fire, or on hot cinders, or in other ways really dangerous. Gun-cotton and dynamite prove much safer than nitroglycerine as regards exploding through concussion. There is not, however (Mr Nobel thinks), that amount of difference between the sensitiveness of nitroglycerine and dynamite which the latter substance generally receives credit for. The main danger of nitroglycerine arose from the sensitiveness to concussion which it acquired through contact with a hard, metallic, strongly vibrating substance, such as the tin canisters in which it was contained. The main safety of dynamite is derived from the absence of any hard vibrating material in immediate contact with the nitroglycerine it contains.

As regards danger from concussion in manufacture and transit, gun-cotton ranks first; but in the hands of miners, the case is reversed, through the rough usage of gun-cotton charges, where, *e.g.*, they are found too large for a bore-hole, for gun-cotton is well known to explode with a blow. The danger most dreaded in modern explosives is from their supposed liability to chemical decomposition productive of heat, which sometimes leads to ignition and explosion. This decomposition is generally due to the presence of acid (chiefly nitric and hyponitric), which every nitrated compound has a strong tendency to retain. From the ease with which the acid can be washed out from nitroglycerine, both it and dynamite show much greater chemical stability than gun-cotton. Most cases of spontaneous combustion of the latter have probably arisen either from imperfect washing, or from drying at too high a temperature (by which hyponitric acid is set free).

Complaints have often been made of the poisonous fumes given off by the new explosives. Where this occurs, it is probably due to an injudicious use of the substance, resulting in imperfect explosion. If a dynamite cartridge partly burns instead of exploding, the temperature is much lower, and fumes of hyponitric acid are given off, which could not escape decomposition at the higher temperature of perfect explosion. The general mistake consists in not securing carefully the detonator cap to the fuse, and especially the fuse to the cartridge.

Blasting by Electricity.—It is known that electricity has a thermal effect on wire through which it passes; and the amount of heat produced in any part of the circuit is proportional to the resistance in that part. Thus a piece of wire of small section and conductivity may be made incandescent by a current. On this principle platinum is sometimes employed to fire blasting charges. In making a fuse of this sort, two insulated copper wires are twisted together for a length of about 6 inches, leaving the extremities free for about half an inch, and separated the same distance. A fine platinum (or iron) wire is stretched across this interval, metallic contact being established with the copper. The other ends of the fuse are connected with a battery. Platinum fuses are not much to be relied on for simultaneous blasting of several charges by one battery; for some of the fuses may take a little more time to reach the exploding temperature than others, and thus, as soon as one explodes, the connection between the others and the battery is broken. The batteries to be used with them are such as generate electricity of great quantity. The Bunsen and Leclanché batteries, in some of their varieties, are well suited for this. Twelve cells of Highton's battery will melt a piece of platinum wire over an inch long.

There is, however, another class of fuses, offering certain advantages over those just referred to, in which the spark produced by electricity of tension is the means used to effect the explosion. It might naturally be thought that an electric spark must inevitably cause explosion in a mass of powder or like substance through which it is made to pass; but this is not the case. The heating power of the spark is often insufficient for explosion. The duration of an induction spark is about the *millionth* of a second; whereas, to ignite powder, it is necessary that a spark should exist for at least the *three hundredth* part of a second. By interposing, however, a suitable priming composition in the interval which the spark is to cross, and in contact with the charge, explosion may be thus effected. In preparing such a composition, the properties of the ingredients as regards conductivity, inflammability, and explosiveness have to be nicely adjusted, according to the degree of tension of the electricity employed. The composition selected by Professor Abel for his fuses is an intimate mixture of subsulphide of copper, subphosphide of copper, and chlorate of potassium. It is a mixture which conducts, but conducts with difficulty, and the fuses made with it are very effective. There are several other varieties, *e.g.*, Ebner's fuse, where the priming consists of a mixture of sulphuret of antimony, chlorate of potash, and graphite.[1]

For generating electricity of tension with the Voltaic battery, Leclanché's battery is, again, one of the most suitable. The elements of this battery consist of a rod of carbon placed in a porous cell and tightly packed round with a mixture of peroxide of manganese and coke; the porous cell is placed in a vessel containing a plate of zinc, which forms the electro-positive element, and a solution of sal-ammoniac is used as the exciting liquid. There are some forms of battery for the same purpose so arranged that the contact of the elements with the liquid takes place only at the time of firing; such are those of Wollaston, Ruhmkorff, and Trouvé.

