2. Wool Scouring Principles and Methods

Errol Wood

Learning objectives

On completion of this topic you should be able to:

- Describe the nature of the main contaminants of raw wool
- List the objectives of wool scouring
- Describe sequence of operations in a scouring plant
- Explain how a detergent removes grease from wool fibres
- List the factors that affect the quality of scouring
- Explain the following:
  - Preparations of wool for scouring (ie, opening, blending, and cleaning operations)
  - The parts of a minibowl and their role
  - How the various contaminants are removed in aqueous scouring
  - Post-scouring operations (drying, cleaning, packaging)
  - How scouring effluent is treated to minimise waste and extract wool grease
- Explain the different requirements in the scouring of fine and coarse wools, and the scouring lines used for each type.

Key terms and concepts

Wool contamination, entanglement, washing, scouring, cleaning, bowls, squeeze rollers, harrows, blending, detergent, chemical treatments, drying, automation, effluent, packaging, sampling

Introduction to the topic

This topic covers the wool scouring process, presenting the principal objectives and functions of the modern industry. Wool scouring is the only operation, other than carbonising, which is unique to the early stage processing of wool fibre. Synthetic fibres are not contaminated to any significant extent, and therefore are not scoured.

The term ‘scouring’ is generally used to describe a process that removes contaminants from raw wool, and includes all steps associated with the process – blending, opening, washing, drying, packaging – and the steps involved in ‘cleaning up’ the effluent produced. Scouring is a critically important step in wool processing. It must be carried out using technology that enables the wool to attain its optimum performance in subsequent processing.

During the growth of the wool fibre it becomes coated with grease (more correctly called wool wax), sweat salts (or suint) and contaminated with dirt, dust, dung and vegetable matter of various kinds. For wool to be a useful textile fibre it is essential that all of these extraneous materials be removed, and wool scouring plays an essential part in this. While wool scouring had very humble origins and was very inefficient and labour intensive up to nearly 50 years ago, today’s industry is technically advanced and makes wide use of sophisticated technologies to minimise costs and achieve the level of quality demanded by the customer. Australia and New Zealand have led the world in innovative scouring developments and the implementation of low cost, efficient scouring of wool.

While wool scouring in simple terms is the washing and drying of wool, in reality there are a considerable number of other operations involved – opening, blending, mechanical cleaning, baling, sampling and testing. On request, various types of chemical treatments may be carried out in conjunction with the scouring process.

Given the importance of wool to the economies of Australia and New Zealand, efficient wool scouring is vital. However, less than 10% of Australian wool is scoured before export while in New Zealand close to 90% of its wool production is exported in scoured form. The principal reason for the difference is that many topmakers around the world (who use mostly Australian fine wool) prefer to control the blending and scouring of their raw material, whereas the majority of woollen carpet yarn spinners (who use a considerable quantity of New Zealand wool) accept fully-specified scoured wool blends which are ready for spinning.

Today's industry is efficient in terms of energy, water and labour resources and is also environmentally responsible. The days are long gone when scour effluent could be discharged into a nearby stream, river or at the sea shore. Modern practices ensure that wool scouring makes minimal impact on the environment.

The book by Stewart (1988) provides the most comprehensive coverage of modern wool scouring practices. Other useful sources of basic information are the book by Teasdale (1995) and the articles by Stewart and Jamieson (1987) and Christoe (1987). The review paper by Wood (1982) outlines the major innovations in wool scouring technologies since the 1950s. Robinson (1991) has authored an IWS Technical Information Letter, *"A Basic Guide to Raw Wool Scouring"*, which is quite informative.

Informative web sites include the major manufacturing of scouring machinery ANDAR (www.andar.co.nz) and AWI (www.wool.com/topmaking_scouring.htm)

Significant developments in scouring technology have been achieved in the past 40 years, especially in Australia and New Zealand. These developments are outlined in the reading *"Innovation in Wool Scouring Technologies"*. Another reading relevant to this topic is *"An Historical Overview of Wool Scouring"*.

2.1 Contaminants of greasy wool

Wool is perceived to be a clean, green, natural fibre. However, raw or 'greasy' wool is contaminated with natural impurities, the type and level depending on the breed of sheep, and the conditions under which the wool is grown. These impurities, which may be up to 40% (or more) by weight, must be washed off before the wool can be used as a textile fibre.

The main contaminants are wool grease, suint and dirt. Wool grease, which is really a wax, is a complex mixture of organic compounds called esters. It is produced by the sebaceous glands in the skin of the sheep and occurs as a stable solid or semi-solid film around the fibre with a melting point around 43°C. While wool grease is insoluble in water, a solution of water and detergent forms an emulsion with wool grease to facilitate its removal from the fibre. Wool grease is soluble in organic solvents such as ethanol and dichloromethane

The amount of wool grease (or wax) present on the wool depends mostly on the sheep breed, with merinos recording the highest amounts. Crossbred wools, which dominate the New Zealand clip, have substantially less wax.

Suint, which is produced by the sudiferous (sweat) glands of the sheep, is dried sweat, consisting mainly potassium salts of organic acids. In wool scouring liquors, at alkaline pH levels, suint has detergent properties. The amount of suint also depends on the breed of sheep, with crossbred wools tending to have higher levels than merino wools.

A third category of contamination acquired by the fleece is termed surface soiling, which includes dirt, dust, faeces and vegetable matter (VM) such as burrs picked up when the sheep is grazing. Traces of dipping compounds (for fly strike or lice) and branding compounds may also be detected.

If the level of VM contamination is high the wool may have to be carbonised to remove it. Certain types of VM are more troublesome than other types and must be removed. A major proportion of the wools requiring carbonising are from Australia and South Africa.

Table 2.1 shows typical contaminant levels in the major Australian and New Zealand sheep breeds.

Table 2.1 Contamination levels in Australian and New Zealand wools.
Source: Hart (1995).

Type of wool	New Zealand Romney			Australian Merino		
	Minimum	Average	Maximum	Minimum	Average	Maximum
Grease (%)	2	6	9	10	15	25
Suint (%)	2	8	12	2	6	12
Dirt (%)	3	8	13	6	20	45

The wide differences in the types and levels of wool contaminants help to explain why different machinery and processes have proved necessary in wool scouring. For example, the large amount of fine dirt on some of the fine wools from Western Australia is very difficult to remove and thus low scouring throughputs are often necessary. On the other hand, high-yielding coarse wool from New Zealand represents the other extreme in being relatively easy to scour with high production rates possible.

While as much contamination as possible is removed as wool grease or sludge, a significant proportion of the contaminants removed from the wool is discharged from the wool scour as an aqueous effluent. The organic effluent load from a typical wool scour is similar to that of the sewerage from a town of 30,000 people.

Due to the nature of the wool fibre and its propensity to felt, wool scourers are faced with a dilemma – they must deliver a product free of scourable contaminants while minimising the level of fibre entanglement. Generally cleanliness and freedom from entanglement are opposing outcomes, (i.e. the cleaner the fibres become the more entangled they are likely to be after scouring). Both characteristics significantly affect the subsequent operations in yarn manufacture.

2.2 The objectives of wool scouring

The principal objectives of wool scouring are to remove all wool contaminants at maximum efficiency, with efficient energy utilisation and with minimum impact on the environment. Quality control objectives for the scoured product are:

- To produce clean wool of consistently good colour, without causing excessive fibre entanglement
- Achieving a specified moisture regain by efficient drying
- Achieving an acceptably low residual grease and dirt content
- To achieve a correct wool pH level (appropriate for subsequent dyeing).

