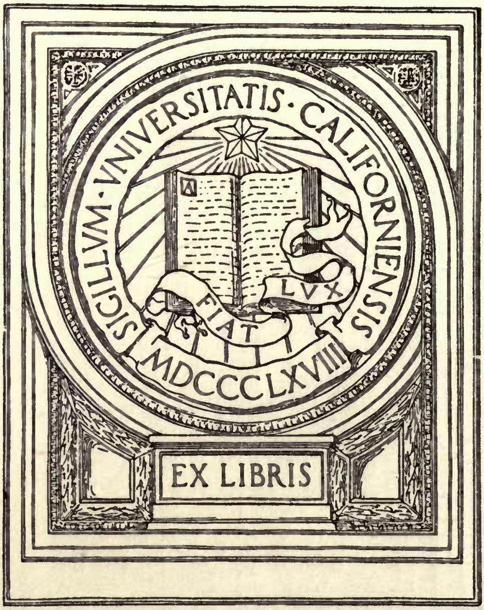


SIGILLVM · VNIVERSITATIS · CALIFORNIENSIS
FIAT LVX
MDCCCLXVIII
EX LIBRIS

MODERN FLAX, HEMP, AND JUTE SPINNING AND TWISTING

NET BOOK.—This book is supplied to the Trade on terms which will not allow of Discount from the published price.

SCOTT, GREENWOOD & SON.

MODERN FLAX, HEMP, AND JUTE SPINNING AND TWISTING

A PRACTICAL HANDBOOK FOR THE USE OF FLAX, HEMP, AND JUTE SPINNERS, THREAD, TWINE, AND ROPE MAKERS

BY

HERBERT R. CARTER
MILL MANAGER, TEXTILE EXPERT, AND ENGINEER
EXAMINER IN FLAX-SPINNING TO THE CITY AND GUILDS OF LONDON INSTITUTE

WITH NINETY-TWO ILLUSTRATIONS

LIBRARY
OF THE
UNIVERSITY
OF
CALIFORNIA

LONDON
SCOTT, GREENWOOD & SON
8 BROADWAY, LUDGATE HILL, E.C.

CANADA: THE COPP CLARK CO. LTD., TORONTO
UNITED STATES: D. VAN NOSTRAND CO., NEW YORK
1907

[*All rights remain with Scott, Greenwood & Son*]

TS178
C3

GENERAL

PREFACE

THIS volume is designed to supplement existing and out-of-date treatises, and to provide, at a reasonable price, a text-book for technical students and a practical hand-book for the use of those engaged in the spinning and twisting of flax, hemp, or jute. The Author has endeavoured to arrange the available information on this subject so as to harmonise with the Syllabus or Programme of the City and Guilds of London Institute. He hopes that his endeavour will be appreciated, and that his work will prove of assistance to both teachers and students, and to foremen and workers engaged in the industries concerned.

H. R. CARTER.

LONDON, *April* 1907.

193639

CONTENTS

PAGE

PREFACE v

LIST OF ILLUSTRATIONS xi

CHAPTER I

RAW FIBRE

Origin of flax, hemp, and jute fibre—Description of the plants—Mode of cultivation—Suitable climate and soil—Sowing—Harvesting—Rippling flax and hemp—Water retting—Dew retting—Extraction of the fibre—Marketing the fibre—Bracquing—Flax, hemp, and jute marks—Comparative prices—Ports of export—Trade centres—Fibre selling conditions—Duty on fibre—Fibre exports . . . 1

CHAPTER II

HACKLING

Sorting and storing the raw fibre—Softening hemp and jute—Jute batching—Cutting—Piecing out—Roughing—Hackling by hand and machine—Tippling—Sorting—Ventilation of hackling rooms . 16

CHAPTER III

SLIVER FORMATION

Spreading line—Heavy spreading system—Good's combined hackler and spreader—Jute breaking and carding—Flax and hemp tow carding—Bell calculation—Clock system—Theory of spreading . . . 38

CHAPTER IV

LINE AND TOW PREPARING

PAGE

Drawing and doubling—Draft calculation—Set calculation—Tow combing—Compound systems—Automatic stop motions and independent heads—Details of preparing machinery—Ventilation—Humidification 60

CHAPTER V

GILL SPINNING

Gill spinning for shoe threads, rope yarns, binder and trawl twines—The automatic gill spinner—Rope and reaper yarn numbering . . 85

CHAPTER VI

THE FLAX, HEMP, AND JUTE ROVING FRAME

Bobbin winding—Differential motion—Twist calculation—Practical changing—Rove stock 95

CHAPTER VII

DRY AND HALF-DRY SPINNING

Flyer and ring frames—Draft and twist calculation—Bobbin dragging—Reaches—Set of breast beam and tin rod 106

CHAPTER VIII

WET SPINNING OF FLAX, HEMP, AND TOW

Hot and cold water spinning—Improvements in the water trough—Turn off and speed of spindles—Reaches—Belting—Band tying—Tape driving—Oiling—Black threads—Cuts per spindle—Ventilation of the wet spinning room 117

CHAPTER IX

YARN DEPARTMENT

Reeling—Cop winding—Cheese and spool winding—Balling shoe thread, reaper yarn, etc.—Yarn drying and conditioning—Yarn bundling—Yarn baling—Weight of yarn—Yarn tables—Duty on yarn imports . 129

CHAPTER X

MANUFACTURE OF THREADS, TWINES, AND CORDS

PAGE

Hank winding—Wet and dry twisting—Cabling—Fancy yarns—Twine laying—Sizing and polishing threads and twines—Softening threads—Skeining threads—Balling twines—Leeson's universal winder—Randing twines—Spooling sewing threads—Comparative prices of flax and hemp cords, lines, and threads 145

CHAPTER XI

ROPE MAKING

Construction of hawsers and cables—Stranding—Laying and closing—Compound rope machines—Rules for rope makers—Weight of ropes—Balling and coiling ropes 165

CHAPTER XII

MECHANICAL DEPARTMENT

Boilers, engines, and turbines—Power transmission by belts and ropes—Electric light and power transmission—Fans—Oils and oiling—Repairs—Fluting 174

CHAPTER XIII

MILL CONSTRUCTION

Flax, hemp, and jute spinning mills and ropeworks—Heating—Roofs—Chimneys, etc. 195

INDEX 201

LIST OF ILLUSTRATIONS

FIG. PAGE
1. Flax break (front view) 6
2. Flax break (end view). 7
3. Hand-scutcher's stock. 7
4. Hand-scutcher's blade 7
5. Belgian treadle scutching machine 8
6. Jute opener 17
7. Jute softener 17
8. Circular hemp softener 18
9. Flax and hemp cutter. 19
10. Horner's duplex stripping rod hackling machine (side view). . 22
11. Horner's duplex stripping rod hackling machine (end view) . . 23
12. Eves' antifriction washer and nut 24
13. Hackling machine holder and channel 24
14. Horner's brush and doffer hackling machine 25
15. Horner's brush and doffer hackling machine (gearing end) . . 26
16. Horner's brush and doffer hackling machine (pulley end) . . 27
17. Eves' tipple press 29
18. Cotton's end comb 33
19. Drawing off the dust from a hackling machine (System Huglo) . 36
20. Ventilation of a hand-hackling room 37
21. Breaker card for hemp tow and jute 39
22. Finisher card for hemp tow and jute 41
23. Tow finisher card 43
24. Hopper or Automatic feed 44
25. Special short fibre card and hopper feed 48
26. Good's combined hackler and spreader, for Manila, etc. . . 50
27. Spreader for long hemp and jute 52
28. Flax spreader with clock 54
29. Gills, fallers, and card staves 55
30. Drawing frame for jute 62
31. Rear view of drawing frame 64
32. Section through tow drawing (spiral). 65
33. Combing machine for tow 69
34. Drosophore humidifier 83

FIG. PAGE
35. Section through coarse gill spinning frame 86
36. Coarse gill spinning frame 87
37. Automatic gill spinner 89
38. Automatic bobbin-dragging motion 90
39. Coarse roving frame 96
40. Section through Fairbairn's roving frame 98
41. Fairbairn's disc scroll and differential motion . . . 99
42. Fairbairn's dry spinning frame 107
43. German dry spinning frame 108
44. Section through Boyd's swing-rail dry spinning frame . . 109
45. Dry spinning frame or Ring system 110
46. Section through German frame showing Bergmann spindle . . 112
47. Section through Bergmann spindle 113
48. Bergmann spindle 113
49. Bergmann spindle 113
50. Hot-water wet spinning frame 118
51. German wet spinning frame 119
52. Lines of a wet spinning frame 120
53. Hygrophant or Hygrometer 121
54. Section through wet spinning frame rollers and stand . . 124
55. Power reel (90-inch swift) 130
56. German stop motion sectional reel 132
57. Section through 90-inch power reel 133
58. Cop-winding machine for hemp or jute yarns 134
59. 12-spindle baller for shoemakers' and saddlers' hemps . . 136
60. Binder twine balling machine 137
61. German automatic slub detecting device 138
62. German automatic slub detecting device 139
63. Yarn bundling press 140
64. Wet twisting frame 146
65. Double cord twisting machine 148
66. Single cord twisting machine 150
67. Bobbin-to-bobbin thread polishing machine (general view) . . 152
68. Bobbin-to-bobbin thread polishing machine (section) . . . 153
69. Soft finish thread polishing machine 155
70. 6-spindle twine baller 158
71. Lock-mesh wound balls 159
72. Baines' 18-spindle automatic spooler (general view) . . . 160
73. Baines' 18-spindle automatic spooler (front elevation) . . 161
74. Section through shaping and guide lifting mechanism . . 162
75. Machine Jack 166
76. Stranding or register machine 168
77. Rope reel 169
78. Rope balling machine 170
79. Internal arrangement of Vortex turbine 175
80. Vortex turbine (general view) 176
81. Vortex wheel and vanes 176

FIG. PAGE
82. Arrangement of a water turbine 177
83. Arrangement of a water turbine 178
84. Single Vortex turbine with part of cover removed . . . 178
85. Fixing of a single Vortex, Lunedale, or Trent turbine . . 179
86. Construction of a single Vortex wheel 180
87. Installation of a Lunedale turbine 181
88. General view of a De Laval steam turbine 182
89. Turbine wheel and nozzles 183
90. Section through nozzle 184
91. Section through nozzle 184
92. Section through centrifugal governor 185

LIBRARY
OF THE
UNIVERSITY
OF
CALIFORNIA

MODERN FLAX, HEMP, AND JUTE SPINNING AND TWISTING

CHAPTER I

THE RAW FIBRE

Flax (*Linum usitatissimum*), Fr. *Lin*, Ger. *Flachs*, is a textile fibre obtained from the stalks of the flax plant, which is extensively grown for the purpose in Russia, Belgium, France, Holland, Germany, and in Ireland. The plant is an annual, being usually sown in the spring and pulled in the autumn. The stalks grow to a height of from 2 to 3 feet, and bear either blue or white flowers, according to the variety of seed sown. The fibre forms one of the outer layers in the stem. It surrounds the boon or woody core, and is only covered by a thin coat of gum, like varnish.

The Hemp plant, which produces the true hemp fibre (*Cannabis sativa*), Fr. *Chanvre*, Ger. *Hanf*, is very similar to the flax plant, but coarser and taller. It grows to a height of from 5 to 15 feet, and is likewise an annual. The stems are hollow and fluted. The staminate or pollen-bearing flowers and the pistillate or seed-producing flowers are on separate plants. The former mature earlier, and should be first harvested. The plant is cultivated extensively in Russia, China, Japan, Italy, Austria, and France. The period of growth varies from three to five months, depending upon temperature and rainfall. In Europe the crop is usually harvested in August and September. Within recent years the name hemp has been made to cover some hard fibres used by rope-makers, such as *abaca* or Manila hemp, aloe fibre, pita, henequen, Sisal, Mauritius hemp, and New Zealand flax or hemp. The Manila hemp or *abaca* plant is a sort of banana or plantain tree, but its fruit is small and not edible. The cultivation of the plant is an important industry in the Philippine Islands, and especially in the provinces of Albay and Camarines on the island of Luzon. The islands of Leyte, Marinduque, Cebu, Mindoro, and Samar also produce large crops. The fibre is obtained from the long leaves which envelop the stem. The leaves, which sometimes attain a length of 20 feet, are cut down periodically, the younger and inner leaves producing the most valuable fibre.

