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fused medicine and food, and was obliged to be drenched in order to get either down: an emetic and cathartic being pre-mised, they were all put upon the same plan; that is, were to take, every three hours, two-thirds of a glass of fresh porter, with two table spoonfuls of yeast and the juice of half a lemon; and the food at intervals was the white of eggs, which Dr. Thornton judged of all things were least subject to putrify*, beat up with some sugar and water, and, as it was the commencement of summer, strawberries were also ordered; and without any farther medicine from the apothecary than the emetic and purge, although the woman was at first obliged to be drenched, yet she and her whole family recovered, and this very rapidly.

Among the poor in St. Giles's nothing is administered by Dr. Thornton, after cleansing the primæ viæ, than two table spoonfuls of yeast in some porter every two hours; and out of above forty cases not one has died under this treatment.

XIII. *On the various Effects produced by the Nature, Compression, and Velocity of the Air used in the Blast-Furnace.*

By Mr. DAVID MUSHET, of the Clyde Iron-Works.
Communicated by the Author.

WHEN it is considered that in the smelting operation the reduction of immense quantities of materials is effected by a compressed current of air impelled by the whole power of a blowing machine, the consequences of the change of air, either in quantity or quality, must be very obvious: when, farther, we contemplate the metal called into existence by means of combustion thus excited; when we consider iron as having the most powerful affinity for the base of that part of the air which maintains combustion; and when we view the debased state to which the metal is reduced by coming into improper contact with it, we must conclude, that the application of blast in the manufacturing of iron calls for the

* We know that eggs are kept for a great length of time, and the white, even under the heat of the hen's body, does not putrify, and it serves as milk to the embryo in the egg;

most minute and thorough investigation. In order to take a comprehensive view of this subject, the following division will be requisite:—

1st, The intimate connection which the quantity of blast bears to the area of the internal cavity of the furnace, and to the nature of the pit-coal.

2d, The various modes by which air is procured, and how these respectively affect the quality of the air.

3d, The various changes to which air is subjected by a change of temperature in the atmosphere, with the consequent effects.

4th, How far increased or diminished velocity and compression alter the results of the furnace.

5th, The form and diameter of the discharging-pipe.

1st, Then, in the construction of a blast-furnace and blowing-machine, the quantity of air to be used ought to depend upon the internal dimensions of the former; which, again, ought to be formed according to the quality of the pit-coal. Upon the softness or hardness of the coal, ought more immediately to depend the height of the blast-furnace. This necessary precaution has given rise to a vast variety of furnaces, of different capacities, from 30 to 50 feet in height, and from 9 to 16 feet diameter at the boshes. Furnaces from 30 to 36 feet are used for the softer qualities of coal, such as a mixture of free-coal and splint. Furnaces from 36 to 45 are appropriated to the burning of splint-coal cokes; and in Wales, such is the superior strength and quality of the pit-coal, that the furnaces admit of being reared to the height of 50 feet.

These various qualities of coal, it has been formerly shewn, have appropriate weights of iron-stone, and, to use the language of the manufactory, are capable “of supporting a greater or lesser burden of mine.” The former qualities admit not of having the air discharged in great quantity, unless it is impelled under an uncommon degree of compression and consequent velocity incompatible with the operations of a steam-engine. The reason is obvious: when air, loosely compressed, or comparatively so, is thrown into a body of ignited fuel, the mechanical structure and continuity of whose particles

particles are soft, the air is much more easily decomposed; the ignition, of course, is more rapid: the descent of the materials is promoted beyond their proper ratio, and long before the carbonaceous matter has penetrated the ore, or united to the metal, to constitute fusibility. I shall adduce an example, as being most illustrative of this doctrine.

Suppose a blast-furnace, 35 feet high, 11 feet wide at the bothes, properly burdened, and producing No. 1, pig-iron. Let the discharge of air be supposed equal to a pressure $2\frac{1}{2}$ pounds upon the square inch, or equivalent to 1-6th of the atmosphere, or 5 inches of mercury: under these circumstances let it farther be supposed, that 1500 cubical feet of air are discharged in one minute; and that the diameter of the discharging-pipe is 2.625, the area of which is equal to 6.890625 circular inches. Let the discharging-pipe be increased to 3 inches diameter, and let the same quantity of air be passed into the furnace; it is evident that as the area of the discharging-pipe is increased to 9 circular inches, or nearly 1-3d more than formerly, the compression of air must be proportionally diminished. This alteration is soon perceived by its effects; the quantity of scoria increases from the furnace, whilst the consumption of the materials above is also considerably augmented. In a few hours the scoria will have undergone a complete change, from pure white, enamelled with various blue shades, to a green, brown, or black colour, considerably charged with the oxyd of iron*. The same effects will continue, in greater or lesser degree, till all the materials are reduced which were existing in the furnace at the period of diminished compression. The philosophy of this fact may be accounted for in the following manner:—