Frictional electricity is the kind generally adopted by military authorities in firing charges,—the machines for generating it being easily made, simple, portable, and powerful. Bornhardt's frictional machine has found extensive use in Austria in ordinary blasting operations. It is contained in a small metallic case, and consists of a disc of ebonite, which can be rotated between two cushions, charging a small Leyden jar placed near it. On pressing a little button from the outside, connection is made between the two coatings of the jar in such a way that the charge is sent through two wires by which the box is connected with the fuse, or fuses, at a distance. Some absorbent of moisture is kept within the box, and it is necessary to see that the machine be kept as warm and dry as possible.

Experiments were made by Messrs Wheatstone and Abel, a number of years ago, with Armstrong's hydroelectric machine, as a source of electricity for exploding charges of powder. They state that in very extensive mining operations, where a great many charges have to be fired simultaneously, and provided all the necessary appliances for success are at hand, the machine could be used very effectively. It is a powerful source of electricity of high tension. There are serious objections, however, to its general use.

Electro-magnetic induction currents (such as are developed in Ruhmkorff's coil) were first applied, and successfully, by Colonel Verdu, a Spanish officer, in 1853. The induction discharge, unlike that of a Leyden battery, is much enfeebled by successive solutions of continuity, so that not more than four mines in a single circuit could certainly be exploded on this system. But M. Savare made an improvement by interposing the fuses in branches of the principal circuit. The mine nearest the apparatus explodes first; and, owing to the abrupt separation of the wires, the current can no longer pass through this branch; thus the electric action is augmented in the other branches, and in a similar manner the explosions necessarily take place in them, and that with a rapidity almost instantaneous. This is also a more efficient plan than that of employing a rheotome for changing the direction of the current, so as to bring wires connected with one or more charges successively into the circuit. The Ruhmkorff coil is, however, objectionable for its delicacy and the maintenance of batteries in connection with it. In experiments made by Messrs Wheatstone and Abel, a powerful magneto-electric machine was found very limited in its power of igniting several charges arranged in succession in one circuit (it only ignited three at most, with certainty); but on M. Savare's plan of arranging the charges in divided circuits, the simultaneous ignition of twenty-five charges was repeatedly effected; on several occasions as many as forty By this plan each charge was connected with a separate branch attached to the main line, and their connection with earth established by means of uncovered copper wire wound round an iron stake driven in the ground. Another form of instrument, devised by Wheatstone, consists of six small magnets, to the poles of which are fixed soft iron bars surrounded by coils of insulated wire; the coils of all the magnets are united together, so as to form, with the external conducting wire and the earth, a single circuit. An axis carries six soft iron armatures, in succession, before each of the coils. With this apparatus twenty-five charges were frequently fired in divided circuit, so rapidly that the effect on the ear was as of one explosion, only of slightly longer duration than when the large magnet was employed The Markus apparatus, largely used in Germany, is on the same principle.

[1] In one form of fuse employed with dynamite, there is connected with the priming just mentioned some mercuric fulminate and loose gun-cotton.

Siemens's dynamo-electric machine, in which electro-magnets are employed, is a very useful machine for simultaneous firing It is found that the residual magnetism left in the coils of electro-magnets, after a current from even a single Voltaic cell has been once sent through them, is always sufficient to have the necessary inductive action on the armature. This inductive action, though very weak at first, generates slight alternating currents in the armature, which are by means of a commutator caused to flow always in one direction through the coils of the electro-magnet, thus increasin the magnetism in the core, which, in its turn, increases the inductive action, causing stronger and stronger currents to be generated in the armature. This action and reaction goes on till the limit of magnetic capacity of the core is reached, and if the coil of the armature be then suddenly connected with the line leading to a fuse, a very powerful current is transmitted. In Breguet's exploder (in which a bar of soft iron is suddenly separated from the armature of a magnet bearing two induction coils) a special arrangement gives rise to an extra-current, and considerably increases the intensity of the current. M. Breguet has lately utilized in this apparatus the new and powerful laminated magnets constructed by M. Jamin. Gramme's machines are also effective in exploding charges, but their volume and high price are against a large use of them industrially.

For more detailed information on the recent developments of blasting, reference may be made to Spon's *Dictionary of Engineering*, art. "Boring and Blasting;" *Professional Papers of the Corps of Royal Engineers*, vols. vii., x., xxii.; *Transactions of the Society of Engineers*, 1869 and 1871; *Proceedings of South Wales Institute of Mining Engineers*, vol. viii., No. 5, vol. ix., Nos. 1 and 2; Dingler's *Polytechnisches Journal*, Oct. 1, 1874; *Annales de Chimie et de Physique*, May 1875; *Journal of the Society of Arts*, May 28, 1875. (A. B. M.)

