UNITED STATES PATENT OFFICE.

ROBERT HADFIELD, OF SHEFFIELD, ENGLAND; JOSEPH D. WEEKS ANCILLARY ADMINISTRATOR OF SAID ROBERT HADFIELD, DECEASED.

STEEL ALLOY.

SPECIFICATION forming part of Letters Patent No. 436,497, dated September 16, 1890.

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To all whom it may concern:

Be it known that I, ROBERT HADFIELD, of Sheffield, in the county of York, England, have invented a new and useful Improvement in Steel Alloys; and I do hereby declare the following to be a full, clear, and exact description thereof.

My invention relates to the manufacture of a new and useful metallic alloy or mixture, the principal constituents of which are iron, (ferrum,) chromium, manganese, and silicon, but which may also contain carbon, as well as other ingredients—such as sulphur and phosphorus—necessarily present in the metal, such alloy having most of the qualities peculiar to ordinary carbon-steel, besides other qualities hereinafter mentioned peculiar to my improved metal. This improved metal I shall speak of as "steel," although the presence of carbon, while not injurious, is unessential, the metal depending for its steely qualities chiefly on the presence of a large percentage of chromium, along with smaller quantities of manganese and silicon, as hereinafter specified.

To enable others skilled in the art to manufacture my improved steel, I proceed to describe the processes which I employ.

The condition of the iron which forms the basis of my improved steel and from which it is manufactured may be that of ordinary pig metal, cast-iron, steel, wrought-iron, steel or iron scrap, or a mixture of all or any of these, and the process or processes by which the iron or steel is manufactured or reduced or subsequently treated is immaterial, the only necessary requirement being that the iron, before the addition of the chromium, manganese, and silicon, should be substantially decarburized, by which I mean not necessarily entirely devoid of carbon, but that the metal should be or should have been previously decarburized wholly or to a great extent. Hence my improved process is applicable to the manufacture of steel by means of the Bessemer, open-hearth, or other decarburizing and refining processes or apparatuses or crucible processes, these processes being carried on in the usual way as regards the Bessemer, open-hearth, or kindred processes until the metal under treatment is nearly or quite decarburized, and then the desired percentages of chromium, manganese, and silicon are added, while if the crucible process is employed the chromium, manganese, and silicon additions may be introduced at any stage of the process.

Hitherto in the manufacture of high-class steels it has been considered necessary to employ the best and most costly qualities of iron. I have discovered, however, that if chromium, together with manganese and silicon, is present in sufficient quantities—say of chromium three-quarters of one per cent. to seven per cent., of manganese one-tenth of one per cent. to twenty per cent., and of silicon one-tenth of one per cent. to five per cent.—the resulting product is a steel of very superior quality, possessing certain marked characteristics, and I have also discovered that when this is the case the presence of sulphur and phosphorus in the pig or other iron, which forms the basis of the process, to a degree which would materially injure ordinary steel is no disadvantage whatever. There is, however, a practical difficulty in the production of an alloy or mixture of chromium, manganese, and silicon with iron, arising from the fact that in the process of refining and decarburizing metal the chromium, manganese, and silicon present are oxidized, so that, especially in the open-hearth, puddling, Bessemer, and other kindred processes, although a large percentage of chromium, manganese, and silicon be present in the charge of iron under treatment, or be added thereto before the carbon has been to a great extent eliminated, or be added thereto previous to the process of reduction, refinement, or decarburization, the chromium, manganese, and silicon present in the charge will be to a great extent oxidized and almost entirely eliminated, even after only a partial decarburization, so that if the chromium, manganese, and silicon additions were introduced previously to or during the decarburizing operation they would not remain in the charge or be present in the resulting product.

In the manufacture of my improved steel I therefore proceed as follows: If pig metal,

cast-iron scrap, or a mixture of these with steel or wrought-iron scrap is used as the basis, the metal is treated in the ordinary way by the Bessemer, open-hearth, or other decarburizing and refining process or apparatus until the melted charge is decarburized entirely, substantially, or to a great extent. I then add the exact amount or percentage of chromium, manganese, and silicon, the amount of chromium, manganese, and silicon having been previously ascertained in the chromium, manganese, and silicon alloys to be added, and the desired percentages will then be present in the resulting steel at the close of the operation.

The chromium, manganese, and silicon are introduced as follows: The chromium is introduced, by preference, by the use of chromium pig-iron (hereinafter referred to as "the chromium addition," a well-known product of the blast-furnace process) or other alloy of chromium—such as ferro-chromium—which is incorporated with the charge either in the solid or melted condition. The gross amount of chromium pig or ferro-chromium to be added will depend on the amount of chromium which it contains, which will be ascertained beforehand, and also, of course, on the percentage of chromium which the resulting steel is desired to contain. I prefer to use for the chromium addition chromium, cast, or pig iron containing eight to ten per cent. of chromium, for the reason that such material is comparatively low in carbon, and, being a special product, is more uniform in its quality and constituents.

