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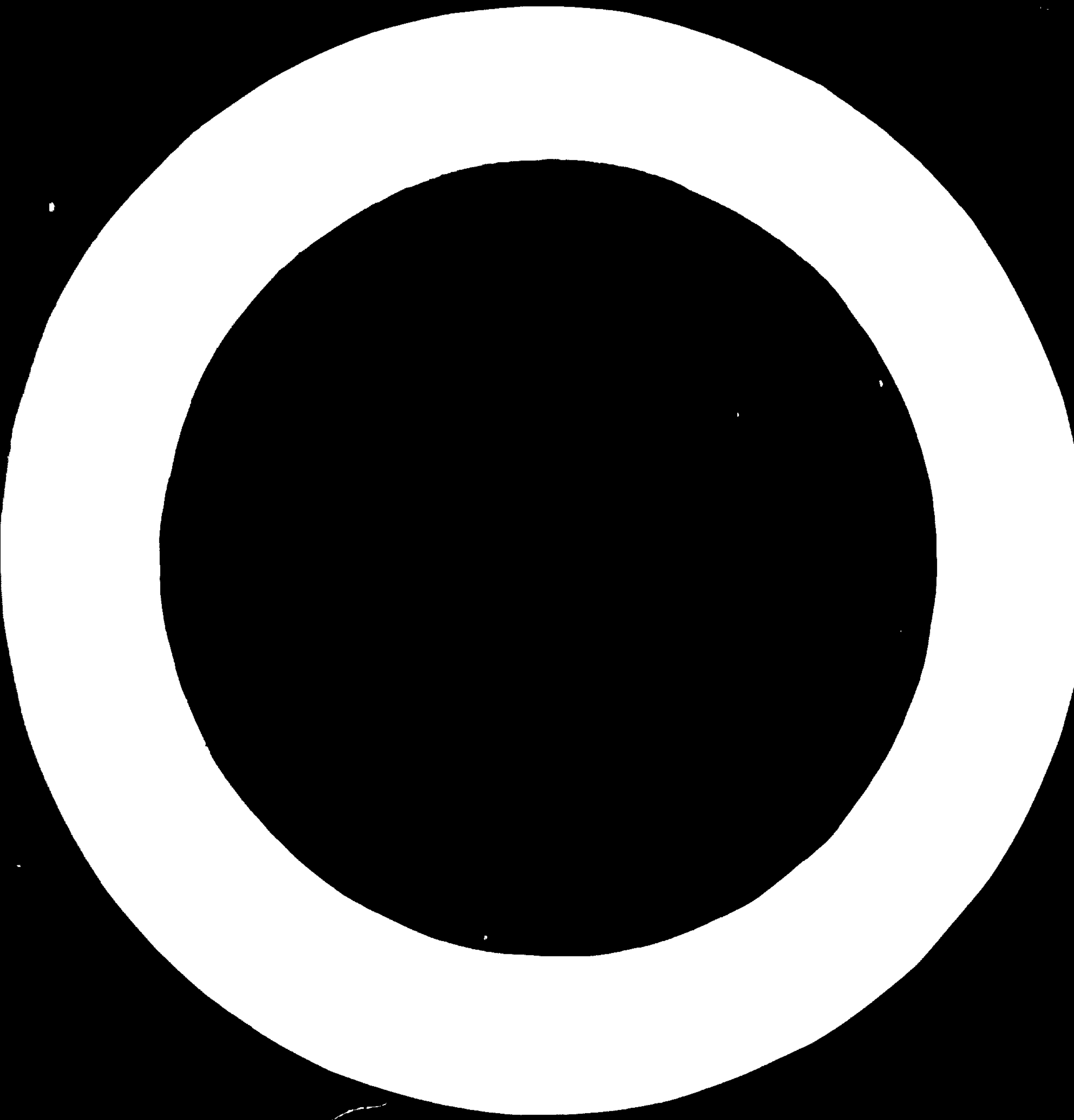
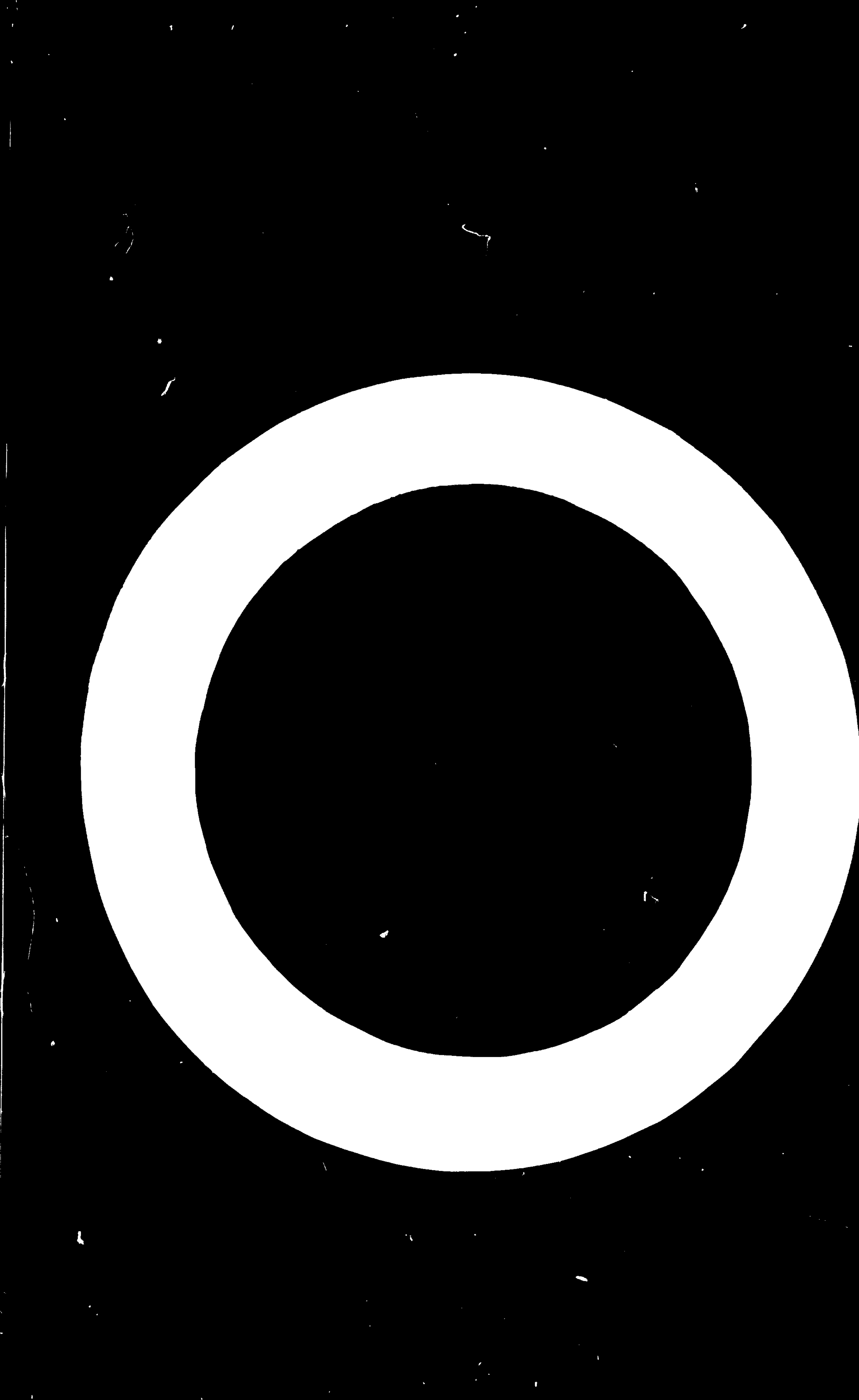
PROCESSING PROBLEMS AND SELECTION OF MACHINERY IN THE WOOLLEN AND WORSTED INDUSTRY

Report of Expert Group Meeting held in

Bursa, Turkey, 4 - 9 November 1968

UNITED NATIONS





UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION, VIENNA

PROCESSING PROBLEMS AND SELECTION OF MACHINERY IN THE WOOLLEN AND WORSTED INDUSTRY

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New York, 1970

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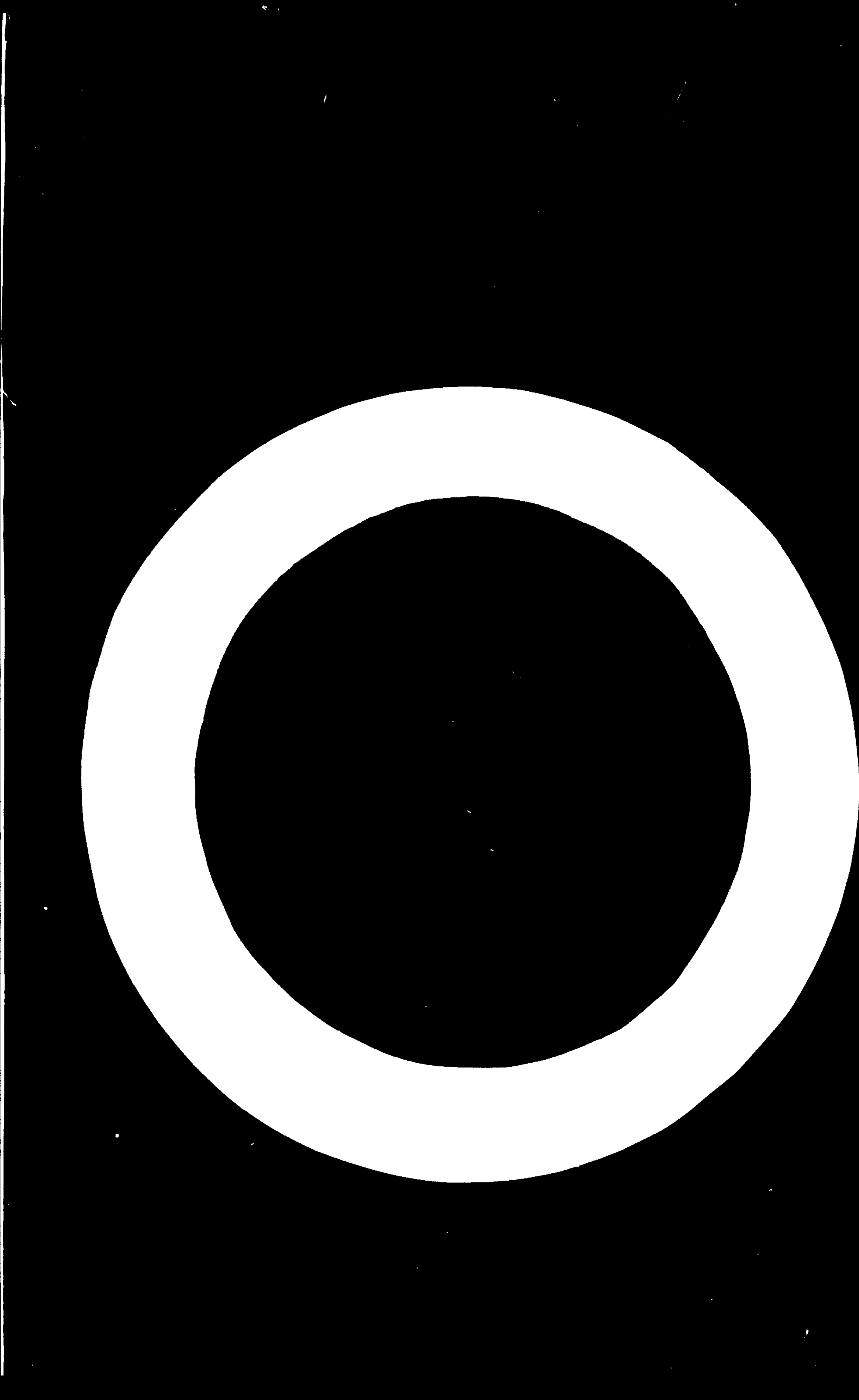
Annexes



Explanatory notes

References to "dollars" ($) indicate United States dollars; one cent equals $0.01.

References to "gallons" indicate United States gallons.

References to "tons" indicate metric tons.

One gallon equals 3.785 litres

One pound (lb) equals 453.592 g

One ounce (oz) equals 31.103 g

One yard (yd) equals 0.914 m (91.4 cm)

One foot (ft) equals 30.480 cm

One inch (in) equals 2.54 cm

One square yard (yd^2) equals 0.836 m^2

One square foot (ft^2) equals 0.093 m^2

One square inch (in^2) equals 6.451 cm^2

One cubic yard (yd^3) equals 0.765 m^3

One cubic foot (ft^3) equals 0.028 m^3

One cubic inch (in^3) equals 16.387 cm^3

One horsepower (hp) equals 0.746 kW

The following abbreviations are used in this publication:

f.o.b. = free on board

h = hour

kWh = kilowatt hour

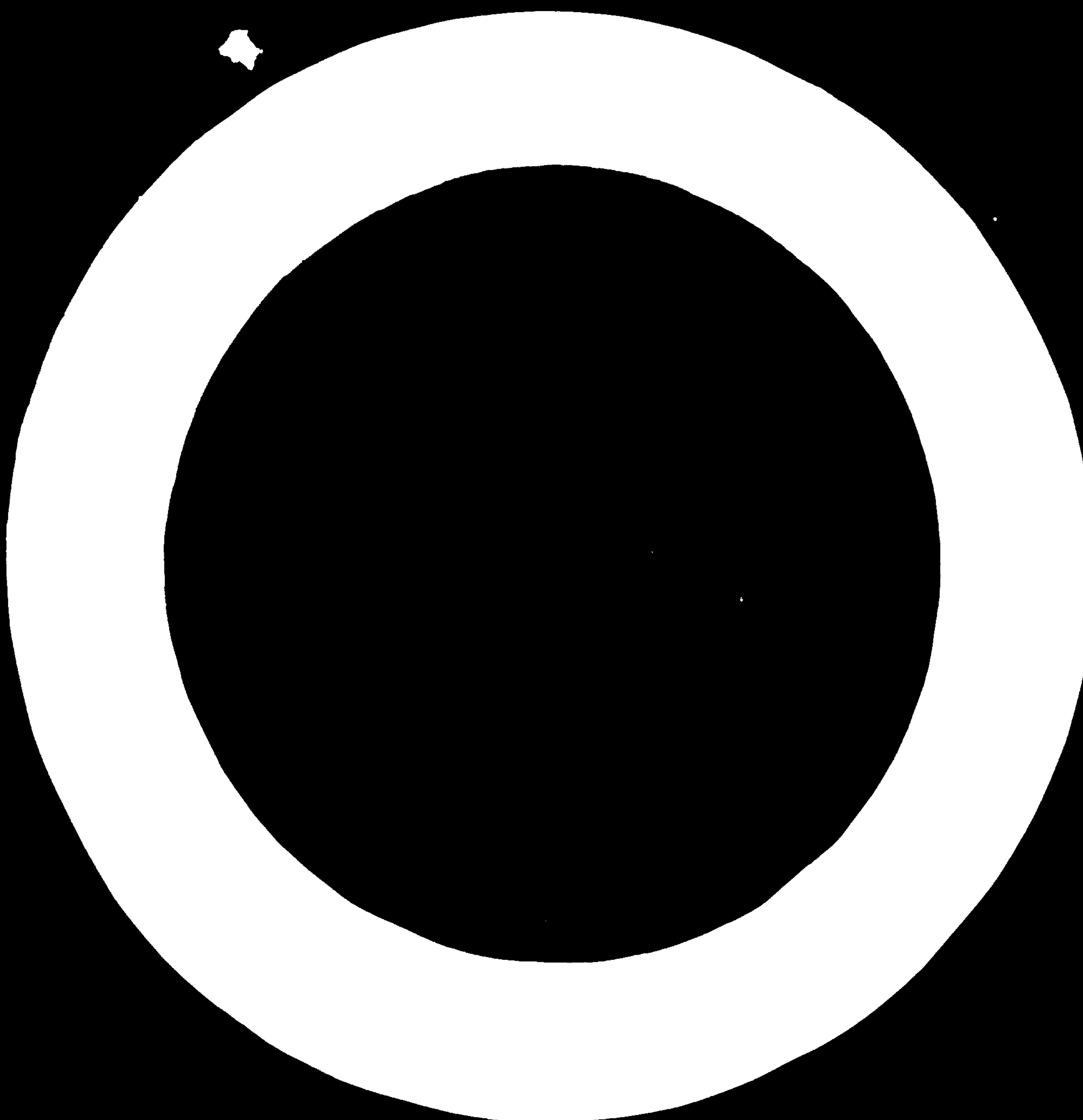
Nm - metric count

npi = needles per inch

ppm = picks per minute

rev/min = revolutions per minute

tpi = turns per inch



Preface

Under its current work programme relating to textiles, UNIDO is organizing a series of expert group meetings on specific problems pertaining to the textile industry in developing countries. The first meeting in this series, held in Vienna in October 1967[1] was devoted to the selection of textile machinery in the cotton industry.

The second meeting, held in Bursa, Turkey, from 4 to 9 November 1968, at the invitation of the Turkish Government and the Sümerbank Organization, dealt with processing problems and selection of machinery in the woollen and worsted industry. For the meeting, Werner Management Consultants Inc. of New York were requested to prepare a working paper, which would serve as a basis for discussion. The report of the meeting is based on this working paper, as subsequently amended and revised to reflect the views of the expert group.

At the invitation of UNIDO, the following wool industry experts participated in the meeting:

Mr. F. Bátori, Technical Director
The Hungarian Wool Spinning and Textile Factory
Budapest,
Hungary

Mr. A. C. Chaudhuri, Secretary General
The Indian Woollen Mills Federation
Bombay,
India

Mr. P. Baum, Vice-President
Nyanza Inc. Dyestuffs and Chemicals
Milledgeville, Georgia,
United States

Mr. S. Davaslıgil
Professor of Textile Technology
Technical University of Istanbul
Istanbul,
Turkey

1/ See Report of Expert Group Meeting on the Selection of Textile Manufacturing in the Cotton Industry, Vienna, 23-28 October, 1967 (ID/WG.8/1), UNIDO, Vienna, 1968, pp.83.

Mr. F. Karsch
Consulting Engineer in Wool Industry
Bremen,
Federal Republic of Germany

Mr. E. Korkut
Textile Project Department
Sümerbank Organization
Ankara,
Turkey

Mr. H. W. Krause
Professor of Textile Engineering
Institute of Technology of
Switzerland
Zürich,
Switzerland

Mr. D. Lepoutre, Technical Director
Ets. Louis Lepoutre
Roubaix,
France

Mr. J. Stiller, Director of Research
Werner Textile Consultants
New York, N.Y.,
United States

Mr. W. Svendsen, Technical Director
Odense Kammgarnspinderi
Odense,
Denmark

Mr. P. P. Townend
Professor of Textile Technology
The University of Leeds
Leeds,
England

Mr. J. Nadrin, Technical Director
S.A. Engineering Vesdre
Brussels,
Belgium

In addition, about thirty-five technicians from Turkish woollen and worsted mills were invited by the Sümerbank Organization to attend the meeting as observers.

Mr. John Stiller was elected Chairman of the meeting and Messrs. Percival Townend and Amal Chaudhuri were elected Rapporteurs.

Mr. Antero Eräneva, of UNIDO, participated in the meeting as technical secretary.

The United Nations Industrial Development Organization expresses its gratitude to Werner Management Consultants Inc. for preparing the working paper for the meeting, to all participants for their valuable contributions and to the Government of Turkey and the Sümerbank Organization for acting as hosts to the meeting.

Introduction

1. Of all the primary textile industry sectors the woollen and worsted sector is certainly the most diverse and complex. This diversity is evident in:

(a) The wide range of raw materials;

(b) The different types of machines that can be used;

(c) The various possibilities of combining and scheduling the different processes to achieve the desired product.

2. These considerations mean that although in analysing cotton processing and equipment, a standard product can be envisaged and a limited number of criteria can be used for specifying equipment, such an approach would be valueless in the case of the woollen and worsted industry, since there is not the same degree of standardization, in product, process or equipment. The discussion must therefore be more general and the guide-lines must be more broadly drawn.

3. In addition to this basic diversity, it must be noted that a similar range of possibilities exists in the methods of establishing a woollen/worsted industry in a developing country and of organizing the individual mill units.

4. In this report, an effort has been made to cover the most important aspects of fibre-to-fabric manufacturing of woollens and worsteds and their main variants and to present significant data about prevailing practices.

5. Attention is drawn to the annexes to this report, which give machinery and operating data for various types of woollen and worsted mills. It must be recognized that these mills are not necessarily suggested as being the optimum sizes for developing countries, since conditions vary. Nevertheless, it is hoped that in most cases the selected sizes represent a suitable basis for planning.

6. The report is in no way an exhaustive text book on woollen and worsted processing, but is intended primarily to assist those in the following categories:

(a) Members of industrial planning or government agencies who are concerned to a limited extent only with the process operating details, but who will be able to utilize the general data on capital equipment and labour intensity, productivity and power requirements, in order to evaluate this sector of the textile industry and perhaps compare it with other industries with a view to selecting priorities.

(b) Textile specialists who are already familiar with the processing techniques and who will find the data useful in dealing with problems of staffing, productivity and selecting equipment.

7. Although many of the recommendations of the expert group may not apply in all cases, it is hoped that they may, nevertheless, be of use as a checklist in implementing projects for the woollen and worsted industry, since the report makes available, in a handy form, considerations of many important factors, the relative significance of which must be evaluated in each particular instance.

Chapter I

RECOMMENDATIONS

8. Sheep-rearing programme: Where the potential exists for developing and improving domestic sheep in developing countries, the group felt that the feasibility of such projects should be carefully studied, although it recognized that this would involve a long-term programme. The recommendation applied not only to fine merino wools but to wools of all qualities.

9. Suitability of indigenous fibres: Developing countries must be fully aware of the possibilities and limitations of processing their domestic wools if they are to make full use of both domestic and world markets. The group wished to emphasize the need for the proper selection of raw materials in relation to end-products, and suggested that some possibilities may exist for developing countries to export carpet-type wools, since the world market for carpets is expanding.

10. Priority of developing manufacturing units by process stage: It is suggested that if developing countries desire to enter the market or expand their exports of woollens and/or worsteds, they should not begin with the installation of sorting, scouring, carbonizing and combing processes but rather consider importing scoured wool or tops. Subsequently, as and when the spinning facilities can make economical use of a modern scouring and combing plant, the installation of such a plant could be considered. This scouring and combing plant could then, as a central unit, feed a number of spinning mills.

11. Feasibility study of power looms: If woven fabric production is intended, a study should be made of the feasibility of setting up economic installations of power looms with related preparatory, dyeing and finishing processes for yarns. The feasibility of such units would depend on the economic justification for importing yarn initially. On the other hand, if domestic raw material is available, it might be more desirable to start by producing yarn. Furthermore, the group wished to emphasize the need for conducting thorough market research before taking any decision.

12. Scouring: The group recommended that the newly developed techniques of aqueous scouring (jet or suction drum) should be considered for new installations. (The solvent scouring methods are still not considered commercially practical.)

13. Carbonizing: The need for extreme care in operating a carbonizing range was emphasized, in view of the necessity of avoiding any damage to the fibre and of balancing the intensity of carbonizing in relation to the vegetable matter content. It was felt that considerable savings could be effected by careful application of this process.

14. Combing: It was the general opinion of the group that the French type of combing for spinning on the dry system should receive prime consideration. The selection of equipment for sorting, scouring, carbonizing and combing must also take into account the raw material characteristics, as well as factors such as location and availability of trained personnel.

15. Blending: A stacking or mechanical batch system should receive prime consideration, having regard to the quality of the raw material, size of lot and factory space. The usefulness of continuous blending systems is not restricted to large production runs, although the trend in woollen blending is towards continuous systems, modified to cope with smaller runs. Extreme care should be taken of the blending in the worsted process, which can be carried out before or after combing. The increasing tendency of the worsted industry to use synthetic fibres demands efficient blending.

16. Semi-worsted system: The group recognized the increasing popularity of the semi-worsted system for certain products, such as carpet yarns. There was, however, a clear demarcation between the worsted and woollen systems, and the group wished to emphasize that the selection of plant and equipment, when deciding on woollen or worsted or semi-worsted, must be made with the different characteristics of the end-product clearly in mind. The group recognized the

possibilities of the semi-worsted process and expected it to be used increasingly for the manufacture of carpet yarns and coarse to medium knitting yarns.

17. Worsted drawing: The group recognized four passages of drawing as being a fairly reasonable combination for the preparation of worsted yarn. For very fine counts of yarn, an additional roving process would be recommended. Furthermore, an additional pre-blending passage may be desirable when processing synthetics or top-dyed raw material, as well as when spinning to fine counts.

18. Spinning system: Ring spinning has been adopted for all counts of yarn, both woollen and worsted, but developing countries must be informed as to the relative advantages of flyer and cap spinning for certain worsted yarns. Textile production managers must realize the need to specify the optimal ring diameters, gauges and other machine characteristics, taking into consideration the quality of the raw material, spindle speeds and the end-product desired, so as to achieve the most economical operation of spinning machines.

19. Highly advanced equipment: Undue importance should not be attached to new and complex developments. In view of the cost and some of the inherent problems that complex machines present, the group strongly recommended that developing nations should not install highly advanced or automated equipment unless and until its economic and operating characteristics have been fully evaluated. Very highly skilled manpower is needed to maintain this type of equipment.

20. Yarn preparation: Although it was necessary to stress the dangers of highly advanced machinery, it was nevertheless important to select an efficient and productive line of preparatory equipment (especially for winding), with particular regard to the quality of the product. (The slashing or sizing process is mandatory if single worsted yarns are to be woven.)

21. Fabric styling: A competent fabric styling and design department is essential to take account of market trends, especially if it is wished to develop an export business.

22. Wet processing: Continuous processing equipment should be considered only where extremely large lots are going to be processed. Many processes are involved in woollen and worsted finishing, and each would have to be considered separately. In view of the fact that there has so far been relatively little experience of the continuous processing of woollens and worsteds,

the group felt that the textile industry in developing countries should be advised to prefer the conventional batch-type equipment.

