bably have kept any single projectile out; how far it would have stood against nineteen rounds may well be questioned. Speaking generally, then, we see that on this scale of armor the chilled shield, 75 per cent. thicker than the wrought iron shield which would have matched the gun, was able to resist nineteen rounds delivered on a very confined space. Herr Gruson does not expect chilled iron to be a match for wrought iron, inch for inch, on this scale of armor; but for armor for the 100-ton gun the advantage possessed by the former metal as the thickness increases would probably have brought the chilled into the position to rival wrought iron of equal thickness. At Tegel, in the year 1874, a turret, with shield, with a maximum thickness of 55 centimeters (21·65 in.), withstood 277 rounds from a 15-centimeter gun, twenty from a 17-centimeter gun, and two from a 28-centimeter gun. At this period, then, Gruson's metal shields deservedly established their reputation in Germany. The Prussian officers observe that while experiments had been going on with wrought iron in England through long series of years, chilled iron had been so far perfected as to be able to be recommended in three or four years.

As we have said above, Gruson's armor has now been adopted by most of the continental powers. It offers a shield readily made, and very simple in character, requiring no backing or supports, but itself forming the structure required. The iron employed should be of superior quality, free from sulphur and phosphorus, and of course of a selected mixture as to gray and white, so as to combine the required hardness and toughness. The chill should not change suddenly to gray, as is sometimes seen in some superior brands of Swedish iron, but should shade off gradually. The cost is estimated at about £30 per ton. It is thought that the required kind of metal would be readily found in most of our colonies, where iron fortifications are under consideration. Fig. 6 exhibits the general form taken by Gruson's armor in a turret or cupola, as it is termed. In this case the turret is made to revolve by hand, the men working on the levers shown beneath. In some of the earlier examples central pivots were employed; but it is much better to dispense with them. The projectiles and cartridges are lifted from beneath, the guns being in all cases breech loaders. Each turret generally contains two guns. Figs. 7 and 8 exhibit the structure of a battery in section and plan showing the arrangements for training the guns through large angles. The form of the battery is such as to give the armor the advantage of the curve of a cupola as far as practicable. It will be seen that the Gruson form of cupola, and battery alike give a great advantage in strength of roof—which can be made strong enough to resist vertical fire. This is an important matter, inasmuch as chilled armor, especially in the cupola form, is likely to be employed in those detached forts which play an important part in detaining an enemy, but which must eventually succumb to a regular attack, without being able in most cases to withdraw the armament or even the men.

Lieut-Col. Kromhout, of the Dutch engineers, has written an able paper advocating the employment of cupolas for these "forts d'arret," as they are termed. He considers that two guns in cupolas may take the place of six in a fort, because it is rarely indeed that six guns directed in diverging lines would be required to fire at the same time, and that two cupolas, by their power to revolve, could probably perform the same work, while they have an advantage in obtaining mutual cover. The saving of four pieces is not merely a matter of economy; it diminishes the prize that may eventually fall into the enemy's hands, not merely by the actual guns, but the corresponding detachments of men and stores. Approaches, bridges, coast defenses, and the detached position about Amsterdam, so Colonel Kromhout thinks, cupolas are specially suited to defend. He calculates that the roof might be made thick enough not only to resist siege pieces, hitherto used for vertical fire, but also a special mortar of Krupp's of 21 centimeters (8·27 in.) caliber, which fires a shell weighing 198 lb., with a velocity of 1,000 ft. per second. Provision would be made for resisting such a projectile, even if its falling velocity were equal to its initial by a roof 15 centimeters (5·9 in.) thick.

To pass from the general question to particular cases, Fig. 9 shows an actual cupola, made to contain a 28-centimeter breech-loading gun, in the course of erection. The segments are lifted by cranes and lowered into their place, after which a mixture of zinc and lead is run in between their joints. This fills up the recessed space seen on the ends of each portion, and gives the entire structure the required solidity, leaving it free, as has been said above, from all liability to langridge, until the entire mass of metal becomes broken up.

