WOOL SCOURING

Serial 470 Edition 1

DUSTING

1. Objects of Dusting.—Previous to scouring, the wool as it comes from the sorter is in the majority of cases passed through a machine known as a **duster.** The object of dusting grease wools is, as far as possible, to remove before scouring such foreign impurities as lumps of dirt, dust, shives, etc. The reason for this is that, as all such impurities are detrimental not only to the finished goods but to the facility with which the processes of manufacture are accomplished, it is advantageous to commence to remove them at as early a period as possible. The wool sorter is supposed to remove burrs and large particles of dirt from the wool during the process of separating the fleece into different qualities, but it is impossible for all impurities to be removed at any one time; and, in fact, they are not all removed until the wool is practically ready for spinning. It is of particular importance to have the wool as free from foreign matter as possible before it is scoured, as the saving in soap and scouring liquor when the wool is dusted and freed from sand, chaff, etc., is very apparent.

2. Another object, although a subsidiary one, is to deliver the wool to the scouring machine in a more open and *lofty* condition, as it is found that scoured wool which has previously been passed through a duster leaves the washing machine more thoroughly and evenly scoured and brighter looking. The reason for this is that the stock is not only partly cleaned by the dusting, but is also opened up so that the scouring liquor will penetrate every portion of it and thus render the scouring more even and more thorough.

TYPES OF DUSTERS

CONE DUSTER

3. Principle of Construction.—The principle on which the **cone duster** operates is simply that of beating the wool

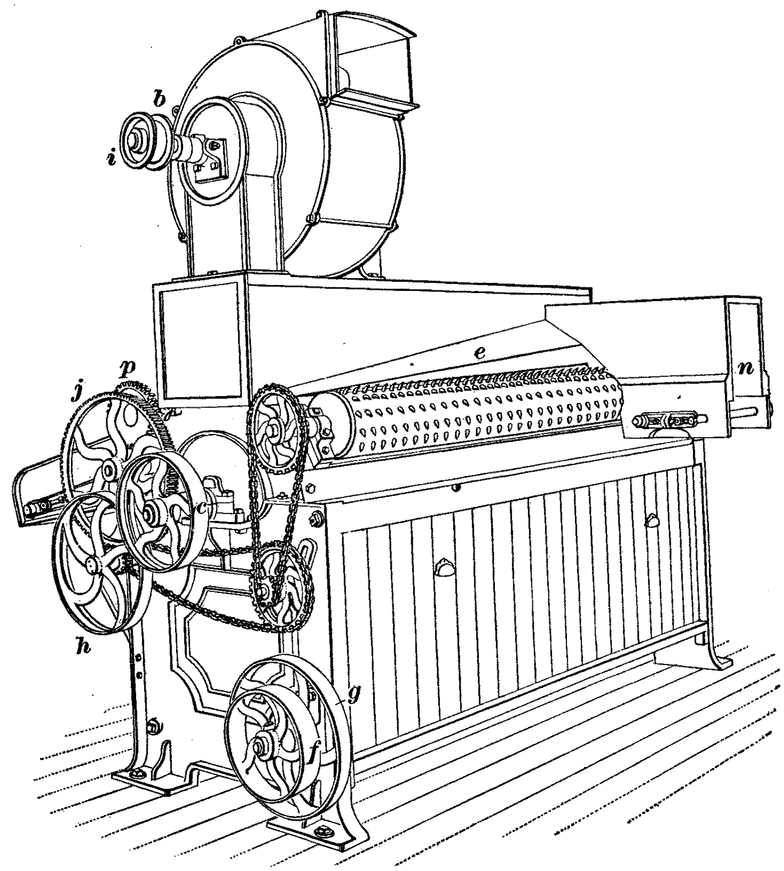

FIG. 1

by means of a rotating cylinder below which is suspended a screen, or grid, that allows the dust and other foreign matter to fall through but retains the stock. The principal features of the cone duster are shown in Fig. 1, while Fig. 2 is a view of the main cylinder of the machine, which cannot be seen in Fig. 1. This cylinder is cone-shaped, the larger end being 4 feet and the smaller end 26 inches in diameter in some

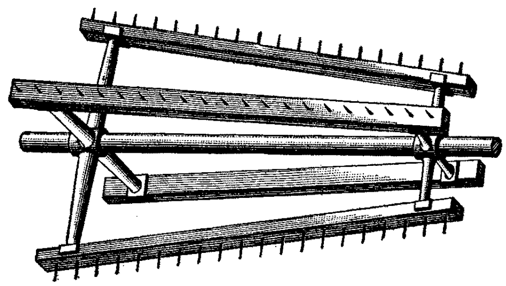

FIG. 2

machines, while the total length is usually about 7 feet. The cylinder is built up on a central shaft with arms, or spiders, to which are attached four wooden lags. Each lag carries iron teeth that project generally about 3 inches from the lag, but in some machines more. Sometimes similar teeth are placed on the frame of the machine so that the teeth lags on the main cylinder will mesh with them.

Below the main cylinder is a grid made in two parts, one of which may be removed from the front of the machine and the other from the rear; the details of one part are shown in Fig. 3. In some machines the grid is so arranged that it may be removed as a whole from one end of the machine. The grid, being removable, is easily accessible for cleaning. Sometimes, instead of a grid, a coarse-meshed screen is used. The dirt that is beaten out by the cylinder falls through the grid into a chamber, from which it can easily be removed.

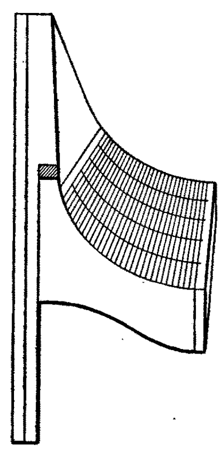

FIG. 3

4. The Fan.—In order to carry off the light foreign matter and dust from the wool, a fan *b* is often used in connection with the duster, which in this case is shown above the machine in Fig. 1. This is a 24-inch fan so connected to the inside of the cover of the cylinder that a current of air carrying away the lighter impurities is constantly passing through the duster and being delivered outside the mill by means of suitable pipes. Beneath the fan is a screen that retains the wool but allows the dust to be removed. The lower part of the machine is made air-tight, so that the air in the space below the screen will be comparatively still; by this means the current generated by the fan will not hinder the fall of the heavy particles of dirt as they are beaten from the wool and drop through the screen.

5. Feed.—Another feature of the machine is the mechanism for feeding, which consists of a traveling feed-apron, or lattice, on which the wool is fed either by hand or by a self-feed. Immediately over the delivery end of the apron is placed a single large cockspur feed-roll, which, working in conjunction with the apron, delivers the wool to the cylinder. Dusters are occasionally built with two cockspur feed-rolls instead of the single roll.

The method of imparting motion to the various parts of the cone duster is as follows, the references being to Fig. 1: The fan is driven from the pulley *c* on the main shaft of the machine, which drives a pulley *i* on the fan shaft. A small pulley fastened on the main shaft behind the pulley *c* drives a pulley *g* on a stud; fast to this pulley and loose on the same stud is a pulley *f*, which drives a pulley *h* with a cross-belt. Compounded with the pulley *h*, is a small pinion gear that drives a large gear *j* on the apron-roll shaft. The single cockspur feed-roll is driven by a gear compounded with the gear *j*, which drives the gear *p* fast to the shaft of the feed-roll. The main cylinder shaft carries tight and loose pulleys on the opposite end of the machine and is driven from the driving shaft of the room. The main cylinder should have a speed of about 400 revolutions per minute, while the fan should make about 1,000 revolutions per minute. It is not necessary to give any speed calculations in regard to a duster as it is a very simple machine and it is seldom that changes are made; if a change is made it is usually in the speed of the whole machine, which necessitates changing only the main driving pulley.

6. Operation.—In operation, the wool is fed on the traveling feed-apron and is delivered to the cockspur feed-roll. The stock is then beaten by the teeth on the lags of the cylinder and all heavy dirt drops by gravity through the screen under the cylinder, while the lighter dust, shives, etc., are drawn off by the fan. The stock travels from the small end of the cone-shaped cylinder toward the large end, and is finally thrown through an opening *n* at the rear of the machine ready for scouring. The wool is now open and lofty and the scouring liquor can penetrate it quite easily; thus more even and more thorough work is assured and there is less need of agitation in the washing machine.