While the just association of proportions remained, the air was discharged under such a degree of compression as to excite proper combustion: the decomposition of the air by means of the ignited fuel, was not effected in immediate contact with the separating metal, but had, by its uncommon degree of density, resisted decomposition in the ignited pas-

* The metal will have lost nearly all its carbon, and have become inferior in value 25 to 30 per cent.

sage, and had been decomposed upon the cokes at a greater elevation in the furnace. As a proof of this, we frequently see a tube formed throughout the whole breadth of the furnace, quite black and apparently cold, formed of the fused materials: when this is removed, a considerable descent momentarily takes place of cokes heated visibly beyond the common pitch: these inflame rapidly, but are soon again cooled to blackness by the incessant discharge of air upon them. The descending mixture of iron and lava are in like manner cooled around the line of blast; the tube is again formed, and, if not removed, will remain for days together, while the furnace will be otherways working in the best manner.

When by accident or design the compression and velocity of the blast are diminished, the tube begins to burn, and throws off a great many red fiery-coloured sparks, the sides and roof fail, and are carried before the blast in all directions. Sometimes considerable cloats of imperfect iron are recoiled with such violence as to escape the vortex of blast, and issue from the tuyre-hole with such velocity as to inflame in the air, and fall down in the state of oxyd. In the end the tuyre will appear to flame, and all the passage inwards shews an astonishing degree of whiteness. The decomposition of the air is instantaneously effected upon its entering the ignited passage; the iron by this means is exposed to the oxygen that is disengaged; and the vast quantity of caloric set free, in consequence of its union with the iron and carbon, produces the astonishing heat now visible, but which formerly took place at a more proper height in the furnace.

From this it will appear, that although a greater apparent degree of heat is visibly produced by the sudden decomposition of the air, and a more rapid descent of materials for some time is the consequence, yet, as the quality of the iron is impaired, and as in the end the furnace will return to its old consumption of materials as to quantity, the effects of a loose soft blast are conclusively pernicious.

It sometimes happens, that when a loose blast is surcharged with a considerable portion of moisture, or comes in contact with cokes which had been wet when introduced into the furnace, the inflammation which takes place at the tuyre is prodigious:

prodigious: fine fire-clay will be melted down and blown to slag in a few minutes; the sides of the furnace, composed of very infusible fire-stone, is next attacked, and in a few hours will be so completely destroyed as to stop the working, and require immediate repair. Effects similar to those now described will be felt when blast is improperly proportioned to coal of a stronger continuity of fracture and superior quality. Besides the effects produced by the sudden decomposition of iron, others of like nature are produced where a soft coal is used, a small furnace, and a great discharge of blast.

It has been found that crude iron, to be properly matured, ought to remain in the blast-furnace, according to circumstances, 48 to 60 hours; that is, from the period that the iron-stone is introduced till such time as the metal begins to occupy its place in the hearth in a state of perfect separation. When the contrary is the case, the mixtures arrive at the hottest parts of the furnace before the metal has taken up a sufficient quantity of carbon from the fuel; the action of the blast, and the immediate heat by which the ore is surrounded, forces the iron from its connections to the bottom of the furnace. The quality is de-carbonated, and reduced in its value: to restore this again, the local portion of fuel is increased; this adds to the expence of manufacturing, and diminishes, in some measure, the smelting of the furnace.

When splint-coal cokes are used in the blast-furnace, the blast admits of being thrown in under the highest possible pitch of compression; the uncommon density of the charcoal sustains a very powerful discharge of blast before it is dissipated to facilitate the general descent. Most frequently, large masses of these cinders pass through the whole ignited cavity, and are thrown out below, possessing all the acuteness of their original form and fracture.

This quality of coal is used in all the Curson blast-furnaces, where, to ensure a respectable produce, the air is discharged under a pressure equal to $3\frac{1}{4}$ pounds upon the square inch, or $6\frac{1}{2}$ inches of mercury.

The same quality of coal was used at the Devon iron-works, where, at one time, having all the blast of a 48 inch cylinder engine thrown into one furnace, the column of
mercury

mercury supported was upwards of 7 inches ; the quantity of air discharged under such an impelling power, I found to exceed 2600 cubical feet *per* minute.

The coals used at the Cleugh, Cleland, and Clyde iron-works, are nearly of the same quality at each—a mixture of splint and soft coal. The Muirkirk and Glenbuck iron-works have a coal different from any of the former, and in some particular spots it considerably resembles the English clod-coal.