Fig. 10 shows a line of cupolas erected for the Prussian government on the principle above described. In Germany there are now at the entrance of the river Weser, near Bremerhafen, the following armor plated works: One fort with five turrets or cupolas, each containing one 28-centimeter gun, and one turret with two guns of 15 centimeters. One fort with three turrets, each containing two 28-centimeter guns, and one turret with two 15-centimeter guns. Also, one battery with nine 21-centimeter guns.

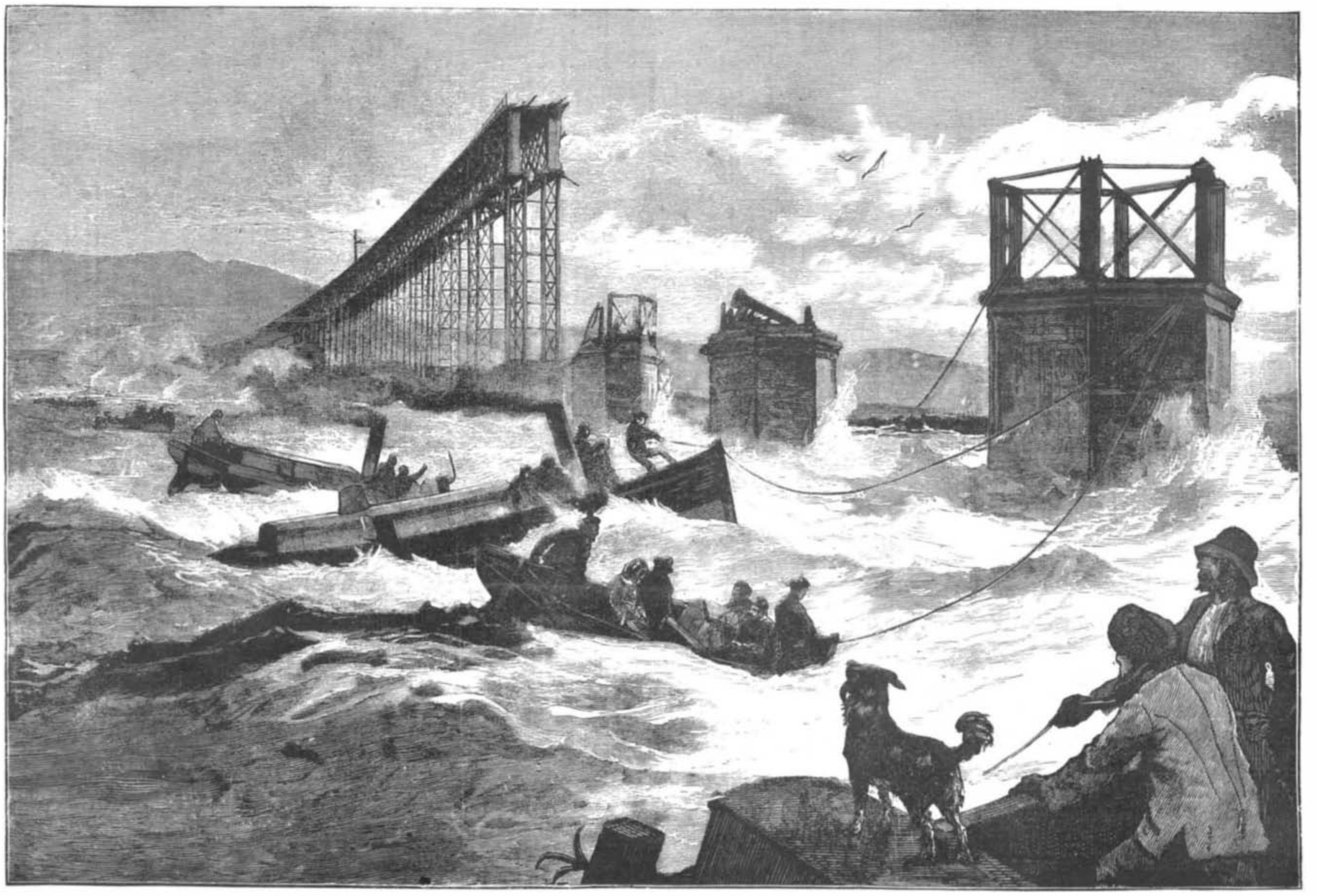
Figs. 11, 12, 13, and 14 show very fully the St. Marie Battery, recently erected for the defense of Antwerp, which place has had special attention bestowed on its protection in the successive stages of the progress of fortification. In Belgium, iron fences have been adopted from their first introduction. One of the first revolving turrets ever constructed stands at Malines. General Brialmont, the chief of the Royal Belgian Engineers, who is well known as an authority on fortification, has advocated the employment of Gruson's armor, although wrought iron had so far found favor as to be previously employed. At Fort Philippe there are now wrought iron turrets which do not appear to give satisfaction. The new St. Marie Battery at Antwerp has Gruson armor of a maximum thickness at portholes of 70 centimeters (27·56 in.), and a minimum thickness of 38 centimeters (14·96 in.); the covering varying from 35 to 20 centimeters (13·78 in. to 7·87 in.) thick. The ammunition is stored under the casemate. The total weight of the battery is 860 tons. A porthole plate weighs 35 tons, a pillar 25 tons, and a covering plate 21·5 tons. These plates were sent to Antwerp by railway in special carriages. A revolving crane was used to put them on board ship, which brought them by the Schelde to the fort. They were then carried and placed in position by means of rails and traveling and steam cranes, as shown in Figs. 11 and 12. Fig. 13 gives a good view of the line of works, and Fig. 14 of the interior.

