3 Materials Preparation Stage II: Fundamentals of the Carding Process

3.1 INTRODUCTION

From the descriptions in Chapter 2, it should be clear that opened and cleaned or scoured materials arrive at the carding stage in the form of small tufts composed of entangled fibers. We learned in Chapter 1 that the purpose of the carding stage is to disentangle these tufts into a collection of individual fibers, the collection being in the form of a web of fibers, and then to consolidate this collection into a *sliver* or *slubbing* of the required count. Cotton or wool tufts fed to the carding stage still contain impurities, which would not be the case for man-made fiber tufts. However, the disentangling of fibers facilitates removal of the impurities.

Definition: Carding is the action of reducing tufts of entangled fibers into a filmy web of individual fibers by working the tufts between closely spaced surfaces clothed with opposing sharp points.

Machines used to carry out this work are called *cards,* and we shall consider three types that are of importance in the processing of cotton, wool and man-made fibers:

1. revolving flat card
2. worsted card
3. woolen card

Before describing the main features and operation of these cards, certain basic principles common to all three will first be explained and then referred to subsequently.

From the definition, it can be easily reasoned that carding is most effective with very small, well opened tufts, i.e., containing only a few tens of fibers. Although the opening and cleaning stage produces tufts on the order of a few milligrams, further opening is required to obtain a uniform feed of suitably small tufts for carding. We have seen earlier that a beater/feed roller system can be used for intensive opening. Small tufts attached to the sharp points (i.e., the saw-tooth wire) of the beater can be easily removed by a second saw-tooth wire-covered beater rotating in the opposite direction at a higher surface speed. The "front of the tooth" of the faster beater would be working on the "back of the tooth" of the slower beater and would "strip" the tufts from the latter. The principle is that *point-of-tooth* to *back-of-tooth* gives a *stripping action* (Figure 3.1a). To disentangle the fibers of the tufts now attached to the faster-moving surface, a stationary or much slower moving surface, covered in sharp points, is required to be in close proximity with the faster surface. The motion of the slower surface may be in the same or opposing direction, but the sharp points would be angled to oppose those of the faster-moving surface. Thus, *point-of-tooth* to *point-of-tooth* gives the *carding action* (see Figure 3.1b). For individual fibers attached to the faster-moving surface, *point-of-tooth* to *point-of-tooth* may also be used as a *stripping action* to build a web of individual fibers. Figure 3.1c illustrates the situation of *back-of-tooth* to *back-of-tooth*, which enables the points on the faster moving surface to lift individual fibers from the base of the

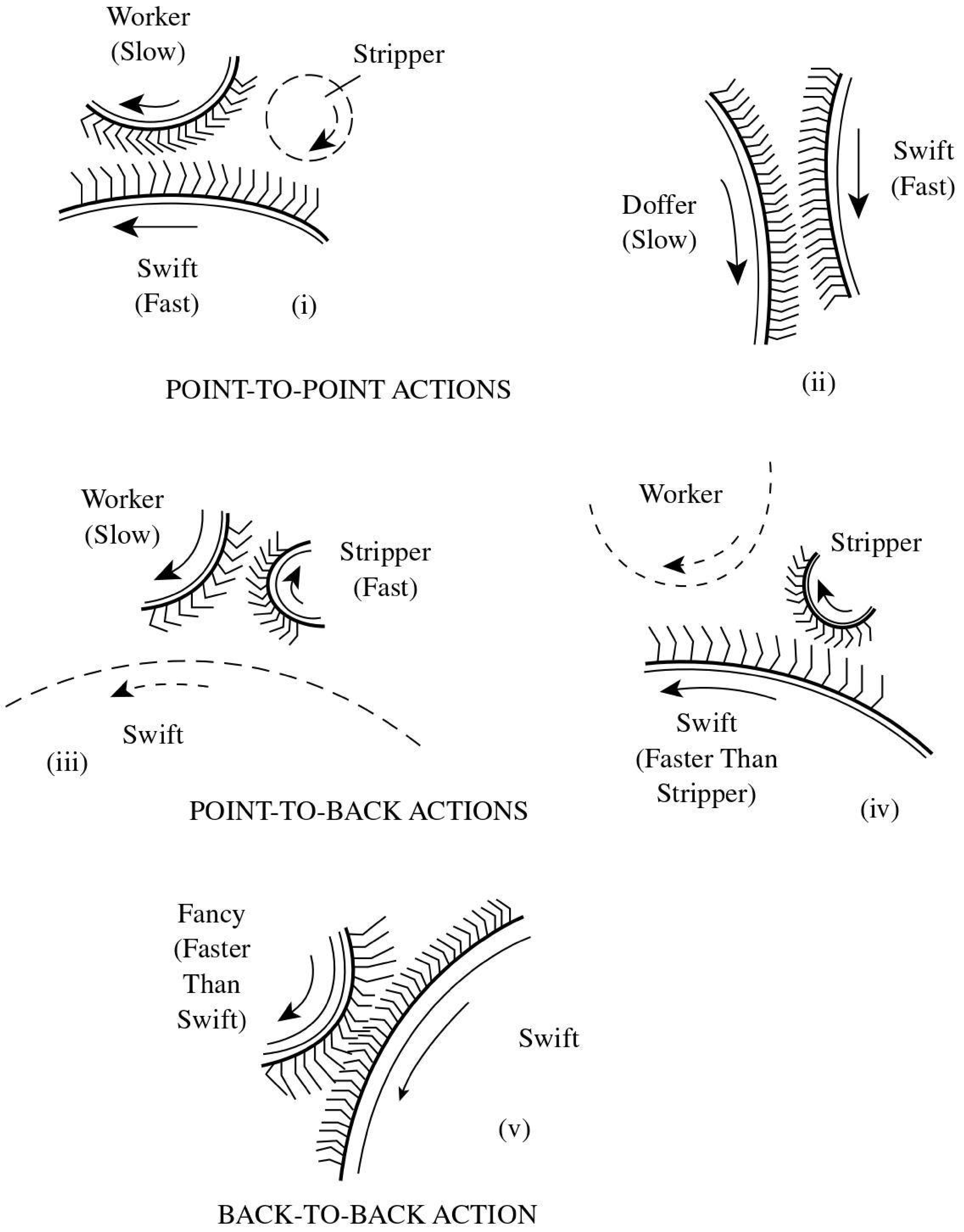


FIGURE 3.1 Basic carding actions. (Courtesy of Brearley, A., pub. Pitmans & Sons Ltd.)

points on the slower surface. This action may be used as an aid to fiber stripping for web formation.

3.2 THE REVOLVING FLAT CARD

3.2.1 The Chute Feed System

Earlier, the value of 500 kg/h was given as an average production rate for the throughput of a short-staple (e.g., cotton) opening and cleaning line. The revolving flat card, also frequently called a *cotton card,* is a short-staple carding machine, and production rates are usually below 100 kg/h, depending on fiber type. In certain situations, production rates of 30 to 50 kg/h are used commercially. The reason for this concerns the opening up of the fiber feed into suitable tuft sizes for the carding action. Equation 2.1 (Chapter 2) applies to the opening part of the card, and we can see that, with all other factors remaining constant, tuft size is largely dependent on the production rate, and that a modest rate will give small tufts. To obtain small tufts at very high production rates would mean increasing the beater speed, and the number of points on the beater surface also may be increased. The difficulty is that increased beater speed may result in fiber breakage. This is, therefore, a limitation to the speed that would be suitable. Fiber breakage in carding is discussed in Chapter 4. Since the production rate of a single card cannot match the blowroom output, several cards must be used and linked to the blowroom in such a way that there is a uniform feed of the fiber mass to each card.

Figures 3.2 and 3.3 illustrate that the tufts are transported pneumatically to each card via distribution ducting. Each card has a chute feed system connected to the ducting. There are various designs of chute feeds, but their working principles are basically similar, and Figure 3.4 depicts an example of the essential features. There is an upper and lower chute separated by a feed roller and beater, and a pair of feed rollers is positioned at the end of the lower chute. Each chute has air-escape holes and a pressure sensor fitted to control a preset compacted volume of tufts in the chute. The upper chute receives tufts from the distribution ducting, and the transporting air is exhausted through the air-escape holes. The feed roller and beater

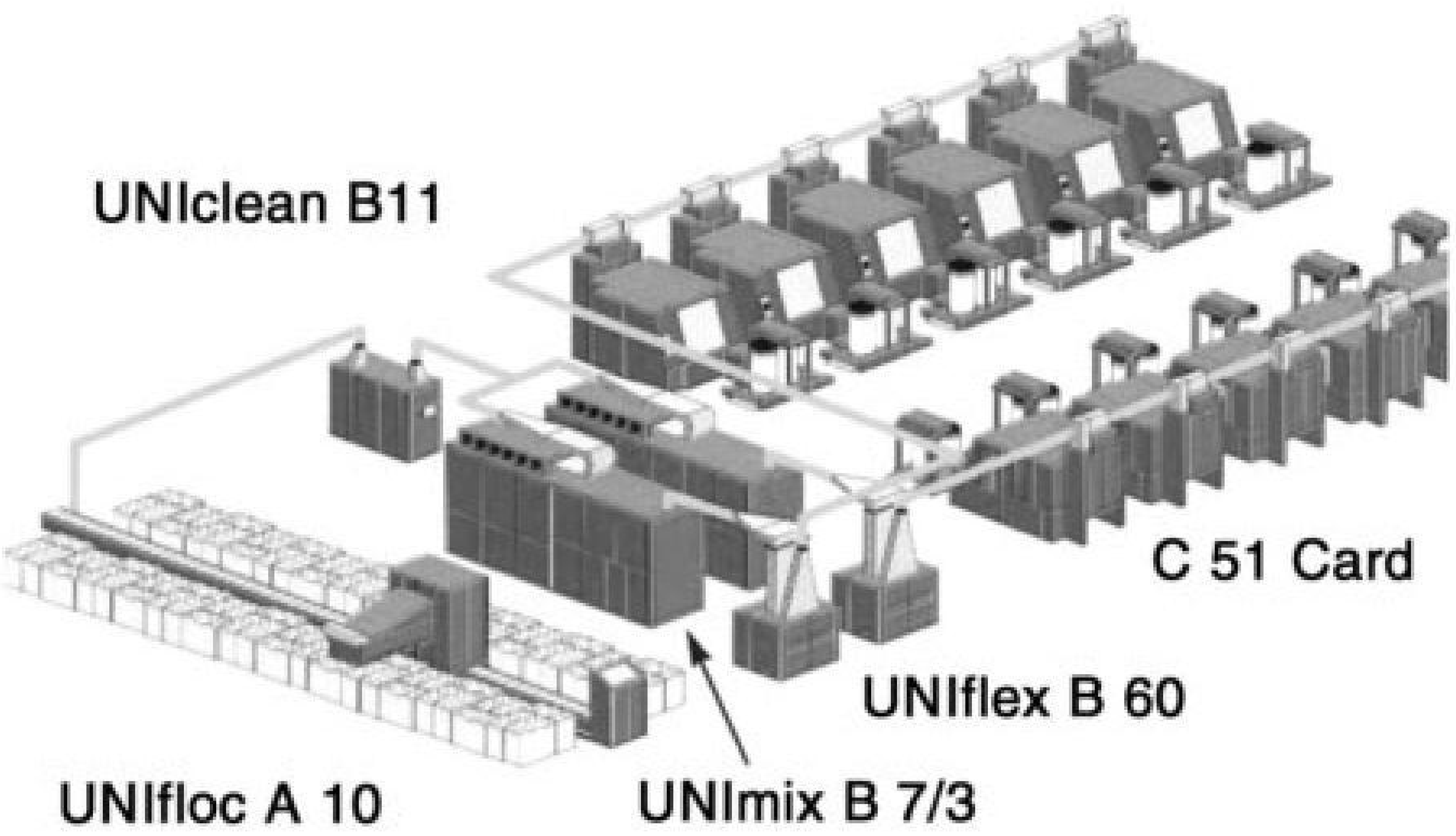


FIGURE 3.2 Short-staple opening, cleaning, and carding lines. (Courtesy of Rieter Machine Works Ltd.)

FIGURE 3.3 Short-staple carding line. (Courtesy of Rieter Machine Works Ltd.)

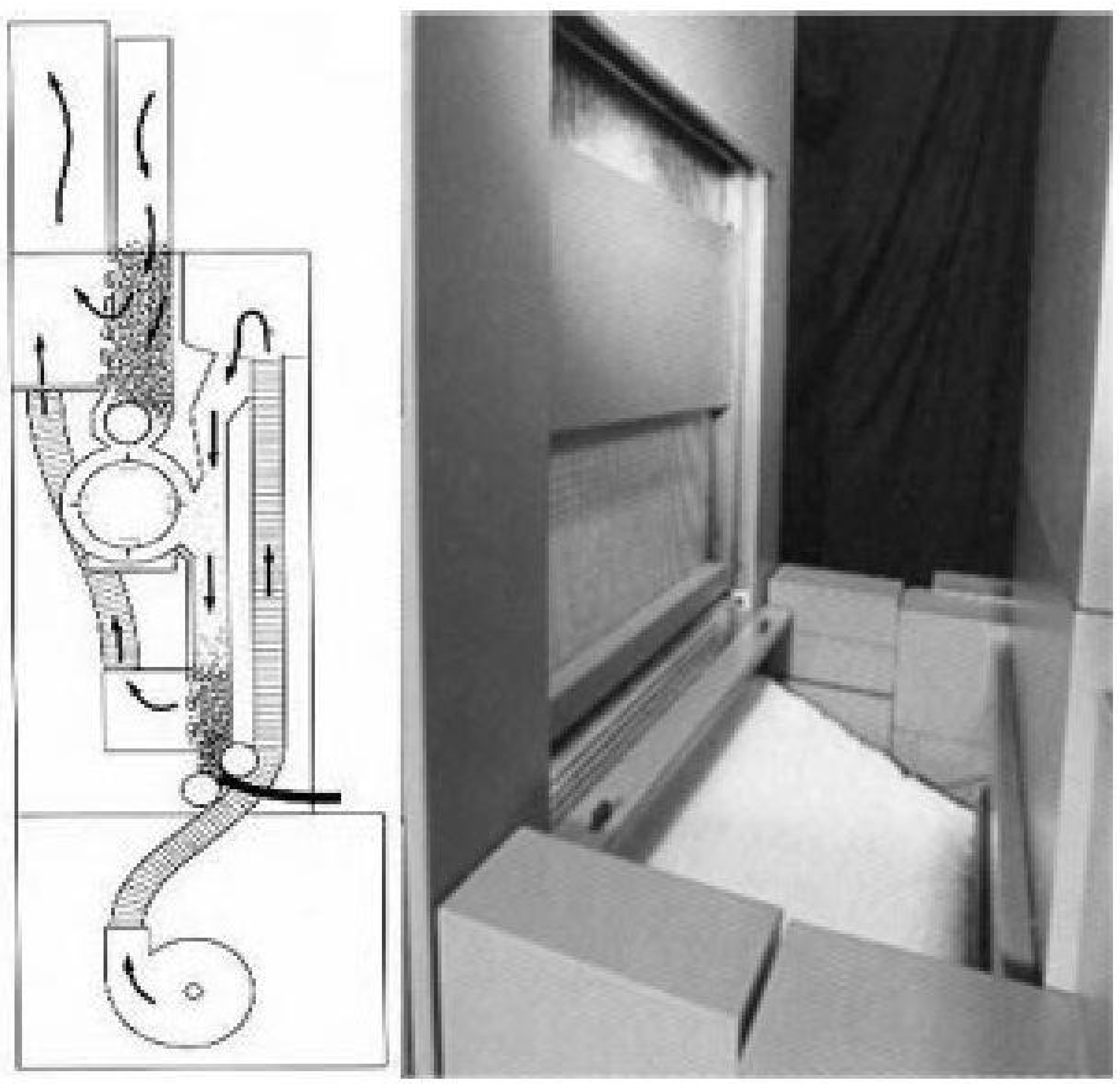


FIGURE 3.4 Basic features of a short-staple chute feed system. (Courtesy of Crosrol UK Ltd.)

remove the material at a slower rate, enabling incoming tufts to build up in this top chute. As the tufts build up and cover the air-escape holes, the pressure sensor detects the associated increased air pressure in the chute, and the tuft feed is closed off. As tufts build up in the top chute, the beater reduces the tuft size and feeds the smaller tufts to the bottom chute. Here, the compaction of the tufts is by air pressure from a fan blower. The rate of removal of the compacted material by the pair of feed rollers is slower than tuft feed, and, much as with the top chute, a pressure switch controls the feed by stopping and starting the upper feed roller.

Figure 3.5 shows the principal elements of the revolving flat card, after the chute feed section, and Table 3.1 gives examples of component dimensions and relative settings. The three main rollers — the *taker-in* (or *licker-in*), the *cylinder*, and the *doffer* — have saw-tooth wire spirally wound around their cylindrical surfaces to cover the surfaces in sharp points; this is referred to as *saw-tooth wire clothing***.**

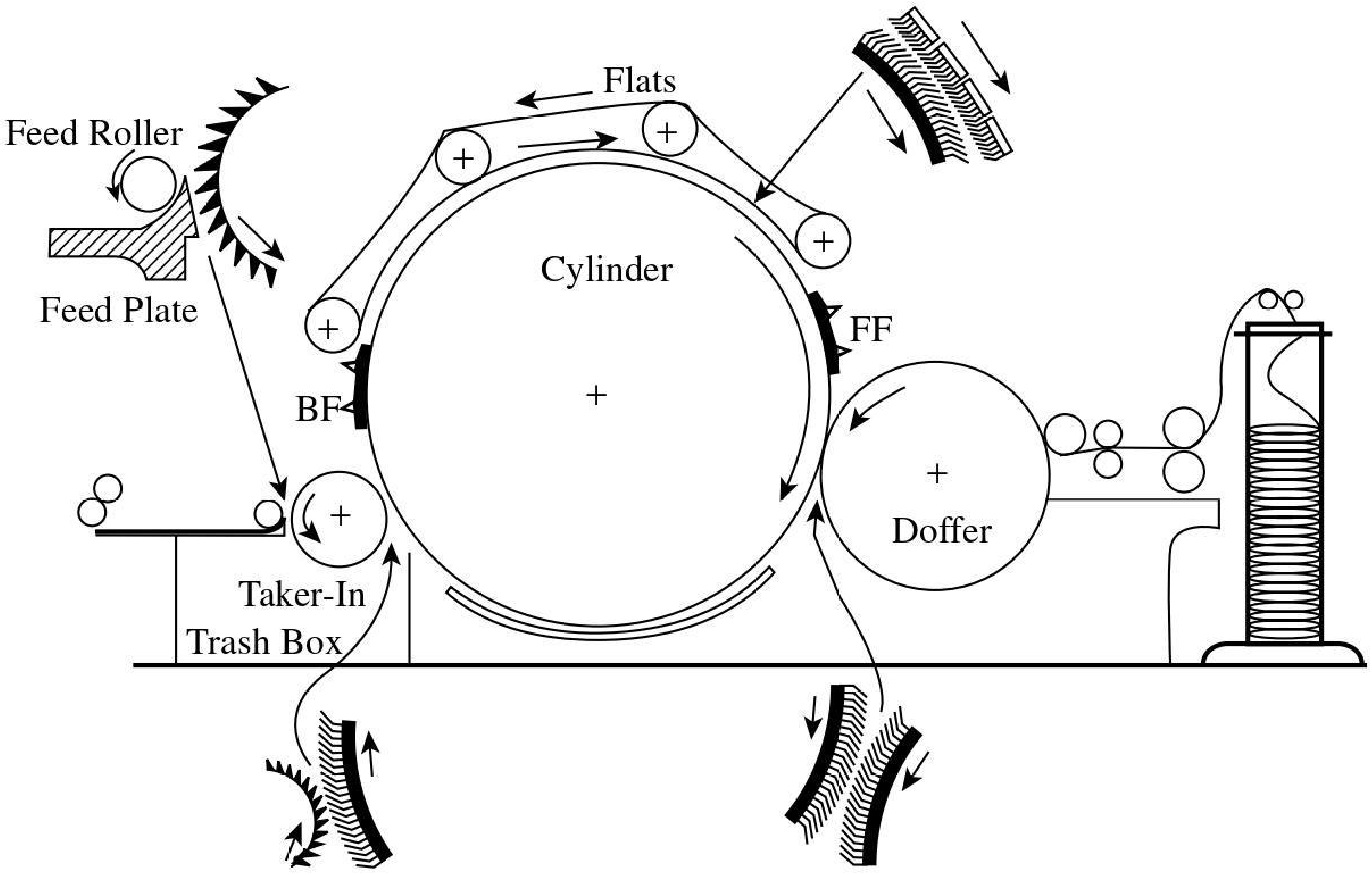


FIGURE 3.5 Basic features of a revolving flat card.

TABLE 3.1
Example of Dimensions and Relative Settings of Revolving Flat Card

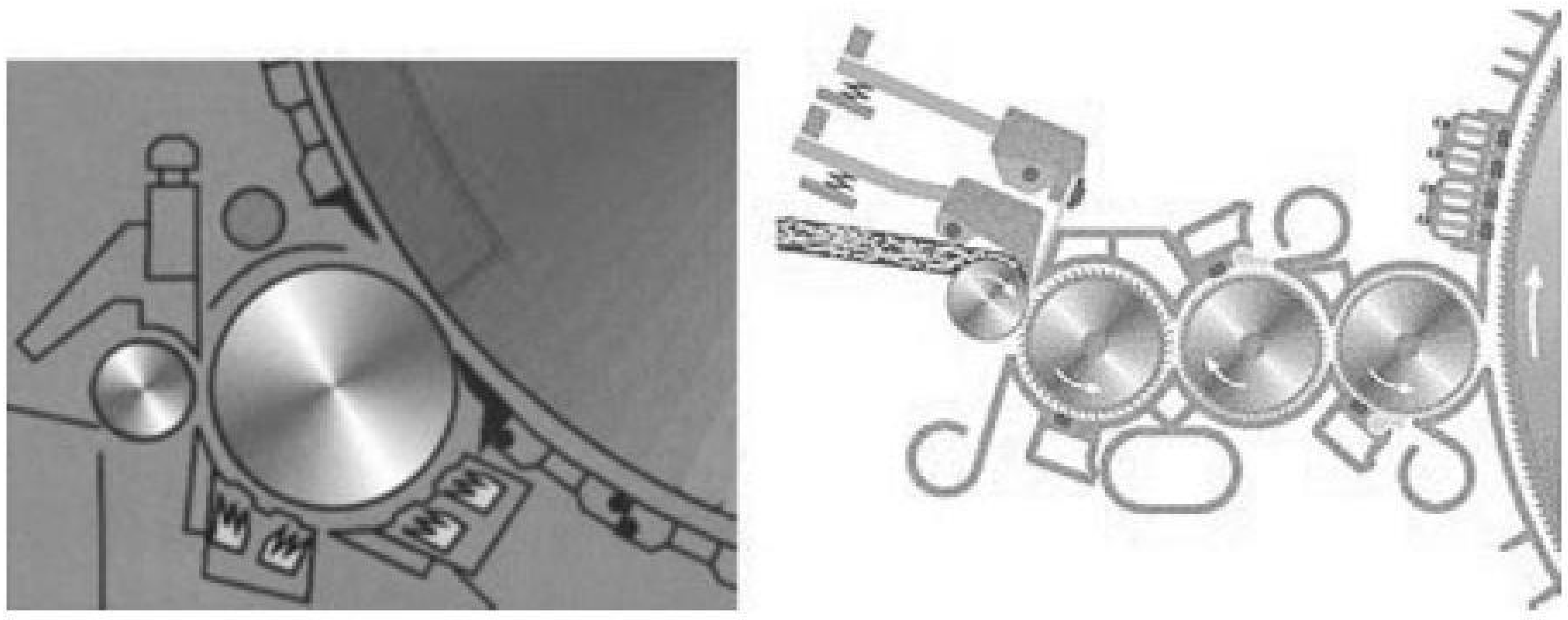
Component	Diameter in mm [in]	Tooth density in pp/cm^2 [pp/in^2]	Speed	Draft	Approximate settings in μm [in]
Taker-in (licker-in)	229 [9] over wire 248 [9.75]	7–8 [40–50]	800 rpm	1000	Taker-in/cylinder 25 [0.010]
Cylinder	1270 [50]	62–100 [400–650]	300 rpm	2.08	Cylinder/flats 25 [0.010]
Flats	44.5 × 1016 [1.75 × 40]	90–100 [600–650]	101.6 mm/min		
No. of	106–110				
Doffer	686 [27] over wire 705 [27.75]	100	16–40 rpm	15–35 times slower than cylinder	Cylinder/doffer 12.5 [0.005]

Positioned above the upper surface of the cylinder is a series of rectangular bars (80 to 116). Each bar has one flat surface, *the working surface,* clothed in sharp points. These components are called *flats*. The clothing specifications of the taker-in, cylinder, flats, and doffer vary with fiber type with respect to geometry and point densities. Appendix 3A discusses card clothing in greater detail.

The flats BF and FF have fixed positions, so they are motionless, with their working surfaces set very close to the cylinder clothing. We refer to these as the *back fixed flats, BF,* and the *front fixed flats, FF*; they may also be called *stationary* *carding elements.* Incorporated in the fixed flats zone is a separator knife edge and suction unit for removing dust and trash particles. The remaining flats have their opposite ends attached to an endless chain of roller bearings so that they can be moved continuously over the upper surface of the cylinder, with around 30 to 46 flats[1] at any time having their working surfaces set very close to the cylinder clothing, with opposing angles of tooth. This circuitous path of the flats results in them being called the *revolving flats.* The diagram shows the directions of rotation of the main cylinders and the revolving flats, and the table gives typical speeds.