23. Special finishes: The group wished to point out the importance of special wool processes such as shrinkproofing and crease resistance and to call attention to the development work being carried out by organizations such as the International Wool Secretariat, which offers comprehensive services to all developing countries for introducing such processes. These processes are important because they impart easy-care properties which make woollens more competitive with synthetics.

24. Waste processing: Since the cost of raw materials is a major factor in the woollen and worsted industry in developing countries, waste must be effectively controlled. The mills should therefore seek to make the best use of re-usable waste and should consider the installation of some special waste-processing equipment.

25. Machine versatility: It should be stressed that the nature of the woollen and worsted industry requires equipment that is versatile in addition to producing quality products. This should always be borne in mind when considering the relative merits of various machines.

26. Working capital: After purchasing the plant and equipment, sufficient capital must be made available to support the operation. In view of the difficulties encountered by some mills in developing countries, it is suggested that at least twelve months' working capital be made available. Woollen and worsted plants in developing areas are often especially vulnerable in this respect, since they require large inventories of raw material (owing to factors such as great variability of sources and packaging), and of spare parts. It is recommended that a two-years' supply of spare parts be purchased.

27. Impact of man-made fibres: The group recognized the tremendous impact of man-made fibres on this industry and wished to stress the importance of selecting equipment that is equally capable of processing synthetic fibres and wool.

28. Knitting: It is well known that certain knitted fabrics can be produced with lower initial investment and more rapidly than woven fabrics. Developing countries are therefore advised to give serious consideration to developing the knitting section not only for internal consumption but also for developing export markets. The group pointed out that in some developing countries it

might be desirable to set up some small knitting facilities of the one-family cottage type, using hand-operated V-bed machines. These small plants could be supplied from central spinning mills, and it is suggested that they would be economically feasible, in many cases, at least to supply the domestic market. The developing countries should not initially utilize warp knitting, such as the Raschel or Jacquard types of knitting; this should be considered only when a certain experience has been achieved.

29. Air conditioning: The group stressed the desirability of installing suitable temperature and humidity controls as integral parts of the installation of plant and equipment to ensure efficient functioning of the process. When setting up new plants, the importance of proper plant location as regards climatic conditions and the consequent requirements for atmospheric control must be considered. The relevance of air conditioning to the comfort and efficiency of the operatives should also be borne in mind.

30. Reserve capacity of equipment: In developing countries, a plant must have very high built-in reserve safeguards in relation to key machinery. There should always be some reserve capacity, even where this may call for the purchase of extra machinery that is critical for the calculated mill balance. This is especially true of equipment units that have very high production in relation to other process units, as with warping, sizing and some finishing machines. An isolated plant with only one of these units becomes extremely vulnerable in the case of breakdown. Similar safeguards must be considered for auxiliary facilities such as power, water, steam generation and air conditioning.

31. Attitude of machinery suppliers: Machinery manufacturers do not always fully appreciate the needs of developing countries. The group made the following recommendations:

(a) Accurate and realistic technical specifications must be supplied. The need for electrical diagrams and machine blueprints of sufficient clarity and size was stressed as being an integral part of the manufacturer's service.

(b) Machinery manufacturers are advised to use built-in gauges to an increasing extent. It was suggested that 20 per cent more gauges and tools should be shipped with new equipment to developing countries than to industrialized areas.

(c) Machinery manufacturers should not attempt to sell newly developed equipment to developing areas until it has been fully proved. The group urged machinery manufacturers to standardize their equipment as much as possible.

32. Mill size and flexibility: The choice of mill size must be critically evaluated, and due regard must be paid to that size of unit which can be efficiently administered by one manager. A balance must be struck between achieving the required flexibility without sacrificing efficiency and specialization in any mills which are to be established.

33. Technique for evaluting investment: Mill management should be more aware of the use of various techniques for evaluating machinery as capital investment. The attention of individuals involved in the evaluation of industrial projects is called to the UNIDO publication Evaluation of Industrial Projects and based on the symposium held in Prague, Czechoslovakia, 11-29 October 1965.[1/] Although the considerations in this publication do not specifically apply to the textile industry, they have broad relevance to the over-all problem.

34. Training: The importance of having fully trained operatives was emphasized so that the plant will be operated as efficiently as possible. Training should be understood as a continuing process and should apply to personnel of all levels. Its relation to discipline and safety is stressed.

35. Maintenance: A plant preventive maintenance system is a necessity. Training centres for this purpose should be established for mechanics and operatives.

36. Machine shops: These should be equipped with metalworking and welding tools and, depending on the ease of obtaining spare parts, they will probably be more extensive than those needed in developed countries.

37. Housekeeping: General good housekeeping is essential, not only from an operating standpoint but also from the viewpoint of safety and general welfare. Adequate provision should be made for medical and first-aid facilities.

38. Space and layout: In the allocation of space for processing and storage, the tendency should be to make generous provisions. Space will probably be relatively cheap, and allowance should be made for future expansion.

39. Quality control and waste control: The group considered that quality-control and waste-control procedures are of sufficient importance to the textile industry to warrant further investigation by UNIDO.

1/ United Nations, Sales No. E.67.II.B.23.

Chapter II

RAW MATERIALS

40. The emphasis throughout this report is on the processing methods and techniques.

41. Nevertheless, as raw materials have a major influence on the manufacturing processes, it is essential to examine some specific characteristics of raw materials for the woollen and worsted industry. In this report the term "raw material" is used to indicate wool, man-made fibres, and waste fibre materials whenever any of these are processed by the woollen or worsted systems.

42. Wool is subject to far greater variations than any synthetic fibre. Many of these variations depend on factors such as the breed of sheep that grew it and the geographical and climatic conditions under which the animal was raised. Staple length and fibre strength are closely related to healthy breeding and rearing. It is recognized that each breed of sheep will produce wool with its own characteristics, which are superimposed on other factors such as climate and soil.

43. The following pages review briefly the character of wool, emphasizing those factors that differ significantly from one type of wool to another. Those properties that are not markedly different from one wool to another, such as specific gravity and electrical properties, or that have a minor influence on the practical aspects of manufacturing are not described, since they are beyond the scope of this report.

Properties of wool

Wool types

44. For purposes of textile manufacturing the various types of wool can be conveniently classified into four major categories: fine, medium, coarse and carpet.

45. There are other classifications but they are of primary interest to wool growers and sheep breeders. The above fourfold classifications can, however, be uniformly applied regardless of the geographical origin of the wool. It also has the advantage of being most significant to the textile manufacturer. Each category encompasses wools from several breeds which may differ in some of the properties. These are discussed below.

Mean fibre diameter

46. From the processing viewpoint, the mean fibre diameter is probably the most important aspect of wool quality. It can be said that average fibre diameter for most wools falls into the range of 17 microns for superfine merinos to about 40 microns for coarse carpet wools.

47. Table 1 below illustrates what may be considered typical fineness relating to the four major categories of wool types listed. The fine and medium categories have been further subdivided into two sub-categories.

Table 1

Fineness dispersion range of wool fibres
(percentage distribution)

Range (microns)	Fine		Medium		Coarse	Carpet
	Super Merino	Merino	Fine	Coarse		
10 - 20	88	41	22	6	2	15
20 - 30	12	57	64	39	18	35
30 - 40	-	2	14	41	27	26
40 - 50	-	-	-	13	40	8
50 - 60	-	-	-	1	10	6
60 - 70	-	-	-	-	3	2
Over 70	-	-	-	-	-	8
Average microns	17	21	24	32	40	36
Grades	90's	70's	62's	48's	36's	-

Source: J. M. Mathews, Textile Fibres, Wiley, London.

48. Fibre diameter is the primary factor related to the fineness to which yarns can be spun. In fact, the original quality number of the wool top was derived from the finest counts that could be spun from that top. This rule no longer holds true in contemporary practice, but the general relationship is still valid, and the finest spinnable yarns are basically known to be related to a known limit determined by the number of fibres in the yarn cross-section.

49. This is illustrated by table 2, which indicates the spinning limits on worsted yarns spun from the range of given top fineness.

Table 2

Spinning limits on worsted yarns spun from the range of given top fineness

Worsted top quality number	Suggested count of actual spinning limit (Worsted Count)	Number of fibres per cross section at limit
70	70	24
64	60	24
60	52	24
58	50	21
56	46	20
50	46	21
48	38	21
46	32	21
44	29	20
40	24	23

Source: Wool Industries Research Association, Leeds.

50. It can be seen that the number of fibres in the yarn cross-section remains relatively constant. It is therefore not the fineness of fibres *per se* that is the dominant factor, but rather the grouping of the fibres in the yarn and their relationship to the cross-sections.

51. Although table 2 illustrates an example in worsted top, this also holds true for all spun yarns regardless of system. Practice has shown that even where yarns are not spun to the limit of fineness, the yarn composed of finer fibres will given better spinning conditions.

Diameter variation

52. Table 1 also indicates the variability within fibre types. It is evident that fibre diameter variability can be expected to increase from finer to the coarser wool types. While fine merino wool normally has a range of about 10 to 30 microns, coarse wools often have a variation of 60 microns, or if they contain the coarser kemp fibres, from 70 up to about 190 microns. Wools that have the least variation in fibre diameter tend to offer the best spinning characteristics and are therefore preferred.

Crimp

53. Evenness of crimp is usually considered as an indication of quality. In general, the finer the wool, the greater the crimp frequency. However, the relationship between crimp and diameter should not be taken as a guide on its own.

54. The general relationship is indicated in table 3. It is important to realize that crimp *per se* is not a major factor in processing. In fact, most of the crimp present in the fibres is lost as they become separated and are subjected to drafting.

Table 3

Fineness/crimp relationship

Wool type		Crimps per inch
Fine:	super merino	16 - 30
	merino	12 - 18
Medium:	fine	6 - 12
	coarse	3 - 6
Coarse		0 - 3
Carpet		0 - 1

Fibre length

55. Although the length of wool staple evidently depends primarily on the length of time between shearings, a relationship does exist between wool fineness and staple length. The coarser the wool, the longer its staple length tends

to be. Some representative data for staple length according to wool type can be indicated as follows:

Wool type	Range of staple length (inches)
Fine	1.5 - 5
Medium	2 - 7
Carpet	3 - 8
Coarse	5 - 14

56. Once again, it is essential to stress that there are many subdivisions within each type of wool, and that wool from a specific breed of sheep is unlikely to vary over the whole indicated range. It is important to take into account the fact that staple length is always shorter than mean fibre length because of the effect of crimp.

57. Inasmuch as fibre length is a factor in the spinnability of wool, it is significant to note that while raw wool has a relatively uniform fibre length, fibre breakage tends to increase this range. This tendency is illustrated in figure 1, which shows the fibre-length distribution for grease wool and for the same wool after carding.

58. The fibre length distribution is usually shown in the form of a cumulative frequency diagram as in figure 2.

Lustre

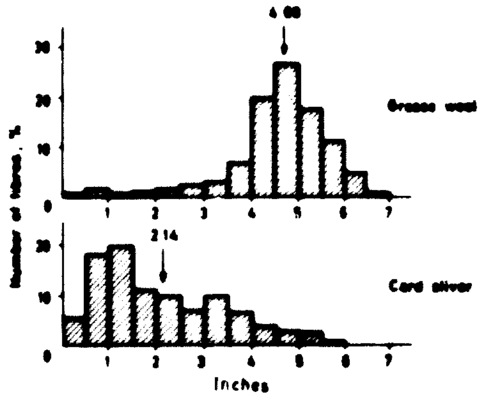
59. The lustre of wool fibre types is related to the surface, size and straightness of the fibres. The various degrees of lustre are pronounced in superfine merinos (known as "silver" lustre) and in the so-called lustre wools (from the Lincoln and Leicester breeds) which are said to have a "silk" lustre. The major effect of lustre is on the finished fabric. Moreover, the inherent lustre in the fibre is not usually subdued during dyeing and finishing processes.

Colour

60. Degrees of whiteness of wool vary considerably between breeds of sheep. This property is basically geographical; although most wools are white, some (such as those from South America) are found to have a strong ivory cast. The presence of individual coloured fibres is most likely to be found in the less domesticated breeds of sheep, such as some that produce wool of the carpet type. The discolouration of wool in processing is considered in a later section of this report.

Figure 1

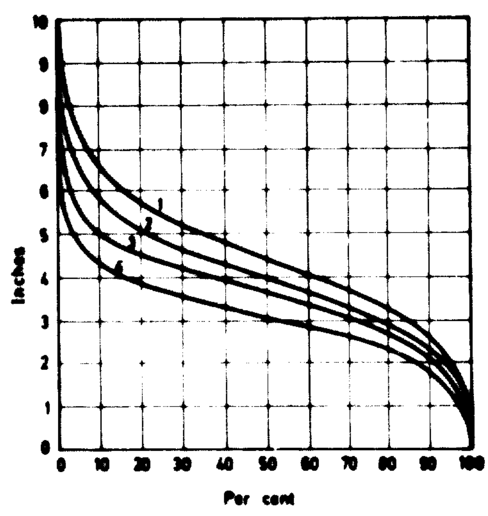
Fibre length distribution (card sliver, grease wool)



Source: Textile Research Journal 26, 665 (1956).

Figure 2

Fibre length distribution



Source: W. von Bergen, Wool Handbook, Wiley, New York (1963).

Tensile properties

61. The strength of wool fibres is related to the fibre fineness, the coarser wools being generally stronger. This relation is shown in table 4, which gives the results of a series of strength tests of single fibres of different diameters. The danger of fibre breakage is far greater in processing fine fibres.

Table 4

Strength of fibres of various finenesses

Grade	Fineness (microns)	Breaking strength single fibre (grams)
80's	19.5	4.75
70's	20.8	5.25
64's	21.9	5.88
60's	23.5	7.14
58's	24.8	8.43
56's	26.9	10.32
50's	30.4	13.82
48's	33.0	16.00
46's	34.8	18.19
44's	36.6	20.35
40's	38.3	23.59
36's	39.3	25.68

Source: W. von Bergen, Wool Handbook, Wiley, New York (1963).

Elasticity

62. The typical stress/strain curve for wool is shown in figure 3 and is true of both fine and medium wools. The curve is characteristized by an initial uncrimping region below 0-extension, followed by a steep (Hookean) portion when stress and strain are proportional. The yield sector characterizes further extension with relatively little increase of force until the break occurs at an extension of about 35 per cent. This property is mentioned since a comparison of the stress/strain curve characteristics of wool with similar curves for other fibres might be useful when fibre blends are processed.

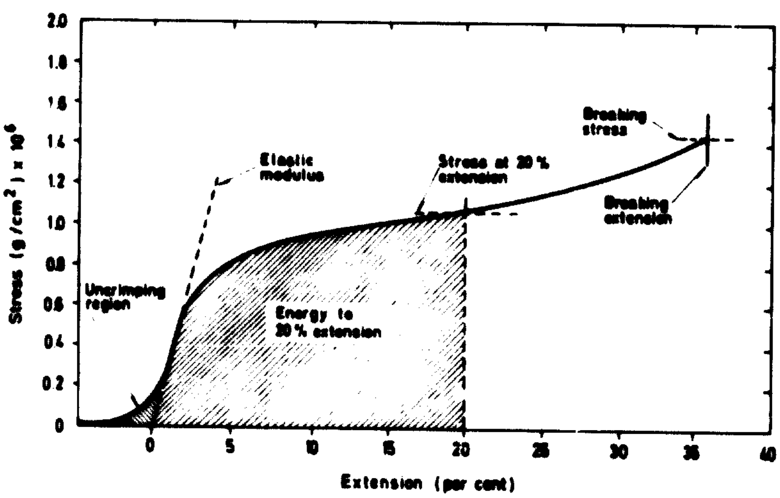
Felting

63. This property is unique to fibres having scaly surfaces and is exhibited only by keratin fibres. Felting takes place when a wool or other scaled fibre mass is subjected to pressure and rubbing under suitable conditions of heat

and moisture. While the felting medium is a vital factor in achieving felting, fibre properties such as resilience, fineness, degree of scaliness and crimp are also very significant in determining the degree of felting that can be expected. Finer wools, which have more surface scales than coarser wools as well as being shorter and more pliable, are more prone to felting under suitable conditions than are the coarser wools. As far as processing is concerned, care must be taken in scouring fine wools to minimize the tangling, which increases fibre breakage during spinning.

Figure 3

Wool elasticity



Source: J. M. Matthews, Textile Fibres, Wiley, London.

Hair fibres other than wool

64. The animal-hair fibres other than wool can be considered as special-purpose or luxury raw materials. They are almost invariably processed by the woollen and worsted sector of the textile industry. Specialty hair fibres can be considered as coming from two principal sources, namely, the goat and camel families. The more important hair fibres originating from the goat family are mohair and cashmere. The major fibres in the camel group are camel, llama and alpaca. In the following discussion, only properties of primary relevance to textile manufacturing are discussed.

Mohair

65. Fineness: The fineness of the mohair fibre ranges from 10 to 70 microns. Kid mohair has the most regular fibre fineness, as can be seen from table 5, which illustrates tentative United States mohair grades and indicates the fineness distribution that can be expected with this fibre.

Table 5

Fineness variation in Texas mohair

Diameter (microns)	No. 1 kid	Grown			
		1	2	3	4
10.0 - 20	20	5	1	-	-
20.1 - 30	71	37	20	2	-
30.1 - 40	9	56	35	31	5
40.1 - 50	-	2	25	41	21
50.1 - 60	-	-	15	18	18
60.1 - 70	-	-	4	6	30
70.1 - 80	-	-	-	2	20
80.1 - 90	-	-	-	-	6
Average	24	30.6	39.8	45	61

Source: W. von Bergen, Wool Handbook, Wiley, New York (1963).

66. Length: The length of mohair fibres covers a range of about 4 to 6 in. for a six-month clip and about 8 to 10 in. for a twelve-month growth.

67. Lustre: Mohair fibres have a very high lustre, the so-called "glass" lustre, and can be considered to be the most shiny hair fibres. This lustre is related to the very low degree of serration on the surface of the mohair fibre, which is also related to its very low felting properties.

Cashmere

68. True cashmere is one of the finest hair fibres. The fine cashmere "down" fibres are grown as the undercoat of the animal and are mixed with coarser outer-growth "beard" hair. The difference between them is shown in table 6, which gives the fineness measurements of hair from the major supplying areas. (The beard hair is not normally processed within the woollen and worsted textile industry.) The cashmere fibre is available naturally in white or brownish shades.

Table 6

Fineness of various cashmeres

Source	Cashmere down (microns)	Wool grade	Beard hair (microns)
China (mainland)	14.5 - 16.0	110	65 - 75
Mongolia	14.5 - 16.0	110	75 - 85
Iran	17.5 - 19.0	90	65 - 80
Afghanistan	16.5 - 17.5	100	65 - 80
India	14.5 - 16.0	110	-
Turkey	16.0 - 17.0	110	-

Source: W. von Bergen, Wool Handbook, Wiley, New York (1963).

69. The typical fibre length of cashmere down fibre ranges from 1 to 3.5 in. Cashmere fibre is generally considered as being rather weak: tests which were carried out on comparable bundles of fibres from tops, indicate that the tensile strength of cashmere is about 1,450 kg/cm^2, *versus* 1,525 kg/cm^2, for 80's wool, and about 2,150 kg/cm^2 for mohair.

Camel

70. Fibre fineness of the camel down hair fibres usually averages between 20 and 25 microns; individual fibres vary from 10 to 40 microns. The length of camel down fibre ranges from 1.5 to 5 in and the bundle strength is about 1.800 kg/cm^2, thus being intermediate between wool and mohair. The fibre is usually available in various shades of brown.

Llama and alpaca

71. These animals are closely related and the relevant physical properties of their hair are quite similar. It is available in white, light brown and black shades, and the average fineness of representative samples is 20 to 27 microns.

72. Strength. Alpaca fibres are normally considered to be about 10 per cent stronger than medium wools.

73. Lustre. Llama and alpaca fibres are usually very lustrous, having a sheen similar to that of lustre wools.

Skin wools

74. It has often been suggested that wool taken from the skin of a dead animal is inferior to shorn wools. There seems to be no evidence for this and, in fact, there is some indication that the opposite may be the case as long as the fibres are removed correctly from the dead skin. Since skin wools are often available more economically than shorn wools, they may be used instead of shorn wools, thus effecting savings in raw materials. Some recent tests carried out by CSIRO (Commonwealth Scientific Industrial Research Organization) in Australia indicated that fibre breakage in carding is less on skin wool than on similar shorn wool. Moreover, in combing, skin wools gave a better tear than shorn wools, although lime or digested wools gave a poorer tear. It is suggested that this is due to the wool fibres being excessively weakened by the digestion processes.

Impurities

75. The impurities that are present in wool and hair fibres are commonly considered to fall into three broad categories - natural, acquired and applied, as follows:

Natural	Acquired	Applied
Wool wax	Dust	Marking fluid
Wool suint	Dirt	Dip (insecticide)
	Dung	
	Vegetable matter (twigs, burrs etc.)	

76. In addition to the above, wool contains moisture to a degree depending on the atmosphere.

77. The amount of impurities present in the wool influence the yield of clean wool. The range of yields that can be expected from commercial wools and hair is indicated in table 7.

Table 7

Variation in amounts of impurities, moisture, and wool fibre found in raw wools
(Content - percentages)

Wool type	Grease and suint	Sand and dirt	Vegetable matter	Moisture	Fibre
Fine	20 - 50	5 - 40	0.5 - 3	8 - 12	20 - 50
Medium	15 - 30	5 - 20	1 - 5	8 - 12	40 - 60
Coarse	5 - 15	5 - 10	0 - 3	8 - 12	60 - 80
Carpet	5 - 15	5 - 20	0.5 - 2	8 - 12	60 - 80
Hair	2 - 10	5 - 20	0 - 1	8 - 12	60 - 80

Source: W. von Bergen, Wool Handbook, Wiley, New York (1963).

Note: The above data should only be considered as giving a general indication of the broad range which is found, and the data will vary with the type of raw material and its source.

78. It is noteworthy that, although the applied impurities are the least significant in terms of weight, they are usually the most difficult to remove.

79. From a practical point of view it must be realized that the finest and most expensive wools generally have the highest percentage of wax and suint, which results in greater amounts of vegetable matter sticking to them. In other words, the most expensive wools have the lowest yield and present the greatest problems.

Processed raw materials (waste)

80. These products find application in the woollen system but not in the worsted system. As man-made fibres are becoming cheaper and are being used more with woollen blends, rags present more problems in reprocessing. Also, as more and more blends are being used, fewer rags are available containing 100 per cent wool, and rags made from blends are more risky to process since it is often difficult to determine their exact composition. It is noteworthy that most of the fibres derived from rags which are used by the Italian woollen industry, which specializes in using reprocessed rags, are only between 12 and 15 per cent as costly as virgin wool. The average staple length of reprocessed woollen fibres ranges between 0.5 and 2.5 in.

Types of waste

81. The various types of waste raw materials used in woollen manufacture can be classified as follows:

(a) Waste originating from pre-spinning processes. Such waste is known as "soft" waste and is gathered from processes prior to the actual insertion of twist into a yarn. It includes products such as noil and worsted card wastes;

(b) Waste re-processed from threads with twist is classified as "hard" waste;

(c) Waste made from fabric is also recovered and reconverted into fibres.

82. It can be seen that, the fewer the processes that have been carried out on a waste material, the higher the value it will have. The reasons for this are basically that:

(a) Fewer processes are carried out on the fibre and fibre breakage is lessened;

(b) Less severe processes will be required to return them to fibre form.

83. Soft waste. This type of waste can usually be fed into the woollen processing cycle without extensive re-processing. Where the soft waste contains considerable amounts of dirt and vegetable matter, a shaking and/or carbonizing process is often useful to eliminate the non-fibrous or cellulosic matter.

84. Hard waste. Thread waste must be passed through a garnetting machine to tear up the yarns. The harder the yarn, the more severe the treatment will have to be, and for hard-twisted yarn a three-swift garnett is advisable. For soft hosiery yarn a two-swift machine may suffice.

85. Noils. These are an important source of raw materials for the woollen industry and are available in the same qualities as the wool top. Factors to be considered in evaluating noil suitability are how the tops from which the noils have been separated were processed (that is, dry or oiled); whether the noils were carded or prepared; how much vegetable matter is contained in the noils (noils are sometimes sold as carbonized). Noils from the various hair fibres are also often used to impart luxury to a woollen fabric.

Volume of wool usage

86. Although this report deals primarily with the processing aspects of machinery for the woollen and worsted industry, it is important to put the position of wool and the general outlook for wool into some perspective *vis-à-vis* other fibres, and with special reference to developing countries.

87. One factor to consider is that the importance of wool as a fibre is diminishing. This is illustrated by figure 4; in which the trend lines show that the output of wool has been fairly static since 1960.

88. The wool figures are based on a clean-yield, scoured basis. The present position of wool as a percentage of total world fibre production can be seen to be less than 9 per cent (3,437 million lb in a total of 39,483 million lb).

89. The considerations in the following paragraphs appear to be of special relevance to developing countries.

90. Wool is a relatively expensive fibre. Moreover, Australia, New Zealand and South Africa supply over 50 per cent of the world's requirements; the developing countries supply only a relatively small amount. In most cases, therefore, if a developing country wanted to go heavily into woollen production, the raw material would quite probably have to be imported. This factor would be of importance in consideration of foreign exchange problems, as shown in table 8, which shows the recent average annual prices paid for two representative wools.