Officers or others who may visit Antwerp are recommended to apply for an order to see this fort, as there is much less difficulty in obtaining access to such works in Belgium than, perhaps, any continental kingdom. It could probably be done through the British Embassy.

The St. Marie Battery is an illustration of the employment of heavy castings, but we believe that in some instances they have been employed up to 50 tons weight. On the other hand, in the Italian passes it was stipulated that the maximum weight should be 13 tons. We cannot better close this description of the Gruson system of armor than by the expression of a hope that we may see some specimen of it fairly tried in this country.—*The Engineer.*

THE TAY BRIDGE DISASTER.

IN our last SUPPLEMENT we gave a full account of the fall of this great bridge on the evening of Dec. 28, 1879, by which a railway train, with every person on board, was suddenly destroyed. We also presented a number of engravings showing the construction of the bridge. We now give (from the London *Illustrated News*) an additional view, showing the appearance of the bridge near the broken part. Immediately after the accident a vigorous search was instituted for the recovery of the bodies of the drowned passengers, the mails, and other property. Several steam tugs with diving apparatus were made use of. But up to the latest dates little progress had been made in the recovery. The divers found the bottom of the river covered with an almost impenetrable network of twisted and broken iron bars. Nearly one hundred lives were lost. Only a few have been recovered.



THE TAY BRIDGE DISASTER.—SEARCHING FOR THE LOST.

COMPRESSED AIR REFRIGERATING APPARATUS.

By HENRY BELL, JAMES BELL, and JOSEPH JAMES COLEMAN, of Glasgow, Scotland.

THIS relates to refrigerative apparatus of the kind in which the refrigerant action is produced by compressing air, abstracting heat from the air when compressed, and subsequently allowing it to expand; and our object is to obtain an improved application of this process for the important purpose of preserving meat or other food or beverages. In attempts hitherto made to practically apply the process referred to, difficulties have been met with through the freezing of moisture contained in the air during its expansion, and our improved apparatus is especially designed to avoid such difficulties by means which insure that the proportion of moisture in the air at the time when it expands shall not be sufficient for the formation of ice or frozen particles.

