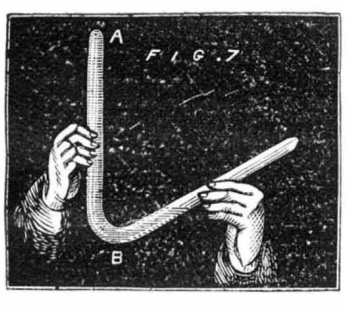
HEAT AND LIGHT.

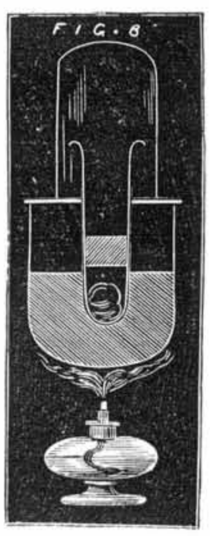
[Report of a recent lecture by Professor John Tyndall, before the Royal Institution.]

Liquids expand in general more than solids. I may here remark that the ordinary definition of the solid, liquid, and gaseous states, given in many text books, is hardly correct. Cohesion is thought to be predominant in the first state of matter, absent in the second, and negative –that is to say, that absolute repulsion exists among the molecules—in the third. But liquids may be strongly cohesive; and, indeed, the researches of many physicists have shown that there is not an absence of cohesion among, but sliding powers possessed by, the molecules of matter in the liquid state. If air is expelled from water, it is still liquid, but the cohesion of its molecules becomes very great.

To M. Donny, of Ghent, we are indebted for the discovery of an interesting property of water, illustrative of the cohesive force it possesses. On heating water, air bubbles crowd to its side long before it boils, rising through the liquid without condensation. The air thus liberated has been held in solution by the water, and one of the remarkable effects it produces is that it promotes ebullition. It acts as a kind of elastic spring, pushing the atoms of water apart, and thus helping them to take the gaseous form.

The tube I hold in my hand, which, after the inventor, is called Donny's tube (Fig. 7), contains water which has been freed from air by boiling. My friend, Mr. Justice Grove, would say it is impossible entirely to free water from air by boiling, but this water has been very nearly freed. Having lost the cushion which separated them, the cohesion of the atoms of water is vastly augmented. One effect, as you hear, is that the water, running from end to end of the tube, strikes against it with as rude a shock as if it was a solid body. You hear the sharp metallic ring it sends forth when I turn it upside down. I bring the water into one arm of the V by tilting the tube; you see it flows freely from one arm into the other. I now tap the end of the arm containing the water on the table. At first there is a slight jingling noise; as long as you hear that sound, the water is not in true contact with the tube; I continue tapping, the jingling soon ceases, and the sound is now perfectly hard—like that of one solid against another; the interstitial air, which it is impossible wholly to exclude from the tube, has been removed, and if I now raise the tube. the water remains in (A B) the arm, the particles of water clinging so tenaciously to the

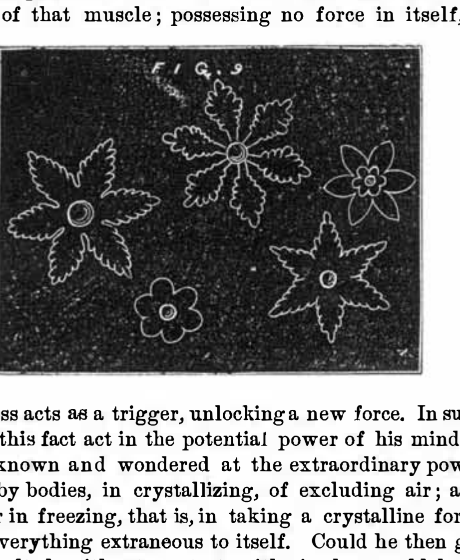




sides of the tube that it refuses to behave like a liquid body; it declines to obey the law of gravitation.

But Donny pushed his researches further, and found that the boiling point of water was very greatly elevated when the water was free from interstitial air; indeed, that it could be subjected to a temperature 50° Fah. above its ordinary boiling point before ebullition took place, and that then, instead of boiling in the ordinary way, molecule by molecule, as it were, that the whole or nearly all the water is converted into vapor at the same time with a sudden crack like an explosion.