A worker *e* is shown in Fig. 1, which is more particularly used in case of dusting card waste, noils, and similar materials. A duster used for grease wools may be built with or without this roll, which is driven from a sprocket compounded with the pulley *h*. This sprocket drives a compound sprocket on a stud that drives a sprocket on the shaft of the worker. The power required to drive a cone duster may be estimated as $3\frac{1}{2}$ horsepower and the machine should be driven by a $3\frac{1}{2}$-inch or 4-inch belt. The floor space occupied by this machine is 9 feet by 7 feet.

SQUARE DUSTER

7. Object of Square Duster.—Another form of duster for grease wools is shown in Fig. 4, being known as a **square duster.** The object of this machine may be said to be the same as that of the cone duster; namely, to free the wool of dirt before scouring. It is, however, more particularly adapted to the longer-stapled wools, such as are used in the fine worsted trade and do not require such severe treatment. The cone duster has a tendency to roll short stock and make the wool *pilly*, while on long stock the

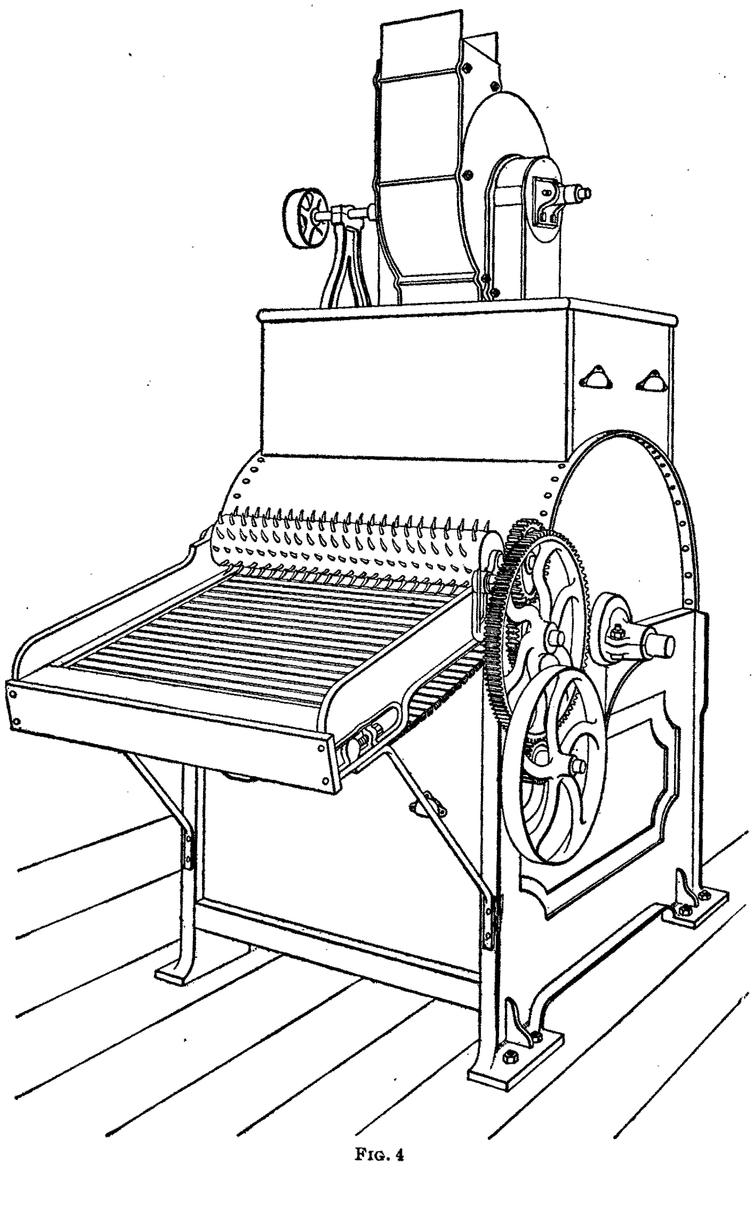

Fig. 4

cone cylinder is apt to make the stock *stringy;* both of these faults are eliminated by the square duster. The principle of the square duster is the same as that of the cone duster, except that in the latter the cylinder is cone-shaped, while in the former the cylinder has the true cylindrical form. The machine is fed by means of a feed-apron, which is made of slats of hardwood, generally maple, as in the cone duster, being fastened on endless belts of leather. The apron runs on cast-iron rolls, which are provided with adjusting screws for tightening the apron when slack. The feed-roll is constructed on the same principle as that in the cone duster and is furnished with cockspur teeth. The advantage of using cockspur teeth for feed-rolls is that when teeth are made curving back from the direction of rotation of the roll they are self-stripping; that is, they clear themselves from wool and the roll does not become matted and choked with stock.

8. Construction and Operation.—The square duster is built with or without a fan. In Fig. 4, a fan is shown on the top of the machine. The advantage of a fan is very apparent, as the strong current of air thus generated cleans the wool of all light impurities and conveys them away through suitable pipes. Since the lower part of the duster is made air-tight, the current of air from the fan will not hinder the fall of the heavier particles of foreign matter through the screen, the air being admitted to the fan through suitable openings in the sides of the duster frame.

In operation, the wool is fed to the machine on the traveling apron. It is then taken by the feed-roll and delivered to the rotating cylinder, which in this duster runs downwards, but which in the cone duster runs upwards. The wool in this machine is subjected to the action of the cylinder for about half a revolution and the fleece opened up for the scouring liquor without rolling it or breaking the fibers. The power required to drive a square duster varies with the amount of wool that is being fed to the machine, but may be estimated at 3 horsepower, a $3\frac{1}{2}$-inch belt being sufficient for driving purposes. The machine occupies a floor space of

5 feet by 7 feet. The speed of the square duster is about the same as that of the cone duster.

9. Management.—The management of either duster is a comparatively simple matter and its success depends largely on the manner in which the duster is attended to in regard to cleaning. Dusters, if not properly cared for, soon choke up and in this condition are useless, so far as dusting the wool is concerned. The dust box under the screen, or grid, should be frequently cleaned out, and care should be taken to clean the grid at the same time, because if it is choked up the dirt cannot fall through into the dust box, even if the latter is empty. In putting up the dust pipes for the fan, care should be taken to have as few angles or bends as possible, so as to obtain a good current of air and also to avoid sharp curves or bends. Round elbows with a full sweep and round piping should be used for conveying dust or stock from a duster, or in fact any machine requiring to be thus connected. Sharp angles in dust pipes destroy the force of the air-current and are liable to become choked with refuse. The dust pipes should be as large as the opening of the fan casing and preferably of galvanized iron.

OPEN, OR CAGE, DUSTER

10. A duster occasionally used in small mills is shown in Fig. 5; it is of so simple a type as to require only a brief description. This is sometimes known as an **open, or cage, duster.** The machine consists of a large rotating horizontal cylinder covered with heavy wire screening. Inside the cylinder is a central shaft on which are fixed eight iron cross-bars about 5 feet long, these cross-bars being fixed to the shaft at different angles to one another. The cylinder is provided with a door through which the stock may be entered and removed.

In operation, the wool is placed in the duster and the iron cross-bars, which rotate, beat out all the dust and dirt from the wool and force it through the screen-covered cylinder. The great objection to this machine is that all the dust and dirt is discharged into the room, where the workmen must breathe the air. Another fault is that the operation is not continuous, the wool being placed in the machine in small lots, dusted, and removed, when another lot is introduced.

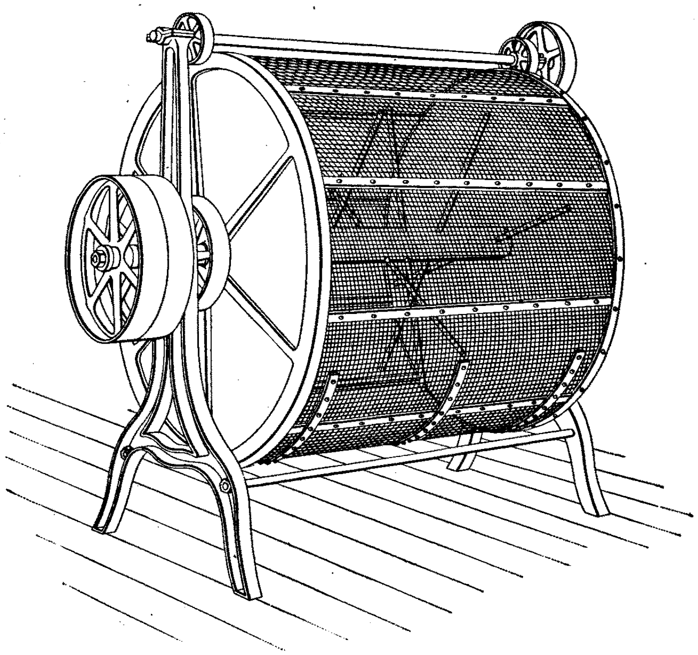

FIG. 5

The open duster does good work so far as the stock is concerned, but the slowness and expense of the operation, together with the unhealthy conditions caused by the dust, are fatal to its general adoption.