BLEACHING

BLEACHING is the process of whitening or depriving objects of colour, an operation incessantly in activity in nature by the influence of light, air, and moisture. The art of bleaching, of which we have here to treat, consists in inducing the rapid operation of whitening agencies, and as an industry it is mostly directed to cotton, linen, silk, wool, and other textile fibres, but it is also applied to the whitening of paper-pulp, bees'-wax, and some oils and other substances The term bleaching is derived from the Anglo-Saxon *blæcan* to bleach, or to fade, from which also comes the cognate German word *bleichen*, to whiten or render pale. Bleachers, down to the end of last century, were known in England as "whitsters," a name obviously derived from the nature of their calling.

The operation of bleaching must from its very nature be of the same antiquity as the work of washing textures of linen, cotton, or other vegetable fibres. Clothing repeatedly washed, and exposed in the open air to dry, gradually assumes a whiter and whiter hue, and our ancestors cannot have failed to notice and take advantage of this fact. Scarcely anything is known with certainty of the art of bleaching as practised by the nations of antiquity. Egypt in early ages was the great centre of textile manufactures, and her white and coloured linens were in high repute among contemporary nations. As a uniformly well-bleached basis is necessary for the production of a satisfactory dye on cloth, it may be assumed that the Egyptians were fairly proficient in bleaching, and that still more so were the Phœnicians with their brilliant and famous purple dyes. We learn, from Pliny, that different plants, and likewise the ashes of plants, which no doubt contained alkali, were employed as detergents. He mentions particularly the *Struthium* as much used for bleaching in Greece, a plant which has been identified by some with *Gypsophila Struthium*. But as it does not appear from Sibthorp's *Flora Græca*, published by Sir James Smith, that this species is a native of Greece, Dr Sibthorp's conjecture that the *Struthium* of the ancients was the *Saponaria officinalis*, a plant common in Greece, is certainly more probable.

In modern times, down to the middle of the 18th century, the Dutch possessed almost a monopoly of the bleaching trade, although we find mention of bleach-works at Southwark near London as early as the middle of the 17th century. It was customary to send all the brown linen, then largely manufactured in Scotland, to Holland to be bleached. It was sent away in the month of March, and not returned till the end of October, being thus out of the hands of the merchant more than half a year.

The Dutch mode of bleaching, which was mostly conducted in the neighbourhood of Haarlem, was to steep the linen first in a waste lye, and then for about a week in a potash lye poured over it boiling hot. The cloth being taken out of this lye, and washed, was next put into wooden vessels containing butter-milk, in which it lay under a pressure for five or six days. After this it was spread upon the grass, and kept wet for several months, exposed to the sunshine of summer.

In 1728 James Adair from Belfast proposed to the Scotch Board of Manufactures to establish a bleachfield in Galloway; this proposal the board approved of, and in the same year resolved to devote £2000 as premiums for the establishment of bleachfields throughout the country. In 1732 a method of bleaching with kelp, introduced by R. Holden, also from Ireland, was submitted to the board; and with their assistance Holden established a bleachfield for prosecuting his process at Pitkerro, near Dundee.

The bleaching process, as at that time performed, was very tedious, occupying a complete summer. It consisted in steeping the cloth in alkaline lyes for several days, washing it clean, and spreading it upon the grass for some weeks. The steeping in alkaline lyes, called *bucking*, and the bleaching on the grass, called *crofting*, were repeated alternately for five or six times. The cloth was then steeped for some days in sour milk, washed clean, and crofted. These processes were repeated, diminishing every time the strength of the alkaline lye, till the linen had acquired the requisite whiteness

For the first improvement in this tedious process, which was faithfully copied from the Dutch bleachfields, manufacturers were indebted to Dr Francis Home of Edinburgh, to whom the Board of Trustees paid £100 for his experiments in bleaching. He proposed to substitute water acidulated with sulphuric acid for the sour milk previously employed, a suggestion made in consequence of the new mode of preparing sulphuric acid, contrived some time before by Dr Roebuck, which reduced the price of that acid to less than one-third of what it had formerly been. When this change was first adopted by the bleachers, there was the same outcry against its corrosive effects as arose when chlorine was substituted for crofting. A great advantage was found to result from the use of sulphuric acid, which was that a souring with sulphuric acid required at the longest only twenty-four hours, and often not more than twelve; whereas, when sour milk was employed, six weeks, or even two months, were requisite, according to the state of the weather. In consequence of this improvement, the process of bleaching was shortened from eight months to four, which enabled the merchant to dispose of his goods so much the sooner, and consequently to trade with less capital.

