

**SAWTRI**  
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**The Reclamation and Reprocessing of  
Cotton Wastes Produced During Yarn  
Preparation**

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# THE RECLAMATION AND REPROCESSING OF COTTON WASTES PRODUCED DURING YARN PREPARATION

by L.A. BATHIE

## INTRODUCTION

Waste is an undesirable but inevitable by-product in any manufacturing process and is frequently undervalued.

In the past waste produced during the manufacturing process was normally collected and sold to waste spinners for relatively low prices. They would clean the wastes, use their expertise in producing blends of wastes derived from various sources and then spin these into yarn. On the other hand, more astute spinners would introduce a proportion of their own waste back into their blend to reduce raw material costs. This was generally the case when they were producing yarn for an end-use which was not too critical. However, they had to ensure that they did not degrade their stock too much by using excessive levels of trash, which would increase the end breakage rate during spinning and adversely affect yarn quality.

The production of waste yarns by the waste spinner was traditionally carried out by condenser spinning<sup>1</sup> in which the material was processed through a card incorporating workers and strippers and condenser bobbins to produce slubbings. These were then ring spun onto large tubes using a low draft and the yarn re-wound onto bobbins. It was usual to add between 3 to 8% oil or soap to ensure sufficient interfibre cohesion for drafting and to produce yarns in the range 60-200 tex at a production speed of 13 to 15 m/min .

With the advent of rotor (open-end) spinning it was not surprising that waste spinners were quick to realise its potential and capability of handling fibres having a wide range of micronaire values and lengths at production rates 6 to 8 times higher than could be achieved with condenser spinning<sup>1</sup>. It was stated<sup>2-6</sup> that at an annual increase of rotor spinning machines installed throughout the world of about 1%, the number of machines would reach 15 million by 1980. In view of the increased use of rotor machines, the steadily rising cost of raw materials and energy, the stagnating worldwide cotton crop, falling profitability and also rising costs associated with waste disposal, such as incineration or dumping, the reclamation and reprocessing of waste in cotton spinning mills have increased in importance over the last few years.

With the aid of purpose-built cleaning machines it is possible to recover waste fibres from ginning, scutching and carding (droppings) to such an extent that not only are they of interest to the cotton-wool and stuffing industry, but that they can also be used for spinning rotor yarns of around 100-125 tex, provided they are suitably admixed. It is claimed<sup>2-6</sup> that these yarns are quite

marketable, especially for use in decorative fabrics, furnishings and blankets.

In the present very competitive market situation, spinners often have difficulty in offsetting rises in processing costs by raising prices; hence they must look for ways to render their processes more economical. The last few years have seen very important advances in improved productivity, but gradually these improvements tend to reach their limits.

As the cost of raw material continues to rise rapidly, costs can be controlled by better raw material utilisation as well as by reprocessing the waste using purpose-built cleaning machines.

Over the years, machine manufacturers have provided installations specifically designed for the recovery of fibres from waste material and many textile factories have introduced complete waste recycling systems for further utilisation of their own waste. These machines are being modified continuously to satisfy the most rigorous requirements with respect to opening and cleaning, dedusting and mixing. Various studies have been conducted and results published on waste reclamation and reprocessing using various opening and cleaning machines and different types of waste.

In the light of increasing interest in the field of waste processing, it was decided to compile a review of the literature published until the end of 1982 concerning the reclamation and reprocessing of cotton wastes produced during yarn preparation.

## **CLASSIFICATION OF WASTE FIBRES**

Spinning waste consisting of good fibres, fly (short fibres), husks and dust, has been classified in several publications<sup>1-5,7-9</sup> and can be broadly divided into two components:

- (a) fibreless waste, and
- (b) fibre waste.

### **(a) Fibreless waste**

The non-fibrous foreign matter in cotton bales which is removed during opening and scutching consists of:

- (i) constituents of the plant (stems, leaf, husks);
- (ii) crushed foreign matter (resembling peppercorns), and
- (iii) sand.

These so-called hard waste materials can either be made into compost or burned. In the latter case a combustion value of around 14 600 kJ/kg (3500 kcal/kg)<sup>2-5</sup> can be achieved. Whether or not it is worthwhile burning this waste in one's own boiler depends largely on the amount of waste accumulated and on other individual circumstances.

## **(b) Fibre waste**

Of greater economic importance is the fibrous waste which falls into three categories:

- (i) Trashy waste:** waste which requires cleaning before reprocessing such as:
  - waste from cotton gins;
  - blowroom waste;
  - carding waste (licker-in, grids), and
  - card flat strips and filter waste.
- (ii) Clean waste:** waste which requires no further cleaning, e.g.
  - comber waste;
  - card, drawframe and combed waste slivers;
  - opened rovings, and
  - filter waste from drawframes, speed frames, ring spinning frames and rotor spinning machines.
- (iii) Hard waste:** waste which requires opening on special machines, such as:
  - twisted rovings;
  - yarns, and
  - textile fabrics.

The remains of laps are not included in any of the above categories as these can be fed back into the mixture via a hopper feeder. It has been stated<sup>2-5</sup> that waste coming from cotton ginning machines (such as gin motes), may be of special interest in fibre recovery since the unripe and stunted seeds adhere not only to immature fibres but also to longer fibres.

## **PERCENTAGE WASTE PRODUCED AT EACH STAGE OF PROCESSING**

The amount of waste produced at each stage of processing depends largely on the grade and type of cotton, make of machinery and machine settings. The percentage waste produced at each stage of processing from raw cotton has been reported by numerous authors<sup>2-6,10-13</sup>. However, if one considers the variables present, it is not surprising that one report may contradict another. For this reason, one report<sup>11</sup> was taken at random as an example. The figures relate to a 'middling' cotton.

	<b>% Waste (approximate)</b>
Opening room	3 to 7%
Carding room	3%
Drawframes and flyers	0,5%
Spinning machines	1 to 2%
<hr/>	
Total	7,5 to 12,5%

Another 10 to 20% may be added for comber noil waste.

The waste may itself be quite fibrous. For example, Spencer and Taylor<sup>15</sup> have processed 100% card flat strip waste and obtained the following percentage waste at various stages of processing:

Blowroom waste	17,6%
Card Waste	13,0%
Spinning waste	3,3%
<hr/>	
Total	33,9%

Thus 66,1% was re-usable.

It will be appreciated that in a spinning mill with a high material throughput, the amount of waste ejected can be considerable and the re-usable portion could also be significant. It is therefore important that mill management should incorporate a good waste control programme in its overall planning<sup>14</sup>.

## WASTE ANALYSIS

With the aid of a Shirley Analyser<sup>16</sup>, it has been possible for cotton growers, traders and spinners to ascertain the proportion of waste in raw cotton, or the proportion of good fibres in spinning wastes.

A number of publications<sup>8, 9, 11, 13, 17-22</sup> quote average values for the percentage of good fibre yield from waste produced at different stages of processing. Different amounts of good fibre yield were recorded by those authors, attributable to the use of different raw materials, different machinery and different machine settings.

