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THE CAUSES AND CONTROL OF WASTE IN WORSTED SPINNING [1]

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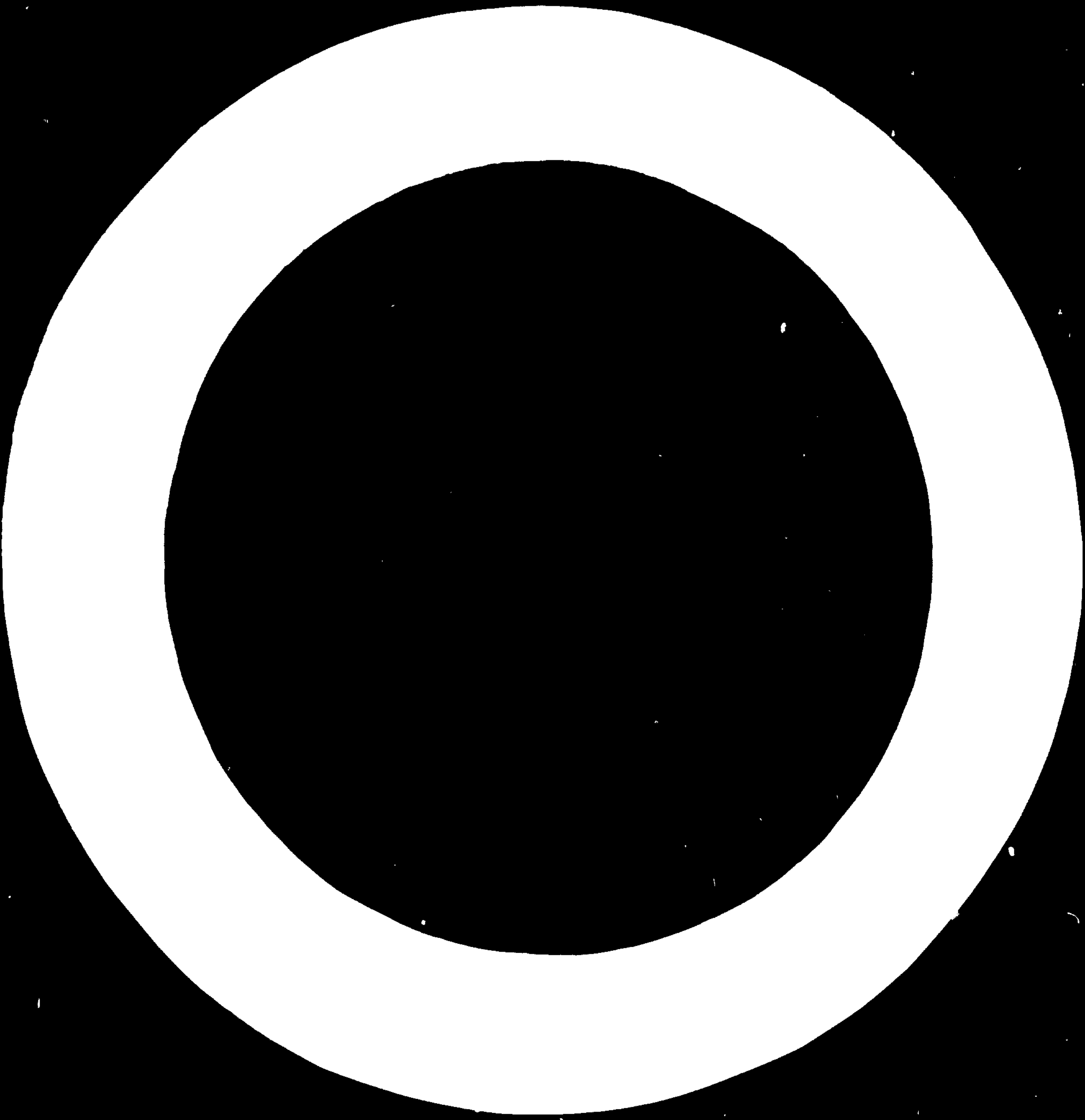

THE CAUSES AND CONTROL OF WASTE IN WORSTED SPINNING

1. Introduction

Modern developments in textile machinery, labour demand and increasing market competition compel the worsted spinner to produce as much satisfactory yarn from a lot of tops as is economically possible. In worsted spinning a fibre loss of at least 4% by weight is encountered(1, 2) and this amount in practice may be considerably higher, especially in mills where small lots of a wide variety of types are processed. It can be seen therefore that waste consitutes a highly significant factor in spinning economics.

The problem of waste is universally recognised by mill management but often little more is done than to collect the waste and then either to sell or reprocess it. In recent times however waste has become a much more pressing problem for the following reasons(3) :-

(a) Raw material and labour costs are steadily rising and taking up a relatively larger proportion of manufacturing costs.

(b) Machinery investment today is much greater than ever before and fixed costs are higher, requiring more hours of machine operation at the highest possible efficiencies.

(c) The rapid changes of lots, blends and speeds are forcing many mills to go to engineering standards based on actual conditions (e.g. cycles, ends down, etc.) rather than set goals and aim for them.

(d) External and internal competition at market level is gradually expanding thus necessitating reduction of prices and/or improvement in efficiency in order to hold a significant share of sales and remain competitive.

It is a popular misconception that the cost of producing waste is mainly a factor of raw material cost. The cost of waste production may thus be severely underestimated since each of the following factors must be considered in any assessment of the losses involved:

(a) raw material cost
(b) processing cost
(c) handling cost
(d) the reduction in machine efficiency and product quality
(e) loss in selling profits
(f) reprocessing cost (if any)
(g) sale value of the waste (if the waste is sold)

Consideration of the above factors shows that the losses progressively increase through the processing cycle, the cost/kg. of producing waste in spinning being significantly higher than in the cost/kg. for the earlier processes. Thus, from a cost point of view more gains may be had by bringing about waste reductions in the later processes. Consider the relative costs of producing drawing and spinning laps for example. Based on a top value of $2.50/kg. the resale value of drawing laps is about $2.30/kg., whilst the corresponding value for pneumafil ring frame laps is about $1.90/kg. The relative cost of spinning is much higher than drawing, except for coarse counts(4). Given the costs for drawing and spinning 6s count as 6 and 10 cents/kg. the corresponding costs for 56s count would be approximately 6 and 60 cents/kg. respectively. This shows that the extra loss incurred in producing spinning waste may be as much as $1.00/kg. more than that for drawing waste.

The foregoing illustrates the need to understand the causes of waste production and a description of our present knowledge in this field follows. Methods of control will then be discussed and a number of typical case studies examined.

2. The causes of waste

The analysis of the causes of waste presents a rather complex problem. Waste varying widely in composition and properties is produced at all points in the manufacturing sequence. The generation of this waste is governed by a large number of related and unrelated variables and this creates difficulties in experimentation and the interpretation of the results. There is no clear relationship between waste and quality since (i) an increase in waste may lead to an improvement quality (e.g. more noil removed in combing will give a better top), (ii) an increase in waste may indicate lower quality (e.g. a less uniform yarn will give more ends down and hence more waste), or (iii) the waste may be independent of quality (e.g. the waste produced in setting up and running out a batch). Fluctuations in a particular waste may or may not be related to quality depending on the factor or factors causing the fluctuation. It is important to note that a reduction in waste at one point may lead to an increase in other types of waste so that the waste situation may in fact be aggravated.

Very little research in spinning has been directed towards examining the causes of waste probably due in part to the above complications. Most work in the spinning area has been focussed on the factors required to produce a strong uniform yarn, such factors as roller lapping and ends down being treated as causes of non-uniformity rather than as waste producers. Spinnability is determined by the end breakage rate since practical difficulties in piecing up are found if the end breakage is above a certain limit. A good deal of information however can be inferred from the experimental results. The number of ends down for example is directly related to waste since the amount of waste produced is proportional to the product of end breakage rate and the average time an end is down. The count limit for a particular set of conditions is also useful since this is the point where end breakage rates become unacceptable. One would expect that if two different conditions give a large difference in the spinning limit then, if the same count is spun under both conditions, less end breaks and hence less waste will be produced for the conditions giving the higher spinning limit. The non-uniformity of the roving or yarn should also be of significance since more end breaks in spinning, twisting and winding might be expected for a more non-uniform product.

A large number of variables affect waste production and these can be conveniently examined under the following headings:

(i) Raw material variables.

(ii) The effect of room and fibre conditioning

(iii) Processing variables.

(iv) Operative variables.

(v) Batch size and variety production effects.

2.1 Raw material variables

The performance of a top, the raw material in worsted spinning, is greatly affected by the characteristics of the initial fibres (e.g. length, diameter, length distribution, etc.) and the preliminary processing (scouring, carding, combing, top dyeing, etc.). Variations in these variables can lead to more or less waste in later processing.