No further modification of consequence was introduced in the art till the year 1787, when a most important change was initiated by the use of chlorine, an element which had been discovered by Scheele in Sweden about thirteen years before. Berthollet repeated the experiments of Scheele in 1785, and by the prosecution of further investigations he added considerably to the facts already known. He showed that this substance (called by Scheele *dephlogisticated muriatic acid*) is a gas soluble in water, to which it gives a yellowish green colour, an astringent taste, and the peculiar smell by which the body is distinguished.

The property which this gas possesses of destroying vegetable colours, led Berthollet to suspect that it might be introduced with advantage into the art of bleaching, and that it would enable practical bleachers greatly to shorten their processes. In a paper on dephlogisticated muriatic acid, read before the Academy of Sciences at Paris in April 1785, and published in the *Journal de Physique* for May of the same year (vol. xxvi. p. 325), he mentions that he had tried the effect of the gas in bleaching cloth, and found that it answered perfectly. This idea is still further developed in a paper on the same substance, published in the *Journal de Physique* for 1786. In 1786 he exhibited the experiment to Mr James Watt, who, immediately upon his return to England, commenced a practical examination of the subject, and was accordingly the person who first introduced the new method of bleaching into Great Britain. We find from Mr Watt's own testimony that chlorine was practically employed in the bleachfield of his father-in-law, Mr Macgregor, in the neighbourhood of Glasgow in March 1787. Shortly thereafter the method was introduced at Aberdeen by Messrs Gordon, Barron, and Co., on information received from M. de Saussure through Professor Copland of Aberdeen. Mr Thomas Henry of Manchester was the first to bleach with chlorine in the Lancashire district, and to his independent investigations several of the early improvements in the application of the material were

No very great amount of success, however, attended the efforts to utilize chlorine in bleaching operations till the subject was taken up by Mr Tennant of Glasgow. He, after a great deal of most laborious and acute investigation, hit upon a method of making a saturated liquid of chloride of lime, which was found to answer perfectly all the purposes of the bleacher. This was certainly a most important improvement, without which, the prodigious extent of business carried on by some bleachers could not possibly have been transacted. Such was the acceleration of processes effected by the new method that, it is stated, a bleacher in Lancashire received 1400 pieces of gray muslin on a Tuesday, which on the Thursday immediately following were returned bleached to the manufacturers, at the distance of sixteen miles, and were packed up and sent off on that very day to a foreign market.

In the year 1798 Mr Tennant took out a patent for his new invention, and offered the use of it to practical bleachers, for a fair and reasonable portion of the savings made by its substitution for potash, then in general use. Many of the bleachers, however, used it without paying him, and a combination was formed to resist the right of the patentee. In December 1802, an action for damages was brought against Messrs Slater and Varley, nominally the defendants, but who, in fact, were backed and supported by a combination of almost all the bleachers in Lancashire. In consequence of this action, the patent right was set aside by the verdict of a jury and the decision of Lord Ellenborough, who used very strong language against the patentee. The grounds of this decision were, that the patent included a mode of *bucking* with quicklime and water, which was not a new invention. It was decided that, because one part of the patent was not new, therefore the whole must be set aside. Lime was indeed used previous to the patent of Mr Tennant; but it was employed in a quite different manner from his, and he would have allowed the bleachers to continue their peculiar method without any objection, because it would have been productive of no injury to his emolument.

In consequence of this decision the use of liquid chloride of lime in bleaching was thrown open to all, and speedily came to be universally employed by the bleachers in Britain. Mr Tennant, thus deprived of the fruits of several years of anxious and laborious investigation, advanced a step farther, to what may be considered as the completion of the new method. This consisted in impregnating quicklime in a dry state with chlorine, an idea originally suggested by Mr Charles M'Intosh of Cross-Basket, then a partner with Messrs Tennant and Knox. A patent for this was taken out on the 13th of April 1799, and he began his manufacture of solid chloride of lime at first upon a small scale, which has ever since been gradually extending, and the manufactory is now the largest of the kind in Great Britain.

The various processes for the preparation of the so-called chloride of lime, or bleaching-powder, as conducted at the present day, and its other applications in arts, will be found described under the head of CHLORINE.