Freedom from entanglement was once considered to be the principal quality objective, assuming that the removal of grease and dirt was satisfactory. Entanglement (or in the extreme case, felting) results in excessive fibre breakage in subsequent yarn-making processes such as carding. Fibre breakage has two undesirable effects:

1. It reduces the mean fibre length in top and yarn, producing products of inferior quality, and
2. The processing yields, as measured by the combing tear in the worsted system, are reduced.

Fibre entanglement is most undesirable in the worsted processing system where it is important to minimise fibre breakage, but is less critical in woollen processing.

More recently, the cleanliness of the scoured product has become more important to the industry, largely influenced by the development of high speed machinery. Another important consideration today is concern for the environment, which has changed the attitude of wool scourers in many countries. This is because the pollution load associated with the conventional aqueous scouring of greasy wool is extremely high. Today, reduction in pollution has become more important to wool scouring than freedom from entanglement; adequate dirt removal and subsequent liquor handling to ensure minimal pollution of the environment are important factors.

The factors that are important in achieving a clean, bright scoured product with a low level of fibre entanglement are:

- Degree of opening given before scouring
- Number of bowls in scouring line
- Detergent and builders used
- Water quality
- Time of immersion in the bowls
- Temperature of scouring bowls
- Amount of mechanical action used
- Efficiency of the squeeze presses.

A number of other key functions are performed in a wool scour:

- Blending auction lots together on instructions from the owner of the wool
- Using mechanical means to remove as much dust and dirt as possible prior to, and after, scouring
- Carrying out optional chemical treatments as requested by the client, eg, peroxide bleaching to improve the wool colour
- Sampling the scoured wool for testing
- Extraction of wool grease from the scour effluent.

Fibre damage in wool scouring

Wool is a relatively weak fibre, compared to other staple fibres. During scouring, wool experiences various adverse conditions which can lead to fibre damage and loss of strength. Three possible sources of fibre damage in wool scouring are mechanical damage, pH and temperature.

Mechanical damage will be fairly minimal since the actions of the moving parts in scouring tend to be relatively gentle. Since wool is a protein fibre, wool suffers a loss of tensile strength when it is wet. The nature of the protein chains in wool mean that the hydrogen bonds are dissociated in aqueous conditions causing strength loss. Disulphide bonds can also be reduced in some conditions, causing a further wet strength loss which is generally reversible.

Wool can also become more susceptible to chemical damage in an aqueous medium since the protein chains can be ionised and are attractive to small, charged molecules such as acids and alkalis. Alkaline conditions are far more damaging to the fibre, and at pH>9.5 will cause yellowing and damage to the fibre.

Thermal degradation of wool will occur with prolonged exposure to even relatively mild conditions, such as those experienced during scouring. This degradation is also manifested as a strength loss and yellowing. The appropriate conditions and controls within in wool scour should ensure that the types of wool damage outlined here are minimised.

2.3 Aqueous scouring using detergents

Detergents are cleansing agents and they contain *surfactants*. The term *surfactant* is the abbreviated form of *surf*ace *act*ive *agent*. A surfactant is a substance that reduces the interfacial tension between water and other liquids. Surfactants are used widely in textile processing in many forms, including wetting agents, emulsifiers, and detergents.

In wool scouring, water alone cannot remove the lubricant and dirt because water molecules cannot penetrate the greasy layer to detach it from the fibre surface. To remove the fibre impurities, such as the film of grease with dirt attached, it is necessary to transfer the greasy film from the fibre into the liquor. To do this, the liquor must first wet the fibres. The presence of a surfactant in a detergent enables water to coat (i.e. wet) a non-wettable (ie, hydrophobic) surface. The wetting reduces the interfacial tension between the grease and the water, so that the grease droplet detaches and floats away from the fibre.

A molecule is the smallest chemical unit of a substance that is capable of a stable, independent existence. It is a group of atoms held together by chemical bonds. Molecules are attracted to one another. For example, each individual molecule of water is attracted to others and they coalesce to form a liquid. However, where the water molecules meet another substance such as grease, a lower attractive force is present between the water and that substance. This lower attraction means that the water molecules pull away from the contact surface of the other substance, and so the water will not penetrate a greasy film.

Removing grease from wool

For effective grease and dirt removal the aim is to spread the water over the complete surface of the fibres, loosen and remove the grease and dirt, and then suspend the molecules of grease and dirt in the liquor so that they can be rinsed away. The detergent, with the required surfactant properties, does this.

While there are various types of detergents (anionic, cationic, non-ionic), in general, a detergent molecule has

a. a hydrophilic ‘head’ (which has an affinity for water and is repelled by oil and grease) and

b. a hydrophobic ‘tail’ (which has an affinity for oil and grease and is repelled by water).

A simplified diagram of an anionic detergent molecule, and the way in which these surround a blob of grease to form a tiny globule called a micelle, is shown in Figure 2.1.

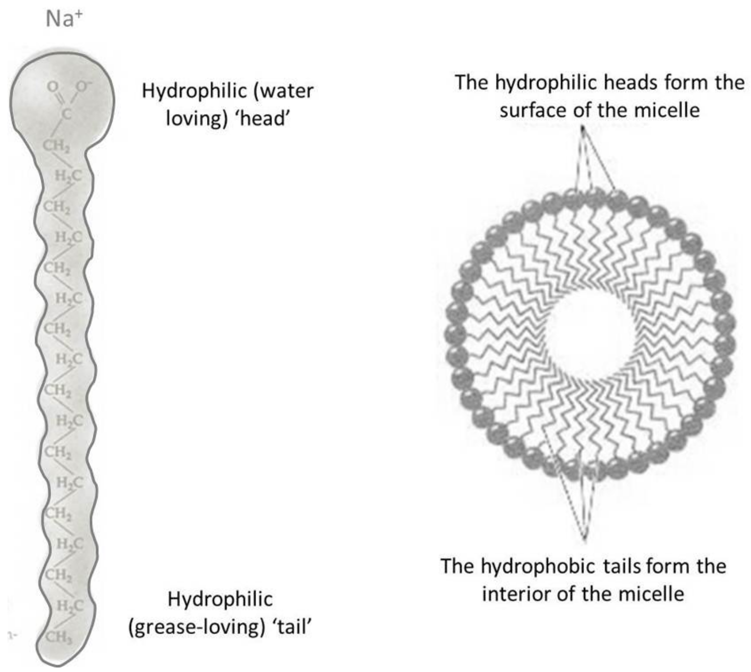

Figure 2.1 Micelle formation by detergent molecules. Source: Wood, 2011.

When the detergent molecules meet the layer of grease on wool fibres, the tails are drawn into the grease but the heads remain immersed in the water. The attractive forces between the head groups and the water are so strong that the grease is lifted away from the surface. The micelle is now completely surrounded by detergent molecules and is washed away by the water. The sequence of grease removal is shown in Figure 2.2.