Consider first the initial fibre properties where the main factor appears to be the mean fibre diameter. Stanbury and Byerley(5) have examined the limiting counts for yarns spun on the conventional Bradford system. Using a wide range of qualities from 40s to 80s they found that at the spinning limit there are about 20 fibres in the cross-section indicating that the fineness of the fibres is directly related to the finest count that can be spun from that quality. Martindale(6) has been able to show that the roving irregularity is governed by the fibre fineness, the finer fibres producing more regular rovings. Bastawisy et al(7) using the Ambler Super Draft system have indicated that the number of fibres in the cross-section is about 20 for the limiting count. Table A summarises their results:

TABLE A

Fibre Group	Diameter (microns)	Limiting Count	Number of fibres in cross section
Australian 64s	21.8	88	20
South American 64s	24.2	72	23
Australian 60s	26.0	72	20
South American 60s	26.0	68	21
New Zealand	28.6	52	20
English	33.6	40	21

Early work(8, 9, 10) has suggested that the uniformity of fibre diameter is an important factor. Bastawisy et al(7) have compared a normal 64s top with one made by blending three tops (60s, 64s and 70s) and have found that there is no difference in performance, the limiting counts being identical. Lang et al(11) compared samples within a single Merino flock producing tops with coefficients of variation of diamter of 18.3% and 21.4%. Using both the conventional Bradford and Ambler systems they found that the higher variability gives more end breaks near the count limit but that there is no significant effect in the commercial range. These conclusions have been confirmed in a subsequent series of experiments using commercial tops and their blends (12).

Grosberg (13) has indicated that the variability in addition to the theoretical minimum is strongly correlated to mean fibre length for yarns spun on the Continental system. Gabceran-Escabat (14), using Merino wool on the Continental system, has given a formula relating the minimum number of fibres in the cross-section of the yarn with its mean fibre length. Increasing the length up to 7.5 cm. gives beneficial effects whilst lengths greater than 9.5 cm. are disadvantageous. Bastawisy et al (7) using the Ambler system have shown that for 60s wool, which differ only in length, the longer fibres give finer limiting counts. This pattern has been confirmed using rayon tops, the overall conclusion being that there is no gain in using fibre lengths over about 10 cm (about 4 inches).

Comparison of fibre diameter and fibre length effects indicate that fibre diameter is the more important variable. This has been shown to be the case in both conventional Bradford worsted spinning (15-18) and the Ambler system.

Variability in fibre length and sliver reversal are also important factors in spinning performance and product quality. Nip fluctuation in drafting is always present and this leads to a fluctuation in the leading fibre end distribution. The trailing fibre end distribution is less affected by these fluctuations so that reversal tends to break up the groupings leading to a more uniform sliver, roving or yarn. When the fibre length in the top is constant then the grouping of trailing ends will be similar to that of the leading ends so that irregularity once produced will tend to remain. An experiment(7) (Ambler system) carried out on nylon tops of uniform and variable lengths has confirmed this pattern since the variable length top can be spun to a much higher count than the uniform length top (110s compared with 75s). It has been suggested that, although improvement can be achieved by using a wider length distribution, there is a distinct disadvantage about a certain limit due to the presence of more short fibres which leads to more fly waste. Bratt(20) using the conventional Bradford system has found that fibres sorted for length (having length variability less than commercial tops) give an inferior spinning performance. The performance of rovings with a diagonal cumulative frequency diagram give less ends down than squarer or more variable fibre length rovings. This effect is also supported by the analysis of some commercial tops and the yarns produced from them. The optimum coefficient of variation of fibre length for rovings is about 50% and is independent of the count spun. Further work by the same author (21) has shown that increased fibre breakage for finer counts tends to alter the top distribution to a more diagonal one and it is concluded that a finer count will require a slightly squarer top than a coarser count.

The effect of fibre crimp has been investigated and shown to be of significance. Yarns spun on the Continental system from wools with the same fineness but different crimp give fewer end breaks for the fibres with higher crimp(22). Lang(23) has indicated a similar effect except that his results are probably a function more of diameter than crimp since he used fibres whose crimps per inch varied inversely with fibre diameter. Spinning on the Ambler system appears to favour fibres with lower crimp levels(7). In wools of constant diameter but differing in crimp it is found that crimps per inch decrease with processing but the same relative difference in crimp still applies. The low crimp fibres give a finer count and less ends down than those with high crimp. A more level roving is produced by the low crimp fibres and this is attributed to less fibre disturbance in drafting due to the straighter fibres. Experiments (7) on high and low crimped nylon fibres have shown less crimp removal in processing with a much finer limiting count for the low crimp fibres. Work on fibres with 'anomalous' crimp has shown that normal fibres are superior(24). Other work on this so-called doggy wool (low crimp, normal strength) has resulted in no difference in performance compared with normal wools(25).

Ross(26) has noted that there is considerable variation in staple strength during the New Zealand wool selling season even in good style and apparently sound wools. Combing trials have indicated that the stronger staples give a smaller combing loss and less fibre breakage in carding and combing, producing a top with higher mean fibre length. It is also indicated that if a tender region exists a better performance is obtained if this region is towards the butt end of the fibre(27). Combing(28) and spinning(20) trials on fibres with varying staple strength have shown an inferior performance for the weaker fibres compared with strong staple fibres. Lots with lower staple strength give significantly more fibre breakage in drawing and spinning. Bastawisy et al(7) have produced fibres of varying strength by various amounts of chemical damage. The 64s tops used have been processed on the Ambler system and Table B gives the results found. These indicate a finer limiting count, less fibre breakage and a large mean fibre length for the stronger fibres. Steely wool (lower than normal crimp and strength) has been shown to be inferior to normal wool (8 times the ends down) and this is probably mainly due to fibre strength(25).

TABLE B

Fibre tenacity (gm/micron^2)	Limiting worsted count	% fibres broken	Mean fibre length (cm)
0.016	86	11	5.5
0.016	86	9	5.4
0.014	72	30	4.0
0.013	72	41	3.7
0.012	64	41	3.7

During growth the tip ends of fibres are subjected to weather damage and can be further weakened in scouring. Walls(29) has found that tip ends representing about 3% of the fibre weight break off during processing, 70% being removed by the card, 16% by the Noble comb and the remainder appearing as fly or droppings in drawing, spinning and weaving. In drawing and spinning the tip content in the fly and droppings decreases slightly through the processing sequence, but is significant that the fly loss is predominantly fibre tip.

Several other factors have also been investigated. Lipson et al(30) have indicated that wools from sheep selected for high fleece weight give less neps and longer fibres in the top. The top yield is increased by 4% and there are less ends down in spinning. Lang et al(31) investigating skirting of fleeces have shown that although unskirted fleeces give more ends down near the spinning limit differences are insignificant when commercial counts are considered. Bowness(32) has investigated the effect of short fibres from second cuts in shearing and has found that more waste and more neps are produced in processing. He concludes that the effect is significant and suggests that shearing needs some improvement. Bownass(33) further indicated that fleece wools suffer more fibre breakage in preliminary processing than skin wools leading to tops with lower mean fibre length.

The preliminary processing (scouring, carding, combing, etc) in producing a top can have a marked effect on the properties of the top and hence on later spinning performance. Fibre breakage modifies the mean fibre length and the length distribution of the top: neps and hooks are produced and vegetable matter may be present in the top. All of these factors will affect the waste produced in later processing.

The scouring process can have a significant effect, the main paramters of significance being fibre entanglement, fibre damage and residual grease content. Chemical damage in scouring causes a reduction in fibre strength leading to more fibre breakage throughout processing as well as more ends down in spinning(7). Increased fibre entanglement leads to more fibre breakage and hence more waste. Solvent degreasing has been shown to greatly reduce fibre breakage and to give much less neps in the top(34). The residual grease content of the fibres affects the top in that for higher grease contents more neps are formed in carding (35) but less fibre breakage occurs(33). The amount of grease also affects gilling and combing(36).

Hook formation in carding is important in that it affects fibre breakage (37,38,39). More ends break when trailing hooks get into spinning and this is particularly significant with the semi-worsted system (38). Fibre breakage in carding has been shown to be proportional to the fibre length (longer fibres tend to be broken)(40). The formation and movement of neps has been examined(35,41-43) and some information about vegetable matter remaining after rectilinear combing has been given(43-45). Lubrication is of significance in combing(46,47) whilst regain has been demonstrated to be important in carding(35) and combing(48). Fibre breakage in combing has been treated(33,49) and it has been shown that a longer top is produced when more noil is removed(50).

Top dyeing can affect the amount of waste in later processing. The problem is that certain colours or types of dyed tops process badly giving excess rubber waste and/or more ends down in spinning; the mechanism for this effect does not seem to be understood(51). Mill experience (Case Study 1) shows that fluctuation in the residual grease content before and after dyeing is important but even after correcting for oil contents the same counts from the same raw material dyed to different shades still give different wastes. Saville et al(52) have demonstrated that top dyeing can give a major increase in slub production on the Continental system. Pressure dyeing gives 30% increase in the number of slubs compared with open dyeing.

Backwashing does not affect the slubs produced or the end down rate but if piecing up in backwashing is not done carefully more slubs are produced(52). Recombing trials using the Noble and rectilinear combs indicate that the Noble coming reduces the ends down in spinning but increases the amount of spinning waste(53).

The use of man-made fibres either alone or blended with wool produces additional problems in spinning. Kirk(54) has discussed the processing of man-made fibres on the worsted system with particular regard to the choice of the fibre length distribution and the system to be used. Roper(55) has indicated the problems in spinning blends of man-made fibres and wool.

2.2 The effect of room and fibre conditioning

The conditioning of the fibre plays a major part in worsted spinning since variations away from optimum conditions can bring about a large increase in the amount of waste produced. The variables to be considered are the relative equilibrium fibre regain at a given humidity, the air temperature (since this affects the/relative humidity), the fibre regain and the fibre conditioning using oils and anti-static preparations.