3.2.2 THE TAKER-IN ZONE

The taker-in, feed roller, and feed plate combination functions as a fine opener, with the taker-in playing the role of the beater as referred to earlier. The compacted tufts moving from the chute feed are brought into contact with the taker-in, which reduces the tufts to microtuftlets and individual fibers. During opening, trash particles and neps are released. The pair of knife-edge plates, termed *mote knives,* that are positioned close to the taker-in surface assist with retaining usable fiber while ejecting the impurities — vis-à-vis an imbalance of centrifugal and aerodynamic forces. The combination of grid bars and perforated plate, also positioned below the taker-in, enables the further removal for trash particles. However, in removing trash particles, fiber can also be removed; the aim is to keep this “lint” content of the waste to a minimum. The effectiveness of cleaning in this area has been improved in two ways. Most short-staple cards now employ two or more of what are referred to as *stationary carding plates* or *combing segments* positioned under the taker-in (see Figure 3.6a). These break up any tufts that might be the result of inadequate opening and reduces the lint content of the waste. Table 3.2 give examples of results obtained from mill trials with and without carding plates fitted to taker-in zone, and it is evident that significant reductions in lint content can be obtained with the use of carding plates. Figure 3.6b shows another development for improving the opening in the licker-in zone. This involves multiple taker-ins, carding plates with mote knifes, and suction slots. Note that, in both diagrams, the feed roller lies below the feed plate. This enables improved opening of the fiber mass, and the feed plate is also used as a sensor for detecting thickness variations in the batt feed for the long-term autoleveling of the fiber mass**.**



(a) (b)

FIGURE 3.6 Carding plates and multiple taker-ins. (Courtesy of (a) Rieter Machine Works Ltd. and (b) Trutschler GmbH & Co.)

TABLE 3.2
Effect of Carding Plates

Fiber	Without	With	Difference (%)
Cotton waste			
• Taker-in waste, %	4.53	3.24	–28.5
• Lint content, %	2.60	1.28	–50.8
• Trash and dust content, %	1.93	1.96	+1.6
Bleached waste			
• Taker-in waste, %	17.6	8.0	–54.5
Cotton: strict middling			
• Taker-in waste, %	3.79	0.89	–76.5
• Lint content, %	3.28	0.68	–79.3
• Trash and dust content, %	0.51	0.21	–58.8
Egyptian cotton			
• Taker-in waste, %	2.75	1.61	–41.5
• Lint content, %	2.29	1.16	–49.3
• Trash and dust content, %	0.46	0.45	–2.2

3.2.3 CYLINDER CARDING ZONE

The microtuftlets and individual fibers retained on the taker-in clothing are transferred to the cylinder clothing by the *point-of-tooth* to *back-of-tooth action*. The cylinder motion brings the fiber mass into contact with the back fixed flats, BF, and the microtuftlets are further opened.

As the fiber mass on the cylinder clothing is transported by the cylinder into the zone of the revolving flats, the *point-of-tooth* to *point-of-tooth* carding action takes place between the revolving flats and the cylinder clothing so that the microtuftlets become caught in the flats. Most fibers (97%), with ends projecting from the flats and held by the cylinder clothing, are removed as individual fibers. Not all fibers have their ends projecting sufficiently close to the cylinder to be pulled from the fiber mass caught in the flats. These remain in the flats and, as each flat leaves the carding zone, the retained fiber mass is stripped from the flat as waste — collectively termed *flat strips.*

The objective of the stationary flats section above the licker-in-transfer is to ensure that any fiber tufts transferred to the cylinder are quickly opened so that, on arriving under the flats, the fiber mass can be easily separated into individual fibers. This prevents long fibers from getting embedded into the revolving flat clothing and allows these fibers to be hooked by the cylinder clothing points for effective carding.[2] Grimshaw[3] reports that these flats are also a barrier to hard trash particles such as seed coatings and therefore protect the revolving flats clothing against damage by such particles, especially at high production rates. Leifeld[4] claims that, at this point, the separate knife-edge and suction unit will remove even large seed fragments.

Nevertheless, the tendency is for fine trash or dust particles to remain attached to fibers, as Figure 3.7 illustrates, and consequently pass into the carding zone. Feil[2] suggests that, in the carding zone, the motion of the cylinder clothing generates air

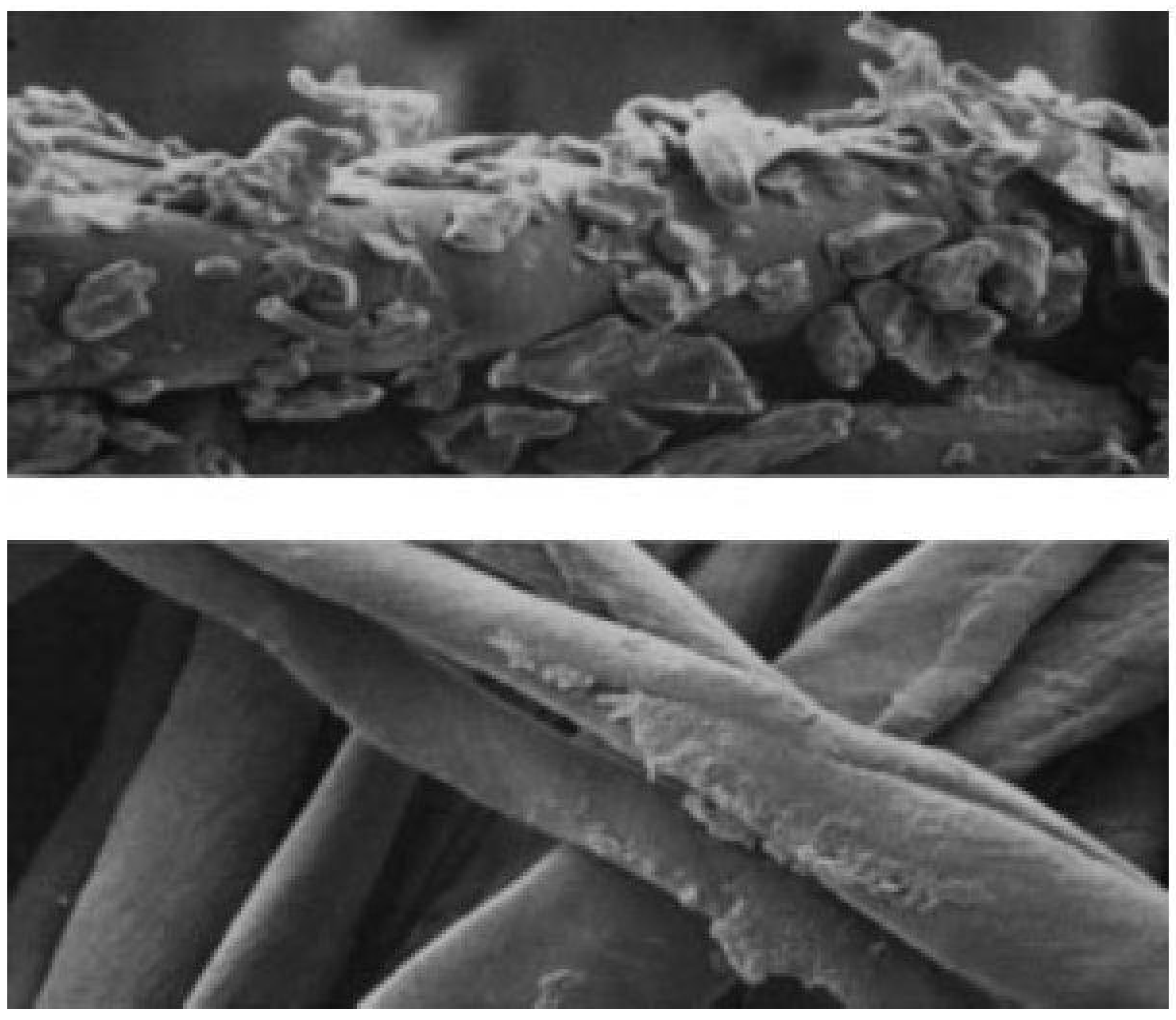


FIGURE 3.7 Trash and dust particles on fiber. (Courtesy of Rieter Machine Works Ltd.)

turbulence that, along with mechanical forces, causes the trailing ends of fibers attached to the teeth of the cylinder clothing to vibrate rapidly and shake loose trash particles and dust. The fiber mass on the revolving flats acts as a filter, and much of the impurities are deposited into it to be later removed as part of the strip. Figure 3.8 shows cotton flat strips containing trash particles and neps. In the carding of cotton fibers, revolving flats are an essential feature of the card. Since man-made fibers do not contain significant levels of impurities, stationary flats may be used in preference to revolving flats (see Figure 3.9).

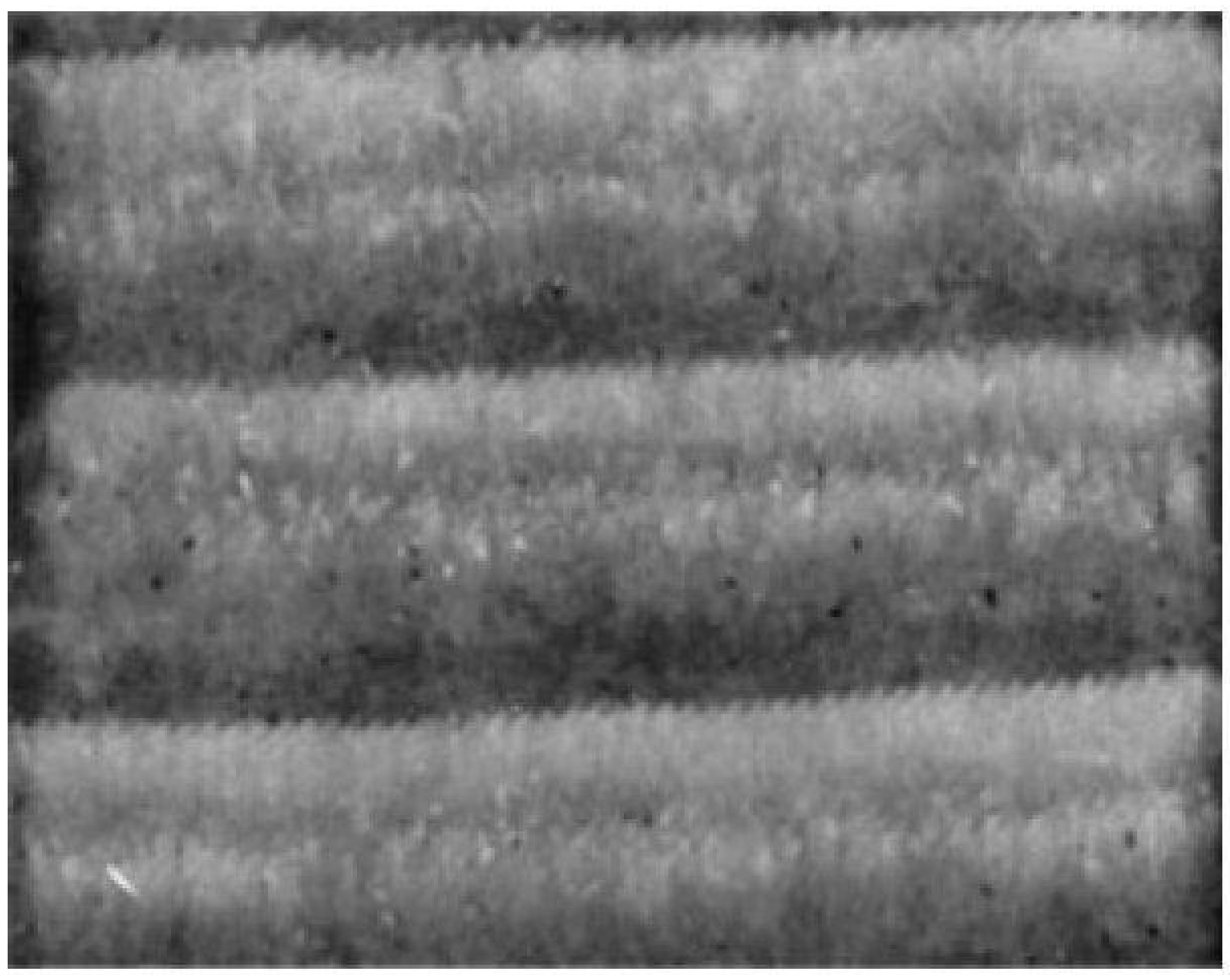


FIGURE 3.8 Cotton flat strips.

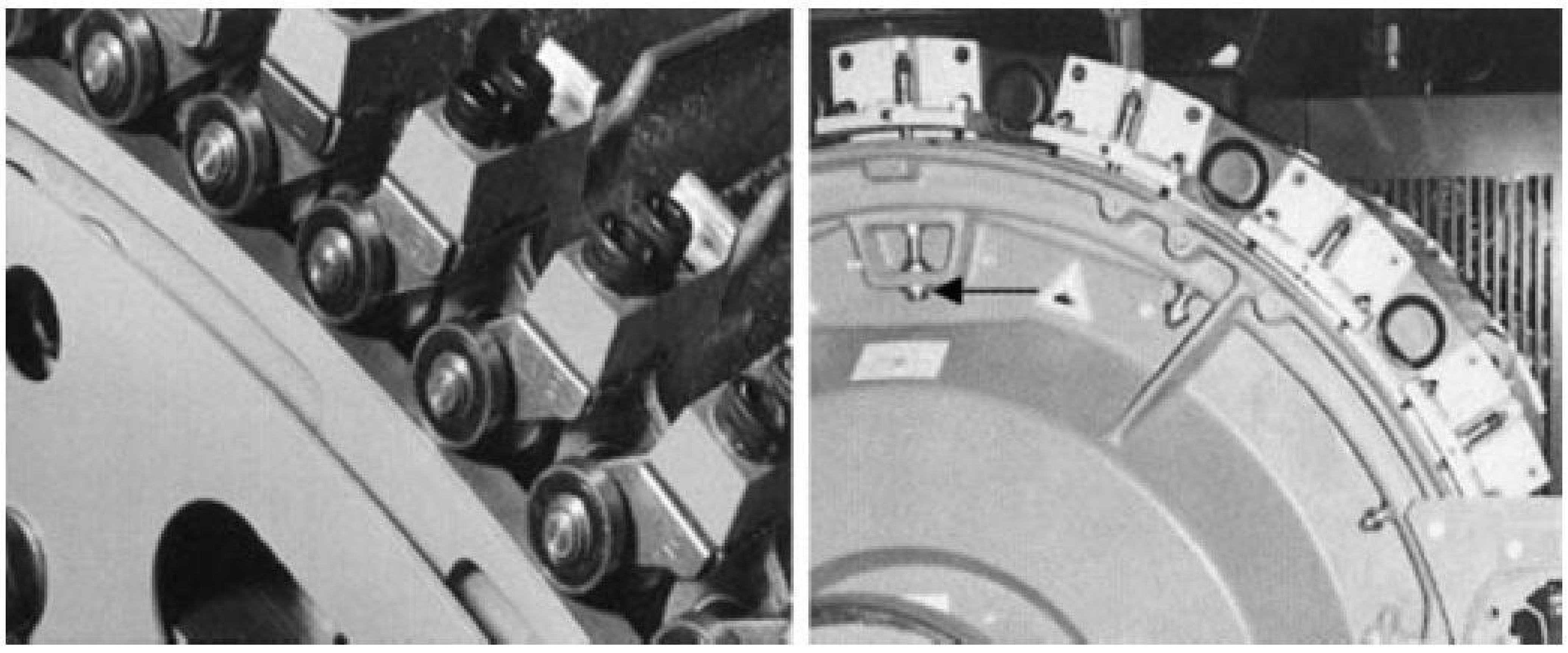


FIGURE 3.9 Revolving and stationary flats. (Courtesy of Rieter Machine Works Ltd.)

3.2.4 CYLINDER-DOFFER STRIPPING ZONE

The individual fibers attached to the cylinder clothing collectively appear as a very light web on the cylinder surface. This web moves with the cylinder rotation and first comes into contact with the front fixed flats, FFs, which further extract neps and fine trash particles and comb the fibers. It then comes into contact with the doffer clothing, which removes the fibers from the cylinder by the *point-of-tooth* to *point-of-tooth* stripping action. This cylinder-doffer area is called the *transfer zone,* since the objective is for fibers to be transferred from the cylinder to the doffer. Not all the fibers, however, are stripped on first contact with the doffer; some remain on the cylinder for several cylinder rotations before being removed. The cylinder underscreen controls the boundary air layer at the cylinder surface to prevent the undoffed fibers being ejected from the cylinder clothing during their motion from the doffer/cylinder area to the taker-in/cylinder area. Feil[2] reports that there appears to be an optimal number of times fibers should go through the transfer zone before being stripped by the doffer; too short or too long a dwell time on the cylinder impairs the quality of the output material, i.e., the sliver.

3.2.5 SLIVER FORMATION

Since the surface speed of the cylinder is much faster than the doffer (see Table 3.1), there is buildup of fibers on the doffer, forming a thicker web of fibers (the doffer web) than that on the cylinder. The rotation of the doffer brings the web to the front of the card, where it is removed (as the card web) by a wire-covered stripping roller (see Figure 3.10) passed through a pair of pressure rollers before being condensed into a sliver and wound into the sliver can (see Figure 3.11). The pressure rollers are used to crush trash particles such as, with cotton, seed coat fragments that may still be present in the web attached to fibers. The crushed particles would then be removed during subsequent processing of the sliver.

3.2.6 CONTINUITY OF FIBER MASS FLOW

Despite the situation that not all fibers are removed from the cylinder on their first pass through the transfer zone, there is continuity of mass flow within a few minutes of running; i.e., rate of batt feed to the taker-in equals the sum of the rate of waste accumulation and sliver production rate.

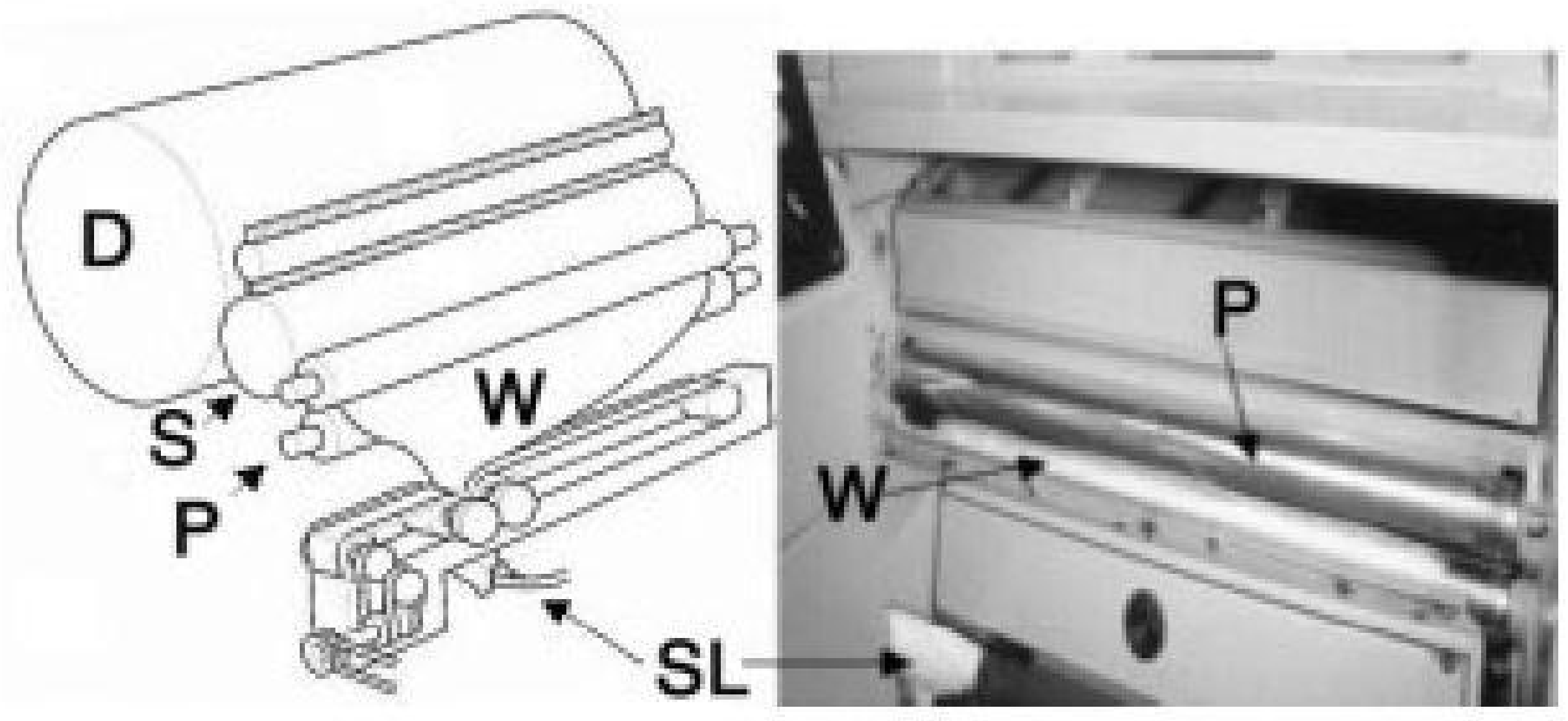


FIGURE 3.10 Stripping of doffer web and sliver formation. D = doffer, S = stripping roller, P = pressure rollers, W = doffer web, SL = sliver. (Courtesy of Rieter Machine Works Ltd.)

3.2.7 DRAFTS EQUATIONS

Let us consider surface speeds of the machine components moving the fiber mass through the card, which eventually forms the sliver that is coiled in the can. For simplicity, we can ignore the speed of the flats, because this only governs the rate of removal of the flat strips from the carding zone. Based on the above description of the operating principles,

$$V_f << V_t < V_c > V_d < V_s < V_{cr} < V_c < V_{sc} \tag{3.1}$$

where V_f = feed roller
V_t = taker-in
V_c = cylinder
V_d = doffer
V_s = stripping roller
V_{cr} = crushing rolls
V_{ca} = calender rollers
V_{sc} = coiler rollers

The above are in units of meters per minute.

The relation of these surface speeds shows that the fiber mass is subjected to a sequence of drafts (see Equation 1.11, Chapter 1) as it moves through the card.

$$D_{ft} = V_t/V_f;\ D_{tc} = V_c/V_t;\ D_{cd} = V_d/V_c;\ D_{ds} = V_s/V_d;\ D_{scr} = V_{cr}/V_s;\\ D_{crc} = V_{ca}/V_{cr};\ D_{csc} = V_{sc}/V_{ca} \tag{3.2}$$

All drafts are >1 except D_{cd}. The drafts D_{ds}; D_{scr}, D_{crc}, and D_{csc} are sufficiently close to one to be ignored. The total draft for the card is given by

$$D_{TM} = D_{ft} \cdot D_{tc} \cdot D_{cd} = V_d/V_f \tag{3.3}$$

It should be evident that the width of doffer web equals the width of the batt feed and that, in consolidating the doffer web into a sliver, the mass per unit length of

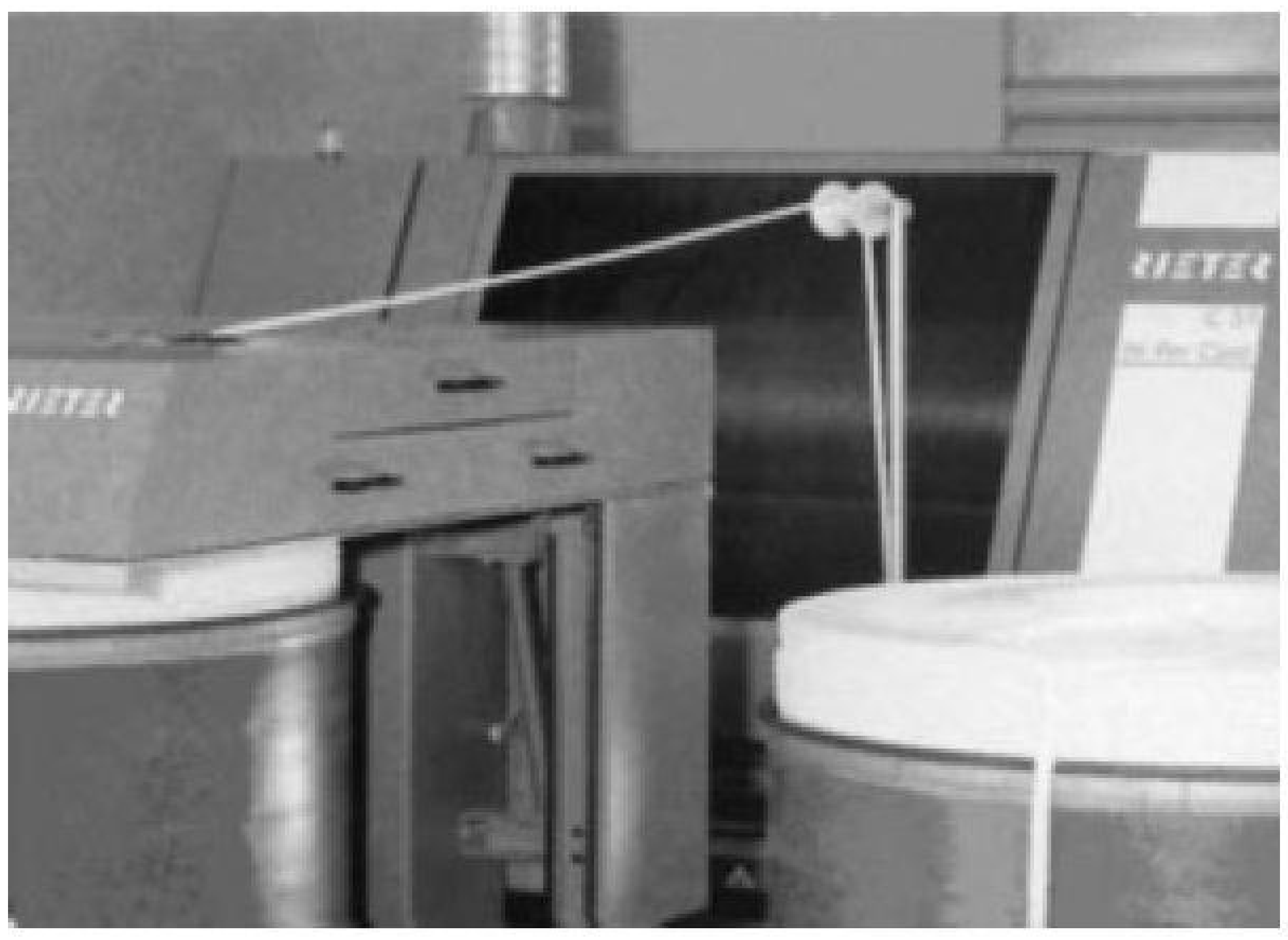


FIGURE 3.11 Sliver can build. (Courtesy of Rieter Machine Works Ltd.)

the sliver equals the mass per unit length of the doffer web, ignoring drafts D_{ds}, D_{scr}, D_{crc}, and D_{csc}. From Equation 1.11 (Chapter 1), we can write,

$$D_{TF} = M_L/S_L \tag{3.4}$$

where M_L = the mass per unit length (in g/m) of the batt
S_L = sliver count in ktex

Since Equation 3.3 deals only with the fiber feed and the sliver, we can relate D_{TM} and D_{TF} by subtracting the percentage waste, W, from M_L removed during carding. Hence,

$$D_{TM} = D_{TF}\,(1 - 0.01W) \tag{3.5}$$

We may refer to D_{TM} and D_{TF} as the total mechanical draft and the total fiber draft. The carding of fibers will generate heat, which may alter the moisture content of fibers. Therefore, in determining W from measurements of M_L and S_L, the effect of moisture regain must be controlled by conditioning each fiber mass in a standard atmosphere.[5]

3.2.8 PRODUCTION EQUATION

Strictly speaking, the last pair of rollers that moves the fiber mass are the coiler rollers, which place the sliver in the sliver can. Therefore, V_{sc} is the production speed in meters per minute. Hence the production rate (P_C) in kg/h is given by

$$P_C = 60 \cdot \mathrm{V_{sc}} \cdot S_L \cdot 10^{-3} \tag{3.6}$$

3.2.9 THE TANDEM CARD

From the above description of the operation of a short-staple card, we reason that the effectiveness of the carding action is related to, among other factors, the number of points used in attempting to separate the fiber mass into individual fibers, i.e., to discretize the fiber mass. Increased point density and surface speed of the cylinder are therefore important factors. The number of points per unit area per unit time can be used to make a judgement of the available carding capacity or carding power. A higher value should enable discretization of the fiber mass to the individual fibers level and permit a high fiber mass throughput, but the fibers will be further stressed. However, the use of two cylinders in tandem, with a higher point density on the second cylinder, will also give greater carding power — but with less stressing of the fibers.

