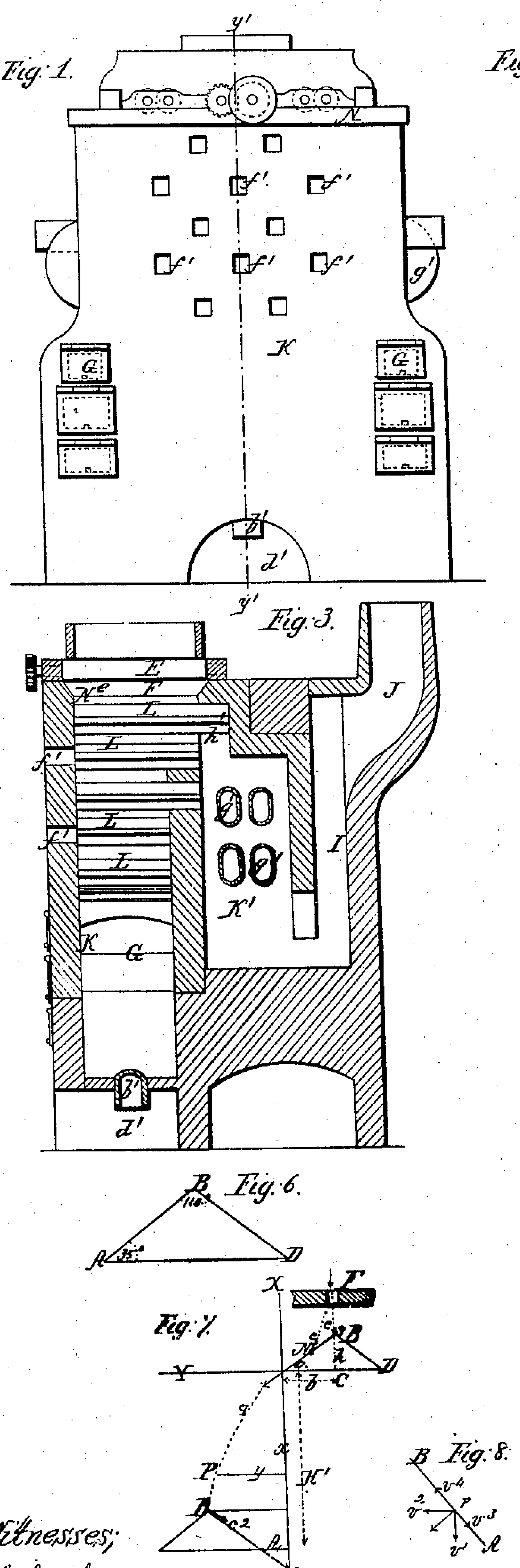
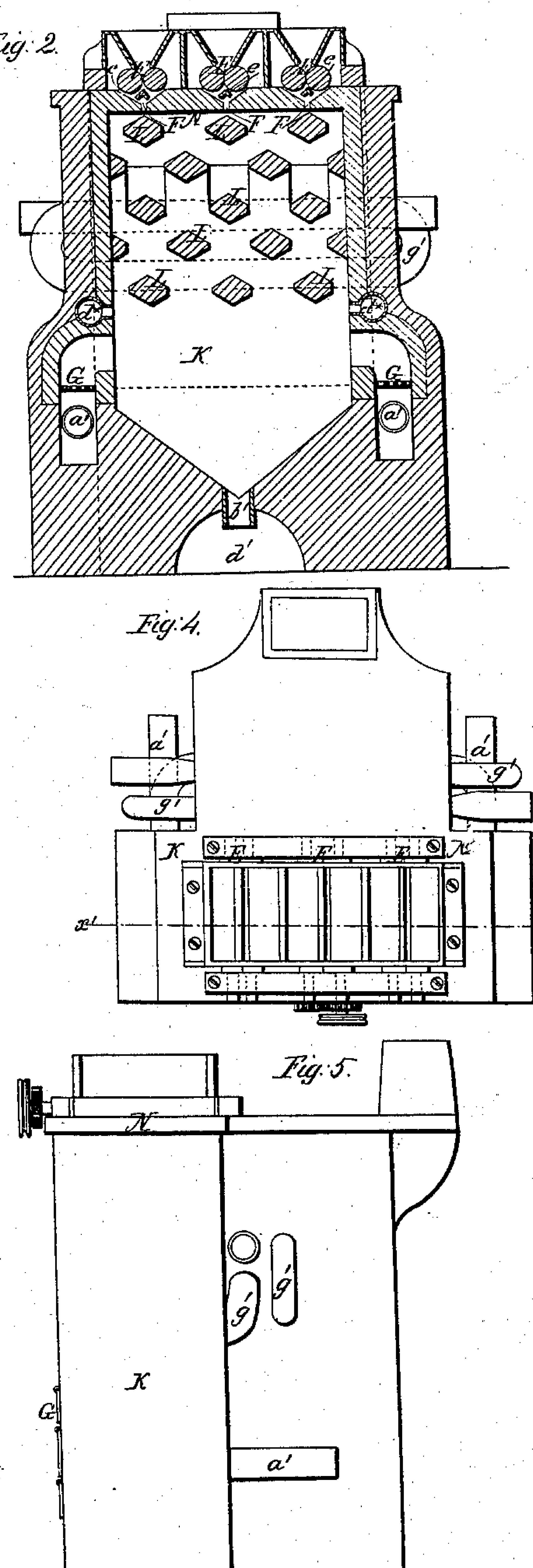
C. A. STETEFELDT.