Table 8

Average price per pound (clean basis) of dominion wools

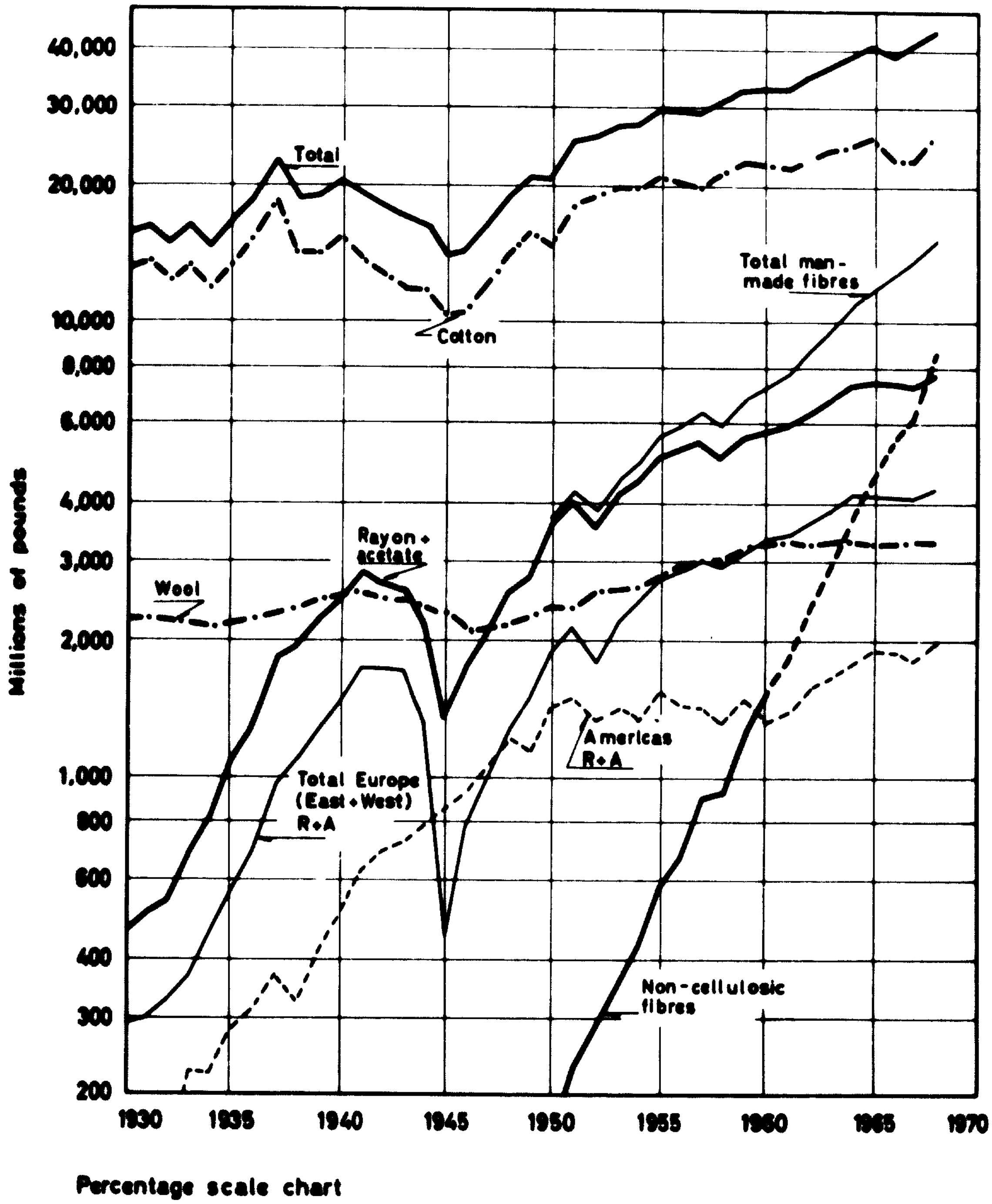
Year	Price of 64's (Bradford) (cents)	Price of 50's (Bradford) (cents)
1960	103.6	81.8
1961	104.5	81.6
1962	109.1	76.8
1963	124.0	92.8
1964	121.9	96.7
1965	106.8	82.5
1966	117.8	83.0
1967	108.1	67.8
1968	105.5	56.0

91. With the price of wool in mind, developing countries that intend to import considerable quantities should consider means of improving the breed of domestic sheep. Such a process is recognized as a long-term undertaking.

92. Many of the developing countries are in climates that are more suited to the wearing of cotton than wool.

Figure 4

World production of certain textile fibres (including rayon and acetate by area)



Source: Textile Organon, Vol.XXXX, No.4 (June 1969).

93. Woollen products are more closely associated with fashion items than cotton and man-made cellulosic fibres. The point is made that the production of wool or worsted garments is closely related to relatively high-style products, certainly as compared to staple goods of the cotton type.

94. All indications are that man-made cellulosic and synthetic fibres will continue to increase their penetration of the market at the expense of the natural fibres. Competition will therefore become more difficult for wool.

95. The Food and Agriculture Organization of the United Nations (FAO) projections for wool consumption in 1975 indicate that, while wool demand will have increased by about 30 per cent (24 to 36 per cent range) between 1962 and 1975, developing countries are projected to remain minor consumers, although their share of world consumption will rise from 9 per cent to between 11 and 12 per cent.

96. Bearing the above in mind, it is essential to remember that the differences between what used to be known as the "worsted" and "woollen" and "cotton" primary textile industries are becoming much less distinct.

97. It is therefore necessary that new wool-processing equipment be as versatile as possible, so that it can also be used to process materials that may have only a small wool content. Furthermore, it is recognized that certain fibres are best suited for certain end-products and cannot be used for others of a widely different character.

Chapter III

PROCESSES

98. The various processes common to the woollen and worsted industries are outlined in this chapter. This is done for reference purposes rather than for explaining the basic details of the process or machinery at each stage.

99. The basic difference between the woollen and the worsted system is related to the fact that the individual fibres lie more parallel to the yarn axis in the worsted than in the woollen system. Fabrics composed of worsted yarns can usually be considered as being lighter and smoother and having a more defined weave than woollen fabrics. In order to achieve the desired fibre parallelization in worsted yarn, a greater number of processes are required than in the woollen system, and the raw material must contain relatively fewer shorter fibres.

Sorting

100. The purpose of sorting is to separate the various qualities of wool in the fleece, depending on end-product requirements and economic considerations.

101. The operation can be considered as a product inspection and separation at the raw material stage. It should be noted that the modern tendency is to eliminate or reduce the sorting process, since the costs of the high labour input do not always result in corresponding product benefits. In the woollen system, where short fibres present no difficulties, sorting is often omitted.

102. Since sorting is still basically a manual operation, the human factor is of major importance, and considerable experience is required of the operative, who sorts the wool according to its fineness, length and impurity content.

103. Since sorting must be carried out manually, it is essential that the materials handled be carefully laid out to facilitate output. Emphasis should be laid on having suitable sorting tables on which the wool is laid out, as well as on making provisions for materials handling of the sorted fibres from the board into suitable baskets.

104. Since sorting is a human rather than a machine process, productivity data are extremely variable. It can be said, however, that an output of 200 to 250 lb per hour is reasonable for normal merino wool.

105. If the wool fleeces have been stored in a cold place, the grease will have solidified and sorting will be very difficult. Fleeces should therefore be brought to about 70°F (21°C) for sorting. This can be done either in rooms where the temperature is maintained at this level or in special ovens.

106. The necessary judgement that must be made in sorting can be developed only through experience. Sorting is especially critical in worsted manufacturing, and especially so when wool prices are high.

107. The following aspects must be considered when setting up a wool-sorting operation in a developing country:

(a) Since there may be a lack of experienced sorters, control of the cost of sorting may be influenced more by aids to operator productivity than by wage levels.

(b) When fine wool is at a premium, a more selective sorting of fine/medium qualities should be considered.

(c) Good natural indirect light is considered the most suitable for sorting. Alternatively, shadow-free artificial lighting is satisfactory.

(d) Care must be taken against danger of anthrax infection; adequate dust control is a prerequisite (dust draught through the table at 1,000 ft^3/min per person.

(e) Where wool fleeces are sorted into only a few categories (less than four), the use of conveyor belts can increase productivity about threefold over traditional table sorting. It may be advisable to have a preliminary sorting made with a conveyor system to sort the fleeces into broad matchings. This can then be followed by normal table sorting for the finest matching to further sub-sort each category.

(f) The sorting tables and equipment are not specialized and can usually be made locally.

(g) The decision must be made whether to set up the sorting for rig sorting (that is, splitting the fleece into two portions along the back centre and sorting the two halves separately) or to sort the fleece as a whole.

108. For the sake of comparison, the operation of one of the more mechanized sorting rooms is outlined below. This is not to imply that is should be used in developing countries, but rather to serve as a guide-line for deciding how far a sorting room should incorporate mechanical materials-handling aids. (This equipment is presently being used in a mill processing 500,000 lb of top weekly, and its applicability to operations processing smaller quantities must be evaluated individually.)

(a) Grease wool is hand fed from bales into a conveyor apron.

(b) Sorters working at the conveyor place "off-sorts" on a sub-conveyor at the right and graded wool into three sub-conveyors to the left.

(c) Partial blending can be achieved, since as many as three bales can be open at each conveyor, and fleeces are alternately taken from each bale.

(d) The conveyors transport the wool directly to bins holding up to 30,000 lb of wool. These bins are placed near the scouring unit feeds.

109. The above method of operation would be especially suitable for a large combing plant.

110. Without doubt, this type of sorting is much more cursory than the sorting into 6 to 10 matchings, which is often done with sorting benches. The conveyor trap system as described above is mainly used in the United States.

111. Normal production on bench sorting will usually range up to 1,000 lb per man per 8-hour shift, depending on the degree of separation desirable and the quality of the wool.

Scouring

Conventional scouring

112. Most wool is still being processed on the basic multiple-bowl scouring range, utilizing an aqueous medium.

113. The typical range contains from three to five bowls, and the wool is propelled through each bowl by a mechanism of the rake or harrow type. The number of bowls and the choice between a rake or harrow is determined by the raw material. The greater the impurities, the number of bowls and the danger of felting, the more advisable are the methods that minimize tangling.

114. Wool wax has a melting point of about 100°F (38°C), and therefore the liquor is kept above this temperature to melt the wax away from the fibres and release most of the dirt.

115. Special consideration should be given to the following aspects:

(a) Finer wools require gentler mechanical propulsion through the scouring bowls (that is, a harrow rather than a rake system).

(b) Finer wools generally call for four to six bowls, compared to three bowls for coarser wools, which have less grease.

(c) Self-cleaning bowls are definitely advantageous.

(d) Temperatures for wool scouring should range between 125° and 110°F (52° and 43°C). (Temperatures over 130°F (54°C) tend to cause greater fibre breakage in subsequent processes as well as reduced tearing.) Temperatures of 115° to 105°F (46°C to 41°C) are satisfactory for coarse wools and hair.

(e) The arrangement of the equipment and its scouring efficiency should be such that time for the wool to be transported through the scouring machine range from 20 minutes to no more than 30 minutes.

(f) Where conventional emulsion scouring is carried out, consideration should be given to soaking the wool in a preliminary bowl at about 90°F (32°C) to remove most of the suint and the largest lumps of dirt. (The so-called "Duhamel" system is similar to this. In it, preparatory to proper scouring, the wool is steeped in water at 100°F (38°C), and the liquor is then centrifuged to isolate the suint, which is added to the wax.)

(g) Although good results have been reported in some installations which used a preliminary desuinting approach such as the one described (the consumption of detergents was considerably reduced), the group did not favour this system, since it has not been generally accepted.

(h) Synthetic detergents are being used increasingly. Since these agents allow scouring in neutral levels, they reduce the risk of alkaline damage to the wool.

(i) The quality of water used in scouring is still of prime importance. The incidence of hardness because of excessive magnesium or calcium salts may call for special water treatment to prevent the formation of insoluble salts. However, this is less of a problem today with the availability of synthetic detergents. Note should also be taken of the problem of scouring-effluent disposal, which may be a source of water pollution.

(j) In view of the relatively large throughput of one scouring range, the economies of scale as related to scouring plants must be evaluated. The feasibility of establishing a central scouring plant to feed a relatively smaller (in size) number of top-making or spinning facilities should be determined.

(k) Prior to passing the wool into the scouring line, it is common practice to shake out as much loose dirt and sand as possible in a pre-opening process.

116. The major defects attributable to scouring are discolouration of the wool, caused by too high temperature, too high alkalinity, excessive agitation which causes felting of the fibres and subsequent fibre breakage, and general deterioration of spinning conditions owing to weakening of the fibres and reduction of their resilience.

117. Although the deficiencies of conventional scouring equipment have long been recognized, the industry has been very slow in developing a new approach to this process. It is noteworthy that although the principle of scouring with solvents[2/] rather than in aqueous systems has been known for about forty years and its potential advantages (of reduced felting danger and no effluent pollution) were recognized, it has found a very limited acceptance.

118. It was the opinion of the group that, despite the potential advantages of solvent scouring of raw wool, it must still be regarded as impractical and should not be considered for developing countries.

Modified aqueous scouring

119. Modifications of the aqueous scouring systems have been developed to overcome the basic disadvantage of the felting danger. This is achieved by reversing the method, i.e. instead of making the wool flow through the liquor system, the scouring liquor is made to flow through the wool. One of the major causes of wool felting is the fact that the rake or harrow goes too swiftly through the wool while the wool flows through the scouring liquor.

120. The following systems all reverse this system and make the liquor flow through the wool and at the same time avoid agitating the wool, as the rake and harrow actions do.

Aqueous jet scouring

121. Since the high-pressure water jets in the CSIRO solvent system were found to cause no appreciable felting, a system has been developed that jets aqueous synthetic scouring liquor through the wool instead of passing the wool through successive bowls of scouring liquor.

122. In practice, the machine consists of a series of bowls (three to five), each of which has four sets of pressure jets that force the liquor through the wool, which is carried on a permeable apron in the bowls.

2/ The term "solvent scouring" is used to denote a system where the aqueous medium is replaced by a volatile solvent (kerosene or trichloroethylene are two examples). It is recognized that water itself is a solvent.

Suction drum scouring

123. In this system the wool is passed through successive bowls in which, instead of the rake or harrow, perforated drums, half immersed in the liquor, rotate and act on the wool. The principle is that suction inside the rotating drums dislodges the impurities, which settle to the bottom of the tanks.

124. The suction within the rotating drums has an "evening" effect on the wool flow, and the fleece is carried in an even layer under the influence of successive drums.

125. A typical layout for fine merino wool will require five bowls, three using scouring bowls with three suction drums, and two serving as rinsing bowls and having two drums.

126. Where new plants are planned for scouring raw wool, the newly developed techniques of aqueous scouring (jet or suction drum) should be considered. These newer aqueous techniques have shown to produce wool with better noilage and/or productivity compared to wool scoured on conventional equipment.

Recovery of wool wax

127. Wool wax contains, among other things, lanolin and is therefore of some value. It can be recovered by a number of different processes, among them centrifuging and several methods of acid cracking. One method of acid cracking is described below.

128. The coarse dirt is allowed to settle, is drained off, and the scouring liquor is brought to 3.5 pH by the addition of acid. The liquor separates into three distinct layers comprising grease, water and dirt. The water is run off and the grease and dirt are heated together to about 200°F (93°C) and pressed through filters. The filtrate forms a cheap type of grease that is used as a basis for oils, and the residue is stored for about eight months and can then be used as fertilizer.

129. The consensus of the group was that the centrifuge separators offered distinct advantages over acid-cracking in terms of quality of lanolin recovered. The centrifuge method is considered efficient and quite satisfactory, although the output of lanolin may not be as high as by other methods. Since this method recovers the wool wax only partially, it will not be sufficient when high cleanness of the effluent is required.

Drying

130. After leaving the last scouring bowl, the wool is passed between the squeeze-rollers and should not contain more than 70 per cent moisture by weight.

131. For drying the scoured wool, care should be taken to specify equipment that provides large-volume air circulation at relatively low temperatures, rather than drying the material at high temperatures with low air movement. Not only is the former more economical but the danger of damage to and discolouration of the wool is much greater with higher temperatures than with lower ones.

132. A point of some importance is that, when the wool is propelled through the bowls with rakes or harrows, it is usually not delivered by the last squeeze rollers in a flow sufficiently even to go directly to the dryer, but rather must be accumulated in a hopper feeder. However, with the newly developed scouring methods previously mentioned, the wool is delivered in a much more regular and thinner sheet and can be fed directly into the dryer. The advantages of this are evident.

133. The design of the heating elements in dryers should have such an efficiency that it takes no more than 1 to 1.5 lb of steam to evaporate 1 lb of water. Power requirements are very variable and usually depend on the characteristics of the particular installation.

Carbonizing

134. This is the process whereby the fibres, either in stock or fabric form, are subjected to an acid treatment, so that the vegetable matter is carbonized after drying. It can then be crushed and shaken out of the textile as fine dust. The acidity of the fibre or fabric must then be neutralized.

135. Wool is often carbonized in fibre form since some types are contaminated with vegetable matter to such an extent that successful mechanical removal is impractical.

136. It should be noted that carbonizing is restricted to the woollen system of processing where the vegetable content is relatively high. Where stock carbonizing follows scouring, it may be possible to pass the wool directly from the scouring range through an aqueous solution of sulphuric acid (usually 5 to 6 per cent strength). The excess acid is then squeezed out, and the material is dried and baked at temperatures high enough to carbonize the

vegetable matter but low enough not to damage the wool. (This temperature would be 180° to 190°F (82° to 88°C) for not more than 30 minutes, followed by a similar baking period at 210°F (99°C).) It must be emphasized that the acid concentration, steeping time, drying and baking time and temperatures depend on the kind and quantity of vegetable matter in the wool. In any event the consideration should be to attain conditions that minimize danger of damage to the wool.

137. After baking, the vegetable matter is quite brittle and easily crushed by rollers, and is then passed through a rotating cage to shake out the dust. The acidity of the wool must then be neutralized. This is usually achieved by immersing it in an aqueous solution of soda.

138. The following factors should be given special consideration in carbonizing:

(a) It has been found that if no wetting agents (especially non-ionic ones) are used, the danger of damaging the wool fibre, resulting in losses in tensile strength and elongation, is increased;

(b) If it is necessary to store carbonized wool before neutralizing it (this may be sometimes desirable if there is only one scouring train and it is scouring stock when wool is carbonized), it is essential to maintain a dry atmosphere, since carbonized wool, if stored in humid conditions without neutralizing, will suffer considerable damage, which is usually manifested in reduced strength and elongation and uneven dyeing;

(c) The effectiveness of carbonizing will be reduced considerably if the wool has not been satisfactorily scoured and still contains more than minor amounts of grease;

(d) The group emphasized the need for close control of all conditions in the carbonizing process. The operating conditions are critical and, unless adhered to, the danger of wool damage is very great. Competent supervision is therefore especially important during this process. Developing countries would be well advised to purchase carbonized wool rather than perform this process themselves.

Blending

139. The objects of blending are to open, mix and clean the material as thoroughly as possible and, in woollen processing, to add the necessary oil.

140. Blending is carried out for reasons of economy and for end-product requirements. It is much more important that a thorough mixing be achieved when processing with the woollen than with the worsted system, since there are no doubling processes before spinning in the woollen system.

141. Stock blending is carried out as part of the woollen system. Blending for worsted processing is achieved by using a number of bales to feed the

scouring, as well as by feeding in several top slivers at the drawing processes.

142. The group felt that emphasis should be placed on the importance of the blending process in order to achieve a satisfactory end-product. This was considered to be specially important with the increasing use of synthetic fibre with wool. Consideration should always be given to the suitability of mechanical blending methods for blends of synthetic fibres and wool.

143. Although stock blending can be carried out manually (and in some developing countries, the extra labour input might not be significant because of low labour cost), the quality of blend intimacy is dependent on the operative. This section will therefore discuss in detail only mechanical blending.

144. The basic approach for improving blending output and quality has been through the application of ducting and rotary spreaders to transport the blend material and through the use of blending lines into which the material is blown and spread.

145. Blending can be carried out either in batches or continuously. In batch blending, each component may be processed first as a unit through an opening machine, and successive lots can be blown from the opening machine and piled into a bin. The blend can then be broken down vertically and fed into another bin. By the suitable arrangement of ducting it is possible to continue the blending from one bin to the next until a satisfactory mix is achieved.

146. The present continuous blending process, instead of piling or stacking the materials, passes them from an automatic weigh pan through a central blending system into an opening/picking machine and into storage bins.

147. If manual blending method is disregarded, the following considerations should be taken into account when selecting blending equipment:

(a) The present continuous process is more suitable for large lots.

(b) The batch system will give more even mixing and may therefore be preferable for stock-dyed lots or where different fibre types are to be mixed.

(c) The blending which takes place on the card in the woollen system can even out only short-term blend differences. In practice, depending on card production and delay factors, it is unlikely that differences between portions of more than about 10 lb can be satisfactorily blended.

(d) If only a small part of one component (for example, less than 10 per cent) is used, some pre-blending may have to be carried out with another component, and batch blending may be preferable.

e) For large batches, continuous blending will be more economical in terms of labour requirements.

(f) Where large-diameter bins are used, there is some danger that the denser and lighter blend components will separate as they are spread by the rotary spreader. On the other hand, tall, slim bins result in blockages of the material as it falls.

(g) Pneumatic conveying should be used wherever possible.

(h) Easy maintenance is of primary importance.

(i) Adequate provision should be made for adding oil to the blend. An atomizer-vortex system has been found to offer good results.

(j) Weighing accuracy is a key factor for adequate blending.

(k) The use of baling machines can save materials handling and storage space. They are especially practical where large lots are blended and then stored.

(l) Where exceptionally dirty or sandy material is processed, a pre-picking passage is recommended to remove the most obvious dirt. If this is not done, the ducts and opening machinery clog very quickly, requiring frequent maintenance.

148. Since such conditions as blend, dirt and mixing required are so variable, comparisons are difficult to make and may be misleading. Moreover, the labour input of automatic blending is quite low, since one man can usually operate a complete continuous line, regardless of its capacity.

Carding

149. The objects of carding are to separate the fibres as much as possible, to blend the fibres, to parallelize the fibres to some extent, to remove as much vegetable matter as possible, and to form a sliver or roving for further processing.

150. In the worsted system, the card typically comprises a hopper feed; followed by either four lickers-in and two swifts (Bradford-type card), or one or two larger swifts preceded by one large breast section (Continental-type card); and a delivery (coiler or balling) system. Special rollers (namely, Norel and Harmel) are also used to remove burrs from the wool in carding.

151. Before describing some of the recent developments, it is worth emphasizing that woollen carding is immediately followed by spinning and is therefore, in many ways, a more critical process than worsted carding. As far as blending and fibre separation are concerned, the opportunity to correct faults does not exist in woollen processing after the carding process has been completed. It

should also be noted that woollen material is often stock dyed and carded, while worsted carding is always carried out on undyed material.

152. The arrangement of the modern woollen card is usually based on one of the following: (a) the American-type machine, which is usually a one-swift first section and a two-swift "finisher"; (b) the Continental type, consisting of three sections with one-swift each; and (c) the semi-Continental, which is usually made up of a two-swift scribbler and two-swift carder (or finisher) section.

153. The Peralta system is now well accepted and has proved an efficient means of pulverizing vegetable content and crushing cellulosic threads in woollen carding. The position of the Peralta in the carding set should be given due consideration.

154. Between each two sections of the card an intermediate feed is used to give additional mixing to the fibres. The so-called Scotch feed is most popular, since it is simple and convenient. The broad-band parallel-fibre feed, which is essentially an improved version of the Scotch feed, is also often specified where extra blending may be required. Other types (such as the Ball and Bank and the Blammaire) are more specialized and less common.

155. The condensing of the woollen rovings from the card, which used to be exclusively carried out by ring doffers, is now being carried out by tape condensers because of their increased productivity. Two types of these condensers are available: the individual-series tape and the endless tape. With the first type, each separate thread from the condenser is served by its own tape, while the endless one is made up of a continuous tape, which is interlaced through the dividers. It is felt that the individual-series tape is preferable, from the point of view of maintenance, so long as the quality of the tape is consistent.

156. Some of the considerations relating to carding and carding equipment are discussed in the following paragraphs.

157. The trend today is to greater width (and larger swift diameters) of the carding equipment. This development was brought about by the need for higher productivity. Therefore, one of the major choices that must be made in the case of equipping mills in developing countries is whether to install cards of the conventional size or the giant cards, which often have a three to four times greater productivity. As a general guide-line, it can be stated that the wider cards are especially practical when producing thicker yarns.

158. The use of metallic cylinders and metallic clothing, together with modern machine manufacturing techniques, has allowed the equipment to be built wider and rollers to be of larger diameter and, at the same time, to be dynamically balanced for high-speed running.

159. This increased size and precision of the equipment has led to more efficient functioning of the machine and has therefore made it possible to reduce the number of swifts throughout the carding train, especially in worsted carding.

160. An example of this can be seen in some of the worsted cards now being made with only one large main swift preceded by a large breast section. (This trend is also in keeping and is influenced by the use of synthetic fibres that do not require as much carding as wool. The use of the "short worsted" system which is specifically intended for wool or wool-synthetic blends of coarse yarns has become well known.)

161. It is noteworthy that carding machines made in the last decade have incorporated many advances in terms of better engineering. These improvements call for more highly trained carding personnel. Among the significant advances can be noted greater use of instruments for machine setting; rollers that can be balanced more exactly; driving shafts at ground level, with bevel arrangements to the individual sections; and better engineering techniques in manufacturing, which permit better balancing of the rollers, thus permitting better setting and higher operating speeds.

162. Individual and variable-speed drives are available to a greater extent, so that specific sections of the machine can be driven individually.

163. Electrical or hydraulic controls are available to activate the hopper feeder and the weigh pan and are said to give more efficient and more accurate feeding than the conventional cam system.

164. Needle and roller bearings are being offered by some manufacturers throughout the machine. These offer definite advantages in terms of reduced maintenance and oiling requirements.

165. Doffing comb speeds are available at up to 3,000 strokes/min to permit the high production rates that are desired. This is usually achieved by using an individual electric motor to oscillate the comb and achieve doffer stripping at high rates of output. This system is specially applicable to carding

of worsted and/or coarse yarns. It should be noted that burr removal is more difficult at these high rates of worsted carding.

166. Where flexible wire clothing is used, vacuum stripping should be considered where possible in cleaning the cards. It not only does a more efficient cleaning than hand stripping but is considerably quicker.

167. The group wished to emphasize the need for mills to maintain an efficient carding-waste control system. It was noted that various systems for reducing the waste produced at carding are available and are of special application for woollen processing. One type of wool reclamation at the card involves an open lattice, which runs beneath the card and carries the waste made during carding to a suction transfer pipe, which is connected to a cleaning unit composed of a combination duster, blower and separator to segregate the fibres from the actual dirt. The reclaimed fibres can then be returned by suction pipe to the hopper feed.

168. A variable-speed intermediate feed is available that tends to minimize the effect of light ends at the side of the card.