In England, a duster is known as a **willow** and this term is used to a limited extent in American mills.

SCOURING

11. Object of Scouring.—The operation that follows the dusting of the wool is known as **wool scouring,** or **washing,** and has for its object the cleansing of the wool from the natural and foreign impurities that, if not removed, would effectually prevent the wool from being worked in the after processes of manufacture. In the dyeing, particularly, great trouble is caused by imperfectly scoured wool and it has been found impossible to fasten the colors on such stock. The primary objects of wool scouring, therefore, are to cleanse the wool of the yolk, or natural preservative, a greasy matter that covers the outside of the fiber, and at the same time to remove such mechanically adhering impurities as dirt, pieces of manure, etc., that have not been loosened in dusting. The proportions of the different components of unwashed, or grease, wool vary greatly, but are usually included within the following limits:

	Per Cent.
Moisture	4 to 24
Yolk	12 to 47
Dirt	3 to 24
Wool fiber	15 to 72

From the above list, it will be seen that wool, as it is clipped from the sheep's back, is a very impure article and contains from 18 to 85 per cent. of impurities, the general average being in the vicinity of 60 or 65 per cent. These impurities may be classified in general under three heads: yolk; suint; matter mechanically fixed on the fiber by the yolk and suint.

IMPURITIES IN WOOL

12. Yolk.—In treating of the structure of the wool fiber, reference has been made to the greasy matter with which the wool of sheep is impregnated. This substance is termed **yolk** and is of great service during the growth of the wool in protecting the physical structure of the fiber from injury. While it is true that the wool grease is commonly termed yolk, it really consists of two distinct parts—the *yolk proper*, which consists of substances that require the use of soaps or solvents for their removal, and the *suint*, or portion that may be readily removed by the application of water only.

13. The **yolk proper,** or **wool fat,** as it is sometimes called, has a composite structure, and is composed of substances known as cholesterine and isocholesterine, both in an uncombined state and as salts of oleic and other fatty acids, the latter mainly stearic and palmitic. Wool fat is insoluble in water, but may be dissolved by such solvents as carbon bisulphide, benzine, naphtha, etc.; or it may be removed as an emulsion by the use of alkaline detergents. The removal of the wool fat necessitates the use of strong scouring agents, and were it not for this substance, the wool could easily be washed in pure water. In washing raw wool, therefore, if it contains an excess of this fatty matter it will be more difficult to scour thoroughly, and will require the use of more soap or alkali. Such wools are often termed **pitchy.**

14. Suint.—This is the portion of the wool grease that is soluble in water and is usually included under the general term of *yolk*, which is the common word for wool grease when considered as a whole. **Suint** is really the collected perspiration of the sheep, commonly called wool perspiration, and consists chiefly of potash salts, principally potassium oleate, palmitate, acetate, and other salts of organic acids. Potassium carbonate, chloride, sulphate, and phosphate (carbonate of potash, chloride of potash, etc.) are also present, as well as a small amount of ammonia (about .5 per cent.); these form the inorganic constituents of wool perspiration. From this it will be seen that the suint, or portion of the yolk soluble in water, is a valuable source of potash salts.

15. Yolk Ash.—In France and Belgium, it is customary to steep wool in tanks before scouring, in order to dissolve the wool perspiration. The dirty brownish water thus obtained is then evaporated in specially constructed furnaces, and a product procured, known as **yolk ash,** from which the potash salts can be recovered. It is said that certain heavily yolked wools will yield, when steeped in warm water, from 70 to 90 pounds of carbonate of potash, and from 5 to 6 pounds of potassium chloride and sulphate per 1,000 pounds of wool. The value of the potash salts obtained in this manner in France alone exceeds $500,000 per annum. In England and America, it is not customary to make any distinction between the wool fat, or true yolk, and the wool perspiration, or suint, the whole being removed in the one operation of scouring, and the waste water allowed to run away in the drains and rivers. Many thousands of dollars are wasted in this manner by American woolen mills, although of late some mills have been taking steps toward retaining these valuable by-products.

16. Analysis of Yolk Ash.—The yolk ash obtained from the water in which the wool is steeped consists of about 60 per cent. of organic matter and 40 per cent. of mineral, or inorganic, substances, these latter consisting largely of potassium carbonate. An analysis of the inorganic matter contained in the yolk ash gave the following results:

	Per Cent.
Carbonate of potash	86.78
Sulphate of potash	6.18
Chloride of potash	2.83
Other metallic elements, as lime, iron, phosphorus, alumina, etc.	4.21
	100.00

Whether wool is steeped for obtaining the potash salts or not, it is always necessary to scour it, since the steeping only dissolves the suint, or wool perspiration, and does not remove the wool fat, or true yolk. The preliminary steeping of the wool, however, is an aid in turning out the stock bright and lofty.

17. Earthy Matter.—The mechanically adhering impurities of wool consist mainly of **earthy material,** such as sand and dirt, which are held on the fiber by means of the greasy, sticky nature of the yolk and suint, to which they adhere or in which they are enveloped. The mechanical impurities are all foreign, and vary greatly with the character of the soil on which the sheep range, in some fleeces being gritty, and in others consisting of a loamy dirt. The percentage of these foreign substances varies greatly, being sometimes as low as 3 or 4 per cent., and in other cases as high as 20 or 25 per cent., of the total weight of the fleece.

In regard to the amount of weight lost by removing the yolk, suint, and dirt from wool in scouring, or in other words the shrinkage from a grease to a scoured basis, it may be said that there is considerable variation. Long luster wools do not contain as much yolk as those of shorter staple. Merino fleeces average only about 35 per cent. of clean fiber, 40 per cent. of yolk and 25 per cent. of dirt being removed during the preparatory processes of manufacturing. The average shrinkage of American wools may be said to be about 60 per cent., but it is in many seasons a little more than this.

SCOURING MATERIALS

18. The scouring agents in most common use for cleaning wools are soda ash, carbonate of soda, soda, or hard, soaps, potash, or soft, soaps, and ammonia.

19. Soda Ash.—This substance is really an impure form of carbonate of soda, as it contains from 65 to 95 per cent. of the pure carbonate. One of the great dangers in the use of **soda ash** as a scouring agent occurs, not from the carbonate of soda itself, but from the impurities found in connection with it. One of the impurities most likely to occur is caustic soda, which is injurious to wool even when present in only small quantities. A caustic alkali should not be used on wool or any other animal fiber, since in the presence of hot water free alkali will entirely dissolve the fiber, leaving in the case of wool a milky solution. Tepid water alone will swell the structure of the wool fiber and cause it to lose some of its luster and brilliancy; therefore, the danger of a caustic alkali in the warm (100° to 120° F.) scouring liquor is apparent.

To test soda ash for the presence of caustic soda, first dissolve a small amount in pure water; then add an excess of barium chloride and filter the solution. The filtered solution may now be tried with a piece of litmus paper, the presence of caustic soda being indicated by red litmus paper turning blue; a more delicate test is obtained by the addition of a small amount of phenol-phthalein, the slightest amount of caustic soda immediately turning the solution pink, while its absence will be indicated by the solution remaining colorless.

20. Carbonate of Soda.—This substance, which is the main constituent of soda ash, may be obtained in a very pure form and is the soda crystals, or washing soda, of commerce. It may, however, be tested for caustic soda in the same manner as soda ash, although it is usually free from any such impurity. The ordinary soda crystals contain 63 per cent. of water, but there are several other forms of sodium carbonate (one of which is known commercially as *crystal carbonate*) that are not open to this objection. **Carbonate of soda** is largely employed for scouring the coarser grades of wool, especially those that are very dirty.

21. Soda Soaps.—**Hard soaps** have soda as a base and are quite frequently used for scouring wool. Soda in any form, however, is not to be recommended for the very finest grades of wool. Soda soaps are made by treating caustic soda with any fatty acid; as, for instance, oleic acid, in which case sodium oleate, which is a hard soap, is formed.