Figure 3.12 is a diagram of a Tandem card arrangement. The first cylinder system is referred to as the, *breaker card,* and the second, which has the closer settings of machine components, is called the *finisher card.* The first cylinder substantially separates the microtuftlets, and the resulting web passes through crush rollers before entering the second cylinder system. The finisher card receives the fiber mass in an

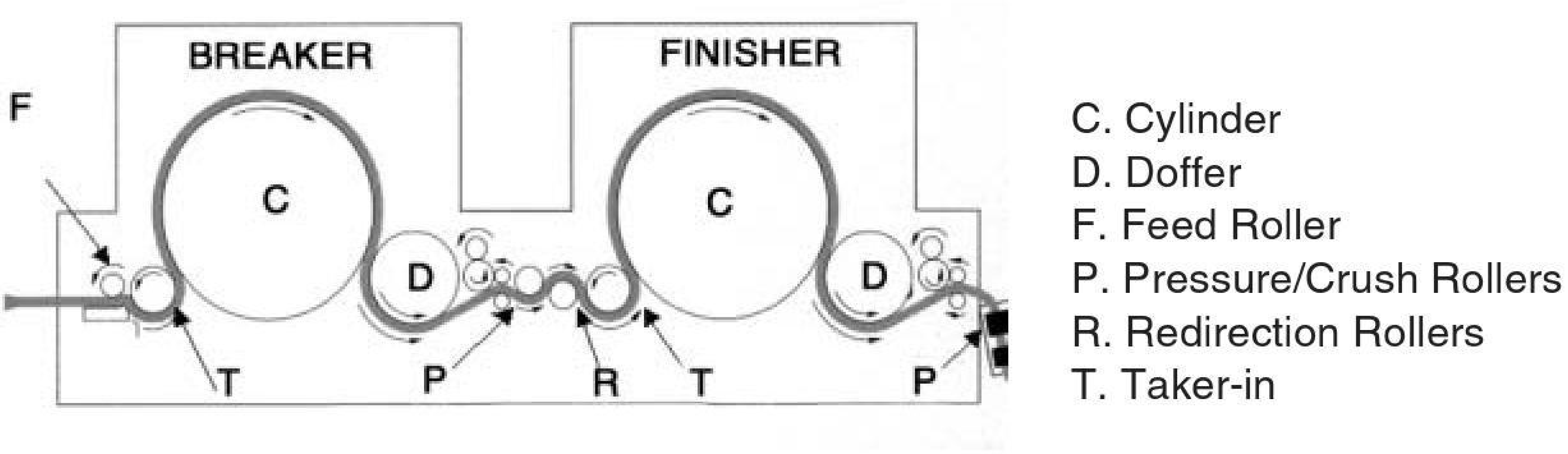


FIGURE 3.12 Schematic of tandem carding system. (Courtesy of Crosrol UK Ltd.)

ideally suitable state for completing the process of fiber separation and trash/microdust removal. Tandem carding gives a relatively gentle and progressive carding action, with less fiber breakage and waste than with single-cylinder cards. The cost of tandem cards is a major disadvantage; therefore, few tandem cards are in commercial use. These are mainly for high-quality cotton processing or where microdust presents problems in rotor spinning (see Chapter 6).

3.3 WORSTED AND WOOLEN CARDS

Figures 3.13 and 3.14 show typical examples of worsted and woolen cards. Collectively, these may be referred to as *roller-clearer* cards, and Table 3.3 gives relative dimensions.

Superficially, these cards appear to be an arrangement of large tandem cylinders with several pairs of large and small rollers positioned over each cylinder and a

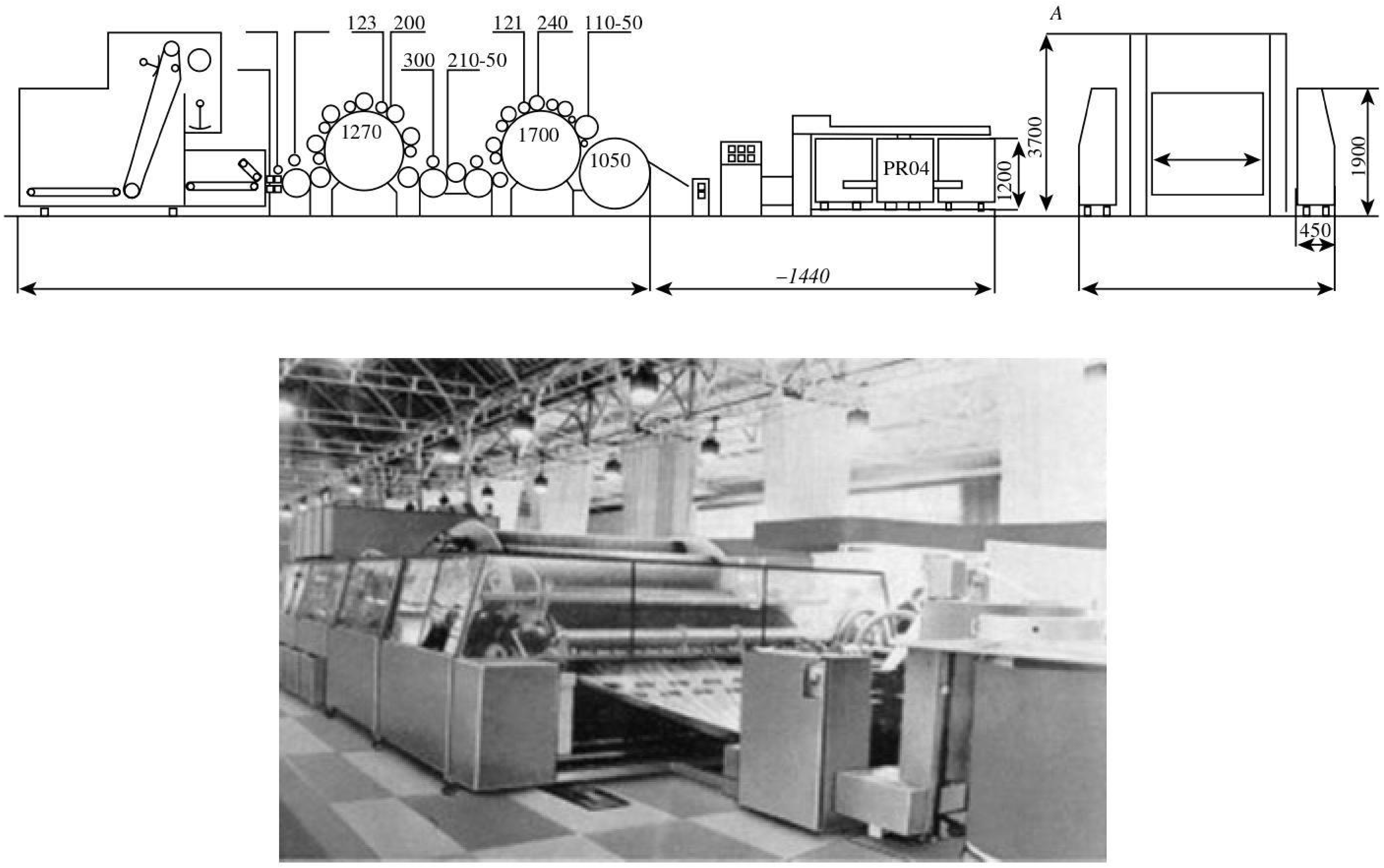


FIGURE 3.13 Worsted carding set. (Courtesy of Befama Ltd.)

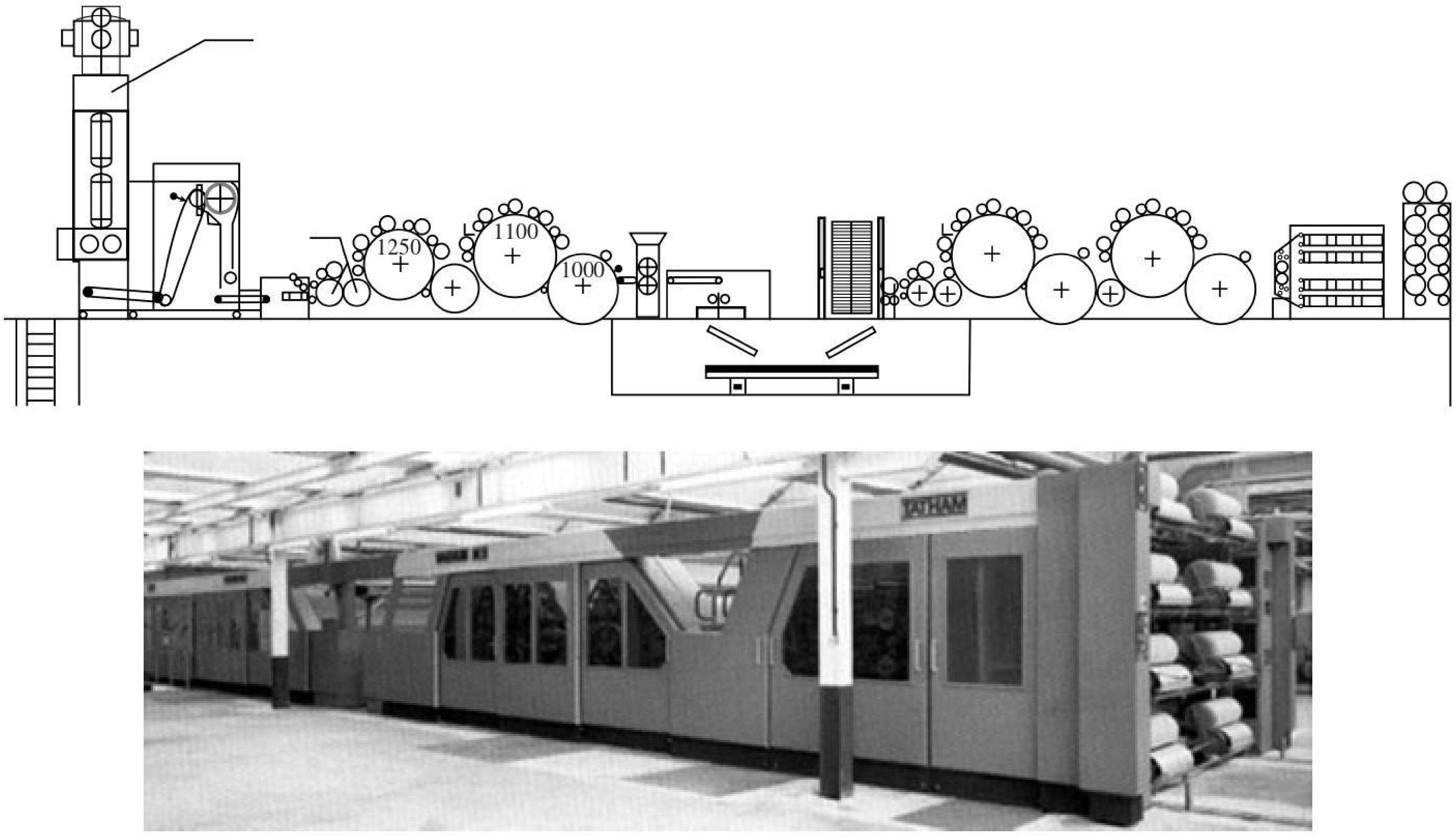


FIGURE 3.14 Woolen carding set. (Courtesy of W. Tatham Ltd.)

TABLE 3.3
Typical Dimensions of Roller Clearer Cards

Worsted carding set: 15-m length × 3.5-m working width

Weighing hopper	Working width: 2–3.5 m Weigh-pan capacity: 0.58–0.75 m^3 Bin capacity: 3.8 – 12.8 m^3
Feed arrangement	Two pairs of feed rollers, 86 mm dia. Taker-in roller, 500 mm dia, with worker/stripper, 215/123 mm dia Transfer roller, 500 mm dia
Breast	Main cylinder, 1.27 m up to 5 workers/strippers 240/123 mm dia Transfer roller, 270 mm dia
Cleaning unit	Two Morel beaters, 500 mm dia Transfer roller, 270 mm dia
Roller card	Swift, 1.5m dia; up to five pairs of workers and strippers, 270/123 mm dia without fancy; four pairs with fancy, 270 mm dia Doffer, 1.27 m dia

Woolen carding set: 18- to 25-m length × 3-m working width

Weighing hopper or volumetric feeder	(As above)
Feed	Two pairs of feed roller, up to 86 mm dia. Taker-in, 500 mm dia Transfer roller, 500 mm dia
Breast	(As above)
Roller cards	(As above with fancy)

double hopper and weigh-pan feed to the card. We refer to these arrangements as *carding sets*. The first cylinder in the set, usually the smallest in size, is termed the *breast,* and each of the others a *swift.* Each large and small roller positioned over the breast or swift is called, respectively, a *worker* and a *stripper.* In a carding set of up to three swifts, the first is referred to as the *scribbler.* This is followed by either a single or two-part *finisher card* or *carder.* One or two swifts may be used as the finisher card, depending on fiber type, fineness, length, and, in case of the woolen card, slubbing count range; in worsted carding, a single swift would be used for wool containing up to 4% VM and a double swift for wool containing VM > 5%.

The component settings and point density of the clothing, respectively, become progressively closer and higher from breast to second finisher. The point clothing on the components of the carding set are very different from those on the short - staple card. Saw-tooth wire and what is termed *fillet wire* are fitted to the working components of worsted and woolen cards. Appendix 3A gives detailed consideration of the clothing types. As the figures show, the output material from the worsted card is in sliver form, and the woolen card produces slubbings (see Chapter 1). Production rates depend on fiber fineness. It is lowest for finer wool and can range from 120 to 150 kg/h for 19 μ wool to 270 to 350 kg/h for 30 μ wool.

At one time, the general thinking was that the shorter wools were better carded on woolen cards and longer wools on worsted cards. However, the woolen card handles a wide range of lengths and length distribution for producing yarns for a broad range of end uses, such as hosiery knitting, woven cloth or carpets, blankets, and felts. Fibers carded cover a wide range of 100% virgin wool for knitting (e.g., lambswool, Hauter 44 mm, 19 to 23 μ; Shetland wool, Hauter 56 mm, 26 to 32 μ) and luxury fibers such as mohair, vicuna, rabbit angora, or camel hair and manufactured and recycled fibers. Worsted cards also process luxury fibers like mohair, alpaca, and cashmere; man-mades; and spun silk.

3.3.1 HOPPER FEED

The fiber is usually supplied from the blending stage into a single or double hopper by pneumatic conveyance or by manual loading into the feeder bin. The principles of operation of hopper feeders and weigh-pan feeding have been described earlier. With double hopper feed, the hoppers work in series; the first hopper supplies the second with a regular uniform rate of fiber mass. The first hopper is not usually fitted with a weigh pan but is set to fill the second hopper when activated by a optical sensor positioned to monitor the reserve bin of the second hopper. The first hopper therefore runs intermittently as required. The double-hopper system is aimed at reducing variation in the feed to the card and to introduce an extra opening. However, compared with single-hopper weigh-pan feeders, there is a significantly increased space requirement and cost. Volumetric feed hoppers may be necessary for high production rates, as the response time of weigh pan hoppers can restrict these rates. Nevertheless, regularity of feed is essential to the uniformity of the carded material, particularly with respect to the slubbings produced by the woolen card. This topic will be discussed in more detail later, when carding quality parameters and autoleveling are considered.

3.3.2 TAKER-IN AND BREAST SECTION

The taker-in and breast sections of the card are for opening the fiber mass into small tuftlets and to start the process of individualizing the fibers. Generally, fibers processed by roller-clearer cards are coarser, longer, and often of a higher crimped state than fibers processed by revolving flat cards. The batt of such fibers is likely to be of greater bulk. The rollers covered with saw-tooth wire clothing are therefore used as the feed-rollers in the taker-in zone. Two pairs of feed rollers (see Chapter 4) may be used to feed the batt fringe to the taker-in. Single or multiple taker-ins may be used depending on material throughput, vegetable matter (VM) content, and fiber type. For high throughput and/or fine fibers, a worker/stripper pair may be used with the first taker-in, and if the VM level is high, a burr beating roller with catch tray may also be fitted. The breast is also fitted with pairs of workers and strippers so as to reduce the tufts transferred from the licker-in into microtuftlets and to begin the progressive process of fiber separation. The worker/stripper units, in combination with the swift, give a carding action (see Figure 3.1) and the burr beaters a cleaning action, which are described below.

3.3.3 INTERMEDIATE FEED SECTION OF THE WOOLEN CARD

In woolen carding, the web from the scribbler is condensed into a thick sliver and cross-fed to the carder; that is to say, the sliver is laid across the feed belt of the carder. This method of transferring the material from scribbler to carder effects an additional blending of the fibers and thereby assists in evening out variations in density across the width of the web from the scribbler to produce regular slubbings.

The device used to accomplish the cross-feed is called an *intermediate feed.* There are different types of intermediate feeds, but the simplest of the popular ones is Scotch feed, which is a sliver plaiting (cross-laying) mechanism. As illustrated in Figure 3.15, the web of fiber is removed from the doffer of the scribbler by means of an oscillating comb and passed through crush rollers to pulverize any remnants of carbonized VM. It is then drawn through a condenser funnel and compressed by a pair of calender rollers to make a sliver. The sliver is guided by a lattice and is laid across the feed belt of the carder by a pair of rotating rollers that traverse across the feed belt. If the web of fibers is moving in the direction indicated by arrows X-X, and the cross-feed by Y, then any thickness variation across the width of the web will tend to be evened out by the cross-feed.

3.3.3.1 Carding Section

As the fibers/microtuftlets are transferred onto the swift in the finisher carding section, they are brought into contact with pairs of workers and strippers. Figure 3.1 depicts the carding action at each worker-stripper pair. The swift has the fastest surface speed, and the clothing points oppose those of the much slower-moving worker. The resulting carding action divides the tuftlets making contact with workers; parts will remain on the swift clothing and be moved forward to the next and subsequent worker stripper pairs for further separation, and then eventually into the doffer stripping zone. The clothing points of the stripping rollers are angled in the

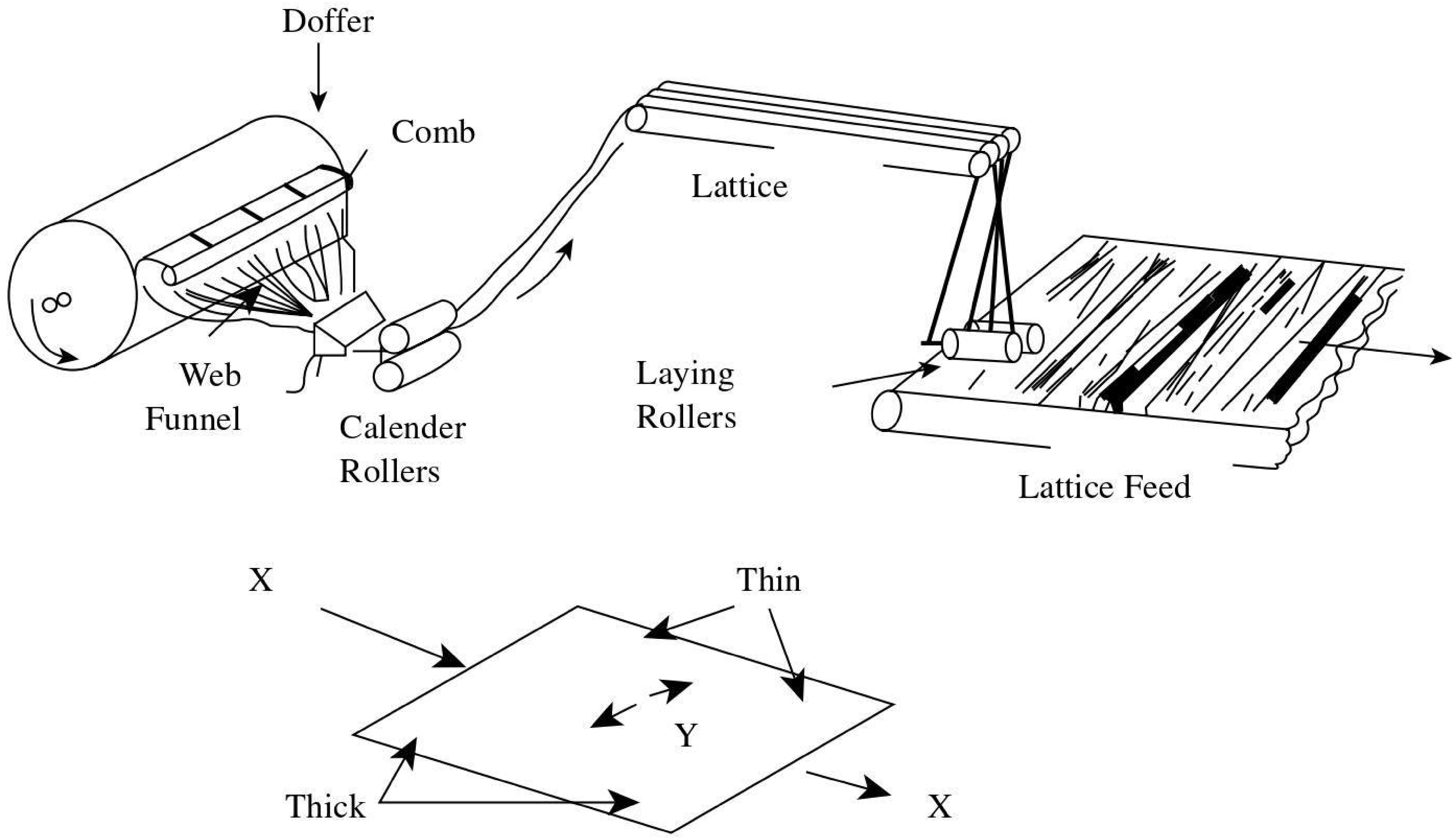


FIGURE 3.15 Intermediate feed: Scotch feed.

same direction as the workers but travel at a faster surface speed. The tuftlet portions on each worker move with the roller until they contact the clothing of the stripper roller, where they are removed by the stripping action. These tuftlet portions are then brought back into contact with swift, which removes them from the stripper to become mixed with other fiber/microtuftlets newly transferred from the take-in. The swift-worker-stripper combination gives both a carding and a blending action. The time taken for the portion of a tuftlet to be returned to the swift may be called the *delay.* The product of the swift speed and the delay would give the distance between the portion that remained on the swift and that caught by the worker and returned by the stripper. This gives a blending action along the length of the card, which is repeated at each worker-stripper pair. Similar to the revolving flats card, not all fibers reaching the cylinder/doffer zone for the first time are removed. Those that become part of the recycling layer can be, on each cycle past the doffer, repeatedly acted upon by the worker-strippers of the particular swift until they form part of the doffer web. Thus, the number of worker-stripper combinations and the cylinder-doffer influence the blending effect. It can be shown that, concurrent with this blending, there is an evening of the fiber mass flow. Chapter 4 describes the theoretical basis of the blending and evening actions of roller-cards.

3.3.4 BURR BEATER CLEANERS AND CRUSH ROLLERS

We know that wool destined for the woolen process is usually carbonized to remove vegetable impurities. Wool used in the worsted process is likely to have a much lower VM content that can be removed mechanically during carding with less chance of damage. The publication, *Textile Terms and Definition,* by The Textile Institute,[6] refers to *burry wool* as wool contaminated with vegetable impurities adhering to the fleece. In worsted carding, VM is removed by what are called *burr beaters*. These are small-bladed rollers for detaching VM particles from the wool and ejecting them into waste trays. Figure 3.16 shows a burr beater positioned above a special wire- covered roller called *Morel roller*. The bur beater may be positioned above the licker-in of the breast section, but it is also used effectively between the breast and the intermediate, and between the intermediate and the finisher section. Here, the burr beaters and Morel rollers are used. The Morel roller has specially designed wire clothing, called a *Morel wire*, that enables VM particles to ride on the surface of the clothing (i.e., on the top of the teeth) and fibers to lie sufficiently below the VM so that burr beaters can strike the impurities from the rollers. The burr beaters rotate in the same direction as the Morel rollers but at higher surface speeds.

Crush rollers, which pulverize any VM remnants in the card web, may be optionally fitted to worsted card but today are rarely incorporated. As discussed in Chapter 4, wool fibers can be damaged by crushing. Crush rollers are, however, present on woolen cards, located after the scribbler and before the intermediate feed, to crush remnants of carbonized VM, which is removed by subsequent carding actions.