FURNACE FOR DESULFURIZING ORES.

No. 43,140. Patented June 14, 1864.





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CHARLES A. STETEFELDT, OF NEW YORK, N. Y.

IMPROVED FURNACE FOR DESULPHURIZING ORES.

Specification forming part of Letters Patent No. **43,140**, dated June 14, 1864.

To all whom it may concern:

Be it known that I, CHARLES A. STETEFELDT, of the city, county, and State of New York, have invented a new and Improved Furnace for Desulphurizing Ores; and I do hereby declare that the following is a full, clear, and exact description thereof, which will enable any person skilled in the art to make and use the same, reference being had to the accompanying drawings, making part of this specification, in which—

Figure 1 represents a front elevation of my invention. Fig. 2 is a transverse vertical section of the same, the line *x′ x′*, Fig. 4, indicating the plane of section. Fig. 3 is a longitudinal vertical section of the same, taken in the plane indicated by the line *y′ y′*, Fig. 1. Fig. 4 is a plan or top view of the same. Fig. 5 is a side elevation of the same. Figs. 6, 7, and 8 are diagrams illustrating the shape and position of the terraces.

Similar letters of reference indicate the same parts in all the figures.

This invention relates to certain improvements in that class of furnaces known as "upright terrace-furnaces;" and the object of these improvements is to regulate the velocity with which the charge passes through the furnace and to reduce the time necessary for a perfect roasting or desulphurization of the ores by the peculiar shape and construction of the terraces, and by their peculiar position in relation to each other; also to reduce the expenditure of fuel and to regulate the temperature throughout the furnace by the application of hot-air apparatus and cold-air pipes in combination with the terraces, and to make such disposition in the internal arrangement that the furnace is applicable for the reduction of gold, silver, quicksilver, and other ores.

The process of roasting is undoubtedly the most important of all metallurgical operations, not only because by means of it metals are directly produced from ores and furnace products—as, for instance, in the manufacture of lead in reverberatories, the production of copper from copper matte, and the extraction of quicksilver from cinnabar—but this process also forms the basis of all other metallurgical operations.

The necessary conditions for a quick and complete desulphurization of ores are as follows:

First. Minute division of the ores and presentation of the greatest possible surface.

Second. Introduction of the steady movement of the roasting-charge against the current of combustion gases and air. Experience shows that when the charge is left perfectly stationary, or even when it is moved with the current of air, the result is an incomplete desulphurization.

Third. Greatest possible use made of the heat generated by the process itself aside from fueling.

Fourth. A continuous and uniform mode of procedure, which renders the success of the process more independent of the attention and skill of the workmen.

My furnace is constructed with the view to fulfill these conditions. The pulverized ore is allowed to fall over a succession of terraces through an inclosed space or shaft, while a heated current of air or flame is conducted in the opposite direction. In the construction of such a furnace the form and arrangement of the terraces is the essential element, as will be apparent from the following thorough and scientific investigation. The greatest or natural slope or talus of loose masses is measured by the angle of friction, Q, inclosed by the plane of the talus and a horizontal plane. This angle will naturally be smaller when the pulverized ore, on arriving on the slope, possesses a certain initial velocity than it is when the ore is heaped thereon by careful racking from beneath. If, therefore, the angle of friction be determined by the latter method, it may be surely assumed that the ore arriving on the terraces with a certain initial velocity will slide off from the same. At the same time care must be taken to make the angle Q of the talus as small as possible, to prevent the ore from passing too quickly through the furnace. By various experiments with different crushed ores the angle of friction for careful piling was found to be about thirty-five degrees. The slope of the terrace measured by the angle B A D, Fig. 6, therefore, is to be thirty-five degrees, and consequently the angle A B D inclosed by the two sloping sides of terrace will be one hundred and ten degrees.

