

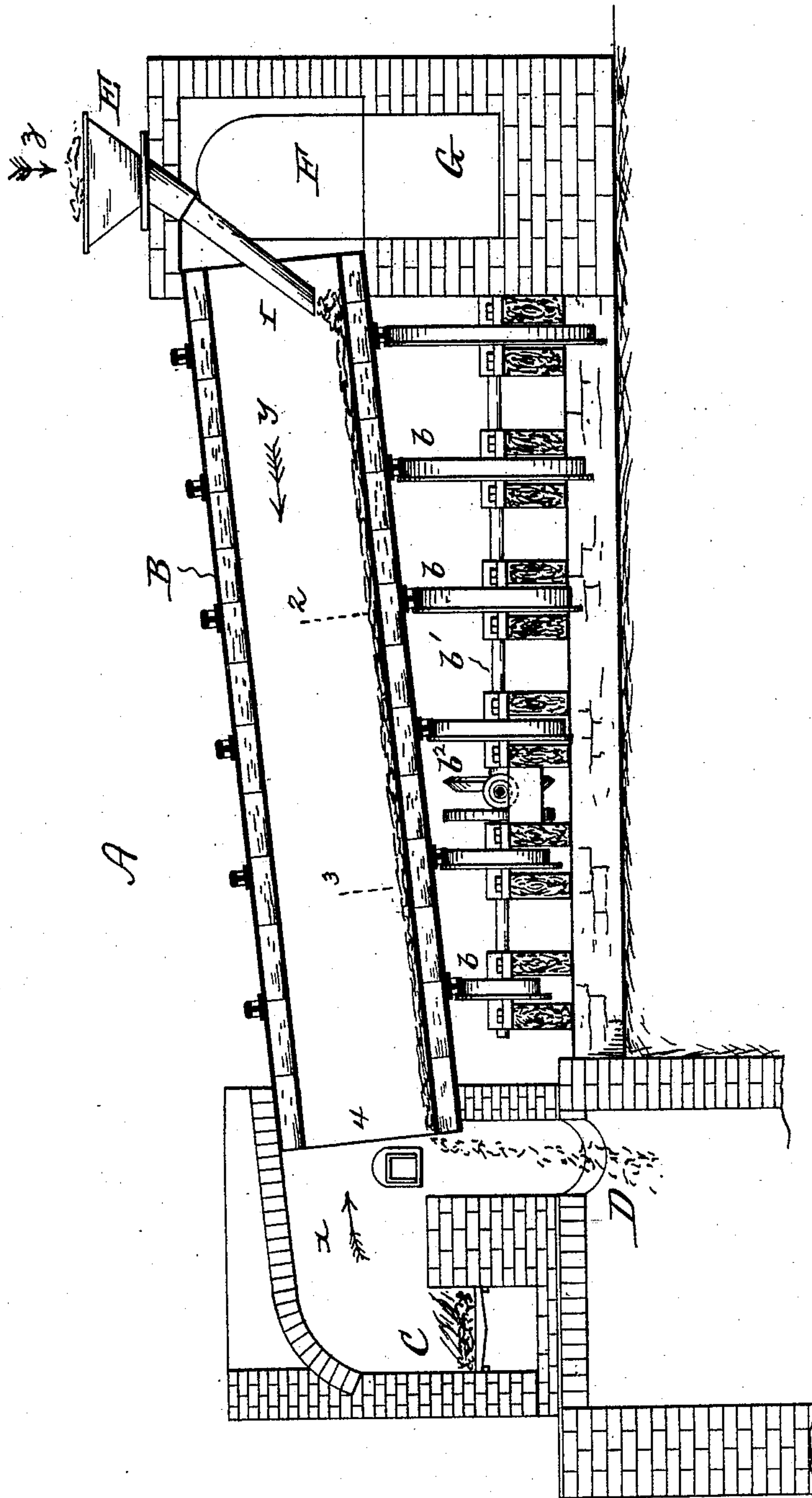
(No Model.)

J. W. NEILL.

METHOD OF TREATING AND CONCENTRATING PYRITIFEROUS ORES.