169. Peralta rollers for burr crushing are now available in the relatively small diameter of 5 in instead of the 12-in diameter rollers that were produced previously.

170. In order to control the count variation from the oondenser, the Wool Industries Research Association (Leeds, United Kingdom) has developed an "Auto Count" device, which varies the speed of the last doffer according to the thickness of the web feeding into the condenser.

Preparing

171. In the worsted system the longer, coarser wools (that is, those running between 7.5 to 14 in) may be "prepared" by a series of gill box passages. This serves to disentangle the fibres and straighten them into a regular sliver formation with successive drafts and doublings. It should be noted that preparing may involve as many as six units, with loose wool being processed into a lap by the first machine, and the lap being converted and processed as sliver at the later preparers. This method is expensive and of low productivity, and is used only for special products.

Pre-combing gilling

172. Before combing, it is essential to pass the carded sliver through two to four gilling processes to further blend and parallelize the fibres. If back washing precedes combing, these passages take place after back washing.

Combing

173. Combing is carried out to achieve the following:

(a) Removal of the short-fibred noil, which is not suitable for worsted yarn;

(b) Removal of the vegetable matter such as burrs and dust;

(c) Removal of neps;

(d) Parallelization of the fibres;

(e) Blending the fibres together better by means of doubling.

174. Combing is carried out either without oiling (dry combed tops) for rectilinear (French) combing or with oil added for Noble combing (sometimes on rectilinear combs, as well).

175. It is unlikely that new mills in developing countries would want to consider setting up wool-combing operations based on Noble combs. Some of the reasons for the preference of the rectilinear combing are as follows:

(a) The rectilinear comb is more suitable for shorter wools, which certainly gives it an economic significance. (In fact, the rectilinear comb was originally developed for cotton processing.)

(b) In the rectilinear comb the whole length of the fibre is combed.

(c) It is easier to produce a very short noil on the rectilinear comb than on the Noble comb.

(d) Finer pinning can be used on the rectilinear comb.

176. Recent developments in the rectilinear comb have included an increase in operating speed due to a higher number of nips per minute. Today 150 nips/min is realistic, and some combs specify a maximum speed of 185 nips/min.

177. Other noteworthy developments on combs are cleaning devices to strip the top comb and blow out any dirt from behind the circular comb and apron; automatic controls and knock-off motions; central lubrication; a conveyor belt or pneumatic system under the machine to remove noils automatically; and large-diameter feeding cans (up to 600 mm).

178. Other developments for both combs and draw boxes are that settings are becoming more simplified and, wherever possible, calibration gauges are no

longer necessary. Dust suction devices are also recommended for the high-speed combs.

179. Typical comb sliver input on the new machines will range from 250 to 350 kilotex with higher inputs being possible with coarser quality wools.

180. Additional factors for consideration are that, bearing in mind the increased productivity of the Noble comb, the production of top in a Noble comb can be increased by raising the feed but only at the expense of a greater percentage of noil. In other words, with Noble combing, the quality of production must be balanced against the over-all value of top plus noil. With Continental combing, n the other hand, little can actually be done to vary the production, which is about 50 per cent that of the Noble comb. In this case, the lower value of extra percentage of noil produced must be balanced against the quality of a top with a specific short fibre content. It should be noted also that, at normal rates, the rectilinear comb will produce less noil than the Noble comb, but that the rectilinear comb noils are shorter and usually less valuable than Noble noils. For certain long wools and mohair, however, the Noble comb is still favoured. Moreover, while sliver can be fed from a can into the rectilinear comb, a special "punch" must be used to wind the sliver into compact balls for feeding the Noble comb. This factor favours the rectilinear comb.

181. In general, it is important to bear in mind that when combing synthetic fibres or dry-combed coarse wools, the speeds must often be reduced since, in the case of the former, there is insufficient adhesion between the fibres at high speeds while, in the case of the coarse wool, the detaching rollers run too fast for the length of material at the high nips-per-minute level. Nevertheless, when speed must be reduced, the input rate can be raised to maintain production.

Re-combing

182. The re-combing of dyed tops is quite often carried out on already combed material to improve the appearance of the sliver, which may have matted during dyeing or other wet treatments.

Back washing

183. The purpose of back washing is to give an additional cleansing to the wool by means of a mild scouring, removing any vegetable dust that may be left, to dry the tops and to pass the slivers through a gilling process. Where the tops are oil combed, as in Noble combing, it is customary to back wash prior to Noble combing, while back washing usually follows dry combing.

184. The back-washing machine consists essentially of a scouring section (usually two or three bowls equipped with suitable guide and squeeze rolls), a drying section, and, in most cases, of a gill box. Detergent is usually added to the first bowl, while the last bowl is for rinsing.

185. If the top is back washed after dyeing or vigorous printing, the back washing should be more thorough, and three or four bowls may then be used advantageously to remove completely any surface dye-stuff. The process is of special importance to the top-maker, who sells the top, rather than to the vertical integrated mill, since it affords an opportunity to improve the appearance of the sliver. The temperature of the liquor in the bowls is usually maintained between 100° and $120^{\circ}F$ (38° and $49^{\circ}C$).

186. The manufacturer has a choice of three types of drying methods for the back-washed sliver: can dryers, hot-air dryers, or perforated-drum dryers.

187. Hot-air dryers are sometimes preferred, since the slivers do not touch hot metal surfaces. The perforated suction drum is also finding good acceptance for drying the back-washed slivers.

188. The back washer and dryer may run in tandem with a gill box, which can be either open or intersecting, depending on whether the top is being produced in the open or Continental system.

189. In the case of the former, oil is usually added to the stock as it enters the gill box. The amount of oil added at this point usually being about 3 per cent of the weight of the wool.

190. The back-washing process may also be used to apply various treatments to the wool slivers in order to impart certain shrink-resistant properties to the fibres. The process would involve modifying back washing so that suitable anti-felting chemicals and wetting agents can be padded on, followed by a short accumulation of the material in some kind of accumulator such as a J-box. This "dwell time" is necessary to allow the anti-shrink finish to

react with the wool. Pre-rinsing, neutralizing, and final rinsing and brightening can then be successively applied prior to drying.

191. It is advisable to have an automatic replenish controller on the padder and neutralizing bowl. Perforated-drum dryers are preferred for this type of treatment. In order to compete satisfactorily, these types of modifications to wool material will assume greater significance so that it could have properties similar to those of the easy-care synthetics. A further recent modification to the back-washing process is the use of a sliver conditioning-tensioning equipment in which the slivers are passed between spray units and are then simultaneously tensioned and dried by a series of heated rollers. The speeds of the rollers are so arranged that tension is imparted to the slivers during drying. Furthermore, this effects a certain straightening of the fibres and allows good control of wool regain. This machine can be placed immediately before the gill.

Drawing
(Including gilling after combing)

192. This is a further drafting, blending and attenuation of the slivers to form uniform suitable products.

193. Here, there are three basic principles:

(a) Open drawing (for oil-combed wools);

(b) Continental (porcupine) drawing for dry-combed wools; and

(c) The "American" system, based on high-speed intersector gills.

194. The finisher drawing or last drawing processes produce a thin roving.

195. The basic concepts of gilling and drawing machinery have not changed much, except in methods of obtaining greater speeds and higher productivity.

196. Pin drafting of the material is also carried out after combing on equipment that is essentially similar in principle to the pre-combing gilling described above. The same general comments are therefore applicable to gilling stages before and after combing.

197. Three major developments have gained prominence:

(a) Can delivery of the output slivers (with or without rotary coilers) instead of balls;

(b) Automatic doffing arrangements for cans and balls;

(c) Autolevelling of sliver thickness.

198. It should be pointed out that the use of cans offers certain advantages, not only in terms of increased efficiency but also permitting fewer joinings to be made in the sliver as well as giving more protection to the sliver during handling and, therefore, minimizing soiling and damage.

199. Perhaps the key factor in the reduction of processes in drawing has been the development of autolevelling devices to control sliver thickness automatically. This has certainly permitted fewer doublings to be used in the process than was possible before. Before autolevelling came into common use, the traditional approach had been that the more doublings through the drawing process the better.

200. The autolevelling device usually relies on a method of constantly controlling the speed of the input sliver, which is regulated according to the weight, while the front delivery rollers run at constant speed. The method of achieving this autolevelling is governed by various systems, including mechanical, electromechanical and hydraulic.

201. Some other developments that have become available are described in the following paragraphs.

202. The improved precision of machinery manufacturing has made possible the production of equipment that can be operated at much greater speeds than previously. For example, conventional screw-type gills are available, which operate 1,500 faller drops per minute. Some gills, in fact, can be operated at 2,000 drops per minute. (It is of interest to note that faller pins are now being imbedded in plastic bodies which, in fact, are being offered as "throwaways", rather than having to be repinned, as is the case with metal fallers. They are also lighter and do not run with so much noise at the high speeds that are being aimed for.)

203. Since the machines often run at high speeds, it has been necessary to develop suitable quick-acting stop-motion devices; photoelectric units are now commonly used.

204. Whereas drawing sets of the older types would have three of four delivery heads at the first processes up to, for example, 24 at the finisher drawing, the modern set has fewer heads per machine. Most modern machines have only one head in the first stages of drawing.

205. The use of hydraulic pressure on rollers instead of the spring arrangement is becoming more common.

206. In order to increase speeds of faller bars further, the traditional screw and cam system may be replaced in the future by chain drives, thus allowing speeds of up to 6,000 faller drops per minute, with an accompanying delivery speed of about 170,000/min. Some makers claim up to 8,000 drops/min at 225,000/min delivery with chain drives.

207. At such high speeds, static electricity becomes a problem so that steps must be taken to dissipate it through metallic rods, anti-static agents and so on.

208. Also, with the increasing productivity of drawing equipment, the use of suction fly-clearing systems has become common.

209. It should be pointed out that of the various systems that have developed from the basic Bradford (open and cone) and Continental drawing systems, the one most popular at this time is the "shortened Continental" system.

210. Apart from the Continental system, mention should also be made of the American pin-drafter system, which also incorporates autolevelling devices. This American system is equally suitable for both dry and oil-combed material Attention should also be drawn to the development of the Uniflex system, which is capable of converting tops into yarns (oil or dry) in three or four stages.

211. It was emphasized that, although the number of drawing stages has been reduced, it is essential (especially in the case of wool-synthetic blends) to have sufficient drawing or pre-mixing processes to ensure adequate mixing.

212. It can be stated that the modern drawing process usually comprises four stages, the first being an autoleveller. The last stage may consist of a flyer system (as in the American-system roving frame); and for finer counts (for example, above 35 Nm), five stages may be utilized.

213. In view of the increasing importance of wool/synthetic blends, strong consideration should be given to having a final roving process rather than finisher drafting. The possible advantages of the slightly twisted roving (such as increased package density, better drafting control at spinning due to slight twist, and reduced danger of roller lapping, particularly in synthetic blends) should be considered. Merinos, cross breds, and blends of wool and man-made fibres with staple lengths up to 300 mm can be processed satisfactorily on this type of machine.

Fibre lubricants

214. While oil is used in yarn manufacture to assist in lubricating the fibres, it must be scoured out in finishing. This consideration affects the selection of the oil. In woollen processing, the oils are usually applied during blending, and olein and mineral oils are most commonly used. In worsted processing, sperm, castor or synthetic oils are more usual. They are applied at various stages (before or after combing or during drawing).

215. The type of olein used depends on the quality of the goods, but in general the best types of oils with high free fatty acid content are preferable. For woollen blends, mineral oil can be used if special emulsifiers are added to it or if it is blended with a great portion of olein.

216. The danger of oil staining because of the presence of oil on yarn in storage should not be ignored, since some oils oxidize quickly and discolour easily. The oxidized oil is usually rather difficult to remove during scouring, so if it is foreseen that greasy yarn will be stored for considerable periods, care should be taken to choose a spinning oil with an iodine value below 90 and containing an antioxidant.

217. In addition to satisfactory lubricating properties, the oil should have a low flash point. It should not discolour or weaken the fibres, or harm the equipment; it should scour out easily and have some antistatic quality.

218. When processing man-made fibres, antistatic agents are often added. Of the various methods of applying lubricants, the group considered the Vortex system the best in giving a fine atomization and most even blend application.

219. In woollen processing the amount of oil applied will usually vary between 6 and 10 per cent for olein types, and a lesser amount may suffice if synthetic types are added. The amount of oil used in worsted processes is far less, but varies considerably according to the type of oil and the processing method.

Worsted spinning

220. The roving is further attenuated (drafted) and twist added to give the required cohesion and strength to the spun yarn. The ring spinning system is now predominant over the flyer or cap systems because it is more economical, suitable to most conditions and capable of spinning yarns of an acceptable quality. For these reasons except in specialized applications, flyer and cap

spinning are gradually being superseded. (The flyer is still sometimes specified for spinning coarse counts of long or hair fibres.)

Drafting

221. The roller drafting system is largely being replaced by apron or high-draft units. Roller drafting is quite limited in the maximum attainable draft and therefore requires finer rovings to be produced to spin a given count. Apron drafting systems can process higher drafts, for example, up to 18 with a single apron and up to 35 with a double apron. Moreover, drafts up to 100 can be achieved with superdraft systems such as the Ambler.

222. It should be noted that the productivity of many ring spinning frames today has reached the point where the traveller speed has become the limiting factor. (In such cases, the potential for using self-lubricating rings should be borne in mind as a means of raising the practical maximum revolutions per minute, and due importance must be given to the choice of travellers, considering the spinning speeds involved.)

223. The following aspects of spinning frame design should be borne in mind:

(a) Fibre control by tension-bar roller drafting allows twistless or twisted rovings to be processed and therefore adds versatility.

(b) Among the various spindle-drive systems, the four-tape drive with drum or single disc should receive first consideration.

(c) Optional attachments such as tip bunching, automatic underwinding, variable speed spinning, should be critically evaluated.

(d) The use of balloon control rings which minimize the tensions in the balloon should receive consideration in the selection of spinning equipment. It is likely to be especially interesting in the case of weak yarns (such as low twist all-wool), with which the end-breakage level might be high.

Wool spinning

224. While there are now more mule than ring-frame spindles in operation, ring spinning is being largely installed in new plants, basically because of its greater economy. Even if this factor is disregarded and the position is taken that labour costs may be unimportant in developing countries, it would seem that the ring frames, being far simpler to operate, would be a much more suitable choice than the mule.

225. It should be noted that the woollen ring frame differs from the worsted spinning frame mainly in respect of the drafting system used and the sizes of

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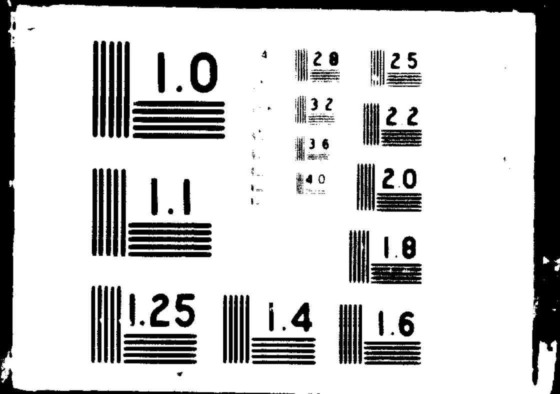


the ring and bobbin. The drafting system of the woollen ring frame includes a means of imparting a false twist to the sliver in order to obtain a yarn of sufficient uniformity. Since the woollen yarns are relatively coarse, ring and package sizes are usually larger than in worsted spinning, and these factors tend to increase the yarn tension in the balloon. To reduce this increasing yarn tension, especially at the higher spindle speeds which are being sought, it has become common practice to use a spindle attachment which, by reducing the balloon height or eliminating the balloon altogether, lowers the tension in the yarn and thus permits higher operating speeds to be achieved without excessive end breakages.

Semi-worsted long-staple spinning

226. Various so-called "semi-worsted" systems have been evolved for producing relatively coarse yarns, usually made up of synthetics and clean wool or 100 per cent synthetic fibres, for use in carpeting (both woven and tufted) and hosiery.

227. It should be noted that the system is not practical for fine wools, since it is basically a shortened long-staple worsted system, which utilizes a single-cylinder card. The layout usually includes a single-cylinder high-speed card that delivers the sliver into a can, followed by two or three passages of drawing, gill or roller drafting, followed by sliver spinning.

228. Two passages of drawing often suffice for the coarser yarn counts, with the autoleveller being incorporated into the first gill-box passage. High drafts are achieved at spinning, often utilizing a double-zone drafting system. Balloonless spinning, similar to that used for woollen spinning, can be utilized.

229. In general, the following points can be noted in respect to the semi-worsted system:

(a) The yarns produced are somewhat different from yarns spun in woollen or worsted systems and can be considered as being interemdiate in character between the yarns of these two systems.

(b) The card used is simpler than either the woollen or worsted card.

(c) It is generally more economical in terms of labour and equipment for producing the yarns for which it is suited. Space requirements are also less than for corresponding woollen or worsted layouts.

(d) Wools that contain a large portion of short fibres cannot be processed satisfactorily by this system. In addition, it should be noted that wool that contains an excessive amount of fatty matter (more than 0.6 per cent) should not be processed by this system.

(e) The moisture content of the raw material must be lower than for regular worsted carding (not more than 20 per cent).

Spinning machine selection (General considerations)

230. On the subject of spinning in general, the decision of specifying package size is indeed critical, since it has a considerable effect on production costs. Every condition varies according to specific costs of labour, power, equipment, space, parts and so on, while the inherent variables of count, twist and machine specifications, such as ring diameter, lift and spindle speed, also have their effects. All of these factors are interrelated so that, for example, specifying smaller rings might result in an increase of production, while at the same time the cost of production would be increased, since the output per operator would have been reduced. On the other hand, with larger rings, spinning costs sometimes are increased because of lower spindle revolutions, and production might drop below the optimum. In practice, it must be borne in mind that, if a wide range of counts, containing a considerable number of fine counts, is to be spun, the smaller rings may be more advantageous. On the other hand, larger rings may be more economical for coarse counts. (It is noteworthy that, because of the complexity of determining the most economical combination of factors such as those mentioned above, certain large textile companies and some of the machinery companies are showing interest in applying computers to identify the most economical conditions for a particular product mix.)

231. Variable-speed drives and anti-snarl devices are also advantageous at the high speeds that are now obtained, especially for high-lift bobbins. (Where balloon suppression is used, the variable-speed drive may not be so important.) Several types of suction cleaning devices are recommended at high operating speeds. It can be said that most manufacturers are trying to reduce yarn tension by using a stationary pigtail in conjunction with balloonless spinning, which is of greatest interest for coarse yarn. Another advantage of the reduced tension incurred with this method of spinning is that piecing is facilitated at high speeds. It can be said that, wherever possible, equipment should be specified that is flexible enough for different tension-reduction systems to be used. It should be noted that size of the bobbin has been increased to the point where bobbin lifts are now available up to 23 in., but this relates to woollen frames only.

232. Automatic doffing is used primarily in the cotton-spinning industry; its use in woollen and worsted spinning appears limited at present. Even in cotton spinning, the general usefulness of automatic doffing equipment has not yet been proved; in developing countries the advisability of installing such equipment at present would be very questionable.

233. It was emphasized that the ring diameter to be specified in ordering equipment must be based on the counts to be produced and the group felt that this factor was often underestimated. The group wishes to emphasize to machinery manufacturers the desirability, from the viewpoint of textile industry, of striving to standardize equipment sizes as much as possible.

234. Although specific factors vary, table 9 gives an indication of machine data that can serve as a guide-line. This table is based on current practice in the worsted and woollen systems, with modern equipment in good operating condition. The general relationship between yarn count, package size and maximum spindle speed is shown.

Table 9

Relationship between yarn count, package size and maximum spindle speed a/

WORSTED							
Count (Nm)	5-20	16-35	25-45	35-65	45-72	55-80	
Ring diameter (mm)	95	70	63	57	54	51	
Tube length (mm)	320	300	270	250	250	230	
Net package weight (g)	400	220	160	130	120	100	
Maximum spindle speed (rev/min)	7,000	9,000	9,500	11,000	11,500	12,000	
WOOLLEN							
Count (Nm)	0.5-4	1-6	2-8	4-10	6-14	8-16	10-25
Ring diameter (mm)	160	140	120	110	95	95	75
Tube length (mm)	520	520	460	420	420	360	320
Net package weight (g)	1,800	1,500	1,050	790	640	550	320
Maximum spindle speed (rev/min)	4,500	5,000	6,200	6,700	7,500	8,000	9,000

a/ The spindle speeds refer to the finer yarns in each range of counts and are based on self-lubricating rings.

Winding

235. With winding, as with other textile processes, the trend is to higher productivity, which is achieved through better machine engineering, design, larger packages and automation of materials handling and knotting. The following points should be considered relative to winding:

(a) It is important to realize that, in many cases, the winding that is carried out on conventional non-automatic equipment, representing a simple and relatively unsophisticated approach with creeling, doffing and knot-tying performed manually, is still satisfactory in many situations.

(b) Automatic winding can be done on machines where the supply yarn is knotted automatically, the operative's major function being to replenish a battery with spinning bobbins and to remove the full packages. Two general types of machines are available: one uses one knotting head per machine, while the other has a knotter at each winding head. With the latter type, yarn breaks can be repaired without the delay caused by the knotter having to travel around the machine. An intermediate approach is also available, whereby a number of winding heads are serviced by one knotter. Automatic cleaning (blowing and suction) can be incorporated to keep the machines relatively free of lint.

(c) In spite of the high productivity of automatic winders, the current cost of these machines is far greater than of non-automatic ones and, in developing countries where labour may not be particularly expensive, the advantages of specifying this equipment must be doubtful.

(d) For knitting yarns, the application of wax by running the yarn over a wax disc is quite common. Where the yarns are wound into skeins for skein dyeing or balled for hand knitting, operating speeds are likely to be considerably lower.

(e) A "pre-assembling" (whereby yarns to be twisted are wound together onto one package to ensure that they are of the same length and relatively fault free) may be carried out prior to twisting in order to improve twisting performance and end-product quality.

(f) The clearing of yarn faults during winding is of high importance. mechanical, photoelectric and electrocapacitance clearers are available and should certainly be considered. The group was in general agreement that mechanical-type clearers (adjustable) were preferable for developing countries. (Where synthetics or blends containing them are processed, electrocapacitance or photoelectric types may be preferred because of their critical tension requirements. In the latter case, it should be borne in mind that those types that sense a gradual change in yarn thickness are preferable, as far as quality goes, to those that can only sense sudden increases in thickness, such as those caused by slubs.

(g) The importance of correct tension and slub-catcher settings for the winding process must be emphasized, and mill standards should be established for the various counts and qualities.

236. In general, the group felt that automatic winding would receive consideration only where the runs of yarn wound are sufficient to justify the cost. One of the key factors to be evaluated would be the frequency of stoppages expected in winding. The group wished to emphasize that, in all cases, decisions pertaining to the winding process must be related to the effect that they will have on fabric quality costs of repair.

Twisting

237. In this process, individual yarns are twisted together for purposes of strength, appearance or balance of structure. The consensus of the group was that the conventional twisting system, utilizing the ring and traveller, should receive prime consideration in developing countries. This system is the most common and probably the simplest. The limitations to the productivity of this system are the factor of maximum traveller speed that can be attained and the relationship between package size and ring diameter whereby a larger ring diameter is accompanied by reduced spindle speed (as in the ring spinning).

238. In order to increase productivity, collapsed or "suppressed" balloon systems are used increasingly in twisting, and machines accommodating larger packages are being designed. Consideration should be given to pre-assembling, as mentioned above in the section on winding.

239. Note should be taken of the availability of the "two-stage" and the "two-for-one" twisting systems, which may offer certain advantages.

240. The two-stage process divides the twisting into two separate phases, whereby initially two single yarns are folded together with a low twist (for example, 20 turns per metre) at a speed of approximately 200 to 400 metres per minute. In this first stage, the yarn is wound onto tubes at low tension and is then taken to the second operation where the final twist is inserted. It should be noted that in the second operation the yarns are "uptwisted" in a spindle sleeve under much lower tension (about half) than in conventional ring twisters. Owing to the large packages, which can be prepared at the first stage and to the low tension, stoppages are very rare, and yarn quality, high machine utilization and productivity increases can be achieved.

241. The two-for-one system uses a stationary yarn package and a hollow spindle arrangement so that two turns of twist are given for every spindle revolution. Pre-assembled yarn packages must be prepared, and the twisted yarn can be delivered directly onto a cone, thus obviating the need for a separate winding

process. It is suggested that the increased productivity resulting from two-for-one or two-stage systems will be especially meaningful for the finer yarn counts, for example above Nm 36. Both the two-for-one and the two-stage processes have the advantage of operating with less waste than conventional ring twisting.

Steaming

242. Where yarn tends to be lively and prone to tangle in further processing, steaming could be introduced. This is done by subjecting the wound yarn to suitable conditions of temperature and moisture so as to relax its inherent strains and to set it. Naturally, yarns with high twist are more likely to snarl and to require a more prolonged steaming.

Weft winding

243. Developments in weft-winding equipment during the last ten years have sought to give higher operating speeds and improved tension control, as well as a modification of the equipment, so that materials handling is carried out more efficiently. (For example, systems have been developed whereby the full bobbins are dropped into magazines, which can then be directly taken to the loom and serve as the pirn battery for weaving. Such systems will also reduce the danger of yarn mixes and yarn soiling that may occur between the pirn winder and the loom.)

244. In addition to the above technical improvements, the development of the Unifil system should be noted, whereby each loom has its own individual weft-winding unit attached, which operates as an integral part of the loom. This offers certain advantages in terms of quality and allows all the weft winding to be carried out at the loom. The potential advantages must be evaluated in each case.

Warping

245. Sectional warping is likely to receive first consideration in the woollen and worsted industry owing to the relatively short runs. Full-width warping should not be considered in this industry, since it calls for high-volume production.

246. Special note should be taken of the tendency to use "singles" yarn in worsted warps for trousering and suiting fabrics, while in the past finer yarns were plied together to give the same resultant count. The tendency to use these more economical single yarns necessitates slashing in order to obtain satisfactory weaving performance.

247. The importance of the quality of the warping process on subsequent weaving efficiency must be emphasized.

248. The general trend can be noted once again to higher machine speeds resulting from improved engineering and machinery design, as well as greater control of the process through the use of gauges and meters.