Faraday took great interest in this experiment, but in his mind it was like the ignition of a match, which instantly produces more light. His mind may be said to have possessed the potential power of a muscle, while a new fact acted like the nerve of that muscle; possessing no force in itself, it

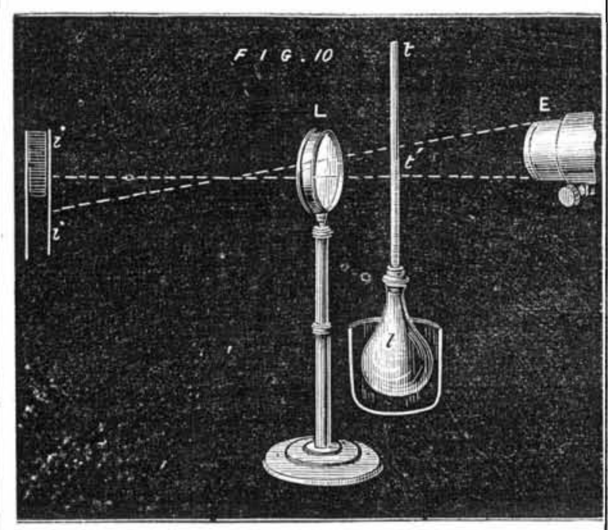


nevertheless acts as a trigger, unlocking a new force. In such a way did this fact act in the potential power of his mind.

He had known and wondered at the extraordinary power possessed by bodies, in crystallizing, of excluding air; and that water in freezing, that is, in taking a crystalline form, excludes everything extraneous to itself. Could he then get pure ice melted without contact with air, he would have water still more perfect than Donny's boiled water, and it ought to produce the same effect. Well, he surrounded his ice with oil—melted it—the oil floated on the surface of the water, and he found that the water could be heated 60° Fah. above the ordinary boiling point, and that when it did boil, it boiled with a sudden explosion.

This experiment was performed: A small lump of ice was placed in a clean test tube in an oil bath, and just covered with oil (Fig. 8), the whole being surmounted by a glass jar to avoid scattering the oil. When the water boiled, it did so with a sharp explosion, violently discharging the oil above it into the jar. A second tube, containing common water covered with oil, boiled tranquilly.

We will now send a beam of heat through a plate of ice, and take down the crystalline structure of the ice. It will pull the crystals to pieces by accurately reversing the order of its architecture; silently and symmetrically the crystallizing force built the atoms up, and silently and symmetrically the electric beam will take them down, producing the beautiful flowers with six petals, with which many of you are familiar (Fig. 9).



When these flowers are examined by reflected light, in the center of each flower appears a spot which shines with a silvery luster; these spots are not air bubbles, but a vacuum, the water occupying less space than the ice previously did. Imagine the flower forming and gradually increasing in size. The cohesion of the liquid is so great that it will pull the walls of its chamber together, or even expand its own volume sooner than give way. But as its size augments, the space which it tries to occupy becomes too large for it, until finally the liquid snaps with an audible clink, and a vacuum is formed. When I first heard this noise, I suspected my imagination to be in fault, but I soon found it to be a reality, and that when water is thus split, one can hear the rend.

Let us now return to our expansions. Most liquids expand by heat and contract by cold. Alcohol is a good example; its expansion continues till it reaches the boiling point, and it contracts again at one even rate to the lowest temperature. It has never been solidified.

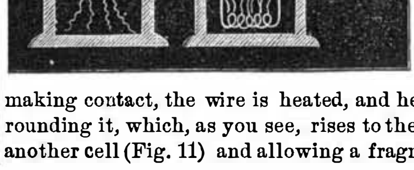
A far more interesting case of expansion is that of water, inasmuch as it exhibits a wonderful exception to the usual law of contraction by cold. If heat be abstracted from water, it goes on contracting till it reaches a temperature of 39° Fah., or thereabouts, at which point contraction ceases. This is the so-called point of maximum density of water; and from this point downwards, till the freezing point is reached, the liquid instead of contracting expands, and when it is converted into ice the expansion is considerable.

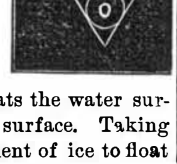
The flask filled with water, A, is tightly corked (Fig. 10); through the cork a tube, *t*, passes watertight, and the liquid rises within it. A strong beam from the electric lamp, E, passes across the tube, and by means of the lens, I, an enlarged image of the liquid column appears on the screen, *i i*. Of course the image is an inverted one, and when the liquid expands, the top of the column will descend the screen. Heating the flask by a spirit lamp, at the first instant the head of the column ascends as if the liquid contracted. This is due to the momentary expansion of the flask to which the heat is first communicated. Now it stops and commences descending the screen, and does so until the liquid reaches the top of the tube, a single drop running over.