BLEACHING OF COTTON

Of the two great staples, cotton and linen, to the whitening of which the art of the bleacher is directed, cotton is the more easily and expeditiously bleached. The basis of all vegetable fibres is cellulose or ligneous tissue, a pure white substance, and it is to obtain this body in a state of purity, free from the resinous matter naturally associated with it as well as from adventitious impurities

imparted in the process of spinning and weaving, that is the object of bleaching. The operations, although apparently complex and numerous, are essentially simple, though frequently repeated, and the greatest variety of detail is connected with the finishing of cloth, which is in reality a separate industry, frequently conducted in distinct establishments under the name of calendering and finishing works. Bleaching proper resolves itself into washing with suitable detergents, and subjecting the washed material to the influence of chlorine, whereby the colouring matter either belonging to the fibre or imparted to it is oxidized and discharged.

The general arrangements of a bleach-house will be made plain from the ground-plan (fig. 1). The various pieces

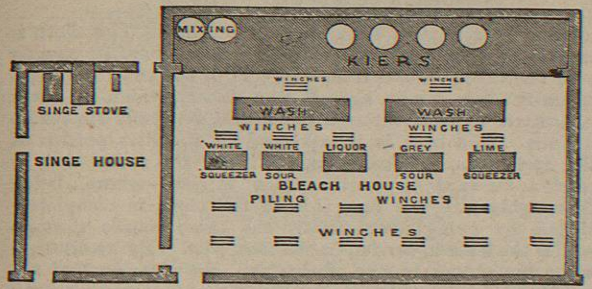

FIG. 1.—Ground-Plan of Bleach-House

of apparatus, the positions of which are there indicated, will be described in connection with the sequence of operations through which the cloth passes in the process of bleaching. In the best arranged works, it should be mentioned, where power is required to work any machine, it is generally supplied by a separate engine attached to the machine itself, instead of by gearing carried from one engine for all the machinery. For this plan, as well as for the greater portion of the illustrations which follow, we are indebted to Mr William Mather, of the eminent firm of Mather and Platt, Salford, to whom we are also under obligation for much valuable practical information. We have also to express our indebtedness to Mr Alexander Crum of Thornliebank, for the fullest access to the important works of his firm, and for the cordial assistance afforded by the managers of its various departments.

The sequence of operations in the bleaching and finishing of calico has undergone no change in its general details since the bleaching-powder process was first introduced; but the mechanical arrangements by which the operations are conducted have been the subject of frequent improvements. The ingenuity of engineers and bleachers has been chiefly directed towards the decreasing of manual labour, economy of fuel and materials, and the rapid completion of the various processes. The application of factory legislation to bleach-works by the Bleaching and Dyeing Works Act of 1860, by imposing a necessity for regular and stated hours of work, still further stimulated the production of apparatus and arrangements for prompt and certain completion of the various operations. Consequently a great part of the old machinery and arrangements of a bleach-house have now disappeared, and the processes are carried on in a continuous series of operations by machinery and appliances to a large extent self-acting. Formerly each piece of goods was separately treated and carried by hand or on barrows from one stage to the next; now the pieces are sewn end to end, as many as 1000 pieces, measuring perhaps 20 miles, being operated on in one stretch.

As various pieces of old machinery are yet in use for certain kinds of work, it has been considered desirable to give descriptions and figures of some of them, and these, at the same time, will serve the further purpose of indicating the nature of the mechanical improvements which have been carried out, in recent years, in bleaching establishments. The important and frequently repeated operation of washing was formerly conducted either at the wash-stocks or washing-mill or in the dash-wheel. The wash-stocks, which are yet in use in many large works, especially where linen is the bleacher's staple, consists of a trough or box for holding the goods to be washed, through which a constant stream of water is passing. A pair or more of heavy hammer-headed wooden beams, hung by long shafts, and playing into the trough, are alternately tilted against the cloth, causing the water by their momentum to work through and squirt out of the mass. This process of washing is rather tedious, occupying on an average about half an hour, and requiring besides a great amount of manual labour. The dash-wheel (fig. 2) is a cylindrical box revolving on its axis. It has four divisions, as shown by the dotted lines, and an opening into each division. A number of pieces are put into each, abundance of water is admitted behind, and the knocking of the pieces as they alternately dash from one side of the division to the other during the revolution of the wheel effects the washing.

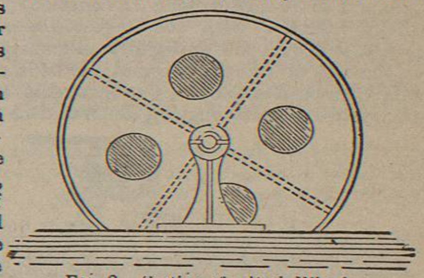

FIG. 2.—Section of a Dash-Wheel.