The initial regain of the tops and the relative humidities in drawing and spinning on the Bradford system have been shown to be important factors in waste production(56). In the tests the top regain varies between 13% and 23% whilst the relative humidity varies independently between 40% and 80%. Rubber waste is collected from the draw box, weighbox and dandy rover whilst fly waste is collected in spinning. The individual wastes (as well as the total waste) decrease as the relative humidity increases from 40% to 70% and then increases up to 80%. A similar pattern is indicated for top regain, the waste decreasing for regains 13% to 19% and then increasing up to 23%. The optimum values for minimum fly and rubber waste are 70% relative humidity and 19% regain. It is found that moisture does not affect the roving regularity or the mean fibre length in processing. For the extremes of 13% and 23% regain, excessive laps, rubber waste and fly waste are generated. The tests indicate that in drawing a relative humidity between 65% and 75% gives best results whilst in spinning a compromise value less than 60% relative appears to be preferable. This latter adjustment is necessary because excessive ends down are produced at higher humidities and this more than offsets the reduced amount of fly waste produced.

The optimum values arise for two reasons. Under dry conditions, the generation of static electricity promotes the formation of feather edged slivers, rovings and yarns, which often become attached to the revolving parts of the machine. The fibres tend to assume a more open state due to mutual repulsion and the loosely held short fibres can easily be removed (fly and rubber waste). On the other extreme, too moist conditions also give trouble. The rubber waste in this case contains more long fibres than the corresponding waste under dry conditions. Although static electricity effects are absent the bottom front rollers still have a definite attraction for the loose fibres. This has been explained as an effect of drafting tensions and the tendency for the roller to become damp. Tensioning of the leading fibre end in drafting is released after the front nip and the recoiling relatively loose fibre end is often attracted to the damp roller by surface tension leading to fibre loss or a fibre with a hooked end.

Ingham(51) again using the Bradford system has varied the relative humidity of drawing and spinning independently between 50% and 70%. End break tests on high count yarns (to promote end breaks) have shown that the end breaks decrease as the relative humidity is lowered. The author also has indicated that a lower relative humidity is preferable when storing rovings.

The use of oil in spinning can be beneficial since it tends to reduce static(57), can reduce the need for more accurate humidity control(58) and can affect the ends down in spinning(59). The addition of oil can also reduce the amount of fly waste(60). Saville et al(52) spinning 64s woll on the Continental system varied the fibre fatty matter between 0.25 and 1.5% and found that an oil content of 0.8% gives minimum slubs. Minimum laps, waste in drawing and end breaks have been found for oil contents between 1.1 and 1.2%, leading to the conclusion that 1% oil gives optimum overall results. Towend et al(61) have examined the relationship between ends down and oil content for the conventional Bradford system and for the Ambler system. For this latter system contents below 2% give more ends down whilst for higher contents the end breakage increases slightly and an optimum of 2 - 3 % is suggested. For the Bradford system a similar relationship exists with an optimum of about 3%. Industrial trials also agree with the findings.

Several investigations into licking of fibres around rollers due to static have been carried out(62-64). King et al(62) indicate that maximum fibre pick up by the rollers occurs when static and oil are present together. The pick up can also be facilitated by the geometry of the roller system. Dolder et al(63) have shown that the pH of the aqueous extract of tops is related to static generation, the most dangerous pH range being 6 - 9. In an emulsion scouring system this pH is towards the upper end of the pH scale. Lubrication reduces the amount and effect of static stored in the fibres and this suggests a reason for the higher fly produced when processing dry combed material. Wegener et al(64) have examined the spinning of all wool and polyester-wool rovings on the Continental system. The relative humidity has been varied between 55 and 85% and the temperature between 20 and 30°C and end breaks have been classified as due to licking in the drafting zone or as due to breakage between the front rollers and the package. They concluded that many end breaks associated with licking can be avoided by the choice of optimum conditions.

The addition of anti-static agents can have important consequences in reducing waste. Anti-static agents allow lower relative humidities since charges are neutralised as soon as they are formed(65). The agents can be a disadvantage in the Continental system because of the hardening of rubbing leathers due to the tendency of the anti-static agent to remove oil from the leather. When blending man-made fibres and wool, the use of anti-static agents is recommened(66). Ingham(51) has shown that anti-static treatment gives less brush waste but the top board waste increases. In this latter case the fibres fall from the yarn itself and it is suggested that a small amount of static could be beneficial. Excessive oil leads to oil on the rollers, fibres tending to stick to the rollers due to surface tension(51, 65). However, when an anti-static agent is present more oil can be tolerated(51).

In the Continental spinning of all wool yarns an atmosphere of 80% relative humidity is commonly employed but care must be taken as too damp conditions produce condensation on the rollers giving as many problems as static in dry conditions(67). When polyamide, polyester and acrylic fibres are blended with wool the relative humidity must be reduced to 65 - 70% and the use of fibre lubricants with anti-static properties becomes important(68). It has been shown that at 65% relative humidity, the charge on synthetic fibres is much higher than that on wool. The addition of 0.1% anti-static agent reduces the charge on the acrylic and polyester fibres to less than that of the wool whilst an addition of 0.15% gives a similar effect for polyamide fibres. When the relative humidity is lowered to 45% the removal of the charge on the wool requires 0.3% addition of lubricant whilst the corresponding charge on polyester fibres is reduced by the addition of 0.1% of lubricant. In the presence of lubricant the order of decreasing charge is in general that of decreasing regain (wool polyamide acrylic polyester). The effect of moisture in the wool fibres is to reduce the concentration of lubricant on the fibre. The results have suggested that the main difference between the lubricants is in their power of dispersion whilst differences between fibres are due to differences in the absorption of matter on to the fibres. This could explain the varied results of spinners when changing blends without changing the percentage or type of anti-static agent.

Sample(69) has examined the case for automatic control of temperature and humidity within textile mills. He points out that there is a popular misconception about the size of humidity fluctuations, the fluctuations being much greater than most people realise. Worsted processing runs best if there is a gradual reduction in the amount of moisture to yarn but with modern high speed machinery more heat is generated producing difficulties in controlling relative humidity so that temperature control is an important factor. Closer control can reduce the use of anti-statics, etc. and Sample quotes a case where this reduction amounts to a substantial saving in cost.

2.3 Processing Variables

As well as the factors mentioned so far processing variables such as doublings, drafts, ratch settings, twists, etc. affect the amount of waste produced. The conversion of top to yarn is a problem of reducing the mass per unit length of the input material whilst maintaining product uniformity. The levelness is affected by the rate of draft, high drafts above certain optimum values producing more irregularity(70). With the advent of high drafting in spinning much more attention has to be paid to accurate settings to maintain quality.

In practice, the reduction in mass per unit length is carried out in stages; each drafting operation introduces fresh irregularity, the irregularity of the final yarn being a 'summation' of irregularities produced by each operation. Doublings are used as a method of improving the product levelness, a compromise having to be made between the benefits of extra doublings and the detrimental effects of the extra drafting which doubling entails. Early work on doublings(70) has shown that there is a limit to the number of doublings which improve yarn levelness and that this limit is considerably lower than the number of doublings normally used industrially. The most promising method of reducing drawing procedure appears to be to reduce the number of doublings used. Modern practice is in fact to have fewer doublings and fewer passages through the machines, the regularity being maintained by autolevelling devices.

Fibre breakage is an important factor since an increase in breakage can lead to more fly waste and more ends down in spinning. Bratt(20) working on the conventional Bradford system has indicated that fibre breakage is higher for the finer wools. His experiments show an average of 14% breakage for 48s/50s quality with a value of 23% for 58s/60s. Further work on breakage(21) shows that most of the breakage occurs in the final stages of processing and is greatest when spinning fine counts. Fibre breakage is a function of two main factors, the ratch setting and the roving twist. It is necessary to set the ratch longer than the longest fibre to avoid breakages since a shorter ratch will break all fibres greater in length than the ratch setting. For a given ratch the extent of machine control over the fibres depends on the length distribution, a wider distribution and a longer ratch leading to less fibre control.

Twist is used to provide cohesion between the fibres so as to maintain control over the shorter fibres. However, this tends to restrict fibre movement and breakages increase. As attenuation is increased the amount of twist must be increased to maintain the strength required to withstand the winding-on tension and the tension of withdrawal from the creel at the next operation. This increase in twist combined with the decrease in the number of fibres per cross-section must inevitably lead to fibre breakage.

The strain and distortion imposed on fibre ends during drafting, due to the initial pull, continually repeated at each operation on alternate ends of the fibre, must lead to an increase in breakage(21). It is to be expected, therefore, that fibres will be beheaded or betailed as a result of this stress and fatigue, the effect being more important for longer fibres. The results show that in fact the longer fibres tend to be broken as is borne out by the increasing proportion of short fibres found in rovings, apart from those which ultimately comprise the fly waste.