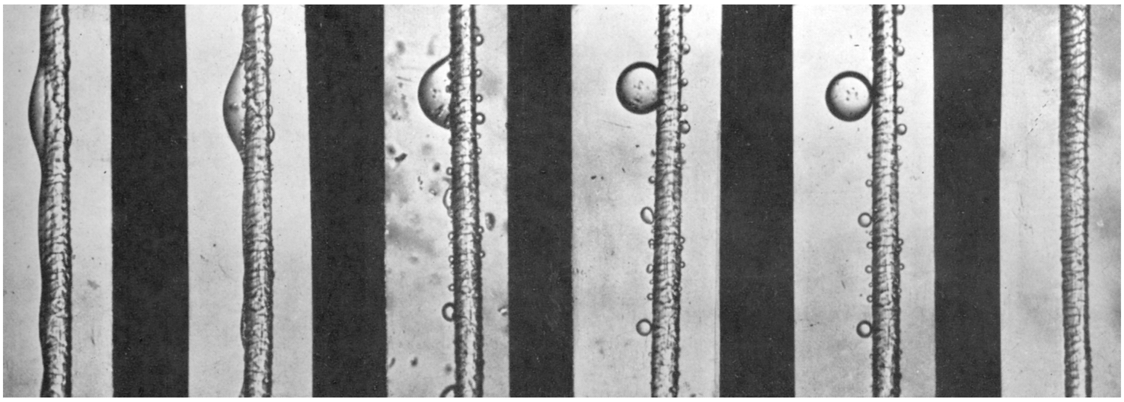

Figure 2.2 Removal of grease coating from a fibre by detergent action, Source: Wood, 2011.

The stages of grease removal in the scouring bowl are:

1. Water is heated to above the melting point of wool grease, which is about 40°C. The heated wool grease forms a stable film over the surface of the fibre. The wool grease is more attracted to the fibre than to itself, and this is why it forms a film over the fibre.
2. The scouring liquor wets the fibre.
3. Surfactant molecules from the detergent cover the film of grease. The grease-seeking tails are attracted to the grease, with the heads in the liquor.
4. Surfactant molecules on the wetted fibre reduce the attraction of the grease to the fibre. The grease rolls up into droplets.
5. The water-seeking heads of the surfactant molecules on the fibre and on the grease droplet attract water to themselves. The water attracted to these molecules pushes between the fibre and the grease droplet. This helps to detach the grease droplet.
6. Agitation by the harrows and the high-speed liquor flow at the squeeze rollers transport the grease droplets away from the fibre.
7. Particles of dirt are removed from the fibre by:

   - agitation of the liquor
   - being washed away with the grease droplets, and
   - mutual repulsion between fibre and dirt.

Emulsion stability is maintained when there is sufficient detergent in the liquor to completely disperse in the water and surround the surfaces of all the fibres and grease droplets.

If the amount of detergent in the liquor falls below the required minimum level:

- There is a quick drop in the amount of wool grease removed from the fibre
- Droplets of emulsified grease may redeposit on the fibre because fewer surfactant molecules surround the droplet
- Droplets of emulsified wool grease may combine to form larger masses. This will, in turn, break down the emulsion and form a layer of grease on the surface of the liquor. Again, the reason is that fewer surfactant molecules surround each droplet of grease.

Removing dirt from wool

Dirt is harder to remove than wool grease and sufficient mechanical action by the harrows is essential for good dirt removal. The squeeze rollers play a key part in dirt removal too. Pressure on the squeeze rollers must be sufficient to ensure that:

- As much dirt and grease as possible is removed from the wool, and
- As little dirty liquor as possible is carried to the next bowl so that less dirt is re-deposited on the wool.

It is important to remove as much dirt as possible during scouring to avoid problems in later processing. For example, dirt in yarn can cause variable light fastness and inferior colours in dyeing. Most dirt and impurities are removed in the first bowl, with the rest being removed in subsequent bowls. After the last (rinse) bowl, almost all impurities have been removed, except for about 0.1 - 0.4% of wool grease (in New Zealand), or 0.3 – 0.8% in Australia.

Research has shown that all the contaminants, not only the grease, can be divided into two fractions – an easy-to-remove fraction and a hard-to-remove fraction (Christoe and Bateup 1987). The former fraction comprises the unoxidised grease, most of the oxidised grease, readily soluble suint and loosely held mineral organic and proteinaceous dirt (i.e. wool fragments). The latter fraction comprises a small fraction of the oxidised grease, slowly-soluble suint, submicron mineral dirt and flakes of proteinaceous contaminants adhering to the fibre surface

The current picture of contaminant removal from raw wool is as follows:

- Penetration of the grease by water and surfactant, followed by rapid swelling of both grease and proteinaceous contaminants (ie, wool fragments);
- Formation of grease globules (unoxidised grease in particular) within the swollen matrix of the contaminants;
- Mechanical action causes most of this matrix to be displaced from the wool into the surrounding liquor;
- The remaining contaminants, which still adhere to the fibre, are removed more slowly to give a clean fibre.

These findings have had important implications in the design of modern scouring lines. The result is that optimal systems for scouring Australian merino wools are quite different to the standard scouring lines designed for handling New Zealand crossbred wools. The major differences in the properties of these wools that are relevant to scouring mean that rather more sophisticated scouring lines are required for the gentler, thorough scouring required for Merino wools (see the comparison of these properties in Table 2.1).

Table 2.1 Properties of New Zealand and Australian wools relevant to scouring performance. Source: Wood, 2006.

Property	New Zealand crossbred wool	Australian merino wool
Fineness	coarse	fine
Staple length	longer	shorter
Fleece density	open	densely packed
Crimp/bulk	low	high
Entangling propensity	lower	higher
Grease content	lower	higher
Proportion of oxidised grease	higher	lower
Dust and dirt content	lower	higher
Suint content	higher	lower

2.4 Steps in the wool scouring process

Figure 2.3 shows the layout of a typical scouring plant for crossbred wools, which generally require more extensive blending machinery.

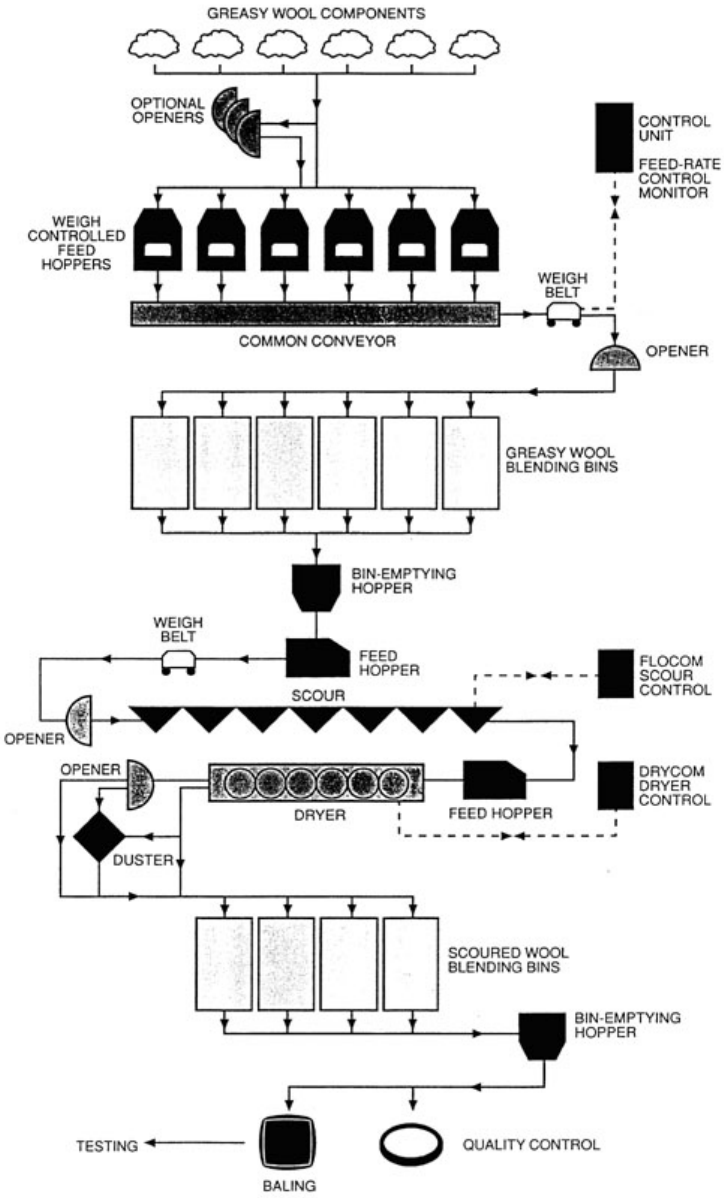

Figure 2.3 Scouring plant layout. Source: Wood, 2006.