In order to determine the position of the several terraces in relation to each other, it is necessary to follow a single particle of the ore in its course through the furnace. The ore on leaving the feeder arrives on the first terrace with a certain velocity which depends upon the vertical distance between the point B of the terrace and the slide or feeder F, Fig. 7. If this distance be designated by S, we have the velocity C, with which the ore arrives at the terrace, expressed as follows:

$$C=\sqrt{2gs} \tag{1}$$

where g represents the acceleration of gravity. On arriving upon the terrace the velocity of the ore is checked and it is compelled to fall in an oblique direction along the inclined plane B A, and it moves toward the point A with a velocity

$$C_1=C \sin Q \tag{2}$$

In falling over the inclined plane B A the ore acquires a velocity which is expressed by $\sqrt{2gh}$, when h denotes the vertical height B C of the terrace, and if b is equal to half the width of the terrace the height h is equal to b tang Q, and on arriving at the point A the velocity of the ore is

$$C_I=C_1+\sqrt{2gh} \tag{3}$$

Those particles also which do not strike the terrace exactly at its apex, but some at point M lower down, will leave it at A with practically the same velocity, since in that case in the equation for C_I the value of the first part, C, will be greater, while the value of the second part, $\sqrt{2gh}$, will be smaller, than in the first case. The falling body, subjected to the further influence of gravitation, and to the uniform velocity C_I in the direction B A, assumes a complex motion and describes the parabola A P, Fig. 7. If a right-angled system of co-ordinates, A X and A Y, be drawn through the point A, the point P can be determined where the ore will be found after the lapse of a period, t_I, reckoned from the moment of leaving the terrace A. The coordinates of that point are—

$$y=c_I t_I \cos Q \tag{4}$$

$$x=g \text{ tang } Q+\frac{g y^2}{2 c_I^2 \cos^2 Q} \tag{5}$$

By means of these two operations the relative positions of the terraces will be determined.

The time t_I which the ore requires to pass from A to P is expressed by the following:

$$t_I=\tfrac{1}{g}\left(\sqrt{c_1^2 \sin^2 Q+2gx}-c_I \sin Q\right) \tag{6}$$

And if t designates the time which the ore requires to pass from the feeder to the terrace, and t_1 the time required by the ore in sliding over the slope of the terrace, we have—

$$t=\sqrt{\tfrac{2s}{g}} \tag{7}$$

$$t_1=\frac{1}{g \sin Q}=\tfrac{1}{g}\left(\sqrt{c_1^2+2g b \text{ tang } Q}-c_1\right) \tag{8}$$

By introducing the value of t_1 into equation 4 we get—

$$y=\frac{c_I \cos Q}{g}\left(\sqrt{c_1^2 \sin^2 Q+2 g x}-c_I \sin Q\right) \tag{9}$$

If the vertical distance between the base of the first terrace and that of the second be called H, and the horizontal distance between the nearest edges A, and I place the second terrace so that the ore coming from the first may strike upon its apex B_1, the ordinates of the terminus B_1 of the parabolic path are—

$$x=H_1-h \tag{10}$$

$$y=A_1+b \tag{11}$$

And by introducing these values into the equations 5 and 9 we obtain the following equations:

$$A_I=\frac{c_I \cos Q}{g}\left(\sqrt{c_I^2 \sin^2 Q+2g(H_1-h)}-c_I \sin Q\right)-b \tag{12}$$

$$H_1=(A_1+2 b) \text{ tang } Q+\frac{g (A+b)^2}{2c_1^2 \cos^2 Q} \tag{13}$$

These two equations afford all the essential elements for the construction of the first pair of terraces, and it is only necessary to determine the velocity C_2 with which the ore begins its motion on the second terrace in order to find the relation of H_1 and A_1 for all further terraces.