No. 472,387.

Patented Apr. 5, 1892.



WITNESSES:

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METHOD OF TREATING AND CONCENTRATING PYRITIFEROUS ORES.

SPECIFICATION forming part of Letters Patent No. 472,387, dated April 5, 1892.

Application filed February 26, 1891. Serial No. 382,947. (No specimens.)

To all whom it may concern:

Be it known that I, JAMES W. NEILL, a citizen of the United States, residing at Leadville, in the county of Lake and State of Colorado, have invented certain new and useful Improvements in Methods of Treating and Concentrating Pyritiferous Ores, of which the following is a specification.

My invention has relation to that treatment of non-magnetic pyritiferous ores which consists in converting the non-magnetic pyrites contained in an ore into a magnetic sulphide of iron, similar to the mineral pyrrhotite, without oxidizing the same, so that it can be separated from the gangue and other associated minerals by passing it through a magnetic field.

My invention has for its object an economical method of converting the non-magnetic pyrites contained in any ore into a magnetic sulphide of iron in such manner that the angularity and shape of the particles of the ore will be kept intact and not run together, and thus remain in condition so that when passed through a magnetic separator the maximum separation of the pyrites from the gangue and other minerals can be effected. This result is accomplished by subjecting successive portions of the ore successively to the action of products of combustion increasing in temperature, resulting in a reaction which changes the non-magnetic pyrites into magnetic pyrites without combining the magnetic pyrites with other elements in the ore, or oxidizing the pyrites, as would be the case if the heat be continued, until the sulphur contents be reduced so far as to render the iron of the pyrites magnetic as an oxide which is a different product and produced by a different process from mine. Other disadvantages not produced by my process would result if the ore be heated past the stage where the iron is magnetic as a sulphide, as the material will in a great part lose its magnetic properties, which can be partly renewed if the ore be then heated to a still greater extent, as part of the iron will become a magnetic oxide; but the other materials—such as sulphide of lead, zinc, and notably silver—will also be oxidized and in a great part volatilized. Furthermore, the particles will lose their identity and fuse and stick together, rendering a perfect separation

impossible. It will be seen from the foregoing that the heating of the material must be stopped when the non-magnetic pyrites becomes a magnetic sulphide. The furnace used and the manner of applying the heat is a matter of indifference so long as the temperature is such as will produce the magnetic sulphide. An ore of the kind described having sufficient sulphur present will almost automatically reach the proper temperature through the heat of the burning sulphur, while, with an earthy ore—that is, a gangue with a smaller amount of pyrites—no flame of burning sulphur will appear, and the proper temperature must be kept up by the fire at the lower end. In both cases care must be taken that the heat is not so great as to cause the white fumes of sulphuric acid to appear, as this shows that oxidation of the monosulphide of iron has taken place. The temperatures which I find give the best results, quoting *Porillet's Table of Temperatures* as the standard, are between 400° centigrade and 1,000° centigrade. Of course the process can be commenced at a lower or higher temperature than 400° centigrade; but a higher point than 1,000° centigrade would, where silver is present, cause the latter to melt. In practice I prefer to start with a low heat—say about 400° centigrade—and slowly increase the heat to, say, 525° centigrade, when the inflammable part of the ore ignites and burns, and then through the several stages of dark red, (700° centigrade,) of commencing cherry-red, (800° centigrade,) of bright cherry-red, (900° centigrade,) to clear cherry-red—i. e., about 1,000° centigrade—when the material is drawn from the furnace and cooled.

It will be seen by the foregoing that my method differs materially from the ordinary method of roasting, wherein the mass ignites almost as soon as it enters the furnace, and by reason of the heat generated thereby the temperature increases to such an extent that the sulphur flame has disappeared before the ore has passed through one-third of the furnace. The roasting and sweating sets in as the sulphur flame disappears, and the ore is then kept from a bright-yellow heat (1,100° centigrade) to white heat (1,300° centigrade.) This roasting occupies many hours and consumes much fuel, and leaves the ore entirely

granular and in part or entirely magnetic as an oxide; but the subsequent separation cannot be accomplished to produce the results obtained by my method—*i. e.*, the changing of the non-magnetic pyrites into a magnetic sulphide to permit of the separation of the said magnetic sulphide from the rest of the matter, forming the ore by means of a magnetic separator.