The problem of fly waste has been investigated by several workers. The amount of fly is related to moisture conditions as indicated earlier(56), but the amount is little affected by anti-static preparations(71). Hamilton et al(72) have found that the fly waste is composed of two groups of short fibres, the first fine in quality and the second coarse fibres (from fibres broken in processing). It is suggested that these groups are those which are most likely to migrate to the outside of the roving and hence the probability of loss is great. Oxtoby(72-74) has made some useful contributions to our knowledge of how processing conditions affect the amount of fly waste. Spinning a 64s Bradford wool top on a cap frame he collected and weighed the amounts of fly waste at the threadboard and at the balloon. He found that small fluctuations in the nominal count are not related to the fly produced and the end breakage rate is independent of the fly percentage. Although both the threadboard and balloon wastes have quite high grease content fluctuations, the amount of grease is not correlated with the amount of fly present. Oxtoby observed:-

(i) When spinning a particular count, the use of a thicker roving (and hence higher draft) gives more fly waste.

(ii) For yarns spun with the same draft the thicker yarns give more fly waste.

(iii) There is little change when different counts are spun from the same roving weight.

(iv) The reduction of twist from 13 turns per inch to 12 turns per inch gives less threadboard waste but more balloon waste; increasing the twist up to 15 turns per inch has little effect.

(v) The use of a spinning twist opposite to the roving twist gives a large reduction in threadboard waste, a small increase in balloon waste and a small decrease overall.

(vi) Increasing the spindle speed increases both wastes.

(vii) Alteration of the roving twist brings about fluctuations in the amount of waste but no clear pattern is evident.

(viii) An increased cap diameter leads to more waste.

(ix) Increasing or decreasing the ratch away from the optimum brings about an increase in fly waste; for longer ratches there is less control whilst for smaller ratches more fibre breakage leads to more fly waste.

(x) As the relative humidity is increased the fly waste decreases (a result shown earlier(56)).

Oxtoby has carried out a detailed length and diameter assessment of the waste. The fly waste divides into two groups, the first being coarse longer fibres of measureable length (WIRA tester) and the second consisting of short fine fibres less than 1 cm. in length ('dust'). The coarse fibres originate from the breakage of long fibres in spinning. The origin of the fine short waste is different for the threadboard and the balloon wastes. The threadboard waste is produced by the breakage of fine fibres in the longer end group during drafting whilst the balloon waste consists mostly of short fibres already broken in the roving. Because of the advent of high speed spinning fly waste has become more of a problem(75). At these higher speeds the same amount of fly accumulates at a much faster rate so that rapid clearing is essential.

End breakages in spinning have also attracted increasing interest(76-84). The insertion of twist is important since a reduction in twist leads to more ends down(70,77,84). There has been a steady trend towards the use of less twist at each stage in drawing, but the direction of this trend has been questioned(82) on the basis of work carried out on the optimum twist levels for cotton rovings(84). With the improved forms of high drafting it has been found that harder twisted rovings give less ends down in spinning(84). Gessner(83) has investigated thin spots in yarns and inadequate twist propagation as potential causes of end breakage. He noted that yarns with weaving twists break at weak spots whilst soft twisted (short fibred) yarns break at thicker spots because of poor twist propagation. Adamson et al(80) have examined end breaks in worsted spinning and have concluded that breakage is caused primarily by the production of thin spots generated in drafting at the spinning frame. They noted also that breakage tends to be caused by fibre slippage rather than fibre breakage. More ends down occur when the ratch is short (due to fibre breakage), for higher roving irregularity, for a smaller winding angle and for higher spindle speeds(77,81).

The machinery used in a particular mill may affect the amounts of waste produced. Gruoner(2) has pointed out that there is less waste produced by modern sets with reduced passages, better lubrication and pneumatic extraction. This latter factor is of importance in high speed spinning since roller laps build up at a very high rate and this can lead to irregular yarn on the adjacent spindle(75). It seems likely that a mill with older equipment will tend to produce more waste than a mill with more modern equipment. Complications can arise due to the type of equipment and the end use since certain machines are preferable for mills spinning small wide variety batches compared with mills spinning large lots (e.g. see Case Study 1). Knowles(101) has shown that stopping a spinning frame has an effect on the waste produced.

Such machine faults as damaged roller surfaces (which cause laps), untrue roller surfaces (uneven slivers and yarns), damaged gill pins, uneven roller pressure, vibrating spindles, ineffective stop motions, inaccurate length measuring knock-off motions, incorrect machine adjustment (e.g. builder motion adjustment), etc. can all contribute to waste production. Gayczak(85) has examined uneven roller rotation, the vibration of rollers, gear eccentricity and inaccurate settings as faults in drafting. Cranberry (86) has looked at gear fault effects and concludes that a closer tolerance is required, a conclusion that is backed up by Barabanov(87). The relationship between slip-stick friction and torsional vibrations in rollers has also been investigated(88). It should be pointed out, however, that with a regular system of checks and maintenance, machine faults should have only a very minor effect on waste production.

2.4 Operative Variables

The operators play a large part in the production of the finished yarn since they are responsible for starting up the batch, keeping a continuous flow of material passing through the machine (by piecing up end breaks and by supplying fresh input at the appropriate stages), running out the batch, handling of material between processes, cleaning, collection of waste, etc. It is not surprising therefore that an excess of waste may arise as a consequence of poor operators and/or incorrect operating procedures. Excess waste produced by a particular operator, however, may not be only his responsibility, but also that of the supervisor and management. It is the responsibility of management to arrange the staffing of the installation, the classification of the work to be carried out by particular types of operators, the setting out of detailed operating procedures and techniques (e.g. the steps to be carried out in a particular operation, the best operating cycles, etc.) and the training schedules for supervisors and operators. It is the responsibility of the supervisor to arrange the operator training and to keep a constant check that the operating procedures are carried out correctly. Excess waste produced by an operator may thus be a function of inefficient operating procedures, inadequate training, poor supervision, lack of skill in carrying out particular procedures and/or operator carelessness.

An important operative effect on the amount of waste is the spinner patrol cycle. For longer cycles the average time an end is down is greater and thus more waste will be produced. If the end is down too long a further loss may occur due to the building up of a malformed package (i.e. one which will not run in later processing).

Merchant(89) has established a theoretical relationship between spinning waste created as a result of end breakages, spindle allotment, and breakage rate and the piecing efficiency of the tenter. He assumes that the tenter operates in a cyclic manner, that there is equal probability of an end break on any spindle at any time, that the time of the tenter is spent in piecing ends and travelling from spindle to spindle (cleaning, creeling times are included in this travelling time) and that the operative effort is not influenced by the spinning waste being produced. The following equation for S, the percentage of roving being removed as waste against N, the number of spindles allotted, E, the end breakage rate per 100 working spindle hours, X, the average time (minutes) to mend an end-break and , the travelling speed of the tenter (spindles/minute) deducting the time spent in mending end-breaks, has been derived:

$$S = \frac{50}{x\,EN}\left[\,x\,EN - 6000 - EN/2\nu + \sqrt{(xEN - 6000 - EN/2\nu)^2 + 2xE^2N^2/\nu}\,\right] \qquad \ldots\ldots\ldots (1)$$

In order to use the equation a particular mill must use a work study to determine x and ν . Merchant gives an example to indicate that as the end-breakage rate increases the waste increases slowly at first but the increase becomes very rapid for high end-breakage rates, the turnover being greater for higher spindle allotments. Merchant defines an index of operative efficiency and illustrates the method of calculation with a practical ease. The corrections to be made for spindle and bobbin effects (the probabilities of breakage are in practice higher on some spindles and some bobbins) and for changes in operative effor for different ends down conditions are indicated.

Subramaniam(90) has criticised the assumption made by Merchant(89) about the average time an end is down (i.e. half the patrol time) and Merchant's method of including the time spent in creeling, cleaning, etc. Subramanian assumes a Poisson distribution for end breakages with different spindles being independent of each other. He begins by ignoring the time spent for extra duties and then includes the effects of creeling, cleaning and resint beside the machine and he has obtained significant differences from Merchant's predictions. His working equations are:

$$\frac{(m')^2 t^2}{6} - \frac{m't}{2} + \frac{S'}{100} = 0 \qquad \text{.............. (2)}$$

and ; $$N^2\left(\frac{M'tm'x'}{100\,C}\,g + yg/C\right) + N\left(y + \frac{M'tm'x'}{100}\right) - \frac{P}{100}\,.t = 0 \qquad \text{............ (3)}$$

where,

$S' = S\frac{(mT + 1)}{(mT)}$

$M' = 100 - S'$

$x' = \frac{mTx + r}{mT + 1}$

$m' = \frac{mT + 1}{T}$

P = percentage of patrol time spent on patrol

C = clock time (min) between consecutive cleanings

g = time per spindle per cleaning (min)

m = end-breakage rate (breaks/spindle running minute)

N = number of spindles attended by tenter

r = time taken per creeling (min)

S = roving waste (%)

T = time (min.) for which one creel bobbin lasts

t = average patrol time

x = time (min.) for one piecing

y = time (min.) for tenter to walk from one spindle to the next

The method of solution is to set S, calculate S', substitute in (2) and solve for t and then substitute in (3) and calculate N. Subramanian also gives equations so that if N is given S can be found. He gives an example to illustrate the effects of reducing the end breakage rate, the piecing time and the rest period. In both cases T = 1800 minutes, r = 0.25 minutes, C = 60 minutes, g = 0.015 minutes and y = 0.008 minutes. In the first example the values are $m = \frac{1}{200}$, x = 0.25 min and P = 75% and this gives:

Size of spindle allotment N	400	450	500	600
Waste (%) S	0.6	1.5	5.6	17.2

In the second example the values are $m = \frac{1}{400}$, x = 0.1667 min. and P = 90% and this gives:

Size of spindle allotment N	400	800	1200
Waste (%) S	0.07	0.26	2.5

Since these earlier papers(89, 90) a continuous discussion about assumptions, corrections, etc. has ensured(91-96).