The component velocities of the ore in the point P of the parabola are (see Fig. 8)—

$$v_1=c_I \sin Q+g t_1,$$

$$v_2=c_I \cos Q,$$

Or, setting for t_I its value from equation 6,

$$v_1=\sqrt{c_1^2 \sin^2 Q+2g (H_1-h)}$$

v_1 separates itself into two components—one perpendicular to the plane A B and one in the direction P A. Calling the latter v_3, we have—

$$v_3=v_1 \sin Q.$$

In the same manner we can separate v_2 into a force, v_4, in the direction A B, and a force perpendicular to A B, and we have—

$$v_4=v_2 \cos Q.$$

These equations remain the same if we suppose P to be the point at which the ore falls upon the second terrace and A B to be the slope of the terrace. We shall then have—

$$c_2=v_3-v_4,$$

$$\text{or } c_2=\sin Q \sqrt{c_1^2 \sin^2 Q+2g (H_1-h)}-C_I \cos^2 Q \tag{14}$$

The ore leaves the second terrace with a velocity, C_{II}, which is—

$$C_{II}=C_2+\sqrt{2gh} \tag{15}$$

The formulæ 12, 13, 14, and 15 may be considered general. If H_n be the vertical distance of the nth terrace from the (n+1)th, A_n their horizontal distances, C_n the initial velocity of the ore upon the nth terrace, C_N the terminal velocity upon the same, we shall have—

$$C_n=\sin Q \sqrt{C_{N-1}^2 \sin^2 Q+2g(H_{n-1}-h)}-C_{N-1} \cos^2 Q \tag{16}$$

$$C_N=C_n+\sqrt{2gh} \tag{17}$$

$$H_n=(A_n+2b) \text{ tang } Q+\frac{g(A_n+b)^2}{2c_N^2 \cos^2 Q} \tag{18}$$

$$A_n=\frac{C_N \cos Q_2}{g}\left(\sqrt{C_N^2 \sin^2 Q+2g (H_n-h)}-C_N \sin Q\right) \tag{19}$$

From these two last equations it will be seen that the essential proportions and dimensions for the whole apparatus are not constant; but they will vary, since, in order to find H_{n+1} and

A_{n+1} the distance between the (n+1)th and the (n+2)th terraces we must substitute in these equations for C_N the different value C_{N+1}. It is therefore by no means indifferent whether we first assume a value for H and find the corresponding values for A, or whether we derive, vice versa, the values of H from A. From a simple consideration it will be apparent that we must take A as constant, since by this quantity the horizontal dimensions of the furnace will be regulated, and if A should be made variable the practical execution of the furnace upon correct principles would be impossible. A being constant, the values of H would be different for each successive pair of terraces—a condition which can be easily satisfied. From a further consideration of the equation 18 it will be seen that it contains only one variable factor—viz., the velocity with which the ore leaves the terrace. H_n therefore consists of a sum of two members, of which the first, (A+2b,) tang Q, is the same for all terraces, while the second, $\frac{g(A+2b)}{2C_N^2 \cos^2 Q}$, is variable. Of these two members the first or constant one is by far the greatest, since in the second the value C_N, which will always be considerable, appears squared as a divisor.

In order to ascertain between what limits the value of H may vary it is necessary to consider the equation 16, which shows that the velocity with which the ore begins to move upon the nth terrace is not always positive, but, on the other hand, can become zero or negative. This will be the case when

$$\sin Q \sqrt{C_N^2 Q + 2g(H_{N-1} - h)} = C_{N-1} \cos^2 Q$$

Since the equation 16 is general we can substitute N for N—1 and obtain for that value of C_N for which the initial velocity upon the next terrace will be zero, the equation

$$\sin Q \sqrt{C_N^2 \sin^2 Q + 2g(H_n - h)} - c_N \cos^2 Q = o$$

The solution of this equation gives

$$c_N = \frac{\sin Q \sqrt{2g(H_n - h)}}{\sqrt{\cos^4 Q - \sin^4 Q}} \quad \ldots\ldots 21$$

the ore will fall in such a manner as to tend to run up instead of down the slope of the terrace and to leap over the summit. The terraces being double, however, this latter motion would be resisted by a similar tendency of the particles coming from the opposite slope. This periodic pause in the downward motion of the ore is extraordinarily favorable for the roasting process, since by it the ore is retained for a longer period in the furnace. The minimum value of c_N is of course $c_N = \sqrt{2gh}$ and the maximum value of H therefore $H_{max} = (A+2b) \text{ tang } Q$. The minimum value of H cannot be in general terms exactly stated, but it is evident that H must always be somewhat smaller than (A+2b) tang Q. The height H depends further upon the values assigned to the dimensions A and b. The question first arises whether A shall be taken as positive, zero, or negative. Positive it cannot well be taken, since in that case the vertical distances of the terraces or height H results too great, and in consequence therefrom the furnace would afford room for only a few terraces. The distance A must therefore be zero or negative, and its limits are o and —b. For the latter value H will be equal to b tang Q=h—that is, all the terraces will form a single inclined plane. From these considerations it might seem advantageous to make the value of A as nearly as possible —b, and by doing so the largest possible number of terraces might be crowded into a comparatively small space, and thereby the ore delayed in its fall; but in that case the resistance to the current of air is increased to such an extent that the pressure of the draft from the bellows will have to be increased in proportion, and in consequence thereof the formation of dust, &c., is augmented, and the regularity in the operation of the furnace is disturbed. By making A=o all the formulæ are simplified, and we obtain for H

