UNITED STATES PATENT OFFICE.

ROBERT HADFIELD, OF SHEFFIELD, COUNTY OF YORK, ENGLAND.

STEEL.

SPECIFICATION forming part of Letters Patent No. 342,867, dated June 1, 1886.

Application filed July 29, 1885. Serial No. 172,984. (Specimens.) Patented in England December 4, 1884, No. 15,949.

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; 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 admixture, the principal constituents of which are iron (Fe) and silicon, (Si,) but which may also contain carbon, as well as other ingredients, such as sulphur and phosphorous, necessarily present in the metal, such alloy having most of the qualities peculiar to ordinary carbon steel, besides other qualities 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 silicon.

To enable others skilled in the art to manufacture my improved steel, I will proceed to describe the process which I employ, which forms the subject-matter of another application for Letters Patent, Serial No. 164,679, filed May 7, 1885.

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 silicon should be substantially decarburized, by which I mean not necessarily 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 iron or steel by means of the Bessemer, open-hearth, or crucible processes, these processes being carried on in the usual way as to the first two named, until the metal under treatment is nearly or quite decarburized, depending upon whether any, and if any, what amount, of carbon is to be present in my improved steel, and then the desired percentage of silicon is added; while if the crucible process is employed, the silicon addition 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, and to reduce the percentage of silicon in the resulting steel to the lowest point practicable—say one-tenth of one per cent. or less, so as practically to exclude silicon therefrom, as its presence in the steel has been supposed to be injurious. I have discovered, however, that if silicon is present in sufficient quantity—say one and one-half per cent. to five per cent.—the resulting product is a steel of very superior quality and possessing certain marked characteristics, and I have also discovered that when this is the case the presence of sulphur and phosphorus in the 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 silicon and iron having the desired percentage of silicon, arising from the fact that in the process of refining and decarburizing the metal the silicon present is oxidized before the carbon, so that especially in the open-hearth, puddling, and Bessemer processes it has been ascertained by analysis of the metal at different stages of treatment that the amount of carbon remains undiminished until the silicon has been removed below the point necessary to produce my improved steel, so that, although a large percentage of silicon be present in the charge of iron under treatment, or be added thereto previous to the process of reduction, refinement, or decarburization, the resulting metal, even after only a partial decarburization, is almost entirely desiliconized.

In the manufacture of my improved steel, 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 to the desired point, more or less carbon being left in the metal, as may be desired. By this time any silicon which was present in

the charge before treatment will have been practically eliminated by oxidation, so that if the oxidizing process is arrested when the silicon is added the exact amount or percentage of silicon added to the charge at that point of the process will be easily determined, the amount of silicon present in the silicon addition being previously ascertained, and will be present in the resulting steel at the close of the operation. The silicon is introduced into the wholly or sufficiently decarburized metal substantially in the same manner as spiegeleisen is commonly added as a final step in the process of making steel by the Bessemer steel-making process. This is done by the use of silicon pig-iron, hereinafter referred to as silicon addition (a well-known product of the blast-furnace process) or other ferro-silicon, which is incorporated with the charge, as above stated, either in a solid or melted condition. The gross amount of silicon pig or ferro-silicon to be added will depend on the amount of silicon which it contains, which will be ascertained beforehand, and also of course on the percentage of silicon which the resulting steel is desired to contain. I prefer to use as the silicon addition silicon cast-iron or silicon pig-iron containing from eight to ten per cent. of silicon, for the reason that such material is 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 of decarburized and desiliconized iron six hundred and fifty pounds of the silicon pig-iron herein referred to; also, if necessary, a sufficient quantity of ferro manganese, but usually the silicon pig contains sufficient manganese without requiring a separate addition thereof. It is desirable to keep the carbon under one per cent. in those steels containing two and a half per cent. of silicon 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 resulting product should have greater toughness, I introduce such amount of the siliconizing addition as will yield a steel having from one and a half to two per cent. of silicon, and where greater hardness is required I increase the amount of silicon in varying proportions up to about five per cent. After the silicon addition is incorporated with the charge, it is ready to be run into ingots 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 operation, and the siliconizing addition is introduced into the crucible at any stage of the process and becomes thoroughly incorporated with the charge.

Manganese may be added to the steel made by my process in the usual way.

My improved steel thus manufactured possesses after tempering peculiar hardness, (depending in degree, as before stated, on the amount of silicon which it contains,) so that it is specially adapted for what is known as "tool steel" purposes, edge-tools, &c. It has also other peculiar and valuable characteristics, among which I would mention that it has great toughness compared with the tool steel now used. It is more waxy and malleable in working when heated than high-carbon steel, and is therefore more readily shaped under the hammer, and when cold is more easily cut and tooled than ordinary steel. It is not so brittle as ordinary steel, and is less liable to be burned in heating, and to what is known as "water-cracking." It is also susceptible of hardening and tempering by the same methods and with substantially the same effect as carbon steel.

I desire it to be understood that in the foregoing specification and following claim I use the word "steel" to designate a metal of which iron is the basis, irrespective of the amount of carbon which it may contain, and having the well-known characteristics of hardening and tempering possessed by carbon steel.

I am aware that cast or pig irons high in silicon are well known in the arts; but these do not possess the properties described as belonging to my improved product, such as malleability and the susceptibility to hardening and tempering; nor does my improved product contain carbon in as high a percentage nor in as great a ratio to silicon as is usually found in these silicons, pigs, or cast-irons. As one example of the composition of my improved product, I give the following analysis, not confining myself, however, to these proportions: Specimen No. 408—carbon, 0.78; silicon, 2.49; sulphur, .09; phosphorus, .07; manganese, .64. This analysis plainly indicates the difference between my improved product and cast or pig irons high in silicon. I therefore do not claim such cast or pig irons.

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

As a new article of manufacture, steel or a malleable silicious compound of iron containing silicon in the proportion of from one and one-half per cent. to five per cent. of silicon.

In testimony whereof I have hereunto set my hand this 15th day of July, A. D. 1885.

ROBERT HADFIELD.

Witnesses:
R. A. HADFIELD,
WILLIAM CROWLEY.