22. Potash Soaps.—These soaps are made with potash as a base and are commonly called **soft soaps. Potash soaps** are made in the same manner as soda soaps, that is, by combining caustic potash with some fatty acid, in which case a soluble soap is obtained. It is commonly supposed that soft soap contains more water than hard soap, but such is not always the case. Soda soaps are hard and potash soaps soft because it is the nature of these two substances when used as the base of a soap to form hard and soft soaps, respectively. A soda soap may contain a much larger percentage of water than a potash soap and yet remain hard and firm. When proper precautions are not taken in manufacturing, any soap may be found to contain caustic alkali in a free, or uncombined, state. Potash soaps, contrary to the general opinion, may very frequently contain caustic potash. When this is the case, the soap may have a more severe action on the wool fiber than a soda soap or than even carbonate of soda. A quick test, and one often employed to test soaps for caustic alkalies, is to place a drop of phenol-phthalein on the soap, when a pink color will immediately indicate any free caustic alkali present.

23. Ammonia.—**Ammonia** is frequently added to carbonate and soap scouring liquors and aids in the removal of the yolk. Carbonate of ammonia, which may be obtained in commercial form, is rarely used. The liquid ammonia of commerce, which is added to the scouring bath in small quantities, contains only about one-third pure ammonia, the other two-thirds being water. Formerly it was the custom to scour wool with stale urine, or **lant.** This substance owes its detergent properties to the presence of ammonium carbonate. The wool was placed in tanks containing equal proportions of lant and water and poled around until the yolk and dirt were removed, when it was taken out and carefully drained and rinsed. This process gave results in many ways superior to the present methods. The action of the lant was mild and, when dry, the wool had that soft, *kind* feeling that it should be the aim of every scourer to obtain.

IMPURE SCOURING MATERIALS

24. Great care should be taken in purchasing scouring materials not only because of the necessity of obtaining an agent that will not injure the wool, but also because of the danger of obtaining an article of inferior scouring properties. There are many so-called patent soaps and scouring materials on the market, but they should, as a rule, be avoided, since they are usually expensive and are all based on the ordinary scouring agents with which every scourer is familiar. Soap is one of the easiest articles to adulterate and also one that is rarely tested unless poor results are traced directly to it. Soda soaps will contain a large percentage of water without any noticeable effect on the soap. For this reason, the manufacturer of the soap is liable to allow a large amount of water to be retained for the purpose of adding weight. To determine the amount of water in a sample of soap, weigh it carefully and then reduce to parings and dry in an oven until the sample ceases to lose weight. Then find the loss in weight, and the percentage of water is easily determined. There is a great loss of scouring power besides the inferior work done, if a soap contains resin, potato starch, or other impurities; in some cases earthy matter is added to a soap for the purpose of increasing its weight. Cases are on record where a potash soap has been analyzed and found to contain 40 per cent. of common salt, a substance of no value as a scouring agent.

A simple recipe for testing soap for impurities is to dissolve a small quantity in water and then add a little sulphuric acid to the solution. The acid breaks up the structure of the soap and all earthy and heavy adulterations fall to the bottom of the solution, while grease and resin, being lighter, float on the surface. The presence of resin in a soap is a disadvantage, especially in the soda soaps, where it most frequently occurs. Resin has a tendency to make the wool yellow; in fact, wool is very apt to have a more or less well-defined yellow tinge if scoured with soda in any form unless great care is taken.

THE SCOURING LIQUOR

25. It may be said that for the finest grades of wool, a fine quality of soap should be used, a well-made potash soap absolutely free from caustic alkali being preferred. The use of soda as an agent for scouring wools that are to be stored for some time before using, invariably results in the yellowing of the fiber and gives the wool a harsh feel. Especially is this true in regard to Australian and other fine wools. For medium and coarse grades of wool, where the strength of the fiber is such that it will resist the action of a stronger scouring agent, soda soap, carbonate of soda, or even soda ash may be used; but in all cases the scouring agent should be free from caustic alkali.

The amount of soap or other scouring agent used should be so regulated that no more than is actually necessary to remove the yolk and dirt is used, and the temperature of the liquor should also be as low as is consistent with the results desired. A potash soap for scouring fine wools should be neutral, and from 3 to 5 pounds should be used to each 100 gallons of water. Ammonia may be added to the liquor in small quantities, or part of the soap may be substituted with ammonia. The water used for the scouring should be soft, as hard water is detrimental, as will be explained later.

For coarse wool, the scouring bath should be made up with from 15 to 20 pounds of sodium carbonate to 100 gallons of water; and for medium grades, soap and carbonate of soda in combination may be used to advantage. Some scourers test the scouring liquor for strength by means of the hydrometer, using a carbonate-of-soda liquor of from 1° to 2° Twaddle, depending on the class of the wool to be treated.

26. Preparation of Scouring Liquor.—The scouring liquor may be prepared by first dissolving the detergent to be used in a pail of boiling water, which is constantly stirred. This makes a stock solution and is added to the heated water (100° to 120° F.) in the washer until an emulsion is formed of the right strength, that is soft and smooth to the fingers when dipped into it and rubbed together. A sample of wool may now be washed, by hand, in the liquor and the liquor squeezed out; if it springs with elasticity on being released and has parted with its grease and dirt, though its natural feeling has not been injured, the liquor is in good condition for scouring.

27. Strength of Liquor.—In scouring wool, the fineness and strength of the fiber should always govern the strength of the liquor used, not the amount of dirt and yolk in the wool, since the finer wools are often the heavier yolked and the fiber would be injured by a severe scouring agent.

In America, the suint is not removed from the wool by steeping before scouring, as in Continental Europe; thus the carbonate of potash that it contains will aid in the scouring of the wool and a smaller amount of scouring material will be necessary.

28. Temperature of Liquor.—In regard to the proper temperature of the scouring liquor, it may be said that a temperature that the hand can just comfortably bear is sufficient, from 100° to 120° F. being the heat generally allowed. The temperature should never be more than 120°, as under the most favorable conditions the natural qualities of the wool are liable to suffer, the luster especially being liable to be diminished. However, many scourers if working on very dirty clothing wools use a temperature as high as 130°, this being done, however, only because of the difficulty in scouring such stock clean. For scouring alpaca and mohair, the heat should be considerably less and should never be more than 100° F., since the luster of these fibers is of prime importance.

HARD WATER

29. As has been stated, **hard water** is detrimental to wool scouring, this being especially true if soap is used as a scouring agent. The substances that are usually found in hard water are various compounds of lime (calcium), iron, and magnesium, the most common substances being the various lime compounds. If water containing these substances is used for the scouring liquor, the soap is decomposed and the tallow and fat in it unite with the acids contained in the lime, iron, or magnesium compounds, which are also broken up, thus forming a lime soap. The disadvantage of this is that while ordinary soap is soluble and forms an emulsion, the lime soap is insoluble in water and is deposited on the wool in the liquor. This lime soap is a sticky, pasty substance and completely envelops the fiber, being almost impossible to remove; yet if the fiber is not cleansed, subsequent dyeing of the wool is attended with great difficulty and is liable to be uneven. Two kinds of hardness are liable to occur; namely, *temporary* and *permanent*.

30. Temporary Hardness.—Water that contains in solution bicarbonates of lime, iron, or magnesium is said to possess **temporary hardness**, since the water may be softened by simply boiling. The effect of the boiling is to drive off one-half of the carbonic acid, thus changing the soluble bicarbonates to insoluble monocarbonates, which are precipitated, allowing the softened water to be drawn off. This method of softening water, however, is too expensive for commercial purposes, since the softening takes place only gradually, and it is therefore necessary to boil the water for at least one-half hour.

31. Permanent Hardness.—Water that contains in solution chlorides or sulphates of lime, iron, or magnesium is said to be **permanently hard**. Boiling simply concentrates the hardness of permanently hard water.

If the water available for scouring is hard, means should be taken to soften it before using; otherwise, much of the valuable scouring materials will be wasted in neutralizing or softening the water, and even then there is danger of the results being impaired, owing to the insoluble lime soap being deposited on the fiber and not being thoroughly removed. Some mills arrange a system of pipes and tanks to catch, for scouring purposes, the rain water that falls on the roof. Rain water is always soft and an excellent water for this purpose. This method is not reliable, however, as during the dry season the mill is apt to suffer from a lack of water of this kind and other means must be used.