The apparatus is designed for the air to be passed through on its way from the cylinder or cylinders in which it is compressed to the cylinder or cylinders in which it is expanded. The well-known process of cooling the air, while being compressed, by injecting water into the cylinder in which the compression is effected, or by incasing the compressing cylinder in a water jacket, or in both ways, is intended to be used in carrying out our invention, and the use of our apparatus, hereinafter described, is to be additional to, and not instead of, such known process.

The apparatus we employ comprises two vertical cylinders, A B, or vessels of any convenient and suitable form, and a set of pipes, C. The first vessel, A, is formed with an inlet, D, at its lower part for the admission of the compressed air from the compressing cylinders, the air passing upward through this first vessel, A, then across, by a connecting passage, E, to the top of the second vessel, B, in which vessel it descends, and from the lower part of which it passes into the set of pipes, C. At the top of the first vessel, A, there is fitted a pipe, F, for the introduction of water

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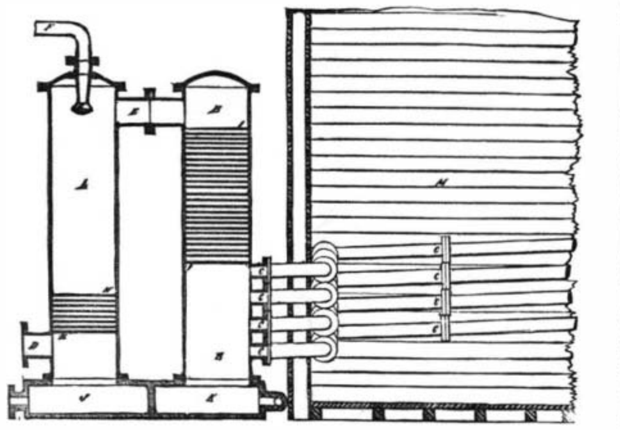
of ordinary temperature (or colder, when conveniently obtainable) such water being forced by a pump, so as to overcome the internal pressure of the compressed air. This water injection pipe, F, is fitted with a rose-nozzle, G, for the purpose of dividing the entering water and distributing it over the area of the vessel, A, it being important that the air and water should intermingle intimately while the air passes upward and the water downward.

To insure complete contact and action between the water and air, so that the water may abstract as much as possible of the heat rendered sensible by the compression of the air, the vessel, A, is provided with suitable materials, down through which the water may drip while the air passes upward through the interstices. For this purpose we employ a number of perforated metal diaphragms, H. which are fixed across the lower part of the vessel, A, but above the air-inlet, D, and it is best to arrange these diaphragms with the holes in each opposite the solid metal of the next above and below, in order that the subdivided currents may have their directions continually changed, and be thereby made to impinge upon the wetted surfaces of the diaphragms. Similar diaphragms, I, are fitted in the second vessel, B; or any equivalent arrangement of materials may be substituted for the diaphragms, I. The purpose of this second series of diaphragms, I, in the second vessel, B, is in a sense the reverse of that of the first series, H, in the first vessel, A. The first series, H, are for bringing the air and water closely together; the second series, I, are for separating as completely as possible from the air any moisture it carries over from the vessel, A. into the vessel, B. The jets of air, passing through the perforations in each plate, I, in succession, impinge on the next plate, and deposit the suspended moisture on the plates. At the bottom of each vessel, A B, there is a casing, J K, to receive the water, which may be withdrawn therefrom periodically or continuously through any suitable water-trap valves.



COMPRESSED AIR REFRIGERATING APPARATUS.