Blending, opening and cleaning

A consignment of scoured wool may comprise a large number of farm lots. Furthermore, the components of a scoured wool blend may vary widely in their characteristics, especially for wool destined for the woollen system. Therefore it is important that blending be undertaken to amalgamate the components into a reasonably homogeneous batch, keeping in mind that further blending will occur in the topmaking and spinning plants.

Figure 2.4 shows a blending line in a modern scouring plant. The system is computer controlled, and each component has its own dedicated hopper, feeding to a common conveyor (at right of photo).

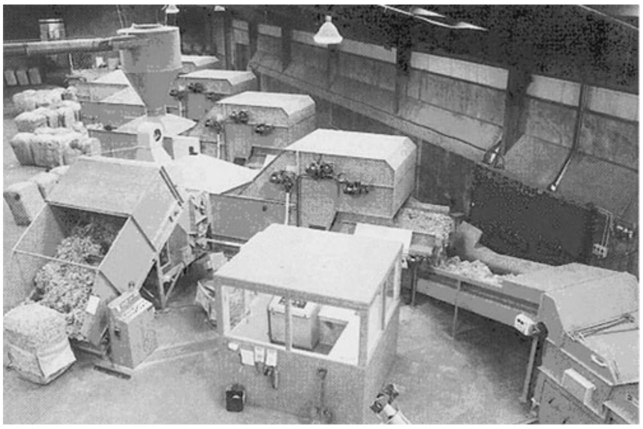

Figure 2.4 Blending system in a wool scour. Source: Andar Holdings Ltd.

Mechanical opening is carried out before scouring to:

1. enable dirt and dust to fall from the fibrous mass, and
2. deliver the wool in a more open form to the scouring bowls so that the liquor can penetrate more effectively.

A range of machines is used for opening and cleaning. The early removal of dust and dirt in a dry form contributes to more efficient and effective scouring. If fleeces are cotted, a decotter may be required to be used as a preparatory opening machine to separate the felted fleeces into smaller clumps.

Because of the relative homogeneity of fine wools entering the worsted processing route, and the huge amount of blending that occurs in this route, these wools require less blending before (and after) scouring than coarser wools that are mostly processed on the woollen processing route.

Scouring

The open, blended wool is scoured in a series of bowls containing hot scouring liquor, followed by cold and hot water rinses. The scouring water is normally around 60-65°C, which is hot enough to melt the wool wax (or grease). Detergent is added to help remove the dirt from the fibres and to emulsify the wax so that it does not re-deposit on the wool.

Figure 2.5 shows the parts of a typical scouring 'mini-bowl', which is the basis of most modern scouring lines.

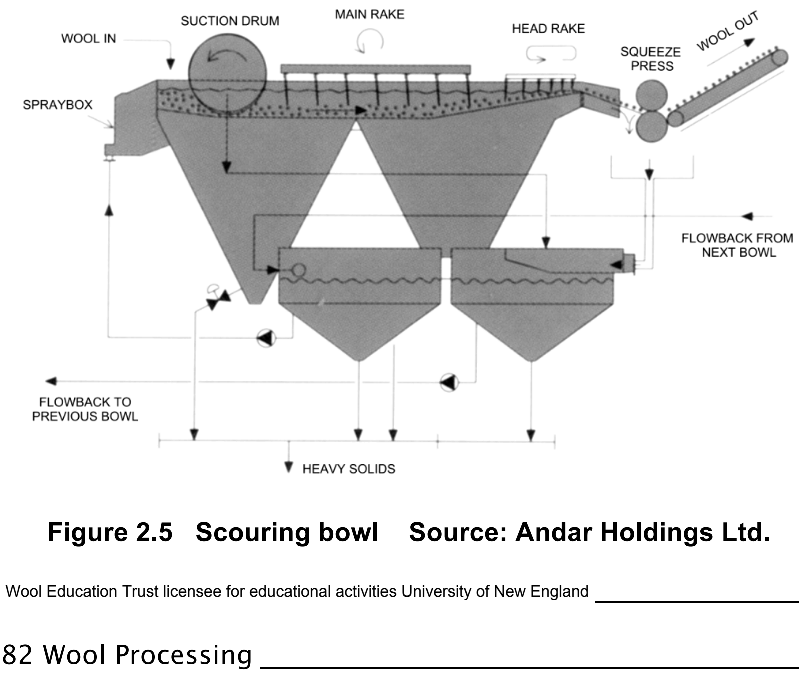

Figure 2.5 Scouring bowl Source: Andar Holdings Ltd.

As the wool enters each bowl, it is pushed under the surface to wet it thoroughly with the liquor in that bowl. A set of metal teeth (rakes or harrows) gently drags the wool through the liquor, as shown in Figure 2.6. When the wool reaches the other end of the bowl it is lifted up into a pair of rollers that squeeze the liquor out of it. The wool is then dropped into the next bowl where the process is repeated.

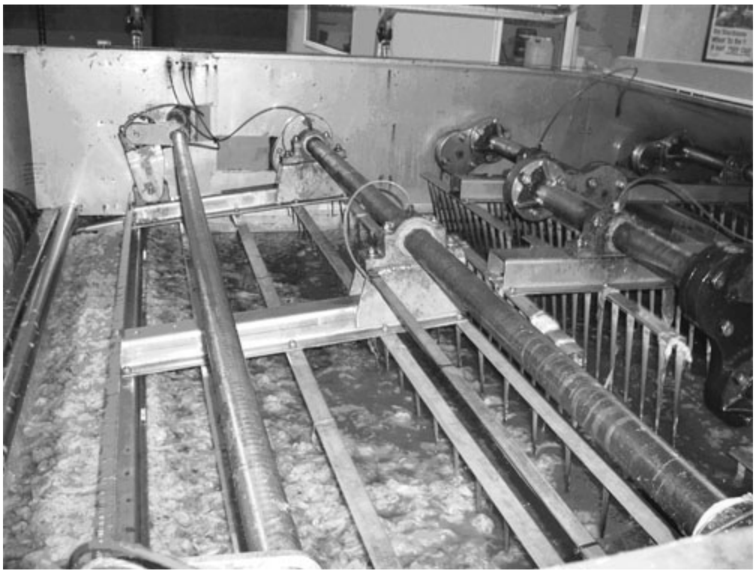

Figure 2.6 Immersed wool being moved by the rakes in a scouring bowl.

(Photo supplied by E J Wood)

The suint dissolves quickly in the first bowl while the wax and dirt particles are steadily removed by a combination of detergent action, mechanical agitation and gravity, and by the pressure applied by the squeeze rollers. As the wool moves through the bowls it becomes cleaner, and moves into cleaner liquor.

