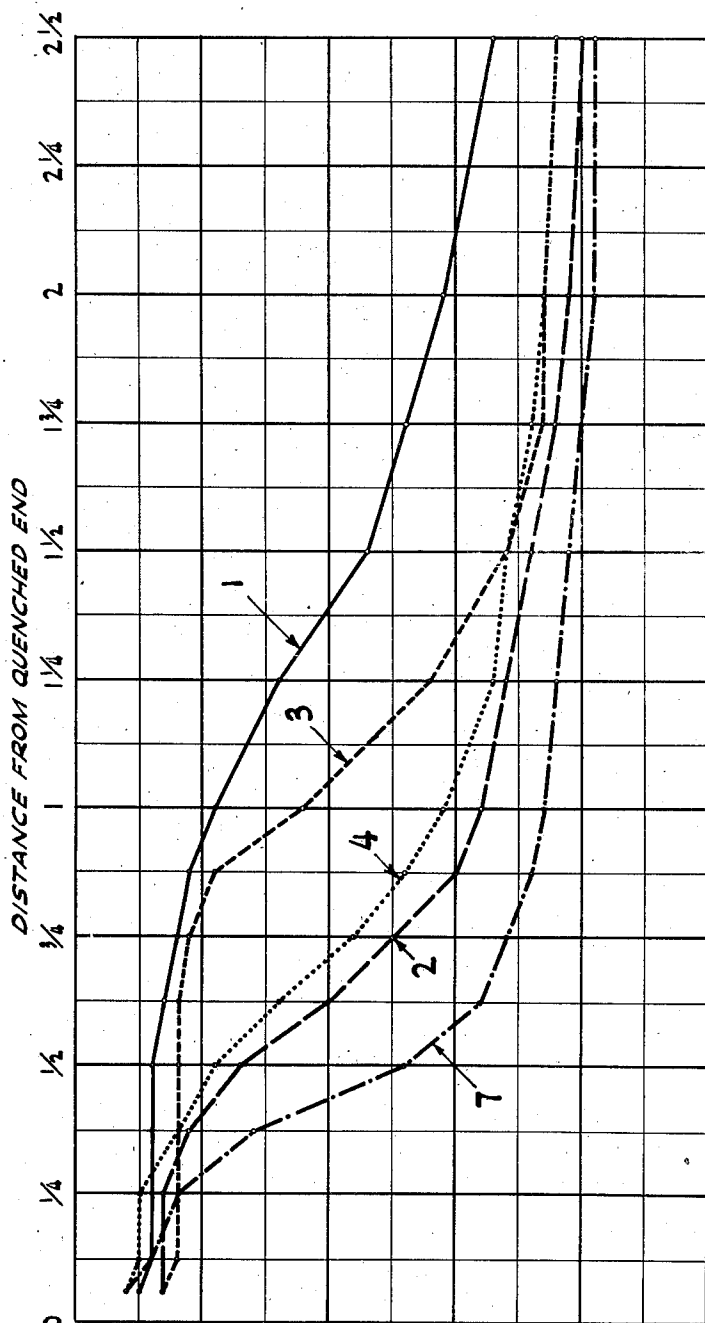
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ALLOY FOR TREATMENT OF STEEL

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ALLOY FOR TREATMENT OF STEEL

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This is a continuation-in-part of my copending application Serial No. 353,918, filed August 23, 1940.

This invention relates to alloys for use in deoxidizing steel or cast iron, and more particularly to such alloys containing titanium, boron, and aluminum, and at least one element of the group manganese, silicon, iron, zirconium and calcium.

Structural or forging steel of fine grain-size, or so treated in manufacture that its grain structure remains fine even though heated to such temperatures as would cause other steel to become coarse-grained, has well recognized advantages that make it desirable for many uses. Some of these advantages, which may occur separately or simultaneously, are superior ductility in a given condition of heat-treatment, a better combination of strength and ductility, higher elastic limit or yield point, and greater resistance to impact or shock. The "hardenability" of such fine-grained steel, however, is generally lower than that of similar steel of coarser grain size. For many uses high hardenability is desirable, since steel having that property does not require such rapid cooling to develop a given hardness, that is, it permits the treated steel to become hard under moderate quenching treatments. As drastic quenching treatments may be harmful to other desired characteristics of treated steel, and are difficult to accomplish with large pieces of steel, it is seen that the ability to harden without requiring such drastic quenchings is very desirable. Thus, it is much easier to harden thicker and heavier parts of such steel which will not cool very rapidly, even though quenched in a rapid and voluminous stream of cold water.