I now cool the flask by plunging it into the freezing mixture of pounded ice and salt. You see the column gradually sinking, now a point is reached at which the contraction becomes very slow, and at last it stops altogether; and now expansion begins; putting in a little more of the freezing mixture, it rapidly increases—for the colder the mixture, the quicker the expansion—and you see it goes on till the water is actually thrust out at the top of the tube by the cold, exactly as it had been by the heat.

The force of this expansion is very great. Mr. Cottrell will place a bombshell and an iron bottle in a freezing mixture, covering them both. Before we follow the result to its consequences, we will show the manner in which heat diffuses itself through liquids.

I have here a glass cell (Fig. 11) into which I plunge this platinum spiral, *a*, which I can heat by means of a small battery, throwing upon it a beam from the electric lamp; I can, by a lens, obtain its image upon this screen, and now





making contact, the wire is heated, and heats the water surrounding it, which, as you see, rises to the surface. Taking another cell (Fig. 11) and allowing a fragment of ice to float upon the water, the difference of refraction between the cold and the warmer water enables you to see the descending current. In the one case the water streams upwards, in the other it streams fast downwards. Thus, in a general way, it is illustrated that the lighter water rises and the heavier water sinks.

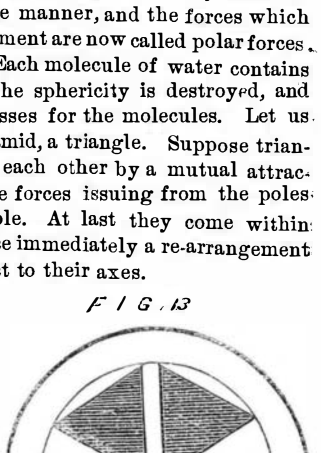
In order fully to appreciate the value, of the infraction of the general law of contraction by cooling, we may examine the case of a lake exposed to an atmosphere below the freezing point. The surface is chilled, the water contracts, becomes heavier and descends, its place being filled by the lighter water from below. This, in its turn, is chilled likewise and sinks. Thus a circulation is established, the cold dense water descending, and the lighter warmer water ascending to the top. Supposing this continued, the whole of the water of the lake would ultimately become one solid block. But just as matters become critical at the temperature of 39° Fah., the water expands by cooling, and swims like a scum on the top of the warmer water beneath. Solidification ensues, and the ice, being much lighter than the liquid, forms a protecting roof over the living things below.

When this fact was first made known, I believe by De Luc, afterwards by Blagden and Hope, it produced a strong impression. Rumford says: "Though it is one of the most general laws of Nature with which we are acquainted that all bodies, solids as well as fluids, are condensed by cold, yet, in regard to water, there appears to be a very remarkable exception to this law. . . . All bodies are condensed by cold without limitation, water only excepted. . . . This exception to one of the most general laws of Nature, a striking proof of contrivance in the arrangement of the Universe, a proof which comes home to the feelings of every ingenuous and grateful mind . . . for though the extensiveness and immutability of the general laws of Nature impress our minds with awe and reverence for the Creator of the Universe, yet exceptions to those laws, or particular modifications of them, from which we are able to trace effects evidently salutary or advantageous to ourselves and our fellow creatures, afford still more striking proofs of contrivance, and ought certainly to awaken in us the most lively sentiments of admiration, love, and gratitude;" and further on, he adds: "I feel the danger to which a mortal exposes himself who has the temerity to undertake to explain the designs of Infinite Wisdom. The enterprise is adventurous, but it cannot surely be improper." I think it is adventurous to attempt to get at the designs of Infinite Wisdom. The case of water is not exceptional. The metal bismuth expands at the time of crystallization by cooling from the molten stand. A bowl of molten bismuth becomes covered with a crust, which is broken through in little craters, as the cooling progresses.

How are we to figure this act of expansion? It is manifestly preparatory to the act of crystallization. The idea of polar force, which we are accustomed to from the study of magnetic phenomena, has been applied to crystals. They build themselves into definite shapes, hence they must arrange themselves in a definite manner, and the forces which produce this definite arrangement are now called polar forces.