2d, The various methods of procuring air for the blast-furnace may be reduced to the following:—1st, That procured by cylinders, and discharged into the furnace by means of a floating piston heavily loaded, and working in a large receiver or regulating cylinder: 2d, That wherein pumping cylinders only are used, and the air thrown into chests inverted in water, called the *water-vault*: 3d, That mode wherein the air is discharged from the pumping or forcing cylinder into an air-tight house, called the *air-vault*.

The first method is the original mode of blowing, and is still much used at those iron-works whose erection has been prior to the last fifteen years. By this mode the quality of the air is less subject to alteration by a change of atmosphere. The principal objection to this manner of blowing, is the want of capacity in the receiving cylinder; which cannot be increased so much as to take away the considerable intervals which occur at different parts of the engine-stroke. This effect is sensibly seen by the speedy and irregular ascent and descent of the column of mercury. In water blowing-machines, where the air is raised by three or four cylinders worked by means of a crank, where the air is received into an air-chest, and forced into the furnace by the continual action of the blast of each successive cylinder, the current of air is steady, and supports the column of mercury with great uniformity.

The use of the water-vault has of late years become very general among new erected works. Its properties are, a steady and very cold blast: the largeness of the receiving cisterns gives them a sufficient capacity to retain every pound of air

raised by the furnace, and distribute it to the greatest advantage. This is not the case with the floating pistons, where a certain quantity of spare wind is thrown out at every return of the engine, lest the great piston and weight should be blown out of the cylinder altogether; which, indeed, sometimes happens. The only objection which remains in force against the use of the water-vault, is the tendency which it has to take up a considerable portion of the water in solution, and introducing it into the furnace. A judicious arrangement of the conducting-pipes would in some measure obviate this, as well as the more dangerous tendency which water has to rise in a pipe speedily emptied of its air by the stopping of the engine: a stream of water thus conveyed to the furnace, would be productive of the most awful consequences.

The air afforded by the air-vault is much inferior to that obtained in the former methods. This immense magazine of compressed air generates a considerable portion of heat, which greedily seizes the damp, which are unavoidable in underground excavations, and conveys them to the furnace. The blast is, however, steady and uniform; and when the inside of the building is completely secured against the passage of air, it is productive of considerable effects in the furnace. In the summer months, however, the air becomes so far debased as to affect the quality of the iron, and change it from grey to white. Every change in the temperature of the atmosphere during this period, is indicated by various changes in the furnace.

The largest air-vault hitherto in use was excavated out of solid rock at the Devon iron-works: the fissures of the rock admitted considerable quantities of water; and the same degree of damp would always prevent the possibility of making the side-walls and roof air-tight by means of pitch and paper, &c.

Besides the various natures of blast, as to the strength and equality of the current afforded by different modes of constructing the blowing-machines, a variety in the quality of the air obtained is also an invariable consequence: this is sufficiently

sufficiently known by the effects which it produces in the blast-furnace, and ought to be subject to scrupulous examination.

In this, as in other countries, larger produces of cast iron are obtained in the winter months than during the summer and autumn seasons: the quality of the metal is also much more carbonated, and with a less proportion of fuel. In many parts of Sweden, where the summer heats are intense, the manufacturer is obliged to blow out or stop his furnace for two or three months: not only is he unable to make carbonated metal, but is frequently incapable of keeping the furnace in such trim as to make a produce of any quality whatever. In Britain, during the months of June, July, and August, more especially in dry seasons, the quality of the iron, with the local proportion of fuel, will be depreciated 30 *per cent.*, and the quantity reduced to 2-3ds or 3-4ths.

In seeking for a solution of this universally acknowledged fact, our attention is naturally directed to an examination of the various states of air. That the quality of the air in winter is more fit for combustion than in summer, is a truth which requires no farther demonstration. Greater coolness, whereby an almost complete refrigeration of moisture takes place, and the presence of perhaps a greater relative proportion of oxygen, may account for this phenomenon. On the contrary, the quality of air during the summer months becomes much contaminated for combustion, by holding in solution a much greater quantity of moisture: the abundance of nitrous particles may also diminish the usual proportion of oxygen.

This will account for the inferior effects of combustion both in common fires and in the blast-furnace; it will also in a great measure tend to solve the curious phenomenon of pig-iron taking up less carbon in summer, although reduced with a superior quantity of fuel. The air discharged most probably contains less oxygen; yet the metal is much less carbonated than at other times, when contrary proportions of these exist. Most probably the deficient carbon is carried off by dissolving in hydrogen, forming a constant stream of hydro-carbonic gas, while the oxygen that is set free unites to the iron; and while it reduces its quality, at the same time

the quantity is reduced by a portion of the metal being lost in the scoria*.