Different grades of cotton yield different percentages of good fibre in the waste. Artzt<sup>23</sup> showed this by analysing the by-products produced in a number of cotton cleaning plants up to the carding stage. The results were as follows:

Grade of Cotton	Percentage Good Fibre in Waste (up to the card)
Good Middling	75%
Strict Middling	75%
Middling	70%
Strict Low Middling	65%
Low Middling	55%
Strict Good Ordinary	50%

The percentage of good fibre in the waste produced during opening and cleaning is constantly being monitored by yarn and machine manufacturers. The wastes from various classical cleaning machines were analysed by Artzt<sup>24</sup> (see Fig. 1) on a Shirley Analyser to determine their fibre content. The settings of these cleaning machines were such that the wastes were minimised. This is normal practice in spinning mills. The analyses yielded the following average fibre fraction in the wastes from the various cleaning stages:

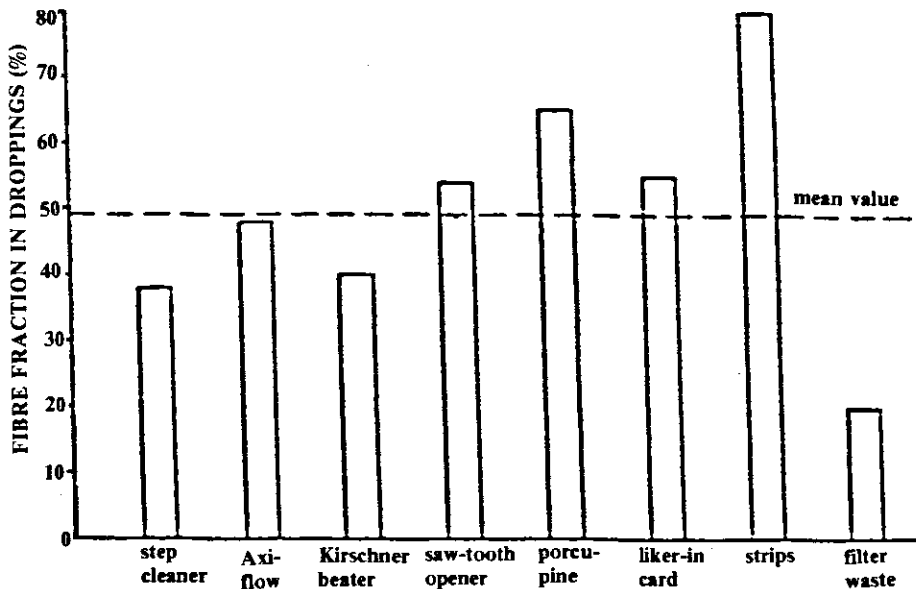


Fig. 1 - Average fibre fraction in the wastes from various cleaning stages<sup>23</sup>.



The percentage of waste collected from the various machines was reported to show little variation. However, the percentage of good fibre varied by as much as a factor of four. Furthermore, repeated passages through the same machine did not significantly improve the cleaning effect. The removal of trash was only possible with a simultaneous removal of a percentage of good fibre. Tests aimed at establishing the relationship between absolute waste quantity and the percentage composition of fibre and trash in relation to grid bar settings have also been carried out<sup>23,24</sup>. On a step cleaner, the grid bars were set in four different positions between closed and open. The speed of the beaters was kept constant and the grid bars had a triangular profile. In this test Chad (African) cotton of  $1\frac{1}{16}$ " strict low middling was used.

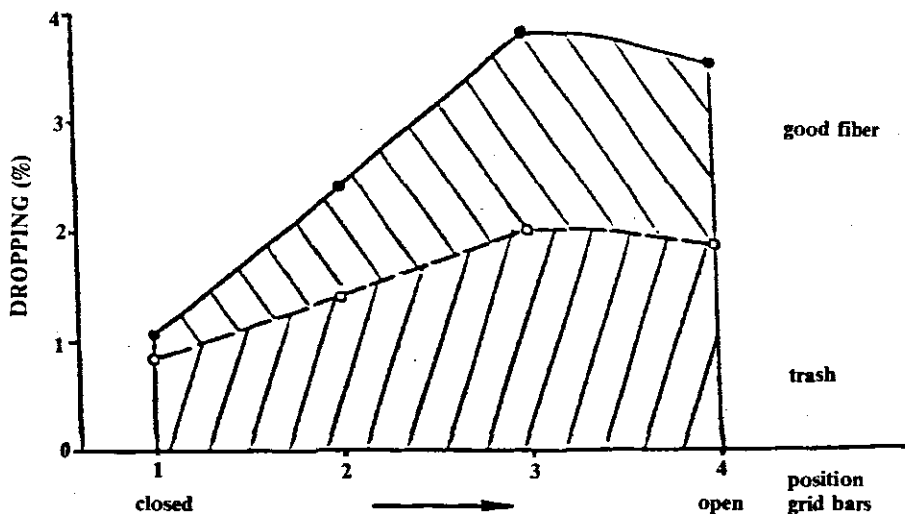


Fig. 2 - The influence of grid bar settings on the composition of droppings<sup>23,24</sup>.

One can see from Fig. 2 that an increase in trash elimination is only possible by increasing the total droppings, including a higher ratio of fibre content. Although position 1, where only about 2% good fibres were eliminated, gave the best ratio, the actual elimination of trash or hard waste was the lowest. Position 3 produced twice as much trash, however the fibre proportion was increased sixfold. It would therefore be necessary to incorporate a by-pass system for recycling the fibres from the droppings and feeding them directly

back to the blender. In spinning mills, the droppings from these machines are considered as waste and for this reason one is inclined to work more closely to setting 1 than to setting 3 and incorporate more beating points, which, unfortunately, does not solve the problem.

Wulfhorst *et al*<sup>13</sup> carried out a Shirley analysis of waste from various cleaning machines (see Fig. 3). It can be seen that a particularly high proportion of good fibres was found and this increased with an increase in the machine passages. On the basis of preliminary considerations, they drew up the following schedule for further developments in the blowroom:

- reduce the number of machine passages in the blowroom and improve the separation of trash by using a machine which is particularly efficient in opening and cleaning, and
- develop a unit for processing waste and a system for feeding the good fibres recovered during the separation back into the spinning process.

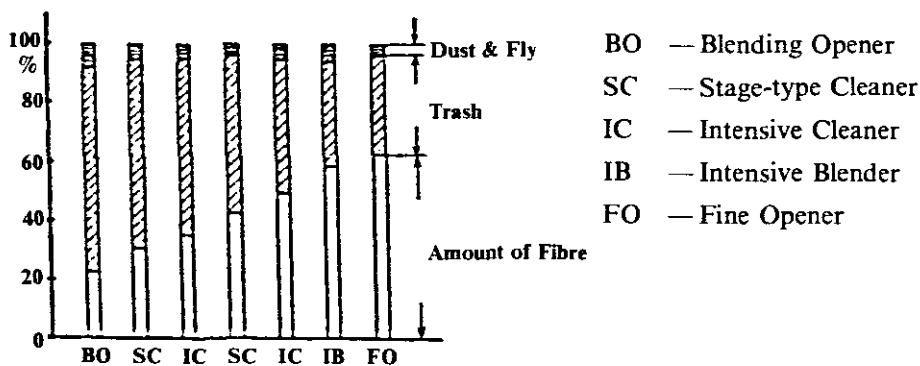


Fig. 3 - Shirley analysis of waste from various cleaning machines<sup>13</sup>.

To summarise on the expected yields of re-usable, good fibres present in wastes produced at various stages of processing, Binder<sup>8,9</sup> has reported the following approximate values (see Table I).