Sisal Hemp (*Agave rigida*) is indigenous to Yucatan, and is also cultivated in the Bahamas and Florida. The fibre is contained in the leaves of the plant, which average 5 to 6 feet in length and 4 inches in width. The leaves are ready for cutting when the plant is three years old, and weigh from 1½ to 2 lbs. in the green state. The Mauritius Hemp plant (*Fourcroya gigantea*), the largest of the so-called aloes, is a very similar plant. The leaves have an average length of about 80 inches and weigh about 5 lbs. The Pita or Henequen plant is grown in South America, and produces leaves of an average length of 3½ feet, from which a coarse fibre resembling Sisal is extracted. New Zealand Hemp (*Phormium tenax*) is likewise found in the leaves of the plant. The fibre produced resembles Manila somewhat, but has not the same quality or strength. The average length of the fibre is about 10 feet.

Bow-String Hemp (*Sansivieria* or *Murta*) is a fibrous plant which grows in India and in Queensland. The leaves, which are from 4 to 7 feet long and from 2 to 3 inches wide, spring up directly from the root, the plant having no stem. The fibre is soft, silky, pliant, and very strong. Fifty lbs. of fibre may be extracted from 1 ton of fresh leaves. One acre yields 13½ tons of fresh leaves, or 6 cwt. of clean fibre. The Jute fibre is extracted from the stems of a plant extensively cultivated in the province of Bengal, India.

Cultivation.—The soil best suited for flax and soft hemp is a nice dry loam, not too light and yet not of a clayey nature. The best qualities of Agave fibre are grown on stoney or gravelly soil of medium quality, as there is less wood and more fibre in the leaf. The finest jute is grown on the high ground, and the middle qualities on the river banks, deltas, etc., known as "Salilands." A hot damp climate without too much rain is most suitable for the proper development of the plant. The Sisal hemp plant thrives on arid land, as too much moisture is bad for the plant. The New Zealand hemp plant grows best on swampy ground.

Flax, soft hemp, and jute are produced from seed, while the hard fibre plants are usually propagated by removing and planting out suckers from old plants. The flax seed generally used is imported from either Holland or Riga. The farmers to the south of Rotterdam make a speciality of producing good sowing seed, for which they obtain good prices on the Rotterdam market. Sowing seed must be fully matured, heavy, plump, and glossy, weighing 54 to 57 lbs. per bushel. Good Dutch seed will germinate from 97 to 100 per cent. Riga seed is lighter and of lower germinating power, being frequently kiln dried. The quantity of flax seed sown per acre is generally $1\frac{3}{4}$ bushels of Dutch seed or 2 to $2\frac{1}{4}$ bushels of Riga seed, according to quality. If Riga seed, having a germinating power of not less than 80 per cent., be sown proportionately thicker than Dutch seed, it generally produces a heavier flax. Flax produced from Dutch seed is generally of fine quality, however. The danger of sowing a low germinating seed lies in the fact that if the weather proves warm and seasonable the flax may grow too thick, and may be "laid" if rough weather sets in, and the crop lost. If the season be unfavourable, on the other hand, the crop may be a failure owing to the seed not germinating in sufficient quantities; so that, on the whole, Dutch seed is to be preferred. In Belgium, flax is usually sown after oats, while Irish farmers usually prefer to sow after wheat or potatoes. In any case, a seven years' rotation should be observed, so that a crop of flax be not taken off the same ground too frequently. In preparing land for flax cultivation, the object to be aimed at is the production of a fine, deep, dry, and clean bed for the flax seed. The ground should be made as even and flat as possible, so that the length of the stems produced may be uniform—a most important point as regards the after-treatment of the fibre. After the seed has been sown broadcast, a fine seed harrow and a light roller should be passed over the field to cover the seed to a depth of about one inch below the surface of the ground. It is advisable to sow rather a full quantity, as the greater the number of stems the larger will be the yield of fibre. In addition, the closer together the stems, the longer and straighter they will grow, and the fewer branches they will produce. Flax seed thinly sown produces plants with many branches, much seed, and coarse fibre. The remarks which have been made with regard to flax seed and sowing apply equally to the true hemp plant, and also to some extent to the jute plant. Jute spinners have had to complain, during the last few years, that the quality of the fibre has been deteriorating, a state of affairs due to the fact that the lands growing jute are becoming exhausted because the crops follow each other too frequently and without sufficient manure, and because land unsuited for jute are being planted with it.

In Sisal hemp, henequen, pita, and aloe plantations the suckers about two years old should be planted in rows about 6 feet apart, or about 700 plants per acre. The fields should be laid out in ranges or sections of 40 acres, and the land got ready in the dry season. In Yucatan large tracts of rocky soil are planted with Sisal hemp, the young plants being placed in crevices. Land under fibre cultivation should be kept carefully weeded. This is especially the case with the flax plant, for a quantity of noxious weeds rising with the flax will seriously check its perfect development. Weeding should commence when the stalks are 5 or 6 inches long. The weeders should have a mat under their knees, always press the stems one way, and work with their faces towards the wind, so that when they pass on the stems may regain their upright position with the assistance of the breeze.

Harvesting.—It has been proved that when flax is pulled between the falling of the flower and the formation of the seed, the fibre is finer and more solid than at any other time, yet in order that the seed may serve at least for feeding purposes, it is the common rule to allow two-thirds of the stalk to become yellow before harvesting the straw. The pullers grasp the stems firmly, and pull them up by the roots in handfuls. The long and short stems should be kept separate as much as possible, and the root ends kept very even.

In America, where farm labour is scarce, the flax and hemp grown is usually cut down like wheat, the hemp when the staminate plants are in flower. The leaves of the Manila hemp plant are cut down periodically, as are also those of the Agaves, Mauritius, and New Zealand hemp plants. In the case of Sisal, only twelve to fifteen leaves are taken from the plant annually, the lower leaves being taken first. The greatest yield of jute fibre is obtained by cutting the plant when dead ripe, but the quality of the fibre from the late cut plant is not so good as that obtained from the plant cut at an earlier stage, or when the small yellow flower appears.

Rippling.—Rippling is the removal of the seed capsules from the stems and branches of the flax and hemp plants by drawing them in handfuls through a very coarse hackle or "ripple."

Retting.—Retting is the first process towards the separation of the fibre from the stems of the flax, hemp, and jute plants. Its object is to dissolve out by fermentation or by exposure to the elements, or both, the gummy matter or pectose which binds the fibre to the woody part of the stem. Flax and hemp are either dew or water retted. Jute is water retted, the fermentation set up softening the tissue in which the fibres are imbedded until they come away quite easily from the woody portion of the stem. The fibrous straw, to be water retted, is tied up in sheaves and placed either in pools of stagnant water or in running streams. The retting water must be free from earth in suspension, and also free from all traces of iron. Retted in muddy water, the fibre lacks lustre and becomes grey in colour, while if retted in water impregnated with iron it becomes a foxy brown colour. Retted in running water, the fibre produced is of a nice cream colour, much prized by spinners. The water-retting process usually requires ten to fourteen days, according to the temperature. Upon the Continent considerable quantities of flax and hemp are dew-retted, the straw being thinly and evenly spread upon a grass field and reduced by prolonged exposure to the rays of the sun and the mellowing influence of the nightly dew.

Considerable success has recently attended the steeping of flax and hemp in tanks under the Loppens and Deschwarte system, and also under the Legrand patents, the straw thus treated producing better fibre than the same straw treated in the ordinary way. The Legrand process, as carried out near Antwerp, consists in putting the straw to be retted upright in an open crate, which is lowered mechanically into a tank filled with water for scouring purposes, in raising and lowering the crate repeatedly to wash away the slime, and then in introducing the crate full of straw into a second tank of water—the retting-tank proper. The crate is again raised and lowered repeatedly, and is finally immersed in a third tank for washing and rinsing. Fresh water is admitted through a filter into the rinsing tank, and caused to flow by means of siphons successively through the retting and scouring tanks. The water enters the first two tanks underneath a horizontal canvas partition, and is thus more evenly distributed. The temperature of the water is slightly raised and the retting more quickly accomplished than in the usual way, the resulting fibre being of a golden yellow colour. The process is based on the assumption of the inventors, that the pectose, which unites the fibres together and to the harl of the stem, comprises two distinct kinds of glueing materials, viz., one a gum which is soluble in water, and another a resin, insoluble in water, which must be decomposed by the retting action before becoming soluble. Retting by the action of the so-called granulobacter or retting bacillus causes fermentation and decomposition, and produces a glutinous substance soluble in water. In order that the retting process may be quickly and efficiently accomplished, the raising and lowering of the straw crate in the scouring tank is indispensable, so that the gum may be washed away. If the stalks be not properly scoured at this stage, the microbe of lactic acid will be developed, the said microbe being an enemy of the retting ferment. The straw crate is raised and lowered in the retting-tank in order to wash away the secretions of the retting bacillus, which retard its development. It is further claimed that air or oxygen is introduced into the water by the raising and lowering of the crate, and the action of the retting ferment thereby highly increased.

Processes such as those of Loppens and Deschwarte and Legrand are particularly adapted to co-operative or company retting, which would prove a boon to small flax-growers. The success of the Courtrai flax trade may be attributed not only to the superior retting properties of the waters of the river Lys, but to the skilful manner in which the flax is handled and scutched—a result brought about by the system of treating the flax on such a large scale. The local crop is not nearly sufficient to supply the demand, and the flax factors of Courtrai are forced to purchase the straw in Holland and

France. From 12,000 to 15,000 labourers are employed during the retting season (April to October), and pass about 90,000 tons of flax straw through their hands. The retting of jute takes place in pools or tanks of stagnant water, or even in running water. Before retting the crop should be stacked for two or three days to allow time for the decay of the leaves.

Grassing.—When water-retted flax or hemp straw have been in steep long enough (10 to 14 days), the bundles should be allowed to drain for a short time and then removed to a closely cropped meadow, over which the stalks should be evenly and thinly spread in rows. Exposure to the sun and air soon renders the woody part dry and brittle, when the straw may be lifted and tied up in neat bundles ready for the cleaning process.

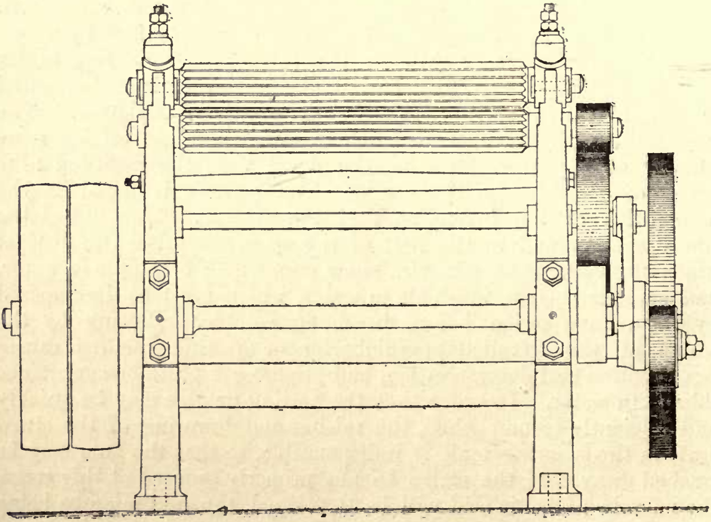


FIG. 1.—Flax break (front view).