The process lasts from four to six minutes. The dash-wheel is used to the present day in the bleaching of curtain materials and fine muslins. In nothing have greater improvements been effected than in the arrangement of the kiers or vessels in which the cloth is boiled or "bowked." An old form of kier is seen in fig. 3. It consisted of a cylindrical vessel AA, 9 feet wide, of wood or iron, having a false bottom BB, on which the goods were placed, about 6 inches from the real one. A small pipe E, in the centre of a wider one CC, conveyed the steam from the steam-boiler. When the liquid boiled at the bottom, where the steam issued, the steam forced its way up the pipe CC, carrying with it a quantity of the lye, which was thrown back by the small cover D, spreading itself over the surface of the goods, and filtering through them into the space below the false bottom, where it was again heated by the steam, reascended the pipe CC, and so on in constant succession, till the boiling was completed. FF is a wooden cover which prevented the cooling of the materials below a boiling heat.

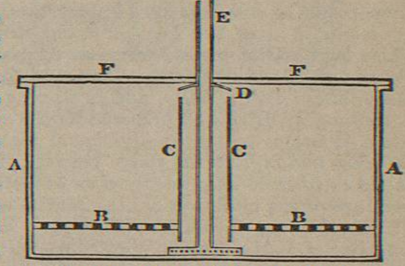

FIG. 3.—Section of Kier (old form).

The bleaching of common calico is divided into two branches—1*st*, print bleaching, in the case of which the goods are bleached as a preliminary to the process of calico printing; and 2*d*, white bleaching, which applies to goods to be finished white or unprinted. The processes differ in some of their details, as in white bleaching it is only necessary to satisfy the eye, whereas in print-bleaching the material must be rendered chemically pure, otherwise the colours in the subsequent printing process would be dull and blotchy. The print bleaching must therefore be more thoroughly done than the other; but as the processes are generally the same, it will be sufficient to indicate the points of difference in the various stages through which the material in both cases passes. A process preliminary to bleaching is

Singeing.—Gray calico as received from the looms is generally in lengths of 37½ and 50 yards. A large number of these, sometimes as many as 1000, measuring more than 20 miles in length, are sewn into a continuous web. At the extremities of each owner's lengths, the name of the firm, or some distinguishing mark, is either stamped on in tar, or marked by means of coloured threads. These long lengths are then submitted to the operation of singeing, which has for its object the removal of the downy pile and short threads from the surface of the cloth, which would interfere with the appearance of finished white goods, and with the uniformity and sharpness of patterns in the case of prints. Several methods of accomplishing this have been employed, but that most commonly used is the system of plate singeing illustrated in fig. 4. A pair of

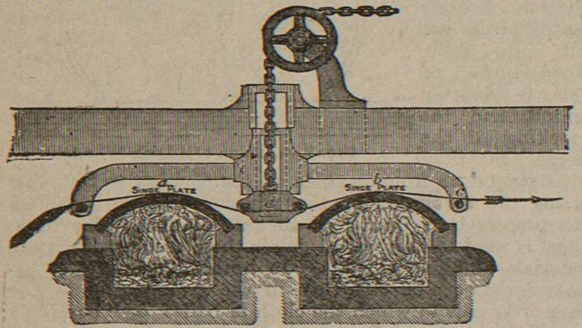

FIG. 4.—Section of Singe Stove.

singe-plates, *a* and *b*, made of thick bent sheets of copper, are mounted over the flues of a fire sufficient to raise a white heat. The plate *b* is most highly heated, *a* being at the end of the flue furthest removed from the fire. The cloth enters over a rail *a*, and in passing over the plate *a* is thoroughly dried and prepared for the singeing it receives when it comes to the highly-heated plate *b*. A block *d*, carrying two rails in the space between the plates, can be raised or lowered at pleasure so as to increase or lessen the pressure of the cloth against the plates, or, if necessary, to lift it quite free of contact with them. The system of plate singeing is found generally sufficient in practice, but the caking of paste and dirt on the plates from the cloth as it passes over them, and variations in the heat of the plates, often lead to irregularities in singeing. A combination of plate and gas singeing is frequently employed to overcome the deficiencies of plate singeing alone. In this case the cloth is passed first over an ordinary plate, and then on to another, along the ridge of which is a long narrow slit, which allows the issue of a gas flame produced from coke burning immediately under it. By this means long loose threads are more effectually burned off than in plate singeing, and a more uniform heat is applied to the gray cloth. Fig. 5 is a sectional view of a very efficient singeing-apparatus introduced by Messrs Mather and Platt. The figure represents the first half of the machine, the second portion being precisely similar in arrangement. The singeing in this case is accomplished by the burning of a mixture of coal-gas and atmospheric air admitted by a pipe *a*, and driven by a fan blast to the burners *b*, *b*, which are regulated by stop-cocks. The mixture burns with an