Knotting, dropper pinning, drawing-in and reeding

249. These steps are commonly carried out to prepare a new warp for weaving. While machines are available to perform all of them, the degree to which textile mills should invest in this type of automatic equipment will be determined by the particular conditions. It was the consensus of the group that a fully mechanized approach to all these operations would usually not be justified. However, automatic machines for the tying-in of new warps should be considered in most cases. On the other hand, it was felt that the placing of drop-wires on the warps, and the drawing-in and reeding processes should, in most cases, be carried out manually.

Weaving

250. Of all the various processes involved in manufacturing yarns and fabrics, it is felt that the machinery related to weaving presents the most critical choice in mill planning. The conventional shuttle loom is still the most commonly used and can be considered as the basic level of the modern weaving process. Improvements and engineering developments have been effected which have made the conventional shuttle loom a most efficient piece of equipment within the scope of its design. The modern shuttle loom can incorporate basic equipment that automatically stop it for a warp or filling break and replenish the shuttle with full bobbins as the old ones run out, without stoppage of the loom. Note should be made of the possibility of equipping an automatic loom with its own pirn-winder head, thus eliminating the need for separate filling, winding and battery filling.

251. In connexion with modern shuttle looms incorporating such items as push-button controls and highly sensitive mechanical systems, the group emphasized that it would be quite incorrect to consider the conventional shuttle loom as an antiquated and outdated machine. None the less, it should be noted that informed opinion is agreed that the conventional shuttle loom has now reached the limit of its development. The woollen and worsted industry has certainly been quick to take advantage of the major development of shuttleless looms.

252. Among the various types of shuttleless looms available, the following are the most important:

(a) The gripper type, whereby a light metal "carrier" is projected and carries the weft across the shed;

(b) A single rapier, which grips the yarn and pulls it across from one side of the cloth to the other;

(c) A system where two rapiers work from opposite sides of the loom and transfer a loop across the weft, without gripping it;

(d) As above, but with the rapiers actually gripping the yarn;

(e) Looms which are crossed by a shuttle in the conventional way, but in which the shuttle does not contain a pirn but rather hooks the yarn around it and transfers it across the loom in a way similar to the single rapier which does not grip the weft, as in (b) above.

253. Most of the machines of this type offer multi-colour filling opportunities, and these would seem to be the ones that are of most interest to the woollen and worsted industries.

254. A characteristic problem with shuttleless looms has been that the selvage is not as neat as on goods woven on conventional looms. However, this problem appears to be of less importance than was originally thought. The fringed selvages that are formed on some shuttleless looms are coming to be accepted.

255. In view of the number and wide variety of types of shuttleless looms, that are available, it is important that very serious consideration be given to the selection of a machine. In other words, before deciding which machine to order, each of the different factors should be expressed in quantitative form and evaluated on the basis of potential return.

256. Consideration must also be given to such factors as beam diameter, system of lubrication (centralized, if possible) as well as the efficiency of the stop-motion devices.

257. The improvements in woollen and worsted fabric quality produced on shuttleless looms have been well established, and the results indicate that lower fabric-mending costs are usually involved in addition to increase in

productivity. Bearing in mind that woollen or worsted fabrics usually are of relatively high value (certainly as compared to cotton goods), this factor may therefore be an important consideration in decisions relating to capital investment in weaving.

Fabric inspection and mending

258. After weaving, the pieces are examined, weighed, measured and numbered for control purposes and are then mended. The mending operation is totally manual and is not dependent on equipment to any considerable extent. In many cases, the mending operation is preceded by a separate fault-marking operation, which involves running the pieces over tables and identifying the faults to be corrected.

259. The group wished to stress that an efficient training system is of primary importance as regards the mending operation. A further consideration that should be emphasized for this department is the provision of mending tables so designed that the menders can perform their work with a minimum of fatigue.

Dyeing

260. Dyeing can be carried out at various stages of textile manufacturing, namely, as loose wool (in the woollen system), as top or sliver (in the worsted system), or as yarn, fabric or knitted garments.

261. The following are some of the major factors relevant to dyeing of woollen and worsted materials:

(a) The choice of dyestuffs and the method of application are mainly determined by fastness requirements, colour, levelling qualities, finishing requirements and economic considerations.

(b) The dyeing process is further complicated today by the increasing use of synthetic fibres, the dyeing characteristics of which differ among each other as well as from wool. The use of high temperature-high pressure dyeing methods has been increasing for wool-synthetic blends, since these conditions give more favourable dyeing for synthetics. Special pressure-sealed equipment is required for such processing.

(c) It should be noted that modern dyeing equipment is almost exclusively made of stainless steel which, despite its higher initial cost, has definite advantages over older equipment in terms of maintenance and cleanliness.

(d) Although methods have been undertaken to develop continuous dyeing for woollen and worsted fabrics, they have not as yet been fully perfected in general practice. Note should be made, however, of the method of continuous sliver dyeing, which is available and deserves consideration.

(e) As far as piece dyeing is concerned, beck dyeing is still predominant. However, note should be made of the "jet" dyeing principle, which has been developed in the last five years and appears to offer certain advantages for dyeing synthetic blends. In this method, the material is dyed in a pressure winch and, rather than circulating the fabric through the dye bath, a jet of dye liquor is projected onto the material so that the liquor passes through the fabric rather than vice versa, as in traditional beck dyeing.

(f) In addition to weaving or knitting yarns of different colours, multi-colour effects can be achieved by cross dyeing fabrics of wool blended with other fibres or with modified (for example, chlorinated) wool, so that by the use of suitable dyestuffs, cross dyeing takes place. This process offers certain advantages in terms of flexibility for marketing and styling.

(g) Bleaching can also be carried out on woollen and worsted materials to improve the appearance of the products and can be considered as a dyeing operation.

(h) Although piece-goods printing finds fairly limited application in the woollen and worsted sector, note should be made of the Vigoreux printing process, whereby the sliver is printed with suitable pigment paste prior to the back-washing process. Vigoreux printing is mostly carried out to give a grey mix (i.e. intermittent bands of sliver are printed with black paste, so that in the final yarn the black and white areas intermingle to give a resultant grey).

Finishing

262. The finishing processes are conveniently classified into wet and dry finishing and are outlined below. It should be noted that, except for some specific advances in dyestuff technology, relatively little development has taken place in the area of finishing woollen and worsted fabrics. The traditional batch processes are still the most common, and it is only in the last few years that new types of equipment have become available. It should be noted that most of this has not yet been widely adopted, and care should therefore be taken to avoid selecting suoh types of equipment until they are fully proved.

263. The very oonsiderable diversity of processes and process sequences that is typical of the woollen and worsted industry should be noted. Nevertheless, the group emphasized the desirability of having eaoh mill standardize its own operations in the finishing area to as great a degree as possible.

Singeing

264. This process is only applied to clear-finished fabrics and is carried out either by a gas flame or by passing the fabric over a hot plate. The projecting fibres are burnt off the cloth surface. Because of the very nature of the process, care must be taken to guard against fire hazards.

Setting or crabbing

265. The purpose of the process is to relax the strains in the fabric and to stabilize them to reduce creasing and distortion in further stages of processing. Crabbing is used only with worsted cloth and is done either continuously or by an intermittent (semi-continuous) process. The continuous process consists of passing the fabric through a series of tanks containing a liquor, so that the fabric is subjected first to relaxation in the water, and then to high temperature and roller pressure. The semi-continuous process involves passing the goods in full width through boiling water onto a roller. This process can be repeated a number of times, three passages being fairly common.

Scouring

266. The scouring operation is necessary to remove any materials or dirt that have been added to the material during processing.

267. The most common machine is still the rope washer for batch processing, whereby the fabric is sewn into an endless rope, then passed between rollers and through the washing liquor. The squeezing action of the roller serves to facilitate the process. (Prior to entering the pieces into the washer, it is often advantageous to run them through a soaping bath so that the detergent is more evenly distributed over the fabric than would be the case if the detergent were added into the scouring liquor.)

268. Continuous washing equipment is available in which the fabric enters at one end and passes through a soaper, over the necessary expanders, and through squeeze rollers and agitating paddles. Good control of liquor level, temperature and extraction are essential. Scouring speeds vary between 5 and 20 yards per minute. Of special interest also are the machines that can be used either for continuous or batch operations and which should be investigated. Some of these machines are available with a kneading system so that they can be used to give a milled finish to the scoured fabric.

269. Conventional batch machines have been refined to give them a much higher output by using a so-called "jet box system". The fabric passes through the machine at a rate of about 180 metres per minute, and comparative trials have indicated that it is possible to reduce the scouring time of most woollen and worsted fabrics by half, as compared to the older open-beck systems.

Milling (fulling)

270. This process makes use of wool's ability to acquire a finish whereby the fabric is consolidated, thickened and shrunk to a required width. Woollen fabrics lend themselves to milling more readily than do worsteds, and the process can be carried out to the point where the weave definition disappears and the cloth has a heavy, matted surface.

271. The milling process is usually carried out in a rotary milling machine in which the fabric is pushed and compressed by rollers into a tapered spout under suitable conditions of moisture, heat and pressure. The following points should be noted:

(a) Since milling usually follows scouring, combined equipment has been developed in which both scouring and milling are carried out in the same machine.

(b) Milling can be carried out under acid or alkaline conditions, the acid conditions being faster. There is an increasing tendency for synthetic detergents to replace soap.

(c) Continuous fulling mills have been developed, although they are as yet not in general use.

(d) The cloth is usually "tacked" before fulling, which involves doubling the goods over so that the face is inside and sewing the two selvages together. This prevents the face of the fabric from damage by the pressure of fulling and minimizes wrinkling and streaking.

(e) After milling, the pieces are rinsed.

(f) It should be noted that the milling process is employed to give the necessary hand. Close control of shrinkage and weight loss is therefore necessary so as to maintain a consistent fabric.

Carbonization of piece-goods

272. The principle is the same as for carbonization of stock. It is usually carried out during wet finishing, after scouring and before or after milling. If carbonization is carried out after dyeing, it is essential to ensure that no change of shade occurs.

273. Carbonization can be carried out by simply immersing the fabric in a winch dyer as in piece dyeing, followed by hydroextraction and passage through a dryer. Alternatively, special equipment, specifically designed for continuous carbonization is available. The equipment will contain a wetting-out tank, an acid tank and a squeeze roller or vacuum extractor, followed by a two-stage dryer.

274. After carbonization, the vegetable matter is removed from the fabric by running it dry in a milling machine. Neutralization of the acid is carried out by rinsing the fabric in a scouring machine, first with water, then with an alkali and then with a final rinse.

275. Continuous crushing units run in tandem with the carbonizer have been developed to replace the practice of dry fulling. This not only makes the process more continuous but also obviates the danger of having carbonized cloth stand near wet finishing equipment and absorbing some of the moisture from the air. Alternatively, carbonized goods may be neutralized continuously by being run through a continuous washer.

276. To obtain even carbonization, a special pre-acidifying tank can be used, and propeller stirrers should be incorporated into the carbonizing bowls to circulate the solution. An infra-red dryer at the entry to the drying chamber can be used to give complete baking, and provision must be made to exhaust the acid fumes. (The practice of re-circulating exhaust from the last dryer sections to the first, although being an economy in heat use, involves the risk of fabric staining from re-circulated greasy fumes. To eliminate excess tension or slack, a drive compensator should be incorporated into the dryer to give even tension and cloth feed.

277. Where pieces are acid dyed after carbonization, neutralization can be omitted, but the goods must not stand more than 24 hours or damage may result.

Scutching

278. This is an auxiliary process used where fabric has been wet processed in rope form. Scutching unwinds the fabric and can be used to de-tack it and to fold it in full-width form for subsequent processing. Vacuum extraction of excess moisture can follow scutching.

Drying

279. Drying in the woollen and worsted industry is usually done by stenters, whereby a pair of endless chains with pins attached hold the selvages of the fabric and carry it through a dryer. The chains are adjustable so that, in addition to carrying the fabric through the machine, they also serve to dry it at the required width. The more modern machines feed the fabric onto the pins automatically and circulate hot air through the cloth by means of fans. Typically, the fabric is passed several times from one end of the dryer to the other before it is delivered in a dry state.

280. Note should be taken of available controls to monitor the moisture and regulate the speed of the cloth through the dryer so as to obtain the required moisture content.

281. It should also be noted that loosely held water can be removed from fabric by squeezing it between pressure rollers, by using a vacuum suction system or by the use of hydroextractors. The first two of these methods process fabric in full width and can operate continuously, while the hydroextractor operates on a batch system. None of these three systems can usually remove more than about 40 per cent of the moisture from woollens, and they are therefore used either where it is not necessary to dry the fabric completely between processes, or where a preliminary drying is given prior to stentering.

Raising

282. This process serves to "raise" the fibres to the surface of the fabric by the action of wire-covered rollers. (Originally, natural teasles were used instead of the wire, and they still find favour for special finish effects.) The raising process may be carried out either on wet or dry fabric, depending on the effect required. The raising machinery can be specified either as "single action" or "double action", depending on the particular arrangement of wire-covered rollers and their direction of rotation.

283. Developments of note in raising machinery are the simulation of the teasles by small individual wire-covered rollers around the main cylinder as well as the application of torque controls attached to the drive, which permits a constant torque to be applied to the fabric regardless of the nap and cloth feed. (To avoid confusion of terminology between American and British practice, it should be noted that the American term for raising is "napping". In British

practice, the form "napping" is used to specify what is known as a "chinchilla finish" in the United States.)

Decatising

284. This process is used to set the fabric. Essentially, the process involves subjecting the fabric, either wet or dry, depending on requirements, to temperature and pressure. Since the fabric is under tension, these conditions will serve to set it and give the required finish and hand.

285. The less severe processes simply involve running the fabric through a hot-water trough at 120° to 170°F (49° to 77°C) and batching tightly onto a roller under pressure.

286. Alternatively, the fabric can be wrapped tightly, together with a blanket, around a perforated roller into which steam can be introduced so that the steam acts on the fabric and thus affects setting. The cloth is then cooled by drawing cold air through the roller.

287. The process can also be done dry, whereby the fabric is acted upon by dry steam. Decatising can be done at atmospheric pressure, or the whole perforated roller and the fabric wound around it can be introduced into a pressure steamer so that the conditions will be more severe (known as full decatising) and a more controlled and quicker setting can be achieved.

Continuous processing

288. As indicated, continuous processing is not widely used as yet in most of the wet processes or in decatising. Nevertheless, continuous equipment has been available for more than five years, and it certainly offers greater production speeds. The results up to date indicate that productivity of about 35 yd/min can be attained by applying the reverse-winding principle to the typical decatiser blanket.

289. Comparisons of continuous and batch processing for woollen and worsted goods are so dependent on the type of product that generalizations are not always meaningful. However, the following indicate some comparative results that were obtained on a run of approximately 6,000 yd of worsted fabric.

	Washing (minutes)	Decatising (minutes)
Batch	1,500	640
Continuous	310	445

290. It can be seen that continuous washing involved only about 20 per cent as much time as batch washing, while continuous decatising was approximately 70 per cent as time consuming as batch decatising. Also worthy of note is the fact that, in continuous decatising, it was found that the equipment was running for 80 per cent of the time, compared to about 75 per cent for batch decatising. In the case of continuous washing, the equipment was running for about 90 per cent of the time, compared to 85 per cent in the case of batch operation.

Shearing

291. This operation serves to trim off undesired surface fibres to give the required finish. The process is done continuously, the pieces passing either through a one- or two- or three-blade machine. The multiblade machines should receive first consideration from the point of view of productivity and efficiency. The three-blade machine can be arranged to shear the fabric so as to give two cuts on its face and one cut on its back.

292. Until recently the shearing machine operative had to be very careful to raise the blade while fabric seams were passing under it, but in modern machines automatic seam detectors can be incorporated that lift the blade over the seam. Metal detecters can also be incorporated to prevent damage to the shear blade or the cloth from any metal (such as raising wire) that may be present in the cloth. With modern equipment, a suction cleaning system is used to remove the loose fibre flock as it is sheared from the fabric.

Pressing

293. Pressing is carried out on worsted fabrics to give the desired texture and to improve the handle and appearance of the fabric. It is usually the last finishing stage for worsteds. Pressing can be carried out either by a rotary or vertical press. The former process is continuous and is effected by a metal cylinder running in a hollow bed; as the cylinder rotates, the cloth is carried, under pressure, between the cylinder and the bed. The face of the cloth is in contact with the bed, and the desired effect is regulated by pressure and temperature. Where possible, this pressure should be hydraulic rather than mechanical or spring applied.

294. Vertical pressing was originally a very slow, intermittent process involving a very large machine, whereby the fabric was subjected to high pressures of about 500 lb/in^2 for 12 to 24 hours. This type of pressing is laborious and expensive. It should be noted, however, that an automatic flat-plate vertical press has been developed that operates on a continuous basis and which has a higher productivity and is gaining increasing acceptance.

295. Prior to pressing, it is common practice to add a certain amount of moisture to the wool to bring it up to regain. The moisture can be applied by a simple arrangement whereby a fine water dispersion is either sprayed on the fabric or a brush rotating at high speed distributes the moisture on the cloth.

Examining, measuring, weighing, folding and packaging

296. These processes are necessary both for control purposes and in order to prepare the goods for final shipment or warehousing. The importance of these processes must not be underestimated. The examination serves as a quality-control stage and ensures that fabric quality is correctly classified.

297. The cloth-rolling process is also critical, since badly rolled fabrics crease and are difficult to handle. It should be noted that more modern equipment has special selvage-alignment devices, which help to wind the fabric stright.

298. Packaging is typically a hand operation, and this would still seem a satisfactory method for developing countries. Equipment has recently been introduced to wrap the fabric mechanically but has as yet not gained general acceptance.

Special finishes for wool products

299. The group stressed the importance of the new finishes that have been developed to enhance the properties of wool. The importance of these developments to the woollen and worsted industries must be recognized if wool is to retain its competitive position in the textile field. Among these special finishes, the following are of major importance.

Shrinkproofing

300. The properties of wool that cause it to felt are also responsible for the fact that it is subject to shrinking. However, there are several different methods for making wool shrink resistant, and all have their own advantages

and disadvantages. Some of the more successful of these shrinkproofing methods are the following:

(a) Wet chlorination, sodium hypochlorite being the usual source of chlorine. Among the various methods that have been tried, a continuous process for top chlorination and a batch process for piece-goods can be singled out as having met with some degree of success.

(b) Dry chlorination with gas. A process using chlorine gas has been developed by the Wool Industries Research Association in Leeds. It can be used on raw stock, tops, yarn or garments.

(c) Resins of various types are also used, with increasing success. The silicone resins are especially promising.

Mothproofing

301. Mothproofing treatments can be either temporary or permanent. Temporary mothproofing involves a wetting out in a suitable fluoride salt, permanent mothproofing is done with suitable sulphates, which are conveniently applied from the dyebath.

Crease resistance

302. It should be noted that, in general, a crease-resistance treatment on wool is very closely related to shower resistance. Once again, silicone resins are used for achieving degrees of crease resistance and showerproofing. The resins are emulsified in water, catalysts are added, and they are applied in open width in a padder. After padding the cloth is dried to polymerize the resin.

303. It should be noted that silicone resins are superior to wax emulsions, which were previously used, since they have superior resistance to dry cleaning.

304. It is essential to realize how important these processes must be if wool is to retain its competitive position in the textile field. Any firm that considers entering the woollen and worsted sector must be aware of the need to make its products competitive with easy-care synthetics.

Bonding and laminating

305. Note should be taken of the potential of bonding. This technique has found special application when woollen face fabrics are bonded to relatively cheap back fabrics. This system is economical, since relatively light face fabrics can be used that, while too flimsy by themselves, can be given the required body by the backing fabric.

306. For many end uses a fabric which has been bonded (laminated) offers a particular advantage to the cutter, in that the lining fabric is attached to the primary fabric, with many resultant economies in processing.

Chapter IV

PROCESSING MAN-MADE FIBRES IN THE WOOLLEN AND WORSTED INDUSTRIES

307. The penetration of man-made fibres into the woollen and worsted system continues to increase. The most recent estimates are that man-made fibres comprise about 20 per cent of the material being processed in these systems on a worldwide basis, and all indications point to the trend being maintained as these materials become increasingly more available and less costly.

308. A detailed analysis of man-made fibres is beyond the scope of this discussion, but probably the most significant differences between these materials and wool, from the processing standpoint, arise from differentials in tenacity, elongation and moisture absorption.

309. Furthermore, a broad distinction can also be made between the regenerated cellulosic fibres and the synthetics, since the former tend to be cheaper, more plentiful, weaker and less resistant to chemicals than the latter. The regenerated cellulosics also have better absorption properties than the synthetics. Some of the specific steps that should be taken in processing both kinds of man-made fibres are discussed below.

Selection

310. Inasmuch as man-made fibres are available in specific deniers, staple lengths and so on, these properties must be chosen in a way that will facilitate their processing with wool. It should be noted that many of the manufacturers of synthetic fibres make different types of each particular fibre for specific end-uses. For example, various polyester or polyamide fibres can be given

desired degrees of strength, resilience, abrasion resistance and so on. The over-all objective should always be to combine the best qualities in a blend for a particular end-use, while giving primary consideration to fabric type, aesthetics, performance and economics.

311. Just as with wool, the finer staple deniers are more suitable for softer fabrics, while the coarser deniers tend to contribute crispness of hand and a certain stiffness. Higher spinning counts are possible with finer deniers and longer fibre lengths.

312. The average staple length of man-made fibres in a blend should be about 20 per cent greater than the average fibre length of the wool component. However, it is usually advantageous to have the man-made fibres of varying, rather than of uniform length.

313. It should also be noted that man-made fibres are more uniform in all their properties than natural fibres. Most of them are crimped, primarily to increase their cohesion and obtain better processing efficiency. The crimping frequency may range from 8 to 15 crimps per inch, depending on the fibre denier.

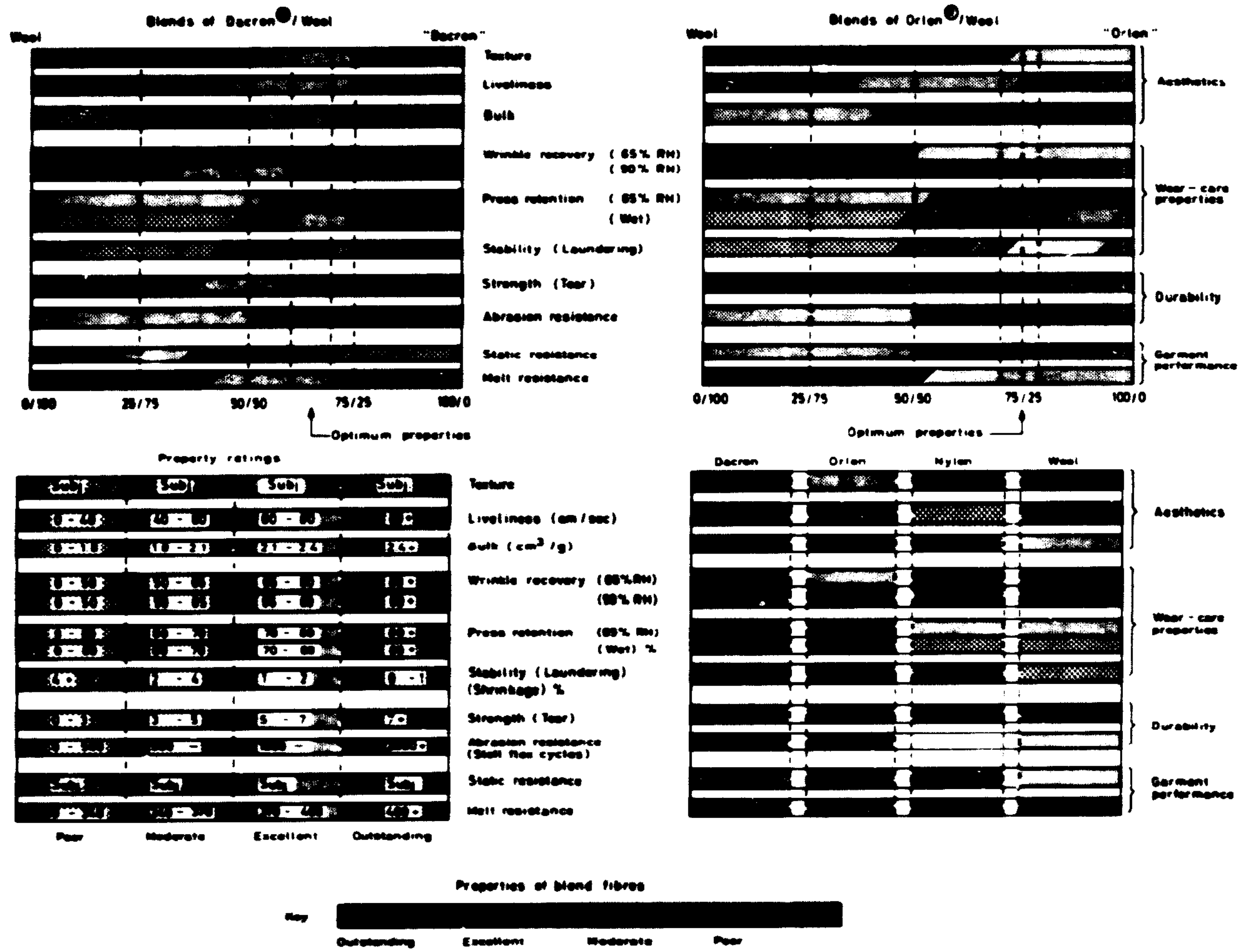
314. It is important to note that most blending carried out in the wool system is of the "intimate" type. In other words, a number of different fibre species are combined as homogeneously as possible into each yarn. Although an enormous diversity of blends is possible, only a few that have become popularly accepted for specific end-uses can be mentioned here. Among these we should note polyester and wool blends in 65/35 and 55/45 proportions. These are widely used to produce fine worsted suitings with wearing performance superior to comparable all-wool fabrics. Likewise, in the woollen system, blending 15 per cent polyamide fibres and 85 per cent wool improves processing conditions as well as product durability.