As an example of manufacture, I add to two thousand pounds decarburized iron six hundred and seventy-two pounds of the chromium pig-iron herein referred to; also, if necessary, a sufficient quantity of ferro-manganese; but usually the chromium pig contains sufficient manganese without requiring a separate addition thereof. It is, however, indispensable to have manganese present in my improved steel in sufficient quantity to remove redshortness, remove the slag, and otherwise improve the steel, so that if the chromium alloy does not contain manganese or does not contain sufficient manganese this must be added by means of a separate alloy—such as ferro-manganese or spiegel—in the usual manner; also, when the chromium alloy does not contain silicon or does not contain sufficient silicon in addition to the manganese it is indispensable to have silicon present in sufficient quantity in order to remove the gases and produce sound steel. This silicon may be added by means of a separate silicon alloy—such as silicon pig or cast iron—or the silicon and manganese may be added by means of one alloy containing both silicon and manganese—such as is known by the name of "ferro-manganese silicon"—or, if desired, the chromium, manganese, and silicon may be added by means of one alloy containing manganese, chromium, and silicon. I prefer, however, to add each metal by means of separate alloys, as a more reliable result can be obtained. Such alloys may be added either in the solid or melted condition, as in the usual way. It is desirable to keep the carbon under one and a quarter per cent. in those steels containing one and a half per cent. of chromium and upward, on account of the difficulty which would be experienced in working the ingots when such percentage of carbon is exceeded.

Where it is desired that the material produced should have greater toughness combined with closeness of grain, I introduce such an amount of the chromium, manganese, and silicon addition as will yield a steel having from one and a half to two and a half per cent. of chromium, two-tenths to four-tenths of one per cent. of manganese, and two-tenths to four-tenths of one per cent. of silicon, and I increase the amount of chromium in varying proportions up to about seven per cent. where greater hardness is requisite. As just mentioned, where greater toughness is requisite I prefer to add the manganese and silicon in sufficient quantities so as to produce in the resulting steel about two-tenths to four-tenths of one per cent. of each metal—that is, two-tenths to four-tenths of one per cent. of manganese and two-tenths to four-tenths of one per cent. of silicon.

The amount of manganese and silicon may be varied between the limits indicated in my specification, according to the purposes for which the steel is required. Thus where the articles to be produced are of intricate form, then either the manganese or the silicon, or both, may be increased, in order to produce greater freedom from honey-combs, the chromium also being varied according to the desired hardness, as before indicated. After the chromium addition—that is, the alloy containing chromium, manganese, and silicon, or the separate alloys of each—has or have been incorporated with the charge it is ready to be run into molds or other forms, as may be desired.

If my improved steel is to be made by the crucible process, the basis of the operation or prime charge being wrought-iron or steel-scrap, or both combined, the process is then conducted in the usual way, the amount of carbon, if any is used, being preferably less than in the ordinary steel-making operations, and the chromium addition—that is, the alloy containing chromium, manganese, and silicon, or the separate alloys of each—is or are introduced into the crucible at any stage of the process and becomes or become thoroughly incorporated with the charge.

My improved steel thus manufactured possesses peculiar hardness, (depending, as before stated, on the amount of chromium, manganese, and silicon it contains,) toughness, and peculiar resistance to compression strains, which makes it especially adapted for the purposes hereinafter mentioned. It also pos-

sesses other peculiar and valuable characteristics, as hereinafter described.

My improved steel may be hardened and tempered either in its cast or forged state in the usual way. When it has been run into molds—that is, when the molten material has been used for producing "steel castings"—although in some cases I then use it as cast—that is, in its unannealed state—yet when the greatest strength and toughness are required I prefer to anneal such castings in the usual way, and after such annealing the material possesses a pecular close grain of special density, as well as toughness and hardness. Bars turned out of such castings in my improved material in its annealed state, and not forged, rolled, or hammered in any way, tested in a Whitworth machine, stand tensile strains of fifty to sixty-five tons per square inch, whereas ordinary steel castings will not stand more than twenty-five to thirty-six tons per square inch.

Notwithstanding the peculiar hardness and closeness of grain from the same material which stands these high tensile strains, shavings have been taken many feet in length, thus showing its toughness, combined with high tensile strain, which makes it of special advantage and specially adapted for a large variety of purposes, such as car-wheels, stamp-castings, projectiles, and many other articles. This steel also possesses extraordinary resistance to compression strains. Test pieces turned out of castings in my improved material and subjected to a compression strain of one hundred tons per square inch in a Whitworth machine only shortened ten per cent. in their length, compared with thirty, forty, and fifty per cent. in pieces turned out of ordinary steel castings and hammered-steel manufactures in the ordinary way.

Having thus described my improved steel and the method of producing same, what I claim for my invention, and desire to secure by Letters Patent, is—

1. As a new article of manufacture, steel containing chromium, together with manganese and silicon, said ingredients being in the proportions of from three-quarters of one per cent. to seven per cent. of chromium, from one-tenth of one per cent. to twenty per cent. of manganese, and from one-tenth of one per cent. to five per cent. of silicon, as hereinbefore described.

2. As a new article of manufacture, steel containing chromium, together with manganese, said ingredients being in the proportions of from three-quarters of one per cent. to seven per cent. of chromium and from one-tenth of one per cent. to twenty per cent. of manganese, as hereinbefore described.

3. As a new article of manufacture, steel containing chromium, together with silicon, said ingredients being in the proportions of from three-quarters of one per cent. to seven per cent. of chromium and from one-tenth of one per cent. to five per cent. of silicon, as hereinbefore described.

In testimony whereof I have hereunto set my hand this 3d day of August, A. D. 1885.

ROBERT HADFIELD.

Witnesses:
R. A. HADFIELD,
CHAS. W. LOW.