Wilson(97) has examined the losses due to malformed bobbin and a formula relating waste to spinner patrol time has been derived (cotton ring spinning filling frame).

The equation is:

$$\text{Waste } (\%) = 1 - \frac{DT}{SM/C} \quad (ED) \quad \frac{MC}{600} \quad \frac{RT/P - \frac{SM/C + DT}{2}}{RT/P} \quad \ldots\ldots(1)$$

Where DT - ends down time (min) to produce a malformed bobbin

SM/C - spinner [illegible] cycle

ED - ends down/1000 spindle hours

MC - machine cycle (minutes) including doffing and interference

RT/P - running time/package (minutes)

The percentage waste is zero when the patrol time is less than the time to produce a malformed bobbin but the waste rises quickly as the cycle time is increased as does ED.

One final operative effect which is worth considering is the effect of trainees or absentees. A spinning room is staffed at a predetermined level so that if the staffing is decreased due to absentees the spindle allocation (and the patrol time) is increased leading to an increase in waste production. The introduction of trainees will also lead to an increase in waste. The effects might be expected to be more important for smaller mills where the workforce is smaller.

2.5 Batch size and variety production effects.

The average batch size varies widely within and between mills. Table C gives the variation encountered between seven Greek worsted mills[93].

TABLE C

Mill	A	B	C	D	E	F	G
Number of lots	70	173	450	60	61	103	118
Average lot (kg)	2649	1117	644	1157	1622	913	948
% lots between 1 and 100 kgms.	26	70	86	55	48	71	77

It is evident from these figures that this is mostly white material since the average coloured lot is about 100 kgs.(10). This average size might have decreased in the last few years due to the pressure of [illegible] demanding a wide range of colours which may be ordered at fairly frequent intervals. The increasing use of man made fibres has also lead to [illegible] the lot [illegible]. The output of different mills [illegible] the difference will range from mills producing large lots (mainly white material) with little variation of counts, etc to those producing a large number of small(4,15) varying [illegible] colour, fibre composition and finished yarn properties. The amount of waste produced will in general increase as the lot size decreases and the variety increases.

One of the first problems encountered is that a much wider variety of waste will be produced, greatly increasing the handling costs in sorting the waste. There will be much less opportunity to reprocess the waste because of such factors as colour and fibre limitations so that most will have to be sold. Increased losses will therefore occur since the sale value of coloured and man-made fibre wastes is significantly lower than white wool wastes(1).

Obtaining the correct processing conditions will create serious problems. Different batches may require different relative humidity conditions for optimum processing but because these batches will have to be processed at the same time an 'average' relative humidity is the only possibility. Thus, there may be no batches for which the ambient conditions are optimum. After dyeing the grease content of the top may vary depending on the fibres used, the dyeing process and the colour. The addition of oil is necessary to enable adequate processing and this creates a further difficulty since our knowledge of the correct amount to add is largely empirical. With large lots (e.g. 1000kgms.) there is the possibility of correction during processing so that the effect of a wrong decision leading to poorer spinnability can be minimised to a large extent. However, with small lots (e.g. 100 kgms.) by the time the spinnability has been assessed the lot has been processed and no correction is possible.

When running any batch there is always a certain amount of starting up and running out wastes and this tends to be little affected by batch size. Thus, the percentage waste due to this source will depend on the batch size, the smaller the batch size the larger the percentage waste produced.

The Control of Waste

It is important to examine the problem of waste control in terms of all processing rather than just the problems involved in spinning yarn from the tops since savings in one department may lead to increased waste in other departments. It is clear for example that significant improvements may be expected by placing more emphasis on a more uniform initial product. Here more waste in preparatory processes will usually accompany less waste in spinning but because of the cost structure (waste costs more to produce in later processes) significant savings may be made even if the actual overall waste percentage is increased. It is also important to think in terms of subsequent processing after spinning (e.g. weaving, finishing, etc.) since any economy in spinning which can lead to a reduction in yarn quality may have adverse effects in later processing.

The control of waste in worsted spinning many be carried out by taking steps to obtain optimum processing conditions and by implementing a waste control scheme. The two modes of attack will now be considered.

3.1 Optimising processing conditions

Given a particular raw material and a particular mill there must be an optimum set of conditions (e.g. relative humidity, grease content, doublings, draft, machine settings, etc.) which will give the best quality in conjunction with minimum waste. No two mills are alike, however, so that the optimum conditions in one mill may not be the optimum in another. Previous work on the causes of waste has indicated a wide range of factors affecting waste but unfortunately the results can only be regarded as qualitative rather than quantitative. It is therefore the responsibility of the individual mill to obtain quantitative information in relation to the particular situation existing within that mill.

In order to obtain the best results it is necessary to carry on a continuing experimental program constantly varying grease contents, roller settings, spindle speeds, traveller weights, etc., until the best combination of conditions is achieved for each count and quality. Careful cataloguing of the results is necessary and the sampling methods used must stand up to statistical demands. Usuaully, it is impractical or unwise to carry out this form of experimentation on a large scale and good results may be obtained by using a small group of frames.

After obtaining the best technical standards for spinning, the next step is to put these standards into practice. At this stage it is important to be on the lookout for the effects of errors occuring during the experimentation (e.g. noting of incorrect roller setting, calculating twist factors incorrectly, etc.) so that the standards can be corrected. The best way to achieve standardisation is to adopt a system of cards for each frame end, which give all the particulars of the standard. When a frame is changed a new card should be issued giving the details for the next lot. It is advisable to institute a system of checks to help to eliminate human error which may result in poorer spinning conditions. It is also necessary to catalogue the performance of each lot as a guide to future experimentation so that standards may be constantly revised to maintain optimum conditions.

The ability to carry out the foregoing procedure will depend to a large extent on the degree of rationalisation of production obtained in the mill. It is much easier to determine and maintain optimum standards in a mill which spin large batches with little variation in properties between batches. The problems increase in difficulty as the batch sizes become smaller and the varieties produced become wider. The standards determined cannot hope to cover all product variations and hence the processing conditions may sometimes be far from optimum.

Another important question to consider is the establishment of the correct spinner cycles and hence the best spindle allocation. As the spinner patrol time increases (the patrols per hour decrease) increased waste is produced(89, 90, 97, 100) and hence costs are increased. However, more patrols per hour lead to a lower spindle allocation and increased labour costs. It is necessary for each count spun from a given roving size to plot a graph of reducing spinning cost due to fewer patrols per hour and on the same graph to plot the corresponding increase in costs due to waste production (waste percentage estimates for a given patrol time may be made by using the derived relationships(89, 90, 100) when variables such as piecing up time, etc. have been determined under mill conditions). The intersection of the two graphs is the correct number of patrols per hour for that count at a particular breakage rate. From this work graphs showing the best patrolling level for each count may be obtained. The time will vary with count because of the differences in costs of spinning coarse counts as compared with fine counts. The cost of spinning fine counts is much higher so that increasing the labour to reduce waste may be uneconomical. On the other hand, because of the relatively lower spinning costs for coarse counts, the waste production losses become increasingly important so that an increase in the patrols per hour becomes an economic necessity.

It is interesting to note the substantial losses that can occur if the patrols per hour are kept at too high a level in order to minimise waste. Knowles(101), for example has compared the costs for spinning 40s cotton at the commonly adopted (in Lancashire) 6 patrols per hour compared with a patrol level of about 2½ patrols per hour which gives minimum cost. For a 40,000 spindle mill working shifts the extra cost is nearly £[illegible],000 sterling per annum. In a case such as this it is necessary to reduce the patrols per hour so that the number of spindles assigned per operator is increased. Knowles also indicates the psychological problems involved in such a change and the methods he has used in overcoming them. An increase in spindle assignments and a longer patrol period reduces the operative work load but in practice it is very difficult to convince the operative that the work load has not increased. Knowles overcomes this problem in practice by making the operative patrol at certain times in the hour and at the end of the patrol the operative is given a rest element of about 5 minutes. It is often found necessary to spend a considerable amount of time with each operative until a new habit routine has been formed.

An important feature in the maintenance of technical standards is the institution of continuous and sytematic quality control(102) and preventive maintenance(103). When these later processes are adequately maintained the likelihood of significant waste due to machine faults is greatly reduced. It should be realised in all spinning room testing that only a very small percentage of spindles are tested so that constant visual checks and periodic resettings are necessary to ensure that these are representative of the whole. The implementation of regular end-break checks can be invaluable as a police action as an aid in the maintenance of end break rates to predetermined levels and in the location of faulty spindles. It is good practice to number every spindle on every frame and to note the spindles on which end breaks occur during the checks so that spindles with high end break rates may be detected.

5.2 Establishing a waste control scheme

The simplest way to establish or improve a waste control system is to call in a firm of waste specialists(3, 101) to do the job. If however a specialist is not available, then a useful and profitable system may be set up by proper use of manpower, methods, materials and machinery.