315. Blends of acrylic fibre and wool in 60/40 proportion have also been developed for woven and knit goods, mostly produced in the woollen system.

316. The characteristics of various blend levels are well demonstrated in figure 5 in the case of polyester (Dacron) and acrylic (Orlon) fibres blended with wool. Comparison of the properties of regenerated cellulosic fibres with those of the polyester and acrylic fibres studied can provide good indications of their relative properties.

Figure 5

Properties of blended fabrics



Source: E. I. du Pont de Nemours & Co., Inc.

317. In addition to the blending of synthetics with wool, note should be made of the increased application of 100 per cent synthetics in systems of the worsted type. This involves processing the tow through one of the "tow-to-top" systems and then usually spinning on conventional or semi-worsted equipment. This process has found most favour in acrylics, giving high-bulk yarns for carpets and hosiery.

Processing: fibre to pre-spinning

318. Although they are uniform, man-made fibres should be blended by feeding the fibre from a number of different bales into the first process. Normally, feeding from six bales assures increased uniformity. It is important, however, not to blend fibres from different producers' merges (extrusion lots).

319. Since the staple is usually packed in very solid bales, some pre-opening is usually desirable to separate the matted fibre. However, such pre-opening must not be excessive, or over-picking will occur. It is usually desirable to open the wool and man-made fibre blend components artificially, so that the wool may be oiled separately. It is important to ensure that the oil for the wool is compatible with any finishes that have been applied to the man-made fibre.

320. Stock blending is essential in the woollen system, and it is important to be aware of the possibility of some separation of the blend owing to differences in specific gravity of the components.

321. One of the dangers of too much preparatory picking of the synthetic fibres is that crimp is lost and uneven feeding from the weigh pan may result. If the ducts are too long, there will be the danger of fibre tangling when transporting the fibre components. Where an intimate colour mix is required, pre-blending should be done. For example, if a black and white blend is desired, part of each component should be dyed black and pre-blended with the undyed fibre before making the final blend of the wool and synthetic fibre. If this is not done, the different wearing properties of the wool and man-made fibre will result in uneven shading at points of wear where one component will abrade more quickly than the other.

Carding

322. Some modifications that should be considered when processing synthetic fibres together with wool are discussed below. The greater the percentage of non-wool components, the greater the degree of modification required will be. Since the synthetic fibres are generally fluffier than wool, it is desirable to have more frequent and lighter weigh-pan feeding than for unblended wool. The feed-apron and front-roll speeds should be increased to maintain productivity. The cards used for fine grades of wool are also suitable for synthetic fibres of up to 3 deniers. Where 4- to 6-denier fibres are processed, it will be similar to medium wool. Equipment for coarse wool can be utilized for 10-denier fibre and higher.

323. The use of divider rods at the condenser tapes is often useful to minimize rubbing of the fibres.

Twist setting

324. Twist-setting equipment can be used for setting yarns of wool blends, although it is important to bear in mind that both longer setting times and increased cooling periods will be required. Unless sufficient cooling time is allowed, especially with high proportions of synthetic fibre, the tendency of the yarn to stretch will be increased, which may cause faults such as tight threads in the finished fabric.

325. In general it can be said that processing tension for blends of wool and man-made fibres is more critical than for all-wool yarns since, owing to the higher tenacity of the synthetic fibre, more stretching takes place, which can cause substantial difference in yarn character. Minimum tensions are recommended, and all contact surfaces for processing should be kept in excellent condition.

Worsted processing

326. Special considerations when running blends of man-made fibres and wool include the following.

327. Where blends with high percentages of man-made fibre are processed, the sliver weight should be reduced as early as possible to minimize problems that may arise from the differential in cohesion between the two fibres. This differential may cause difficulties in drafting.

328. If the product is to be combed, the blending should be carried out on the combing machine. If further blending is required after combing, additional blending processes must be performed to ensure a sufficiently intimate blending. This may be done either in gill boxes or by using a special blending attachment at the top converter.

329. In worsted carding, it is often found that less dense wire pinning is more satisfactory than for wool carding, and that the burr-cleaning section can be removed. The card speeds used for all-wool should usually be increased to prevent excessive loading. Wider ratches can be set at drawing as the percentage of wool is reduced, and it should be noted that combing is required only for synthetic blends to remove any neps found in previous processing, since there will be no noil, as in wool. Combing may be omitted for synthetics.

Spinning

330. Strict control is essential when processing blends of wool and man-made fibre as regards humidity, static problems and lapping.

331. The importance of fibre segregation when processing different types of fibre must be emphasized, since mixtures or foreign fibres in the fabric cause difficulty in dyeing. Fugitive tints, which are easily scoured out, can be used to identify fibre types. However, care should be taken that the tints do not react adversely with oils or with chemical additives.

332. The relative humidities for processing blends of regenerated cellulosic fibres with wool should be kept at levels similar to those for all-wool. With blends of wool with synthetics, relative humidities should be kept about 5 per cent lower than for all-wool.

333. Since the moisture-absorbing properties of the synthetics vary considerably from those of wool and the needs of the two fibres are different, it may be advisable to make special use of anti-static additives as well as static eliminators in the carding, pin-drafting and draw-frame processes.

Weaving

334. Blends of wool with other fibres generally weave better than all-wool, since the blends usually have higher strength for any given count and are therefore less subject to broken ends and the like. However, care must be taken not to use excessive tension, since the risk of tight threads is greater

in fabrics made for such blends. This risk calls for special care during pre-weaving processes such as winding and warping as well as during weaving itself.

Dyeing

335. Some synthetic fibres tend to attract oily dirt more readily than does wool. Consequently, the following points should be borne in mind. Although acid does not damage synthetic fibres, it is nevertheless preferable to carbonize the wool before blending. (Regenerated cellulosic fibres cannot be carbonized under any conditions.)

336. Owing to their hydrophobic nature, the polyester, polyamide and acrylic fibres behave differently from wool in dyeing. These synthetics may require different dyestuffs and must be dyed at higher temperatures and for longer periods than wool. The use of carriers is often necessary, especially for polyester fibres. Where temperatures above the boiling point can be used, savings in dye and chemical costs can result. For example, the amount of carrier required at 230°F (110°C) is approximately half that required when dyeing at the boiling point (212°F). Care must be taken not to degrade the wool while it is subjected to these high temperatures; the addition of chemicals such as formaldehyde will protect it to some extent.

337. Pressure dyeing equipment, which allows the dyeing to be carried out under greater than atmospheric pressures, is becoming more common.

338. As noted earlier, the use of blends permits cross-dyed effects to be achieved that give added versatility to fabric design.

Finishing

339. Synthetic fibres often have softening points below the temperature which would damage wool; consequently, special care must be taken not to exceed the critical temperatures when treating them. The use of accurate temperature controls is therefore mandatory.

340. It should be noted that synthetic fibres can be heat set to improve their dimensional stability and wearing properties.

341. Additional general considerations are that since synthetic fibres are stronger than wool, all mechanical finishing equipment must be maintained in perfect condition. For example, shearing equipment will require more frequent

sharpening, problems of static tend to be increased in dry finishing and correct shearing and singeing are necessary to reduce the danger of pilling in the end-product. (The danger of pilling is especially critical with blends of polyester fibres and wool.)

Chapter V

MATERIAL YIELDS IN WOOLLEN AND WORSTED PROCESSING

342. Waste levels in the woollen and worsted industries are closely related to raw material and end-product type. However, in order to give a broad indication of industry experience, typical levels that can be expected are shown and, until standards based on experience can be established, these levels could be adopted as initial objectives. The data given are based on experience with 100 per cent wool blends; where synthetics are processed, the losses are somewhat less.

343. It can be seen that often 20 per cent of the clean wool is lost in its conversion into the finished fabric. This indicates a vital need for an effective control programme to monitor and help reduce waste levels and improve quality. The installation of such programmes is considered an essential part of a modern mill organization.

344. Typical material yields for the woollen system are as follows:

100 lb scoured wool
98 lb opened and blended wool
88 lb carded roping
86 lb spun yarn
84 lb grey woven fabric

345. The amount of material lost in finishing woollen fabrics depends primarily on the type of finish and there is often a loss of from 5 to 15 per cent in weight from woven to finished cloth.

346. Typical material yields for the worsted system are:

100 lb clean wool
96 lb carded or prepared sliver
95 lb sliver from pre-combing gilling
87 lb top (8 lb noil)
84.5 lb finisher sliver
83.5 lb spun yarn
82 lb grey woven fabric

347. In worsted finishing, weight losses are usually lower than in woollen finishing, since milling is very minor and raising is not done. (These two processes account for most of the material loss in woollen fabric finishing.) The usual range of "dead loss" in worsted finishing is between 2 and 5 per cent.

348. It should be noted that the running weight of the finished cloth per yard is not simply altered by the dead loss factor from woven to finished fabric, since the over-all change in weight of the fabric depends also on the degree of length shrinkage which takes place during finishing.

Chapter VI

ATMOSPHERIC CONDITIONS IN WOOLLEN AND WORSTED PROCESSING

349. The importance of correct atmospheric conditions for textile processing is well recognized. The following key factors should be considered in planning:

(a) Wool fibre is basically hydrophilic, and it is essential that it be kept pliable during processing. The character of processing is such as to induce static electricity into the fibre and thus make its control more difficult. Correct moisture regain and atmospheric conditions are therefore essential to avoid processing problems caused by lively fibres and the like.

(b) As machine speeds continue to increase, there is a concomitant increase in the generation of heat, which dries the moisture in the material and the ambient atmosphere. This moisture must be replaced.

(c) The efficiency, health and comfort of the workers must be borne in mind as well as the processing conditions.

(d) The hazard of fire should also be considered, especially in severe processes such as garnetting and rag-tearing. Anti-static devices and adequate sprinklers are recommended.

(e) Moisture can be added to the atmosphere in the form of vapour or as an atomized mist sprayed into the air into which it readily evaporates. Automatic controls are available and should certainly be considered for new installations.

(f) The broad range of recommended atmospheric conditions for processing wool at various stages is indicated according to departments in table 10. It should be noted that in order to maintain the indicated humidity and at the same time have satisfactory operating conditions, the ambient temperature of the processing room should be maintained between 72^{o} and $80^{o}F$ (22^{o} and $27^{o}C$).

(g) It is of interest that, in the worsted system the humidity should normally be higher when processing dry-spun, as compared to oil-spun material, since the oil in the latter tends to control the fibres to some degree and reduce the effect of static.

(h) Where synthetic fibres are processed and the danger of roller lapping exists, this may be obviated by applying anti-static devices or additives rather than running at excessive humidities.

(i) In view of the high capital cost involved in air conditioning systems, the possibility of using localized control systems must be considered. Critical areas such as spinning and roving may call for more precise atmospheric control than, for example, blending.

(j) Care should be taken that the relative humidity in the storage areas is not excessive (if possible, not above 55 per cent).

(k) Although conditions vary, the following levels of relative humidity can be considered as guide-lines. The processes from carding through spinning can be considered as the most critical in woollen and worsted processing, there being more leeway in the other processes. It may be possible to use atomizers or window fans in the less critical departments, especially if the buildings are old and impractical to seal off.

Table 10

Suggested atmospheric conditions for woollen and worsted processing

Department		Relative humidity at 72°-80°F (22°-27°C) (percentages)
Storage		50 - 55
Carding:	worsted	60 - 70
	woollen	65 - 75
Combing:	oil	65 - 75
	dry	75 - 85
Drawing:	oil	55 - 60
	dry	60 - 70
Spinning:	oil (worsted)	55 - 65
	dry (worsted)	65 - 80
	woollen	65 - 75
Winding		55 - 65
Warping		55 - 65
Weaving		55 - 65
Knitting		50 - 60

Chapter VII

LIGHTING, POWER AND SPACE REQUIREMENTS IN WOOLLEN AND WORSTED TEXTILE MANUFACTURING

Lighting requirements

350. Where new plants are being built, it is not uncommon to enclose them totally so that control of atmospheric conditions is more easily effected. In such cases, the lighting is completely artificial. Recommended lighting to serve as reference for both artificial light and daylight is given in table 11. Wherever possible, tubular fluorescent lamps should be used, since they offer definite advantages and are largely superseding filament lamps in industry. It was the opinion of the group that many textile mills pay insufficient attention to the need for good lighting, and it was suggested that improvements can often be effected quite easily.

Table 11

Recommended lighting in woollen and worsted processing

Process	Lux
Grading and sorting	200
Opening and blending	200
Carding	200
Drawing, combing, spinning	400
Twisting, yarn preparation	400
Weaving, knitting	400-800 a/
Dyeing, shearing	200-400
Other finishing processes	500
Inspection	800

a/ Where a range is indicated, the higher levels are required for coloured goods.

Power requirements

351. The diversity of available machines is such that the specification of power requirements according to individual machines would involve the compilation of a series of catalogues. In most cases, this variety is compounded by the fact that most machines are available in a series of sizes and gauges, and it is therefore considered more meaningful from the point of view of planning, to list by department the gauge points for power requirements for certain hypothetical outputs. This is done in table 12.

352. It should be noted that most textile plants, especially the woollen and worsted sectors, operate at power levels far below optimal values. It must be recognized that two different types of energy demands exist in the textile industry. The first is the case of dyeing and finishing facilities, which mostly require heat, and the second is the case where most of the demand is for electrical power, as in the case of grey mills.

353. Whereas the smaller mills usually draw their power from the outside, it should be borne in mind that relatively small diesel generators are increasingly available and should be investigated.

354. For most larger mills, the following considerations should be given some weight. Comparisons must be made between the costs of producing the power internally and buying it outside. Internal power generation is usually by diesel or gasoline engine. Internal steam-generating plants of the turbine type are generally not justified, inasmuch as very few mills are large enough to utilize units of this size.

355. In general, it can be stated that while it is unlikely that spinning and weaving mills should generate their own electricity, in the case of integrated operations with large dyeing and finishing departments, it may often become economic to install a heating and generating plant. In cases where demand fluctuations are expected because of varying heating requirements and the like, it is usually feasible to contract for outside power sources to supplement the internal supply.

356. It should be noted that specific machines, due to the nature of the particular process, require special consideration. Among these points, the following may be noted:

(a) Motors used for wet processing should have special splash-proof installations.

(b) Motors for machines used in spinning and the like should be screened against lint dust etc.

357. Special attention should be given to the optimal use of heat-exchangers and heat-economizers, which are too often neglected in the textile industry. The installation of boilers is also a point of importance; not only the boilers themselves, but also the piping system throughout the plant should be insulated. Condensation-return systems should be incorporated and, wherever possible, closed condensation systems should be installed to conserve heat. The proper layout of condensate piping systems must be emphasized so that the condensate can be recovered from the steam vapour. Regular checks of the heating system will maintain performance and increase economy of operation. It is pointed out that relatively simple control systems can be installed to monitor the energy balance on a periodic basis, so that power losses may be quickly traced.

358. It is noteworthy that, as far as power required to drive equipment is concerned, the use of the more modern machines generally results in a reduction of the power input per unit of end-product output.

359. Table 12 indicates power requirements for the various processes for some of the machines used in the woollen and worsted industries. The broad range shown results from the wide choice available in specifying equipment. As a guide-line, it can be said that the actual power consumption will be 85 per cent of the motor ratings under typical industrial conditions. In the wet processing stages, it is noted that the bulk of the energy will be required in the form of heat rather than as directly connected power. To give some indication of expected requirements, it can be stated that about 30 lb of steam (at 100-125 lb/in^2) will be required per pound of cloth to be produced. This figure covers both dyeing and finishing processes.

Table 12

Installed power required for various woollen and worsted equipment

Machine	Installed kilowatts
Openers, pickers	10 - 15
Scouring range	15 - 22
Dryer (stock)	3 - 8
Card (per cylinder)	4 - 6
Combs	1.5 - 2
Back washer	4 - 7

Table 12 (continued)

Machine	Installed kilowatts
Gill boxes	1.5 - 4
Finishers, rovers	4 - 8
Spinning frames (per side)	15 - 30
Warpers	5 - 12
Slashers (sizing machines)	5 - 8
Winders (non-automatic; 25 - 35 spindles) (automatic; 5 - 6 spindles) (pirn; 8 spindles)	
Twister frames	7 - 15
Reelers	0.5 - 1
Looms	1 - 3
Drying ranges	40 - 100
Washers) Dye vats) Milling machines)	4 - 15
Shears	5 - 7 (per blade)
Decating machines	2 - 5
Napping	10 - 14
Press (rotary) (flat)	18 - 20 18 - 25
Cloth winder	2 - 4

Space requirements

360. Space requirements for the woollen and worsted industry are so varied that it is practically impossible to give detailed process breakdowns that would cover more than a few specific installations. However some indication of the space requirements for certain hypothetical mills is given in the six annexes to this report.

361. To develop a broad estimate for processing plant space requirements without preparing a full layout, it has been found sufficient to multiply the actual floor space occupied by machinery by a factor of 4 for processes up to weaving, by a factor of 3 for dyeing and finishing.

362. Similarly, for the warehousing of grease wool, it can be stated that for baled raw materials and access passageways, a volume of 12 to 18 m^3 per ton is estimated.

363. In general, clearances to the roof should be at least 20 feet, but in some areas more clearance will be required as in the case of blending installations.

364. In determining the most suitable layout, special consideration must be given to requirements for storing raw, in-process and finished materials. The following suggestions are made.

Raw materials storage

365. This area should be kept as open as possible; pillars should be minimized. Loading bays should be built in, and conveyor systems should be connected to scales for the weighing out of raw materials.

Blending, carding, spinning

366. Where possible, and certainly in the case of new equipment, provision should be made for waste collection and suction ducts. Piping can be laid in the floor, overhead or both.

Storage of yarn and yarn preparation

367. Here, also, open areas are recommended, if possible, and conveyor systems should be tied in to weighing scales to facilitate materials handling.

Warping and weaving

368. Space must be left for beam racks, which should be accessible from both sides. Overhead conveying systems may have to be designed, and space for them must be allowed.

369. In certain operations, provision may be required for incorporating a system of segregating certain areas to minimize dangers of contamination. Mesh curtains or polyethylene sheeting can be used for this purpose.

Finished-fabric warehouse

370. Depending on the inventory foreseen, a decision must be made what type of storage system will be established. At this time, except in very large plants, random-access storage has not been found to be feasible, since the extra cost of the required computer facility has been found to be economically impractical.

371. As far as clerical and general office areas including locker rooms and washrooms are concerned, about 25 m^2 per person should be allowed.

Chapter VIII

EQUIPMENT

Equipment costs

372. The data given in this chapter should be taken only as a general indication of current trends. Furthermore, it can be seen in table 13 that the range of prices indicated for most equipment is extremely broad, since it is based on equipment from several manufacturers in each case. In most cases it can be assumed that the more costly equipment is more sophisticated in terms of controls, machine application, design and degree of automation. In addition, the costs given are based on single units of equipment rather than on complete lines. For example, the capital investment required for an opening and blending department would depend on how many openers, rotary spreaders, bins and the like were specified.

373. It should be noted that all equipment prices are on the basis of new machines f.o.b. at the manufacturer's plant.

Table 13

Equipment costs

Primary equipment for the woollen and worsted systems	Price range (dollars)
Scouring	
Harrow or rake	60,000 - 90,000
Aqueous jet	90,000 - 110,000
Suction drum	90,000 - 120,000
Drying after scouring	40,000 - 45,000

Table 13 (continued)

Primary equipment for the woollen and worsted systems	Price range (dollars)
Opening and blending	
Hopper feeder	7,000 - 10,000
Opener	7,000 - 10,000
Oiling system	2,500 - 5,000
(Conveyor ducting and fans are not included)	
Carding	
Worsted card (2 cylinder)	45,000 - 75,000
Woollen card (3 cylinder, 2,000 mm)	65,000 - 100,000
(Above costs include appropriate feeding and delivery arrangements)	
Back washing	
(including drying and gilling)	40,000 - 65,000
Comb (rectilinear)	7,500 - 9,000
Intersector	7,500 - 11,000
Autoleveller	11,000 - 18,000
Finisher - per head	1,800 - 2,300
Roving - per spindle	225 - 275
Spinning	
Worsted - per spindle	65 - 80
Woollen (ring) - per spindle	125 - 215
Sliver - per spindle	100 - 160
Twisting - per spindle	75 - 100
Warping	
(section warper and creel)	20,000 - 30,000
Winding	
Non-automatic - per head	90 - 100
Automatic - per head	600 - 750
Pirn winding - per head	350 - 400
Looms	
Shuttle 4 x 1	4,000 - 5,000
Shuttle 4 x 3, 4 x 4	6,000 - 7,000
Shuttleless	13,500 - 18,500

Table 13 (continued)

Primary equipment for the woollen and worsted systems	Price range (dollars)
Scouring machines	
Batch	10,000 - 14,000
Pressure	25,000 - 35,000
Continuous	35,000 - 50,000
Milling machines	9,000 - 14,000
Carbonizer	50,000 - 60,000
Dryers (stenter, multi-passage)	40,000 - 45,000
Raising machine	16,000 - 19,000
Shears	
Single-blade	14,000 - 16,000
3-blade	35,000 - 50,000
Crabber (4-bowl)	35,000 - 45,000
Padding mangle	9,000 - 11,000
Semi-decatiser	15,000 - 25,000
Full decatiser	30,000 - 35,000
Rotary press	14,000 - 18,000
Cloth-rolling machine	6,000 - 9,000

Equipment productivity

374. More than any other sectors of the textile industry, the woollen and worsted areas are characterized by a multiplicity of methods, operating conditions, speeds, settings and so on. Therefore, taking into account all of these variables, the usefulness of trying to set out productivity data may be questioned, since so many different systems may be equally satisfactory, depending on circumstances. This difficulty is in no way mitigated when it is considered that a developing country often has labour customs that differ significantly, not only from those of industrialized areas but also from those of other developing countries.

375. Nevertheless, it seems essential to provide guide-lines for productivity that can be expected from equipment and operators. The following data should be taken as providing a general indication of the conditions that prevail in

the better textile mills of industrialized countries. Within this context, the levels can be considered as comparative guide-lines for developing areas. These levels assume that the equipment is in good operating order, that personnel are fully trained and that the normal production volume runs which are met in competitive conditions appertain. (It should be noted that the data are primarily based on European, rather than North American, mill conditions.)

376. These data are based on actual output; that is, the effect of operating efficiency losses has been taken into account. The actual efficiency that can be expected from the various equipment under conditions of full demand is shown separately.

Scouring

377. Using a representative 5-bowl set, a 1,800-mm working width on the basis of 60-64s Australian wool, an output of 1,500 lb/h can be considered as practical. Using this as a guide-line, the major variables to be considered in other cases will be:

(a) Width of the train;

(b) Impurities in the wool;

(c) Number of bowls.

378. It is assumed that adequate drying capacity is available to dry the output of the scouring train satisfactorily.

Blending

379. Productivity in the blending process is highly variable, depending on whether the continuous or the batch system is used. In addition to the quality of the equipment, other major variables are:

(a) The number of components in the blend;

(b) The type of components in the blend; that is, how much they differ. If the difference is great, pre-blending will be required;

(c) The number of opening passages required (that is, the condition of the material and the degree of matting and dirt).

Bearing the above in mind, normal productivity may be expected to range anywhere from 500 lb/h for manual batch operation to 1,500 lb/h in a continuous system.

Opening

380. Assuming a working width of 1,500 mm, a productivity of 1,500 lb/h through-put per unit can be taken as a guide-line on the basis of a 60-64s material.

Carding (woollen)

381. Although carding output will vary with the raw material as well as with machine operating characteristics, the following data are put forward as guide-lines. These figures refer to modern 60-inch-wide cards in good condition and can be extrapolated approximately for other widths:

Card roping (Nm)	Production (kg/h)
4.75	55
7.00	42
9.5	32
11.75	27
14.25	25
16.75	20

Worsted carding

382. Based on an output of 44 g/m, worsted carding output normally varies between 40 and 60 kg/h.

Woollen spinning

383. Output per spindle in woollen spinning, based on the use of a variable-speed drive, can be expected to fall close to the following levels:

Spun yarn count (Nm)	Production (kg/spindle hour)
3.33	0.27
4.00	0.21
5.00	0.16
6.65	0.12
10.00	0.09
15.00	0.06

384. The traveller-ring system is also limited by a maximum ring velocity. At present, this can generally be taken as 30 m/sec for steel travellers on self-lubricated rings, and slightly higher with nylon travellers. The output shown above is considered indicative of practical output that can be achieved on modern and well-maintained equipment.

Gilling and intersector drawing processes

385. An estimated productivity of 60 to 100 kg/h can generally be assumed as normal for most of these processes.

Combing

386. Based on an expected output of 140 nips/min, combing productivity will vary from 10 to 20 kg/h.

Finisher

387. A typical output count of 0.7 Nm will have a productivity between 20 and 24 kg/h.

Roving

388. Based on an output weight of 3.2 Nm, at 1,000 rev/min and 0.95 turns per inch (tpi), productivity per spindle can be expected to be around 0.45 kg/h.

Spinning (worsted)

389. The factors affecting spinning output have already been outlined but the following data, based on a typical warp yarn twist level, indicate a range of outputs:

Count (Nm)	Output (g/spindle hour)
20	46
25	38
30	31
35	26
40	25
50	18
60	14

Processes preparatory to weaving

390. Average cone-winding speeds will vary from 300 to 800 m/min, covering the whole range of yarn counts normally encountered in this industry.

391. Twisting speed will normally vary between 5,000 and 10,000 rev/min for most types of equipment presently available. Two-for-one twisters can give output equivalent to 14,000 tpi on fine counts.

Pirn winding

392. Typical output per spindle hour will range from 5.5 kg/spindle hour on counts of Nm 4, down to about 1 kg/spindle hour on a count of 20 Nm. The above is based on an automatic winding operation, with 40 g of material on each pirn. Older equipment will have proportionally lower output.

Warping

393. Productivity is influenced both by the number of ends and the number of sections in the warp, as well as by the type of material. A fair estimate of actual operating speed would be 500 m/min, while the warping beaming-off speed is usually taken as 60 m/min. The efficiency normally associated with warping is extremely low because of the down-time at creeling and changing from one section to the next.