**TABLE I**

**SUMMARY OF TYPES OF WASTE AND EXPECTED YIELDS OF RE-USABLE FIBRES<sup>8,9</sup>**

TYPE OF WASTE	Approx. Yield of Re-usable Fibres (%)
<b>1. DIRTY WASTE</b>	
1.1 Waste from cotton opening lines	25 - 50
1.2 Waste from blowing room lines	35 - 55
1.3 Waste from cards (taker-in, grid)	35 - 55
1.4 Waste from cards (flats, filter)	65 - 75
<b>2. CLEAN WASTE</b>	
2.1 Noil	95 - 97
2.2 Sliver waste from cards, drawframes, combs	100
2.3 Roving waste (opened)	95 - 97
2.4 Filter waste from drawframes, speed frames, ring and rotor spinning frames	95 - 98
<b>3. HARD WASTE</b>	
3.1 Roving (twisted)	95 - 97
3.2 Yarn	No figures available
3.3 Textile fabrics	No figures available

**PHYSICAL PROPERTIES OF WASTE FIBRES**

Al Ali and Schenek<sup>11</sup> have reported on wastes obtained from several spinning mills. Examination of the wastes revealed that in the card flat strips, in the licker-in waste and in the step cleaner waste, there was the highest percentage of good re-usable fibres. The fibre tuft strength (Fig. 4) and the micronaire value (Fig. 5) were measured and it can be seen that the properties of the good fibres from the step cleaner (normal scutcher waste) were generally speaking, quite acceptable, whereas with the other machines, quite clear differences in the quality of the various wastes were apparent. For example, the quality of the card licker-in waste was always inferior to the other wastes. It was stated<sup>11</sup> that when comparing properties of recovered fibres with those of good quality cottons, the waste fibres were quite acceptable. The fibre length distribution of each waste was measured using the Fibrograph. Fig 6 shows the fibre length distribution of

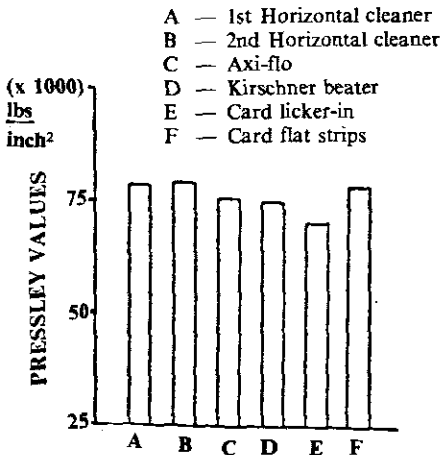


Fig. 4 - Fibre tuft strength of good fibres recovered from various wastes <sup>11</sup>.

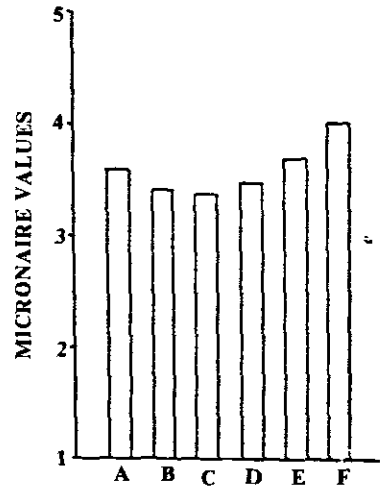


Fig. 5 - Micronaire values of good fibres recovered from various wastes <sup>11</sup>.

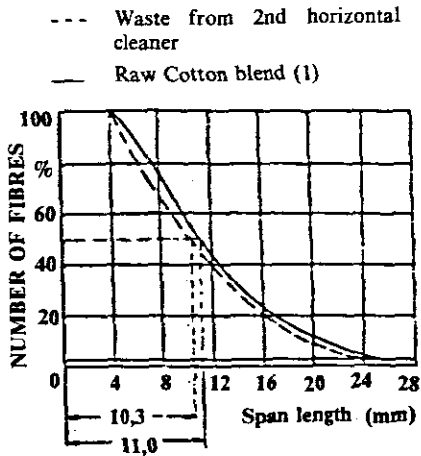


Fig. 6 - Fibre length distribution of raw cotton (1) and cleaned scutcher waste <sup>11</sup>.

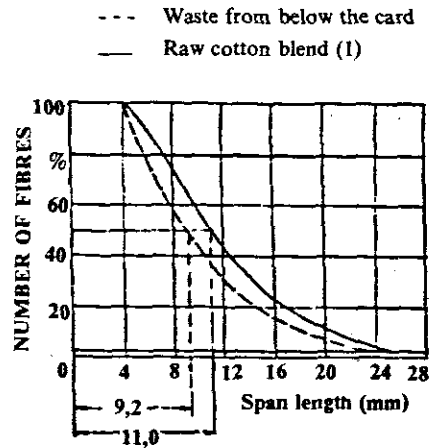


Fig. 7 - Fibre length distribution of raw cotton (1) and card licker-in waste <sup>11</sup>.

--- Waste from Axi-Flo  
 — Raw cotton blend (2)

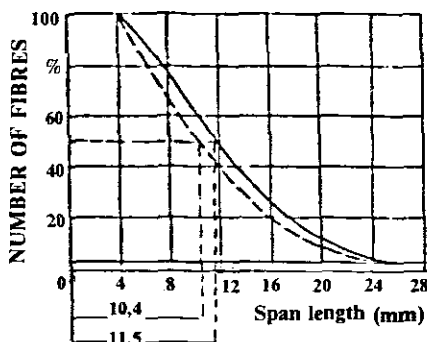


Fig. 8 - Fibre length distribution of cotton blend (2) and cleaned Axi-flo waste <sup>11</sup>.

--- Card flat strip waste  
 — Raw cotton blend (2)

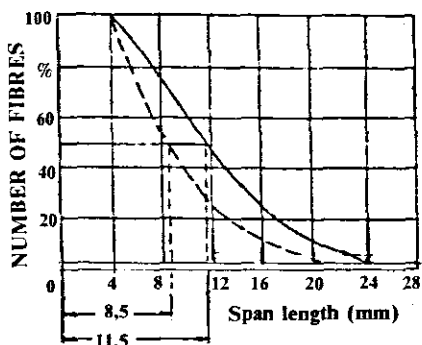


Fig. 9 - Fibre length distribution of cotton blend (2) and cleaned card waste <sup>11</sup>.

raw cotton blend (1) and the corresponding fibre recovered from the step cleaner. The fibre length distribution of raw cotton blend (1) and licker-in wastes are compared in Fig. 7. Figs 8 and 9 show the fibre length distribution of the Axi-flo waste and the card flat strips respectively compared to the raw cotton of cotton blend (2). The differences in the quality of the various wastes are very apparent. Naturally, the fibre length distribution of the recovered fibres depends on the raw material, on the efficiency of the machine and on the machine settings. In every instance examined<sup>11</sup>, the fibres from the licker-in waste were most inferior and the fibres from the step-cleaner and the Kirschner beater the best.

Al Ali<sup>19</sup> reports on laboratory tests carried out to determine the fibre characteristics of the good fibres from reprocessed scutcher waste (obtained with the aid of a Shirley Analyser) and compares them with the fibre characteristics of a commercial Low Grade Brazilian cotton of 31/32" staple length.

Fibre length distribution was measured on a Fibrograph and the results showed that the good fibres in the reprocessed scutcher waste were considerably longer than those in the Low Grade cotton (see Fig. 10). Consequently fibre length should not present any problems in the spinning of the yarn<sup>19</sup>. Fibre bundle strength was also measured on a Pressley tester and the tests on the good fibre portion (Pressley value) were no less favourable for the good fibres from the scutcher waste than those from the Low Grade cotton (see Fig. 11). The

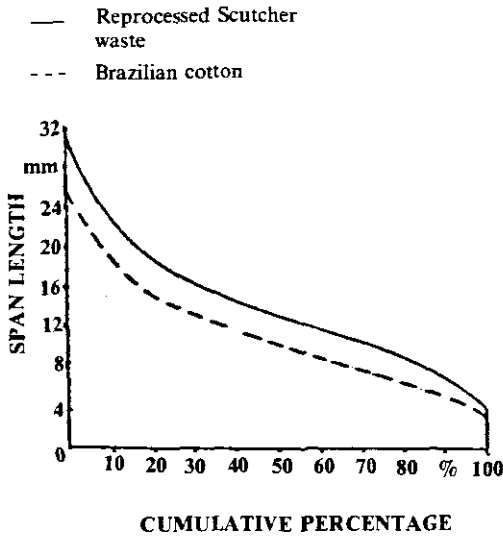


Fig. 10 - Fibre length distribution of a reprocessed scutcher waste sample and a Low Grade Cotton <sup>19</sup>.