10 In practice the operator determines by an examination of the ore how rapidly to pass the material through the furnace. If the ore has sufficient sulphur to create the necessary heat, the ore very quickly reaches the temperature that makes withdrawal from the furnace necessary. If there be little pyrites in the ore, the operator determines at the start the rate of speed and the amount of heat necessary to produce the result, he arriving at that conclusion by observing the shades of color in the mass as the heat is applied. The end of the process can be judged fairly well by the eye as the mass falls from the furnace or cylinder, as that is the point where the blue flame of the burning sulphur gives way to sparks of incandescent ore and a white smoke which they give off. The best method, however, is to remove a part of the material and test with a hand-magnet, the proof of the test being that the particles do not adhere to one another, are approximately of their original size and shape, and are of a black hue and not red or spongy, and that the residue left after the magnetic pyrites are removed show no traces of oxidation if there be zinc-blende or galena, or both, present.

In practicing my method I proceed to prepare the ore for the furnace, where the method is carried out in the following manner: The crude ore as it is mined is usually wet, or at least damp, and is composed of pieces or fines of various bulks or volumes. This crude ore is first subjected to a crushing operation to coarsely reduce it to a comparatively uniform size. From the crusher it falls into a storage-bin or receptacle of any suitable kind. From the latter the crushed ore is transferred by means of suitable elevators or conveyers or otherwise, as desired, to a drying-cylinder heated either by the waste heat from furnaces or other heating appliances used in reduction works or by independent firing, or by both. This cylinder is preferably inclined and is somewhat long and is caused to revolve upon its axis at any speed desired per minute. The ore rolling gradually through this cylinder is subjected to heat and thoroughly dried. Falling from this drier into storage-bins the dried ore is transferred from the bins to crushing machines and rollers or other equivalent devices to pulverize the same to the necessary or desired fineness to pass through a screen of a certain mesh. The necessary fineness of the ore and mesh of screen vary with different ores and must be determined by experiment, the object of such screening being to remove any material not

reduced to the fineness necessary to pass through said mesh, which material so removed is then recrushed and rescreened.

The means for varying the angle of inclination is not shown in the drawings, which represent a longitudinal section of a roaster or furnace.

B is a cylinder having an outer shell of iron, to which the driving machinery b , b' , and b^2 is attached or geared, and an inner lining of brick to prevent the outer shell from being destroyed by the heat. Its upper end abuts against or projects into a flue F G, which gives draft to the fire and carries off the smoke and fumes. Through the upper end, by means of spout E, ore is charged continuously. At the lower end of the cylinder is the fire-box C, having its bridge-wall about one foot (more or less) distant from the end of the rotating cylinder, thus giving room for the ore to be discharged, when it reaches the lower end of the cylinder, into a receptacle or bin D, where it is allowed to cool or may be transferred. The necessary fineness must be in each case determined by the nature of the ore and by practical tests; but usually a screen of twenty (20) meshes to the linear inch will be of sufficient fineness.

The pulverized and screened crude ore, when taken from the storage-bins, is cold, dry, and non-magnetic, and is transferred by elevators, conveyers, or like apparatus to the feed-hoppers of the reaction-furnace, which is similar in form to the drier—that is to say, it preferably consists of a revolving cylinder of some length, and is operated by worm-and-gear chain or other belting, as is usual on such furnaces, by which said cylinder is caused to revolve slowly upon its axis, and this speed for the cylinder may be varied by means of cone-pulleys or other regulator devices used in connection with its driving mechanism. The furnace is inclined slightly, and is preferably so arranged that its angle of inclination can be changed to suit varied conditions and different ores.

The furnace preferably consists of an outer shell of iron, to which the driving machinery is attached, and an inner lining of brick to prevent the outer shell being destroyed by the heat. At its upper end the cylinder abuts against or projects into a flue or stack, which gives draft to the fire and carries off the smoke and fumes. Through this upper end the ore is charged continuously and automatically by a conveyer, spout, or other device.