The liquor flows in the reverse direction to the wool movement and is discharged from the first bowl for treatment. Wool grease is extracted from this effluent and refined for a variety of uses.

Finally, the wool is rinsed to remove the detergent and to eliminate the remaining solids. The first rinse is normally done with copious quantities of cold water, followed by a final rinse in hot water before drying.

Fine wool scouring systems

The Andar Topmaster range of scouring lines exemplifies the most modern systems available for scouring fine wools (Figure 2.7). The scouring line includes a suint bowl where dirt and suint are removed while protecting the fibres from damage or entanglement. This is achieved by operating the bowl at a temperature lower than the emulsification point of wool grease.

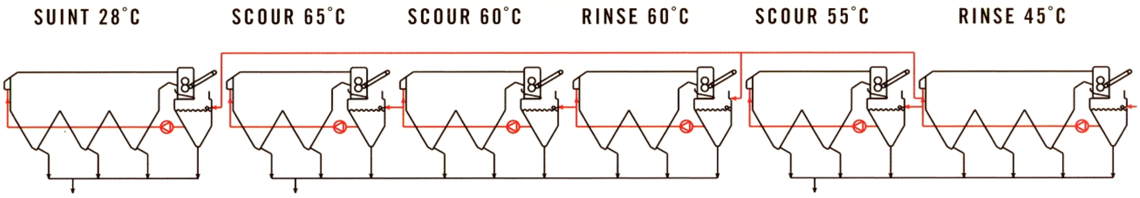

Figure 2.7 A scouring line for combing wools. Source: Andar Holdings Ltd.

Three different bowl configurations are available in the range, as shown in Figure 2.8. These configurations, all based on rake bowls, are designed for high yielding, medium yield and low yield wools. In each case the first bowl can be a suint bowl.

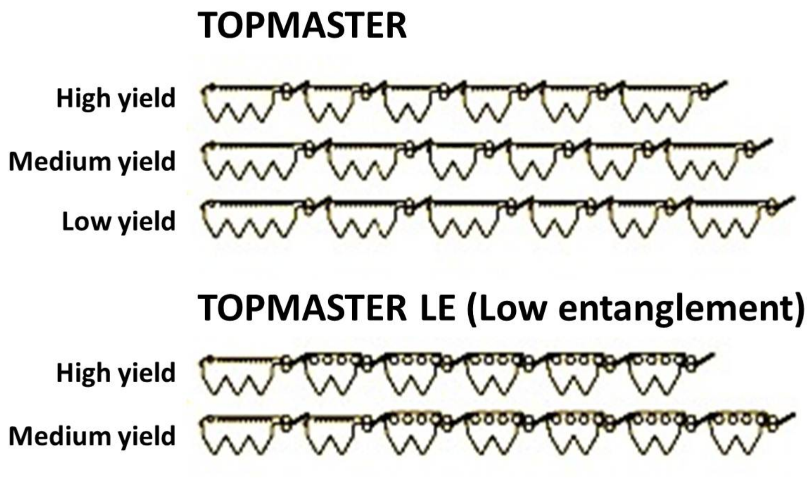

Figure 2.8 Topmaster and Topmaster LE configurations for fine wool scouring. Source: Andar Holdings Ltd. (b).

Also shown in Figure 2.8 are the configurations for the Andar Topmaster LE (Low Entanglement) range of scouring lines. Using the most advanced scouring technologies and processes (incorporating suction bowls in which a set of suction drums gently transport the wool), the fibre entanglement of fine wools (which is of major concern to topmakers) is minimised.

Two versions of Topmaster LE scouring lines are available:

(a) High yield – designed as a specialist system for topmaking, to provide the highest levels of performance for all fine and superfine types. The six bowl line can include one suint bowl if required

(b) Medium yield – this is a seven bowl system, with two rake action bowls to remove most of the heavy contaminants before entering the suction bowls.

The suction bowl design is shown in Figure 2.9.

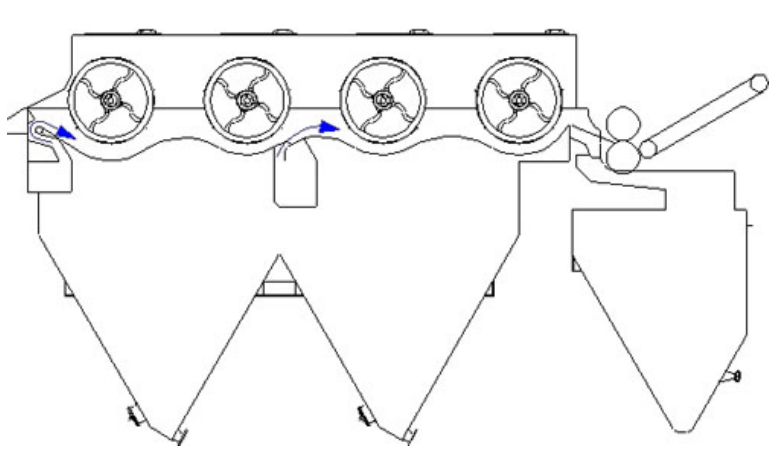

Figure 2.9 Suction bowl. Source: Andar Holdings Ltd. (b).

Accompanying these fine wool scouring lines are sophisticated systems for the removal and treatment of the various components of the effluent – water, woolgrease and heavy solids. These systems are designed to minimise waste and the impact of scouring on the environment.

Coarse wool scouring systems

The WRONZ Comprehensive Scouring System with mini-bowls revolutionised the scouring of coarse wools in the 1960s. Modern scours for carpet wools are based on this system and fine wool scouring systems developed since then have been adaptations of the WRONZ approach. Features of the WRONZ system were:

- small-volume mini-bowls minimise water and energy use,
- The integration of the contaminant removal systems into the operation of the scour so that all heavy effluent (i.e. that originating from the hot scouring bowls rather than from the rinsing bowls) received treatment before discharge. Such treatment included the removal of fibre and heavy solids and the recovery of woolgrease.
- Batchwise operation, where the scour bowls were 'dumped' to drain periodically, was replaced by a fully continuous process.
- Liquor management also became better controlled, with the avoidance of bowl overflows and the use of bowl-to-bowl flowback running in the opposite direction to the wool flow
- The 'flowdown' of heavy liquor to the drain was at a controlled rate that could be set manually or automatically by measuring the clarity of the liquor
- Heat was recovered from the flowdown and used to pre-heat fresh water being fed to the scour.

The entire system is computer-controlled. Figure 2.10 shows the WRONZ Comprehensive System with seven mini-bowls.