Assuming that the water employed and introduced by the pipe, F, is of the ordinary temperature, it cannot, of course, reduce the heat of the air below that temperature, and at this temperature the air will still retain some moisture, which will be precipitated and possibly congealed on the air being subsequently expanded and becoming of considerably lower temperature. It is the purpose of the set of pipes, C, to cause the separation and deposition from the air before it reaches the expansion-cylinder of any moisture which would thus tend to congeal, and thereby interfere with the proper working of the apparatus. These pipes, C, are placed in an atmosphere of a lower than the ordinary temperature, and, being inclined upward from the vessel, B, the moisture deposited in them in consequence of the additional cooling of the air in passing through them drains back from them into the vessel, B. We place the pipes, C, in the chamber, M, in which the meat or other substances to be preserved by maintaining a low temperature are placed, and thereby obtain the required cooler atmosphere in the most convenient and economical manner. The object of passing this compressed air through pipes in the provision-chamber, M, is not for the purpose of cooling the air in this chamber; but, on the contrary, the object is to complete the cooling of the air in its compressed state in these pipes by the cold air of the provision-chamber, and this before this compressed air passes into the expansion cylinder, where its rarefaction produces the required degree of cold

The pipes, C, should be of considerable length, the precise length in each case depending on the temperature intended to be maintained in the chamber. M, and other circumstances.

Where several chambers, M, are to be kept cool by the same refrigerating apparatus—for example, a number of vans composing a railway-train, or several separate compartments in a ship—the pipes, C, may be arranged in only one compartment of the series.

MACHINE FOR CLEANING WOOL.

AN extremely useful machine has been invented by M. Emile Hübner. of Paris, the object of which is to separate from wool, or other textile materials, any foreign materials which may be intermingled with the same, such as fiber of herbs, pieces of grass, or other vegetable substances, etc.

It is most advantageous to treat the wool, etc., in this machine after it has passed through the ordinary carding or combing machines, because the foreign substances have a tendency to resist the action of the combs, and are generally in more or less great quantities retained in the combing machine.

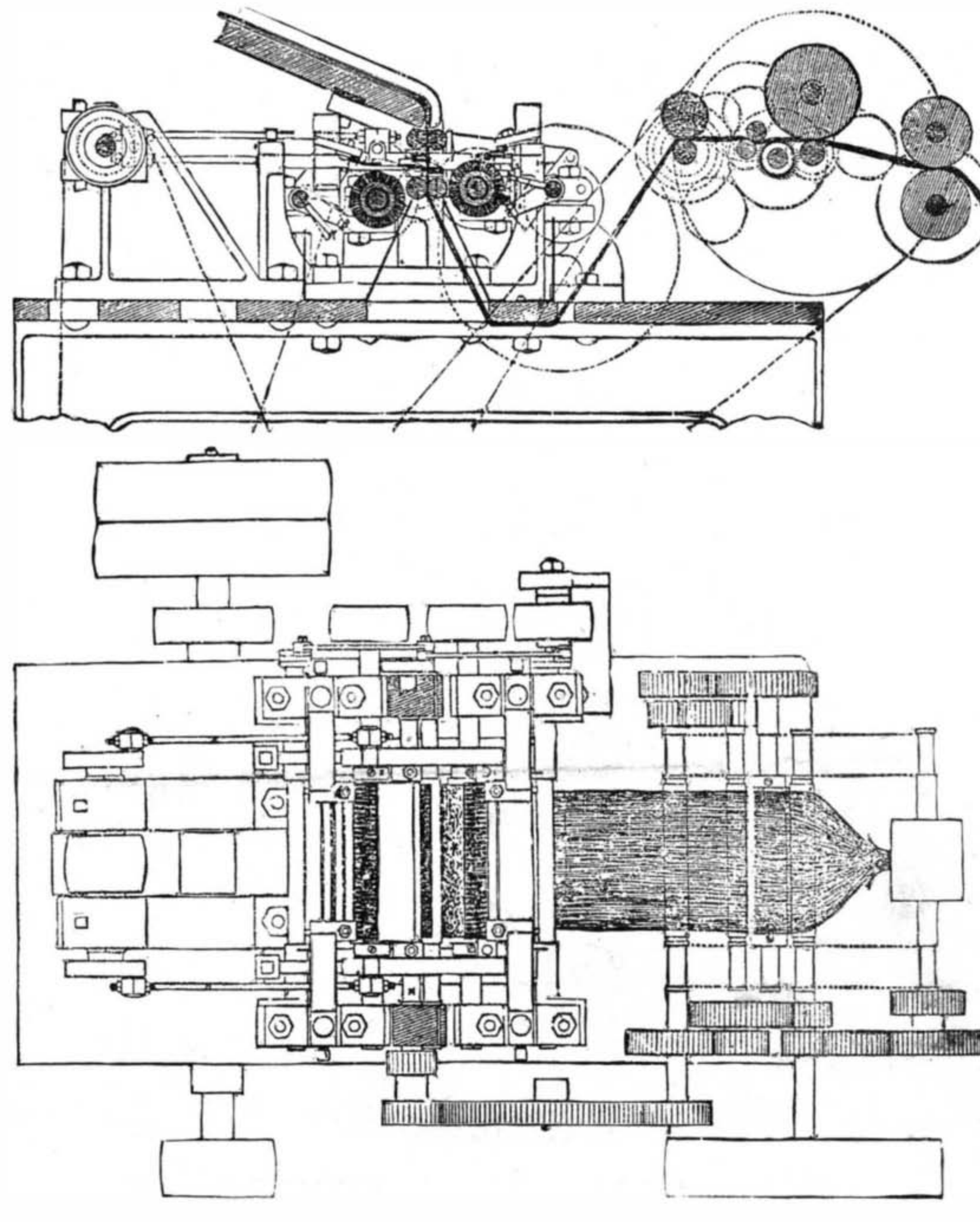
For the purpose of effecting the separation of the extraneous substances from the fiber, a comb is employed, the teeth of which are very fine and closely set, and which is alternately introduced rapidly into the bend or sliver of material to be cleaned, and pulled out again with the same rapidity.