32. Softening Hard Water.—There are several methods of softening hard water and there is apparatus especially designed for this purpose; but for wool scouring the cheapest method is to precipitate the lime or other compounds with caustic soda. From 3 to 5 pounds of powdered caustic soda should be added to each 1,000 gallons of hard water, the amount added depending, of course, on the degree of hardness of the water. This will remove both temporary and permanent hardness and works as well with cold as with warm water. The caustic soda precipitates all the lime magnesium and iron salts as insoluble compounds, leaving the water soft and ready for use in washing wool.

EFFECT OF IMPROPER SCOURING

33. Wool properly scoured should be open and lofty and of a clear color; the luster of the fiber should not be impaired. Wool improperly scoured, with too high temperature, too strong liquor, or a liquor in which free caustic alkali is present, has a *harsh*, rough feeling. The fiber is also rendered stiff and brittle, is apt to be yellow in color, and much of the natural elasticity of the wool is injured. The serrations on the surface of the fiber are also injured and the value of the spinning and felting properties of the wool deteriorated.

FIG. 6

Fig. 6 shows the appearance of two fibers of wool under the microscope; *a* is a fiber carefully scoured at a mild temperature and with a suitable detergent, while *b* is a fiber that has been injured by excessive heat or alkali. The appearance of the serrations on the fiber marked *b* shows why wool improperly scoured feels rough and harsh.

34. Effect of Soda.—It is contended by many persons that the use of soda in any form as a scouring agent will produce the results shown at *b*, Fig. 6, it being claimed that soda destroys the nature of the wool and renders it brashy and brittle. To a certain extent this is true, that is, when either soda soap or carbonate of soda is improperly used. It must be remembered that soda in any form is a much more powerful scouring agent than potash and therefore must be used in correspondingly smaller quantities. Potash being milder in its action and present in the wool itself, may be said to be a natural scouring agent; but on the other hand, many scourers, if working on a medium or coarse grade of wool, use carbonate of soda as a scouring agent, and the results obtained by proper treatment justify its use.

SUMMARY

35. The following rules for wool scouring are a summary of what has been previously stated and should be followed in all cases where the quality of the work is an object.

1. A fundamental rule is to use as weak a scouring liquor and as low a temperature as is possible to thoroughly remove the yolk.

2. Nothing but perfectly neutral soaps should be used for the best results, at any rate when the yolk is easily started from the fiber. A potash soap, free from caustic alkali, is to be preferred. When the wool is very dirty and the grease stiff and hard, a slightly alkaline liquor will cut the grease from the fiber more quickly; but the greatest care should be taken to prevent injury to the surface structure of the fiber.

3. The less the stock is agitated, the better will be the results, provided that the dirt is thoroughly removed. When the cellular structure of the fibers is swelled by the action of the warm scouring liquor, the wool is more liable to become felted than when in a dry state and, especially when worsted stock is being scoured, the greatest care should be taken to avoid felting and matting.

4. As the higher-lustered fibers, such as mohair and alpaca, are even more sensitive to heat and free alkali than wool, the greatest care should be taken in washing all fibers of this description where luster is important, both the temperature and strength of the scouring liquor being reduced with advantageous results.

5. The water for the scouring liquor should be soft and should not contain either organic or inorganic impurities, although the former do not occasion as much trouble as the latter.

THE SCOURING PROCESS

36. Introductory.—The old method of scouring wool, which was accomplished by means of kettles or tanks in which the wool was worked in the scouring liquor and rinse boxes in which the stock was rinsed, has given way to scouring by means of scouring, or washing, machines. The method of immersing the wool in solutions of lant, while it gave excellent results owing to the mild action of the lant, was apt to roll and mat the stock by the excessive poling to which it was subjected during the process.

The old process of wool scouring is frequently used today in small concerns, with the exception that potash and soda soaps or carbonate of soda have entirely replaced lant as scouring agents. The stock to be scoured is thrown into tanks that contain the scouring liquor, and worked with poles for 15 or 20 minutes in order to remove thoroughly the yolk and dirt from the wool, which is then forked out and allowed to drain on wooden racks and is afterwards rinsed with pure water in another tank. The great disadvantage of this method is that, in the poling and forking, the stock becomes more or less rolled and felted, causing the fibers to be broken when the wool is burr picked and carded, thus reducing its value proportionately. Modern scouring machines have been constructed, therefore, with a regard to keeping the stock in an open and lofty condition as well as cleansing it of its yolk, or natural grease, and are so arranged as to agitate the wool as little as possible consistently with removing the impurities; and since this is the case the stock should come from the washer open and lofty, free from grease and dirt, and having a bright, natural color with the luster but little impaired.

The essential parts of a scouring machine are a long bowl, or tank, which contains the liquor; a mechanism for propelling the stock through the bowl; at one end a feed-apron, and at the other a pair of heavy squeeze rolls equipped with weights for the purpose of squeezing the liquor from the stock and returning it to the bowl. The machines should be so constructed that two or more may be coupled together, making a combination of two, three, or four bowls as is desired.

THE RAKE WOOL WASHER

37. A type of washing machine that was formerly used to a great extent is the **rake machine,** which consists of a long bowl *a*, Fig. 7, with the usual feed-apron and squeeze rolls, the stock being propelled through the liquor in the bowl by means of **stirring,** or **stirrer, forks,** or **rakes,** marked *b*, which are actuated by cranks *c*. In Fig. 7, will be noticed the method of operating the rakes by means of the cranks driven by bevel gears from a central shaft *d*.

The wool on entering the bowl that contains the scouring liquor is immersed by the **duckers,** or extra tines, *e* attached to the first rake and then passed along through the scouring liquor by the rakes. A carrier *f* then takes the stock from the liquor and passes it between a pair of heavy press rolls, which remove the excess of liquor from the saturated stock. There is a tendency in this machine to string the stock in long ropes, owing to the action of the forks, which move in the arc of a circle. Many of these washers are in use today, but they are being supplanted by improved machines.

THE PARALLEL RAKE MACHINE

38. Construction.—This machine may be said to be the best type of wool washer in use at the present day and is largely employed in the scouring plants of American

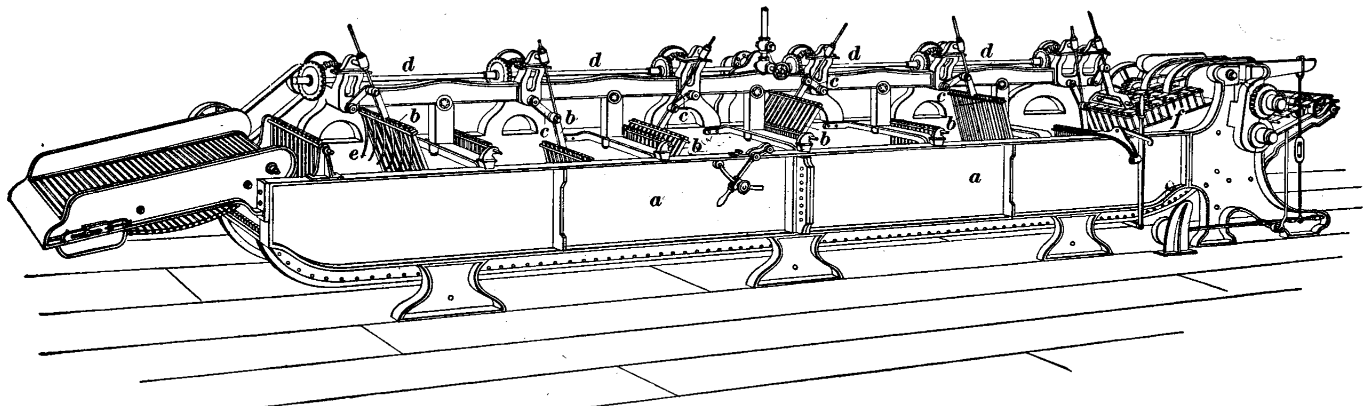

Fig. 7

mills. The main features of this washer are shown in Fig. 8; it will be seen that it consists primarily of a long iron bowl, which is built in different lengths and widths according to the capacity of the machine. The bowl is usually made 16, 21, 27, or 32 feet in length, the sides being made in sections so that any desired length may be obtained. (Fig. 8 illustrates one of the shorter machines.) The width of the bowl varies from 24 to 48 inches.