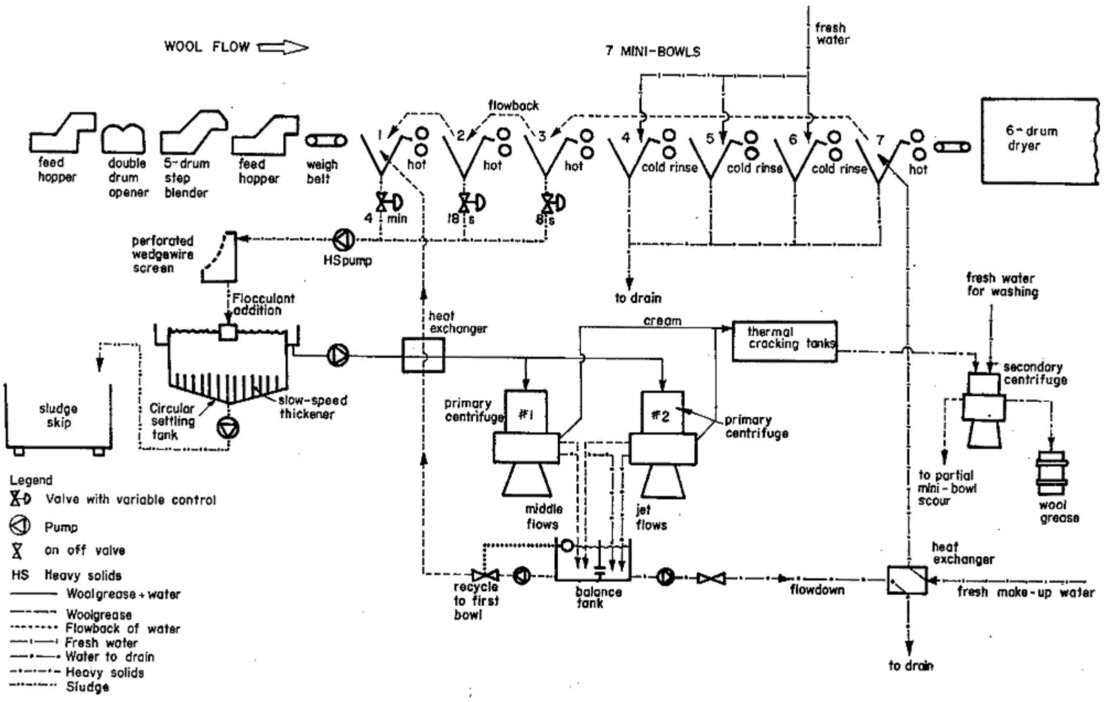

Figure 2.10 WRONZ Comprehensive Scouring System. Source: Wood, 2006.

The WRONZ system with mini-bowls have been found to give the following benefits compared with the traditional coarse wool scouring systems:

1. An increase in wool grease recovery of about 50%
2. Recovery of about 80% heat from the effluent by using heat exchangers
3. Effective effluent treatment before discharge, including:
    (a) maximum removal of heavy solids, fibres, and wool grease, and
    (b) less discharge to about 2 litres/kg of scoured greasy wool
4. Less water used through positive control. A set, regulated amount of:
    (a) fresh water enters the bowls, and

(b) scouring liquor leaves the system

5. Less energy or power is used. With less effluent discharge, less steam is needed to heat the water. Heat recovered from the effluent also saves energy
6. The scouring runs before bowl cleaning are longer. The liquor has a higher detergency with a more effective contaminant removal, and so the bowls need washing out only about once a week. In the old system, the bowls were washed more often
7. Longer runs mean increased production
8. Efficiency is improved and scouring is easier.

The Cardmaster scouring system, manufactured by Andar, is the latest version of the WRONZ Comprehensive Scouring System, with enhancements. This system is designed to handle the rigorous demands and high volume processing associated with coarser carding and carpet wools. This system is capable of processing in excess of 5 tonnes of wool per hour.

Figure 2.11 shows a typical configuration, with the three scouring bowls and three rinsing bowls.

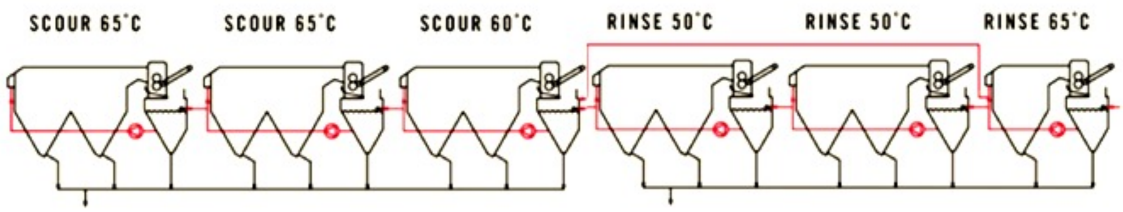

Figure 2.11 Cardmaster scouring line. Source: Andar Holdings Ltd. (b).

Longer bowls are available for scouring low-yielding wools to provide a longer residence time and maximise dirt removal at high throughput rates. Figure 2.12 shows a 'quad' bowl with four hoppers, supplied by Andar.

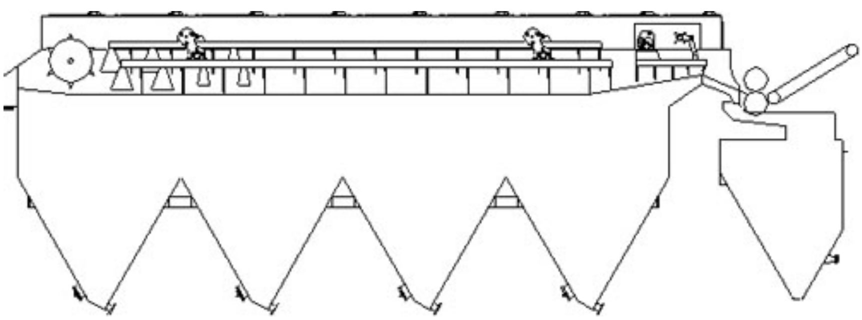

Figure 2.12 Four hopper rake action scouring bowl. Source: Andar Holdings Ltd. (b).

The amount of wool that a single scour train can process depends on the width of the train – the typical range is from 0.6 – 5 tonnes per hour. The wool passes through the entire plant (scouring, drying and baling) in about 20-30 minutes.

Dealing with scouring waste

Wool scouring produces a highly polluting effluent stream which is very difficult to degrade by biological microorganisms, especially the grease component. Other components of the effluent include pesticides, which are applied to wool to control various sheep parasites, and potassium, a nutrient which is contained in the suint. All pose significant problems in effluent treatment and disposal. A typical scour produces an organic load in its effluent that is equivalent to a town of around 30,000 people.

Dealing with the effluent provides one of the biggest challenges in a wool scouring business, which is often faced with increasingly stringent regulations. These demand an environmentally responsible performance in all aspects of wool scouring operations and sophisticated systems are now used to ensure that scouring wastes are dealt with efficiently and responsibly. The principles of waste minimisation involve (Figure 2.13):

1. Reducing the generation of waste through the recovery of wool grease (wool wax);
2. Reusing any waste where possible. While the waste cannot be used directly, the reuse of process liquors by passing them through contaminant recovery loops maximises the reuse of water and chemicals;
3. Reclaiming waste that cannot be reused. Ideally, all scouring wastes should be reclaimed;
4. Recycling as much unused reclaimed material as possible. If all the available water in the effluent was recycled, then there would be no liquid effluent discharges to the environment.