It is important to note that a "waste drive" will be virtually useless unless it is followed up by systematic methods and supervision. It is often not good enough to call in supervisors to tell them that their departments are producing too much waste and that they had better do something about it. As a first step the problem should be explained intelligently in terms of cost, quality and job security to all key supervisors and their cooperation should be enlisted. The appointment of a capable person as waste technician to run the scheme would be advisable so that the various aspects may be adequately coordinated.

The next problem is to determine the location of waste problems, the reasons for any excess waste and ways in which a particular situation may be improved. This will usually involve the combined thinking of supervisors and management and this can be arranged by organising a series of conferences on waste attended by all concerned. Each supervisor should be encouraged to talk about his particular waste problems and to suggest methods of reducing the waste. Joint discussion of each problem will help put each in true perspective with respect to the overall situation. Properly handled, the talks can generate a good deal of enthusiasm and this should lead to a number of ideas for improvement, many of which may be very effective. The point to remember here is that the answer to some particular problem is often extremely simple, and if this is the case then the solution is quite likely to be suggested at one of these conferences. For more complex problems however an improvement may only be realised after systematic experimentation.

It is essential in any waste control program that a scheme of classification and sorting of wastes should be set up. Waste in worsted spinning is found in a wide variety of forms, each having different properties. Walker(1, 104-106) has described the classification, properties, uses and value of wastes produced in worsted processing and these papers should be very useful as a guide in any classification scheme. The classification of combing and spinning wastes as given by Walker(104) is shown in Table D.

TABLE D

Combing Wastes

(i) Card waste and stripping - from the floor under the card or from the cylinders.

(ii) Burrs and fribs - from the burr beaters - fribs are from low burr wools.

(iii) **Preparing** and **faller waste** - **from the floor under the gill box or**
from the faller pins.

(iv) Noils - prepared - when gilling precedes combing
oil combed - shorter fibres prepared by carding
schlum - from rectilinear comb
second - inferior waste from the second noil box of
rectilinear comb
carbonised - from carbonised wool
coloured - from recombing after top dyeing
recombed - white noils from recombing
hair

(v) Comb pickings - from the pinned circles of the Noble Comb

<u>Spinning Wastes</u>

(i) Laps - small lengths of sliver, roving, etc. from the piecing up of
a broken end - from starting up a running out of batches

(ii) Faller waste

(iii) Brush waste

(iv) Sweeps

(v) Thread waste

In his articles Walker has indicated the relevant properties of each of these wastes giving details about the likely variation in properties within each classification. The uses of each are given together with any modifications necessitated by fluctuation in the properties of a particular type of waste. The market value of the waste depends on the fibre quality, the fibre mean fibre length and length distribution, the colour, the amount of impurities present, the presence of man-made fibres, etc. The value is also affected by supply and demand, e.g. if the carpet trade is busy the the price of the coarser quality wastes rise. Walker[1] has given an extensive table showing the approximate market value of each type of waste and this has been summarised in Table E below where the approximate prices given as percentages of the top value are shown.

TABLE E

Waste Classification	Approximate Percentage of top value
A. Combing wastes	
Fribs	20
Raw burrs	10
Carbonised burrs	45
Willey waste	40
Comb pickings	35
Greasy faller	25
Preparing waste	25
Noble noils	55
Schum noils	45
Second noils	15
B. Worsted Spinning	
White drawing laps	90-95
Pneumafil laps (white)	95
Pneumafil ring laps (white)	85
Coloured drawing laps	85
Coloured ring laps	75
Coloured pneumafil ring laps	80
White thread waste	75
Coloured thread waste	35
White brush waste	25

White rubber brush waste	35
Coloured brush waste	10
White sweeps	5
Coloured sweeps	2
C. Man-made Fibre Mixtures	
(i) Terylene and wool	
White laps	60
Coloured laps	40
White thread waste	25
Coloured thread waste	5
(ii) Nylon and wool	
White laps	75
Coloured laps	65
White thread waste	55
Coloured thread waste	25

There are several important features to be noted from the table. Man-made fibre blend waste is worth much less than all wool waste (due to problems in reprocessing(105)). Coloured wastes are worth less than white wastes the relative difference being higher for the lower quality wastes and man-made fibre blend waste.

Walker's papers indirectly give some valuable pointers in setting up a waste classification scheme within a particular mill. In general it is desirable that only wastes which have similar properties (fibre quality, fibre length, trash content, degree of fibre separation, etc.), similar values and similar final end uses, should be mixed together. Other mixtures can lead to a considerable loss in value since the value will drop because of the necessity for the buyer to sort the waste and in cases where this is not possib the final end use will be greatly restricted. It is particularly important not to mix fibres (different wool qualities or wool and man-made fibres) and/or colours. The degree to which a particular mill can achieve these aims will depend on the size of the mill and the type of production. For mills producing a large variety of smaller batches the number of classifications may become excessively large and therefore some compromise must be made since the cost involved in maintaining waste separation may more than offset the increased waste value. A similar problem may exist for small mills where the handling costs may not justify the extra price received. Thus, in any mill the final separation will depend on the cost of handling and storage compared with the sale value of the waste. The mixing involved however must be made in such a way that minimum mixing of wastes with different properties occurs and Walker's papers should be a useful guide in this respect.

After establishing a classification scheme, a systematic plan for weighing and recording wastes must be implemented. It is desirable that check weighings should be made at the end of each shift to enable the supervisor to pin-point his waste black spots or his waste-prone operative quickly and efficiently. "It is amazing how much waste is reduced by operatives who know that the amount they have made will be checked at the shift end"(101). If it is not practical to weigh at such short intervals, then a good idea may be to place one or more waste containers beside each machine to enable quick discovery of points of excess waste.

It is essential that machine operatives do not weigh their own waste and it is desirable that the recording should be done by the person responsible for the control of that particular class of waste. Control graphs should be set up to show the week by week progress of the waste campaign. Adequate waste records (by individuals, processes, shifts, departments or by the particular classifications which suite the particular mill) should be placed at strategic points for all to see. "Many mills use posters and cartoons to emphasise the high cost of waste"$^{(3)}$. Particular ones placed at the points of origin of a type of waste may serve to keep operatives from becoming careless.

Practical cases may be to emphasise care in setting up, running out, handling, etc. It is important that these posters or cartoons should be changed from time to time since their effectiveness may easily be lost unless changes are used to act as reminders.

The next question to consider is that of setting up of standards. These should not be set up hastily and theymust be kept realistic. Each individual mill may have quite different problems so that standards set for the same conditions may easily be quite different. Initially, it may be a good plan to delay the setting of standards for several months, but standards should be set up as soon as useful data is available. Where there is no other guide it may be useful to set standards on the basis of average experience and the improvement expected in a particular time. The experience gained in this manner should be very useful in the establishment of new standards. Standards must be made flexible and it may be necessary to review them periodically so that either higher standards may be set or impossible standards may be relaxed.

Consider the setting of standards for the spinning frame waste produced by end breaks. For a given patrol time the amount of waste produced depends on the ends down rate and the operative efficiency. In order to obtain a standard waste value the expected operative efficiency (time to piece-up, clean, etc.) must be determined by work study of the actual operators. When reasonable estimates are obtained the waste for a given end breakage rate can be estimated using the references previously discussed. Any fluctuation in waste above this level will be as a consequence of failure to maintain end breakage-rates and/or inefficient operatives. It should be noted that the weight of the waste removed by the vacuum system will be increased by the presence of fly, the amount of which can be estimated using a method suggested by Wilson(100) (for cotton ring frames). The question of revising standards will depend on whether methods can be found to improve operator efficiency (e.g. an improved piecing method) and on whether processing conditions can be adjusted to obtain less end breakages.

The final aspect to consider is the training of the operators in waste methods. It is preferable to use a rational approach rather than pressure methods, the latter method sometimes works but only for a limited time whilst the former usually helps to generate and perpetuate employee co-operation. The supervisors should explain waste methods to all of the work force and train them in these methods. It is important to explain that some waste is a natural consequence of the processes and that the intention is not to invoke penalties as a consequence of waste produced in the normal operation of their jobs. The main aim is to analyse and solve the problems so that the level of waste is finally reduced since even small saving in waste (small from the operatives' point of view) may bring about a substantial cost savings.

After the initial approach management and supervisor must continuously try to maintain interest, awareness, enthusiasm and desire among the employees. Supervisors must maintain close supervision, ask questions (the operators are closest to the waste and may therefore have some good ideas), examine the waste frequently and insist on the accuracy of measurements and records.

The use of incentive bonuses based on the amount of waste produced by the operator in relation to the standard may work in some instances, but it is often not a good idea. The aim in any program should be to maintain quality and reduce the waste produced but not to advance one at the expense of the other. The disadvantage of incentive schemes is that they may lead to sub-standard quality being passed on to the next process as well as a proportion of the waste leaving the mill via pockets or sewers.

3.3 Waste and its control in developing countries

It has been suggested that a few paragraphs should be added to this paper particulary referring to problems that might be encountered in developing countries. Although the basic principles would be the same, the approach might require modification to suit local conditions. The first effect worth examining in a developing country would be the cost structure. In general the labour costs in processing would be a relatively lower proportion of production costs. The value of the waste produced will depend to a large extent on whether there is a ready local market for the waste. Even if the latter exists in most cases it will not be sufficiently developed to cope with the wide variety of wastes produced. In the absence of a local outlet the waste would have to be exported. Whatever the situation it is likely that the value of the waste will be lower than in the developed countries. It seems likely therefore that the production of waste will mean greater costs and this fact, coupled with the lower labour costs, may make it more economical to increase labour in order to reduce waste. A particular case might be in spinning where the optimum patrols per hour could be significantly higher than in developed countries. The cost structure involved in keeping wastes separate might be expected to differ so that classification procedures may require modification.