At the lower end of the furnace is the fire-box, the opening or fire-bridge being about one foot (more or less) distant from the end of the rotating cylinder, thus giving room for the ore to be discharged on arriving at such opening. As it passes through the latter it falls into a suitable bin, where it can be allowed to cool, or it may be transferred to a cooling-floor. The cold non-magnetic ore is slowly fed into the revolving cylinder in a continuous stream and acted upon by gravity,

due to inclination of the furnace, and by the rotation of the latter each particle of crude pulverized material is carried by a spiral movement toward the lower and heated end of the cylinder and is also rolled over and over as the cylinder revolves under it. Thus said particles are heated evenly and for the same length of time. The temperature at the upper end of the furnace is not allowed to increase to redness. At the lower end the temperature is, however, when properly fired, a "bright cherry-red," preferably. The ore in passing through the furnace-cylinder slowly increases in temperature until about the middle of the furnace, whereat the sulphur contained in the ore ignites and burns with a bluish flame, the whole mass not yet being red-hot. Soon after the sulphur ignites the temperature increases until the whole mass reaches an even red heat, which should be maintained to the end. Before the ore is discharged from the furnace the flame of burning sulphur has nearly disappeared from the part about to be discharged; but such part has not begun to oxidize or "roast" or "sweat"—that is, the ore about to be discharged does not show white-hot spongy spots or particles, (somewhat resembling stars,) which give off white vapor or smoke of sulphurous acids, as the latter indications, when they occur, show that the treatment has gone too far, and that therefore the temperature of the furnace must be lowered and that there is imminent danger that the pyrites in the ore will have passed beyond the magnetic condition, and that other associated minerals will be decomposed or fused and the ore be rendered unfit for the treatment herein described. The desired condition of the ore in the furnace or the proper temperature therefor can be regulated by the amount of firing, the volume or amount of ore fed, and the inclination and speed of rotation of the furnace-cylinder, and thus the proper reaction can be obtained for various kinds of ores.

The length of time necessary to complete the reaction in the furnace varies with the quantity of pyrites in the ore. After the ore has attained a red heat the reaction is usually finished in about twenty minutes, approximately.

Some care must be exercised in conducting the reaction. Thus, for instance, if the ore is heated too long or too intensely the particles will frit or adhere together and the magnetic separation will be seriously impaired or interfered with. If the heating be carried so far as to drive off too much sulphur, the pyrites will become non-magnetic, and thus the process will be vitiated. Further, if other minerals of value—such as galena or zinc-blende—be present in the ore the heating must be such as to not decompose these minerals, as such decomposition would result in a change in the relative specific gravities, and the minerals could not be separated and saved by the ordinary methods of wet or other concentra-

tion which would naturally follow for the separation of the galena from the zinc-blende. When the reaction is properly performed, the treated ore, after cooling, presents a black appearance, not red, and the particles have apparently lost none of their angularity or configuration, they do not adhere to each other at all, and, in fact, are apparently unchanged in shape, so that the pyrites in the ore is in the best condition to be subjected to magnetic influence. Such pyrites in the ore being now magnetic by reason of having been by proper heating changed chemically to a lower sulphide similar to the mineral pyrrhotite, can be readily and cheaply separated by suitable magnetic appliances from the gangue or other associated minerals which still remain non-magnetic. The ore after passing through the reaction by heating in the furnace-cylinder, and being cooled in the receiving-bins or otherwise, as desired, is then ready for concentration by magnetic separation, and for this purpose it is transferred by suitable elevators or conveyers to the hoppers of any suitable magnetic separator wherein the low sulphides of iron are separated from the gangue and other associated minerals in the usual way.