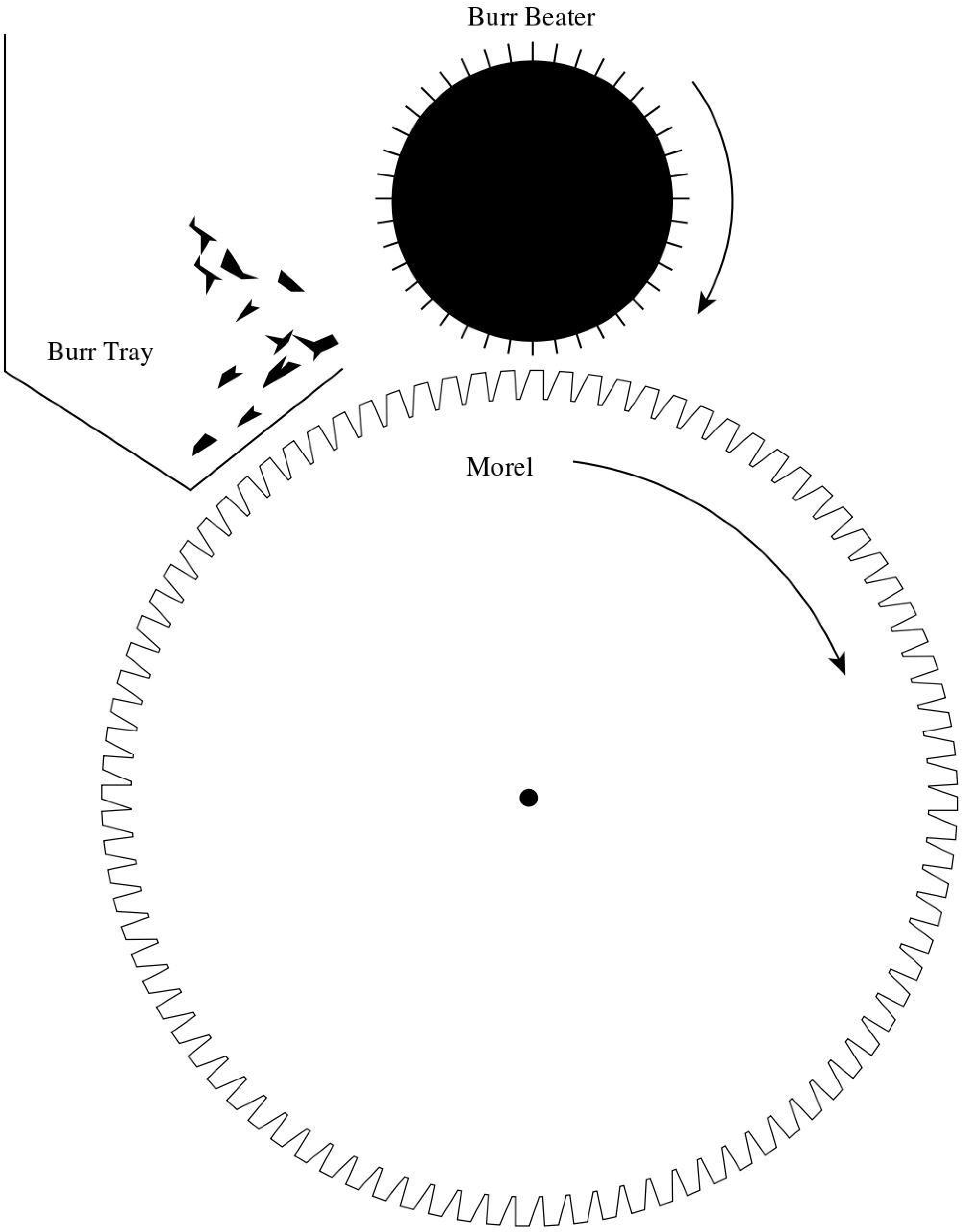


FIGURE 3.16 Burr beater and morel roller.

3.3.5 SLIVER AND SLUBBING FORMATION

Fibers are removed from the swift to form the doffer web in a similar *point-of-tooth* to *point-of-tooth* stripping action as described for the revolving-flats card. However, as we will see below, the wire clothing of the swift can be of such length that fibers at the base of the wire clothing need to be raised to the tips of the points for effective fiber transfer to the doffer. This is performed by the *back-of-tooth* to *back-of-tooth action* with a wire-clothed roller, called a *fancy*, mounted close to the surface of the swift just before the doffer. Figure 3.1 shows the location of the fancy roller in relation to the swift and the doffer.

On the worsted card, the doffer web is removed either by a high-speed oscillation comb (fly comb) or by redirecting rollers and is then consolidated into a sliver, whereas, with the woolen system, the doffer web is converted into slubbings. Slubbings have the appearance of soft, twistless string, and they require only small amounts of attenuation before being twisted to form a yarn. To produce slubbings, the web from the finisher card is split into many strips, each of a width that will give the required slubbing count. Each strip is then rubbed to condense and consolidate it into a soft, twistless string. The part of the carding set that converts the finisher card web into slubbings is called the *condenser*. There are two general types of condenser, the tape condenser and ring-doffer condenser.

3.3.5.1 Tape Condenser

This comprises a set of rollers around which is threaded a series of narrow belts (called *tapes*) or an endless narrow belt to form a line of tapes across the width of the machine (see Figure 3.17). Appendix 3B describes three different tape threadings used for the tape network. The tape width and the mass per unit area of the web determine the slubbing count, and card manufacturers usually recommend tape widths to cover a range of counts. The web is pulled into the network of tapes by entry rollers and, at the dividing rollers, is split into ribbons by the scissor-like action of the tapes.

Positioned after the tapes are pairs of rubbing aprons (or rub aprons); their lengths span the width of the machine. The scissor-like action between the tapes splits the web into ribbons that are then transported to the rubbing aprons. Depending on the width of the tape and of the woolen card, there may be four or six pairs of rubbing aprons placed one above the other. Each pair of rubbing aprons feeds a bobbin build unit (see Figure 3.18).

What is depicted in Figure 3.17 is a part of the tape network that is repeated across the card. For example, for a four-apron set, odd repeats would supply ribbons to rub aprons 1 and 3 in the set, and even repeats run aprons 2 and 4.

The rubbing aprons have two actions: they are driven circumferentially and simultaneously reciprocated lengthways, moving from side to side across the machine (see Appendix 3B). Each pair of rubbing aprons has the side-to-side movement of the aprons in opposite directions, so when one apron moves toward the left side of the machine, the other moves to the right.

On entering the rub aprons, the ribbons are consolidated by the rubbing action of the reciprocating movement of the aprons. The rubbing of the aprons rolls the

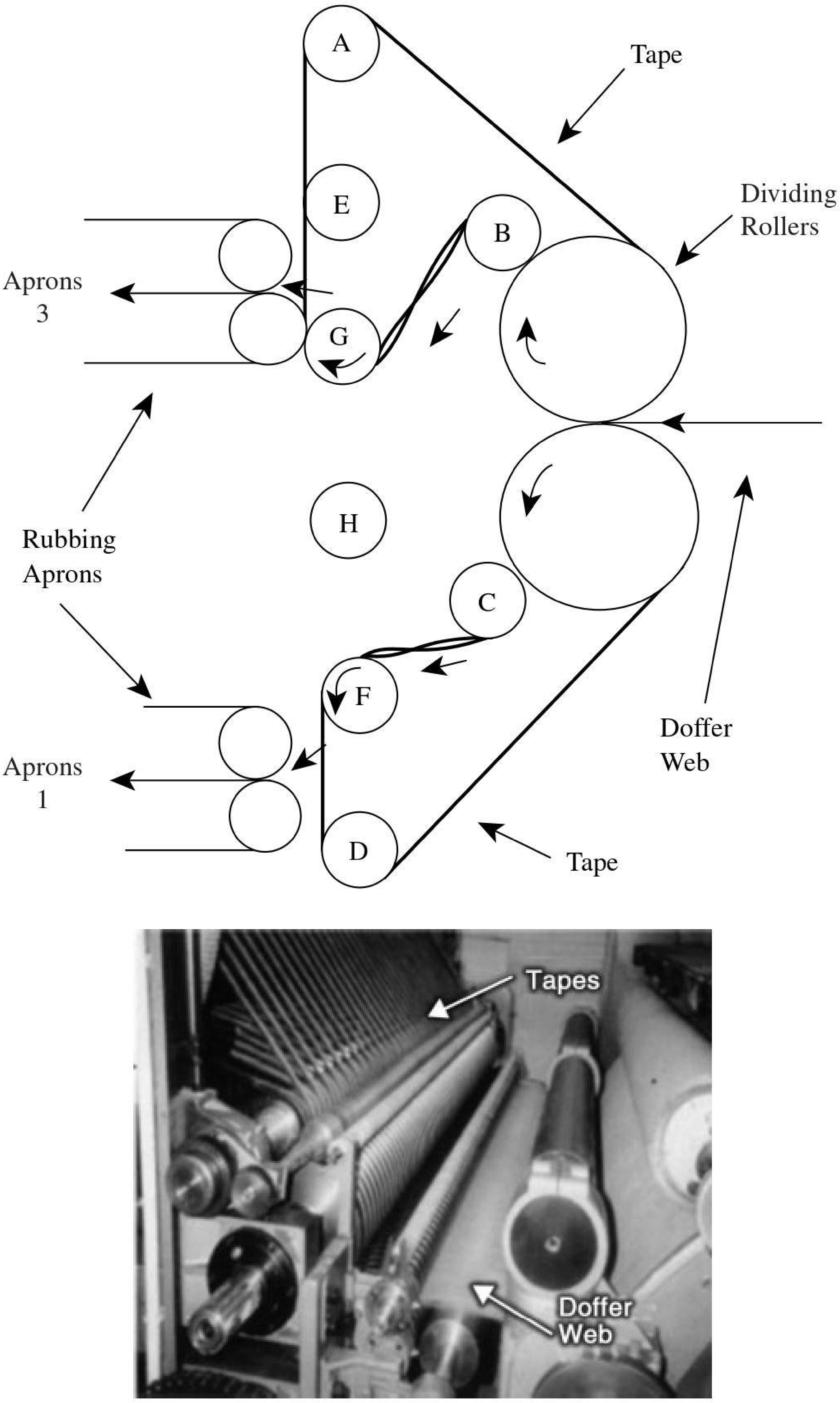


FIGURE 3.17 Tape condenser feed to rubbing aprons. (Photo courtesy of Befama Ltd.)

ribbons into slubbings. The slubbings are simultaneously fed by the aprons onto bobbins, each of which accommodates several winding positions and is driven to wind up the slubbings.

3.3.5.2 Ring-Doffer Condenser

This is an alternative method of slubbing formation, but it is not widely used. The last swift of the carder may be fitted with two or four doffers. The point clothing of each doffer is divided into a series of bands across the card width, each band

FIGURE 3.18 Bank of Rub Aprons. (Courtesy of Befama Ltd.)

being separated from the next by a narrow leather or plastic tape fixed to the doffer circumference. Thus, as fibers are transferred to the doffer, they form a series of ribbons on the doffer surface across the width of the card. The ribbons are removed from the doffer by oscillating combs and guided by separator rollers to the rubbing aprons to be condensed into slubbings.

3.3.6 PRODUCTION EQUATIONS

The draft equations for roller and clear cards can be derived along similar lines described for the short-staple card. As a worsted card produces sliver, the production rate of the card may be calculated using Equation 3.6.

The production rate, *Pc*, of the woolen card is determined by

$$P_c = 1.885 \times 10^{-7} \cdot C \cdot N_{dr} \cdot D \cdot N_{th} \tag{3.7}$$

where C = slubbing count (tex)

N_{dr}, D = rotation speed and diameter (in mm) of condenser bobbing drive rollers

N_{th} = total number of threads

3.4 SLIVER QUALITY

Much research has been carried out to establish an in-depth understanding of the physical principles of carding. Consideration of the reported findings and hypotheses merits a chapter in its own right, and therefore Chapter 4 deals in more detail with the theoretical aspects of carding. Here, it is important to consider the matter of sliver and slubbing quality in relation to the effect of various process parameters.

In carding technology, the parameters that may be used as performance indicators with regard to the sliver or slubbing are the trash and dust content (i.e., the cleaning efficiency), the amount of neps and short fiber content resulting from fiber breakage, and the level of irregularity of the sliver or slubbing. As we will see in Chapter 6, yarn quality is directly related to these parameters. The reader is to referred to the list of recommended readings to become aware of the commonly used test methods for measuring these quality parameters.

Also of importance, with respect to yarn quality and spinning performance, are the degree of fiber individualization and the types and distribution of fiber hooks. These, however, are not easily measured characteristics, so they are not used in the general practice for monitoring quality. The quality of a yarn is determined primarily by the processes prior to spinning, and the card quality parameters are of fundamental importance to the resultant yarn quality.

3.4.1 CLEANING EFFICIENCY

The importance of cleaning efficiency solely concerns the carding of natural fibers (in particular cotton) on the short-staple system and wool in the worsted and woolen processes.

3.4.1.1 Short-Staple Carding

With cotton fibers, a low level of neps and trash particles in the sliver is a major objective,[4] particularly as the impurity content of cotton slivers will increase almost linearly with carding production rate.[7] As we have seen earlier, the licker-in, fixed and revolving flats, and the cylinder play important roles in the removal of trash particles and neps.

Since the trash is embedded in the tufts that constitute the batt, how well the licker-in opens the fiber mass will largely determine how effectively trash particles are removed from the flow of fibers through the card. Although there are a number of devices fitted around the surface of the taker-in to improve cleaning, the impurities must be removed with a minimum of fiber loss, and in this the taker-in speed is the controlling factor. Figure 3.19 and 3.20 show, for different cylinder speeds, how the impurity level in the sliver decreases, but the undercard waste increases

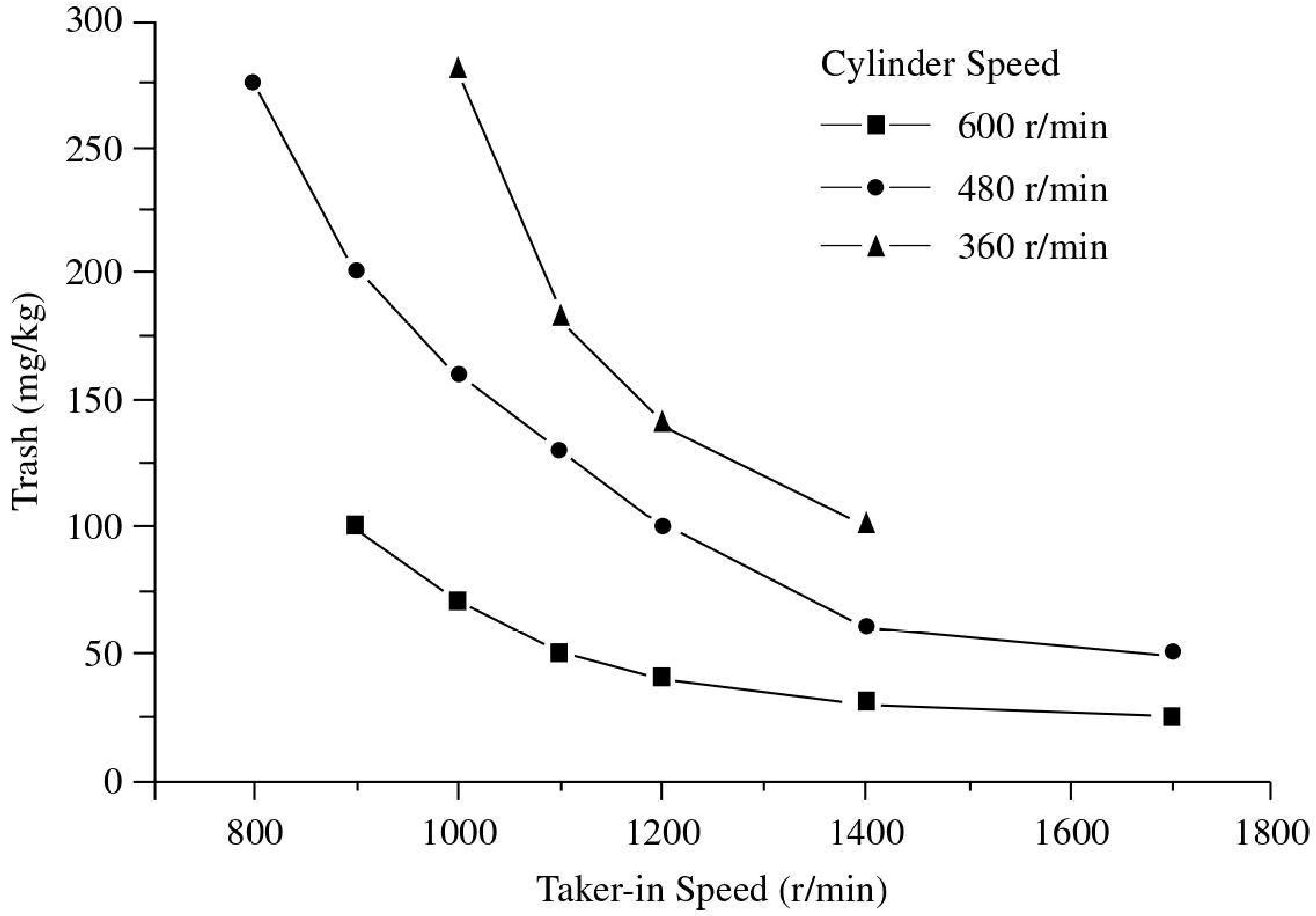


FIGURE 3.19 Trash content with increased taker-in speed.

with licker-in speed. Increasing the speed above 1500 rpm gives negligible improvement on sliver cleanliness but can lead to fiber breakage and increased waste (see Figure 3.20).

The removal of neps and trash improves with carding intensity, so the cylinder and flats speeds are important factors. Figures 3.19 and 3.20 show that, over the range of 300 to 600 rpm, high cylinder speeds will reduce trash content by greater than 50%, depending on taker-in speed, but may also caused more fiber breakage than high taker-in speeds. Increased flats speed will reduce the sliver impurity but increases flat strip waste. Adjustment of the setting of the upper edge of the top front plate to the cylinder clothing can be used to reduce flat strip waste. A close setting reduces the amount of flat strip, and a wide setting increases the waste, but reducing the waste by this means will cause much of the impurities to be fed back into the material flow and subsequently into the card sliver. Close flat settings give more intensive cylinder-flat interaction with the tuftlets; however, Van Alphen[7] found flat setting to have no significant effect on the level of impurities in the carded sliver. Front fixed flats reduces neps and fine trash particles, referred to as *pepper trash.*

Artzt[8] used a sensor fitted to the flats to determine the forces present in carding. Reportedly, the carding force, which is indicative of the stresses on fibers, showed an increase of up to 50% over the cylinder speed range. An increase of 10 to 20% was assumed to be tolerable with respect to fiber breakage. The rate of decrease in sliver impurities with rotational speed becomes asymptotic at 500 to 600 rpm, meaning that further increase in speed gives little improvement. The fiber breakage is evidently an important quality parameter. Consequently, trash and nep count on the one hand, and fiber damage on the other, are mutually conflicting quality parameters.

The overall carding system has an efficiency of 95%, which is much higher than the 65% for the opening and cleaning lines of a well equipped blowroom. Taking

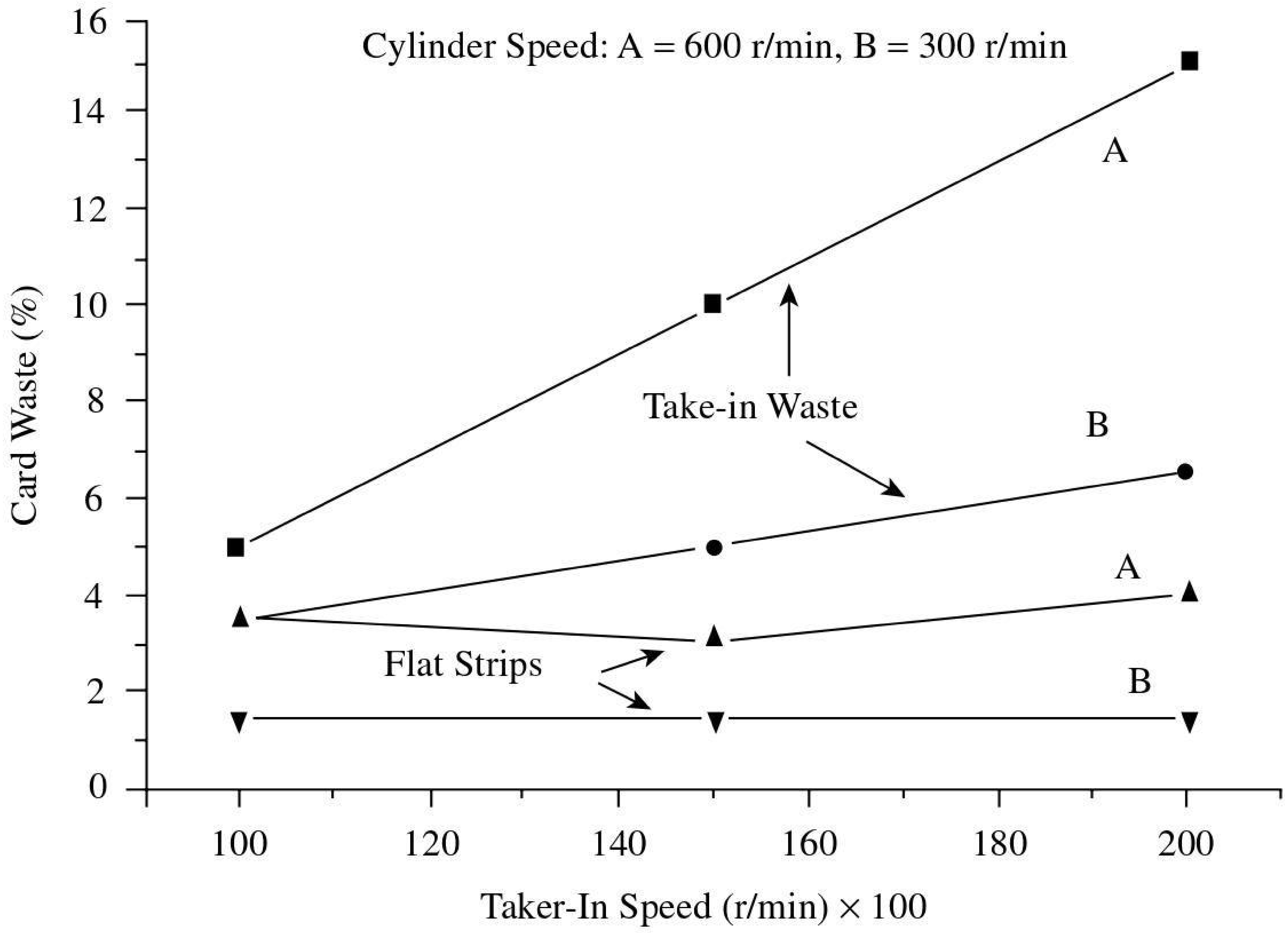


FIGURE 3.20 Card waste with increased taker-in and cylinder speeds.

the carding zones individually, the cleaning efficiency of the licker-in on its own approximates to 30%, the carding segments give 30%, and the cylinder/flats give 90%. The cylinder/flats carding action therefore gives the highest cleaning effect. Carding efficiency is better the higher the number of points, the closer the settings, and the higher the cylinder speed; the limitation on the values used for these parameters will be fiber breakage.

3.4.1.2 Worsted and Woolen Carding

VM contamination is considered to be an important problem, especially in fine wools. The number and location of deburring points and the use of crush rollers have been studied by Townend and Russell.[9] Low burr roller speeds and high Morel roller speeds were found to improve VM removal, but the waste may contain up to 60% fiber. It was also found that VM was more easily removed when the fitted card clothing was flexible fillet, as opposed to metallic wire (i.e., saw-tooth wire). See Appendix 3A. Several mechanical devices,[10,11] based on taker-in developments in short-staple carding, have been developed for improving VM removal with reduced fiber loss, but these have yet to be adopted commercially. The effect of fixed flats positioned above the licker-in/cylinder transfer point on the roller and clearer was found to give much lower nep and VM content and a better fiber orientation in output material.[12]

3.4.2 Nep Formation and Removal

The formation of neps and fiber entanglements at various stages of the preparatory processes and the removal of neps particularly in carding have been well researched.[13–21] The important fiber characteristics attributed to nep forming potential have been identified and, in the case of cotton, a neptometer,[15,16] has been devised as a useful instrument for comparative evaluation of the nep potential of cotton blends.

Definition: A nep is one or more fibers occurring in a tangled and unorganized mass.[6]

While this is a useful general definition, when it comes to cotton processing there are various types of neps. Particles that have been identified as neps in the spun yarn may be classified into four categories as described in Table 3.4.[13,19] Figure 3.21 shows typical figures for the relative proportions of each category determined with the use of an *inspection stop* fitted to the USTER® yarn irregularity tester.[13] The number of neps per gram of sliver can be measured by an instrument known as the AFIS system,[24,25] or the nep content of the card web counted manually or by online measurement with a digital camera as a sensor fitted to the card.[4] Figure 3.22 shows that there is a high correlation between measured card web neps and yarn neps. Such measurements are therefore useful for monitoring nep levels in the card slivers.