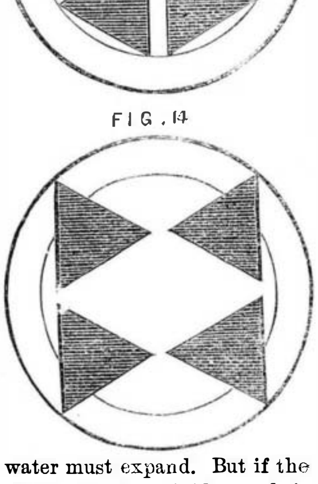
Now to revert to water. Each molecule of water contains three atoms (Fig. 12); thus the sphericity is destroyed, and we have pyramidal little masses for the molecules. Let us next take a section of a pyramid, a triangle. Suppose triangular molecules to approach each other by a mutual attraction of the general mass; the forces issuing from the poles would be for a time insensible. At last they come within each other's play, and produce immediately a re-arrangement of the molecules with respect to their axes.

FIG. 13



This model will in a rough way demonstrate the point (Fig. 13). The bases of the triangles are facing each other, as they are drawn together, the center of gravity of each being one third of the length of the line bisecting the base, drawn to the opposite angle; when they are brought thus close, we may imagine that the polar force is brought into play as against the gravitating force, and that the vertices are drawn face to face (Fig. 14). The center of gravity is two thirds from each vertex, and as you see by their encroachment on the outer circle, expansion is the result. The triangles now take up more room than they did before.

FIG. 14



[The burst bomb and iron bottle were now shown, and reference made to the influence of pressure upon the freezing point.] To solidify, water must expand. But if the vessel be rigid it cannot do so, hence, in a rigid vessel, it would remain longer liquid. For every additional atmosphere of pressure, the freezing point is lowered 1-75th of a degree Fah., and it is raised 1-75th of a degree when atmospheric pressure is removed.—*Mechanics' Magazine.*

A STATUE of Shakespeare has just been erected in Central Park, New York. The sculptor was J. Q. A. Ward. As a work of art, it is considered a great success. Some say that it is the best Shakespearean sculpture evermade. Crowds of people flock to see it.

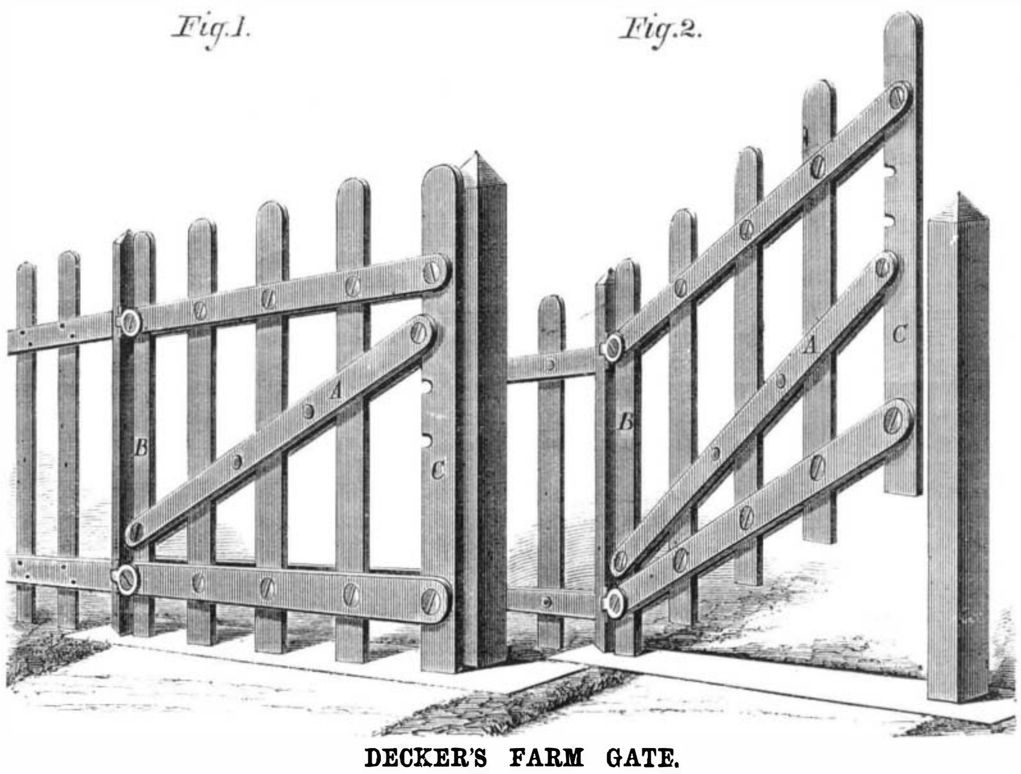
Improved Farm Gate.