Fibre extraction.—Breaking or crushing is the first mechanical operation necessary to separate the flax and hemp fibres from the woody part of the stem. Figures 1 and 2 show a flax break with several pairs of heavily weighted fluted rollers, between which the boon or woody matter is broken up into small particles. Hemp straw is usually broken in a sort of primitive wooden press composed of intersecting bars, after which treatment the woody particles can usually be shaken out, leaving the fibre comparatively clean. Broken flax straw, on the other hand, must be scutched or beaten with a

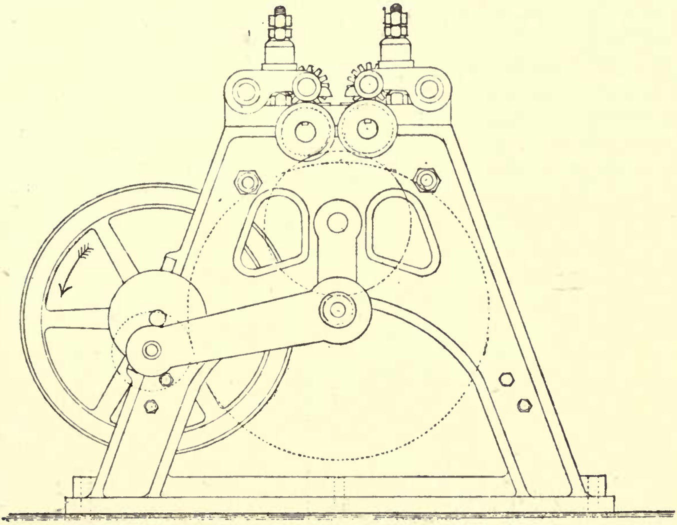


FIG. 2.—Flax break (end view).

wooden blade, in order to separate the fibre, and at the same time to soften it and make it finer. Figure 3 shows the stock or notched wooden plank in which the handful of flax straw is held while it

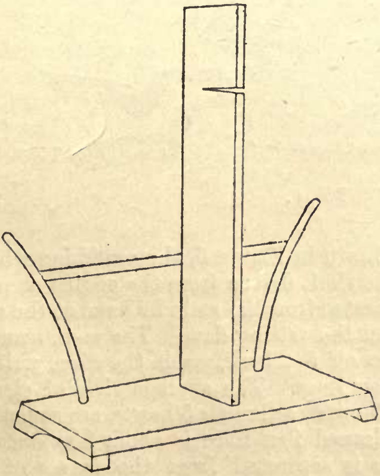


FIG. 3.

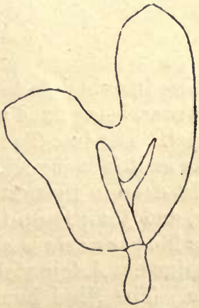


FIG. 4.

is being struck with the scutching blade, Figure 4, in the operation of hand scutching. Figure 5 shows a treadle scutching machine much used in the Courtrai district of Belgium. The principle is the same, the beaters or blades being merely fixed upon a wheel turning in a vertical plane, and close to the stock in which the flax straw is held while under treatment. Scutching mills driven by water power, gas or oil engines, are numerous, their machinery consisting of one or more roller breaks, and a series of scutching stocks similar in principle to that shown in Figure 5, the scutching wheels, however, being fixed upon one shaft driven from the engine or water wheel. The jute fibre is separated from the stalk by hand at the same time as it is being lifted from the retting dam. The men, standing waist deep in the water, strip off the bark, wash the fibre, wring it out, and hang it up to dry on lines. The average yield of cleaned jute fibre per acre is about 15 cwts., although 30 cwts. are sometimes obtained. A fair yield of cleaned flax fibre is about 30 stones per acre. The Sisal hemp fibre is separated from the leaves of the plant by an extractor, a heavy machine of the Prieto or Villamore

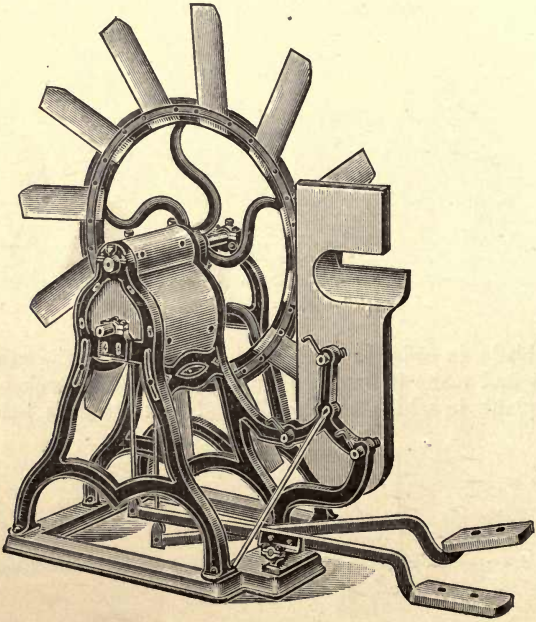


FIG. 5.

type, in which scrape wheels, acting against a wooden block or shoe, scrape off the woody pulp from the fibre, which is left comparatively clean. The green leaves yield about 8 per cent. of fibre. The fibre of the New Zealand hemp plant is separated from the bark by means of machines of the ordinary flax scutcher type, combined with handwashing and scraping. The fibre is then grassed and rescutched. African grown pita or henequen is of the hardest class, and very resistant to the extracting operation, which consists in passing the leaves several times through a crushing machine, the grooved rollers of which flatten the leaves out, soften them, and take out the sap, and then through an extractor provided with a scraper wheel and blocks. Water streams constantly upon the blocks from an overhead reservoir and washes away the woody pulp as removed by the scrapers. A machine with single feed will clean 15 leaves per minute, and gives employment to two men and a boy. The average yield of clean fibre is about 70 lb. per 1000 leaves, or 1500 lb. of fibre per acre per annum. Manila hemp is hand cleaned by native labour, the pulp being scraped from the newly cut leaf-stalks by drawing them under a rudely constructed scraper knife fixed in a bamboo framing, or merely by scraping them with a flat piece of wood. The fibre when cleaned is hung out to bleach and dry. That found in the central layer, called the "bandala," is the common fibre of commerce. The white, brilliant and fine portion coming from the heart of the saga is called *lupis* or *quilot*, and is sold at a higher price. The trade is in the hands of Spanish and Chinese merchants, who buy from the planters and re-sell to the shippers. The average yearly shipments amount to about 1000 tons, the greater part going to the United States and to England. There are three classes of Manila hemp, *i.e.* "current," "fair current," and "brown." Merida is the centre of the Yucatan Sisal hemp industry. The fibre is baled and shipped from Prognesso, the United States being the largest consumers. There are three current qualities of Mauritius hemp, *i.e.* "fair," "fully fair," and "good." New Zealand hemp is classed as "good fair Wellington," "fair Wellington," etc.

Three-fourths, or about 3000 tons of American hemp is raised in Kentucky, Lexington being the principal market. American hemp is also cultivated at Fremont and at Havelock in Nebraska. Italian water-retted hemp is among the finest and most valuable of the European hemps. The recognised base is the mark PC. Naples and Bologne are two of the principal markets. The chief Russian hemp-growing areas are situated in the governments of Orel, Poltava, Smolensk, Kalonga, Mohilew, Simbirsk, Tambow, Hernigow, and Koursk. There are three current qualities of St. Petersburg hemp, *i.e.* "clean," "outshot," and "half-clean." Köenigsberg hemp is generally of a green shade, and is classed as "clean," "cut," and "schiking." The principal French hemp-growing centres are Picardie, Anjou, and Bourgogne. The most important of the Indian hemps are Bombay, Jubbalpore, Allahabad, and Sunn hemp. The importance of the Russian flax industry renders some sort of standard classification necessary. Flax fibre grown upon the crown lands is sorted and exported under the following marks, put in the order of their value:

ZK = Zins Kron—well-scrutched fibre of good spinning quality, and of a dark colour.
HZK = Hell Zins Kron—similar in quality to above, but of a lighter colour.
GZK = Grau Zins Kron—similar in quality to above, but of a grey colour.
WZK = Weiss Zins Kron—similar in quality to above, but of a very light colour.
WSPK = Weiss Superior Puik Kron—a very light-coloured clean fibre of rather lower spinning quality than Zins.
GSPK = Grau Superior Puik Kron—same quality as above, but of a grey colour.
HSPK = Hell Superior Puik Kron—fibre of similar quality to the former, but of a lighter colour.
SPK = Superior Puik Kron—the same fibre, but dark in colour.
WPK = Weiss Puik Kron—a less carefully scutched flax, of middling quality and a white colour.
GPK = Grau Puik Kron—similar fibre, of a grey colour.
HPK = Hell Puik Kron—fibre of similar quality to the above, but of a yellow colour.
PK = Puik Kron—similar fibre, of a dark colour.
WK = Weiss Kron }
GK = Grau Kron } low-quality fibre, of a colour indicated by the initial letter.
HK = Hell Kron }
K = Kron—low-quality fibre, of a dark colour.

The lowest mark, K, is usually taken as a base in quoting prices—the "rise" in pounds sterling per ton for the several marks being H = 1, P = 3, S = 4, G = 3, W = 4, and Z = 10, so that if the value of K be £20 per ton, the value of GSPK, for instance, will be 20 + 3 + 4 + 3 = £30 per ton.

Hoffs Dreiband flaxes are other water-retted marks exported from Riga. They include—

HD = Hoffs Dreiband—a badly scutched weak flax, of a darkish colour.
PHD = Puik Hoffs Dreiband—rather better than K Riga.

FPHD = Fein Puik Hoffs Dreiband—rather better than PK Riga.
WHD = Weiss Hoffs Dreiband—poor dirty flax, of a light colour.
WPHD = Weiss Puik Hoffs Dreiband—rather better than WK Riga, of a light colour.
WFPHD = Weiss Fein Puik Hoffs Dreiband—of similar quality to WPK Riga.

Pernau "district" or Pernau Hoffs Dreiband is marked xHDx, and is flax grown in the neighbourhood of Pernau, and shipped in the state in which it leaves the peasants, with a good deal of shive left in the top end. Pernau flax, marks D, HD, and R = risten, is this "district" flax opened out in Pernau and rescutched, increasing its value by £2 per ton. Pernau flax comes from one of two districts, *i.e.* Livonia or Fellin, the latter being the finer quality, and fetches £2 per ton more.

The Wrack flaxes, beginning with the best quality, are classed as GPW, WPW, PW, and W.

The Dreiband flaxes comprise PD, PLD, D, and LD.

The marks of the Dreiband Wrack flaxes are DW and DWII.

Slanetz or Dew-retted Dreiband is classed either as PSD or as SD, while SDW and SDWII are the marks of the Slanetz Dreiband Wracks.

Flax exported from Reval and Dorpat has usually been rescutched, and is marked G, R, HD, D, 0D, and 00D, according to quality.

The word Motchenetz, in connection with Russian flax, means water-retted.

In Russia, flax is bought and sold at so many roubles per berkowitz = 360 lbs. A rouble is value for 3s. 1½d., so that flax costing say 25 roubles per berkowitz, is worth £24, 6s. per ton.

Friesland flax is perhaps the only other flax besides Russian which is classed according to quality by letters, and the qualities subdivided into sorts by crosses thus: F, Fx, Fxx, G, Gx, Gxx, etc. Friesland as well as Dutch flax is sold at so many stuivers per stone of 6 lbs. 3½ oz. The Dutch stuiver is worth about 1½d.

In most of the Irish markets home-grown flax is sold at so many shillings per stone of 14 lbs., while in a few others the custom is to sell at so much per cwt.

In the Courtrai district of Belgium the price of flax is reckoned in crowns per sack, the value of a crown being 4s. 7d., and the weight of a sack of 41 bottes = 127½ lbs. avoirdupois. The flax is exported in 2 cwt. bales, each containing 72 bottes. In the Bruges market flax is priced in stuivers per stone of 8 lbs. 4¾ oz., the Belgian stuiver being worth nearly 1d. The real weight of a stone of flax as sold in the Waereghem market is only 6 lbs. 11 oz., while in Ghent, Wetteren, and Welle its value is still less, being only 6 lbs. 9½ oz. The weight of a stone of Lokeren, Malines, or St. Nicholas flax is only 6 lbs. ½ oz. The confusion caused by the local differences in these old weights has led to the almost universal adoption of the French method of payment in francs per 100 kilogs. or 2 cwts. Flemish dew-retted or Walloon flax is sold at so many sous per botte of 3 lbs. 3 oz. The value of a sou is about equal to ½d.

The best-known French flaxes are Hasnon, Flines, Douai, Bergues, Picardie, Moy, and Bernay.