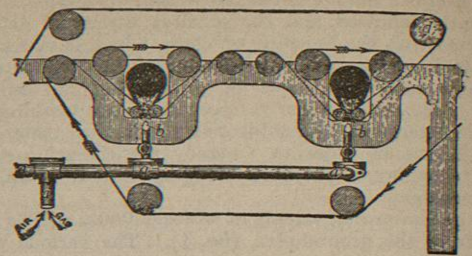
FIG. 5.—Gas Singeing Apparatus.

intense heat and a blue smokeless flame. The cloth is carried by a series of rollers to the gas jets, and in passing over the rollers *c*, *c*, *c*, *c* the one side of the cloth impinges laterally four times against the flame, which is never permitted to pass through the fabric, but only shaves its surface. The back is thus singed in the first portion of the apparatus, and being turned over on roller *d* it is carried forward to another pair of jets, where, being thoroughly dry, the face side of the cloth is completely singed by going over exactly the same course through which the back is carried in the first part. By an arrangement not shown in the illustration, the attendant of the machine can instantaneously lower the gas burners by a treadle movement in case of any stoppage or accident, and thus prevent the cloth from being burned. With a proper pressure of gas this machine singes at the rate of 60 yards per minute.

At this stage the cloth has now in addition to the brown coloured incrusting substance and the resinous material proper to the fibre, a dark-coloured carbonized surface, caused by the singeing process, the weaver's paste or dressing, tallow or other fat introduced in the process of weaving, and the accumulation of dirt which the handling of weavers and others may have produced. The object of the subsequent processes is to wash out the mechanical impurities and resinous substances from the cloth, to render soluble by chemical agencies such as are otherwise insoluble in water, and to oxidize the colouring matter of the cotton by the chloride of lime as already explained.

Liming.—In some cases it is the practice immediately after singeing to steep the pieces in water and pile them up wet for a night, in order to loosen and partly ferment the weaver's paste, which is then in large part removed by washing in a machine to be subsequently described. The "gray-backs" which have been used in calico-printing have always to be thus steeped, and at one time it was the practice to leave the cloth so long in this steep that it acquired a most offensive odour. This preliminary steeping and washing facilitates the percolation of the liquor through the fabric in the process of boiling, but notwithstanding this advantage it is generally dispensed with, and the good pass direct from the singeing to the liming process. The pieces are formed into a loose coil or rope by being passed through circular rings of glass or pottery called "pot-eyes," and worked up and down several times in a strong milk of lime, in order that the whole may be uniformly and thoroughly impregnated. The arrangement for liming will be understood from fig. 6, which is a sectional view of a "squeezer," an apparatus used repeatedly in subsequent operations as well as in this of liming. The cloth passes up and down as indicated by the arrows, dipping several times into the solution, and before passing finally on to the kiers for boiling it is slightly "nipped" between the

"bowls" of the squeezer to extract superfluous moisture. These bowls are thick cylinders of wood, usually in this case made of beech. From the lime squeezer the cloth is carried over winches. and guided through pot-eyes into the kiers.

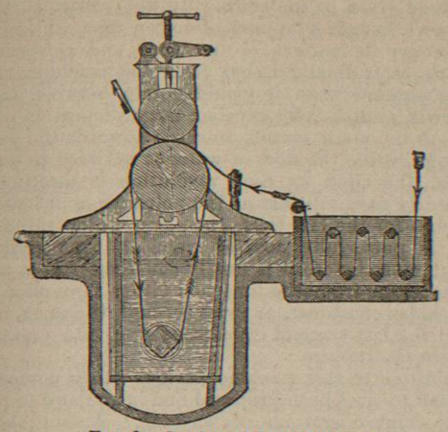
FIG. 6.—Section of Lime Squeezer.