To correct these occasional imperfections in the quality of the air, and to devise methods to procure air always fit for proper combustion, ought to be an object of much consideration to the manufacturer of cast iron. Whether such a consideration has given rise to the different modes of receiving and discharging the air now in use, I cannot say; I rather think not: a great quantity of air has hitherto been a greater object than a certain and uniform quality; and in a country where there is more temperate and cold weather than hot, it is by far the most important object: to unite both, however, would be an attainment of the greatest utility, and would rank the discoverer amongst the well-deserving of his country. How far the mechanism of our present machinery has been adapted to the exigencies of our atmosphere, will appear upon examining the nature and properties of the air, judged by its effects upon the blast-furnace.

The air produced by the blowing and receiving-cylinder is less changed, and less subject to change, than that produced and lodged in contact with a vast body of air or water. If the blowing-cylinder is fixed in a dry cool spot, the only difference which the air undergoes is an increase of temperature; this is so very considerable, that upon entering the blowing-cylinder immediately after stopping the engine, I have found the thermometer rise 15 to 17 degrees higher than the surrounding air. That this heat is generated in the cylinder is unquestionable; but whether it is occasioned by the friction of the piston leather upon the sides of the cylinder, or expressed from the air by its severe compression, I have not yet been able to decide. It very probably arises from both causes, although the latter is sufficient to produce a much greater degree of heat. What effect this increase of temperature has upon combustion we are unable to say, as the degree of heat accumulated will at all times bear a reference to the temperature of the surrounding air, and as

* May not the superabundant azote of the summer atmosphere produce part of these effects, by dissolving a portion of the carbon, and forming carbonated azotic gas, as has been proved by M. Lavoisier?

there is no method likely to be devised where heat would not be generated by the action of the particles of air upon each other. When the bulb of a thermometer is held in the middle of the current of blast, as it issues from the discharging-pipe, a temperature is indicated as much lower than the temperature of the surrounding air, as the temperature of the cylinder was higher; and it is most probable that a much lower degree would be obtained, were it not for the previous expression of some heat in the blowing-cylinder. Upon the whole, I think, the quality of the air obtained in this way of blowing uniformly most fit for combustion, provided the numerous pauses and irregularities of the current of air were done away.

Air forced into the furnace under water pressure always contains a considerable portion of moisture; the blast of course is colder, as it issues from the discharging-pipe. The temperature differs so much from that of the external air as to sink the thermometer from 54° down to 28° and 30° . Such effects are produced by air coming into contact with water, that, although the temperature of the atmosphere is 60, 65, to 70, yet the blast at the orifice seldom rises above 38: the cold produced in this manner is much increased if the air is furcharged with so much water as to be visible in the state of a fine spray. The leading feature, therefore, of the water-vault, as to its effects upon the quality of the air, seems to indicate an almost uniform degree of temperature in the blast: this can only be occasioned by the warm air in summer taking up a greater portion of the water in solution, the escape of which at a small orifice, and under a great degree of compression, produces the very great depression of the thermometer. I have already hinted at the bad effects produced by moist blasts, and shall, in a proper place, more minutely attend to them.

The most inferior quality of air used in the blast-furnace is that thrown into the air-vault, and afterwards expressed from thence by its own elasticity and the successive strokes of the engine. The capacity of such a building is from 60 to 70,000 cubical feet; this, when filled, generates a much superior degree of heat to that sensible in the blowing-cylinder.

As

As this heat is produced many feet distant from any mechanical motion, it is most evident that it is extricated from the air, and will readily unite with the moisture which penetrates the building: the quality of the air introduced into the furnace will therefore be in proportion to the quantity of moisture taken up; this will be much more in summer than in winter, as the temperature of the former exceeds that of the latter. The sensation, on entering the air-vault in the coldest months, immediately after stopping the engine, is exactly similar to that experienced upon entering a crowded room in the hottest summer day; the walls are covered with damp, and the superior regions of the vault readily obscure the flame of a candle. The feeling, upon remaining in the air-vault when the engine is at work, is less marked than would be expected where so great a compression of air existed; the sense of hearing, owing to the moisture in the conducting medium, is considerably impaired, and respiration is performed with some difficulty; the light of a candle is faint, and not visible at the distance of a few feet.

XIV. *Some Remarks on the Scotch Distillery, and a Description of an improved Still, which may be charged and run off Seventy-two Times in Twenty-four Hours* *.

THE improvements that have taken place in the common distillery business in Scotland within these few years are such as cannot fail to excite the wonder of men of science, while they serve to prove, at the same time, that, to insure progressive improvement in any branch, the most effectual mean is that stimulus which results from interest.

It is not necessary, and it would be tedious, to describe the progress of the distillery in Scotland, since it first began to assume a form of some consequence, about twenty years ago. It may, however, not be thought improper to mention what gave occasion to the licence act being introduced into

* Extracted from the Report of the Committee of the House of Commons, July 1799.