Jute fibre is sorted in the various trade centres of Bengal, packed and pressed for shipment from Calcutta, Chittagong, etc. In sorting, the woody and hard root ends are separated and named "cuttings." The lowest class of fibre is called "rejections." The bales weigh 400 lb. The finest variety of jute is Uttariya, which is strong and fine, but not so soft as Deswald, which is the next best quality. Desi is the jute which is principally used for making gunny bags. Deora is that most used for ropes. Other well-known sorts are Daisee and Maraingunge. Jute marks are very numerous, consisting of letters, circles, hearts, or triangles. The letters frequently indicate the name of the exporters, the well-known C.D.M. mark, for instance, being connected with the name of its originator, the late Mr. C. D. Mangos. The comparative prices of the various sorts of flax, hemp, and jute fibre, in the order of their values, is approximately as follows, at the time of writing:

Courtrai flax	£40 to £240	per ton
Flemish and Dutch flax	36 to 140	,,
Irish flax	36 to 80	,,
Brittany flax	52	,,
Russian flax, Archangel 4th Cr.	48	,,
Manila hemp (fine marks)	50	,,
Italian hemp PC	44	,,
Manila hemp (good current)	48	,,
Russian Bejetsky flax	37	,,
Russian hemp FSPRH	31	,,
Russian flax tow, Kama ½ and ½	37	,,
Russian hemp, Riga summer dried FSPHR	31	,,
Naples hemp, I Paesano	40	,,
Manila hemp, "fair current"	42	,,
Russian flax, Yaropol	31	,,
Manila hemp (Sorsogon current)	42	,,
Sisal hemp	33	,,
Naples hemp, II Paesano	36	,,

Russian flax tow, Mologin ½ and ½	£33 per ton
Russian Königsberg navy hemp	22 ,,
Manila hemp (superior seconds)	41 ,,
Naples hemp, I Marcianise	36 ,,
Naples hemp, I and II Canapone	36 ,,
Russian Pernau flax HD	31 ,,
Naples hemp, II Marcianise	35 ,,
Manila hemp, "good brown"	39 ,,
Russian flax (Opotzka)	26 10s. ,,
Russian flax (Livonian K)	25 10s. ,,
Russian hemp, St. Petersburg	23 ,,
Manila hemp, "fair brown"	36 ,,
New Zealand hemp, "fair Wellington"	36 ,,
Russian flax, Hoffs HD	20 ,,
Fine Maraingunge jute	36 ,,
Red DS Daisee jute	25 ,,
Indian Sun hemp	12 10s. ,,
Jute (in double triangle grade)	26 ,,
Jute Cuttings	11 10s. ,,
Jute (Red SCC in circle grade)	23 ,,
Jute Rejections	14 ,,

Russian flax is exported from Riga, Pernau, Reval and Cronstadt; Dutch flax from Rotterdam; Flemish flax from Ghent; jute from Calcutta.

The principal consuming centres are: for flax, Belfast, Ghent, Lille, Roulers, Armentières, Trautenau, Bielefeld, and Richenberg. The jute-spinning centres are Dundee, Calcutta, and Dunkerque. The consumers of hemp are the rope works situated chiefly in the principal seaports of the world, and notably in Belfast, Sunderland, Newcastle-on-Tyne, London, Hull, etc.

The latest statistics show the number of flax-spinning spindles in the world to be as follows:

	Total Spindles.	Flax grown.
Ireland	833,268	8,069 tons
England	106,610	practically nil
Scotland	107,755	,,
Austria-Hungary	280,414	60,071 tons
Belgium	280,000	11,000 ,,
France	545,492	19,453 ,,
Germany	295,796	19,000 ,,
Holland	8,000	9,931 ,,
Italy	77,000	20,000 ,,
Russia	(flax and hemp) 300,000	497,341 ,,

The average value of the flax grown in the various countries is as follows:

Belgium	£65 per ton
Holland	51 ,,
France	44 ,,
Germany	30 ,,
Russia	35 ,,
Ireland	52 ,,

Ireland	imports about	35,000 tons of flax annually.
Great Britain	,, ,,	40,000 ,, ,,

The average yield of fibre per acre is as follows:

Ireland (flax)	29 stones per acre
Austria (flax)	39 ,, ,,
Hungary (flax)	39 ,, ,,
Belgium (flax)	32 ,, ,,
France (flax)	49 ,, ,,
France (hemp)	46 ,, ,,
Germany (flax)	35 ,, ,,
Holland (flax)	37 ,, ,,
Italy (flax)	24 ,, ,,
Italy (hemp)	46 ,, ,,
Russia (flax)	17 ,, ,,

Belgium exports about 36,000 tons of flax per annum at an average price of £72 per ton. Holland, 30,000 tons at £62 per ton. Russia, 195,000 tons at £28 per ton. Italy exports about 47,000 tons of hemp per annum at an average price of £35 per ton. Other countries spin their own production of fibre.

The usual conditions under which fibre sales take place are the following: C.I.F., C.&F., and F.O.B. C.I.F. means that the selling price covers the cost, the insurance during transit, and the freight. C.&F. that the freight is included in the price, but that the buyer must insure. Under F.O.B. conditions the seller must merely put the fibre on board a ship chartered by or approved of by the buyer. The seller is not bound to replace fibre lost or destroyed by shipwreck or fire during transit.

Raw fibre enters free of duty into almost every country, the few exceptions being—Russia, which imposes an import duty of nearly £6 per ton on raw jute; the United States, which taxes raw flax at the rate of ½d. per lb., and flax and hemp tow at the rate of 85s. per ton; and Switzerland, which imposes an import duty of 5s. per ton on raw flax, hemp, and jute.

Russia exports annually about 200,000 tons of flax, 39,000 tons of tow, and 39,000 tons of hemp.

Belgium—26,000 tons of flax, 9400 tons of tow, and 4800 tons of hemp.

France—13,000 tons of flax, 400 tons of tow, and 300 tons of hemp.

Holland—30,000 tons of flax, 1400 tons of tow, and 13,000 tons of hemp.

Italy—50,000 tons of hemp and 3000 tons of hemp tow.

India—11,000 tons of hemp and 560,000 tons of jute.

CHAPTER II

HACKLING

The raw fibre, be it flax, hemp, or jute, should, on arrival at the mill or rope works, be stored in a cool dry store into which the direct rays of the sun cannot enter. Heat of any sort has a tendency to dry out the natural oil or spinning "quality" of the fibre, and render it hard, dry, and hairy. The bales should be piled in such a way that the different qualities and shades of fibre are kept separate, the selection of suitable fibre for the various numbers and qualities of yarn being thus facilitated.

In the manufacture of jute the handling of the raw material commences with the process of batching, opening, and softening. In baling, the fibre has been doubled up and pressed in layers in the hydraulic press to such an extent that before the "stricks" or heads can be readily separated, the layers of jute must be passed through the machine shown in Figure 6, which represents the jute opener as made by Messrs. Urquhart, Lindsay & Co. Ltd. of Dundee. The action of the rollers of this machine is to render the "heads" of fibre soft, pliable, and easily handled by the batchers, who piece out the fibre into handfuls weighing about 2 lbs. each. While this "piecing out" or "streaking up" process is going on, the fibre may be sorted to some extent, inferior jute being put to one side for use in a lower grade yarn. The handfuls of fibre which have been prepared by the batchers are next run through the Jute Softening machine, Figure 7, made by the same firm, and usually consisting of from 31 to 63 pairs of straight or spirally fluted rollers pressed together by spiral springs. While passing through these rollers, a mixture of mineral oil and water is applied in the proportion of 8 gallons water and 2 gallons oil to each 400 lb. bale of jute. The water and oil are often supplied by separate pipes from overhead cisterns, the water being first applied and then the oil. The rate of delivery of oil and water pipes may be adjusted and regulated at will. Zinc trays should be provided beneath the rollers, so that all waste of oil may be avoided. Application of the oil and water in this way is known as machine batching, in distinction to the older method of hand batching or watering the fibre with a can of the batching mixture. The object of batching jute is to lubricate the fibre and make it pass more easily through the subsequent processes of carding, drawing, and spinning, without lapping upon the rollers, as it would otherwise have a tendency to do. Leaving the softener, the stricks of jute are laid upon a barrow or waggon, which when filled is put to one side and allowed to stand for twenty-four hours, so that the oil may percolate through and be absorbed by the fibre before it is removed to the card room. A batch is usually composed of about 1 ton of jute of uniform colour and of the desired average quality and price.

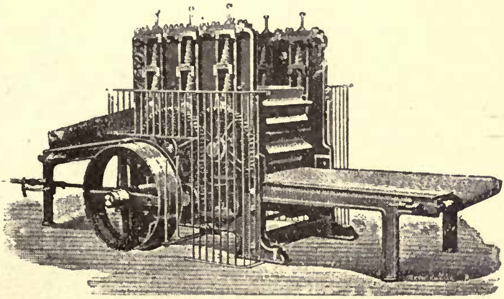


FIG. 6.—Jute opener.

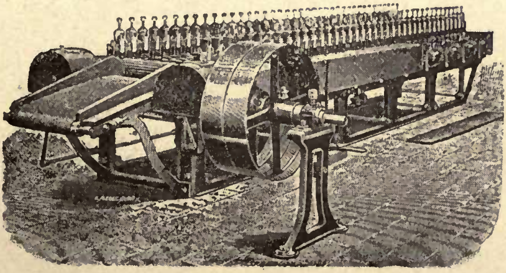


FIG. 7.—Jute softener.

The spinning quality of true hemp is much improved by rolling and softening. Horizontal softening machines, similar in principle to the jute softener (Figure 7) are employed for this purpose, as well as the circular machine shown in Figure 8 made by Samuel Lawson & Sons, Leeds. The rollers of hemp-softening machines are straight-fluted, and are often given a reciprocating motion, the forward motion being superior to the backward, causing the stricks to pass through the machine. The advantage

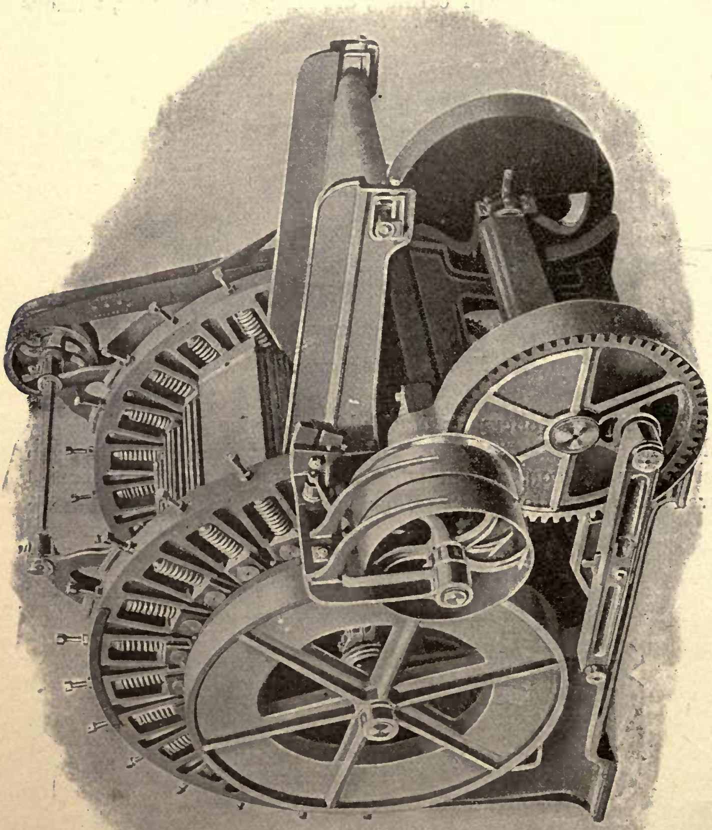


FIG. 8.—Circular hemp softener.

of a circular machine is its compactness, or the small floor space which it occupies as compared with a horizontal machine of the same number of rollers.