The bowl is furnished with a suitable exhaust pipe, through which the liquor can be flushed when too dirty for further use, and is made water-tight so as to retain the scouring liquor. Water is supplied by means of suitable pipes, and the bottom of the bowl is fitted with removable perforated brass or copper plates, which allow the sediment

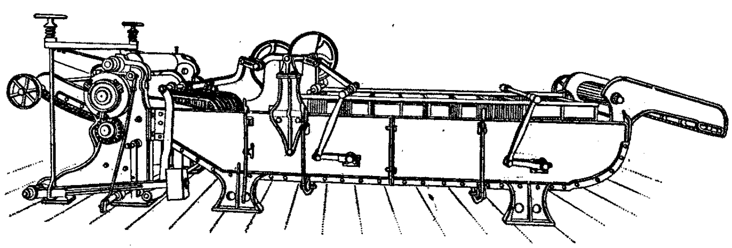

FIG. 8

of the scouring liquor to be deposited underneath them so as to keep the wool from coming in contact with the dirt removed by the scouring. The bowl also has valve and pipe connections for supplying steam to the liquor in order to heat it to the right temperature, and should be filled with liquor to within about 3 inches of the top. In order to save time in replenishing the bowls, a good arrangement is to have a hot-water tank heated by steam from which hot water can be run into each bowl.

39. Rakes.—The most important feature of this machine, and the one that led to its supplanting the old-fashioned rake machine, is the motion of the rakes, which will be explained with reference to Fig. 9, which shows a larger machine of the same type as Fig. 8. At one end of the bowl is a feed-apron, or lattice, *a* of the usual construction, on which the

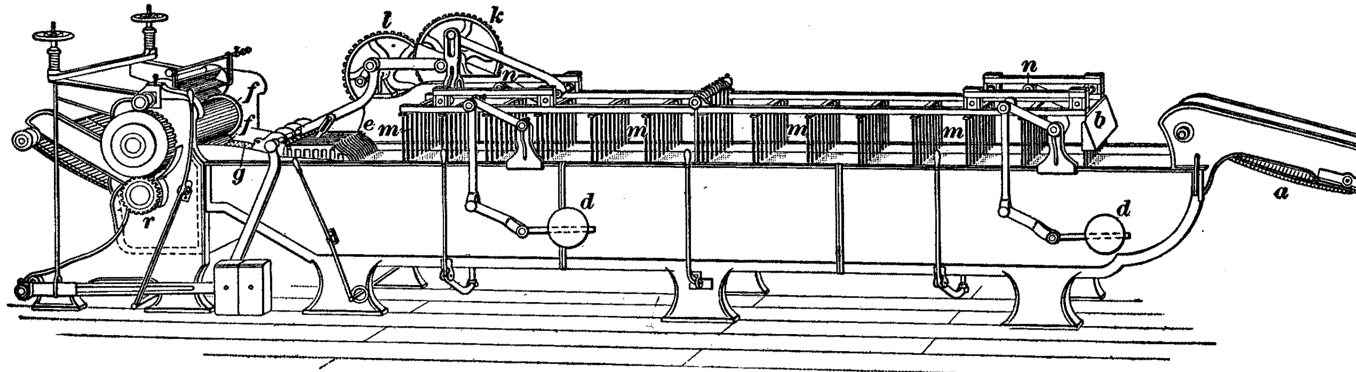

FIG. 9

stock to be fed to the washer is evenly spread. The rakes *m* that propel the stock through the liquor are constructed of brass or forged-iron tines, and are fastened to a frame so that they all move in unison. The weight of the rakes is balanced by means of the weights *d*, which relieve the strain on the working parts of the machine when imparting motion to the rakes.

The motion of the rakes is derived from the main shaft of the washer, which is not shown in Fig. 9, being on the opposite side of the machine. This shaft should run about 56 revolutions per minute, and carries a gear of 18 teeth, which meshes with the gear *k*, shown in Fig. 9, having 144 teeth. This gear actuates the rakes by means of a crank through suitable levers, which are so arranged as to result in a rectangular motion, the whole rake frame when actuated by the crank and levers sliding forwards on small rolls placed at *n*. The forward motion of the rakes is generally arranged so as to be about 14 inches.

The rakes drop into the liquor perpendicularly, and when the points of the rake tines are close to the perforated false bottom of the bowl they move forwards in a straight line, carrying the stock with them. When the end of the motion is reached, the rakes are withdrawn from the liquor in a vertical direction and travel back to their first position with the tines clear of the liquor. By this motion, the wool is carried forwards in practically a continuous film with no danger of stringing or felting. Attached to the end of the rake frame at *b* is a **ducker**, or **immerser**, which plunges the wool under the surface of the liquor as it enters the bowl, thus remedying the fault of the stock's floating on the surface of the liquor for some distance.

40. Carrier.—There is a **carrier** at the end of the bowl for the purpose of taking the stock from the liquor and delivering it to the heavy squeeze rolls; this is shown at *e* and consists of an arrangement of brass fingers, or tines. In its forward motion, it carries the stock over a perforated brass table *g*; in its backward motion it is lifted over the wool and returns to its former position, moving forwards again with a fresh supply of stock. The carrier is operated by means of a crank connected with a gear *l* of 118 teeth, which is driven by a gear of 60 teeth on the main shaft of the machine, on which there are also tight and loose pulleys, 24 inches in diameter, for driving. The speed of the carrier is much faster than that of the rakes, as will be understood by the gearing, the carrier making nearly four motions to one of the rakes; thus there is no chance for the stock to accumulate and roll at the delivery end of the bowl, and the feed to the squeeze rolls is rendered more even.

41. Squeeze Rolls.—The carrier takes the wool to a pair of heavy squeeze rolls *f* that remove the excess of liquor and pass the stock forwards to a traveling apron that drops it on the floor or into a truck. The bottom squeeze roll is sometimes made of brass, but generally a steel roll is used. The great objection to brass for squeeze rolls is that it wears unevenly when in actual operation, and unevenness in squeeze rolls is to be avoided. The top squeeze roll is able to make a slight vertical movement and may be covered with rubber, waste, or cloth, a good rubber-covered roll being preferred, although its expense does not always warrant its adoption. If the top roll is wound with waste, care should be taken to use only pure woolen or worsted waste, because if cotton is used, and the covering wears, the cotton will become mixed with the wool that is being washed, causing specks in the cloth when dyed. Waste- and cloth-covered rolls give excellent service and are inexpensive.

The roll should be springy in order to pass the stock forwards without injury, which is liable to occur owing to the great pressure that is obtained by means of a combination of levers and weights. The weight of the squeeze rolls varies from 1,000 to 1,200 pounds each, and the amount of pressure applied varies from 6 to 8 tons, depending on the amount of stock that is being passed through the washer; the more stock going through the rolls, the greater should be the pressure in order to remove the scouring liquor.

The bite of the rolls is a little above the level of the scouring liquor, which is retained by means of a water-tight partition. The wool in passing to the squeeze rolls does not emerge from the liquor but passes along, actuated by the carrier, in an even sheet. In some machines the bite of the squeeze rolls is at least 6 inches above the level of the liquor in the bowl instead of nearly level as it should be. The consequence is that the carrier pushes the stock up the inclined perforated plate until a considerable quantity accumulates, when it is caught by the rolls and passes through in a bunch, being imperfectly squeezed and often breaking the gear on the end of the squeeze-roll shaft. A receptacle is shown, by dotted lines, at *r* into which the liquor squeezed from the stock by the squeeze rolls falls, and from which it is removed by a small pump on the floor, which discharges through suitable pipes into the bowl near the feed-end of the machine. In operation, the stock is fed to the machine on the feed-apron by hand, or by a self-feed, in which case the apron is dispensed with, the feed dropping the stock directly into the scouring liquor. Occasionally, the wool is discharged from the duster directly into the washer.

42. The wool, being open and lofty, has a tendency to float on the surface of the liquor but is immediately immersed by the copper ducker *b*. The rakes, descending perpendicularly into the stock and then moving forwards in a direction parallel to the bottom of the bowl, convey it without any unnecessary agitation toward the delivery end of the machine, where it is acted on by the carrier *e*. In its passage through the bowl, the impurities are removed by the action of the liquor, and the particles of sand and dirt are loosened from the grease that previously held them to the fiber and drop through the perforated false bottom of the bowl. The carrier then takes the stock from the bowl in an even web and carries it over the perforated table to the squeeze rolls *f*, where the liquor is extracted and the wool passed to the delivery apron, from which it falls either to the floor or into a truck. The wool is now taken to a rinsing tank, through which there is a strong current of water passing. The water used for rinsing should be soft and free from alkali; otherwise, an insoluble lime compound will be formed with any soap that remains on the fiber; and this being a pasty, sticky substance removed only with difficulty, the subsequent dyeing of the stock will be uneven.