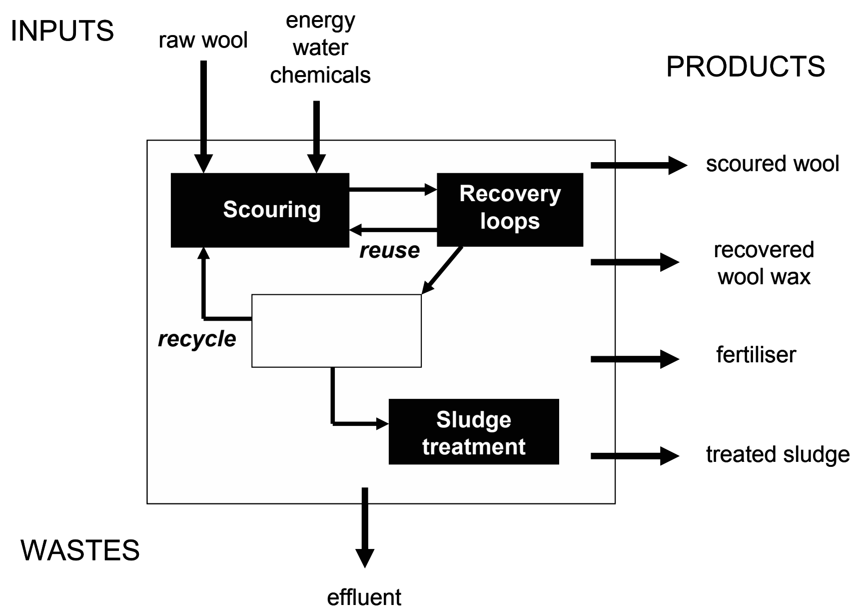

Figure 2.13 Waste minimisation in wool scouring. Source: IWS

Primary treatments

Basic (ie, primary) treatment systems involve combining the various aqueous discharges and after centrifuging these are discharged from the plant with or without further treatment. Only a proportion of the wool grease and dirt (around 30%) is removed from the recovery loops that continuously treat the scouring liquors before returning them to the scour. The remaining contaminants are discharged from the scour as waste water.

Modern scouring effluent treatment systems:

1. Reduce the amount and variability of the discharge,
2. Remove settlable solids and fibre, and
3. Recover as much wool grease and heat as possible.

Figure 2.14 shows one such system as developed by WRONZ (Wool Research Organisation of New Zealand).

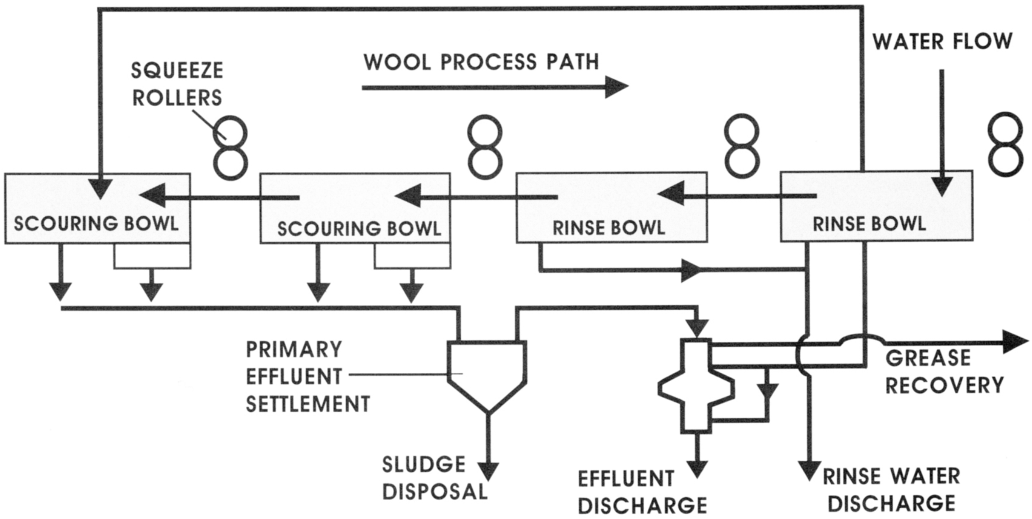

Figure 2.14 WRONZ effluent treatment system. Source: IWS

A counter-flow system is used, with the liquor flowing from the first bowl passing through a primary dirt removal stage and then to a grease centrifuge. A proportion of the partially degreased water is returned to the first main scouring bowl.

Different techniques are used to remove the various types of pollutants in the scour effluent:

- ***Fibre removal*** is carried out on hot liquors using screens, which must be cleaned at regular intervals to remove grease and grit.
- ***Suspended solids removal*** is carried out in a settling tank where the particles of dirt fall to the bottom of the tank to be removed as a sludge.
- ***Grease removal*** is the major pollutant and about 45 - 50% of grease can be removed by centrifuging.
- ***Heat removal*** by heat exchangers reduces the heat content of the primary effluent before it is discharged.

More complex (secondary and tertiary) treatment systems enable more wool grease to be removed from the effluent stream, and reduce the amount of water and solids discharged to the environment through the recovery of various components for use as fertilisers etc.

Other treatments

Wool scouring, as a wet process, also provides an opportunity for various chemical treatments that may be undertaken in the scouring or rinse bowls. For example:

- Hydrogen peroxide is often used as a bleach to further brighten good colour wools
- Sodium metabisulphite is sometimes used as a bleach to reduce the yellowness of average and poor colour wools
- Insect resistant (i.e. mothproofing) chemicals may be added
- Organic acids such as acetic or formic acid can be added to adjust the pH of the wool
- A bacteriostat may be added to sanitise wool destined for bedding products
- Various ‘fibre differentiation’ treatments that modify the lustre, dyeability and other wool characteristics are conveniently carried out as wet processes in a wool scour.

Drying

Drying is a crucial part of wool scouring. Once the wool has been squeezed for the final time it may still hold 50% water (by weight), while the scourer's clients will require the wool dried to a precise level at around 16 or 17%. The wool is dried by hot air in a chamber, with the drying process being monitored by a computer-controlled sensing system that ensures that the required moisture level (or regain) is maintained. Figure 2.15 shows the three main types of dryers used in wool scouring: suction drum, conveyor dryer and Unidryer.

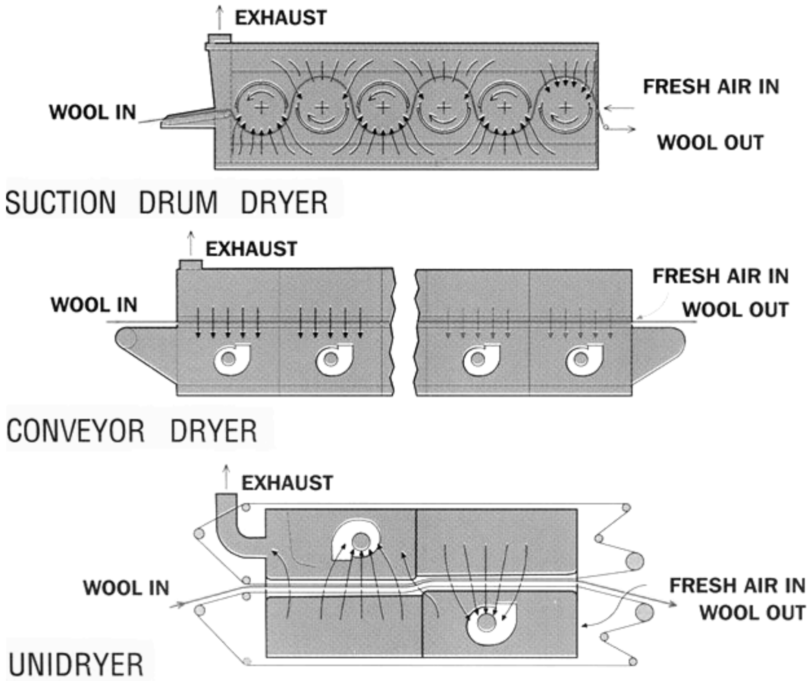

Figure 2.15 Types of dryers using in wool scouring. Source: Andar Holdings Ltd.