The roots and tops of the flax and hemp plants, and the root end of the jute plant, usually produce fibre of inferior quality to that extracted from the middle portion of the stem. The reason is that the root end ripens first; while as to the tops, the branching of the stem lowers the spinning quality of the fibre. In the flax and hemp plants, the inferiority of the root end shows itself in the flatness and "haskyness" of the fibre, while the fibre of the top end of the plant is often very "nappy."

a pairs

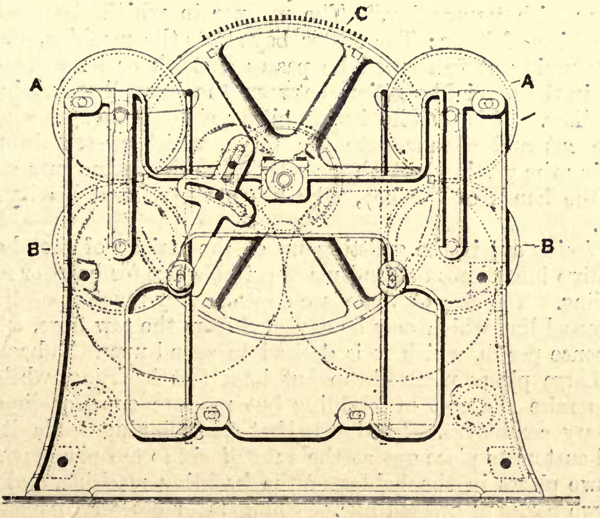


FIG. 9.—Flax and hemp cutter.

When a fine quality jute yarn is required, the root end of the fibre is usually cut off upon a steel blade about 3 feet long and 6 inches broad, fixed in a wooden frame. The hard root ends of some sorts of hemp are often combed off in a "knifing machine," consisting in a revolving-toothed drum and reversible feed rollers. Good quality jute, to be hackled and prepared as "long line," hemp for hand or machine hackling, and flax for "cut line," are cut into convenient lengths by the cutting machine shown in Figure 9. As it will be seen, this machine consists of four pairs of grooved and heavily loaded retaining rollers *aa*, *bb*, placed on either side of the quickly revolving cutter *c*, so that their point of intersection lies in the same vertical plane as the periphery of the cutter, from which they are distant about one inch on either side. The cutter is about 21 inches in diameter, and will work well when turning at the rate of about 1000 revolution per minute. The best blades are built up of three steel rings, each about $\frac{1}{4}$ inch thick, placed side by side and keyed up the cutter spindle, one end of which carries the driving pulley, and the other a pinion, which drives, through intermediate and reducing gearing, the holding rollers *a, b* at two or three revolutions per minute. Projecting from the rim of each of the rings composing the cutter blade, are diamond-shaped teeth placed at distances of about 3 inches apart. These teeth must be quite blunt, as it is most important that they should break through, and not shear the fibre, for reasons which will be fully explained in our next chapter when dealing with "spreading." The manner in which the machine is worked is as follows: The cutter boy starts the machine, and while it is running at full speed he passes a strick or large handful of fibre, in the required position, between the inwardly-revolving holding rollers. It is thus held upon either side of the spot where it is to be cut and advanced to the blade, which passes through it, severing the portions, which are released as the rollers turn onwards, into the hands of the boy, who has never relaxed his hold upon them.

Piecing out is the splitting up of the stricks of flax, hemp, or jute fibre into pieces or handfuls of suitable size for hand or machine hackling. The size of the piece depends very much upon the yield of dressed line which may be expected from the raw fibre, and upon the pence per lb. which it is desired to spend upon the hackling of it. Large pieces mean cheap but imperfect hackling, while small pieces raise the cost of hackling but produce superior line under ordinary conditions. In the Belfast flax-spinning trade it is the usual custom to piece out at the rate of six to ten pieces per lb., to put two pieces in the holder of the hackling machine, and to take out two pieces of dressed line. Spinners of coarser numbers often cheapen production by piecing out "double pieces," *i.e.* three or four per lb., one of which is put alone into the holder and taken out in either one or two pieces. The removal of the line in two pieces from the holder of the machine produces smaller pieces of dressed line, and tends towards better sorting and spreading, but of course adds to the cost of the former operation.

In piecing out, the root end of the fibre should be kept square and even. If the fibre is very valuable, or if it has been badly handled in the pulling or scutching processes, it must be "roughed" to avoid loss through the passage of long fibre into the tow. Roughing consists in first pulling the top end of the piece through a coarse hackle, in which are deposited any straggling fibres which are not held by the hand of the rougher, as well as any scutching tow which may have been allowed to remain in the end of the piece.

UNIVERSITY OF CALIFORNIA

Turning the piece the rougher treats the root end in a like manner, and then catching the longest of the fibres which remain in the hackle along with the piece, he draws them out in such a way that they again become part of it, their extremities lying level with the root end. The piece is thus squared to some extent, and its length made to correspond with that of the fibre. The rougher next proceeds to comb out the piece in order to straighten and render parallel any matted and displaced fibres which would otherwise find their way into the tow produced by the first round of hackles of the hackling machine. To do this he laps the piece once round his right hand and spreads the end well out between his forefinger and thumb, so that it may be well dispersed over the hackle. Two "blows" upon the hackle usually suffice to open the root end, after which the rougher laps the piece round the fingers of his right hand and the extreme end loosely round his "touch-pin," and with a sharp tug breaks off or pulls out any loose or irregular fibres which remain, and deposits them in the hackle. Turning the piece, he treats the top end in a like manner, and when finished lays it down upon his bench beside some others, withdrawing his hand in such a way that the lap or twist remains, thus effectually keeping the pieces separate and enabling them to be easily lifted by the machine boy without tossing. Layer by layer a bunch is produced weighing about 40 lbs., and tied round with three cords. The short fibre which remains in the rougher's hackle is "worked off" by him into the tow when it accumulates too much. The longest of the short fibres which remain in his hand are called "shorts." These he makes into a small bunch to be worked separately on the machine. A rougher's hackle is composed of steel pins about 7 inches long and 5 B.W.G. set in a beech stock or plank about 1¾ inches thick, 16 inches long, and 5 inches wide. The hackle proper, however, only covers an area of 9 inches by 4 inches in the centre of the stock, there being often eleven pins per row in length and five in breadth. The touch-pin is a square or triangular steel pin about 2 inches long, set in a wooden or metal block, which is bolted to the beam to the left-hand side of the hackle. The edges should be smooth but not sharp, for they must not cut the fibre. The roughing process well performed, including the piecing out of the fibre into pieces about ten per lb., must be paid for at the rate of about 1s. 8d. per cwt.

Hand-dressing or hand-hackling, which in the case of weak material often gives a greater yield of dressed line than machine hackling, is still practised, especially in small mills, on flax and hemp. The hand-dresser is provided with three tools, *i.e.* the rougher's hackle, a "ten," and a "switch." The first has been already described, the second is finer, having often 26 pins in the row, which is 7¼ inches long. There are usually 17 rows in breadth, making the tool 2⅜ inches wide. The pins should be about

4¼ inches long over all, and 13 B.W.G. The pins of the "switch" cover the same area, but are much closes set, 80 or 100 in the row being a suitable number for coarse flax and Italian hemp. There

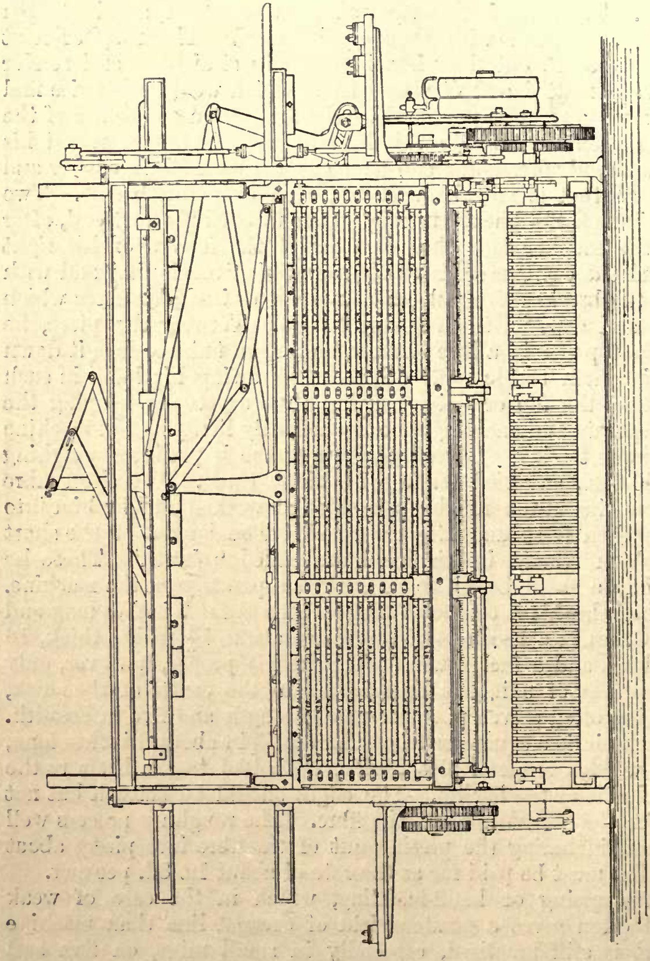


FIG. 10.—Horner's duplex hackling machine.

are usually 22 rows in the width of 2⅜ inches, and the pins are 2 inches long over all. The hand-dresser's first duty is to piece out and "rough" the fibre, even more thoroughly than already explained, and then to thoroughly hackle, first the root end and then the top, upon his "ten" and switch. This he does in spreading out the roughed piece as flat as possible, root end foremost, upon his "ten," before grasping it tightly in the middle with his right hand and pulling it repeatedly through the points of the hackle pins, turning the piece over once, so that both sides may be hackled alike. The same operation is repeated with the top end, and again with both ends, upon the switch before the piece is finished, when, holding the piece between the finger and the thumb of his left hand, he laps some of the fibres of the root end around the piece, forming a lap which keeps the pieces separate, when they are built into a bunch, and enables each to be lifted without tossing the others. Laying down the pieces in layers, one piece overlapping the other, he builds a firm bunch weighing about 20 lbs., ties it with three bands and "tipples up" the ends, when it is ready for the line store or spread board. "Tippling up" consists in bringing together the ragged ends of the pieces composing the bunch, and holding them in the left hand, in lapping around them, in the form of a top-knot, some of the loose fibres drawn out for that purpose.

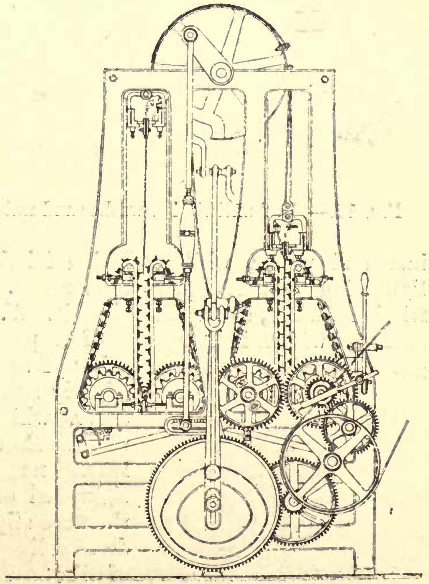


FIG. 11.—Horner's duplex hackling machine.