Mr. E. B. Decker, of Carrolton, Greene county, Ill., has made an improvement in gates, which we here illustrate. The invention appears a good one, and is likely to obviate a great many defects in other farm gates.

Fig. 1 is a view of the closed gate. It is constructed of upright slats and horizontal rails which, instead of being firmly connected, are riveted together so as to be able to move freely round the rivets. The position of the gate is maintained by the brace, A, which diagonally crosses it. This brace is composed of two pieces, which are riveted together as shown in the engraving, the rear end being pivoted to the hinge slat, B, and the forward end being supported, by its rivet, in a notch in the front slat, C, and, at the same time, bracing the front slat, so that it cannot fall lower and bring the gate out of position. It is obvious that, if the front slat were raised, it would allow the brace to fall into the next notch, and so on until the gate reached the position shown in Fig. 2, in which the brace would firmly hold it. The brace will thus admit of the gate being raised without being opened, to allow of sheep, cattle, etc., passing under it and to clear the winter snow; while sagging is prevented in any position.

Patent is now pending through the Scientific American Patent Agency.

Further information may be had by addressing the inventor as above.



DECKER'S FARM GATE.

IMPROVED PUDDLING TOOL.

The process of hand puddling, in the ordinary reverberatory furnace used for the purpose, can be divided into four stages:

(1) Melting. The pig iron, together with a proportion of hammer slag, is charged on the bed, previously lined with either puddling mine, bulldog, or both, and plastered over with wet hematite ore. As the cast iron gets softened by the heat, it is broken into smaller pieces and stirred up with the cinder. This is done by the hand rabble, which has to be continuously moved over the whole surface of the bed. This stage lasts about thirty-five or forty minutes.

(2) In the second or boiling stage, the iron has to be violently rabbled in order to bring it into a state of ebullition or boiling. In this operation, the puddler has to exert himself very considerably, working the rabble to and fro, and from side to side, over the bed.

(3) "Coming to nature." The iron now begins to thicken and to get tougher and tougher; the "boil" stops, and it "comes to nature" or begins to assume the consistency of heated wrought iron. The puddler works it in this pasty consistency from side to side of the furnace, separating it into different pieces.