The operation and effect of the new machine is based upon the fact that the fibers of the foreign matter contained in the textile material to be treated are much thicker than the fibers of the material itself. The rapidly reciprocating combs are formed either with one or several rows of very fine teeth, which are set at such distances apart that the space between them permits the fibers of the textile material to pass freely, while, on the contrary, the thicker fibers of the foreign matter become firmly wedged in between the teeth, and can thus be drawn off the sliver.

The accompanying figures from *L'Ingénieur Universel* represent a wool cleaning machine constructed on this principle, combined with an ordinary wool drawing mechanism, which rolls up the clean and picked sliver.

Fig. 1 is a side elevation, and Fig. 2 a plan with the upper feeding cylinders cut away.

A is the main shaft carrying three pulleys, B, C, D. The two circular brushes, E, receive their motion from the pulley, B. The crane shaft, G, is driven from the pulley, C, and the pulley, D, operates on an ordinary wool drawing or rolling mechanism. The latter imparts, by means of an intermediate gear wheel, O, a very slow movement to the two sets of cylinders, H and H¹. The wool or other fibrous material arrives through the trough, P, and passes between these two coupled pairs of cylinders, H and H¹, and during its progress between them the picking and removal of the foreign fibers, particles of straw, etc., takes place. The two combs, K, formed in the shape of hackle bars, are fixed transversely on the two sleeves, J, J, and form therewith a frame which slides on the two rods, Q, Q. This frame receives a rapidly reciprocating movement from the two crank disks, F, on the shaft, G, by means of the two connecting rods, H, H¹. The two combs, K, plunge alternately from both sides into the body of the sliver, receive and hold between their teeth the vegetable fibers and other foreign matters, and remove them from the material. On its return movement each comb comes in contact with and is cleaned by a circular revolving brush, E. A curb comb, R, having a very slow reciprocating movement, rises till it touches the brush, E, which now deposits thereon what it has taken off from the comb, K, and on its downward movement, the full card comb, R, comes in contact with a second stationary card comb, S, which serves to clean the comb, R, and let foreign fibers, straw, etc, fall down into a receptacle. A straight fixed brush, L, is placed over each of the combs, K, at the back end of their stroke, the object of which is to facilitate the drawing of the cords. The slow movement is imparted to the card combs, R, by means of the crank disk, V, and the two converting rods, X, X. The sliver thus cleared is guided towards and passes through the drawing mechanism, Z, which rolls, and transforms it into a round strip of perfect regularity, which may fall into any suitable receptacle, or may be wound up on a bobbin.