In general, one would expect that the average mill will be smaller and that the average batch size will be lower for underdeveloped countries. Colour and variety should be less of a problem particularly if the mill output is for internal sale within the country where the pressure of fashion would be only minor. Thus, the problems encountered should be related to those of smaller mills with reduced batch sizes and these effects have been discussed previously.

The machinery used in the mills may be less modern and this will inevitably lead to higher waste generation. When air conditioning plant is unavailable or of low standard, additional problems, depending on the local climatic conditions, could be encountered. Additional attention may therefore have to be paid to lubrication of the fibres to offset adverse climatic effects. The problems involved in obtaining optimum conditions should be more involved since the mill personnel will have less previous experience on which to make their decisions and the training standards may be lower. This effect will depend to a large extent on the number of overseas or overseas trained personnel employed.

The setting up of a waste control program by calling in the services of waste control specialists(3, 101) may not be possible. Overseas advisers might be brought in but it is often preferable to send competent employees overseas. The policy finally adopted will have to take into account the attitudes of the operatives within the mill. The methods used to get employee co-operation and to maintain interest, awareness, enthusiasm and desire among the work force will be different. The employee's attitude to his work and his knowledge and understanding of the economic factors involved in waste production must all be considered. Incentive bonus schemes for example may be more practical propositions in some circumstances.

4. Case Studies in the Textile Industry

The following describes a number of case studies within the textile industry. Case studies 3 to 5 (devoted to non-worsted mills) have been included because they were readily available(3) and since they illustrate many of the general principles involved.

Case Study 1 - Australian Mill A

Mill A represents a good case study in the disadvantages of small batch and variety production. In most cases the fibres are top-dyed, the fibres being wool, wool-snthetic mixtures and mohair. The range of materials and colours being processed side by side is quite large and the final yarns range widely in count, twist, colour and fibre composition.

The main waste problem encountered arises from the control of the atmospheric conditions and the lubrication of the fibres. These may be considered in turn:

(a) atmospheric conditions

In order to obtain ideal spinning conditions for each batch it is necessary to vary the atmospheric conditions to suit the material being processed but because of the wide variety of throughput this is not practical. Even after partitioning different parts of the mill in order to provide varying atmospheric conditions, there may be as many as 10 different lots being processed simultaneously in the same room. Because of this an average atmosphere has to be maintained and hence optimum conditions for a particular batch are raely encountered.

(b) Fibre lubrication

Difficulties areise here in the determination of the optimum amounts of oil to add to each batch. From long experience and experimentation, Mill A finds that a reasonably satisfactory forumla for estimating the oil required is to measure the residual oil content and to add enough oil to increase this value to 1%. This often does not give optimum conditions but because of the small batch sizes there is little chance of correction during processing. The mill itself does not seem to be in a position to do much about this situation; it believes that the amount of research it can undertake itself is limited. A mistake made in any investigation can be quite costly so that the tendency is to stop experimentation as soon as reasonably satisfactory conditions are achieved.

Dyeing in the top form creates a serious problem in the determination of optimum conditions. The initial tops are bought with a residual grease content of about 1% but the actual value may range from 0.8% to 1.2%. After dyeing the grease content is in the range 0.2% to 0.5% but the actual value can vary even for the same initial tops. Consider for example the case where the same raw material is to be dyed to a black and a pastel shade. If the initial material has a residual grease content of 0.8%, the black dyed top may have a residual grease content of 0.2% compared with a value of 0.5% for the pastel shade. If the initial tops have a grease content of 1.2% then these values will be different. Even after correcting the oil content before processing it is found that even if the same counts are produced from the same material dyed to different shades the amounts of waste will be different.

Because of the small batches there is a problem in setting up and running out wastes. Mill A also feels that it is at a disadvantage because the new machinery it purchased is not the most suitable for its purposes. If the trend towards smaller and more varied batches had been known at the time of purchase it is certain that the mill would have been re-equipped differently. Mill A is thus faced with the problem of making do with machinery which leads to an increase in waste production. On the question of machine faults it is thought that the maintenance program keeps this effect down to insignificant proportions.

Mills A feels that the major waste problems it faces arise from the foregoing causes. It believes that operative efficiency has a much smaller effect than the effects so far mentioned. Detrimental effects occur only when staff are absent or new staff are being trained.

Table F is a table of waste figures for the years 1963 to 1968. The percentages given are the average waste productions (all types of waste included) for each process. Waste figures are calculated for weekly intervals, the range figure being the maximum and minimum weekly values for each year. The figures are interesting in that they illustrate the effects of the change to more colour batches and smaller lots. This is particularly so in combing where for example a dramatic increase in the Noble Comb waste has occurred when white production ceased in 1966. The values given for open twisting show a significant downward trend over the twisting. This reduction in work load has lead to easier control and hence to lower waste.

It would appear from the mill's point of view that the main advance it requires is an increased knowledge of the best lubricant conditions for each batch. Much more research is required in this area to determine what differences in properties exist between materials which spin well and those which do not and to establish the best method of producing the required properties. What seems necessary from a practical point of view are several quick tests that can be applied before processing so that the material adjustments can be made.

Case Study 2 - Australian Mill B

This mill is faced with similar problems involving smaller batches as Mill A but the magnitude of the problem is less since Mill B tend to specialise in white top processing. The staff here have quite different ideas about the reasons for waste production.

Mill B finds similar difficulties in the control of atmospheric conditions and fibre lubrication. However, the amount of oil for optimum condtions

TABLE: F.

MILL A YARN PRODUCTION DEPARTMENTS - PERCENTAGE WASTE PRODUCED
YEARLY MEANS AND RANGES - PERIOD 1963/1965 INCLUSIVE

	1963		1964		1965	
DEPARTMENT	Mean	Range	Mean	Range	Mean	Range
Colour Backwash	.27	.12 to .36	.28	.18 to .42	.49	.20 to .54
Colour Mixing	.73	.21 to 2.35	.57	.21 to 1.62	.53	.20 to 1.21
Noble Combing (White prod. stopped late 1966)	.59	.51 to .74	.79	.76 to .81	1.03	1.01 to 1.07
French combing	.65	.49 to .86	.78	.45 to 1.10	.73	.55 to .84
Roberts Drg. No. 1	.25	.21 to .28	.19	.17 to .21	.18	.16 to .24
Roberts Drg. No. 2					.38	.31 to .44
Open Drawing	2.95	2.79 to 3.14	3.45	3.10 to 3.72	3.44	3.14 to 3.64
Open Spinning	2.72	2.29 to 3.09	2.82	2.64 to 3.04	2.89	2.61 to 3.32
Roberts Spg. No.1	3.16	2.79 to 3.56	2.67	2.43 to 2.84	3.53	3.01 to 4.27
Roberts Spg. No.2					3.74	3.53 to 4.12
Open Twisting	2.42	2.23 to 2.77	2.84	2.12 to 3.62	2.79	2.49 to 3.01
Camel Twisting					1.00	.85 to 1.16
Warp Winding	.82	.77 to .92	.93	.67 to 1.25	1.15	1.10 to 1.24

TABLE: F.

Mill A YARN PRODUCTION DEPARTMENTS - PERCENTAGE WASTE PRODUCED YEARLY MEANS AND RANGES - PERIOD 1966/1968 INCLUSIVE

	1966		1967		1968	
DEPARTMENT	Mean	Range	Mean	Range	Mean	Range
[illegible] Backwash	.47	[illegible]	[illegible]	[illegible]	[illegible]	.33 to .50
Colour Mixing	.38	.30 to 2.18	[illegible]	.29 to .49	.25	.14 to .42
Noble Combing (white prod. stopped late 1966)	1.75	1.37 to 2.25	2.02	1.6[illegible] to 2.36	2.03	1.85 to 2.10
French combing	.79	.63 to 1.04	.95	.85 to 1.03	1.20	1.09 to 1.34
Roberts Drg. No. 1	.22	.20 to .23	.20	.16 to .27	.27	.22 to .31
Roberts Drg. No. 2	.54	.34 to .86	.43	.32 to .61	.37	.29 to .55
Open Drawing	3.08	2.90 to 3.34				
Open Spinning	3.05	2.71 to 3.39	2.87	2.46 to 3.20	2.49	2.30 to 2.62
Roberts Spg. No. 1	3.51	3.19 to 4.07	3.70	3.55 to 3.80	4.39	2.91 to 4.55
Roberts Spg. No. 2	4.29	3.97 to 4.68	3.63	4.33 to 4.60	3.70	3.51 to 4.06
Open Twisting	2.25	1.99 to 2.77	1.75	1.37 to 2.00	1.50	1.04 to 1.91
Hamel Winding	1.12	1.02 to 1.27	.94	.52 to 1.01	0.96	0.87 to 1.06
Warp Winding	1.15	.82 to 1.53	.80	.68 to .93	.85	.77 to .95

is considerably higher in a number of cases, the amount varying depending on the blending with man-made fibres. The practice is to bring the amount of oil up to 3% based on the weight of the wool present in the blend. All wool tops are thus corrected to 3% whilst a blend containing x% of wool is adjusted to a value of (0.03 x x)%, e.g. a 50/50 blend of wool and Terylene will be brought up to a value of 1.5%. Mill B are at present carrying out experiments with other oils in an attempt to reduce costs and to produce greater optimisation.