When flax, hemp, or jute is to be hackled by machine, the bunches of "roughed" pieces or the piles of "pieced out" fibre are removed to the machine room and placed upon the table at the "filling end" of one of the hackling machines shown in Figures 10, 11, 14, 15, or 16. All these machines are of what is known as the vertical sheet type, while they differ in the way in which the hackling sheets are stripped of tow; the machine shown in Figures 10 and 11 being of the stripping-rod type, while the others are of the brush and doffer type. In all, the pieces of fibre to be hackled are screwed into the holders seen in Figure 13. These holders consist in two plates of steel from 10 to 12 inches long and about

4 inches wide, bolted together by means of a screw and nut, as seen in the figure. The screw, of coarse pitch, say five per inch, projects from the centre of the lower plate, into which it is screwed, and secured at the back by a lock nut. Figure 12 shows a means of gaining increased power, while reducing friction and wear and tear, in tightening up the square holder nut. It represents Eves' anti-friction washer, as supplied by Mr. W. Carter, 28 Waring Street, Belfast, which is composed of a pair of circular steel washers, grooved as shown, to hold a ring of steel balls. The top washer is slightly taper, and is held in place by a cover, which is riveted to the holder plate as shown. The use of this washer leaves no excuse at all for badly tightened or slack holders, which let the fibre slip and diminish the yield of dressed line very materially. The inside of the holder plates are lined with corrugated rubber and thick flannel or felt, the former glued to the bottom plate and the latter to the inside of the lid. This lining aids materially in holding the fibre firmly, and prevents individual fibres from being drawn out. When the holder is tightened up it should be impossible to pull out any of the fibre it contains, but in order that that may be so the pieces must be evenly spread over the length of the holder. The machine boy or "filler," whose duty it is to put the raw fibre into the holder, takes either two single pieces from the rougher's bunch or one piece of double pieced roughed or pieced out fibre, and spreads

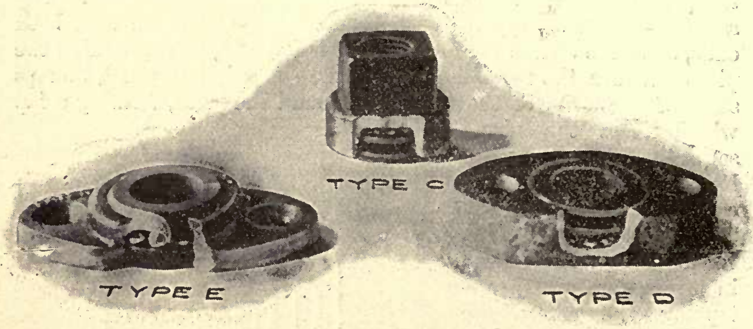


FIG. 12.—Eves' antifriction washer and nut for hackling machine holders.

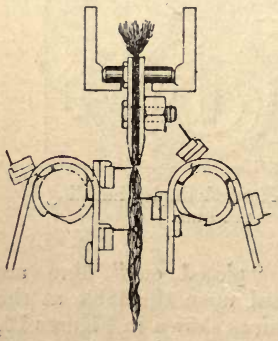


FIG. 13.

it evenly over the length of the holder which lies open upon the table before him. In the former case he spreads a piece on either side of the holder screw, and in the latter case he opens the piece slightly in the middle to permit of the passage of the holder-screw.

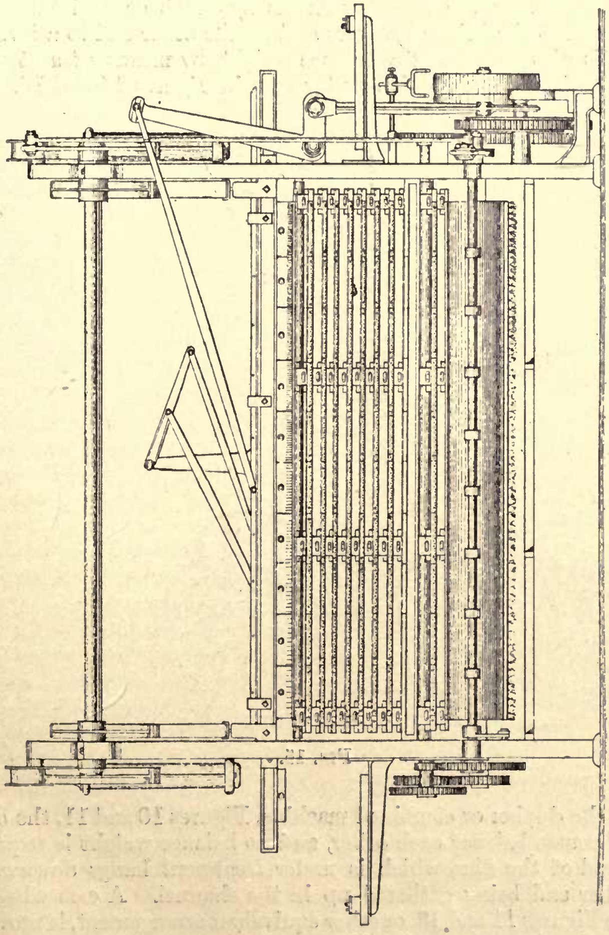


FIG. 14.

When uncut fibre is being dealt with, the root end should be kept to the front and allowed to project a distance equal to rather less than half the total length of the fibre. When cut fibre is under treatment, about half the total length should be left protruding from the holder. The holder is then slid into the channel or head of the machine, which, as can be clearly seen from Figure 13, consists in two angular bars, along which the holder slides upon pins projecting from the holder plates. The channel extends the whole length of the machine, and, as may be seen from Figure 15, is suspended vertically over and between the hackling sheets by straps or chains attached at one end to the bridge brackets and at the other end to a lever, to which is also suspended a balance weight, by means of a strap or chain passing over the guide pulley seen in Figures 15 and 16.

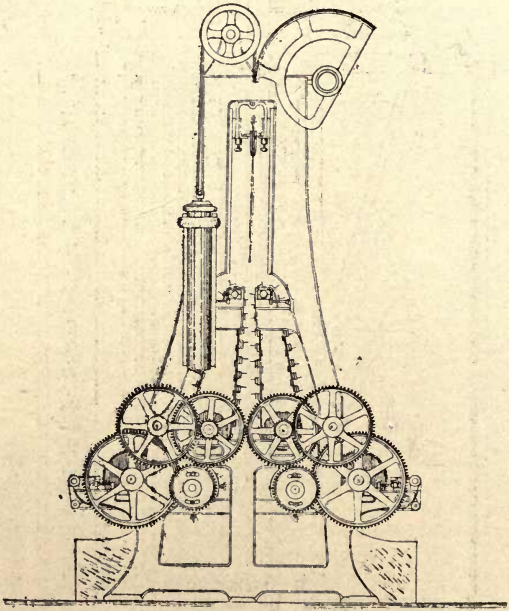


FIG. 15.

In the duplex or combined machine, Figures 10 and 11, the channels of course balance each other, and no balance weight is required. That end of the fibre which is under treatment hangs downwards, the other end being gathered up in the channel. A cam wheel, as seen in Figures 11 and 16, or other equivalent arrangement, is provided to give the channel or "head" a regular up-and-down motion with or without a "rest" at the top, and generally with a rest of fixed or variable duration at the bottom. In the duplex machine of course the rest at top and bottom must be equal, since the rest at the bottom of one side of the machine coincides with the top rest of the other. The lifting cam is not seen in the figure, being upon the reverse side of the wheel. The eccentric channel seen on the front face of the head wheel in Figures 11 and 16 is provided as a means of shifting the holders forward, a distance equal to their own length or to that of each tool, while the head is rising or while at rest at the top. This arrangement is quickly going out of fashion, however. It is being superseded by Cotton's bevel gear arrangement, actuated from the top lifting shaft. In any case, a catch bar, carrying "dogs," is moved forward with each rise of the "head," and drawn back again as the head descends. As it moves forward, the "dogs" upon the catch bar engage with the projections upon the holders, and move them the required distance along the channel. As the catch-bar draws back, the "dogs" slip over the holders they encounter, being inclined at such an angle that while they can push they cannot pull. The two endless revolving sheets of hackles, between which the end of the piece of fibre hanging from the holder is lowered as the head descends, is formed upon endless leather straps, about 70 inches in circumference, running around the sheet rollers seen in the figures. These straps or "leathers" are united by bars, twenty-four to thirty of which form the round. The leading makers of hackling machines adopt the Cotton system of fastening the bars to the leathers by means of brass eyelets, which serve the purpose of receiving the conical projections upon the bottom sheet roller, insuring the turning of the sheet without slippage.

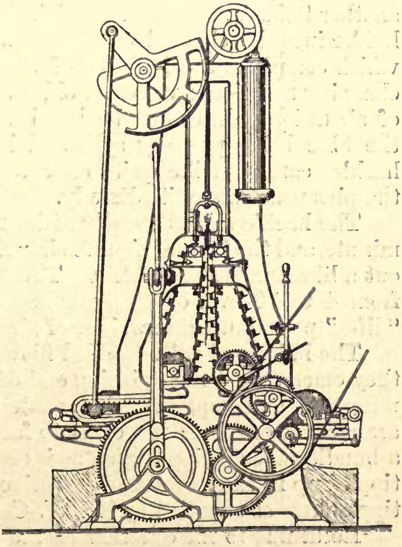


Fig. 16.

The hackles, which are pieces of wood 10 to 12 inches long, 1 inch broad, and $\frac{3}{8}$ inch thick, set with one or two rows of steel pins $\frac{1}{4}$ to 50 per inch in the row, are not directly attached to the bar. They are screwed to wing pieces which project from it, and which rise tangentially to the top sheet roller as the bar passes round the latter, thus causing the pins of the hackle to strike directly into the fibre close to the "nip" of the holder. The hackle stocks should be covered with sheet brass to prevent the wood splitting, as it is apt to do, especially in the finer hackles. One row of pins in the hackle is now becoming the almost universal practice in brush and doffer machines, as the brush is not capable of passing through and properly cleaning two rows of closely set pins, especially if the material being hackled is at all gummy. Upon entering the machine the fibre is first exposed to the action of the coarsest round of hackles, and then, as the holder moves onward by degrees, to succeeding finer and finer rounds of hackles. When the holder is at length pushed out at the finishing end of the machine, it is taken by a boy called the "changer," who places it in a stand upon his table, spreads and tightens the hackled end of the fibre into another holder, unscrews the original holder and introduces the new holder into the channel of the second machine, similar to the first, which completes the hackling of the piece in its entire length. In changing the piece from one holder to the other, a "shift" or space of about 1½ inches must be left between the holders to ensure of the fibre being properly split and hackled at this part, since the hackles cannot strike quite close to the nip of the holder, nor do the pins penetrate quite directly.

The hackle sheets usually make four to twelve revolutions per minute, and the "head" four to six "lifts" in the same time, throwing out a like number of holders. Thus a pair of machines can hackle from 4 to 10 cwt. of fibre per day of ten hours, according to the "lifts" per minute and weight of pieces.

The holders of fully hackled fibre are taken by a machine boy as they emerge from the finishing end of the channel, placed in a stand, unscrewed and emptied of their contents. The pieces of hackled fibre are crossed one over the other to facilitate lifting, and formed into a bundle called a tipple, such as is seen in Figure 17, the ends being tippled up in the way already described. Figure 17 represents Eves' tipple press as supplied by Mr. W. Carter 28 Waring Street, Belfast.

Returning to the question of the stripping of the tows from the hackles upon the revolving vertical sheet, the stripping-rod method, which will no doubt in time become obsolete, consists in the use of stripper rods or wooden laths 3 to 4 feet long, about 2 inches broad and ¼ inch thick, which, shod with metal ends or "stripper cocks," work in radial slots in the bottom sheet rollers. With the revolution of these latter rollers the stripper rods shoot out by gravity to the lower end of their slots as they pass under the centre of the roller, falling back again to the other end of the slot when they get over the centre again. When falling outwards the rod passes close to the pins of the hackles, loosening the tow from them, the tow being received upon a "tow-catcher" or oscillating board armed with spikes upon one edge, which deposits it in the tow box every time the head rises.

When the brush and doffer stripping method is employed, a wooden roller set with about eight straight rows of hair, brushes the tow from the hackles as they pass round the bottom sheet roller, the speed of the brush being so regulated to the speed of the sheet that each row of hair or bristles strikes each row of hackles at the proper moment and at the correct angle, so that the tow is neither beaten into the hackle nor the stock of the latter touched. The leading continental maker of hackling machines keeps his brush rollers farther out than in English practice, the bristles consequently striking the hackles later, and when the pins of the latter are in a more horizontal position. Some spinners are of opinion that this arrangement of the brush produces better tow. The brushes deposit their tow upon revolving doffers or rollers about 14 inches in diameter, covered with knee bent card filleting, which retains the tow until it is stripped off by an oscillating doffer knife, which strikes it down into the tow boxes placed underneath.