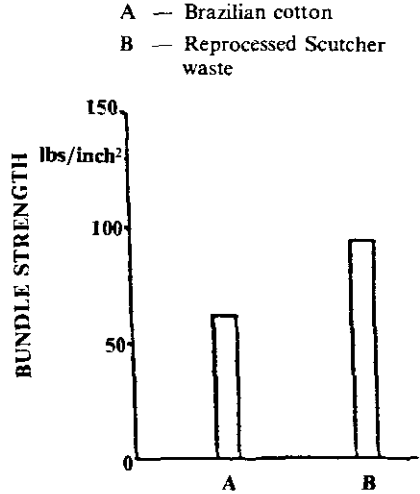


Fig. 11 - Fibre bundle strength (Pressley) of a reprocessed scutcher waste sample and a Low Grade cotton <sup>19</sup>.

micronaire value of the good fibre samples was also determined and these lay between 3,7 and 4,8 which showed that the fibre fineness was also within an acceptable range.

The physical properties of fibres recovered from beater waste and in one case beater waste together with card waste, produced in three German spinning mills, have been measured<sup>23,24</sup> and the results compared with the respective raw cottons taken from the bales.

Spinning mill A processed a Russian cotton;

Spinning mill B, a blend from Texas, Turkey and the Sudan;

Spinning mill C, an American cotton.

They reported that the differences in micronaire values of raw cotton from one area to another within a region, are similar to differences between raw cotton and the separated waste (see Fig. 12). With regard to maturity, classifying the separated waste into 'mature', of average maturity and 'immature' corresponds closely with the classification for the raw cotton (see Fig. 12). With

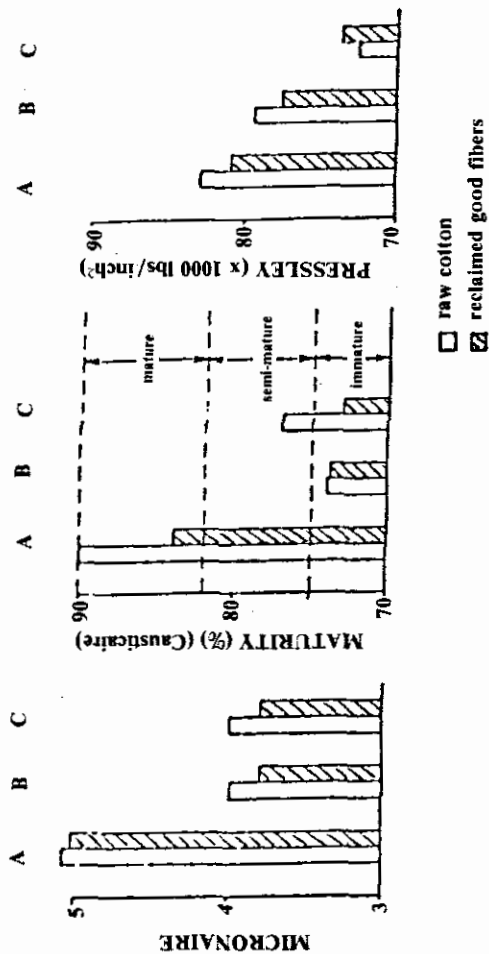


Fig. 12 - Micronaire, maturity and Pressley values of raw cotton blend compared to reclaimed good fibres from the droppings for each mill<sup>23, 24</sup>.

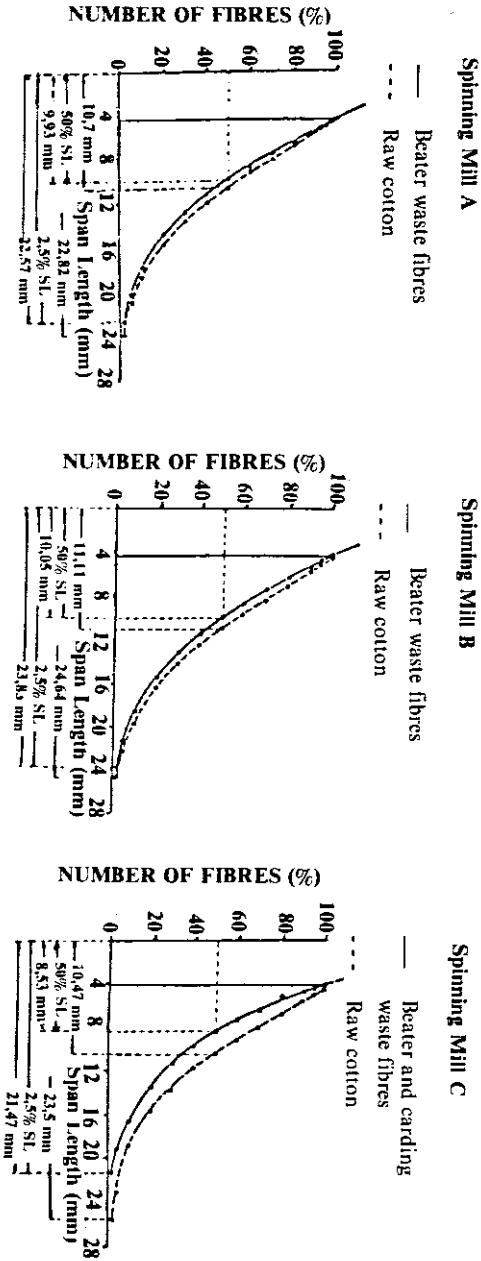


Fig. 13 - Fibre length distribution of recovered good fibres compared to raw cotton for each mill 23, 24.



regard to fibre length distribution Artzt also reported a slight shortening of the recovered waste compared to the raw cotton (see Fig. 13).

Spencer and Taylor<sup>15</sup> have reported the fibre properties of flat strip cotton waste fibres (see Table II) used for processing 25, 30, 50, 60 and 80 tex rotor spun yarns. The yarns were spun via the tandem and single card routes and were found to be satisfactory.

It has been stated<sup>25</sup> that for most cottons, the effective length of fibres in the comber waste should generally be around 70% of the effective length of the fibres in the feed. If the effective length of the waste fibres is appreciably higher than this value, it is a sure sign that too many long fibres are being extracted. One obvious reason for this may be insufficient grip at the nipper assembly and also incorrect timings.

**TABLE II**  
**FIBRE PROPERTIES OF CARD FLAT STRIP COTTON WASTE<sup>15</sup>**

2,5% Span Length (mm)	23,88
50,0% Span Length (mm)	9,30
Uniformity Ratio (%)	39
Maturity Ratio	0,80
Fineness (mtex)	165
Micronaire	3,69
Zero Gauge (cN/tex)	34,7
Pressley (1000 psi)	78
3,2 mm Gauge Tenacity (cN/tex)	19,6
Bundle Extension (%)	5,6

## WASTE COLLECTION

Automatization of the spinning process and high performance spinning were taken in hand by textile machinery manufacturers towards the end of the 1950's and this work was continued into the 1960's<sup>26</sup>. While the aim was initially to increase productivity, a second requirement soon arose, that being the improvement of working conditions in terms of a cleaner, and as far as possible, dust-free environment. A third factor was the recognition of the fact that fine particles of dust are the cause of byssinosis. A guide value of 1 mg/m<sup>3</sup> of air has been reckoned with in the past as a maximum permissible workplace concentration<sup>26,27</sup>. However, today the legal limits have been reduced to 0,2 - 0,75 mg/m<sup>3</sup> in the United States of America, depending on the department and to 0,5 mg/m<sup>3</sup> in the United Kingdom.