The treatment of molten steel shortly before casting with such deoxidizing agents as aluminum, titanium and zirconium, either separately or in combination, is well known to be an effective means of producing fine-grain characteristics in the steel. This treatment, however, does not generally improve the hardenability of the steel. The addition of small amounts of boron has been found to definitely increase the hardenability of a given steel, but its addition as ferroboration, even when accompanied by a grain-refining amount of aluminum, separately added, tends to coarsen the grain size.

In accordance with the present invention, it has been found that both fine-grain characteristics and high hardenability may be conferred on the same steel by adding thereto a deoxidizing alloy containing, in combination, titanium, boron

and aluminum, and preferably also containing manganese, silicon and iron. The use of such an alloy has been found to confer many of the beneficial characteristics not obtainable when the alloy constituents are added separately to the steel being treated. Thus, the cleaning action of these elements has been found to be more effective when the several deoxidizing elements act on the steel simultaneously and in a single addition than when the same deoxidizers are added as separate ferro-alloys. Of especial importance, as pointed out above, is the fact that fine grain-size and improved hardenability cannot be obtained in the same piece of steel by separately adding aluminum (the element normally used to secure fine grain size) and boron (the element used to secure improved hardenability). In previous practice, in fact, it was not thought possible to secure both these characteristics in high degree in the same piece of steel.

Alloys suitable for use in the practice of this invention may contain from about 0.25 to 5% boron, 5 to 25% each of titanium and aluminum, and the balance iron with up to 10% zirconium, up to 30% manganese, up to 40% silicon, up to 5% calcium, up to 3% carbon, and small amounts of phosphorus, sulfur, copper and other impurities. The titanium and aluminum contents should each be at least two or three times the boron content. The presence of manganese, silicon and calcium in the alloy is beneficial but not essential for the purpose of simultaneously improving the hardenability and securing fine grain characteristics in the steel. Preferably, the amount of manganese is 5 to 30%, and of silicon 10 to 40%. The relative proportions of titanium and aluminum are also important, as the presence of too much aluminum in excess of the titanium causes the steel to be "dirty" due to the inclusion of aluminum oxide; and the presence of too much titanium in excess of the aluminum causes the steel to be coarse-grained, unless excessive amounts of the alloy, such as will give comparatively large residual titanium contents in the steel, are used. Accordingly, the amount of titanium preferably does not exceed twice the amount of aluminum, and preferably should not be more than half again as much. Likewise, the amount of aluminum preferably does not exceed twice the amount of titanium, and preferably should not be more than half again as much. Very small amounts of boron are sufficient to produce a significant effect on the hardenability of steel, while an excess may impair the rolling

quality, so that the amount of boron should be less than 5%.

Finally, iron usually comprises a substantial percentage of the alloy, and may be varied considerably, depending upon the concentration of the remaining elements that is desired for a specific purpose. For instance, a heavier alloy, which would therefore necessarily be more dilute in active elements and higher in iron, might be better for adding to large ladles of steel, while for mold additions, or in small ladles of steel or cast iron, a more concentrated and active alloy, lower in iron, might be preferred. In all these alloys, carbon usually comprises a small percentage, but is kept as low as conveniently possible, and is preferably less than 3%.

In the preparation of these alloys, aluminum is usually added as such. The silicon and manganese may be added as silico-manganese, and the titanium as ferro-titanium. The boron is conveniently added as borax to the slag formed in the manufacture of the alloy, as the aluminum in the alloy reduces boron from such a slag. The calcium, if present, may be incorporated into these alloys either by direct reduction from a slag of high lime content, or preferably by adding the metal or one of its metallic compounds, such as calcium-silicide, to a previously formed melt containing the other ingredients. The invention is not limited to any particular method of manufacture, however.