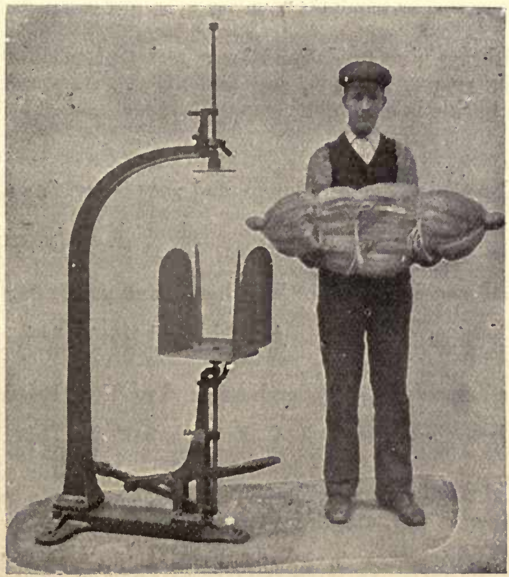


Fig. 17.—Eves' tipple press.

The niceties of machine hackling, which are not generally understood by spinners, especially those engaged in the coarse end of the trade, consist in attention to those details which influence the yield in dressed line under a given amount of hackling. Such details are the gradation and grouping of the hackles, and their intersection, as well as the length of the "shift."

As already explained, when the rough fibre is put into the machine it is first hackled by the coarser tools, and then by the finer. The hackles must get very gradually finer, for if the number of pins per inch increases too rapidly the space between the pins is not sufficient to allow the coarser fibres to pass, and they are consequently cut away or broken, and pass into the tow. Gradation, then, is the rate at which the succeeding tools become gradually finer. In arranging the gradation it must be borne in mind that a rise of say six pins per inch in the finer hackles is no more severe on the fibre being hackled than a rise of ¼ pin per inch in a coarse hackle.

Herewith we give gradations for a series of machines suitable for hackling coarse, medium, and fine fibres. As a single row of pins in the hackle is now pretty general, all tools are to be considered as such.

9-tooled machine for jute, hemp, and very coarse flax:

Pins per inch	¼	⅜	½	¾	1	1½	2	4	6
No. of wire B.W.G.	10	11	12	14	15	15	16	17	18

12-tooled machine for finer jute, hemp, and coarse flax:

Pins per inch	¼	⅜	½	¾	1	1½	2	3	5	7	10	14
No. of wire B.W.G.	10	11	12	14	15	15	16	16	17	18	19	20

14-tooled machine for Italian hemp and medium Russian flax:

Pins per inch	¼	⅜	½	¾	1	1½	2	3	5	7	10	14	20	28
No. of wire B.W.G.	10	11	12	14	15	15	16	16	17	18	19	20	22	24

16-tooled machine for medium Flemish, Irish, Dutch, and Courtrai flax, fine Russian flax, and fine Italian hemp:

Pins per inch	¼	⅜	½	¾	1	1½	2	3	5	7	10	14	20	26	34	42
No. of wire B.W.G.	10	11	12	14	15	15	16	16	17	18	19	20	22	24	26	28

18-tooled machine for fine Dutch, Flemish, Irish, and Courtrai flaxes:

Pins per inch	¼	⅜	½	¾	1	1½	2½	4	6
No. of wire B.W.G.	10	11	12	14	15	15	16	17	18
Pins per inch	8	11	14	18	22	26	33	40	48
No. of wire B.W.G.	19	20	21	22	23	24	25	26	28

20-tooled machine for fine Courtrai flax, etc.:

Pins per inch	½	⅝	¾	1	1½	2	3	5	7	10
No. of wire B.W.G.	12	13	14	15	15	16	16	17	18	19
Pins per inch	14	18	22	26	30	34	38	44	50	56
No. of wire B.W.G.	20	22	23	24	25	26	27	28	29	30

The total length of the pins should be about 1 inch, which gives a good stiff hackle. If large double pieces are being worked a 1⅛-inch pin is sometimes used, but in order that the hackles may not be weakened it is desirable to employ a rather heavier wire in this case. Intersection is the amount by which the points of the pins in the hackles on one sheet overlap those upon the other sheet.

It is the custom in many mills to open out the sheets at the coarse end of the machine, so that there is a space of about ⅛ inch between the points of the pins of opposite hackles, the object being to attack the fibre gradually. The idea is, in the writer's opinion, a mistaken one, as the centre of the piece remains untouched until it is attacked by fine hackles, which break away the coarse unprepared fibre. If the gradation of the machine is right, the proper way is to set the pins point to point at the coarse end and to give them an intersection of $\frac{1}{16}$ to ⅛ inch at the fine end of the machine. The points of the pins upon either sheet should of course be equidistant from a line dropped perpendicularly from the centre line of the holder when in the channel, due allowance being made for the thickness of the piece in the holder, and the angles which the sheets make with this line should of course be similar on either side.

In the construction of the hackles for the machine the hackle-maker should make all the coarser hackles, say up to 20 per inch, in groups or series, no two hackles in the same group being *exactly* similar as regards the position of the pins, the object of grouping being to avoid the striking of the fibre in exactly the same place by the pins of the following hackles. The number of hackles in the group depends upon the number of bars in the round upon the vertical hackle sheets. For coarse hackles the number of hackles in the group may correspond with the number of bars on the hackle sheet, but for finer hackles it is quite sufficient that the number of hackles in the group is a factor of that number. For instance, in a 24-barred machine the hackles up to 8 per inch may be grouped in 24, while for those of from 8 to 20 per inch it will be quite sufficient to group in 8 or 6.

A very good method of grouping the hackles while under construction is to place together upon a flat surface, squarely and evenly, a number of hackle stocks exceeding by one the number of hackles in the group, and then to trace the position of the first pin in the first hackle at a distance from its end consistent with strength, and that of the first pin in the last hackle at a similar distance plus the pitch of the pins. In joining these two points together, a line will be drawn upon which the first pin in each hackle of the group must be placed, the extra hackle stock being of course put to one side and used over again. The remaining pins in each hackle are of course spaced off at their proper distances, starting from the first, the position of which has been found as described. The hackles in the group should be numbered consecutively. In screwing the hackles upon the sheet, all the No. 1 hackles of each sort should be placed upon the same bar. Of course when there are groups of 6, 8, 12 and 24, for instance, this is only possible with one bar. In setting the sheets to each other, this No. 1 bar on one sheet should follow No. 12, for instance, upon the other, the hackles furthermore being evenly spaced, as seen in Figure 13, so that there may be no possibility of their striking and injuring one another. The distance from the nip of the holder, at which the pins first strike the fibre, should be carefully noted. Double this distance, plus about ½ an inch, gives the distance which the two holders must be apart when in their stands at the changing end, so that the fibre may be thoroughly hackled throughout its entire length without loss of yield through being unduly hackled in the centre.

The sheets are usually run at from 6 to 12 revolutions per minute, the hackles consequently striking the fibre at the rate of from 144 to 360 strokes per minute. Their speed may of course be counted, but the calculation is made as follows:

Speed of the line shaft, say 180 revolutions

Drum on line shaft	12 inches	diameter
Pulley on machine	20	,,
Sheet pinion on pap of pulley	24	teeth
Stud wheel	90	,,
Sheet change pinion, say	48	,,
Sheet wheel	90	,,
Pitches in sheet roller	10	
Bars in sheet	24	

$$\text{Speed of sheets} = \frac{180 \times 12 \times 24 \times 48 \times 10}{20 \times 90 \times 90 \times 24} = 6{\cdot}4 \text{ revolutions.}$$

The speed of the head of the same machine may be calculated with the aid of the following additional particulars:

Head pinion on pap of pulley	22	teeth
Stud wheel	98	,,
Head change pinion, say	21	,,
Head wheel	112	,,

$$\text{Speed of head} = \frac{180 \times 12 \times 22 \times 21}{20 \times 98 \times 112} = 4{\cdot}5 \text{ lifts per minute.}$$

When the end of the piece is very hard, flat-fibred, or nappy, an end-comb, such as is shown in Figure 18, may often be used with advantage. It is geared up at the fine end of the machine, the channel of which is prolonged so that it overhangs the sheets of the comb. The latter may be raised or lowered by means of the square threaded screw seen at the bottom of the figure, so that any desired length of the end may be acted upon. The single round of hackles upon its sheets are much finer than the finishing round upon the hackling machine proper, so that all naps may be removed and flat fibres cut away.

Erskine's ending machine is applied in a similar manner. It has no hackles, but a pair of scored rollers, pressed together and turning inwards, draw off the loose fibres and break off or cut away as much of the end as required.

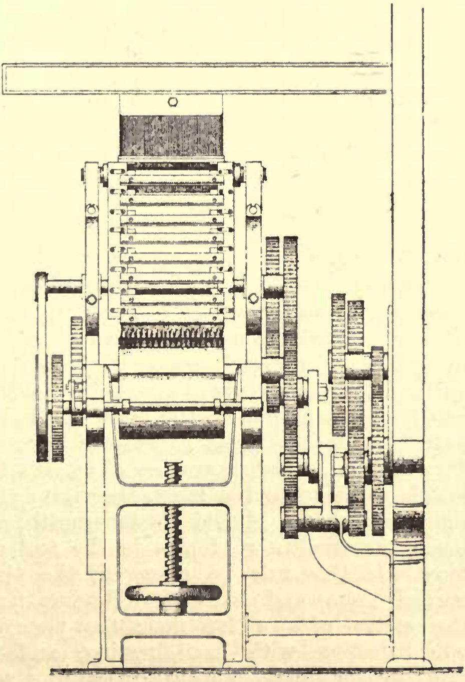


Fig. 18.—Cotton's ending machine.

The sorting process is one which it is only advisable to add when expensive fibre, such as the better class flaxes, are being dealt with. Flax to be sorted is taken in tipples from the hackling machine to the sorting shop. The sorters are provided with "berths" similar to those of the hand-dressers. They require but two tools, the "ten" or "eighteen" and the switch, the latter sometimes supplemented by a "nap extractor." The latter is a single row of very closely set flat pins, edge on, soldered between two strips of brass, attached to the stock of the switch in such a way that the extractor is in reality an extra row of pins placed in front of the others. The pins per inch in the extractor should be at least five points finer than in the switch. Thus an extractor set with pins 42 per inch may be used with a 280 switch. Since the sorters are often required to break the ends of the piece with the object of removing impurities, they are generally also provided with a touch-pin.

The operation of sorting is as follows: The sorter places a tipple of machined flax, the root ends away from him, upon his berth in front and to the left of him. He untipples the ends, and lifting off a piece, spreads the root end smoothly and evenly over his "ten," and grips it tightly close to the holder mark in his right hand, forefinger underneath and thumb on top, well spread out, fan fashion, between the two. He draws it twice through his "ten," and then wrapping the piece around the fingers of his right hand, he catches the extremity in the fingers of his left, and wraps it loosely and without twist around his touch-pin. With a sharp and dexterous jerk the end is severed and laid beside his touch-pin, to be worked up with other ends into a separate bunch. He gives the root end one or two more blows upon the "ten" before finishing it upon his switch, concluding by "nipping the end" or lapping any loose fibres remaining in the extremity around the corner pins of his tool and thus pulling them out, taking care to support the pins and hold the fibre tightly close up to the hackle with the fingers of his left hand while so doing, lest either pins or fibre should be broken. Turning the piece upon his knee, he repeats the same operation with the top end of the piece, giving it additional work upon the switch, however, in order to work out any "naps" which may remain in the end. It takes some time for an apprentice hackler to learn how to switch out the end properly. It is done by a series of short, quick strokes, more easy to demonstrate than describe. The support which should be lent to the piece by the left hand placed close up to the hackle is of great importance in preventing breaking of the fibre and an undue proportion of sorter's tow. The sorter should hackle right up to the hand, that is to say, the forefinger of his right hand, which should be underneath, as we have said, should touch the front row of pins in the tool every time he makes a blow. If this rule be observed, the piece will be thoroughly opened from end to end. Having "nipped" the top end, the sorter puts a lap upon the piece, in the way described when dealing with hand-dressing, and builds it with others into one of several bunches, according to the quality he finds in it.

It is a very general practice in the fine trade to number the flax upon the warp number principle, that is to say, fibre supposed to be fit to spin a good 25's warp, for instance, is termed 25's, and so on. Weft flax classed on this basis will spin up on the basis of 40's for 100's ordinary weft, and to higher numbers in proportion to the squares of the warp numbers. The bunches of fine and valuable fibre are well worth the expense of being covered with paper or enveloped in a linen cloth to protect them from the dust and light when put into the line store for a considerable time. The line store should be cool and dry, and kept as dark as possible, and should be conveniently situated with regard to the preparing room. One or more clerks should be employed to weigh the machine tow and tipples, "weigh in" the sorters' dressed line and tow, "weigh out" line to the preparing room, and post up the lot book and other books recording these weights, so that the average sort and yield of dressed line, together with its cost, may be made out whenever a "lot" is complete.