Scoured wool handling

Dried, scoured wool may be further processed, mainly to remove any dust remaining and to provide further opening and blending. A widely used cleaning machine is the stepped opener blender, as shown in Figure 2.16. As the wool is moved up the 'steps' by the spiked rollers, the dust falls through perforated screens and is removed by a vacuum duct.

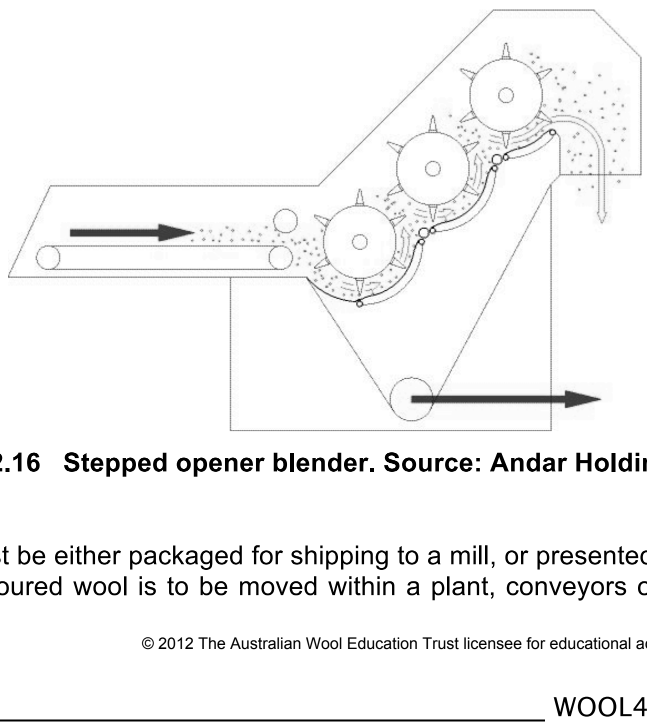

Figure 2.16 Stepped opener blender. Source: Andar Holdings Ltd.

Finally, the fibre must be either packaged for shipping to a mill, or presented to the next stage of production. If the scoured wool is to be moved within a plant, conveyors or pneumatic ducting are used. Alternatively, wool may be pressed into farm bales (around 130 kg) or into high density bales (300-450 kg).

Packaging scoured wool in high density bales, restrained by steel bands, minimises the volume that each bale occupies in a shipping container and hence reduces transportation costs. The bale wrapper, which is a nylon or polypropylene fabric, protects the wool from soiling and contamination until the bale is opened for subsequent processing.

It is usually required to regularly take samples of scouring production for quality control purposes (ie, in-house testing) or testing by a test house (for certification purposes). A set of narrow tubes with sharp ends are driven into each bale to extract a representative core sample of wool for both testing purposes.

Figure 2.17 shows a high density bale at the core sampling station.

Figure 2.17 Core sampling of a high density bale. Photograph supplied by E J Wood

Readings

The following readings are available on the web learning management system

1. Robinson, B. 1991, *A Basic Guide To Raw Wool Scouring,* IWS Technical Information Letter, TIL/ET-6, 1991.
2. Wood, E. J. *Wool scouring* (adapted from AWI web site – www.wool.com
3. Wood, E. J., *Innovation in wool scouring technologies*
4. Wood, E.J., *Effluent treatment in wool scouring* (adapted from AWI web site – www.wool.com)

Summary

In the past 50 years the scouring industry has seen major advances in terms of technology developments, processing efficiencies and the adoption of environmentally responsible practices. All these aspects are briefly covered in this topic.

In simple terms wool scouring is the high production washing and drying of wool. However, there are a considerable number of other operations involved including opening, blending, mechanical cleaning, baling, sampling and testing. While the principles are the same for scouring fine wools and coarse (carpet) wools, there are significant differences in the scouring systems used for them. Wool scouring also provides the opportunity for other chemical processes to be undertaken. The treatment and disposal of effluent to recover heat and wool grease is an important aspect of wool scour operations.

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Glossary of terms

Aqueous process	A process involving the use of water
Carpet wool	Wool from a crossbred sheep, generally coarser than around 33 microns
Detergent	An agent that cleanses, including soap (but today the term is mostly used for synthetic detergent. See Surfactant.
Centrifuge	The use of a high rotational velocity (high centrifugal force) to cause a liquor to separate into its phases
Cracking	The use of heat to destabilise an emulsion containing woolgrease, thereby making more easy the subsequent separation of wool grease by a centrifuge
Cream	The phase that is richer in the dispersed component, obtained by separating an emulsion (e.g. by centrifuging)
Decanter	Pour off a liquid, leaving the solid material (sediment) behind
Dump	The process of relieving a scouring bowl of its contents
Effluent	The liquid waste stream from a scouring line, from which the woolgrease is extracted
Emulsion	A colloidal suspension where the particles or droplets of one material are dispersed in another material, e.g. milk
Flocculate	Finely divided particles in a suspension amalgamate to form larger particles
Flowdown	Liquor discharged from a scouring bowl
Harrow	A set of rakes moving in unison to move wool along a scouring bowl
Hauteur	A measure of mean fibre length of a sliver or top (in mm)
Heat exchanger	A device in which a flow of warm liquid transfers its heat energy to a flow of cooler liquid
Heavy solids	Another name for sludge
Hydration	Formation of a chemical compound of water with another compound
Hydro-extractor	A machine which applies a high centrifugal force to wet wool to extract a large amount of water
Hydrophilic	A liquid that mixes readily with water
Hydrophobic	A liquid that resists mixing with water
Liquor	The liquid contents of scouring bowl, consisting of warm water and detergent
Micelle	A cluster of surfactant molecules, which may enclose a droplet of grease or oil
Mini-bowl	A scouring bowl, shaped somewhat like an inverted pyramid, designed for efficient scouring
Non-polar solvent	A solvent having a symmetrical molecule so that no extremities are charged (positive or negative); has no affinity for water
Polar solvent	A solvent with a molecule having opposite charges at the extremities (has an affinity for water)
Rake	A row of teeth, used to move the wool along a scouring bowl
Sludge	A slushy sediment, the dirt, sand etc. that falls to the bottom of a woolscouring bowl

Soap	The product of a fat, oil or grease reacting with an alkaline liquid such as caustic soda
Solvent	A liquid that is capable of dissolving a material; an organic solvent, as used in solvent scouring dissolves oils, fats and grease
Suint	Dried sweat of the sheep coating the wool fibre, mostly potassium salts
Suint bowl	A bowl which may be optionally be used as the first bowl of a fine wool scour for the removal of dirt and suint before detergent action commences on the grease in the second bowl. It operates at a low temperature, i.e. around 28^{o}C
Surfactant	Surface Active Agent – a liquid capable of altering the surface tension of a liquid; the active agent in a detergent
Topmaking	The conversion of scoured wool into a uniform rope of fibre (a top), by carding, gilling and combing machines; the first half of the worsted processing route for yarn manufacture
Whiteness	A measure of the brightness (as opposed to greyness) of wool; equivalent to the Y tristimulus value from a colorimeter
Woolgrease	Technically, woolgrease is a wax secreted by the sebaceous gland of the sheep and coats the fibre with a thin film. This term is used once it is removed from the wool fibre
Wool yield	The amount of clean fibre in a quantity of greasy wool; the ratio of weight of scoured wool / original weight of greasy wool, expressed as a percentage