$$H_n = 2b \text{ tang} Q + \frac{gb^2}{2c_N^2 \cos^2 Q} \quad \ldots\ldots 23$$

and

$$H_{max} = 2b \text{ tang } Q + \frac{b^2}{4h\cos^2 Q} = \frac{b(1+8\sin^2 Q)}{4\sin Q \cos Q} \ldots 25$$

The width of the terraces 2b must be fixed by practical experience. If taken too large it would make H very great; but it must be large enough to meet the requirements of durability, absorption of heat, and resistance of air.

The bearing and scope of the equations hereinbefore given will be fully understood from the following example:

Let b=0.4 ft., Q=35°, s=0.4 ft., g=32.2 ft., and we have

$$H_n = 0.5601 \text{ ft.} + \frac{3.8390 \text{ ft.}}{C_N^2} \quad \ldots\ldots 25$$

And H_{max}=0.5601 ft.+0.2043 ft.=0.7644 ft.,

For—

$C_N = C_n + \sqrt{2gh}$,

We obtain—

C_N=4.2470 ft.+C_n 26

Since—

C=5.0754 ft. and C_1=2.9111 ft.,

We have—

C_I=4.2470 ft.+2.9111 ft.=7.1581 ft.,

And it follows that—

H_1=0.[illegible] ft.+0.0749 ft=0.6350.

Further—

C_2=3.6152 ft.—4.8031 ft.=—1.1879 ft.,

From which—

C_{II}=4.2470 ft. and H_2 will be the maximum H.

H_2=0.7644 ft.

Further—

C_3=3.4950 ft.—2.8497 ft.=0.6453 ft.

C_{III}=4.2470 ft.+0.6453 ft.=4.8923 ft.

H_3=0.5641 ft.+0.0164 ft.=0.5665 ft.

Again—

C_4=2.9434 ft.—3.2828 ft.=—0.3394 ft.

C_{IV}=4.2470 ft.

H_4=0.7644 ft.

It is unnecessary to continue the calculation any further, since the values of H will be alternately 0.5663 feet and 0.7644 feet. The velocity of the ore will therefore become zero after passing two terraces, and a periodical or intermittent motion will be the result, which is of the greatest importance for the success of the roasting process.

By the aid of the equations 6 and 8, and by using the values of C_{II}, $(H_2—h,)$ C_3, C_{III}, and $(H_3—h)$ as determined by the above example, we find the value of T, the time of one period: $T = 0.2299 + 0.1136 + 0.1976 + 0.0631 = 0.6042$ seconds; and since each period covers two terraces, it follows that if the furnace contains twenty terraces the ore will remain in it 6.042 seconds.

The quantity of ore which may be thrown upon the uppermost terrace is limited by the velocity of the current of air in the sections of the furnace. This velocity ought to exceed five feet per second, and taking the following dimensions as a basis, we can find the quantity of the charge: Let the length of the terrace be three feet, h, 2b, &c., the same as above stated, and the charge consists of iron pyrites, which are to be deprived of their entire contents of sulphur—viz., 53 per cent. We assume that 25 per cent. of the oxygen does not take part in the roasting, but escapes unchanged. The temperature in the furnace shall not exceed 700° centigrade, (1,223° Fahrenheit.) Three English feet being 0.916 meters, there will pass through the section of one feeder in one second 340,840 cubic centimeters of air heated to 700° centigrade. At a temperature of 0° centigrade, and the barometer at 0.76 meter, (30 inch,) this air would take up a space of 95,594 cubic centimeters, weighing 123.6 grams; but of this quantity 21.01 grams of oxygen act in the process and unite with 21.01 grams of sulphur to sulphurous acid, $(SO_2.)$ This result corresponds to 39.65 grams of pyrites per second, which will give for twelve hours 1,713,000 grams, or 34.26 hundred-weight @ one hundred pounds @ five hundred grams to the pound. For a furnace with five feeders, the product of twelve hours will be one hundred and seventy-one hundredweight. Pulverized ores contain about one-third of their volume in empty interstices, and since the specific gravity of pyrites is 5′, the 39.65 grams of ore required per second will take up a space of 11.9 cubic centimeters, which the feed-rollers must supply. If the latter are supplied with semicircular flutes, it will be easy to calculate the number of revolutions required per minute.