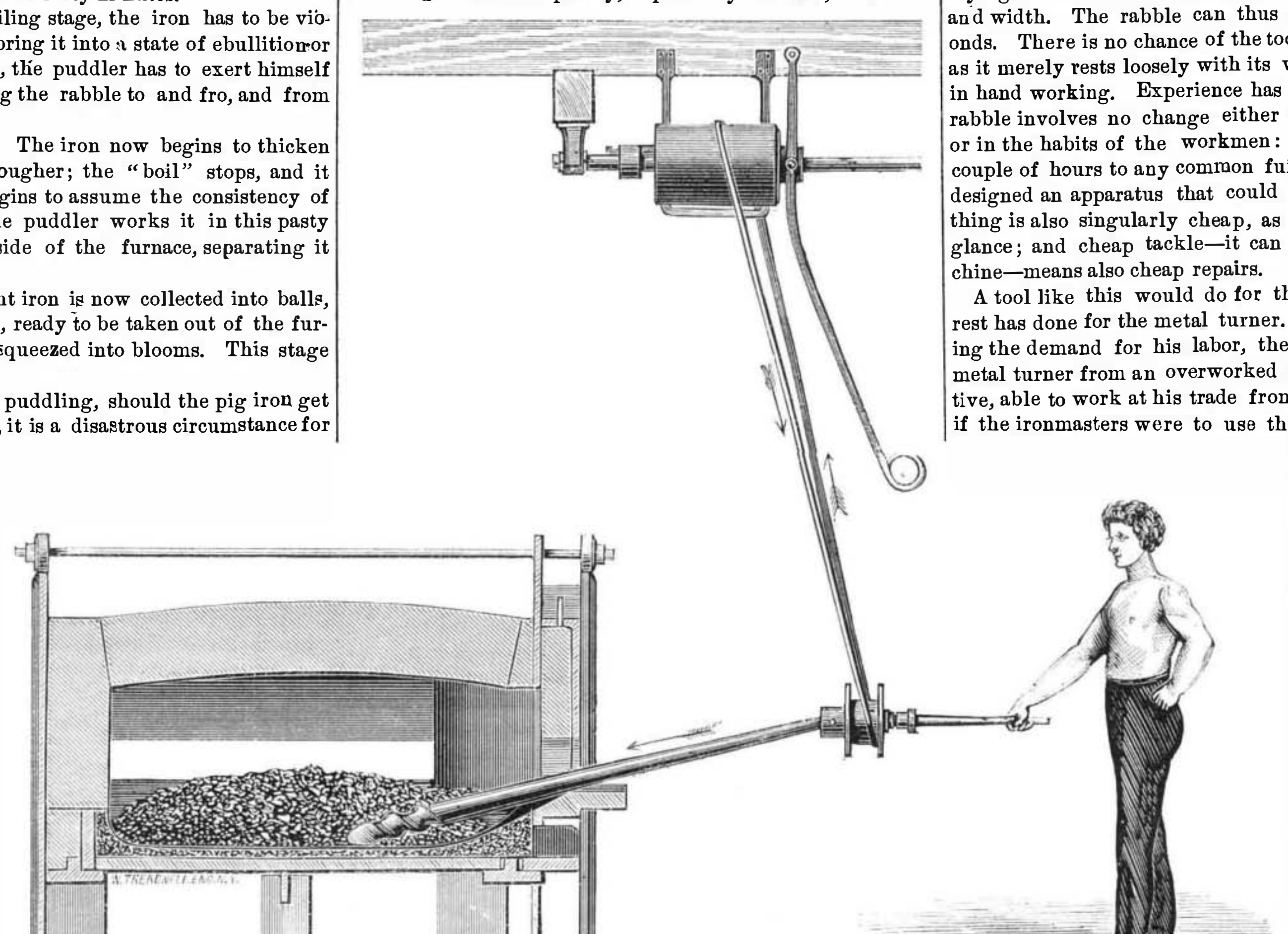
(4) Balling. The wrought iron is now collected into balls, varying in weight and size, ready to be taken out of the furnace to be hammered or squeezed into blooms. This stage takes about ten minutes.

In the ordinary mode of puddling, should the pig iron get entirely melted on the bed, it is a disastrous circumstance for the puddler. The bath of metal, with its even surface hidden under the lighter cinder, offers very slight surfaces of contact to oxidation. To meet this, he is forced to very violently exert himself in stirring up the metal; and he is obliged to shovel in quantities of hammer slag, cinder, or other sources of oxygen, which cool down the metal and lower the quality of the product.

There can be no doubt that an unaided man's strength is insufficient for this labor. Dr. Percy, whose opinion as a metallurgist, chemist, and medical man is universally known to be of the very highest importance, states that the majori y of puddlers "die between the ages of forty-five and fifty years; and, according to the returns of medical men to the registrar, pneumonia, or inflammation of the lungs, is the most frequent cause of their death. This is what might have been anticipated from the fact of their exposure to great alternations of temperature under the condition of physical exhaustion." They are also liable to cataract, induced by the intensely bright light of the furnace; and the forearms and faces of some puddlers are also often scorched to a bright red tinge in a curious way. As Dr. Percy observes, "it is not surprising that puddlers should manifest a growing disinclination to bring up their children to his occupation, to which, as a general rule, their strength ceases to be equal beyond the age of forty-five or fifty." On the puddler more than Adam's curse seems to have fallen—copious drops transpire, not merely from his brow, but from all his almost naked body, while engaged in what Mr. W. Bridges Adams has termed "the absurdity of setting a number of human beings to stir up a metallic pudding in order to throw off the scum."

To Mr. Edward Hutchinson, of Messrs. Pease, Hutchinson & Co., Skerne Ironworks, Darlington, England, belongs the merit of having first invented and experimented with the revolving rabble. His trials were very successfully carried out as long ago as 1865, being, however, relinquished during the same year, and without having been published in any way. M. Dormoy quite independently took up the same idea, and has been perseveringly working it out since 1866.

Any puddling machinery must be essentially simple and non-liable to get out of order by the roughest and most careless usage. This simplicity, required by the men, is also required by the furnace; the high temperature of which, with the attendant rapid current of air passing through, must not be interfered with.