HYDRAULIC WASHER

43. A type of scouring machine known as the **hydraulic washer** is sometimes, although not frequently, met with in American mills. This machine, as its name indicates, carries the wool through the bowl by means of a current of liquor without the use of rakes. The liquor pours from a long inlet extending across the machine at the feed-end, and is supplied by a pump that takes it from a compartment under an inclined carrier table at the delivery end. The wool, as it enters the bowl, is submerged by a revolving drum, and is then carried along by the current of warm liquor to the inclined table and carrier and is delivered in an unbroken web, or film, to the squeeze rolls. As the web passes through the machine in the liquor, it is operated on by duckers that tilt without breaking or otherwise disturbing it. This aids the scouring liquor to remove the larger particles of dirt, which fall through a perforated false bottom.

44. Combinations of Washers.—The description so far given has dealt with a single-bowl machine, but it should be remembered that these washers are built so that they may be arranged in combinations of two or more bowls. In the case of the two-bowl combination, the first bowl contains the scouring liquor, while the second bowl may contain a weaker scouring liquor or be used as a rinsing bowl, thus doing away with the rinse box and consequent handling of the stock.

Scouring machines are coupled together in this manner in combinations up to four bowls for special stock, such as some kinds of carpet wools. The three-bowl combination is used in many mills for fine stock, especially for combing wools. The first bowl contains a strong scouring liquor;

the stock passes through a pair of squeeze rolls into the second bowl, which contains a weak liquor; and then to the last bowl, which is used as a rinser when scouring stock for woolen yarn, but when scouring combing wools is filled with a weak scouring liquor. Combing wools for worsted yarn are never rinsed. It may be said that the best results are obtained by the use of four bowls in the case of dirty clothing wools, the first three containing scouring materials and the fourth tepid water only. This combination will give better results than the three-bowl combination so often used. When the liquor in the first bowl becomes too dirty to use, it is flushed out and the liquor in the second bowl is then run into the first and raised to the required strength, while fresh liquor is made for the second. The production of such a combination is from 8,000 to 12,000 pounds per day, according to the condition of the stock.

In combinations like those described, an extra function is performed by the squeeze rolls. The wool very often contains hard lumps of manure, dirt, and solidified grease, which cling to the fibers with more or less tenacity, but as they pass through the squeeze rolls from one bowl to the next they are broken up and easily removed by the second immersion. The squeeze rolls between the bowls also prevent the dirty liquor of the first bowl passing into the liquor in the second bowl, etc., thus rendering it dirty more quickly than would otherwise be the case. A single-bowl machine requires about 3 horsepower for driving purposes.

SELF-FEED ATTACHMENTS TO SCOURING MACHINES

45. There are three methods of feeding the stock to wool washers in common practice: (1) Allowing the duster to discharge directly into the bowl of the washer; (2) spreading the stock on a feed-apron, which conveys it to the bowl of the washer and drops it into the scouring liquor; (3) by means of a **self-feed,** of which there are several suitable machines.

The advantages of a self-feed are apparent, one of the greatest being that the machine fed by this means does not require the constant attention of a workman, as all self-feeds are provided with a hopper large enough to hold the stock for 15 or 20 minutes' feeding. In Fig. 10 is shown a self-feed that is built with especial reference to feeding wool

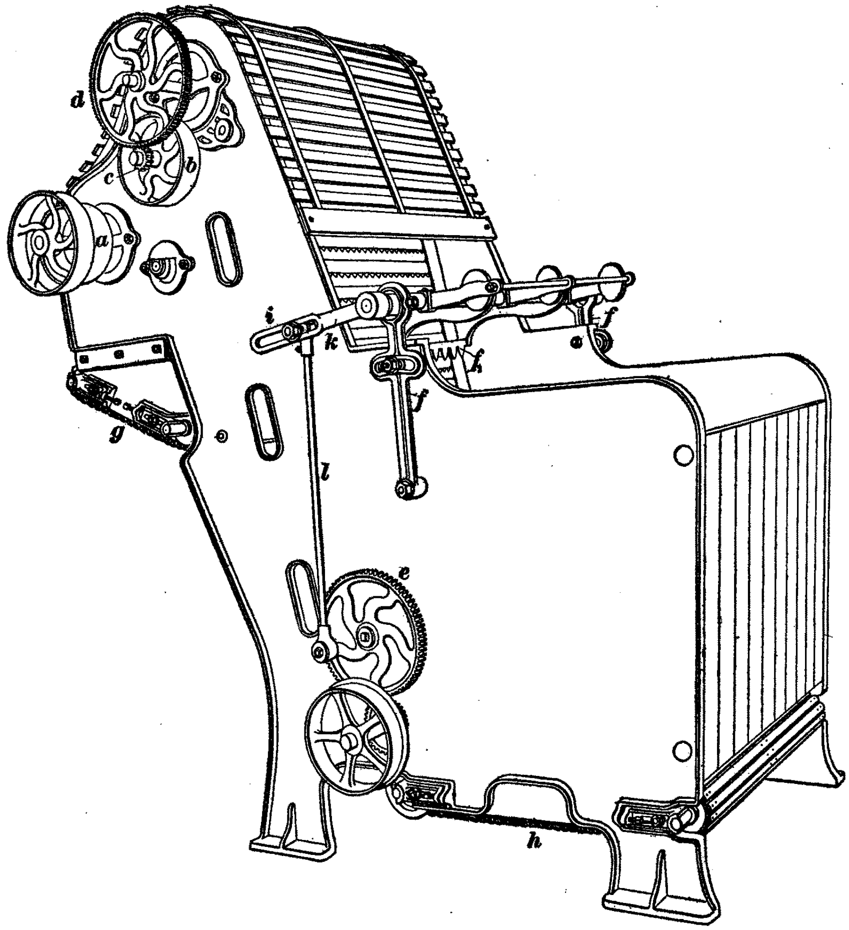

FIG. 10

washers. The main object of this machine is to feed the stock continuously and uniformly to the washer; another object, although a subsidiary one, is that of opening out the stock, rendering it easier for the scouring liquor to penetrate.

46. The principle of the feed is that of a spiked lifting, or elevating, apron, which extracts an amount of stock from the mass in the feed-box, or hopper, in excess of what is needed, the excess being removed by means of an oscillating comb. A stripping, or doffer, beater is so arranged in connection with this apron that the wool which it conveys may be removed from the apron and passed to the machine to be fed. The framework of the feed is of iron, with the exception of the rear of the hopper, which is enclosed with boards. The top of the machine is enclosed with a flexible covering composed of wooden strips, or slats. The elevating apron is made of half-round slats, generally maple, securely riveted to four belts, and is filled with sharp spikes about $1\frac{1}{4}$ inches apart. The apron is driven by means of a pulley *a* on the beater shaft, which drives a pulley *b* on a stud. Attached to this pulley is a gear *c* that drives a gear *d* on the shaft of the top roll of the lifting apron. The gear *c* is the change gear for altering the speed of the apron; an increase in its size drives the elevating apron faster and gives a heavier feed to the washing machine. In the bottom of the hopper is a traveling apron *h* for the purpose of keeping the stock constantly pressed against the elevating apron, thus insuring a constant supply of wool for the lifting apron as long as there is any left in the hopper.

The oscillating comb f_1 is driven by a crank from a gear *e* on the side of the machine. There is a slot *i* in the lever *k* attached to the comb shaft, which allows a change in the position of the connecting-rod *l*, thus increasing or decreasing the throw of the comb. Provision is also made for moving the comb closer to, or farther from, the lifting apron by means of slots in the stands *f* that carry the comb shaft. This allows an alteration in the feed of the machine at this point, as the nearer the comb is placed to the apron, the more stock will be knocked back into the hopper and the lighter will be the feed. The spiked apron on the rear side passes over a binder roll, making an angle with its front side. The doffer beater that strips the stock from the apron is placed at the vertex of this angle, thus helping to prevent the beater from winding with stock. The beater is usually constructed with four blades attached to spiders on the beater shaft. The beater shaft carries the main driving pulley of the machine and should make about 150 revolutions per minute.

Beneath the doffer beater is a doffer apron *g* on which the stock drops and is carried to its edge, from which it drops into the scouring liquor in the washing machine. This apron is not absolutely necessary, as the beater will allow the stock to drop in practically the same manner; the machine is therefore built either with or without the apron, as desired.