From the foregoing it will be noted that the crude ore from the mine is first coarsely crushed, and this is done for the reason that the pieces of ore after such crushing being of more uniform size can be more readily and economically handled, elevated, and transported, and also because more surfaces can be thus exposed to heat, and such crushed ore can therefore be more quickly and economically dried; that the coarsely-crushed ore is then dried for the purpose of facilitating the operation of further pulverizing the ore and also to facilitate its passage through the screens after such pulverization, and, further, to facilitate and thus cheapen the process of the reaction in the reaction-furnace, as if the ore were charged into this furnace in a damp state it would roll up into lumps or balls, and thus seriously interfere with the progress of the reaction and the evenness of the product and thus with the ultimate results of the separation; that the coarsely-crushed dried ore is then further crushed and pulverized and screened, as described, first, to sever each and every particle of each distinct mineral from every other particle of like or different nature, so that in the following separation each material may follow the right course. If the comminution be not carried far enough, a particle of other mineral to which is attached a particle of pyrites will, after the treatment and reaction, carry this particle of other mineral into the concentrates, and thus partially vitiate the process and require a further and expensive re-crushing and re-treating. Further, by this fine division of the ore each particle is in a condition to be most readily and successfully acted upon by the heat of the reaction-furnace. Should coarse and fine be

charged together into this furnace, the time of the reaction cannot be so gaged as to deliver both coarse and fine together at the proper temperature. Either the fine will be
 5 overheated or the coarse will not be heated sufficiently. This pulverization is therefore a great saving in fuel, in labor, and in time, and on the successful pulverization of the ore depends much of the success of the process.
 10 Exactly the contrary conditions exist if the ore be subjected to greater than a drying heat before the preliminary crushing and screening—for instance, by roasting in kilns, heaps, or piles—as the then subsequent reaction
 15 would be uneven and the following separation ineffectual on this account, rendering a further treatment necessary or involving a large loss. Furthermore, such treatment by heating in kilns, piles, or heaps requires much time and
 20 expense for labor, such heaps often burning for months, while by this invention the necessary reaction can be quickly, cheaply, and more certainly obtained and regulated, the ore being exposed to heat generally for less
 25 than an hour's time. Many ores on which the reaction can be readily and economically conducted, as above described, could not be treated at all by heap roasting or heating in piles or kilns, as the associated minerals—
 30 such as galena, zinc-blende, &c.—would be either decomposed or would melt and fuse together, thus vitiating the reaction and rendering the whole unfit for final separation by this process or any other usual method. If
 35 heating in piles, kilns, or heaps be attempted on ores containing pyrites, the reaction cannot be controlled at all, and either a large part of the pyrites would remain unchanged or it would be converted into a non-magnetic
 40 state, as oxide, and thus the object of such heating be frustrated. A very small proportion of the pyrites in any pyritiferous ore which has been roasted or heated in kilns, heaps, or piles will be found to be magnetic,
 45 and such ore will for that reason, when so roasted, be unsuitable for concentration by

this or any other economical method. That the pyritiferous ore is passed through the furnace at a temperature which only vaporizes a portion of its sulphur in order to convert the pyrites therein into a sulphide of iron, which is magnetic, and this is done without oxidizing the iron; or, in other words, the angularity, shape, or configuration of the pyrites and associated minerals is apparently
 55 preserved and the particles do not fuse or run together, so that when passed through a magnetic field the pyrites is in the best possible condition to be separated from the gangue and other associated minerals in an economical manner and with the maximum percentage of saving. By my process it is obvious that non-magnetic pyritiferous ores of all kinds can be more effectually and economically
 60 treated than can be done by processes involving kiln, heap, or pile heating, roasting, or oxidizing of such ores.

While I have described my invention as especially applicable for pyritiferous ores, I do not limit myself thereto, as it is obvious
 70 that copper or other ores of similar non-magnetic character, which when subject to the treatment herein described become magnetic, and thus are rendered suitable for corresponding separation or concentration, are included within the scope of my invention.

What I claim is—

The process of rendering magnetic non-magnetic ores of the class specified, which consists in subjecting successive portions of
 80 the ore successively to the action of the products of combustion increasing in temperature and then withdrawing the ore from the action of the heat before the particles have lost their angularity.

In testimony whereof I affix my signature in presence of two witnesses.

JAMES W. NEILL.

Witnesses:

FRANK W. OWENS,
 C. F. DOWLING.