Neps usually migrate to the yarn surface during the spinning process and result in poor yarn and fabric appearance; they prevent the uniform appearance of dyed or printed cloth, instead giving spotty looking fabrics of lower market value.[22] In

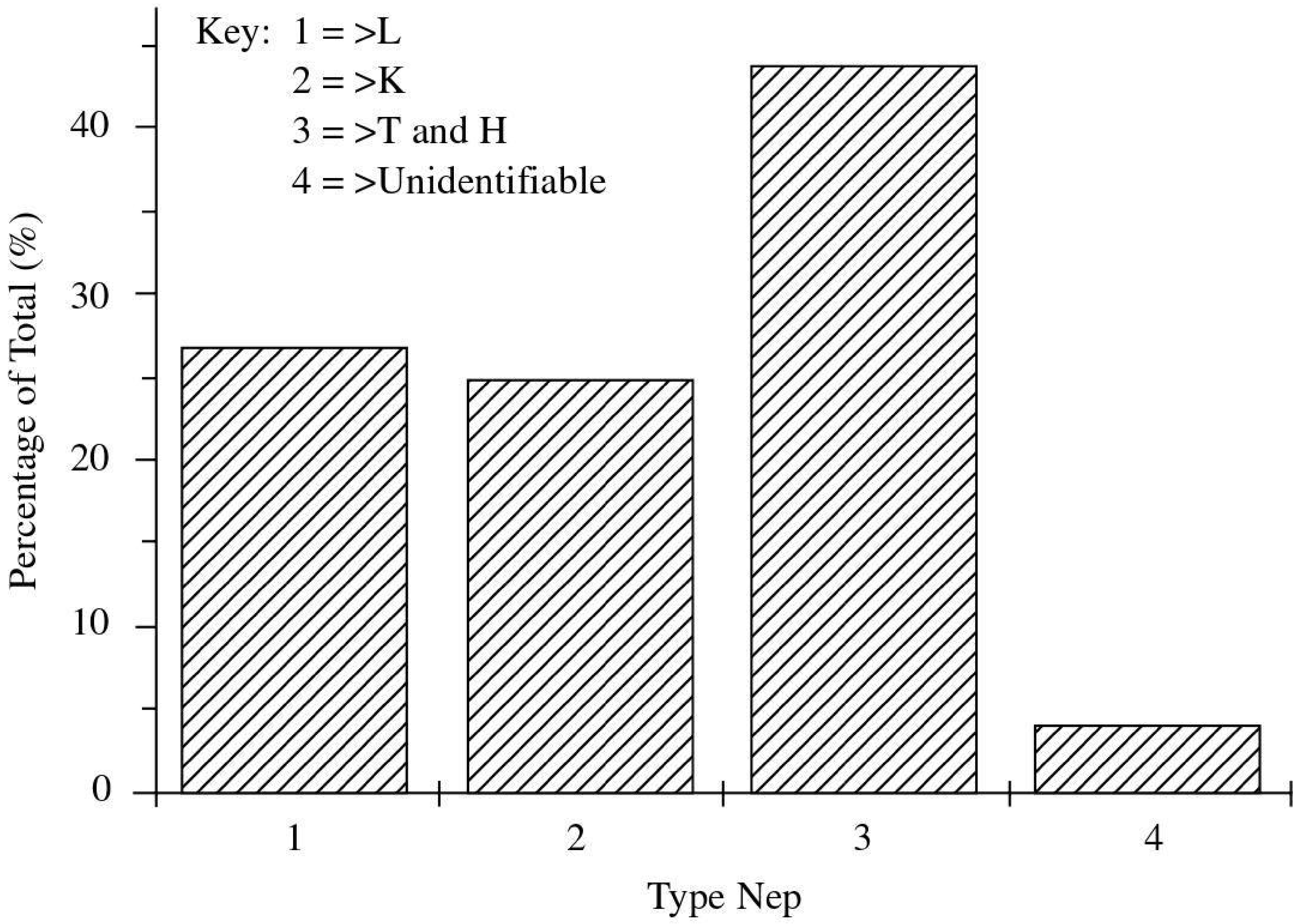


FIGURE 3.21 Types of neps in cotton fiber: analysis with Uster inspection stop. (Courtesy of Frey, M. and Schleth, A., Examples of data acquisition for fibres and the application in the spinning mill, Proceedings of the 22nd International Cotton Conference, Bremen, Germany, 1994, 1–30.)

TABLE 3.4
Nep Classification for Cotton Fibers

Nep class	Class abbrev.	Description
Loose fiber neps (may also be referred to as knops or burls)	L	A discrete entanglement of fibers larger than 1 mm; can be disentangled
Knot fiber nep	K	A discrete tightly knotted or highly entangled small (less than 1 mm) group of fibers or a single fiber; cannot be disentangled
Trash nep (not applicable to man-made fibers)	T	Leaf, stem, VM particle fragments at the core of an entanglement of a small group of fibers
Husk nep (only in cottons)	H	Seed coat fragment at core of the entanglement of a small group of fibers or with fibers attached to them

spinning, large neps may restrict twist propagation, which, for fine yarn counts, can result in unacceptably high end breakage rates. Thus, large neps may limit the fineness of count that can be spun. H-type neps can pose particular problems in certain spinning systems, in particular rotor spinning (see Chapter 4), where they account for up to 30% of thread breaks.[19]

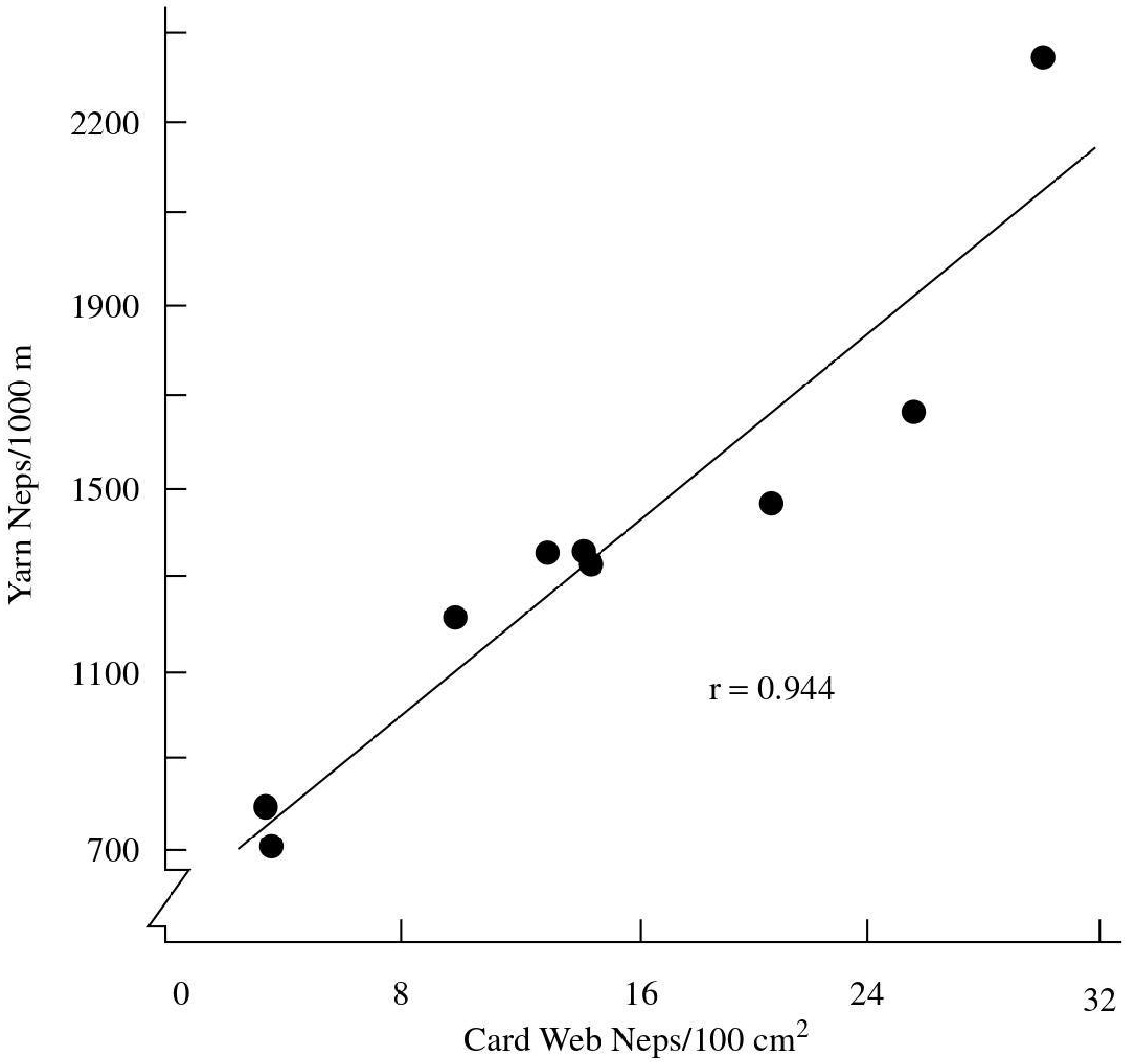


FIGURE 3.22 Relation between neps propensity in cotton yarn and card web. (Courtesy of Perkins, H. H. and Bargeron, J. D., Nep forming on a cotton card — Honeydrew —Additives as a means to reduce air-borne dust, *Melliand Textileberichte,* 2, 1981, 129–131.)

Neps generally are more conspicuous in finer-count yarns because of the diameter ratios. Such counts are often used for high-quality fabrics; therefore, the level of neps in the processed fiber mass reaching the spinning stage must be kept as low as possible. To do so, it is important to ascertain how neps are formed and how they can be removed.

3.4.2.1 Nep Formation

Neps are usually formed during the mechanical opening and cleaning processes, including ginning in the case of cotton fibers. Along with remnants of dirt, husk and trash particles in the opened mass, neps should be removed by the card. However, depending on fiber properties and carding conditions (i.e., machine settings and operating speeds), neps can be formed during carding, thereby reducing the amount that is removed. In worsted and woolen systems, the number of mechanical opening and cleaning points is much lower than in short-staple processing, which, in appropriate carding conditions, can increase the nep propensity.

Figure 3.23 shows the typical nep propensity profile for cotton processing from bale to spun yarn. L neps show a slight increase, and K neps a marked increase, during opening and mechanical cleaning, and both types decrease significantly in carding. T neps decrease at each process stage but particularly in carding. However,

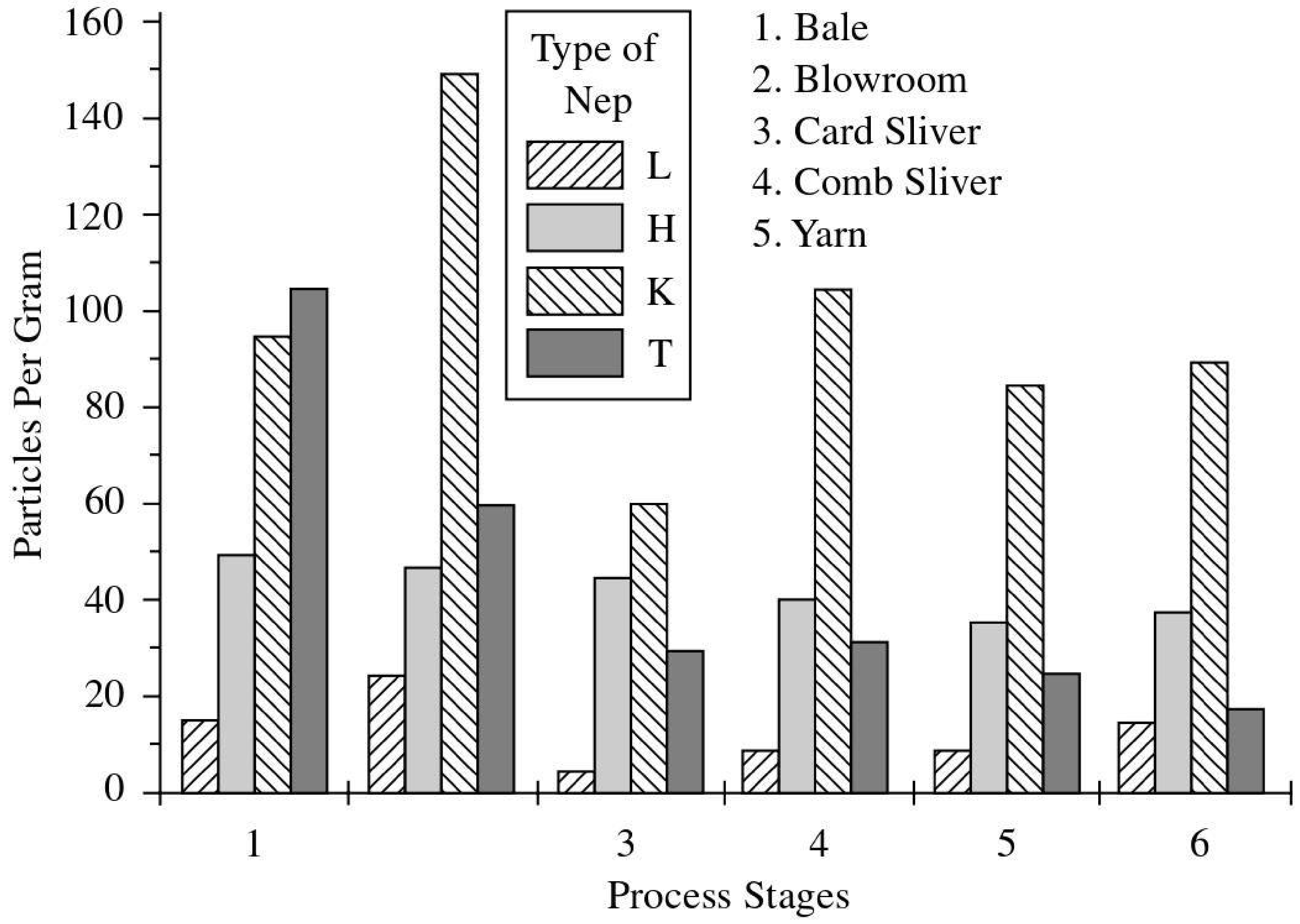


FIGURE 3.23 Typical nep propensity for cotton fibers at process stages. (Courtesy of Liefield, F., The importance of card sliver quality for the running behaviour and yarn quality in unconventional spinning methods, *Int. Text. Bull., Yarn Forming,* 4, 1988.)

H shows no major change. It should be noted that the propensity profile refers to the number of particles per gram, not particle size. Generally, the revolving flat card has a cleaning efficiency of 90% or more, and this includes the extraction of the various nep classes. For example, if 1% of the mass of the material entering the card is H neps, then only 0.1% should be present in the sliver. The measured particle count, however, shows little difference between input and output values, and this suggests that, if only 0.1% by weight is present in the sliver, the particle sizes must be much smaller. It was found that the average nep size decreases from one process stage to the next, small neps increasing significantly at the carding stage.[17–19] Similar findings have been reported for worsted processing.[9] In effect, what is happening is that, during opening, cleaning, and carding, the closer settings used for reducing tuft sizes enable large neps to be subdivided into successively smaller sizes, thereby increasing the number of small neps. The large neps in the early process stages are a mixture of fiber entanglements with the presence of large particles of VM, trash, or seed coat. Some of the smaller neps in the later process stages contain small particles, but the majority are entirely of fibrous material. The card will remove some neps at the taker-in and via the flat strips; others are subdivided by the cylinder-flats carding action, some of these being fully separated into individual fibers. However, new neps can also be formed during carding. The objective, of course, is to optimize the carding conditions so that the formation of new neps is minimized and the subdivision and disentanglement of incoming neps is maximized to result in significant total nep reduction.

There are two possible ways by which fibers can be formed into a nep. One is when a fiber or a small group of fibers is loosely caught between two surfaces moving in opposite directions (e.g., the surfaces of two cylinders both rotating clockwise or counterclockwise) or between one stationary and one moving surface.

The frictional contact with the two surfaces will cause the fiber length(s) to buckle and roll up into an entangled knot. To avoid this mechanism of nep formation, the setting or clearance between components must ensure that the motion of fibers is controlled so that they are not free to roll.

The second mechanism of nep formation is associated with fiber breakage. During processing, fibers are stretched and thereby get elastic energy. If the fiber is broken, the tension is suddenly released, and ends of broken lengths will recoil. In so doing, the lengths will buckle and may become entangled on themselves or around neighboring fibers. It is likely that the shorter lengths of the broken fibers entangle on themselves to form a nep. The entangled mass may disentangle or tighten into a nep with further mechanical actions. To avoid this kind of nep formation, machine component speed needs to be optimized to minimize fiber breakage.

It should be appreciated that the above mechanism can occur with all types of beater actions, not only carding. However, fundamental to nep formation, and also removal, is the degree of fiber entanglement in the mass to be separated into tufts, and, in the resulting tufts, mini- and microtuftlets. Townend[9] found that the most important cause of nep formation in worsted carding of wool was the entangled nature of the scoured wool fed to the card. We can see, then, that the problem of nep formation is attributable to the fiber properties important to nep-forming potential, and to the processing machinery conditions used in converting baled fiber mass into continuous strand.

3.4.2.2 The Effect of Fiber Properties

The fiber properties likely to affect the degree of fiber entanglement in a tuft, and therefore, nep formation, are

1. fineness (diameter and length, i.e., aspect ratio)
2. crimp level
3. impurity content of the baled mass (not strictly a fiber property but dependent on grade)

Townend[23] reports that, for a fixed diameter, longer fibers have a greater tendency to form neps in worsted carding. This is because longer fibers have a greater probability of being broken, the recoil of the shorter length causing it to become entangled into a nep. By analyzing neps, Alon and Alexander[21] found that, in carding 50-mm 3.3-dtex acrylic fibers, 28% of the fibers forming neps were short, broken fibers, whereas, in the associated card sliver, only 7% of fibers could be classified as short fibers, and only 2% in the bale raw stock. Based on Alon and Alexander's observation, we may assume that around 72% of the fibers forming neps were either the longer lengths of the broken fibers or entanglement of these with unbroken fibers. They report that the number of fibers found to constitute a nep varied from 5 in a small nep to 24 in a large one. Neps were identified as having a dense center where one or more fibers were located that initiated the nep formation. These fibers were looped or had very complex knot configurations and could be short broken lengths or longer fibers.

Although the above discussion is about fiber length, we must remember that an important factor in nep formation is the buckling of the fibers, either by the effect of rolling or by the sudden release of tensile stress. Therefore, in addition to length, other important fiber characteristics are elastic modulus and fiber fineness. Alon and Alexander found that the propensity for fibers to form neps is related to a buckling coefficient,

$$\sigma L^2/\Lambda \tag{3.8}$$

$$\Lambda = EI$$

$$I = \frac{\pi d^2}{64} \tag{3.9}$$

where σ = fiber stress
L = fiber length (2.5% fibrograph span length)
Λ = fiber stiffness or rigidity
E = elastic modulus
I = fiber cross section moment of inertia
d = fiber diameter

For a range of cottons, a definite linearity was found between measured neps per gram in the cotton slivers and the buckling coefficients of the cottons.[21] Clearly, stiffer fibers should have a lower nep propensity. Thus, the parameters within the buckling coefficient that combine to have the greatest effect on nep formation are fiber diameter and elastic modulus. Fiber diameter also controls the number of fibers entangled in a given tuft size, i.e., mass. We learned in Chapter 1 that, within a cotton variety, fineness and maturity are represented by micronaire; the higher the micronaire, the coarser and more mature the fiber and the greater its rigidity. Figure 3.24 shows that, as the micronaire of cottons increases, the nep level of a card web decreases.[15,16]

Immature cotton fibers have low micronaire values, and Gulati and Ahmed[26] and Pryor and Elting[27] observed that neppiness was significantly correlated with the number of immature fibers in a cotton mass. Evenson[28] considers the variation in fineness and maturity within a given grade to be of equal importance. Blending with higher micronaire cottons can therefore reduce nep levels. Table 3.5 shows a similar trend for wool and mmf with respect to fineness.[23]

Table 3.6 indicates that nep levels increase with the degree of fiber crimp. The higher the crimp level, the greater will be the entanglement within fiber tufts and the more severe the shear action required to individualize fibers causing fiber breakage and associated neps.

Aside from the properties that define the buckling coefficient, it should be evident that the frictional characteristics would have strong influence on the disentanglement of neps in carding. Therefore, surface finish and applied lubrication to the fiber stock are of importance. Townend[23] also found a correlation between moisture content of the opened wool fed to the card and the neps per gram of sliver. Although not strictly a fiber characteristic, the type of particulate impurity in the baled fiber mass can

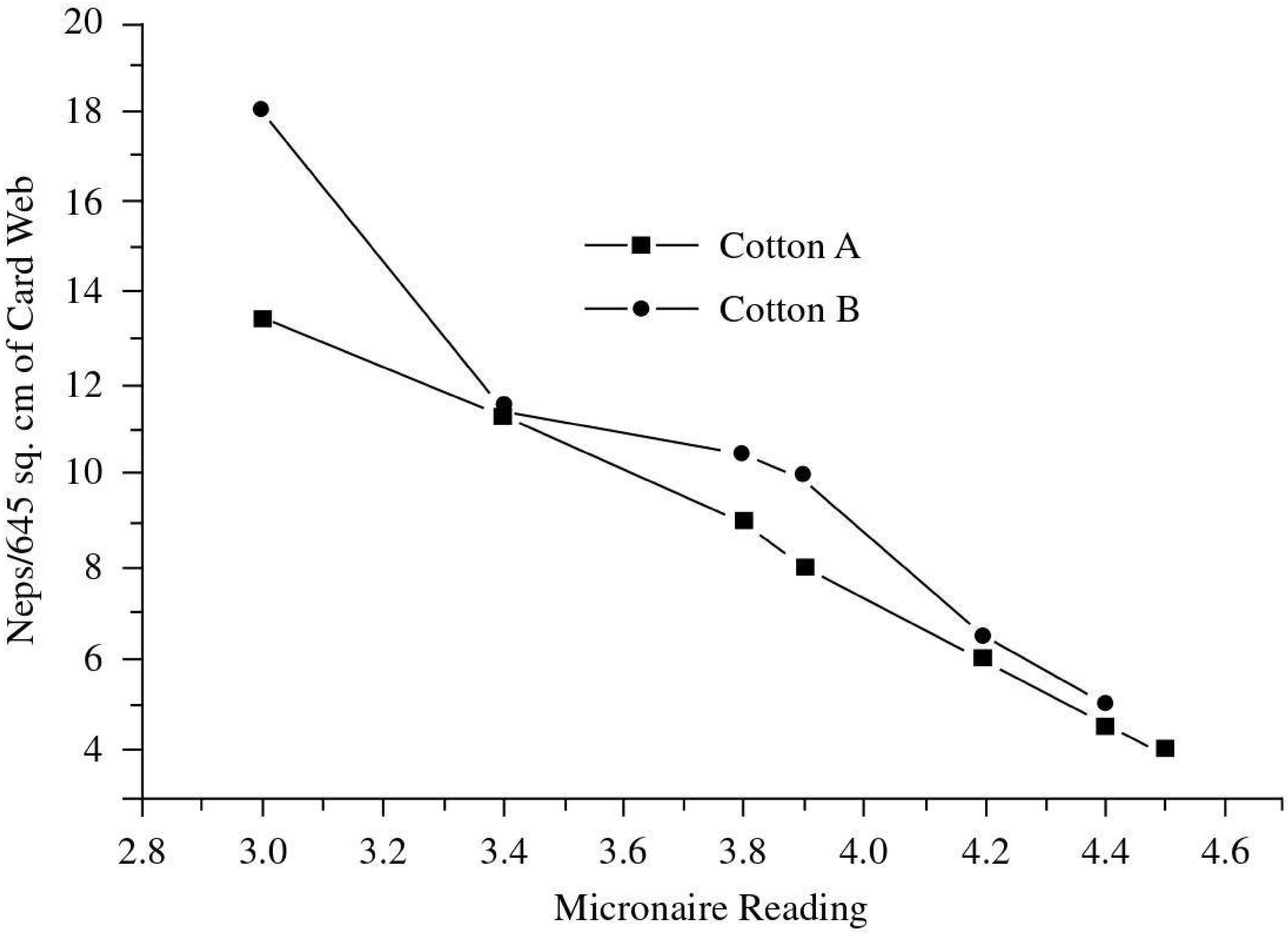


FIGURE 3.24 Effect of cotton micronaire on card web nep levels. (Courtesy of Perkins, H. H. and Bargeron, J. D., Nep forming on a cotton card — Honeydrew — Additives as a means to reduce air-borne dust, *Melliand Textileberichte,* 2, 1981, 129–131.)

TABLE 3.5
Effect of Fiber Fineness on Nep Levels in Card Sliver

Fiber type	Mean fiber diameter (μ)	Neps/g of card sliver
Australian 64s–70s	20–22	1,466
Australian 58s–64s	22–26	1,135
New Zealand 58s	26	640
New Zealand 56s	28	410
Mew Zealand 50s	31	277
New Zealand 46s	34	204
Nylon 3.3 dtex 57mm	19	474
Nylon 5.0 dtex 57mm	23.5	381
Nylon 8.8 dtex 57mm	33	100
Nylon 16.5 dtex	46	16

Courtesy of Townend, P. P., *Nep Formation in Carding,* WIRA, Leeds, U.K., 1983.

influence the nep level. Particles that are difficult to remove from tufts may require very intensive beater action and therefore cause high level nep to be generated during the mechanical opening and cleaning stages. This can lead to greater sliver neppiness.

3.4.2.3 Effect of Machine Parameters

The production rate employed in carding has a negative effect on nep removal, particularly when processing fine dtex man-made, low-micronaire cottons and low-

TABLE 3.6
Effect of Fiber Crimp on Nep Levels in Card Sliver

Fiber type	Crimps/cm	Neps/g of card sliver
Nylon 3.3 dtex 57mm	4.3	220
Nylon 3.3 dtex 57mm	6.3	294
Nylon 3.3 dtex 57 mm	7.9	361
Acrylic 5.0 dtex 57mm	2.0	6
Acrylic 5.0 dtex 57mm	5.5	78
Acrylic 5.0 dtex 57mm	9.5	205

Courtesy of Townend, P. P., *Nep Formation in Carding,* WIRA, Leeds, U.K., 1983.

micron wools. It is likely that, with increased production speed, the higher cylinder loading results in a lower subdivision of neps entering the card and in increased fiber breakage, thereby forming new neps. However, Harrison and Bargeron[16] found that the tandem carding of cottons was more effective in nep removal than single-cylinder high-production cards. Kaufmann[29] reports that, with a revolving-flats card, taker-in speeds below 700 rpm have little influence on nep count at the card, but, above this value, the nep count in the card web increases significantly with speed. Harrison and Bargeron[16] found that this increase with speed was applicable only to low-micronaire or immature cottons; generally, for coarser cottons, taker-in speed has no meaningful effect.

The settings and surface speeds associated with the flats-cylinder-doffer actions on short-staple cards, and likewise those for the worker-swift-fancy-doffer on roller and clear cards, have a significant effect on the nep level of the card web — so, too, the wire specifications for these components. Table 3.7 summarizes the reported findings with regard to these parameters.