At present the mill is experiencing considerable problems in maintaining end breakage rates to acceptable standards. Although the reason for this is not obvious it is through that the effect is partly due to an operative efficiency below optimum levels. At the present time the mill is engaged in a reappraisal of operative training methods and they are engaged in an operative retraining program. As an initial step in this program they are having personnel trained whose job it will be to supervise the training or retraining of each operative.

Waste figures for Mill B are not available but the waste produced shows similar trends to that of Mill A, the differences being due to different specialisation and machine type involved. As far as machinery is concerned Mill B shares the same problem as Mill A in that the machinery is not very suitable for processing small batches.

Case Study 3 - The Springs Cotton Mills, Fort Cotton Mills, Fort Mill, South Carolina, U.S.A. (reference 3)

Springs is a large mill processing over 1,000 bales of cotton per day. They have been able to bring about substantial waste reductions by reorganising their waste program. As a first step the importance of waste control has been stressed to all personnel from top management to the mill workers. A waste specialist has been called in to give instructions on the latest and best methods of waste control to all key personnel. A waste technician is employed to co-ordinate the program.

The first problem is to determine reasonable (but not impossible) standards and this has been accomplished in the following manner. A standard is derived on the basis of the challenge "Your waste is now x%. What can you do to reduce it?" After the standard is set the waste technician and the supervisors discuss the problems of (i) how to meet the standard, (ii) howe to correct the standard, (iii) how to lower the standard and (iv) in some instances, how to raise it.

The waste technician acts in an advisory and educational capacity only, being used as an aid rather than as a police action. This relationship between the waste technician and the rest of the staff is stressed. Discussion of pertinent waste problems is carried out at almost every supervisor's meeting in an attempt to find ideas for solution. As an educational aid poster, graph and charts pinpointing the origins of waste are placed at strategic points throughout the mill. Another aid which has proved highly effective is the display of cartoons drawn by the mill personnel.

Springs have examined techniques which lead to waste production and the following are simple methods which they use to minimise waste.

(i) Carding - excess lap waste was solved by setting up a shorter lap cycle where operators lay 15 cards at the same time.

(ii) Drawing - the main requirement is proper creeling and doffing of the big cans. The main thing here is technique, i.e. make the first layer of sliver as good as the last, take care that tangles do not occer and prevent the sliver from getting under the can springs.

(iii) Combing - the aim here is to minimise waste by running out as much lap as possible.

(iv) Roving - at the front of the frame operators are instructed to break out a bad bobbin immmediately, place it at the head of the frame, straighten it up and send it to spinning as a partial bobbin (do not stack it in the box). The most important factor is to build a good bobbin, handle it carefully and above all do not throw it into the box.

(v) Spinning - waste is minimised by properly seating the bobbin, by insisting that ends down are put up as rapidly as possible and that the correct patrol times are observed, and by adjusting the builder motion to ensure a correctly shaped bobbin. Spinning doffers are trained not to hold the bobbin at the top of the taper since this causes sloughing off at winding.

(vi) Winding - a close watch is kept for imperfect cheeses

(vii) Warping - the main thing here is to keep the length of the sections beams correct to avoid a bad run out at slashing. This is done by seeing that the length measurement is started as soon as the yarn starts moving.

(viii) Slashing - the big problem here is selvage damage due to improper storage. The secret is to use spacer bars on the storage rack to prevent the beams from colliding and to wrap paper around the beam so as to maintain the correct moisture content and to prevent the warp from getting dirty!

(ix) Weaving - Careful handling of the warp to prevent damage is emphasised. The minimum amount of yarn is used in the tying operation and operators are instructed to minimise pull over waste. Careful setting of looms is carried out to reduce the yarn left on the pirn and the shuttle and transfer motion settings are checked regualrly. Operators are trained not to cut off warps too soon to keep warp knots to 6 inches or less and to keep rags from 0 to 9 inches.

(x) The overall performance is constant calculated using an IBM computer where timekeepers make out the IBM cards and sendthem to the central office.

It can be seen from the above that the techniques used are mainly 'commonsense' principles. By using these methods however Springs have brought about substantial improvements in the amounts of waste produce and these gains are shown in Table G.

TABLE G

Process	Improvement in reworkable waste (%)	Improvement in thread waste (%)
Picking	27	-
Carding	64	-
Drawing	16	-
Combing	4	-
Roving	55	-
Spinning & Winding	-	52
Warping	-	50
Washing	-	22
Weaving	-	29
Warp knots	-	65
Rags	-	70

Case Study 4 - W.J. Dickey and Sons Inc., Oella, Maryland, U.S.A. (reference 3).

This firm a manufacturer of high class woollen outerwear goods has been able to save 140,000 dollars per year in filling waste in weaving. By carrying out a series of exhaustive tests they have derived a simple formula to calculate a standard waste weight, the value of which depends on the style and weight of cloth. After estimating the standard for a given style of goods, the actual amount of waste is measured at the conclusion of weaving. The weighing (done daily) is made using a printweight scale which stamps the amount of waste on an individual weaving ticket so that tracing back to the machine and the operator is facilitated. Weekly charts on waste progress are posted for all to see.

The waste produced can be affected by the following conditions, (i) the adjustment of the filling feeler, (ii) forgetting to reset the feeler when the yarn number is changed, (iii) false transfer of semi-full bobbins and (iv) the amount of yarn pulled off to place in the yarn holder. If by comparison with the standard a particular loom appears to be making too much waste then these four factors are checked to determine the cause of the excess.

By installing optical electronic bobbin feelers, Dickey have eliminated false starts, increased loom production by 2%, improved the quality, and cut the amount of yarn left on a quill from 9 yards to 4 yards. Warp waste is also examined but no formal programme has yet been established. The main aim here is to weave cloth as long as is practically possible.

Case Study 5 - Fieldcrest Bleaching and Finishing Mills, Spray, North Carolina, U.S.A. (Reference 3).

Fieldcrest, a group of finishing mills, has had a waste control programme in operation for 5 years (at time of publishing reference 3) and has established savings of 50,000 dollars per year. A consulting firm has been retained to help set up the scheme, and management men and supervisors have attended special classes on waste. In these periods specific waste problems have been assigned to the personnel in order to give each person experience in reviewing and analysing real problems. The aim of these sessions is to "learn by doing" active participation being encouraged in determining the losses in terms of money, the effects and causes of the waste and methods for elimination or reduction of the waste.

After completion of this training Fieldcrest has appointed a full-time waste supervisor to coordinate the programme and the results of the course have been incorporated into a reference manual. Methods of waste classification have been derived and employees assigned to regularly weigh the waste. As an aid to separation of wastes containers for different wastes are painted with eye catching colours. Waste is collected each shift or if the volume is small semi-weekly or weekly. Fieldcrest find that collection at the end of shifts is the best method since this facilitates easier tracing of the source of, the reason for, and who made the defect and whether it can be eliminated.

Since there are no generally recognised industrial standards for the waste produced in finishing, the standards have been ignored for the first few months until sufficient waste records have been accumulated. Standards have been arrived at by taking the waste from average experience and subtracting the improvement expected in some specified time interval. This latter method is used as the method of standard review at the beginning of each production year. In this manner a continuous reduction in standards has been achieved since the institution of the programme.

Each week the department foremen give the waste control supervisor the total for each type of waste at each control point. The reports are assembled into a mill-wide analysis which gives the weekly analysis together with the year-to-date progress in the scheme. The report gives detail for each control point in each department in terms of input (pounds) and the actual and standard wastes (pounds and percent). To make the report more meaningful the gains and losses are given in dollars.

Success is impossible without employee cooperation and since the employees are closest to the waste they are often in the best position to suggest a remedy. The employees have been instructed in the methods and importance of waste saving. Operators are assured that they will not be penalised for waste that occurs as a normal part of their job. Supervisors and management continually strive to develop, interest, awareness, enthusiasm and desire among the employees. Supervisors must ask questions, examine the waste frequently and quickly follow up any unusual waste production. A weekly mill waste report is issued promptly and this is discussed jointly by the supervisor and the operators.

In addition to the large saving of 50,000 dollars per year, 'Fieldcrest say its programme has been accompanied by greater production, higher quality, better housekeeping, improved delivery schedules, decreased work-in-progress need, smoother production flow, and decreased

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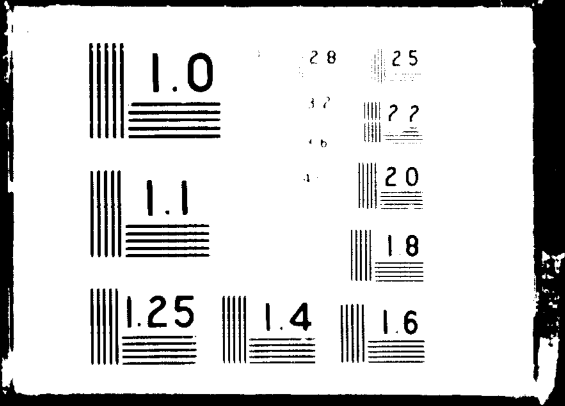

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