47. In operation, the stock, which has been dusted to remove as much of the loose dirt as possible, is placed in the hopper of the feed, the traveling apron at the bottom keeping it pressed against the lifting apron, the spikes of which are inclined upwards and catch the fibers and locks of wool. The stock is thus lifted to the oscillating comb, which is balanced so as to run smoothly and which knocks off large bunches of wool clinging to the apron. This process makes the feed more uniform and the apron is more evenly loaded. After passing the comb, the stock is carried over the top of the elevating apron to the beater, which takes it from the apron and either throws it directly into the scouring liquor or on the traveling apron, which drops it into the washer. When connected to a scouring machine, this feed occupies a space 6 feet 8 inches in length and is adapted to all kinds of grease wools, including long and coarse carpet wools.

SOLVENT PROCESS

48. Mention has been made that certain volatile liquids, as for instance, *naphtha*, *benzine*, and *carbon bisulphide*, will entirely dissolve the yolk of wool. On this fact there is based a new method of scouring wool known as as the **solvent process.** This method of cleansing wool of its natural grease, while not adopted to a universal extent on account of the expense of proper apparatus for treating the wool, has been introduced in a few of the largest mills in the country; and it is claimed that the results fully warrant the expense of the equipment, especially where large amounts of combing wool are to be cleansed. By this process, the stock to be scoured, or rather degreased, instead of being immersed in a soap or carbonate scouring liquor, is treated with naphtha in large tanks, or *keirs*.

49. The wool is stripped of its grease by the naphtha and emerges from the closed compartments without the slightest odor, as the liquid is volatile and does not remain in contact with the fiber. The whole process is carried on in the presence of some inert gas that will not form explosive combinations with naphtha nor with air, carbon dioxide being generally used for this purpose; this gas also acts as an extinguisher of fire. The object of this is to guard against the danger of explosions and fires, which are a constant menace where large quantities of explosive liquids, like naphtha, are used. Not only is the degreasing accomplished in the presence of this gas, but the gas is compressed and serves as a motive power for conveying the naphtha through the various *digesters*, etc., that are necessary in an equipment for scouring by this process.

The plant of one large mill that has introduced this method of scouring is so perfect that, although thousands of gallons of naphtha are in motion, there is not the slightest odor to indicate its presence about the works. After being treated with the naphtha, the stock is carried at once to ordinary washing machines, in which it is passed through tepid water only (sometimes, however, a little soap is used); from these it issues absolutely clean and sweet, brilliantly white, and in a perfect workable condition. The previous treatment requires the minimum mechanical action on the fiber in the washing machines, and no highly heated water nor unnatural soaps and alkalies come in contact with the fiber, the potash that occurs naturally in the wool being of sufficient quantity to remove the dirt completely when the wool is treated with warm water in the washing machine.

None of the staple or fiber is broken by this process; neither is the wool tangled nor matted, as is likely to occur in the ordinary method of washing; and the amount of waste in the succeeding processes is greatly reduced. The wool grease, which is known under the French term of **degras**, is retained by this process and forms a marketable by-product largely used in the manufacture of leather and also in the preparation of oils for use in the manufacture of woolen and worsted yarns.

THERMOMETERS

50. A **thermometer** is an instrument for measuring (in degrees) the temperature, i. e., the amount of heat present either in the air or in any other body. The most common form consists of a glass tube sealed air-tight and containing a small amount of mercury, or, as it is commonly known, *quicksilver*. For its effectiveness, the instrument is dependent on the expansion and contraction of mercury under different conditions of heat and cold, thus causing the column of mercury to rise or fall in the glass tube as the case may be, the reading being obtained by means of a graduated scale that registers the height of the mercury column, in degrees.

51. There are three standard thermometers in use; namely, the *Fahrenheit*, *centigrade*, and *Réaumur*. The **Fahrenheit thermometer** is the one most generally used in America for ordinary purposes. The **centigrade thermometer** is sometimes known as the **metric thermometer** and is generally used for scientific and experimental work. This thermometer is the simplest and will no doubt, in time, come into general use. The **Réaumur thermometer** is of very little importance in America, although it finds a limited use on the continent of Europe.

There are two constant, or standard, temperatures on a thermometer, the freezing and boiling points of water, and the different thermometers vary only in the methods of graduating the degrees of heat or cold. The boiling point of water is indicated on the Fahrenheit thermometer by

212°, on the centigrade by 100°, and on the Réaumur by 80°. The freezing point of water is indicated on the Fahrenheit system by 32°, and on the others by zero. In other words, zero Fahrenheit indicates a lower temperature than zero centigrade, while 100° centigrade indicates a higher temperature than 100° Fahrenheit, etc. Fahrenheit readings are indicated by the letter F. following the indicated number of degrees, centigrade by C., and Réaumur by R.

52. Interchanging Thermometer Readings.—The following rules will enable the student to transpose Fahrenheit and centigrade readings from one system to the other.

Rule I.—*To change Fahrenheit readings to centigrade, subtract 32° from the Fahrenheit reading and multiply the remainder by* $\frac{5}{9}$.

EXAMPLE 1.—Change 140° F. to centigrade.

SOLUTION.— $C. = \frac{5}{9}(140° - 32°) = \frac{5}{9} \times 108° = 60°$. Ans.

Rule II.—*To change centigrade readings to Fahrenheit, multiply the number of centigrade degrees by* $\frac{9}{5}$ *and add 32°.*

EXAMPLE 2.—Change 40° C. to Fahrenheit.

SOLUTION.— $F. = (\frac{9}{5} \times 40°) + 32° = 104°$. Ans.

SPECIFIC GRAVITY

53. Definition.—The **specific gravity** of a body is the ratio between its weight and the weight of a like volume of some other substance taken as a standard, which must be invariable. For solids and liquids the standard adopted is pure, or distilled, water at a temperature of 4° C., or 39.2° F.

Rule.—*The specific gravity of a solid or liquid is equal to its weight divided by the weight of an equal volume of pure water at 4° C.*

EXAMPLE.—If a given volume of olive oil weighs 115 grains and a like volume of water at 4° C. weighs 125 grains, what is the specific gravity of the oil?

SOLUTION.— $115 \div 125 = .92$. Ans.

It will be noticed that in this case the specific gravity of the oil is a fraction; this indicates that the oil is lighter than water for equal volumes.

HYDROMETERS

54. For the more convenient determination of the density of liquids, instruments called **hydrometers** are used. The form of hydrometer generally used in mill work is the constant-weight hydrometer, shown in Fig. 11, which consists of a glass tube near the bottom of which are two bulbs. The lower, or bottom, bulb is loaded with shot or mercury in order to make the instrument float upright, while the upper bulb contains enclosed air, which makes it lighter than water. The point to which the hydrometer sinks when placed in pure water is marked zero and the tube is graduated above and below zero, the graduation being sometimes on a piece of paper placed within the tube. As a long tube would be inconvenient, it is customary to have two instruments, one having the zero near the top for liquids heavier than water (the hydrometer rising according to the density of the liquid) and another having zero near the bottom for liquids lighter than water.

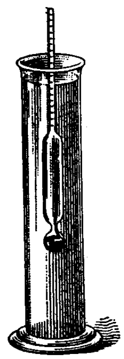

FIG. 11

If any substance is dissolved in water, the liquid becomes heavier and more dense. This density is registered in degrees on the hydrometer. For liquids lighter than water the specific-gravity value is commonly used. Two hydrometers are commonly used as standards; namely, *Baumé's* and *Twaddle's*.

Twaddle's hydrometer is almost exclusively used in England, while in the United States and on the continent of Europe the Baumé hydrometer is more generally in use. Twaddle's hydrometer bears a direct relation to the specific gravity of a body, while the Baumé hydrometer with zero in pure water as a starting point, assumes a density according to the percentage of saturation of pure water with common salt.

The table on the opposite page gives a comparison of Baumé and Twaddle hydrometer degrees.

COMPARISON OF BAUMÉ AND TWADDLE HYDROMETERS

Baumé Degrees	Twaddle Degrees	Baumé Degrees	Twaddle Degrees
1	1.4	18	28.4
2	2.8	19	30.4
3	4.4	20	32.4
4	5.8	21	34.2
5	7.4	22	36.0
6	9.0	23	38.0
7	10.2	24	40.0
8	12.0	25	42.0
9	13.4	26	44.0
10	15.0	27	46.2
11	16.6	28	48.2
12	18.2	29	50.4
13	20.0	30	52.6
14	21.6	31	54.8
15	23.2	32	57.0
16	25.0	33	59.4
17	26.8	34	61.6