MACHINE FOR CLEANING WOOL.

IMPROVED KNEADING AND MIXING MACHINES.

A LARGE demand exists for a special class of machinery required for kneading or mixing materials, such as bread, biscuits, vermicelli paste, etc., as well as for the thorough incorporation of rubber and gutta-percha, colors, printing ink, and a variety of other manufactured articles. Of this class are the machines illustrated on next page, designed, says *Engineering*, by Mr. Paul Pfleiderer, of 37 Farringdon street, London, and which possess several features which appear to be of considerable merit. As will be seen from the illustrations, the machine consists of a set of blades revolving at a high speed within a casing into which the material to be mixed is fed, and of appliances for reversing the motion of the blades with facility. The following are some of the principal characteristics of the machine: The blades or mixers are so arranged as to dispense with the central bosses for securing them on their shafts, and motion is transmitted to them through radial arms, which serve also as fixed scrapers; these arms extend beyond the central line of the axis of the blade, and are adapted in form to suit the required purpose. The clearance for the passage of the material to be mixed may be increased as required by taking out a large portion of the blade on one side of the axis, or two portions on opposite sides, retaining the central bosses of the blades or dispensing with them as desired. Two or more such blades or mixers revolving at different speeds may be employed with a concave bottom having a bridge between them.

By another arrangement, a number of blades or mixers may be grouped round a common central axis, on which the trough in all its several portions is mounted and made to revolve. The trough in this case forms a kind of drum on the central axis. For the admission and discharge of the material it is provided with one or more openings, which can be closed as required by means of slides, or valves, or otherwise. The trough may be tilted or lowered from the driving gear, or from the blades or mixers, as may be required for emptying or cleaning, without the necessity of having the axis of the driving shaft of the machine coinciding with the axis of the trunnions on which the trough can be turned.

To effect this, either the whole trough or the bottom only in connection with the ends of the trough, are mounted on trunnions, the action of which coincides with that of one of the blades or mixers, or, if preferred, the trough may be taken away entirely.

Figs. 1 and 2 are two sectional views of a machine in which one end and a part of the bottom are mounted on an axis, and can be lowered as shown for the purpose of emptying. In this arrangement one of the compartments is lower than the other, and the blades are actuated by gearing from the shaft, *a*. These blades are driven by and coupled with the driving wheels by means of bushes with square holes in which the pins, *d*, fit. It will be noticed that these pins can be easily withdrawn, and the blades removed without interfering with the gearing. The mode of driving is shown in Fig. 2 by a modification of combined pulleys and clutch.

The arrangement consists in the combination of two loose pulleys on one shaft, one pulley being driven by an open strap, and the other by a crossed strap, with friction or other clutches, by moving which clutches as required, either of the two loose pulleys can be made fast and motion transmitted or reversed with facility and certainty. The clutches are formed of projections, one on each side of a disk, secured on the shaft between the two pulleys, so as to be capable of sliding on the shaft; each of these projections can, by moving the disc on the shaft, be caused to engage with corresponding parts in either pulley, as required. The disk is moved on the shaft, as required by means of a tapped hand-wheel, which also keeps the disk in any required position thereon. For stopping the machine, the hand-wheel has simply to be held fast, while for starting it

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