Guided by the results obtained by this investigation I built my furnace in the following manner:

K represents an upright shaft of rectangular section built up of brick and lined with fire-brick or any other suitable material. This shaft contains the terraces L, which are diamond-shaped, as clearly shown in Fig. 2 of the drawings, so that they can be turned if the upper side has been injured, and thus will be more durable and absorb and recommunicate more heat than they will if made with a triangular cross-section. They must be made of fire-clay and had better be covered with a coating of graphitic clay, which resists most perfectly the chemical action of the roasting-charge. A square iron rod is placed in the center of each terrace, so that the same can be built in the rear and front wall of the furnace. The roof N of the furnace which is formed of fire-clay contains the feed-openings F, and above these are situated the rollers E, by which the ore can be conveyed regularly and in the desired quantities to the furnace. These rollers may be fluted in a direction parallel to their axis. From the rollers the ore drops upon a roof-shaped surface, *e*, which checks its velocity. The sides of this roof are perpendicular to the slope of the sides of the feed-openings. On both sides of the shaft K are the fire-places G, which serve for heating up the furnace, and in certain cases for keeping up a fire during the process of roasting. The fire-places and ash-holes are so arranged that a draft can be created from beneath through the pipes *a′*. After the ore has passed down over the terraces L, it collects in the lower part of the shaft and can be removed through an aperture, *b′*, and a subterranean passage, *d′*. When blende is roasted, it may be advisable to prolong the lower end of the furnace into a hearth. Above the arch of the fire-place in each side of the furnace a pipe, *d*, is set, which conveys the heated air from the bellows. This pipe may set lower down into the furnace below the fire-places on the sides of the pipes *a′*, in which case the number of terraces may be increased by putting an additional number below the level of the fire-bridge. Between this level and that of the arch of the fire-place no terraces should be put, since they would prevent the uniform distribution of the flame in the furnace.

While building the front wall of the furnace, holes *f′* should be left opposite each terrace, so that the temperature in the shaft may be observed and disturbances may be remedied by means of proper tools. During the roasting these openings must be closed.

Behind the shaft K is a chamber, K′, Fig. 3, which contains a series of oval pipes, *g′*. These pipes communicate with the bellows, and through them the air for the bellows is heated. The shaft K communicates with the chamber K′ by means of a flue, *h′*, which is partially occupied by the uppermost terraces. On leaving the chamber K′ the gases pass into the channel I, which leads to the chimney J, and above this channel the wet ores from the stamps are spread to be thoroughly dried.

This furnace is applicable to the desulphurization of ores of every description, but particularly for treating auriferous sulphurets and metals which are afterward to be treated by amalgamation. For materials rich in sulphur no fire will be required after the furnace has once been heated. It will then run itself, heating its own air, and requiring only to be kept charged. Zinc blende can be desulphurized with very little fire. When it is desired to desulphurize ores and furnace products only to a certain degree, (which is the case in most smelting operations,) the process can be perfectly regulated by the amount of ore conducted through the feeders, the quantity of air admitted, and the height given to the furnace.

For many purposes, especially for roasting auriferous sulphurets, the bellows can be entirely dispensed with and a chimney with a strong draft substituted.

I am aware that a mode of roasting analogous to mine in its general principles is described in a patent granted to Keith, Behr, and Keith on the 9th of September, 1862; but my process is superior to theirs, by reason of the use of hot-air blast and the means afforded for applying a greater amount of heat to the ore within a given height of shaft.

I am also aware that the general idea of terraces is not new, and that a roasting-shaft is described by Whelpley and Storer in their patent of January 12, 1864.

What I claim as new, and desire to secure by Letters Patent, is—

1. The employment or use of an upright terrace-furnace, substantially such as herein described, for the purpose of reducing gold, silver, quicksilver, and other metals from the sulphureted ores.

2. The peculiar construction, proportion, and disposition of the terraces L in the shaft K, as based on the rules deduced from the formulæ 1 to 24, whereby a complete and rapid desulphurization of the ores is accomplished.

3. The combination of a hot-air apparatus with an upright terrace-furnace, for the purpose substantially as set forth.

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