In the use of these alloys, they are added to molten steel in well known fashion. Generally, the amount of boron which should be added to steel by the use of the present alloys should be 0.001 to 0.01%, the amount of titanium 0.01 to 0.1%, and the amount of aluminum also 0.01 to 0.1%. Additional aluminum may also be added as a separate alloy addition, sufficient to bring the total aluminum addition to 0.05 to 0.15%, but to secure the necessary fine grain characteristics at least one quarter of the added aluminum must come from the titanium-boron-aluminum alloy of the present invention.

The following table illustrates typical compositions of alloys in accordance with the present invention:

TABLE I

	Example number		
	1	2	3
Boron.....	1.78	2.19	1.23
Titanium.....	18.06	8.28	9.00
Aluminum.....	14	10.18	11
Manganese.....	23.40	14	15
Silicon.....	27	20	19
Iron.....	15	41.5	42.5
Carbon.....	0.76	1.25	1.22
Calcium.....	0	2.62	1.04

The effect of these alloys on the hardenability of steel may be demonstrated by Jominy's method. This method involves quenching the test specimen at one end only, according to a definite procedure, and then measuring the hardness at different distances from the quenched end. For this demonstration a series of steels containing about 0.4% carbon and 1.8% manganese was prepared as follows: The basic charge for each heat was 10 pounds Armco iron and 6 pounds of clean low-carbon sheet steel scrap. When melted, this charge was deoxidized with 15 grams of 50% ferrosilicon and about 500 grams of pig iron was then added to give the desired carbon content. In the first two heats all this pig iron was the regular foundry grade, rather high in phosphorus and silicon. When it was found that heat No. 2 contained 0.042% phosphorus and 0.028% sulphur, half the pig iron addition in subsequent heats was made in the form of a lower phosphorus iron, and in heat No. 3 the phosphorus content was down to 0.032%. This same charge was used for all the other heats. After the pig iron was dissolved, additions of 50% ferrosilicon and 80% high-carbon ferromanganese were made to provide the proper amounts of those elements, and aluminum was added two minutes later. One minute later a special deoxidizer was added to each heat, the composition of the special deoxidizers used being shown in Table II below. Two minutes later the steel was poured into the ingot mold. The ingots were rolled into 7/8 inch rounds, which were cut into suitable lengths for test specimens before heat-treatment.

TABLE II
Composition and deoxidation of the steels used

Heat No.	Chemical analysis, percent			Aluminum added gms.*	Gms.*	Special deoxidizer added, approximate composition (C omitted unless over 1 percent and Fe omitted)
	C	Mn	Si			
1.....	.40	1.75	.27	3	16	18% Ti, 14% Al, 24% Mn, 27% Si, 1.5% B.
2.....	.414	1.84	.27	3	16	20% Ti, 13.7% Al, 24.6% Mn, 27.6% Si.
3.....	.404	1.82	.26	3	25	9% Ti, 11% Al, 14% Mn, 20% Si, 1.5% Ca, 1.5% B.
4.....	.42	1.75	.26	3	25	10% Ti, 13.7% Al, 13.6% Mn, 19.2% Si, 3% Ca.
5.....	.404	1.79	.14	3	12	15.5% Ti, 9% Al, 25% V.
6.....	.396	1.86	.16	3	16	35.6% Zr, 24.3% Al, 4.8% Si.
7.....	.398	1.74	.16	5	10	26.7% Ti, 10.2% Al, 38.5% Mn, 1.7% Si.
8.....	.394	1.84	.16	3	10	26.7% Ti, 10.2% Al, 38.5% Mn, 1.7% Si.
					10	14.5% Ti, 21.1% Al, 2.7% Si, 3.7% C.
9.....	.394	1.78	.27	6	16	37.3% Zr, 1% Al, 37.9% Si.
10.....	.396	1.80	.22	6	16	20.7% Ti, 32.0% Si, 25.4% Cr.
11.....	.402	1.80	.24	4	12	19.7% Ti, 15.8% Al, 9.5% Si, 36.6% Mo.
12.....	.394	1.84	.24	3	10	10.6% Ti, 59.1% Mo.
					10	14.5% Ti, 21.1% Al, 2.7% Si, 3.7% C.
13.....	.404	1.87	.25	3	12	15.5% Ti, 9% Al, 25% V.
14.....	.402	1.87	.26	3	16	35.6% Zr, 24.3% Al, 4.8% Si.