TABLE 3.7
Effect of Machine Settings and Component Speeds on Card Web Nep Levels

Component	Parameter	Nep/g
Worker/cylinder/doffer	• Sharpness of tooth: increased land area of tooth	–ve
Flats/cylinder/doffer	• Surface speed: increasing	+ve
Swift/doffer Cylinder/doffer	• Working angle of tooth: greater for cylinder and swift	+ve
Worker/cylinder/doffer Flats/cylinder/doffer	• Setting between components: close setting	+ve
Fancy/swift	• Setting: close setting	+ve
	• Speed: increased speed	+ve

+ve = improvement in web quality; –ve = deterioration in web quality.

Clearly, subject to the avoidance of fiber breakage, close settings and increased speeds reduce nep levels. This is because both parameters influence the shearing action of microtuftlets and neps entering the carding zone and any fiber agglomerates entering the cylinder-doffer zone. Townend[23] reports that improved performance with respect to nep removal is obtained with closer settings of the worker to the swift. Kaufman[29] claims that the cylinder-doffer transfer point is an important carding as well as stripping point, and that the intensification of the carding action here will produce a cleaner, less neppy web. A reduction in doffer surface speed increases the carding action and was found to reduce the nep level. The reason why this finding conflicts with the trend given in Table 3.7 is likely to be that increased doffer speed (at a fixed production rate) gives a lighter web, thereby dispersing neps over an effectively wider doffer surface area, which enables better contact between neps and wire points and thereby intensifies the carding action in the cylinder-doffer zone.

With regard to wire specifications, Table 3.7 indicates that the smaller the land area of tooth (i.e., the sharper the wire points), the lower the nep level, since the wire points can better penetrate neps to separate the fibers. It is also evident that reduced neppiness occurs when the working angle of the doffer is smaller than the swift or cylinder. The smaller doffer-wire angle gives a better transfer coefficient (see Chapter 4) and therefore less fiber in the recycling layer on the cylinder, resulting in a reduced cylinder load and a reduced chance of fiber breakage.

Ashdown and Townend[30] have shown that the point density of a card clothing is an important factor in reducing the nep level of the card web. The point density of a card wire clothing depends on the tooth pitch and the spacing between rows of teeth, and the wider the spacing, the greater the chance for neps to become lodged between rows of teeth and escape the carding action. However, as the point density increases, the possibility of fiber breakage increases. Consequently, an optimal specification has to be reached, depending on production rate and fiber type.

Husk and trash neps are not usefully affected by the shear action during carding. However, the combination of knife-edge and applied suction at the fixed flats may remove some of these neps, and others may be caught in the flat strips. The crush rolls are also used to dislodge particles from their attachment to fibers to be subsequently removed in downstream processes.

Although cotton stickiness in carding, i.e., honeydew, is not a nep-forming characteristic, it is a recurring problem that can have a disrupting effect on production and a degrading one on quality. Cottons contaminated with honeydew are difficult to card because of severe sticking and buildup of fiber on working components. This is particularly evident on the crush rolls, where the result is frequent breakage of the card web. Stickiness is largely associated with freshly cropped cotton and can become less problematic when the cotton is stored for three to six months.[31] The cotton may then be processed by blending them with uncontaminated fiber, but a suitable blend proportion has to be determined by trial and error. Perkins and Bargeron[20] found that sticky cottons can be processed with little difficulty by a tandem card, but that the stickiness problem resurfaces in the downstream stages. However, when a dust-control additive or overspray[31] was applied to the stored cotton, this generally alleviated the stickiness in carding and downstream processing.

The additive on the cotton continuously coats the surfaces of the working components with a thin film of lubricant to prevent the honeydew from gaining a purchase on the surfaces.

3.4.2.4 Short Fiber Content

What is meant by the short fiber content (SFC) of a fiber mass was explained in Chapter 1. In the production of short-staple, worsted, and semi-worsted yarns, SFC can present difficulties in processes downstream of carding and, as a result, lower yarn quality. It is important that, during the carding operation, fiber breakage be kept to a minimum. With woolen spinning SFC is much less of a problem, since the slubbings produced at the woolen card are subjected to only a small draft in the subsequent spinning stage, and the method of drafting is effective for nearly all fiber lengths.

We learned above that nep formation is closely linked to fiber breakage. It is not too surprising to find that, for cotton fibers, the typical SFC profile for the process stages from bale to yarn is very similar to the typical nep propensity profile. Figure 3.25 shows the changes in SFC associated with the various stages of material preparation.

Cotton bolls have very few short fibers. A significant amount of fiber breaking occurs in the harvesting and ginning of cottons, which results in the baled fiber mass having an SFC of around 10%. As is the case with nep propensity, the mechanical opening and cleaning in the blowroom increases the %SFC, but the level is reduced in carding, since most of the flat-strip waste is composed of short fibers.

In worsted processing, the lower number of mechanical opening and cleaning steps means that, similar to neps, the SFC of the card sliver is mainly dependent on the carding conditions. Hence, the factors enabling low nep levels in the card sliver

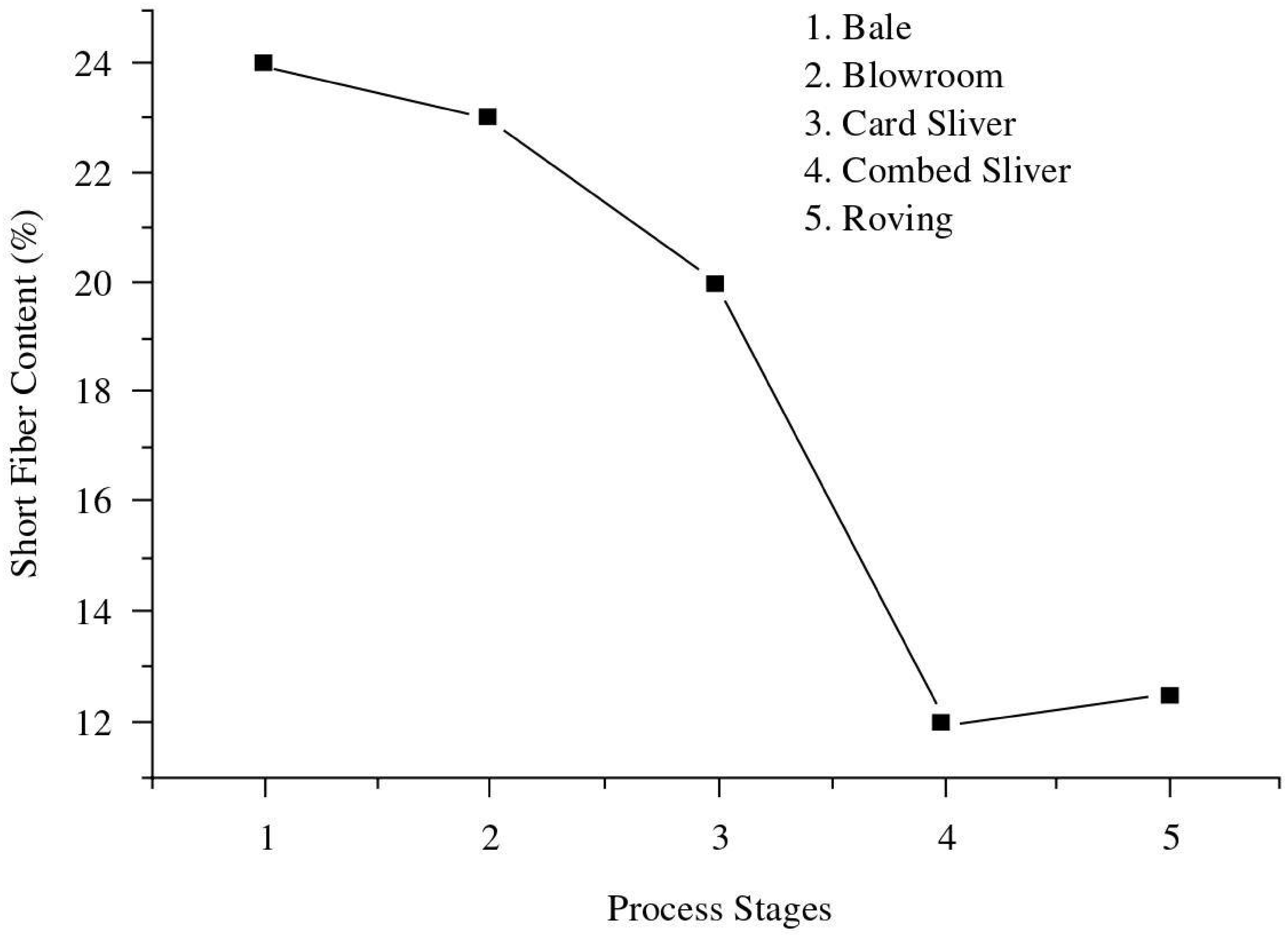


FIGURE 3.25 Changes in SFC during material preparatory. (Courtesy of WIRA.)

will also keep SFC to a minimum. Fiber-card wire friction experiments[32] have shown that the lubricant viscosity is a key factor in reducing fiber breakage in worsted carding. The optimal viscosity was found to be 20 centipose, and the optimal add-on around 0.5% by weight. Appendix 2A discusses the application of lubricant to scoured wool.

3.4.3 SLIVER AND SLUBBING REGULARITY

The variation of the thickness of a yarn along its length and the measured yarn count, as we shall see in Chapter 6, are very important yarn characteristics to the quality of woven and knitted fabrics, and the variation of the sliver thickness is a contributing factor. The terms used in referring to thickness variations along the length of linear fibrous assemblies are *levelness, evenness, regularity, unevenness,* and *irregularity.* The latter will be used in this and subsequent chapters, since it conjures up the appropriate mental image of a linear assembly of fibers in which the number of fibers in the cross section is not uniform along its length.

The Basic Concepts of Irregularity

In considering the basics concepts of irregularity, what will be explained is applicable not only to card slivers but also to all linear fibrous assembles of subsequent processes, i.e., drawn and combed slivers, rovings and yarns. It is, therefore, appropriate to use the general term *linear fibrous assembly (LFA)* during the following descriptions.

The variation in thickness along the length of an LFA is related to the variation of the number of fibers in the cross section throughout that length. Therefore, the variation in mass per unit length can be taken as a measure of the irregularity of the LFA. There are several ways by which the variation in mass per unit length can be determined, but the most widely used instrument for doing so is the Zellweger Uster irregularity tester.[5] This is based on a capacitance method in which a sample length of the material is made to run between a parallel-plate capacitor approximately 1 to 2 cm long, depending on the type of LFA; a 2-cm capacitor would be used for slivers and a 1-cm for yarns. The changes in capacitance reflect the mass variations between successive 1- or 2-cm lengths along the sample length, and if plotted on a chart would look similar to Figure 3.26a. This shows the irregularity of a card sliver, caused by cardfeed variation, as a random waveform in which the peak values, or amplitudes, are the actual measurements. The coefficient of variation of the measurements, the CV%, may then be stated as the irregularity value for the sampled length of the LFA. This measure of mass variation with respect to 1 or 2 cm length is commonly called the Uster irregularity or Uster CV%.*

It is generally accepted that the most uniform arrangement of fibers that can be obtained with current process machinery is one in which fibers are randomly distributed. A number of researchers have developed mathematical models for such an ideal LFA.[33–35] Martindale[36] has shown that, theoretically, the CV% for such an arrangement can be calculated from

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* In many of the older references cited, U% values are given, representing the *Uster values*. The U% is the percentage mean deviation (PMD). CV% = 1.25U%.

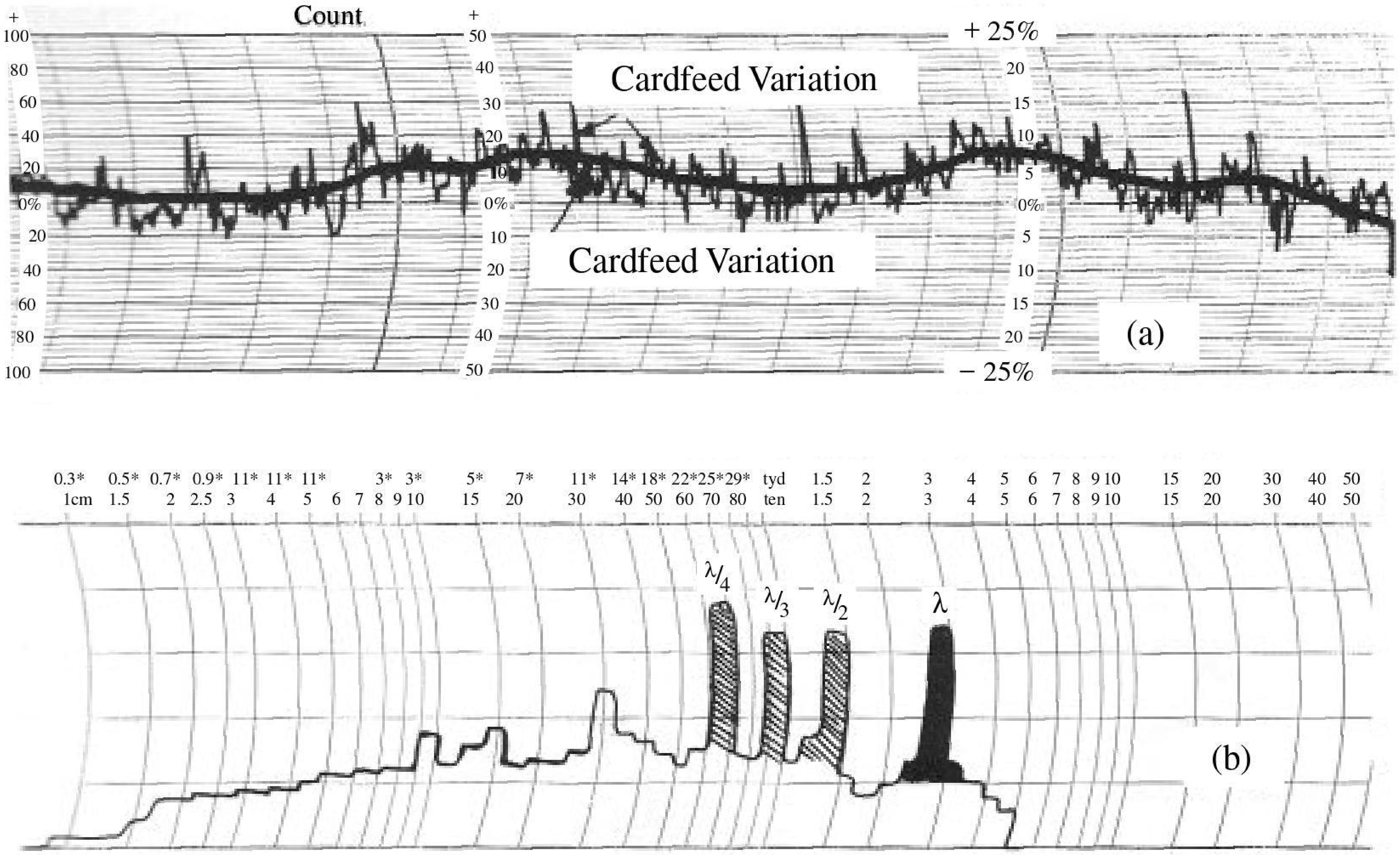


FIGURE 3.26 Irregularity trace and spectrograph of LFA. (Courtesy of Hattenschiler, P. and H. Muller, *Introduction to the Art of Quality Control in Yarn Manufacturing,* Zellweger Uster AG, 435.)

$$(CV_{min}\%)^2 = \frac{(CV_f\%)^2 + 10^4}{n} \tag{3.10}$$

where $CV_{min}\%$ = theoretical minimum coefficient of variation of the LFA
$CV_f\%$ = coefficient of variation of the fiber linear density
n = average number of fibers in a cross section of the LFA

(See Appendix 3C.)

By measuring the actual irregularity $CV_{act}\%$ and calculating $CV_{min}\%$, the following ratio can be used as an *index of irregularity, I*:

$$I = \frac{CV_{act}\%}{CV_{min}\%} \tag{3.11}$$

Thus, the greater the value of I above unity, the more irregular the LFA will be. The index of irregularity, however, is a useful indicator of quality only if no machine faults or processing errors occur to add significantly to the measured CV%.

Because of such faults, there may be recurring particular values of amplitude within the random waveform. These values denote periodic faults, and the distance between a particular reoccurring amplitude within the random waveform gives a measure of the periodic wavelength related to the fault.

As we shall see later, steps can be taken in post-carding processes to reduce a high CV% of a card sliver. Little, however, can be done with periodic faults. Therefore, periodic faults of sizeable amplitudes are detrimental to yarn quality and are very likely to result in seconds-quality fabrics. Since periodic faults can occur at any process stage, it is essential to identify the process at which they occurred so that the problem can be rectified. A graph of the periodic amplitudes plotted against their wavelength is used to highlight significant periodic faults. This wavelength spectrum is called a *spectrograph* or *spectrogram,* and Figure 3.26b shows an example of the spectrogram relating to the irregularity chart, Figure 3.26a, for the card sliver.

The chart shows several periodic amplitudes among the random waveform, and the spectrogram depicts the associated amplitudes along the ordinate and the wavelengths along the abscissa. The pronounced amplitudes are the significant periodic faults. Periodic faults may be classified according to their wavelength using the fiber length as a unit length.[37]

- 1 to 10 times the fiber length: short-term variation
- 10 to 100 times the fiber length: medium-term variation
- 100 to 1000 times the fiber length: long-term variation

The classification is important, since it can be used to trace the source of a periodic fault. The reader wishing detailed information on the tracing of periodic faults should consult References 38 through 42.

From the chart in Figure 3.26a, it can be seen that the center line drawn through the random waveform also varies. This indicates an inconsistency in the sliver count and is attributable to variation in the feed to the card.

If a sufficiently long sample of an LFA were to be tested by the capacitor method, the measured values obtained could be divided into groups having an equal number of measurements. The sum total of each group would vary, and the product of the number of measurements and the capacitor length would give the set length on which the variation would be based. Hence, the CV% of the linear density for this set length could be calculated. Clearly, the CV% values for a range of set lengths could be determined in this way, the Uster CV% being one. The Zellweger Uster irregularity tester may be used to perform this task electronically and to plot a graph of CV% values against set lengths. The resulting graph is called a variance-length curve and is illustrated in Figure 3.27, plotted on logarithmic scales. It should be evident that, as the set length increases, the average total number of fibers constituting the length also increases. Consequently, the CV% of the fluctuations in the mass per unit length should decrease with increased set length. If the trend deviates from a straight line as shown, it signals unacceptable variations in the mass flow of the material during production. The source of the problem can be determined in a similar manner to the periodic faults described above. Variance-length curves are mainly used for yarns. With slivers and slubbings, the following alternative approach is considered more practical.

The irregularity of a sliver is determined for three types of variability: short-, medium-, and long-term changes.

Short-Term Irregularity

The Uster CV% of a sliver is a measure of the irregularity of short reference lengths along the sliver, but it is not a useful predictive indicator for the Uster CV% of the

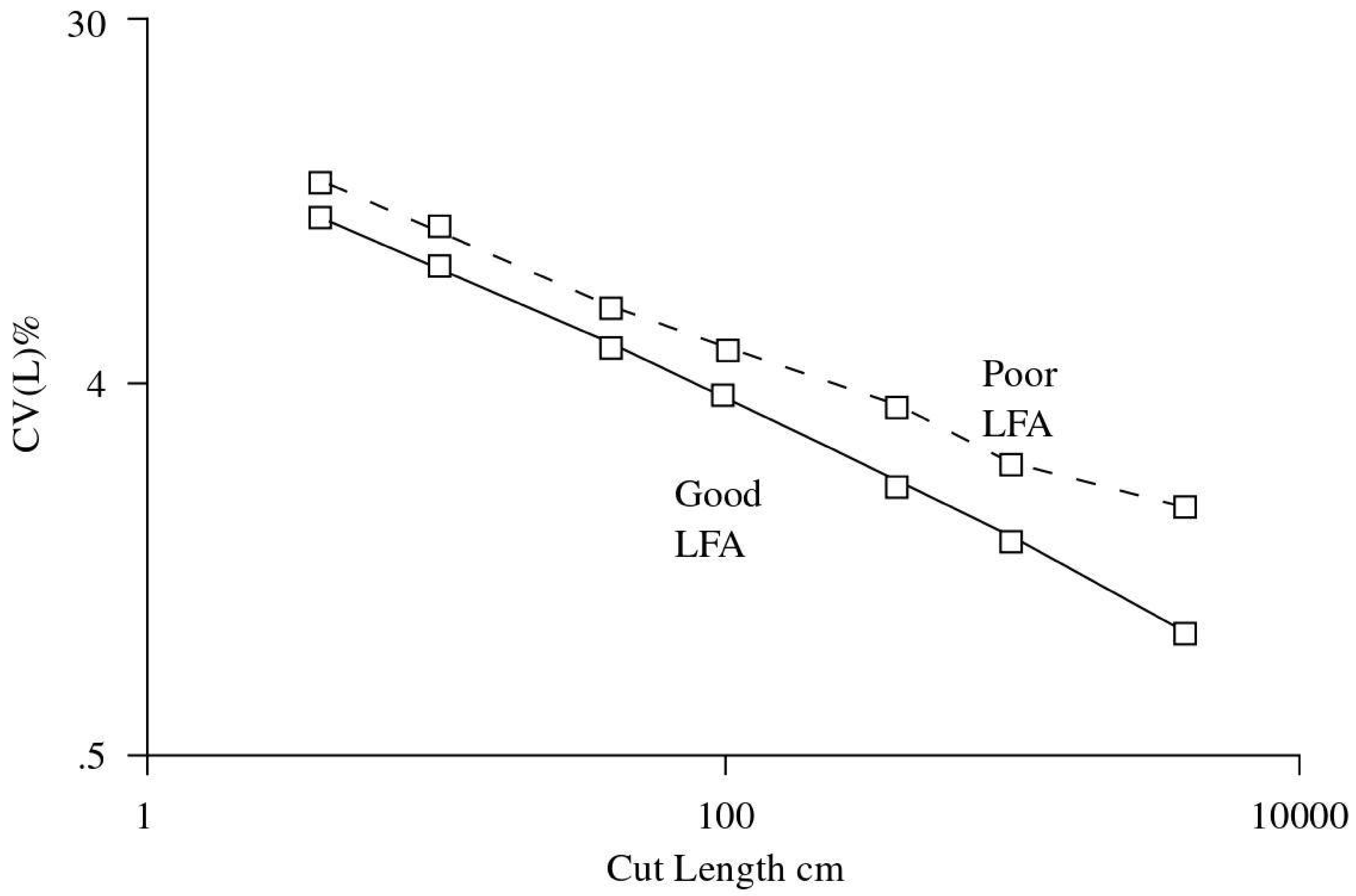


FIGURE 3.27 Variance-length curves of LFAs. (Courtesy of Saville, B. P., Physical Testing of Textiles, The Textile Institute, Manchester, UK, Woodhead Publishing Ltd., Cambridge, UK, and CRC Press, Boca Raton, FL, 1999.)

yarn.[43] This is because the short-term irregularity for a yarn is more dependent on the short-term variations introduced during post-carding processes in which there is attenuation of the sliver count to obtain the yarn count. However, the yarn resulting from the further processing of a sliver is usually checked for count consistency by using100-m yarn lengths, and these would have originated from much shorter lengths of the sliver. Thus, the sliver Uster CV% is important to the measured count variation within, say, a given yarn package.

During carding, with each cylinder rotation, the doffer removes only a fraction of the fiber mass on the cylinder, and the recycled fraction gives a blending and evening effect to the mass flow while the card is running. This is of particular importance to roller-clearer cards, as is explained in Chapter 4. The effects of the evening action are reflected in the Uster CV% of the sliver.

In woolen spinning, the card web is not consolidated into a single sliver but split into a series of ribbons, and each is consolidated to make a slubbing. The slubbings are subsequently given only a small attenuation during conversion to a woolen yarn. Thus, the Uster CV% of the slubbing has importance to both the yarn Uster CV% and the measured count variation within a yarn package.

Medium- and Long-Term Irregularity.

Figure 3.28 illustrates the medium- to longer-term variability of a sliver; that is to say, the irregularity of a sliver length that comprises a full can of sliver and the variation between cans of sliver. The Uster CV% is not a measure of this variability. The CV% of sliver count measurements, made at random intervals during carding, is therefore an appropriate indicator of such variations. The importance of monitoring and controlling medium and long-term variability can be seen from Figure 3.29.

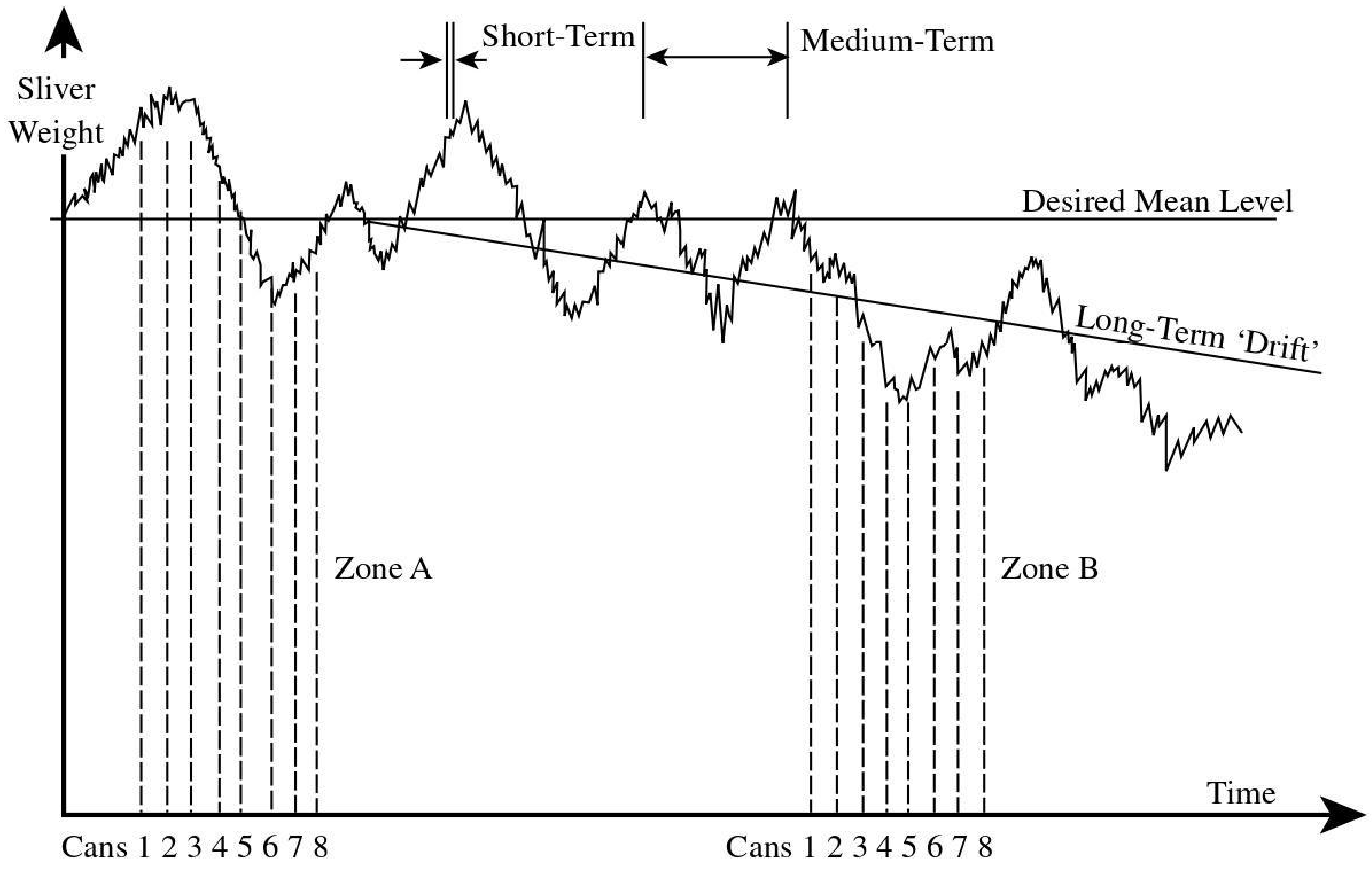


FIGURE 3.28 CV% of Sliver count: short-, medium-, and long-term irregularities. (Courtesy of Crosrol UK Ltd.)