For years the collection of waste was carried out manually. The operative would proceed from one machine to another cleaning the waste chambers or filter boxes and then place the waste in receptacles such as baskets, trucks, cardboard boxes and bags. This method of collecting waste was not only a health hazard but very time consuming.

Instead of emptying the waste chambers by hand, most spinning mills now use automatic installations which remove the waste continuously and gather it in a centrally situated chamber. The use of intermittent suction<sup>2-6,26</sup> for each waste chamber of the cotton cleaning machines is advisable. This requires less air and hence less power than the continuous methods of exhaustion<sup>2-6,26</sup> and the pipes can be relatively smaller diameter. Although it is stated<sup>2-6,26</sup> that there is insufficient cleanliness and dust removal with intermittent suction, this no longer applies to modern cleaning machinery which have completely enclosed steel constructions.

A fan of 4000 m<sup>3</sup>/h capacity (7,5 kW, 2800 rev/min), for instance, is adequate for a normal cotton cleaning installation. For larger installations which require a greater air capacity, one can build change detectors into the piping. This ensures that suction is applied only to those pipes which are in operation and not to the whole system.

In waste evacuation installations, the piping can be arranged overhead or located under the floor and machines are generally equipped for both types of connection.

In spinning mills today, where facilities for recycling wastes are not available, the waste materials transported by intermittent or continuous suction are collected and baled. The wastes may be baled continuously or discontinuously if semi-automatic presses are preferred. A graded range of baling presses and feeding silos are available<sup>2,28-30</sup>. A bale of secondary waste can weigh between 110 and 130 kg and one of usable fibres (secondary raw material) about 90 to 110 kg and should have dimensions of 600x1200x800 mm to conform with European standards.

In spinning mills with a centralised vacuum waste extraction system it is possible to clean the waste continuously and recycle the reprocessible fibres back into the production process without having to collect and bale the waste. This type of operation is called the By-Pass system<sup>20,23,24</sup> which normally incorporates an opening and cleaning system. The By-Pass system operates on a continuous basis at a production rate that ensures optimum regeneration of the fall-out fibres.

## **MACHINES FOR THE OPENING AND CLEANING OF COTTON WASTE**

A comprehensive range of opening and cleaning machinery is available from most of the major textile machine manufacturers specialising in this

field<sup>2-12,17-22,24,31-50</sup>. These machines are designed to give optimum opening, cleaning and dedusting efficiencies and are normally equipped to handle specific types of waste or all types of waste material produced in cotton spinning mills.

Installations for the purification of fibre waste must be planned according to the operational situation. The following points must be considered when planning the type of machine or range of machines to be used:

- type of waste material;
- amount of contained impurities;
- the production required and
- the end product.

Depending on the type of material to be opened, machines may be equipped with 1 to 6 cylinders fitted with fine needles or saw-tooth clothing. With one cylinder the main purpose of the machine may be to open soft wastes such as rovings and non-woven webs, whereas the machine with 5 or 6 cylinders may be used for reclaiming spun yarns<sup>35-37</sup>.

For cleaning small quantities of particularly dirty waste, cleaning machines may incorporate one saw-toothed drum<sup>42</sup>. Larger quantities of dirty waste may be processed through cleaning machines incorporating two saw-toothed drums<sup>42</sup>. However, the mechanical action of such drums may cause further shortening of the fibres. On the other hand, larger batches of extremely dirty waste may be cleaned through a machine incorporating a step cleaner and six beaters, shaped to clean the waste material with the greatest care<sup>2-6,10,44-46</sup>.

Waste materials which are to be rotor spun, should be processed through machines which place particular emphasis on the removal of fine dust particles (micro-dust)<sup>2-12,17-22,24,39-41,43-45,48-50</sup>. This will ensure higher spinning efficiencies, and should the machine have a fully enclosed steel construction and operate at negative pressure<sup>7-9,21-39</sup>, a healthier working condition will also be secured.

Through technological advances it is now possible to produce machines which can clean scutcher waste and card strippings to a level comparable with the original cotton<sup>11,12,17-20,22,24,40,41</sup>. With the removal of fine fibre dust and dirt particles along with unspinnable short fibres, rotor yarn of 100% waste can be spun<sup>11,12,17-20,22,24,40,41</sup>.

The number and type of opening, cleaning and dedusting operations depends largely on the required degree of material cleanliness and quality of the end product. It would appear that a wide range of machinery is available from textile machine manufacturers for meeting most requirements.

## **INSTALLATIONS FOR WASTE RECOVERY**

Various installations are available for the recovery of waste

materials<sup>2-5,7,8,10,21</sup> and these can be adapted to meet the requirements of a particular operation. Most installations are flexible and can be extended in many ways to allow either:

- (A) Waste recovery with delivery of materials to bale press;
- (B) The simultaneous recovery of waste materials such as:
  - Pheumafil waste;
  - Roving waste, including carding and drafting waste;
  - Heavily contaminated waste from beaters, etc., noils and card flat strippings and
  - cotton clippings and yarn wastes, or
- (C) The automatic recovery and preparation of low grade cotton and cotton waste for rotor spinning.

In case B, the waste materials which are normally obtained by direct connection to automatic waste transport from the production machines, would be stored in chambers separated according to grade. For further treatment, the materials could then be delivered in the form of pressed bales or in loose form from a hopper feeder to, for example, a flock mixing plant. In this way it is possible to mix the most varied types of waste, metered in a selected ratio, with the necessary carrier fibres. Whether or not a special dust removal operation (essential for rotor spinning), a further process or a multi-mixer are to follow, depends on the requirements of each case.

For a spinning mill which re-uses its own waste from its blowroom and from carding and combing, installations applicable to case C are available. This would be particularly advantageous to large spinning mills which generate large quantities of waste. Reasonably priced ginning and beating waste, as well as low-grade cotton fibres could also be brought in as carrier fibres. The material from such a line is immediately carded and then spun on rotor spinning machines.

There are many possibilities available when it comes to planning an installation, all largely dependent on individual circumstances.

## **SECONDARY RAW MATERIAL BLENDING LEVEL**

When yarn quality is of particular importance, the mixing of recovered good fibres with the normal batch must be controlled to such an extent that no significant deterioration in yarn quality can be detected.

Due to the large, inevitable quantity of comber noils occurring (between 10 and 20%), the mixing of this waste has always been carried out as a means of reducing raw material costs. Many mills<sup>51</sup> have been using 10 to 15% of comber noils in superior mixings for spinning warp yarns as fine as 25 or 27 tex. It has been stated<sup>52</sup> that an admixture of 25% comber waste to an ordinary carded

cotton hardly influences the yarn evenness as measured by an Uster instrument and yarns have been produced<sup>53</sup> from 100% comber noils from card sliver processed on the rotor system and have proved to be satisfactory. In fact, they were recorded as being some of the best yarns ever produced by that company. Cotton wastes from carded yarn spinning mills have also been used for producing yarns. Of the fifteen Italian spinning mills equipped with rotor spinning machines, nine use these machines to process 100% cotton waste or blends of other fibres with the cotton waste. The most usual is the processing of 100% comber waste or blends of comber noils and flat strips or other kinds of waste into rotor spun yarns<sup>12</sup> ranging in linear density from 25 tex to 71 tex. Comber noils when added to the mix, within certain limits, do not significantly affect yarn properties<sup>54</sup>.

Recovered fibres from scutcher waste and card strips can be added to the normal mix in the usual way to about 20% without sacrificing quality and spun into yarns in the 50 to 100 tex range<sup>17,18</sup>. The Clean-Star system<sup>11,12,17-20,22,24,40,41</sup> assumes particular importance for rotor spinning, because the cleaned cotton waste may be spun on its own<sup>17,18</sup>. In fact, rotor yarns as fine as 25 tex<sup>17,18</sup> and in the 50 to 100 tex range<sup>11</sup> have been produced from pure scutcher waste.