Weaving

394. Shuttleless weaving machines have proved to be capable of operating at up to 220 picks per minute (ppm) based on 85-in width. Conventional automatic shuttle looms at 84-in reed width can be expected to produce at an effective output of 100 to 130 ppm. The above represents the broad range of practice being performed with the whole range of equipment in use at the present time in the industry.

Productivity for woollen and worsted dyeing and finishing

395. In the case of fabric finishing, it is not considered realistic to specify productivity in terms of output volume since the number of variables involved make this primarily a function of such factors as dyeing system used, the procedure followed, the dyestuffs selected and the number of fibres in the blend, rather than of dyeing the equipment.

396. The following information may serve as a general guide-line for dry finishing:

Stentering	700 m/min
Fabric winding	2,000 m/h
Singeing	45 m/min
Shearing	12-15 m/min
Rotary pressing	10-15 m/min

397. It should be noted that normal practice in the industry is to operate with very low efficiencies in the dry finishing processes while utilizing the operators to the maximum on as wide a variety of machines as possible. The

typical efficiencies of some prime equipment used in woollen and worsted processing are shown in table 14. Since most dry-finishing machines have output considerably greater than most other equipment in the mill, it is not uncommon for one unit in the dry-finishing range to cope with all the output of many typical facilities. It must also be remembered that many fabrics utilize only some of the dry-finishing equipment.

Table 14

Typical efficiencies (per cent) of prime equipment in woollen and worsted processing

Woollen system	Per cent
Carding	85
Spinning	90
Cone winding (manual)	60
Quilling - pirn winding	75
Warping	20 - 50
Weaving	80 - 90
Worsted system	
Carding	90
Gilling	70
Back washing	75
Finisher gilling	75
Pin drafting	75 - 80
Roving	75 - 80
Spinning	85
Doubling	70
Twisting	80 - 90
Winding (non-automatic)	55
Reeling	25 - 35
Quilling - pirn winding	75
Warping	20 - 50
Weaving	90
Continuous finishing processes (such as shearing, singeing and drying)	40 - 60
Scouring, dyeing	40 - 60

Auxiliary equipment

398. In addition to the primary machinery, which has been described, various auxiliary types of equipment are also essential, such as bobbins, cans, beams and materials handling equipment. However, a general tendency can be noted towards the use of larger packages at all stages of processing, which to some extent has reduced the need for carrying as large an inventory of these items.

The following guide-lines are suggested in determining the number of particular items necessary.

399. For woollen yarn manufacturing, the number of card bobbins can be determined by multiplying the total number of bobbins on spinning frames by 6.

400. In worsted manufacturing, the number of cans to be ordered should be based on the number of cans normally used at the machines at any time, multiplied by a factor of 3.

401. The requirements for cones, spools and the like, as used for winding will be determined largely by the practice to be followed in holding yarn inventories, but a minimum guide-line should be based on the number of cones in use at any time in all equipment, both for winding and warping processes, multiplied by a factor of 3. The estimated inventory requirement will then determine the additional number of packages that will be needed.

402. The number of loom beams needed should be estimated by multiplying the number of looms by a factor of 2.5.

403. Requirements for materials-handling equipment will depend on the degree of automation that is planned. It should be noted that many materials-handling aids are incorporated on currently available equipment. Special mention can be made of automatic baling after opening and blending where the stock is to be stored before carding; of automatic can-changers at intersectors and gill boxes; of automatic doffers at spinning; of beam-handling equipment, both at warping and at looms, by means of overhead cranes and special trolleys; of the use of special magazines at pirn-winding operations which can, in fact, be used as bobbin batteries at the loom.

404. While many of these materials-handling aids may serve to reduce the incidence of faults and material damage to some extent, their use certainly calls for greater sophistication among the operatives. It would seem, therefore, that the decision on the degree of sophistication to be chosen for materials handling would be determined on a strictly socio-economic basis, paying due regard to such factors as the desire to generate employment, safety factors, and over-all considerations of whether it is preferable in the particular instance to expend resources on capital equipment rather than on labour.

Quality factors of modern equipment

405. In spite of the considerable increases in production speeds and the elimination of some processes that had been characteristic of the textile industry, it can be fairly stated that these advances have not been achieved at the cost of a reduction in product quality. Indeed, in most cases it can be said that product quality has improved.

406. Whereas in the past high quality could be achieved only by giving extreme care to each process and by placing considerable reliance on operator skill to minimize processing faults, the tendency with more modern equipment is to prevent, to as great an extent as possible, such faults from occurring.

407. The incorporation of various types of automatic and semi-automatic fault detectors and control devices has served to enable equipment to operate at higher speeds while at the same time reducing the incidence of faults.

408. As well as noting the use of special control attachments such as metal detecters, evenness controls at various stages, safety knock-offs and slub-catohers, the roles played by testing equipment and improvement of mill control in maintaining product quality should also be recognized. Such factors as the tendency to use larger paokages at all stages has also contributed to the improvement of product quality through reduction of knots and so on.

Chapter IX

KNITTING

409. The knitting process forms a fabric structure by interlocking a series of loops made in yarn which is fed in one direction and looped through itself to form stitches. This report is also concerned with the knitting sector, which utilizes the yarns produced in the woollen and worsted industries. It is recognized that cotton and filament yarns are also extensively made into knitted fabrics.

410. Over the last fifteen years, knitting has made considerable inroads into primary textiles. Although up-to-date knitting has been applied mostly in industrialized countries, this method of manufacturing can also be expected to make similar progress in developing countries. The reason for this is that knitting offers several advantages, which should make it particularly attractive to developing countries.

411. Of primary interest for developing countries is the consideration that knitted fabric production can be carried out with a lower capital investment than for woven fabrics. In the past, developing countries have not built up their knitting sectors as quickly as their weaving sectors. Of the several underlying reasons for this, a basic one may have been the tendency to try to copy fairly closely the industrial progress in the more developed countries.

412. As industry develops in developing areas, it is recommended that opportunities for knit-goods manufacture be considered so that knitting can become a major factor in these areas at an earlier stage of growth in their textile industries than was the case in Europe and North America.

413. Knitting is broadly classified into weft knitting and warp knitting.

414. Weft knitting has far greater applicability for yarns of the woollen and worsted types, and it is this principle that is of major interest to this paper. Warp knitting on the other hand, is of limited interest to the woollen and worsted industry because of the knitting principle involved. The bearded needles used and the fine gauges required are generally considered unsuitable for woollen and worsted spun yarns.

415. However, warp-knitting machines operating on the Raschel principle, utilizing latch needles, are suitable for spun yarns. At present, however, they are being used only for highly styled fashion fabrics, and in the near future it is not likely that they will be developed to any great extent by the textile industries of developing countries. It is strongly recommended that, if the situation arises where plans are under study to establish a manufacturing plant for producing high-fashion outerwear or upholstery and drapery materials in developing countries, consideration should be given to equipment of the Raschel type.

416. In general, knit fabrics differ from woven fabrics in the following respects: looser structure, less dimensional stability, greater production speed and less preparation required in terms of warping and sizing. It is emphasized that these differences are greatly influenced by the type of knitted structure and merely represent a broad comparison.

Raw materials (woollen or worsted) for knitting

417. Knitting yarns can usually be spun with lower twists than weaving yarns since they need not be as strong. Both woollen- and worsted-system yarns are used, depending on the end-use. Yarn bulkiness is more sought in knit goods than in woven fabrics.

Speciality hair fibres

418. Whether in 100 per cent form or as blends, yarns containing hair fibres (camel, alpaca, mohair) are generally considered to serve the high-fashion luxury markets. The key factor to consider in manufacturing hair yarns is that utmost care be taken at every stage. Fabrics containing hair yarns are most often knitted on full-fashioned equipment, because these machines are specifically designed to produce high-quality garments in keeping with the raw material quality, and furthermore, because the panels are knit ("fashioned") to shape, there is no cutting waste involved and therefore no loss of expensive yarn.

Synthetic fibre blends

419. Synthetic fibres are making inroads into the knitting fields as into other areas of textiles. The advantages of durability, ease of care (crease retention, wrinkle resistance) and product uniformity are well known. Blends of wool and polyacrylic fibres have been especially popular for outerwear knits, since the acrylics possess good bulk properties which are specially applicable for knitwear. Polyester and polyamide fibres are often spun with wool for reinforcement purposes, especially in men's half hose.

Wool-viscose and wool-cotton blends

420. These blends are used for outerwear knit goods for reasons of economy; viscose rayon and cotton are not only usually cheaper than wool, but they add strength to the blend.

421. Knit goods of the woollen type can be expected to find major acceptance in the following end-uses:

(a) Light to heavy sweaters;

(b) Light to heavy cardigans;

(c) Light blouses;

(d) Suits, costumes;

(e) Half hose.

Types of knitting equipment for woollen and worsted products

422. In considering the various types of weft knitting machinery suitable for products of the woollen and worsted types, an overview can be seen from the following list, which breaks down the major categories of flatbed, circular yard goods, and circular sweater-strip machines. (Full-fashioned machines are considered separately.)

Circular

Latch needles; for yardgoods

Single knit (cylinder only)

plain; jersey
fancy; stripe, jacquard

Double knit (cylinder-dial)

plain; links-links, piqué, rib, interlock
fancy; links jacquard, stripe, jacquard, 8 lock (interlock)

Latch needle; for sweater strips

links-links, transfer, plain rib, jacquard, interlock

<u>Flatbed</u>

V-bed)
) single or double lock; plain or jacquard
Links-links)

<u>V-bed flat machines</u>

423. This type of knitting machine, whether hand or power operated, can be considered as the most versatile equipment available to the outerwear knitting industry. It is employed primarily for producing semi-fashioned articles, such as sweaters and blouses. Machines are usually available with gauges up to 14 needles per inch (npi), 8 npi being considered as a medium gauge. This equipment is usually very sturdily built and requires relatively little maintenance compared to other knitting equipment.

424. This equipment should not be considered as suitable for producing long-run work economically and is therefore not utilized in high-volume production.

425. The V-bed flat machines are also employed in conjunction with full-fashioned knitting equipment for full-fashioned garments, where the V-bed flat machines are used to produce solid borders and trims.

426. Owing to their relatively coarse gauge and slow operation, V-bed flat machines are well suited to wool and wool blend yarns, especially the former, which are generally relatively coarse.

427. Of major importance to developing countries is the fact that V-bed flat machines are available in three levels of sophistication, namely, hand operated, semi-automatic and fully automatic. Equipment is available with needle beds ranging in widths up to 185 cm. Normally the hand machines are not available in widths over 120 cm, since larger ones are difficult to operate.

428. Typically, the motor-driven machines offer twice the productivity of hand-driven machines on plain goods. When knitting with complicated stiches, the potential productivity advantage of automatic machines is even more significant (up to 5 times the output) since, with a manual model, much time is lost in selecting the needles.

429. Equipment is available with double or single systems, the former giving higher productivity, since it knits two rows with every traverse of the carriage.

430. Machines for trims and borders normally do not require sophisticated needle-selection or stitch-transferring devices, since these products are usually simple knits.

Circular-knit piece-goods machines

431. Circular-knit machines are characterized by high productivity and good flexibility. They produce continuous pieces of circular-knit fabric, and the consideration in buying such equipment for developing countries should be to obtain equipment that is versatile but not overly complicated. Most modern piece-goods latch-needle machines have revolving needle cylinders.

432. Usually these machines range from 6 to 33 in in diameter, 30-in units probably being the most popular. Striping units and needle-selection patterning devices are often standard, and jacquard machines are available with individual needle selection. A great variety of patterning methods is available, including pattern wheels, discs, jacks, drums, and punched film or cards.

433. The selection of the particular machine and patterning system will be predicated by the end-product, so general guide-lines are difficult to draw.

Sweater-strip machines

434. This equipment knits the fabric in the form of a tube, comprising individual sweater panels, joined together by a removable draw-thread which separates the panels.

435. It should be noted that in most sweater-strip machines, the cam boxes and bobbin creel revolve, while the fabric take-up is stationary. (The opposite is usually the case in yard-goods machines.) Sweater-strip equipment can usually be classified as either a high-production, limited-purpose machine with multiple feeds and a diameter of 30 or 33 in or as versatile multipurpose equipment, with lower productivity, and available in diameters ranging from 10 to 33 in. While the limited-purpose machines usually have 48 feeds, the multipurpose machines rarely have more than 24.

Full-fashioned equipment

436. The full-fashioned machine is capable of knitting individual panels to the required shape. The stitches at the edges of the panels are subsequently looped together to form the required garment. Since no cutting is involved, the waste levels are much lower than with other methods of garment making.

437. Since the panels are knitted to shape, the garment usually has a superior fit and appearance than where cutting and subsequent sewing are carried out. (Trim and border sections are usually knitted on V-bed flat machines onto a full-fashioned garment.) Full-fashioned equipment is usually available from 6-gauge (4 npi) up to 36-gauge (24 npi). Machines having from 4 up to 20 sections are available, and a wide range of patterning devices can be incorporated. The knitting heads are usually 30 to 32 in wide for garment bodies, and 16 to 20 in wide for sleeves.

438. In view of the complexity of full-fashioned machines, as well as the investment required, it is essential that developing textile industries be extremely careful about installing such equipment.

439. The group wished to emphasize that, where there has been little experience in knitting manufacture, the safest and most logical approach will be for an industry to establish itself first with V-bed flat machines, which are versatile and basically simple. The next step might be the installation of large-diameter circular equipment, either piece-goods or sweater-strip. Full-fashioned equipment should only be considered where the industry is well established and expertise has been developed in weft knitting.

440. It should also be noted that the weft knitting industry is usually on much closer terms with the garment industry than is weaving. Except for large-diameter yard-goods knitting, the other weft-knitting methods demand a good knowledge of garment make-up techniques. (In fact, in developed countries the same company very often knits the garment parts on V-bed, full-fashioned or sweater-strip machines and subsequently processes them into the knit garments.) This factor is important, not only from the point of view of technical considerations, but the decision must also be made from an economic aspect on the degree of integration desired between the primary textile and garment producing sectors.

441. If the main consideration in establishing industry is high-volume fabric output, with relatively little emphasis on styling and the like, and if the garment industry is already established, the manufacture of knitted piece-goods should be considered first, since it will give the highest output of fabric.

Dyeing and finishing of woollen/worsted knit goods

442. Dyeing may be carried out at various stages from the fibre to the garment process. For example, where woollen yarns are processed, the raw stock is

commonly dyed after scouring and before carding. Where worsted yarn is knit, it is usually dyed in top or yarn form. Skein dyeing remains a suitable method for yarns in which it is essential to maintain or develop bulkiness and for specialty hair-fibre knitting yarns. It is also convenient for small lots. (In knitting dyed yarn, note should be taken that there will be less garment or piece shrinkage than with grey yarn.)

443. The dyeing of all-wool knitted piece-goods is relatively rare; although it would seem to offer certain savings, it contains some inherent problems. Among these are the tendency to felt, the difficulty in retaining a clear finish and good stitch definition, and relative ease of distortion (compared to woven fabrics, for which most piece-dyeing equipment was designed). Efforts are being made to perfect piece-dyeing techniques for all-wool jersey fabrics by using equipment that was primarily designed for synthetic knit goods. It should also be noted that paddle-drum equipment can be used to dye sweaters and sweater strips.

444. For sweaters and sweater strips, a washing treatment may be advantageous in order to relax the stitches from the knitting tensions and improve the finish, as well as to remove dirt, oil and the like. Also, for certain blends, a partially felted surface may be desirable, and the shrinkage induced will help to stabilize the fabric. A drum unit with a revolving perforated cylinder is usually used for this process. Synthetic detergents are recommended. Hydro-extracting and tumble drying in perforated stainless steel drums is commonly used to dry the sweater strips or garment bodies.

445. A framing or pressing process whereby the initial form of the garment is restored by spreading it out on a metal frame may be recommended for woollen yarn garments. Steam is introduced into the frame and sets it to shape. Open steam tables or presses may also be utilized for this purpose.

446. Note should be taken of the recently developed method of solvent scouring which appears to have special application for knit goods. This appears to be one area where solvent scouring is achieving practical application in the developed countries. Advantages claimed are better quality, greater economy and good surface clarity. Commercial equipment that can process about 250 lb of knit goods per hour is available. About 95 per cent of the solvent is usually recovered, which makes the process economical. Safety precautions are essential where flammable solvents are used.

Finishing of worsted jersey piece-goods

447. The finishing of worsted jersey piece-goods usually involves the following stages:

(a) Slitting, which cuts the knitted tube into an open-width fabric;

(b) Slitting is usually combined with calendering, which relaxes the fabric by releasing the strains imposed on the yarn during knitting, as well as achieving some width setting. (If the knitted fabrics are scoured after knitting, this will have some relaxation effect, and calendering and steaming may be omitted.)

448. The main relaxation medium for the fabric is steam. Some knitted fabrics are subject to a semi-decatising process similar to the one used in processing woven fabrics. This is done to achieve a firmer finish on the fabric, but generally this finish is not permanent.

449. It should be noted that knitted fabrics are not always subject to scouring as part of finishing, since they may be considered clean enough for sale, and the danger of felting during scouring is avoided. If the fabrics are scoured, this will have a relaxation effect, and it may be decided to omit calendering and steaming, as described above.

Machine down time

450. The term "machine down time" means the time during which machines do not run, for whatever reason. Percentages of down time will naturally vary, and a 25 per cent figure has been taken as a realistic average. The reasons for down time are as follows:

(a) Time used for adjustment of needles. (This will include needle changes owing to pattern requirements, replacement of broken needles and changing the yarn metering of the needles.);

(b) Time used for yarn changing, creeling and yarn repairs;

(c) Preventive maintenance;

(d) Pattern changes;

(e) Other incidental losses of time.

Material losses in knitting

451. Waste-control programmes are essential in the knitting mill. Two types of waste can be identified.

452. The first type is yarn left over on the cone and waste caused by rewinding and by damaged cones. Two per cent waste at this point is accepted as normal.

453. The second type of waste is fabric remnants. This waste will depend considerably on the type of fabric knitted and machines used. As regards cutting and sewing waste, which is the major factor here, circular yard goods will normally have 25 per cent waste at cutting and sewing, mostly during cutting. Remnants will also be produced in the knitting and finishing equipment, as well as losses of oil and moisture. On circular sweater strip fabrics, 22 per cent of waste is normal. On V-bed flat-knitted fabrics, waste is between 15 and 20 per cent. With borders and trims, however, only 0.5 per cent will be normal. These relatively high levels of waste indicate why, for expensive yarns, investment in full-fashioned equipment is usually justified.

Power requirements

454. Power requirements for circular knitting machines vary depending on the number of feeds and diameter from 1.5 hp to 3.5 hp. Some examples are given in table 15.

Table 15

Power requirements for circular knitting machines

Machine type	Diameter (in)	Feeds	Power (hp)
Double jersey	33	48	3
Double jersey	31	24	2.5
Sweater-strip transfer machine	26	24	2
V-bed flat			0.5 - 1

Finishing	Power (hp)	Steam (lb/h)
Stiffening	0.5	
Calendering	3	304
Semi-decatising	10	304

Auxiliary operational equipment

455. The following auxiliary equipment is needed:

(a) Paper tubes - for fabric take-up. Three tubes are required per operating machine. However, extra tubes must be calculated for fabric rolls stored in inventory. The number of these extra tubes will depend on the size of the inventory.

(b) Yarn stands - for holding and transporting full cones which are about to be knitted. One yarn stand is usually sufficient for ten circular knitting machines.

(c) Hand trolleys - for transporting doffed fabric rolls.

(d) Garment trolleys - for transporting bundled garments between sewing operations. One trolley is required per sewing position. However, this too can vary, depending on the layout and sewing system adopted.

Plant layout

456. Layout as related to a knitting mill must take into account the relationship of the knitting equipment to the yarn supply as well as to the subsequent finishing and garment-fabricating operations.

457. There are various ways to arrange production equipment. A rectangular system is often used to position machines of comparable type and gauge adjacent to each other. For circular machines, the L-shaped layout is also popular, since it affords good access to individual machines and also permits the positioning of the V-bed flat machine within the L.

458. The space required for the creels must be considered, since they project beyond the actual knitting machine; in other words, the perimeter of the creel, rather than of the base of the machine, is taken as the boundary. A minimum of 30 in between creels is desirable to allow sufficient space for creeling and cleaning. A main alley-way of at least 6 ft between the bases of the machines should be allowed for yarn and fabric handling. (Since the creels are usually about 7 ft above the ground, they do not interfere with normal materials handling.)

459. The space requirement in the actual knitting area can be satisfactorily approximated by assuming that 144 ft^2 are required for each circular knitting machine.

460. The layout for the V-bed flat machines should, if possible, place them opposite each other with an alley space of 2 to 3 ft between them. A space of at least 18 in is required behind the machines for yarn cones and necessary maintenance work.

461. The usual floor-space requirements for V-bed flat machines can be estimated as between 36 and 48 ft^2 per machine.

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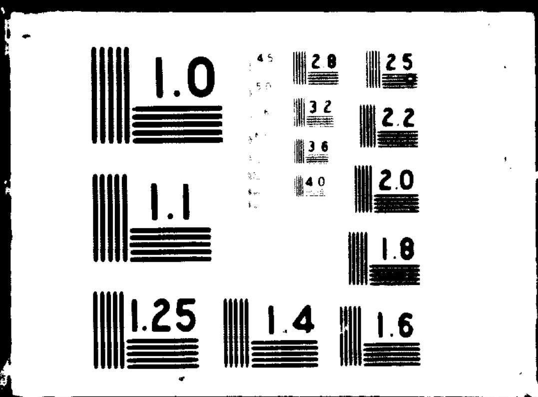


462. The approximate area requirement for machine and operating space relevant to circular and V-bed machines, basic finishing equipment and garment making (for V-bed operation) is as follows:

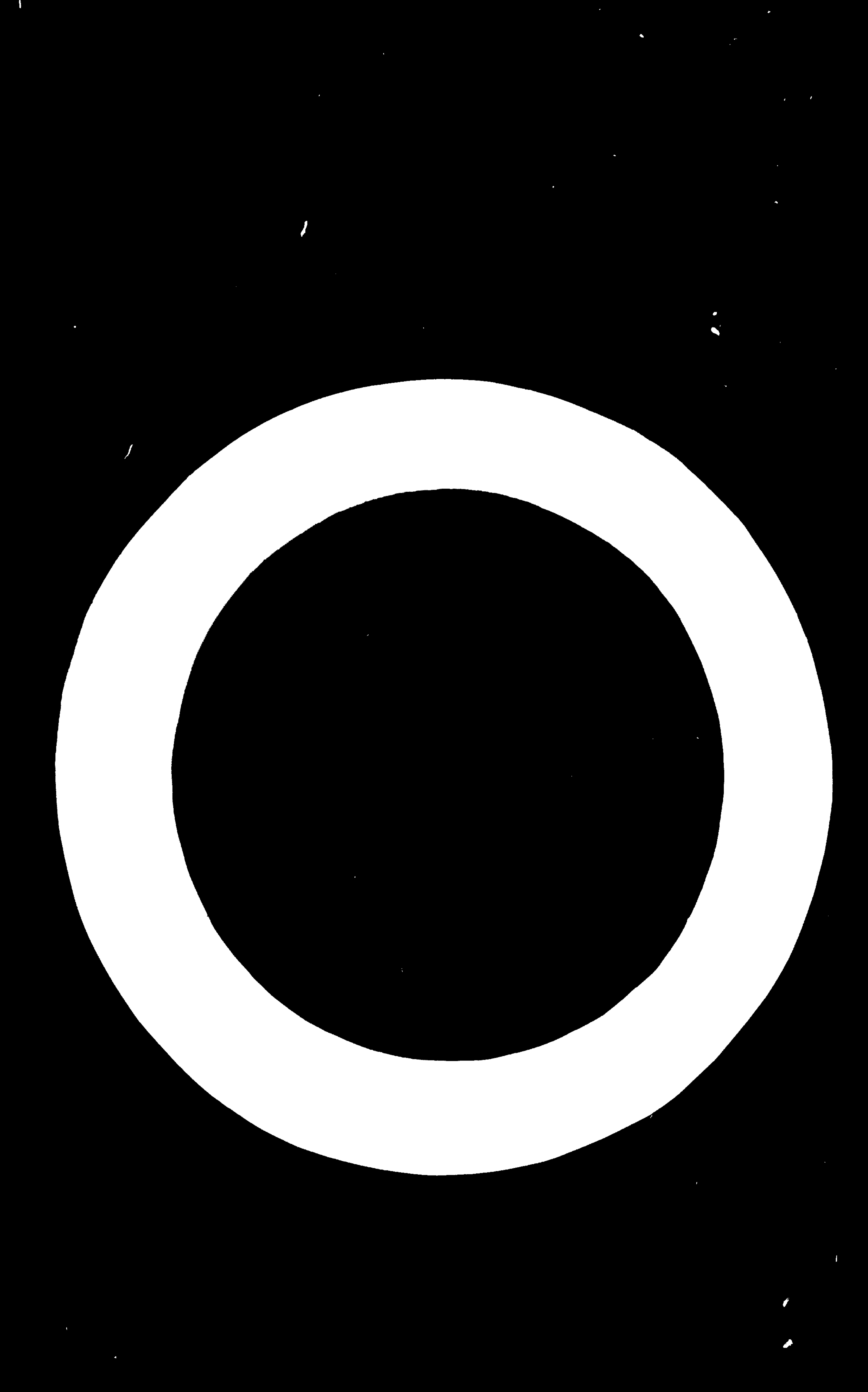
Circular knitting (30-in diameter)	144 ft^2/machine
V-bed flat knitting (71-in working width)	40 ft^2/machine
Semi-decatising	220 ft^2/machine
Calendering	275 ft^2/machine
Sewing[a]	36 ft^2/machine
Looping[a]	15 ft^2/machine
Pressing[a]	64 ft^2/unit groups
Cutting[a]	60 - 300 ft^2/table (depending on length of table)

a/ These are garment-making operations, often associated with V-bed knitting, but are outside the scope of this report.

ANNEXES

The following pages outline machinery and operating data for various production plans covering a wide variety of stages and products in the industry sectors under discussion.

The information should be used as a check list for reference when installing similar plants. Since in all cases the hypothetical mills have been set up to approximate the economic scales of operation, it was felt unlikely that the most sophisticated (high-volume) equipment would be justified at this level. However, if the size of the operation is expanded, these high-output machines can be specified.