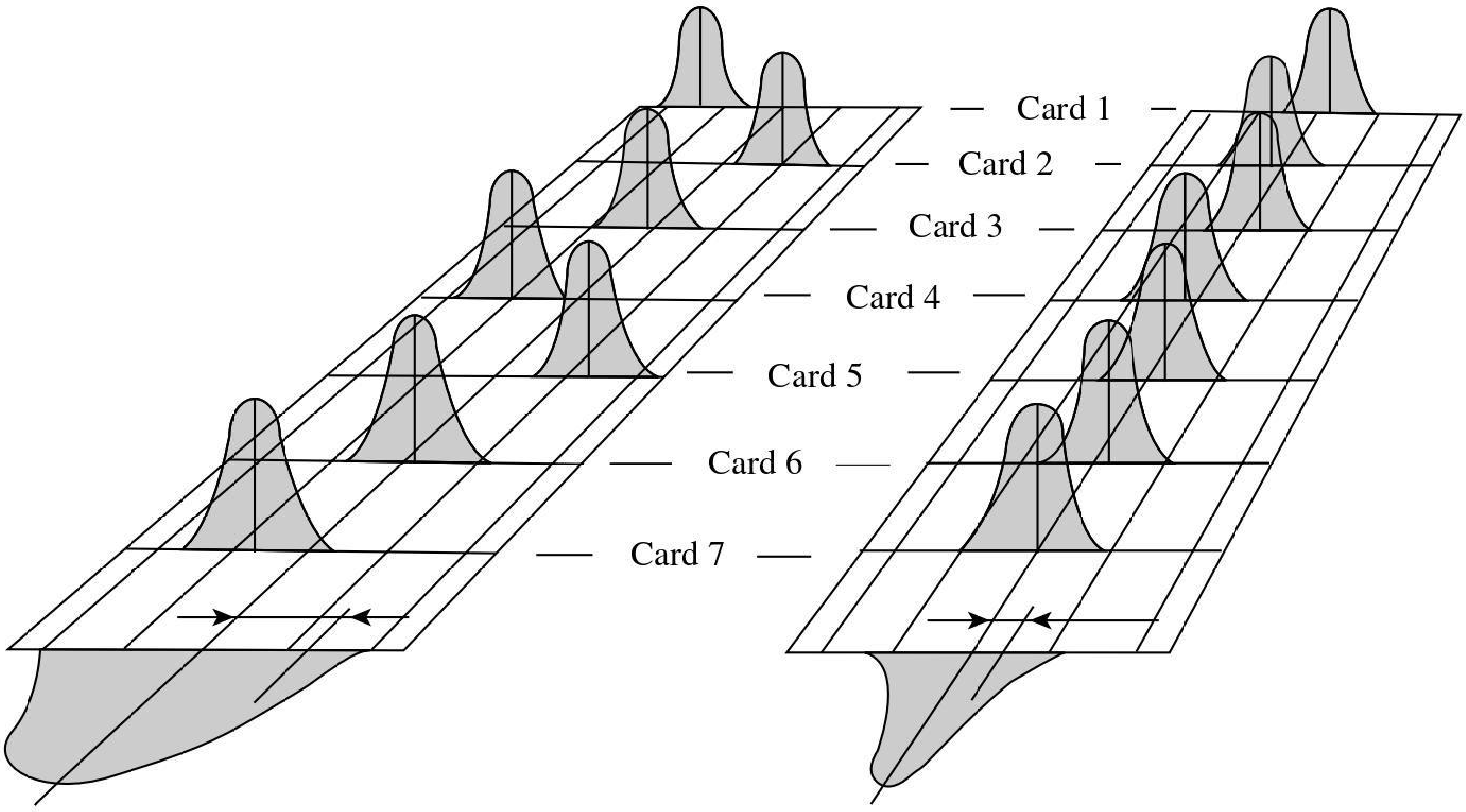


FIGURE 3.29 Count variations within and between cards. (Courtesy of Crosrol UK Ltd.)

Where there are several *drawing* process steps following carding; the short- and medium-term irregularities can be significantly reduced during these processes. However, these processes cannot readily correct for the long-term drift of the sliver count. The problem is particularly important for short-staple processing where a multiple of cards are needed to match the blowroom production. Long-term drift associated with each card can result in unacceptable sliver count variations. Thus, at any given moment during production, the mean sliver counts of each card may give, statistically, a widespread distribution for the carding process (see Figure 3.29). To overcome this difficulty, autolevelers are usually fitted to the cards.

In woolen carding, variation in the mass per unit area of the card web across the width of the woolen card will cause the produced slubbings to have significantly different counts as well as different Uster CV% values. One of the purposes of the intermediate feed section between the scribbler and the carder is to keep this variation to a minimum. However, long-term drift of the output from the scribbler may occur and cause a statistically wide spread distribution of the slubbing count that is unacceptable. Autoleveling is therefore also of importance in woolen carding.

3.5 AUTOLEVELING

The principles of autoleveling are based on the fundamentals of control theory, which is beyond the scope of this book. However, the reader wishing to study the theoretical aspects of autoleveling should find Reference 44 informative.

Essentially, the basis of an autoleveling system is to control the consistency of output from a process by deliberately altering the input so that a measured value of a parameter characterizing the output has minimum deviation from a preset value. Alternatively, a measured value characterizing the input may be monitored and, when deviating from a preset value, the input is deliberately changed with the intention of maintain minimum variation of the output. The first approach is referred to as closed-loop autoleveling, and the second as open-loop autoleveling. Figure 3.30 depicts the main features of these two types of control system. S and A represent the locations of the sensors and actuators, the dotted lines show the signal path, and the solid lines illustrated the material flow.

The open-loop system results in a quicker response time to the deliberate changes, since the lag time of the process is avoided. However, there is no feedback from the output to ensure that corrections made achieve minimum variation of the output characteristics. Most autoleveling systems on cards employ the closed-loop principle. The idea is for the sensor to monitor the sliver irregularity and the control unit to interpret the electronic data in terms of variations in the sliver count from the preset count required. Then, according to the size of any unacceptable differences and whether they are greater or less than the preset value, the control unit automatically modifies the draft of the card by slowing or increasing the feed roller speed. The time elapsed between changing the feed roller speed and its effect detected in the output sliver is the *response time* of the carding process or the *lag time* resulting from the process. Carding has a slow response time, so, when closed-loop systems are used to adjust feed roller speed, only long-term sliver irregularity can be controlled, and the system is called a *long-term autoleveler.*

Various types of sensors may be used to monitor the sliver irregularity,[45] but the tongue-and-groove device is probably the most popular and is considered to be very simple and reliable. This basically consists of a grooved bottom roller through which the sliver passes while under compression by a top roller that fits the groove. Variation in the sliver thickness causes the top roller to rise and fall, thereby monitoring the sliver irregularity. The movement of the top roller is converted into an electronic signal, which is fed to the control unit. Figure 3.31 illustrates the tongue-and-groove system and also shows the use of two pairs of rollers to provide a quicker response time for the control of short-term sliver irregularity, i.e., a *short-term autoleveler.* The two pairs of rollers are used to apply a small draft of up to 1.5 on the output sliver. These rollers precede the tongue-and-groove sensor. The very small movements of the top measuring roller are amplified by a low-friction lever arrangement that, in turn, moves a hydraulic valve to vary the rate and direction of oil flow to a piston. The piston mechanically operates a speed variator that increases or decreases the speed of the draft control rollers. The speed of the coiler rollers depositing the sliver into sliver cans is also varied to avoid uncontrolled changes to the sliver count.

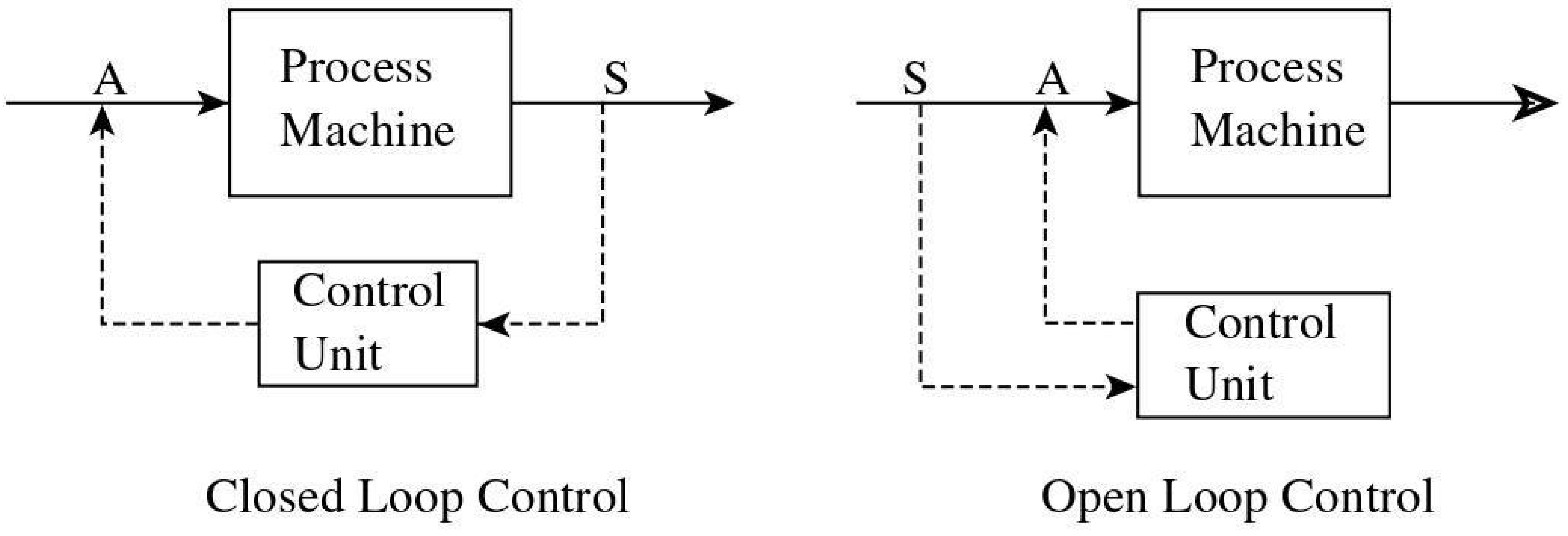


FIGURE 3.30 Closed-loop and open-loop control systems.

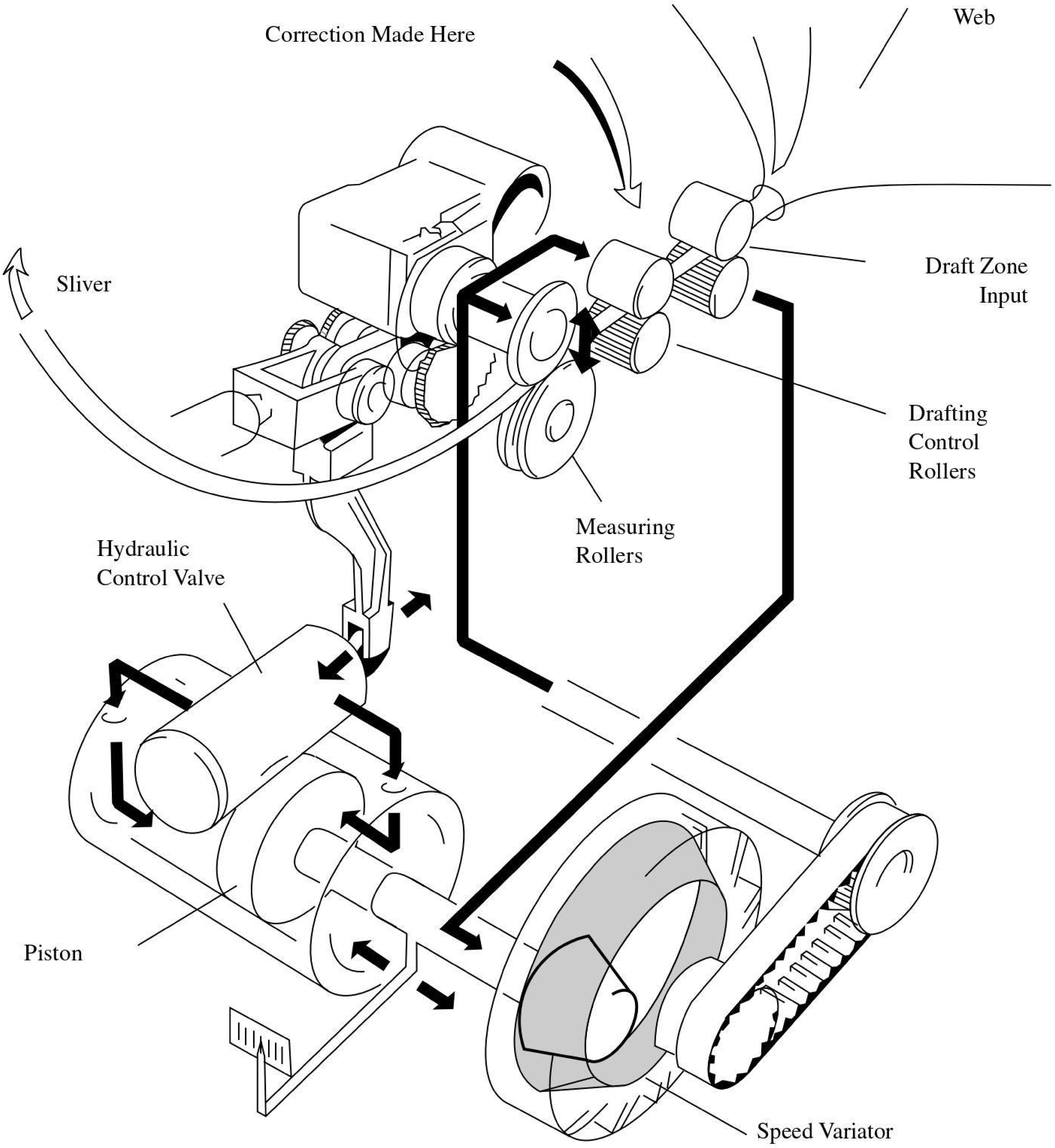


FIGURE 3.31 Tongue-and-groove device fitted for short-term closed-loop autoleveling at the card. (Courtesy of Crosrol UK Ltd.)

In woolen carding, the web leaving the last doffer is monitored for unacceptable variations. The sensor is an optical device that measures the intensity of a beam of light passing through the web. Variations in the mass per unit area of the web are detected through changes in the intensity of the transmitted light and the data received electronically by a control unit. To avoid a very slow response time caused by the size of carding set, or even that of the carder section, the control unit is made to alter the doffer speed so as to minimize variations of the mass per unit area of the web from the preset value required. The system, however, is capable of controlling only medium- and long-term variations in the carded web.

Open-loop systems, as indicated earlier, are fitted to the feed device to the card. The sensor either monitors thickness of the batt or mass per unit area. This is done prior to the measured portion of the batt being fed forward by the feed roller, and the necessary change to the feed roller speed is regulated to increase or reduce the feed rate. The thickness may be monitored, as illustrated in Figure 3.32, for a short-staple card. The pressure senor is fitted at the front of feed plate, where the plate and feed roller forms a wedge to progressively compress and nip the batt; changes in the batt thickness are readily detected.

An alternative thickness monitor, known as the Servolap system (developed by the manufacturer Houget Duesberg Bosson) and fitted to roller-clearer cards, uses gamma radiation to penetrate the fiber mass and a scintillation tube to detect the ray intensity transmitted through the mass. The measured changes are used to control a chute or volumetric hopper feed to the card, so the control system is in fact a closed-loop autoleveler for the hopper feeder rather than an open-loop system for the card.

Figure 3.33 illustrates the use of a weigh plate positioned between the lattice feed and the feed-rollers on the forepart section of the woolen card. As the fiber mass passes from the chute feed or hopper feed to the feed rollers, it crosses over the weigh plate. Deviations in mass per unit area from the preset required value are then corrected by automatically adjusting the speed of the feed rollers.

Most autolevelers will correct fluctuations in the monitored fiber mass of up to ±30 percent and minimized deviations to within ±1 to ±2%, based on the mass of 5-m lengths of sliver. Closed-loop, short-term autolevelers and open-loop systems, because of their faster response time, give good levels of control over short lengths.

3.6 BACKWASHING

Traditionally, after worsted carding the wool sliver may be given a wet-cleansing treatment called *backwashing*. This would be done to remove soiling, which may have occurred during carding.[46] Since washing and drying of the sliver disturbs the fiber arrangements, the slivers have to be lubricated and gilled in preparation for

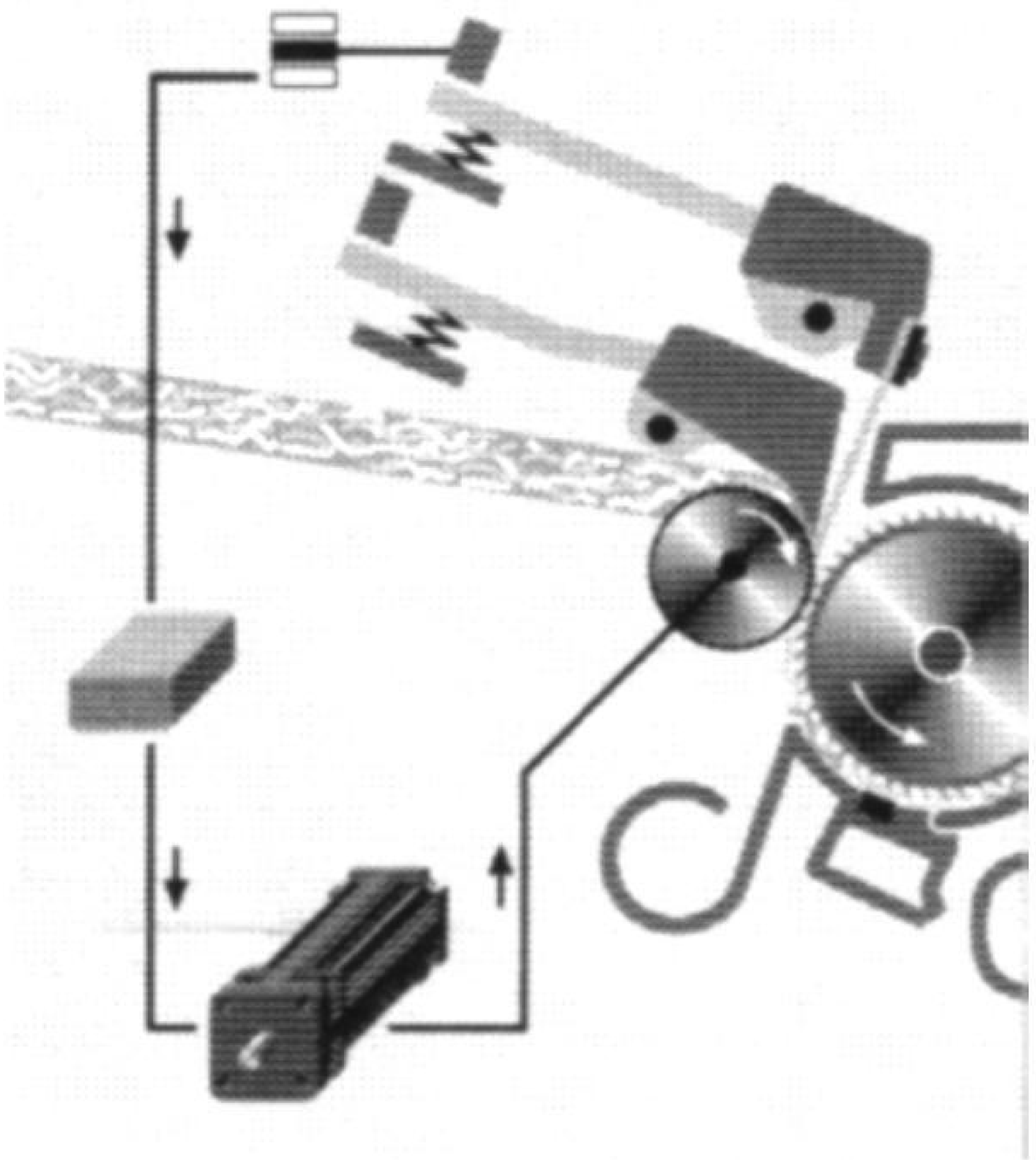
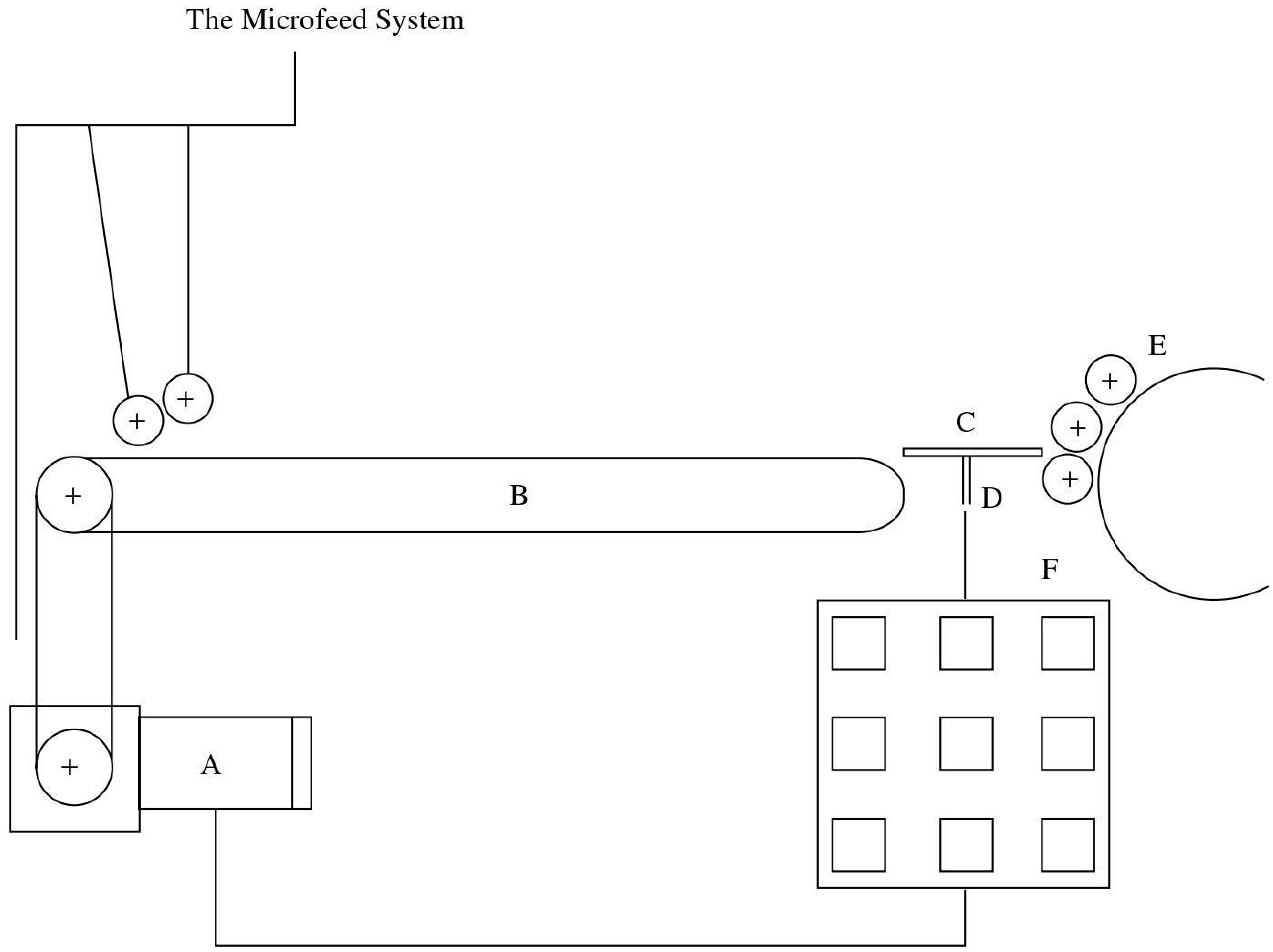


FIGURE 3.32 Open-loop autoleveler on short-staple card. (Courtesy of Rieter Ltd.)



A. Drive Unit
B. Hopper Feed Sheet
C. Weighing Plate
D. Load Cells
E. Feed Rollers
F. Display Panel

FIGURE 3.33 Use of weigh plate in open-loop autoleveler.

combing. Backwashing is not always practiced today because of the prohibitive cost and because improved lubricants applied at the blending stage reduce soiling during carding.