Work has been reported<sup>7-9</sup> in which a  $1\frac{1}{16}$ " cotton with 1% trash content and a micronaire of 4.65 and blends of this cotton with 5%, 10% and 20% of secondary raw material from trashy waste derived from this cotton, were spun into 20 tex carded ring yarn and 30 tex rotor yarn. It was found that for the 20 tex ring yarn, blending in 2.5% of secondary raw material gave satisfactory yarn. Adding 2.5-5% gave slightly poorer yarn properties, while blending more than 5% was critical and depended on the required quality of the end product. With the 30 tex rotor yarns more secondary raw material could be added. A 5% blend gave satisfactory yarn values, adding 5 to 10% gave slightly poorer yarn values and blends exceeding 10% were critical and once again depended on the quality of the end product.

Extensive tests<sup>21</sup> have proved that, for carded ring yarns, as much as 2.5% reclaimed fibres can be blended back into the same mix without causing any noticeable degradation in yarn quality. Under favourable circumstances up to 5% is feasible, whereas blend proportions equal to or greater than 10% are critical unless a lower grade of yarn is to be spun. For rotor spun yarns even higher proportions of reclaimed fibres (up to 5%) can be blended with generally no problems<sup>21</sup>.

Generally, depending on the yarn linear density, 2 to 5% recycled good fibres from conventional cleaning lines can be blended without having a detrimental affect on yarn quality<sup>13</sup>. Another study<sup>23,24</sup> ascertained that, with 29 tex yarn, 5% reprocessed fibres could be blended in without loss of quality. With finer yarns the admixture should be reduced to 2.5% to maintain the yarn

quality. The reblending of secondary raw material via by-pass plants is kept, as a rule, at levels below 5%<sup>55</sup>.

## **SPINNING OF RAW COTTON/SECONDARY RAW MATERIAL BLENDS**

Most fibres recovered from waste have a very short staple length and often the normal drafting system cannot be set with the rollers close enough to control the number of "floating fibres" in such waste blends. Drafting of this type of material via a roller drafting system would produce drafting waves<sup>56</sup>. The manufacturers of rotor spinning machines were the first to show that this waste fibre could be successfully reprocessed on a rotor spinning machine to produce "upgraded" yarn superior to that which could be spun from the same raw material on the condenser spinning system<sup>1</sup>.

The ability of the rotor spinning system to handle very short staple fibres is now widely exploited for processing cotton waste blends, because in terms of cleanliness, fineness and strength, waste fibres are in every way comparable to longer staple materials.

Practically all wastes can be processed, on condition that the waste is opened, cleaned and dedusted thoroughly, so that the rotors can work at high efficiency and produce good yarn<sup>45</sup>.

One distinct advantage of the rotor spinning machine is its ability to spin yarn directly from drawframe sliver. However, if the card is equipped with a Short-term Autoleveller (corrects wavelength irregularities over 1 metre), the drawframe process can be eliminated and high grade yarns can be produced directly from card sliver<sup>57</sup>. This is particularly advantageous in those cases where the fibre length is so short that adequate control on conventional roller drafting systems is impossible. However, it has been recommended<sup>12</sup> that two drawframe passages should be incorporated when spinning relatively fine yarns (finer than about 50 tex) to improve fibre parallelisation in the sliver. When spinning coarse counts the drawing operation may be eliminated.

Various publications<sup>2-9,11,15,17-19,53,58,59</sup> deal briefly with pure reprocessed wastes or blends of wastes and other fibres which have been rotor spun into various yarn linear densities and some yarn physical properties are given<sup>8,11,19</sup>.

More in-depth studies<sup>21,54,55</sup> have been carried out on the rotor spinning of raw cotton containing cotton waste and involve a comprehensive study of yarn physical properties.

Dutta *et al*<sup>54</sup> have spun Indian cottons containing different percentages of card waste, comber noils and inferior short staple Indian cottons on the rotor system to 30 tex and have analysed the yarn physical properties. They showed that the proportion of cheaper fibres that could be added to the mix with consequent saving in raw material cost was largely dependent on the acceptable

level of mean yarn strength. The reduction in mean strength compared to the ring yarn may be compensated by the improved evenness and strength regularity of the rotor spun yarn.

Peyer<sup>21</sup> reported that the cleaning process has a direct influence on the rotor spinning performance in respect of the number of ends down. A Russian cotton, type 4, showing a very high trash content, was processed through a blowroom line containing 2 to 4 cleaners. The material was carded, given two drawframe passages and processed into 30 tex rotor yarn. The fibre characteristics found in the respective card slivers indicated that with each additional fine cleaner added to the line, damage was caused to the fibres. The average staple length was shortened noticeably. The ends down per 1000 rotor hours increased by one third with 3 cleaners and to more than twice the original level if a fourth cleaner was added. The number of cleaning steps had to be kept to the minimum if high processing efficiencies were to be achieved.

Work has been carried out<sup>55</sup> to determine the proportion of waste which can be applied without sacrificing quality. Raw material was spun to relatively

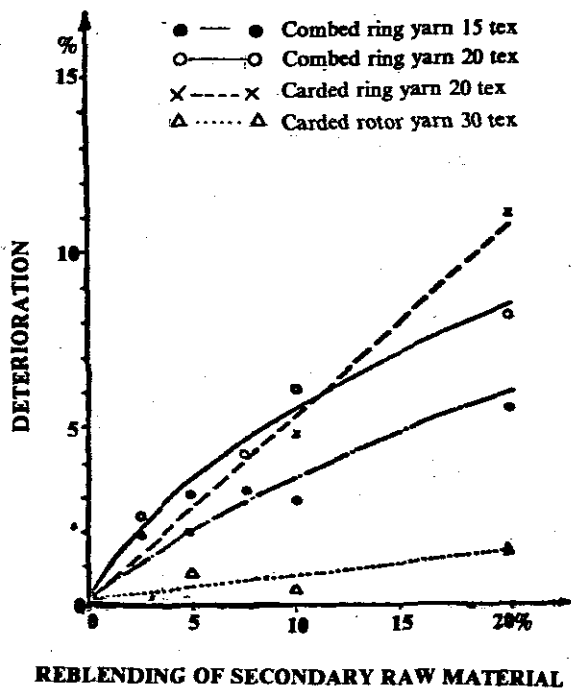


Fig. 14 - Relative effect of reblending on yarn evenness<sup>55</sup>.

fine counts of 15 and 20 tex (ring) and 30 tex (rotor). The "relative" quality change (i.e. the change relative to the product containing no waste fibres) was adopted as a criterion. This has the advantage that every spinner can estimate the acceptable waste rebinding level according to the spinning process and quality standards required. Fig. 14 shows that different spinning systems respond differently to rebinding. It is common knowledge that yarns spun on the ring frame drafting system react sensitively to different short fibre content, hence the linear deterioration of up to 10% when rebinding 20% secondary raw material.

In absolute terms, 10% relative change alters the Uster values by no more than 1,0 - 1,5 U%, which is of the same order as the variation liable to occur within a spinning lot. The finer yarn (15 tex) reveals even less deterioration with regard to yarn evenness.

Rotor Spinning is of course, less affected by the short fibre content. It shows only insignificant changes when the quantity of rebinded raw material is increased.

The Classimat fault level for the 20 tex combed ring yarn was recorded. Eight out of the sixteen fault classes were plotted (see Fig. 15). It can be seen that recycling does not itself lead to a deterioration or increase in the Uster Classimat fault level.