Bowking.—A bowking kier is an apparatus in which the cloth is boiled. To one old form of kier allusion has already been made. Bowking is now mostly accomplished in closed kiers worked up to a considerable pressure of steam. In the boiling for white bleaching about 80 ℔ of lime are required for 2700 ℔ of cloth, and the boiling is continued for ten hours at a pressure of about 30 ℔. A form of kier very generally employed consists of a strong vessel made of boiler plate, with a man-hole in the upper part, which can be screwed tightly down. The vessel is about 10 feet in depth, and 5 or 6 feet in diameter, and has a false bottom made of a gird of wood or iron, on which the lowest layer of cloth rests. Up the centre of the kier passes a pipe or tube which reaches higher than the cloth can be piled, and is surmounted by an umbrella-shaped plate. Steam is admitted at the lower part of the kier,

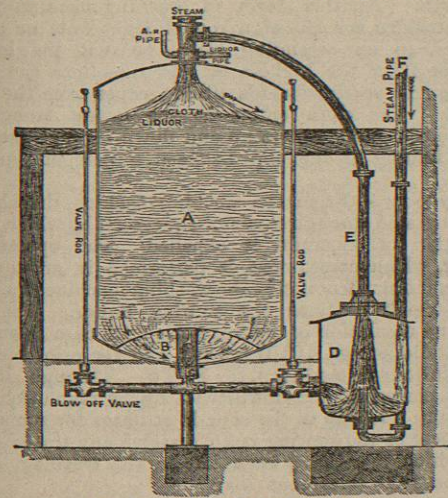

FIG. 7.—Taylor's Circulating Keir.

and as the pressure accumulates it gradually forces the liquor upwards through the central pipe till, by-and-by, it is dashed with great violence against the umbrella-shaped plate, and thrown over the upper surface of the cloth. It gradually percolates down through the cloth to the bottom, where it is again caught and forced up through the central pipe, and thus a constant circulation is maintained. A very efficient circulating kier, the invention of Mr Taylor of Berchvale, has recently been introduced, of which a sectional representation is given in fig. 7. This kier in outline is like the previous, but it has no central distributing pipe. Instead, the liquor is carried by an external pipe to the top of the kier, where it enters and is forcibly thrown against the surface of the cloth. The kier A has a false bottom B as in the previous case, and when filled with cloth and liquor, the liquor percolates by a pipe C into the receiver D, where it finds its own level in the ascending pipe E. Steam is admitted at the lower part of the receiver by the steam-pipe F, and forces the liquor upwards through the pipe E to the top of the kier. The vacuum created in the receiver is supplied from the lower part of the kier, and the flow is facilitated by the pressure of steam from above, and thus a constant steady circulation is maintained. This kier is very useful in cases where a comparatively low pressure is desirable, as in white bleaching, where the coloured headings of the cloth (Turkey red or other coloured threads introduced at the end of a web) have to be preserved.

The bowking apparatus generally used by printers is Barlow's high-pressure kiers, an arrangement in which the kiers are worked in pairs. A pair is shown in fig. 8, one

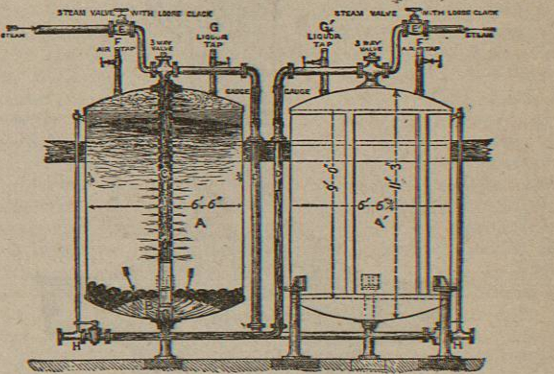

FIG. 8.—Barlow's High-Pressure Keirs.

being seen in section; the dimensions of the vessels are inserted in the figure.

The novelty these kiers introduced when first brought out, was that in using steam of 40 ℔ instead of 5 ℔, a greater economy of time and drugs would be effected. Their world-wide application has proved that the inventor's theory has found ample confirmation. The cloth is carried or rather drawn by winches, and dropped into the wrought iron boilers or kiers AA′, through the man-holes in the top, two pieces in all cases running side by side. As the pieces are delivered continuously in the kiers, a lad in each spreads a pile of the cloth all round the kier, as equally as possible, so that, when full, the kier shall be packed uniformly to the top. This cloth rests on what is termed a false bottom, simply a grid or plate with holes in it, as shown at B. Upon the grid are generally placed a few smooth stones, through the spaces between which the liquor drains from the cloth.

Down the centre of the kier is a pipe C, perforated with holes, for the purpose of distributing the liquor freely into the mass of cloth. The kiers are connected by a pipe D, leading from the bottom of one to the top of the other, and *vice versa*. The steam is introduced through the valves EE′. After the kiers are filled with cloth, each holding about 6000 ℔, the man-hole lids are screwed down and all made steam tight. A little steam is then turned on to discharge the air from the cloth, which escapes through the pipes FF′. This steam, moreover, gradually warms the goods. The alkaline liquor or lime water, having been mixed to the proper strength.