DORMOY'S REVOLVING RABBLE APPLIED TO COMMON FURNACES.

A glance at the accompanying illustration will render the whole apparatus intelligible. A common belt, driven from shafting six feet above the furnace, rotates the sheave, loosely jointed at one end to the puddling rabble, and at the other turning on a pin held in the hand of a puddler. To prevent any jarring action to his hand, the pin he holds may be wound round with spun yarn or gasket, embraced by a leathern or india rubber tube. The strap thus rotates the rabble, supports part of its weight like a suspension link, and acts as a universal joint, much as in the familiar instance of the rotating hair brush. The belt must evidently adapt itself with ease to the great variety of positions which have to be taken by the tool in every part of the furnace, to the necessity for removal when too hot, and to the progressive changes in the metal.

Mechanism could easily be applied to the rotating rabble in order to work it regularly to and fro; but this additional complication has not been found necessary. Its great speed, from 300 to 800 revolutions per minute for white pig, and from 800 to 1,000 for gray metal—is found to give it all the mechanical energy required. The end of one form of rabble, about $4\frac{1}{2}$ inches in diameter, when revolving with 500 revolutions, necessarily has a speed at its circumference of nearly 600 feet per minute. On the other hand, the iron, even when boiling, is not thrown up. The centrifugal impulses are not sufficient to overcome the cohesion of the hot metal. The power required has been indicated by Herr Biedermann, now of Floridsdorf, near Vienna, at from one quarter to one half of a horse power per furnace per hour; but the draft would necessarily increase towards the end of the heat. There is no bearing near the furnace necessarily liable to get hot; no gearing to break on any sudden resistance; and the strap itself acts in its usual way as an admirable friction brake. It is difficult to imagine how the apparatus can come to grief in any other way besides breaking the strap. For such a case, a spare belt is kept hanging on the shaft; or the puddler could even merely go on in the ordinary way. If kept well greased, however, the belt lasts from three to four months without renewal. Any diminution in speed can be obtained by slightly relieving its weight off the belt—thus allowing more or less slip. On the other hand, any unusual resistance can be overcome by the puddler pressing the tool down on the belt. Simply by crossing the strap, the rabble can be rotated from left to right, or *vice versâ*, alternately, as required. The tools, in spite of their extra weight, are easily removed from the furnace by taking them off the strap, by means of a hook on a light chain suspended near the furnace from the roof, and laying them on small trestles about eighteen inches in hight and width. The rabble can thus be changed in thirty seconds. There is no chance of the tool disturbing the fettling, as it merely rests loosely with its weight on the bed, just as in hand working. Experience has shown that the revolving rabble involves no change either in the plant of the works or in the habits of the workmen: it could be adapted in a couple of hours to any common furnace: and the author has designed an apparatus that could be at once applied. The thing is also singularly cheap, as can be seen at the first glance; and cheap tackle—it can scarcely be called a machine—means also cheap repairs.

A tool like this would do for the puddler what the slide rest has done for the metal turner. While actually increasing the demand for his labor, the slide rest has raised the metal turner from an overworked drudge to a skilled operative, able to work at his trade from youth to old age. Even if the ironmasters were to use the revolving rabble merely to relieve their men, and without requiring a greater number of heats from them, they would gain:—(1) A great improvement in the quality of the iron produced; (2) a great diminution in the number of ruinous "cobbles" or "wasters;" (3) the capability of working up very gray or also inferior kinds of pig, without using any "fined metal;" (4) diminution of loss in mill scale between the rolls.

Perhaps the most important truth which has been lately elicited touching mechanical puddling is its effect in improving the quality of the puddled bar. Mr. Danks has worked up almost every kind of American and British pig metal with excellent results as to quality. Mr. Adam Spencer has in his revolving furnace produced excellent iron from Middlesbrough metal containing 2 per cent of phosphorus. As already noticed, experience with oscillating rabbles points to more or less improvement in the quality. Mr. Hutchinson, as we have seen, improved the quality of Cleveland iron with his revolving rabble. M. Dormoy has puddled with success some old cannon balls the Turks left behind them at Temesvar, in Hungary, so white and containing such a large quantity of arsenic as to be utterly intractable by the ordinary process; he has also operated at Zeltweg, in Styria, upon pig metal alloyed with copper and sulphur; upon the sulphurous pig metal of the Loire and