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APPENDIX 3A

Card Clothing

Two types of card clothing are used today: flexible or fillet wires, and saw-tooth wires (commonly called *metallic wires*). Historically, flexible clothing was the first to be fitted to all card components. Metallic wire became prominent in the early 1960s with the increase in production rates from 5 to 20.5 kg/hr of cotton cards. Fillet wires tend to require regular cleaning (termed *stripping and fettling*) to remove trapped waste fibers, whereas metallic wires dispense with this requirement. The use of metallic wire rapidly spread into worsted and semi-worsted carding as economics underlined its nonfettling advantages.

Fillet wire is still widely used in woolen carding because of its advantage over metallic wire in being able to process blends of very different fiber types, color mixtures, and oil and grease content, and because it provides a gentler action for weak fibers. However, metallic wires are used on the forepart of a woolen card set, where large tufts have to be opened, with the fillet clothing being fitted to the carder section where a high point density is required for more precise separation of fibers. The focus of this appendix will be on metallic wires. The subject of flexible card clothing is well covered in a monograph by Alan. G. Brydon.[47]

3A.1 METALLIC WIRES: SAW-TOOTH WIRE CLOTHING

Figure 3A.1 shows the key parameters of saw-tooth wire geometry that govern the performance of metallic wire clothing, fixed flats and revolving flats. Table 3A.1 gives the range of typical values for the parameters.

3A.1.1 TOOTH DEPTH

In Figure 3A.1, ←a→ is the working depth of the tooth. This determines the fiber-carrying capacity of a tooth. Taker-in wires are required to perform the initial task of breaking down and opening up the entangled fiber mass, and as such the tooth depth should be large. Cylinders, swifts, and stripper wires should have short working depths so as to prevent high fiber loading and to keep the fiber at the tip of the tooth to maximize the shear force of the carding action. Workers and doffers should have large working depths so as to hold the fiber mass for effective carding and fiber

Tooth Depth	a and b
Tooth Angles	Θ and Φ
Point Population	m / in. and n/ in.
Point Dimension	x and y

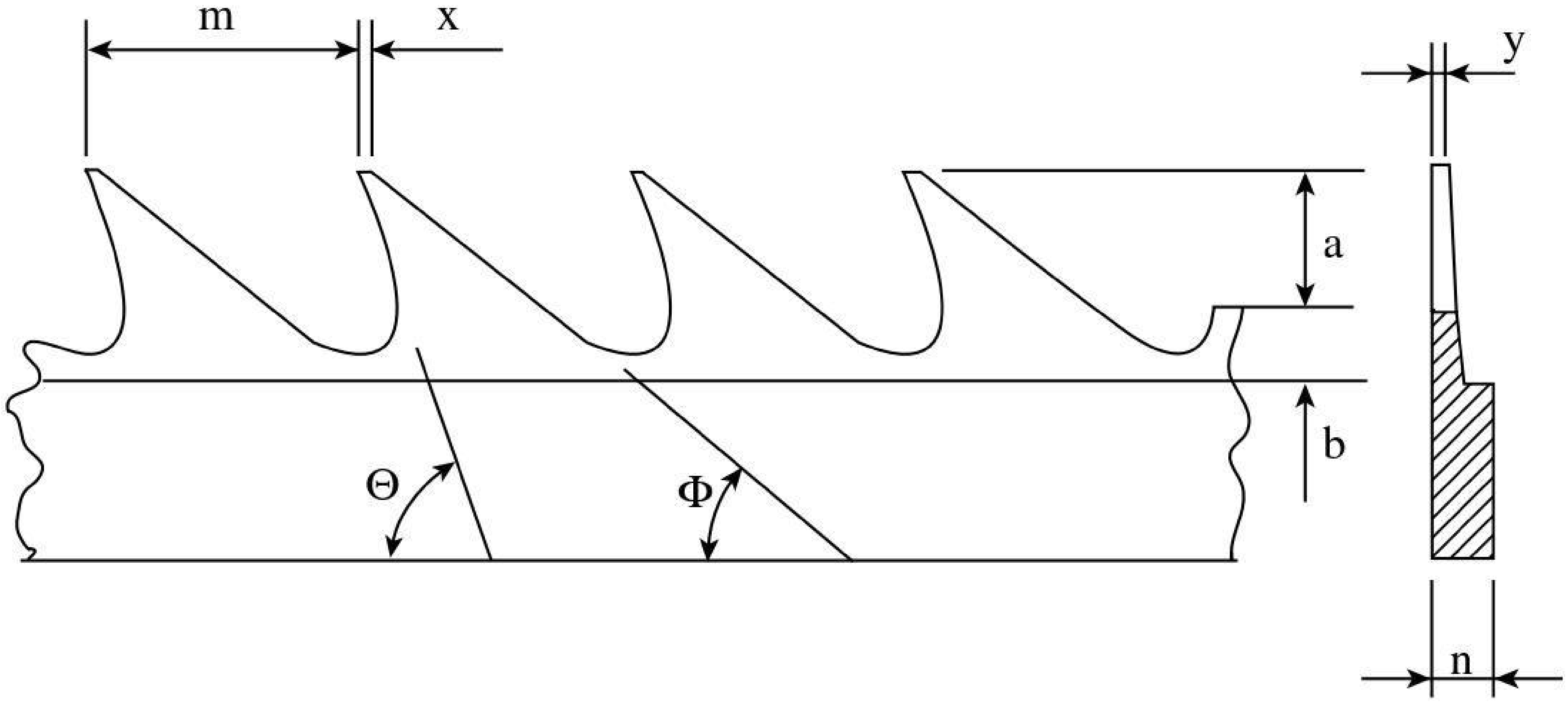

FIGURE 3A.1 Saw-tooth wire geometric parameters.

TABLE 3A.1
Revolving Flat Cards and Roller Clear Cards

Component	Θ	*m* (mm)	*a* (mm)	ppsi
Revolving flat cards				
Taker-in	78–90°	1.95–760	(a + b = 5 − 6.65	27–208
Cylinder	50–80°	1.30–3.0	(a + b) = 2.0 − 2.65	240–1075
Doffer	60°	1.80–2.20	(a + b) = 3.70 − 4.70	298–403
Roller clear cards				
Taker-in	50°	5.30–8.60	1.34–2.74	19–78
Swift	70–80°	1.80–3.20	1.46–1.85	224–398
Doffer	50–55°	2.50–3.10	0.95–1.25	166–272
Worker	50–60°	3.00–4.15	3.00–3.43	52–215
Stripper	50–75°	4.10–4.25	1.23–3.00	62–105
Morel	50°	3.80–5.50	1.60	73–212

transfer during doffer web formation. Morel wires have shorter depths, since the aim is to keep VM particles above the web of fibers and in easy striking range of the burr beater.

Measurement ←b→ is the base depth of the tooth, which is usually free of the fiber mass but is important to the aerodynamic effects generated by the rotating components. Too shallow a depth can result in pressure points and fiber blowouts, producing a patchy web.

D3 → is the tooth depth of the revolving flats. Strictly, the revolving flat wires may be either flexible, semirigid (as illustrated in the diagram), or rigid (metallic saw-tooth). Currently, flexible and semirigid are most widely used, but much research and development is being invested in increased use of rigid wires. The clothing is flexible if it deforms under temporary bending stress and then resumes its original position. Basically, this is achieved by the base of the round wire lengths being held in a laminated foundation fabric, which has suitable elastic properties. Semirigid clothing is of a similar construction, but flat wire is used for increased rigidity, and base fabric is made of denser material. Since the vital function of the tops is to provide an effective holding of tuftlets during the carding action and to retain short fibers and impurities, the tooth depth must not be shallow.

3A.1.2 TOOTH ANGLES

Front angle, θ. This determines the fiber-holding power of the tooth. For roller-clear cards running without a fancy roller, the tooth angle of the swift clothing should be near upright, i.e., ranging from 70 to 80 °, with the use of a fancy roller a shallower angle may be used, 60 to 70°. The teeth of swift clothing are required hold and carry fibers through the carding zones but enable a controlled release of fibers to the doffer. The doffer and worker clothing require more acute angles than the swift, which, combined with tooth depth, give greater fiber-holding power.

With the short-staple card, a more acute angle (60 to 66°) is necessary for cottons, since the fibers are more entangled than for man-made fibers (70 to 75°). For carding a blend of cotton and man-made fibers, cotton wire specifications are mainly used. Similar to roller-clear cards, the angle of the doffer wire is critical to the control of the fiber transfer efficiency and therefore the sliver quality. With too low a transfer efficiency, the cylinder load will be high, causing the sliver to have a high nep count. Reducing the tooth angle of the doffer should assist in rectifying the problem. However, if the transfer efficiency is too high, the card web will appear patchy with very small groups of unseparated fibers, and therefore the doffer tooth angle should be increased.

Back angle, β. This assists the holding power of the clothing in that a large angle assists fibers to become embedded in the teeth. This is an advantage for the worker and doffer clothing but not for the cylinder, swift, and stripper clothing.

Flats carding angle, α. The working angle of the flats is within the range of 75 to 80°. Low angles will too strongly resist the cylinder wire removing fibers and can result in fiber breakage. Conversely, too large an angle prevents effective carding and also results in neps.

3A.1.3 POINT DENSITY

Essentially, point density or tooth density is an important contributing factor to the carding capacity or carding power, and the amount of carding power needed to separate fibers is defined by a combination of the fiber length and fineness within fiber mass to be processed. The carding power is the number of teeth present on the working surfaces for processing the fiber mass passing through the card. Thus, the number of teeth per fiber can be determined from the equation for the intensity of opening. Carding quality improves when the number of teeth per fiber is just less than one for both the taker-in and the cylinder (or swift of the carder section). However, too low a value may increase the short-fiber and nep levels.

3A.1.4 TOOTH POINT DIMENSION

The x and y dimensions are important to point penetration into tufts. When $xy = 0$, the teeth has a needle point. This gives the best penetration and reduces nep levels but is most susceptible to damage and is important for the cylinder wires when carding fine fibers. With roller-clear cards, the tooth point dimensions should be finer on the carder section — particularly on the swift.

3A.2 FRONT AND REAR FIXED FLATS

The metallic wires used have a simpler geometry than the other wire clothing. To withstand the impact from large particle impurities, the rear fixed flat has a high front angle, θ, a low back angle, β, and a low population. The front fixed flats have a similar geometry so as not to hold fibers but to prepare fibers for doffing in a more controlled manner.

3A.3 WEAR OF CARD CLOTHING

Although heat treatment and wear-resistant coatings are used, the performance of card clothing degrades overtime because of tooth point wear. For example, in carding cotton, the cylinder and flats clothing usually must be repeatedly reground to sharpen the teeth after 200 to 1000 tonnes of throughput, depending on production rate and cotton grade. Even though grinding improves the performance of a worn clothing, the tooth point dimension would have increased, and therefore the effectiveness is less than when the clothing was new. With successive grinding treatment, clothing will reach a stage at which nep levels are considered unacceptable, and the clothing will then need to be replaced.

APPENDIX 3B

Condenser Tapes and Rub Aprons

3B.1 TAPE THREADINGS

The examples below are for a four-apron layer.

3B.1.1 THE FIGURE 8 THREADING

In this configuration (see Figure 3B.1), each tape is threaded in a figure 8 and, from one end, placed around and along the dividing rollers. Tensioning rollers A, B, C, and D are then brought into contact with the tapes. Tensioning rollers F and G are then positioned so that odd-number tapes feed the odd-number aprons (i.e., aprons 1 and 3). Similarly, rollers E and F are positioned so that even-number tapes feed even-number aprons (i.e., aprons 2 and 4). The half twists in the belts ensure that the same belt surface is always in contact with the dividing rollers, thereby transporting the fiber ribbons to the rubbing aprons.

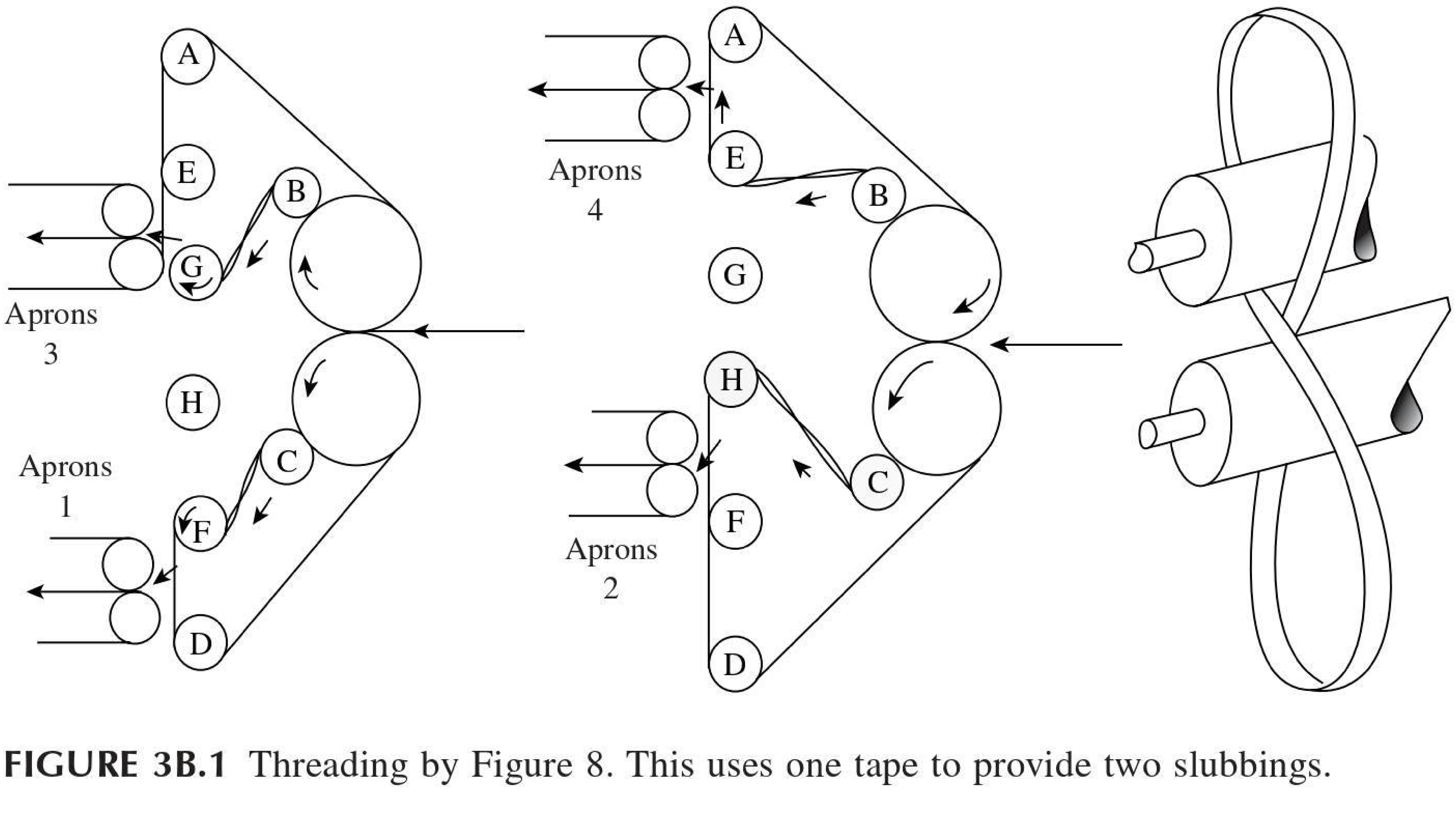

FIGURE 3B.1 Threading by Figure 8. This uses one tape to provide two slubbings.

3B.1.2 Series Threading

Series threading (Figure 3B.2) uses one tape to provide one slubbing. For a one-to-one arrangement the card web must pass between the entry rollers so that odd-number tapes are above it and even-numbers are below or visa-versa The scissors action of the tapes divides the web and ribbons are transported to the relevant rubbing aprons. Again a half-twist is put in the tape but on the return path.

3B.1.3 Endless Threading

Here, an endless tape is made to follow the two paths shown in Figure 3B.3 alternately across the card width, thereby providing the network for feeding the rubbing aprons.

3B.2 RUBBING APRONS

Figure 3B.3 shows diagrammatically the main features of one of a pair of rubbing aprons. The endless leather (or plastic-covered) apron is mounted on three rollers.

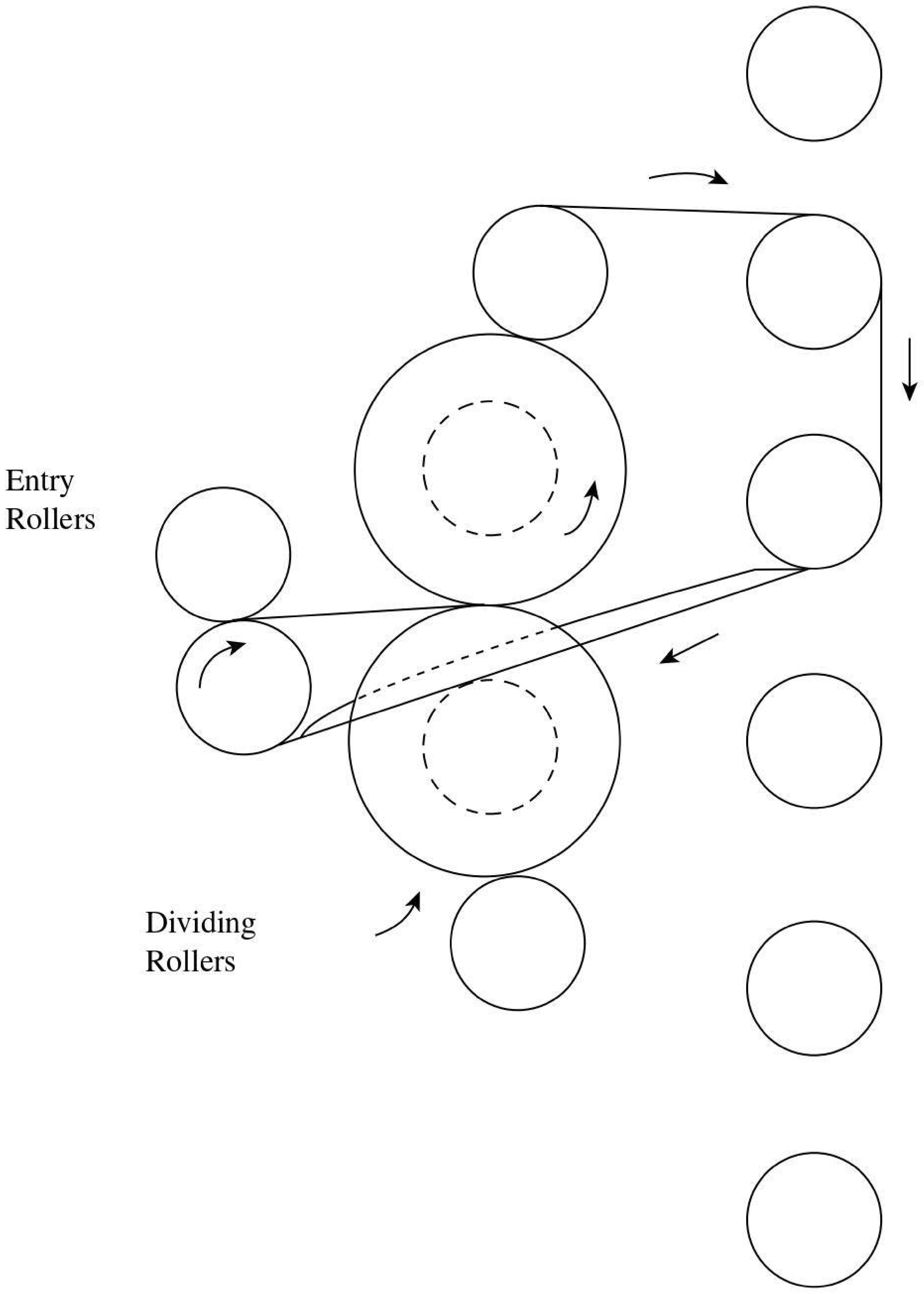

FIGURE 3B.2 Series threading.

The whole assembly stretches the width of the card. A gear wear fitted to the shaft of one of the rollers is free to slide in a driver gear wheel (not shown). This allows the reciprocating action of the aprons to proceed without hindering the rotation of the driven shaft and thereby the circulating movement of the apron. A driven shaft with a double eccentric gives the rubbing aprons their reciprocating action. Thus, the reciprocating action consolidates the fiber ribbon while the circulating movement simultaneously feeds the formed slubbing to the package build device. The number of rubs per minute may be 200 to 600. A higher rate is needed to make finer slubbings than that required for coarse ones, and the use of two banks of rubbing aprons in tandem improves slubbing consolidation.

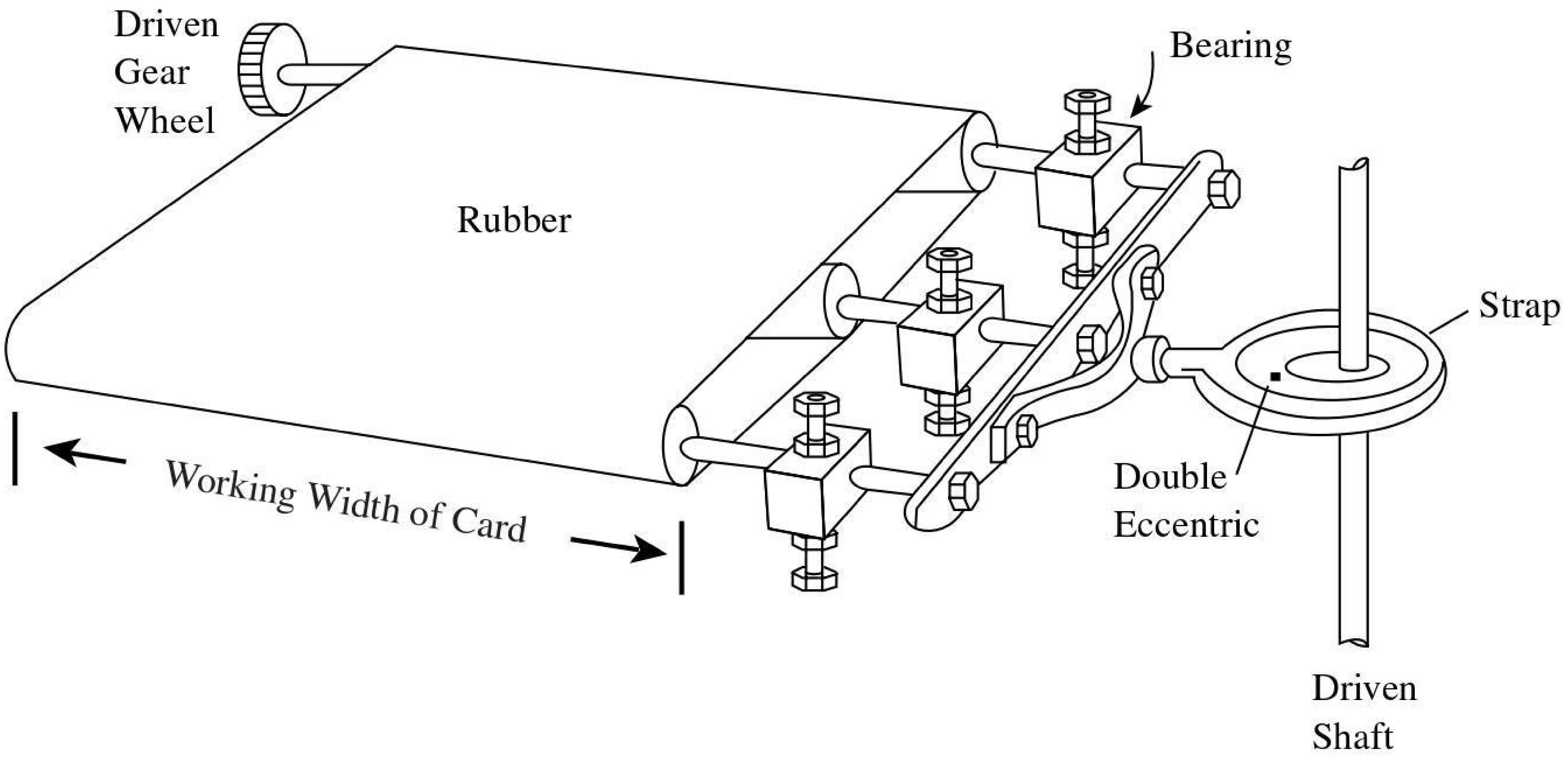

FIGURE 3B.3 Rubbing aprons.

APPENDIX 3C

Minimum Irregularity and Index of Irregularity

The theoretical minimum irregularity of a sliver can be derived as follows. In a sliver where fibers are randomly arranged, let the average number of fibers per cross section be *n*. Thus, the standard deviation of the variation is

$$\sigma_n = \sqrt{n}$$

The relative coefficient of variation or the minimum sliver irregularity resulting from variations in the number of fibers in the cross section is

$$CV_{\mathrm{min}}\% = \frac{100\sigma_n}{n} = \frac{100}{\sqrt{n}}$$

This equation is applicable for any fiber length and length distribution, provided all the fibers are uniform along their length and are of the same fineness. It is therefore also the minimum CV% of the linear density. However, if the fiber linear density varies, this effect must be added to the effect of the variation of the number of fibers so as to obtain the minimum variation of the sliver linear density.

With wool, the fiber fineness is given by the measured diameter. If CV_d is the coefficient of variation of the measured diameters, then

$$CV_{min}\% = \frac{100}{\sqrt{n}}\sqrt{(1 + 0.0004\ \mathrm{C}V_d^2)}$$

With other fibers, fineness is expressed by their linear densities, and therefore

$$CV_{min}\% = \frac{100}{\sqrt{n}}\sqrt{(1 + 0.0001\ CV_f^2)}$$

where CV_f = coefficient of variation of fineness

The above can be rewritten in the more general form,

$$CV_{min}\% = \frac{100a}{\sqrt{n}}$$

where a = the fiber irregularity factor

By calculating $CV_{min}\%$ and measuring the actual irregularity $CV_{act}\%$, the following ratio can be used as an index of irregularity, I:

$$I = \frac{CV_{act}\%}{CV_{min}\%}$$

Thus, the greater is the value of I above unity, the more irregular the sliver or linear assembly.