* Three grams per heat is equivalent to about 0.038%, or three-fourths of a pound per net ton.

The test specimens were machined to $\frac{3}{4}$ inch diameter, normalized at 1600° F., heated for one hour at 1550° F., and then quenched at one end according to Jominy's method. The hardness tests were made on strips ground flat about $\frac{1}{8}$ inch wide on opposite sides of the $\frac{3}{4}$ inch diameter test specimens. Hardness tests were made on both sides of each bar, and the results were averaged to obtain the values reported in Table III below, and plotted in the accompanying graph.

TABLE III

Rockwell C. Hardness of specimens quenched from 1550° F. at one end only, according to Jominy's method

Heat No.	Inches from quenched end to location of hardness test																	
	$\frac{1}{16}$	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1	$1\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{3}{4}$	2	$2\frac{1}{4}$	3
1.....	55	54	54	54	54	53	52	51	49	44	37	34	31	27	23			
2.....	53	53	53	51	47	40	35	30	28	26	24	22	21	20	20			
3.....	53	52	52	52	52	52	51	49	42	32	26	23	23	22	21			
4.....	56	55	55	52	49	44	38	34	31	27	26	24	23	22	21			
5.....	55	54	53	49	40	33	29	27	26	25	24	23	23	22	22			
6.....	55	54	53	49	42	34	30	27	25	24	23	22	21	20	20			
7.....	56	54	52	46	34	28	26	24	23	22	21	20	19	19	18			
8.....	56	54	53	44	33	26	26	24	23	21	21	21	20	20	19			
9.....	56	54	52	45	38	31	28	26	25	23	22	21	20	19	18			
10.....	54	55	52	50	44	38	35	30	28	26	25	23	22	21	20			
11.....	54	53	52	46	38	34	32	30	29	28	27	26	26	26	25			
12.....	55	53	52	49	42	35	33	31	29	28	27	26	26	25	25			
13.....	55	55	53	51	47	41	36	32	30	28	27	27	26	26	25			
14.....	54	53	50	46	45	40	34	30	28	26	24	23	22	21	20			

Some of the results of Table III are shown graphically in the drawing, in which the curve numbers refer to the respective heat numbers of Table III.

Heat Nos. 1 and 3 were deoxidized with alloys corresponding approximately to Examples 1 and 3, respectively. The deoxidizers used in heats 2 and 4 were approximately the same as the deoxidizers of heats 1 and 3, respectively, except

that the boron was omitted from heat 2, and was substituted by an equal amount of calcium in heat 4.

As many modifications are possible within the scope of this invention, it is not intended to be limited except as defined by the appended claims.

I claim:

1. An alloy for deoxidizing steel and iron, said alloy containing 0.25 to 5% boron, 5 to 25% titanium, 5 to 25% aluminum, 5 to 30% manganese, 10 to 40% silicon, and the remainder being principally iron with a small amount of carbon and other impurities.

2. An alloy for deoxidizing steel and iron, said alloy containing 0.25 to 5% boron, 5 to 25% titanium, 5 to 25% aluminum, 5 to 30% manganese, 10 to 40% silicon, an appreciable amount up to 5% calcium, and the remainder being principally iron with a small amount of carbon and other impurities.

3. The method of treating forging steel to improve hardenability while maintaining fine grain size and the superior physical properties produced thereby, comprising adding to the molten steel a small amount of an alloy containing 0.25 to 5% boron, 5 to 25% titanium, 5 to 25% aluminum, 5 to 30% manganese, 10 to 40% silicon, and the remainder being principally iron with a small amount of carbon and other impurities.

4. The method of treating forging steel to improve hardenability while maintaining fine grain size and the superior physical properties produced thereby, comprising adding to the molten steel a small amount of an alloy containing 0.25 to 5% boron, 5 to 25% titanium, 5 to 25% aluminum, 5 to 30% manganese, 10 to 40% silicon, an appreciable amount up to 5% calcium, and the remainder being principally iron with a small amount of carbon and other impurities.

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