Measurements with the Toray hairiness tester revealed differences between the spinning routes, but no trend correlating with the rebinding of secondary raw material could be found (see Fig. 16).

Yarn strength was determined with the Uster Dynamometer. In contrast to the parameter of yarn evenness, rotor spun yarns react more sensitively to blending of recycled raw material (see Fig. 17). The rebinding of shorter fibres causes a linear reduction of yarn strength by about half the value of the percentage of rebinded stock. With ring yarn, the combed lots react less markedly than the carded ones.

All yarn types display a similar behaviour, and up to 5% rebinding of secondary raw material may even result in a quality improvement under certain circumstances. With 10% of rebinding and more, the yarn strength remains practically unchanged.

A report has been published on the hybrid spinning of cotton waste<sup>60</sup>. The hybrid spinning (or HS) method was basically designed to produce yarns that would combine the high production of rotor spinning machines with the higher breaking tenacity of ring spun yarns. The yarn delivered by the rotor head is further twisted by the conventional method, the result being a yarn with a two-component twist, namely, rotor twist and spindle twist. Cotton waste of unknown origin was fed directly to the rotor head and a 73 tex yarn was spun. The HS method was found to offer prospects for improving tenacity at break. An improvement in yarn appearance was evident as well as an increase in production.



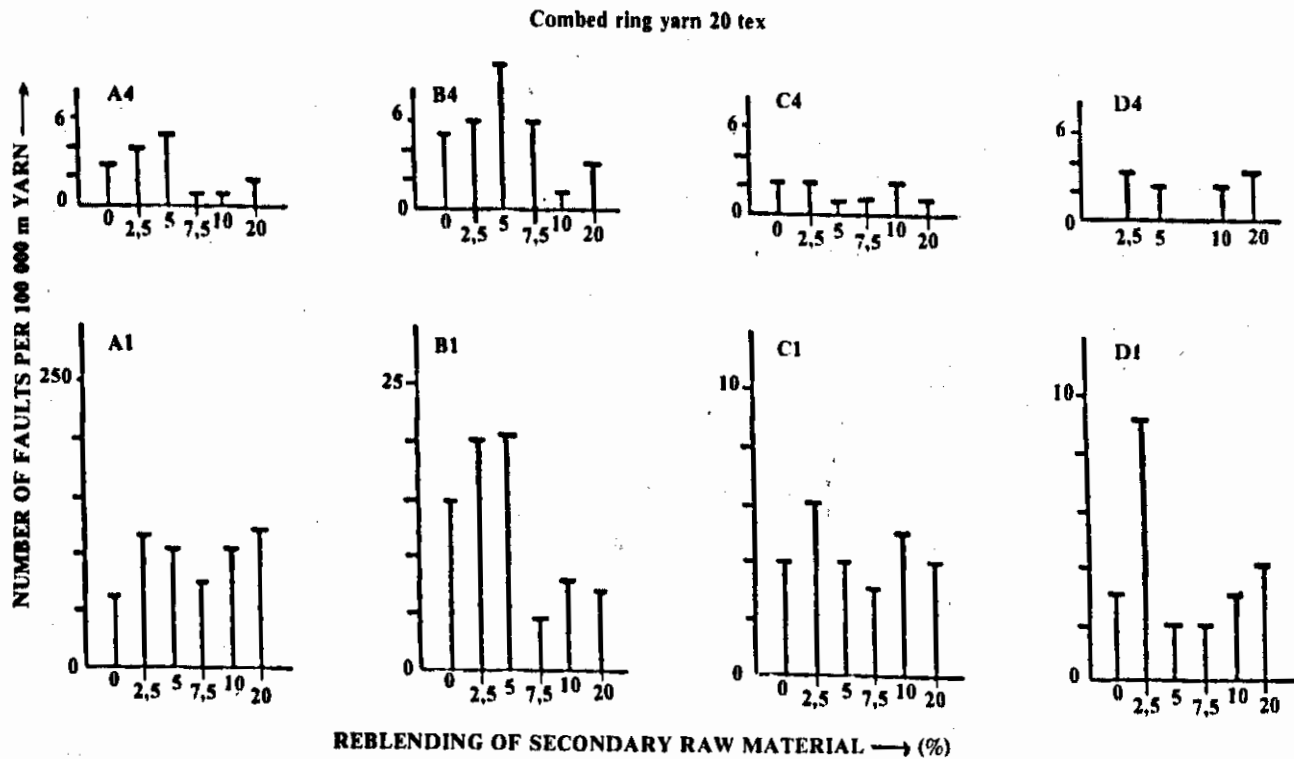


Fig. 15 - Effect of rebleding on Uster Classimat yarn fault level (absolute values, 20 tex combed ring spun yarns)<sup>55</sup>.

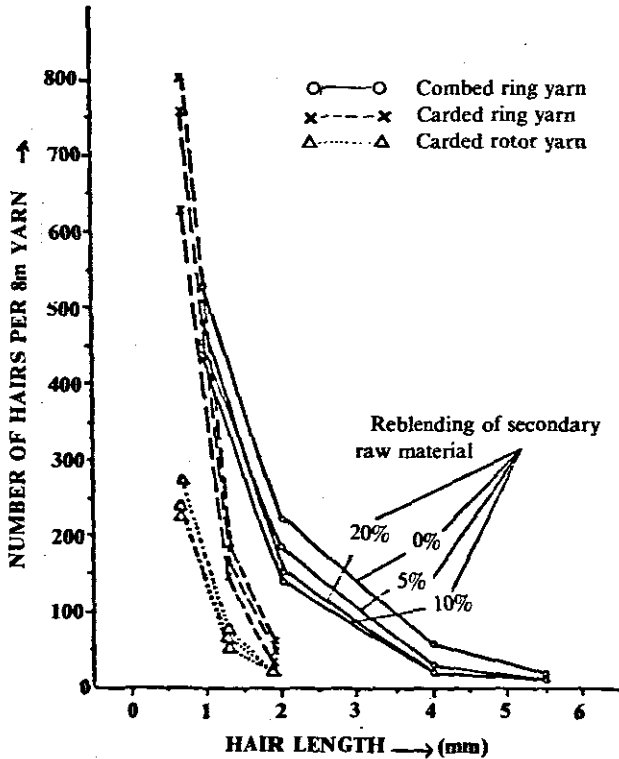


Fig. 16 - Effect of reblending on hairiness (absolute values)<sup>55</sup>.

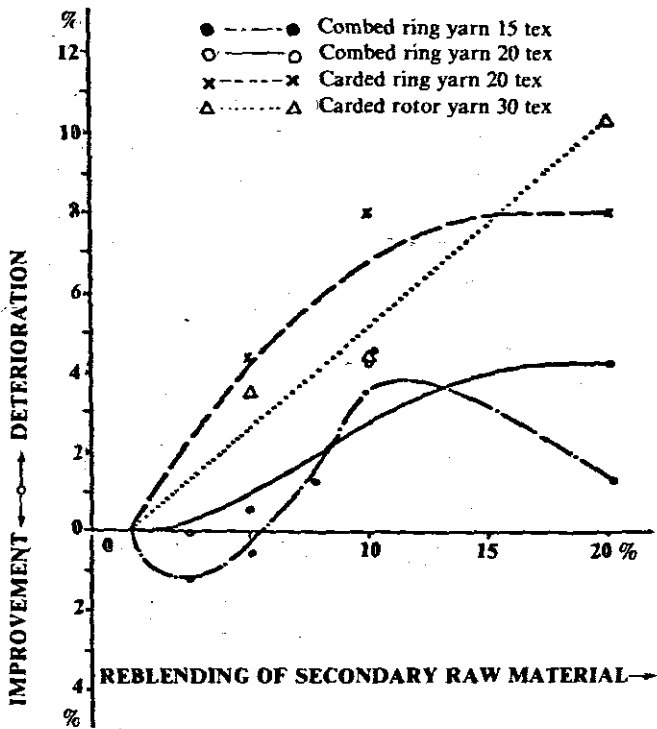


Fig. 17 - Effect of rebinding on single yarn strength (relative values)<sup>55</sup>

## ECONOMICS OF WASTE REPROCESSING

The more expensive the raw material, the more important the reprocessing of waste becomes. Spinners who depend on raw material imports know that they cannot count on the costs of raw materials falling in the future. Fig. 18 shows the development of the price of cotton over the past 20 years with a forecast up to 1985<sup>22</sup>.