Annex 1

WOOL-SCOURING PLANT

The following outlines a minimum-size wool-scouring facility. It is based on one scouring train, operating two shifts (16 hours) per day. A facility of this size might be considered where the wool is grown locally and a co-operative effort is made by local growers to market their wool in a scoured state. It can be expanded as required.

Basis

Capacity for 5,000,000 lb per annum of grease wool.

Considerations

(a) The plant must be located with access to water (approximately 30,000 gallons per 16-hour day), power, warehouse space, transportation and a waste-disposal system.

(b) The costs of utilities, especially steam, decrease substantially if the scouring is continuous.

(c) Raw wool is brough to the plant in 220- to 330-lb bales.

(d) Commonly, the wool is passed through a partial opening process prior to scouring to remove as much of the acquired impurities as possible. The first machine is a heavy beater known as a "duster", which shakes out dust through a screen. This is often followed by an opener (usually a 2-cylinder beater). From the opener the wool is fed into a feed lattice and directly into the first scouring bowl. If the wool is to be carbonized after scouring, it may be more economical to hydroextract it rather than to dry it completely prior to carbonizing.

(e) It should be noted that grease recovery is usually economical only if the wool contains sufficient grease and if the volume is sufficient. It is suggested that unless the wool is predominantly 60s and finer, the grease content is not likely to be sufficient.

(f) The space requirements for a plant such as outlined should be:

Warehouse	1,100 - 1,250 m^2
Plant	850 - 1,000 m^2

Scouring and drying equipment

	Approximate cost (in dollars)
48-inch automatic feed for opener	10,000
Duster-opener	12,000
48-inch automatic feed for scouring train	10,000
5-bowl scouring train	90,000
72-inch automatic feed for dryer	11,000
8-foot dryer - 6 sections	42,000
Hydroextractor	12,000
3-bowl carbonizer (48 in); neutralizer bowl; feed and delivery	70,000
Conveyor	5,000
Elevator, 3,000-lb capacity	5,000
48-in x 24-in hydraulic baling press	7,000
Softener and brine tank	7,000
Boiler and accessories	8,500
Miscellaneous (scales, solution tanks, sorting tables, trucks, pumps, miscellaneous equipment, belts, piping, valves, fittings, wiring, office equipment)	25,000
Total	314,500

Operating labour complement (2-shift operation)

	Shift 1	Shift 2
Production Manager	1	-
Clerical	1	-
Foreman	1	1
Boilerman	1	-
Machinist	1	-
Machine operators	3	3
Warehousemen	2	2
Total	10	6

Annex 2

WORSTED YARN MILL

This annex sets out the basic details relating to prime equipment, space, power, cost, labour and supervision required to operate a worsted yarn plant.

The following factors should be noted:

(a) It is assumed that raw material in the form of top is available, whether from local sources or imported.

(b) Even if there is no local top-making, it may be more economical (from an industrial planning viewpoint) to start manufacturing yarn from imported tops, since this would be a flexible and a relatively economical way of producing local yarn for local knitting and weaving sectors.

(c) The mill outlined here is based on the American worsted system. It is simple and productive. The total installation based on less than 6,000 spindles can produce 3,000,000 lb per year, based on a 3-shift operation producing an average count of 20s worsted (a 560 hank equals 22.6 Nm).

(d) The hypothetical mill is based on a minimum of two machines at each stage. This allows a certain safety factor at the pre-roving stages. However, it is pointed out that a preliminary mill could be established initially with half the machinery complement at each stage to produce about 1,500,000 lb *per annum*. Moreover, it is suggested that a plant half the size presented here would in fact represent the minimum practical scale of economic operation for this type of end-product; it could be expanded as required. However, it is recognized that with only one machine at each drawing process, a breakdown in any one drawing machine could cause severe production problems. This can be partially safeguarded by installing an extra autoleveller pin-drafter, which could be put into service in an emergency.

(e) The reason for specifying 240-spindle frames (which is a relatively low number of spindles per frame considering that up to 400 spindles per frame can be specified) is that this will give high flexibility in spinning different yarns. This may be important if the plant has to be geared to supplying many fairly small clients such as small knitting plants. If this consideration is not relevant, larger frames can, of course, be specified.

Production scheme

First-process: autoleveller

Input 11 ends of 262.5 g/yd; draft 8.8; sliver delivered 328 g/yd.

Output/h/machine at 75 per cent is 280 lb.

Second process: (2-head) pin drafter

Input 4 ends, 328 g/yd; draft 8.2; sliver delivered 160 g/yd.
Output per hour per machine at 80 per cent is 273 lb.

Third process: (4-head) pin drafter

Input 6 ends, 160 g/yd; draft 8.7; sliver delivered 110 g/yd.
Output per hour per machine at 70 per cent is 342 lb.

Roving

Input per spindle 110 g/yd; draft 13.3; roving delivered 8.33 g/yd (equals 1.5 worsted count) (1.7 Nm).
Output per spindle per hour at 70 per cent is 1.68 lb or 130 lb/h per 80-spindle frame.

Spinning

1.5 worsted count fed in and drafted 13.3, to give 1/20s worsted count (22.6 Nm).
Estimated output per spindle per hour at 89 per cent is 0.092 lb or 22 lb/h/240-spindle frame.

Twisting

4.5 tpi ply twist; 7,100 rev/min; output/spindle/h at 88 per cent is 0.415 lb or 91 lb/220-spindle frame.

Winding

Winding speed 750 yd/min.
Machine requirements: 240 spindles for single winding (at approximately 55 per cent efficiency).
96 spindles for ply winding (at approximately 75 per cent efficiency).

Costs of prime equipment

	Dollars
2 autolevellers at $18,000	36,000
2 2-delivery pin-drafters at $13,000	26,000
2 4-delivery pin-drafters at $13,500	27,000

	Dollars
4 80-spindle rovers at $20,000	80,000
24 240-spindle spinning frames at $18,000	432,000
6 220-spindle twisters at $18,500	111,000
6 winders (4 x 60 spindles; 2 x 48 spindles)	44,000
Total prime equipment	756,000

Note: The above are average (December 1968) prices f.o.b. machine manufacturer. Erection costs are not included.

List of major supplies and auxiliary equipment

Sliver cans: 110 - 20 in x 42 in
1,000 - 15 in x 42 in

Roving bobbins: 12,000

Spinning bobbins: 28,000

Twisting bobbins: 2,000

Miscellaneous: bobbin trucks
yarn-conditioning oven
laboratory equipment
machine-shop tools
shipping supplies
office equipment

Note: For a new worsted yarn mill as outlined above, the costs of auxiliary equipment can usually be estimated for practical purposes at 15 per cent of the prime equipment cost, in this case $115,000.

Estimated labour requirements

	Shift			Total
	1	2	3	
Pin drafting	2	2	2	6
Roving	2	2	2	6
Spinning	7	7	7	21
Doffing and cleaning	4	4	2	10
Twisting	4	4	4	12
Winding	6	6	6	18
Sweeping, carrying	2	2	2	6
Trucking, general help	4	4	4	12

Estimated labour requirements (cont'd)

	Shift 1	Shift 2	Shift 3	Total
Warehousing	2	1	-	3
Maintenance mechanics	3	2	1	6
Foreman	1	1	1	3
Machine fixers	3	3	3	9
Clerical	4	-	-	4
Laboratory, quality control	3	1	1	5
Manager	1	-	-	1
			Total	122

Estimated building requirements

Production area	32,000 ft^2
Warehousing, shipping service area	6,000 ft^2
Offices	1,500 ft^2
Total	40,000 ft^2

Estimated power requirements

	hp	kW
(a) Machinery at 85 per cent load		
Pin drafters	40	29.8
Rovers	35	26.1
Spinning	420	313.3
Twisting	160	119.3
Winding	25	18.6
Total machinery	680	507.1
(b) Lighting at 2 W/ft^2	110	82.0
(c) Air conditiong	100	74.6
(d) Miscellaneous (compressor, machine shop, boiler etc.)	70	52.3
Total estimated	960	716.0

Annex 3

WOOLLEN MILL

This annex outlines a woollen system mill capable of processing 225 yd/h of finished fabric. This is equivalent to an output of 900,000 yd 58- to 60-inch wide *per annum* on a basic 2-shift (80-hour weekly) operation. It is suggested that this unit, if run efficiently, will offer an adequate level of economic operation in terms of plants that are being newly established.

It is assumed in this context that the product mix can be exemplified by two basic fabrics, as follows:

70 per cent (630,000 yd *per annum*) 10-11 oz flannel.

30 per cent (270,000 yd *per annum*) 18-19 oz coating.

The fabric specifications are as follows:

	Coating	Flannel
Finished weight/58-60 in.	18.6 oz	10.4 oz
Warp ends	2,314	2,777
Loom width	83.4 in	80.5 in
Warp	11.3 Nm	15.3 Nm
Filling	5.6 Nm	15.3 Nm
Picks per inch (grey)	29	29
Warped yards per piece	80	90
Woven yards per piece	73.6	82.8
Finished yards per piece	66.2	76.2

Mill balance

In order to produce 225 yd/h of finished fabric of the specified product mix, the following mill balance will be required by department, taking into account material losses.

Scoured wool usage (consumption 255 lb/h (115.5 kg/h))

Process	Output
Opening and blending	248.4 lb/h (112.5 kg/h)
Carding	223 lb/h (101.2 kg/h) (3.8 Nm - 30.8 kg/h) (7.75 Nm - 14.5 kg/h) (10.5 Nm - 55.6 kg/h)
Spinning	227 lb/h (103 kg/h) (5.4 Nm - 31.3 kg/h) (10.8 Nm - 15 kg/h) (14.7 Nm - 56.7 kg/h)

Process	Output
Winding for warping	15 kg - 10.8 Nm 29.5 kg - 14.7 Nm
Pirn winding (assuming shuttle looms used)	30.8 kg - 5.4 Nm 26.8 kg - 14.7 Nm
Warping	267 yd/h (244 m/h)
Weaving	245 yd/h (224 m/h)

Prime equipment

The following equipment complement can be used as a guide-line for the above output.

Opening and blending

The system consists of the following: 1 mixing picker with automatic feed, spray oiler and rotary blender-spreader; 1 burr-picker. All necessary ducting and fans to be included. Cost: $20,000 - $30,000.

Carding

Six 3-cylinder cards (1,500 mm) with automatic feeds, Peraltas, intermediate feed, 4-level, double-rub condensers, 120 ends/card. Cost: $65,000 - $90,000.

Spinning

Eight 180-spindle frames comprising 6 frames with 95-mm rings, 400-mm tubes and 2 frames with 110 rings and 420-mm tubes. Balloonless spinning should be specified for a new installation. Probable cost: $30,000 - $36,000 frame.

Warping

One high-speed warper with 200-end creel should be specified. Where possible difficulties are envisaged because of the danger of machine breakdown in isolated location etc., it may be desirable to specify 2 machines, in which case less sophisticated equipment can be utilized. Probable cost: $25,000.

Cone winding

One 60-spindle winder (non-automatic) would be sufficient at the specified scale of operation. Automatic winders do not appear justified for a plant of this size. If it were decided to use shuttleless looms, an additional 20-cone winding spindle should be specified. Probable cost: $100 per winding head.

Pirn winding

Forty-eight spindles of pirn winding should be specified if conventional looms are to be used. Probable cost: $360 per winding head.

Weaving

Forty-four automatic looms would be sufficient based on a grey-cloth output of 5.6 yd/loom/h, which can be considered realistic on these cloths. This is based on the usual 120 picks per minute. For greater flexibility, it may be desirable to specify some looms as 4 x 1, and some as pick-and-pick looms. This, of course, depends on the particular market being served.

If shuttleless looms are specified, it is estimated that 26 looms could produce the required volume on a 2-shift operation.

The cost of the automatic shuttle looms required for this mill would probably be about $5,500 per loom. If shuttleless looms were specified, the cost would be $14,000 to $17,000 per loom.

Dyeing and finishing

In dyeing and finishing woollens and worsted, the equipment is normally never utilized fully, since many fabrics require only some of the process stages. The aim should be for the employees in dyeing and finishing to be versatile and able to operate the machinery properly at several processes so that even though they are not actually required, several machines will be in place so that the operator has a full job when accomplishing a process. This gives better utilization and greater productivity per man-hour.

For a unit to finish 225 yd/h of coatings and dress flannels, it is estimated that the following machinery would be necessary.

Dyeing equipment: raw stock

1 1,000-lb dyeing machine

1 extractor

1 dryer

Yarn dyeing

1 50- to 100-lb dyeing machine

1 tray dryer

<u>Piece dyeing</u>

1 1-piece dye beck

2 2-piece dye becks

2 6-piece dye becks

2 8-piece dye becks

1 pair of squeeze rollers

<u>Finishing equipment</u>

3 washers

5 fulling mills

1 extractor

1 carbonizer and baker

1 dusting fulling mill

4 nappers

1 decatiser

1 semi-decatiser

1 pressing machine

1 dryer

1 pin stenter frame with an open steaming mechanism and roll-up head

1 brusher and shearer

1 electrifying machine

6 inspection tables.

It should be noted that all of the above dyeing and finishing equipment is of the conventional kind, and no continuous scouring, dyeing or decatising is specified in this basic mill.

Prices of dyeing and finishing equipment are extremely variable, and the complement outlined for dyeing and finishing would probably cost between $500,000 and $700,000.

Floor-space requirements

This plant would require about 70,000 ft^2 of floor space distributed to as follows:

Raw wool storage and blending	9,000 ft^2
Carding	9,000 ft^2
Spinning	8,000 ft^2
Winding, warping and weaving[a]	10,000 ft^2
Mending	4,000 ft^2

Wet finish and dyehouse	12,000 ft^2
Dry finishing	10,000 ft^2
Offices and services	8,000 ft^2

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a/ If shuttleless looms are used, 6,500 ft^2 will suffice.

Power requirements

The motor horsepower requirement for the plant is estimated at 1,000 (746 kW). It is estimated further that actual brake horsepower will be 80 per cent of rated horsepower, giving 800 hp (597 kW) to operate the machinery.

With respect to illumination, it is estimated that the over-all requirements will be 1.8 W/ft^2 which is equivalent to 128 kW per hour for lighting. Total power requirement can therefore be estimated at 768 kW per full operating hour.

Process steam requirements

As a basis for estimation, 30 lb of steam per finished yard of woollen cloth can be used to calculate the requirements for both dyeing and finishing. (The typical steam system normally operates at a pressure of 100 to 200 lb/in^2 in the pipes.) On this basis, 7,750 lb of steam will have to be generated per operating hour.

Water

Consumption in dyeing can be estimated at 7.5 gal/yd. Even though it is recognized that some of the goods will be stock and yarn dyed, for the purposes of estimation these can be considered as requiring the equivalent amount. On this basis 1,700 gal would be required per hour for the dyeing department.

Water consumption in finishing can be estimated at 80 gal/yd or 18,000 gal per hour.

In addition to process water, per capita consumption for personal requirements of the staff can be estimated at 20 gal per day.

It is essential to recognize the importance of a safety margin for the water supply, and in mills such as that outlined here, a system capable of supplying 21,000 gal per hour is recommended.

Work force

The following labour complement is based on a two-shift operation and shows total labour on both shifts.

Opening/blending/warehouse	5
Carding	20
Spinning	26
Cone winding, pirn winding, warping	25
Weaving (conventional)	32
(shuttleless)	22
Grey examination and mending	17
(if shuttleless)	13
Dyeing	9
Finishing	39
Maintenance and services	15
Total	188

In addition, the supervision for the mill would probably be comprised of:

Mill manager	1
Production manager	1
Designer	1
Production planner	1
Quality controller and assistant	2
Clerical staff	7
Carding foreman and assistant	2
Spinning foreman and assistant	2
Weaving foreman and assistant	2
Finishing and dyeing foreman and assistant	3
Total	22

Annex 4

WORSTED FABRIC MILL

This annex outlines a plant suitable for producing worsted suitings for men's wear. The plant size is considered to be close to what would normally be considered as economical when setting up a new worsted weaving and finishing operation.

As representative of processing conditions, the preparatory weaving operations are based on 2/30s worsted count (Nm 2/33.9) for warp and filling. Although a variety of fabrics will be manufactured, the following basic construction is taken as representative of the production balance:

(a) Loom width, 70 in; 68 ends/in in warp' total ends 4,760;

(b) 60 picks/in in grey;

(c) Finished: 82 ends/in, 68 picks/in, 11.8 oz/linear yard (58 in).

It is assumed that all the production is yarn dyed and is therefore aimed for the higher-price market. The basis for the mill is a production of 27,500 yards of finished fabric per week. It is assumed that the major departments would operate on a 3-shift (120-hours per week) basis.

Equipment requirements

Pirn winding

It is estimated that the actual productivity per winding spindle on 2/30s worsted count (2/33.9 Nm) is taken as 1.25 lb per spindle per hour. At this output, two 32-spindle winders would be required.

Warping

It is estimated that, based on an average of ten sections per warp, a production equivalent to 175 woven fabric yards per hour should be achieved. Therefore, two warpers would be required.

Slashing

Normally, a two-ply yarn is not sized or slashed. However, since a trend towards single-yarn warps is apparent, it may be desirable to have a slasher in the warping department. For worsted yarns, the slasher dryer should be based on hot-air circulation rather than the drum or can dryer common in the cotton industry. One slasher would be sufficient for the required production, and it is likely that the use of the slasher would be intermittent in practice, since most fancy worsteds are made from ply yarns that do not require slashing.

Weaving

For conventional automatic shuttle looms, an operating speed of 128 picks per minute (ppm) is reasonable, and assuming a 90 per cent operating efficiency, the output per loom per hour would be 3.2 yd. It is therefore estimated that 82 conventional looms would be installed.

If shuttleless looms were specified, 47 shuttleless looms would be required for this volume, and 48 looms would probably be ordered to even out weaving layout and operator assignment.

The projections for market requirements would determine whether these looms would be specified as pick-and-pick or 4 x 1.

Grey examination, burling and mending

Two grey-examination perches are usually required, and it is suggested that the tables for burling and mending be satisfactorily made locally in most instances. It is pointed out that this task is almost exclusively a female occupation. Although productivity varies in an extreme range according to fabric quality, market requirements and operator skill, under average conditions a productivity of 20 yd per mender per hour should be realized for medium and fine worsted fabrics.

Finishing

The finishing plant of a worsted operation of this size would have at least one machine of most types of equipment required to finish all types of worsted fabrics. The result is intermittent usage of certain portions of this machinery complement, but fabric style changes from year to year make it expedient for the mill to be extremely versatile. The manufacturing routine for the processing of a clear-finish worsted fabric would comprise most of the basic finishing operations common to this industry, and the following processes are not necessarily in order of occurrence.

Singeing

Expected productivity is 2,250 yd/h. One machine would therefore be sufficient.

Crabbing

Expected productivity is 325 yd/h. One machine would therefore be sufficient.

Scouring

It is estimated that, for the fabrics under consideration, the pieces would be washed in full width and by open, non-continuous process, and that eight pieces could be run in one batch. At a resultant productivity of 4 pieces/h, one machine would be sufficient for the production of the plant.

Scutching

An actual productivity of 3,600 yd/h is possible, and one scutching unit would be sufficient.

Drying

Representative productivity for this process can be taken as 12 yd/min at a machine efficiency of 60 per cent, or the equivalent of 432 yd/h. One dryer is therefore adequate.

Shearing

A brushing process could be run in tandem with the shearing.

Decatising

Based on a productivity of 4 pieces per hour, one decatising machine would be sufficient.

Pressing

Where high quality is desirable, consideration should be given to installing a continuous-plate press. One machine would be sufficient for the projected volume.

Final inspection

Normal productivity on this type of fabric can be taken at 180 yd/h so that two examination perches would be required.

In addition to the above finishing processes, for added versatility, consideration may be given to installing some piece-dyeing equipment, and a dye beck with a 4-piece capacity should be considered.

Labour complement for this operation

Based on a 3-shift (120-hour) operation, the labour requirements by department are as follows:

Department	Employees
Weft winding	6
Warping	9
Weaving	64 (40 with shuttleless looms)
Burling and mending	
Menders	40 (32 with shuttleless looms)
Floor helpers	6
Wet finishing	12
Dry finishing	22
Examination	6
Packing, warehousing	5
Total	170

Administration and supervision	
General manager	1
Designer	1
Office and clerical staff	11
Maintenance	11
Weaving foreman	1
Mending forelady	1
Finishing foreman	1
Examination/shipping foreman	1
Total	28

Space requirements	
Yarn store	5,000 ft^2
Yarn preparation and weaving a/	17,000 ft^2
Mending	6,000 ft^2
Finishing	15,000 ft^2
Office and services	11,000 ft^2
Total	54,000 ft^2

a/ 12,000 ft^2 if shuttleless.

Power requirements

Actual consumption is estimated at 300 to 350 kW per hour. Lighting requirement would be about 60 kW per hour.

Process steam

This would be mainly used in finishing, and it is estimated at 22 lb of steam per finished yard of the specified fabric.

Water consumption

Fifty gallons of water per finished yard can be taken as standard finishing requirement on the specified fabric in batch processing.

Annex 5

DATA ON PRIME EQUIPMENT FOR A SMALL (V-BED) KNITTING MILL

The following data supply guide-lines for a knitting facility that would require minimal investment in plant, equipment and operating cost. The following factors should be noted:

(a) This type of operation is small enough to be considered suitable for a cottage-type industry.

(b) At this scale, dyed yarn would be bought and inventory kept to a minimum.

(c) An output of 1,600 (men's) sweaters per week is predicated on three shifts (120 hours/week) in the knitting section and one shift in the sewing section.

(d) The six knitting machines should be scheduled so that two machines concentrate on sweater front panels, two on sweater back panels, and two on sleeve sections. (One of the sleeve machines can be switched periodically to body sections to maintain balanced output.)

(e) With only twenty operators shown, the labour scheduling should be as flexible as possible. Some of the operations will not constitute a full task, and labour scheduling should be flexible to run on an "as needed" basis. (For example, winding will only involve rewinding the yarn "rests".)

(f) Finishing operations would be limited to a steam pressing.

(g) This type of plant would be suitable for all-wool as well as wool-synthetic blends.

(h) Space requirements for an operation of this size would be about 3,600 ft^2.

(i) Yarn requirements for the specified production would be approximately 1,350 lb/week of worsted yarns, yielding sweaters weighing about 12 oz after material losses.

Prime machine requirements and approximate costs

No.	Machine	Approximate cost (in dollars)
6	V-bed flat knitting machine (5 cut, 60 in)	36,000
1	Winder (12 spindles, non-automatic)	1,200
3	Side-seaming machines	1,500
3	Sewing machines	1,500
1	Press	500
Miscellaneous equipment (tables, bins etc.)		1,500
	Total	42,200

Labour requirements

	Per shift	No. of shifts	Total
Flat-bed knitters	2	3	6
Mechanic (foreman)	1	3	3
Cutter	1	1	1
Seamers and sewing-machine operators	6	1	6
Presser	1	1	1
Packing and shipping	1	1	1
General help	1	2	2
Manager	1	1	1
Clerical	2	1	2
Total			23

Annex 6

KNITTED PIECE-GOODS

It may be considered desirable to establish a production facility for wide knitted jersey piece-goods rather than an integrated knitting and garment set-up. In this case the following outline can serve as a guide.

It is assumed that an output of about 20,000 lb of fabric per week (120 hours) is required, with an average yield of 12 oz per linear yard.

The knitting-machinery complement comprises six plain double jersey interlock machines and six double jersey jacquards. An average yarn count of 1/32 worsted count (Nm 36) is assumed for the plain fabrics and 1/27 worsted count (Nm 30) for the jacquards.

It must be recognized that the jacquard machines are complex and will require specially trained mechanics. Nevertheless, it is considered that this type of manufacturing is having such an impact on the textile industry that it should be covered briefly.

The fabrics produced on such machines will be primarily for women's wear, about two thirds of it being single-colour, the remainder being patterned (jacquard) fabrics. The jacquard machines usually have considerably fewer feeds than the plain circular machines and are accordingly less productive.

For added versatility on the plain machines, consideration should be given to specify special camming on both cylinder and dial to allow convenient changeover from interlock to piqué constructions. It is noted that the interlock stitch is suitable for a wide range of fabrics, utilizing spun or filament yarns in a broad variety of counts and would therefore offer a basic fabric type for production into a variety of different effects.

Prime machinery

Knitting

Six plain double jersey interlock 33-in diameter, 22 cut, 48 feed. Operating speed 22 rev/min, production per hour per machine at 80 per cent equals 18 lb. Cost per machine: $15,000.

Six double jersey jacquards, 31-in diameter, 18 cut, 24 feed, operating speed 19 rev/min, production per machine per hour at 80 per cent equals 9 lb. Cost per machine: $20,000.

The above equipment will run 120 hours (3 shifts) per week.

One winding machine, 12 winding units for yarn rewinding. This would be a non-automatic unit and would be run on as needed. Cost: $1,200.

Finishing

Finishing equipment has a high output and one shift operation will suffice to process all the production of the knitting machines. The equipment will comprise:

1 slitter)
1 steam calender) (approximate cost $7,000 to $9,000)

1 semi-decator (approximate cost $16,000 to $19,000)

2 examining and cloth-rolling machines (approximate cost $4,000)

The operating speed for the whole finishing range can be based on 30 yd/min which at an effective efficiency of 50 per cent gives 900 yd/h.

Space requirements

Space requirements for the above unit will be approximately 6,000 ft^2 and will be subdivided as follows:

Knitting and yarn storage	2,200 ft^2
Finishing	800 ft^2
Fabric storage and packing	1,500 ft^2
Offices	1,500 ft^2

Labour requirements

	Per shift	No. of shifts	Total
Knitters	4	3	12
Shift mechanics	1	3	3
Foreman-chief mechanic	1	1	1
Pattern make-up	1	1	1
Floor help (doffing, cleaning etc.)	1	3	3
Maintenance	1	2	2
Finishing, examining and wrapping	4	1	4
Manager-designer	1	1	1
Assistant (quality control, testing services)	1	1	1
Clerical	2	1	2
Total			30

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