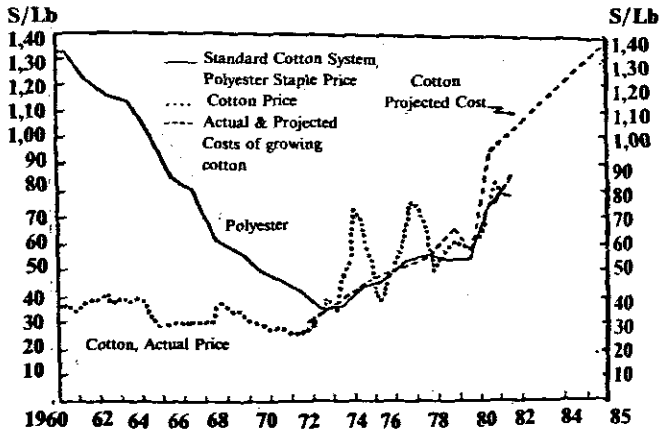


Fig. 18 - Development of the price of cotton and polyester <sup>22</sup>.

Without taking into account short-term fluctuations, it is anticipated that cotton prices will rise. Comparing the price trend with that of polyester it can be seen that oil also has a direct effect on the price of cotton. This becomes clear when the costs for producing cotton are all combined<sup>22</sup>.

From this it can be seen that the combination of production costs for cotton in the future will be roughly the same as that of past figures. So it follows that rising prices for fertilisers, insecticides and fuel have a direct effect on production costs. This emphasises the importance of better utilisation of raw materials.

**TABLE III****A COMPARISON OF THE PAST AND FUTURE PRODUCTION COSTS OF COTTON<sup>22</sup>**

	1979	1986
Fertiliser, insecticides, fuel, ginning, bale pressing	40%	44%
Machine costs	22%	19%
Wages	12%	10%
Seed	2%	1,4%
Irrigation, interest, repairs, administrative and operating costs	24%	25,6%

As well as production costs, the economics of reprocessing trashy waste depends on<sup>22</sup>:

- the price of the secondary raw materials, and
- hourly production.

The production costs are made up of<sup>22</sup>:

- capital charges: plant size, number of machines, buildings, air conditioning and filtration plants;
- wage costs for attending the plant, e.g. strapping bales, manual feeding, maintenance, part of administration costs;
- energy costs: machinery, lighting, air conditioning;
- cost of operating materials: spare parts, building and machine maintenance, accessories such as filters, bale strapping materials, etc.

These costs vary from one country to another and from one mill to another, but they affect the calculations considerably.

Binder<sup>8</sup> has graphed the annual savings obtained by reprocessing trashy waste (see Fig. 19) and the figures are bounded by the following conditions:

- operating hours: 6000 h/year;
- price of secondary raw material: 2,50 Sfr/kg;
- production costs of plant: Sfr 150 000 a year.

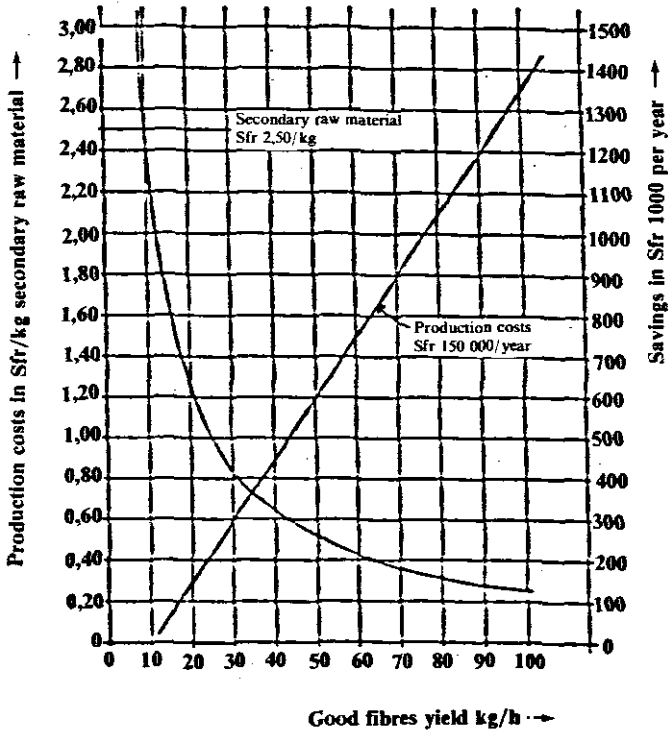


Fig. 19 – Annual savings vs production costs, yield and price of secondary raw material <sup>8</sup>.

It can be seen from the diagram that plants with a yield of approximately 10-15 kg/h are at the lower limit of profitability. This means that boundary conditions like buildings, number of machines, attendance and transport are critical. If a mean good fibre yield of 50% is to give 10-15 kg/h, the spinning operation must produce at least 20-30 kg/h trashy waste. With about 6% trashy waste, this means an hourly throughput of 300-500 kg/h. Profitability is assured in a spinning mill producing 300-500 kg/h, and rising raw material prices are making the economics increasingly attractive<sup>8</sup>.

Locher<sup>56</sup> shows an amortisation calculation for a combing mill spinning approximately 454 kg/h. The resulting comber and card strip waste, approximately 91 kg/h, is available for spinning on a rotor spinning system. His calculations show quite effectively that the capital investment required to set up

a plant to process waste fibre via rotor spinning can be amortised in less than one year.

A comparison between the return on investment of a separate cleaning line and a by-pass cleaning line has been drawn by Artzt<sup>23</sup>. After taking into account the basic factors governing an economic analysis, Artzt has shown that a separate cleaning line results in a saving of 3,80 DM/kg, whereas with a by-pass line the saving is 4,40 DM/kg. By using a by-pass line there is a faster return on investment. Raw material costs in the average spinning mill represent 50% of the total costs<sup>23</sup>. With a 3,7% to 4,0% saving of raw material costs there is a 2% reduction in total costs or more profit. One can see from this that a small saving at the beginning of the operation can result in significant savings on the final product.

Kistler<sup>22</sup> has stated that with a fibre recovery of merely 2% and taking a raw material consumption of approximately 5 million kg/annum, the recovery of good fibres amounts to 100 tons. This multiplied by a raw material price of say 4 DM, amounts to a saving of 400 000 DM p.a.

Simple, but effective utilisation of cotton waste can result in significant savings. This was achieved by the Republic of Turkmenia<sup>61</sup>. Their annual cotton crop was previously packed in fabric produced from valuable raw cotton. The cotton crop is now packed in fabric produced from waste cotton. The use of the "new" material will thus save thousands of tons of cotton yearly.

## CONCLUSIONS

It would appear that machine manufacturers are continuing to encourage spinning mills to reclaim their secondary raw materials and reprocess them in a way that will reduce raw material costs without sacrificing yarn quality and bring increased profitability to the textile industry.

Rising costs of raw materials are making the economics of reprocessing cotton waste more attractive, as economic surveys have shown that the effective utilisation of waste can result in significant savings on the final product.

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