The machine tows are usually divided into four numbers, 1, 2, 3, and 4, the tow boxes being subdivided with that object. Taking the coarsest first, we have then the Roughing Tow, Nos. 1, 2, 3, and 4 machine tow, and the sorters' tow, their relative values being often in the ratio of 32, 35, 38, 40, 42, and 46. If the tow store is situated underneath the machine room, as it conveniently may be, the bales of tow may be thrown down through a series of trap-doors, according to its quality, and the labour of sorting the tow reduced to a minimum. In the tow store the various sorts of tow are mixed according to quality and price to obtain large blends, or lots of good average quality and colour. In making the mixes, the bales of tow should be opened out and the tow spread in layers over the entire surface occupied by the blend. The tow being then taken "out of the face," the dangers of "striped" and uneven yarn are minimised.

The quantity of dust given off in the roughing, machining, and sorting of flax, and in the hackling of hemp and jute, render a thorough ventilation necessary to the health of the workers in this department of the mill. The dust given off is composed of earthy particles, of small pieces of woody matter, and of short fibres. In fine dust there is a high percentage of flinty particles, which have a particularly injurious effect upon the lungs. The ventilation of the hackling machine room is very difficult. Too strong suction below the machine may cause the fall and loss of fibres from the brush or doffer. The author advises the use of underground suction ducts of about 100 square inches section, covered with movable covers, which can be removed for cleaning and permitting of frequent small suction openings. In addition, and in order to assure a *plenum* in the room and to replace the air which has been evacuated by pure air, either cold, hot or moist, according to the weather, a centrifugal blower should be used to blow fresh air through distributing ducts placed overhead, and thus produce fine and well distributed downward currents of air, which will prevent the dust from rising and spreading, and cause it to settle and be drawn away.

Figure 19 shows a system of machine room ventilation which has been adopted in some continental mills. It will be seen that practically the whole machine is covered in, there being a dust chamber underneath the machine exhausted by the fan shown, which expels the dust along a common flue connected in a similar manner with other machines.

In the hand-hackling shops (roughing, hand-dressing and sorting) dust rises from the fibre as the workman pulls the handfuls through the hackle. The simplest and best way of drawing off this dust is that shown in Figure 20, a system now rendered obligatory by the English, French, and Belgian factory inspectors. It consists, as will be seen, in placing a suction duct behind the tow boxes and extending the whole length of the row of benches. This duct has an opening opposite each berth, through which the dust is drawn downwards and away from the mouth of the hackler. In order that the openings close to the fan may not draw too strongly whilst the others produce but little useful effect, it is necessary either to diminish the section of the duct as it recedes from the fan, or to increase the size of the openings in proportion to their distance from the fan.

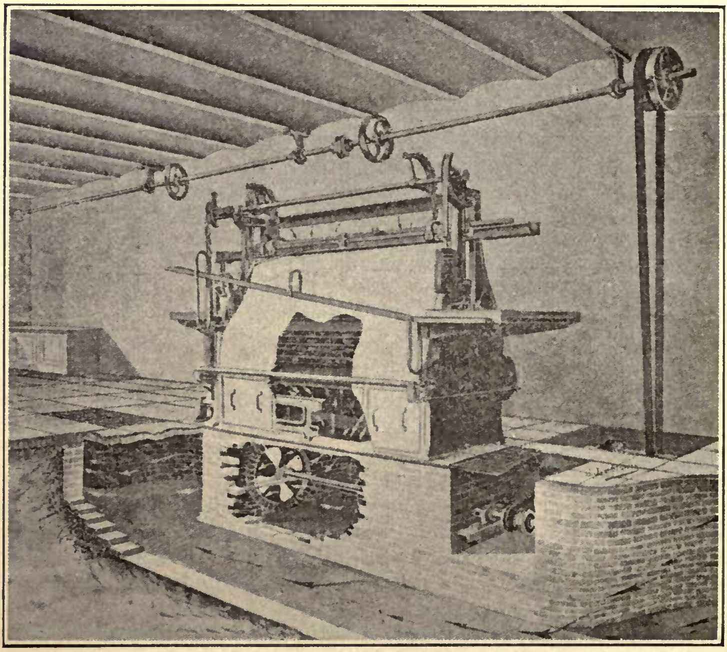


Fig. 19.—Machine-room ventilation (Huglo's system).

The English law requires the exhaust draught in hand-hackling, roughing, and sorting shops to have a minimum velocity of 400 feet per minute, and fixes at 50 square inches the minimum area of the

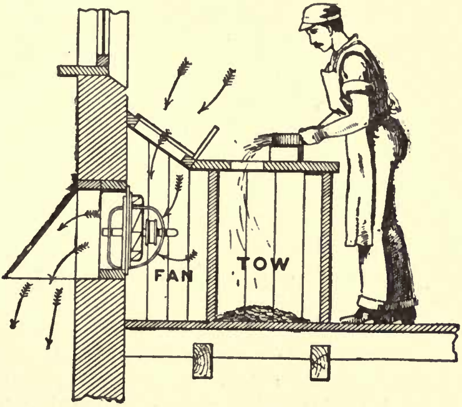


FIG. 20.—The ventilation of hand-hackling shops.

exhaust openings opposite to each hackler. These openings should be covered with wire gauze or perforated zinc, to prevent the passage of fibre.

CHAPTER III

SLIVER FORMATION

THERE are two ways of forming flax, hemp, and jute fibre into sliver, *i.e.* spreading and carding. The former is only possible when dealing with fairly long fibre in comparatively parallel order. The latter is applicable to both long and short fibre, whether parallel or entangled in the form of tow. When long fibre is carded it is said to be "broken up." Carding is the cheaper process, and is the only one applicable to tow, while by reason of its cheapness and because it combines hackling and cleaning with sliver formation, it is generally adopted for coarse cheap fibre, such as jute, low class flax, aloe fibre, etc.

Figure 21 shows a jute breaker, as made by Messrs. Fairbairn Macpherson, Leeds, the type of card used for "breaking up" jute, hemp, and coarse flax. In the flax trade it usually goes by the name "Devil Card." Such a card is often composed of a main cylinder of 6 feet face and 4 feet in diameter, striking downwards, two pairs of workers and strippers, one feed roller and shell, one doffer with drawing-off rollers, and two tin rollers below the strippers. The effective diameter of the workers is 8½ inches and of the strippers 12½ inches. The doffer is about 15 inches, and the feed roller 10½ inches in diameter. The feed sheet rollers and the drawing-off rollers are both 4 inches in diameter. The action of this card is as follows: The fibre, spread as evenly as possible upon the feed sheet, is drawn in between the feed roller and the shell, being broken up over the edge of the latter by the downward blows of the cylinder pins. The latter carry the fibre forward to the first worker, the pins of which, set in the opposite direction to those of the cylinder, comb out, clean, and parallelise it. The workers make about 20 revolutions per minute, turning in a direction such that their pin points recede before those of the cylinder. The fibre which remains embedded in the worker pins is stripped off by the action of the stripper, which, making about 130 revolutions per minute, strips the worker, and is in turn itself stripped by the cylinder, which has a surface speed about five times superior to that of the stripper. The same cycle of operation takes place in connection with the second worker and stripper, the fibre being further cleaned and parallelised before passing on to the doffer,

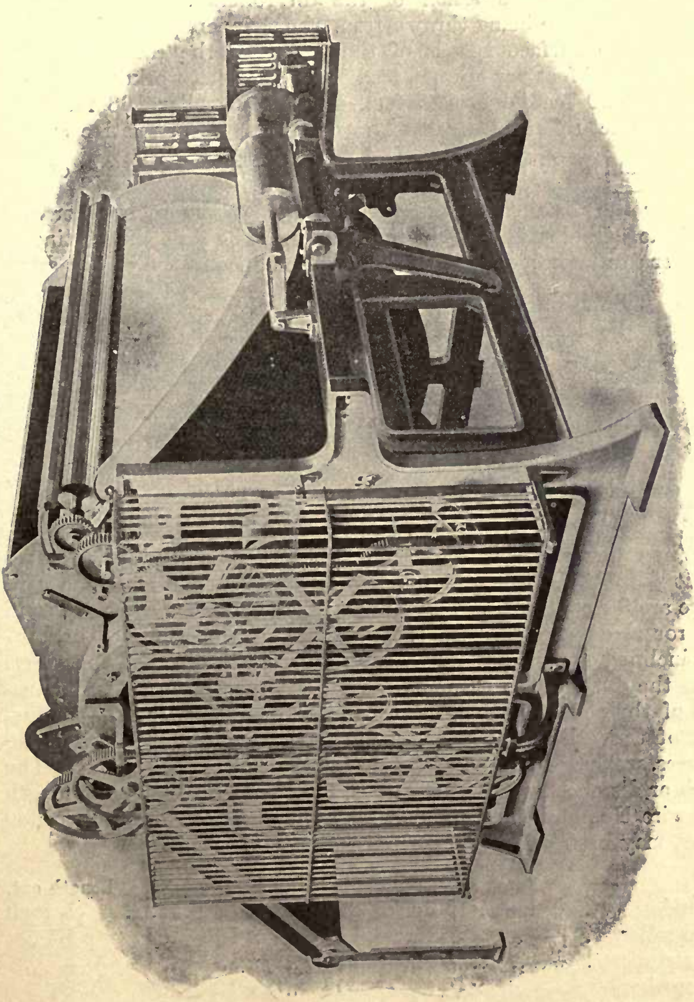


FIG. 21.—Breaker card.

which, turinng in the same direction as a worker, produces a like effect. It is, however, stripped by a pair of metal rollers extending across its face, which, being closely set, seize the long fibre and deliver it in parallel order, in the form of a fleece, down the inclined condensing conductor to the delivery roller, which, being provided with a calender roller, compresses it and delivers it into a can in the form of sliver. The action of the tin rollers referred to, is to prevent long fibre being thrown from the strippers producing waste. The relative surface speeds of the rollers of the card are thus: cylinder 2470 feet per minute, feed roller $12\frac{1}{2}$ feet, workers $47\frac{1}{2}$ feet, strippers 420 feet, doffer 85 feet, drawing-off roller 168 feet, and of feed sheet roller $11\frac{1}{2}$ feet. The draft, being the relative speeds of feed and delivery, is thus $\frac{168}{11 \cdot 5} = 15$ nearly. The setting of the card, or the distance of the various organs from each other and from the cylinder, is of great importance. The following setting of breaker card corresponds with the usual practice in the jute trade:

Shell to cylinder . . .	$\frac{7}{16}$ inch
Feed roller to shell . . .	No. 9 B.W.G.
„ „ cylinder . .	„ 16 „
No. 1 worker to cylinder . .	„ 12 „
No. 2 „ „ . .	„ 14 „
Strippers to workers . . .	„ 16 „
Strippers to cylinder . .	„ 14 „
Doffer to cylinder . . .	„ 16 „
Doffer to drawing-off roller .	„ $\frac{3}{16}$ inch

The rollers and cylinder are covered with beech "lags" or staves about $\frac{3}{4}$ inch thick and 2 feet long. Thus in a 6-foot face card there are 3 rounds of staves on the roller, the number of staves in the round depending upon the diameter of the roller. The pins are inclined at various angles according to the duty of the roller. Thus the duty of the strippers being to carry the fibre, the inclination of their pins to the surface is but 30 degrees, while the inclination of the others are often—cylinder 75 degrees, feed rollers 60 degrees, workers 40 degrees, and doffer 35 degrees respectively. The pitch or distance, apart of the pins, together with their total length and wire No., and the distance which they project from the wooden stock, may be taken as follows for a jute-breaker card:

	Pitch of pins.	Pins.	Length out.
Cylinder .	$\frac{5}{8}$ inch × $\frac{5}{8}$ inch	1 inch × 12 B.W.G.	$\frac{5}{16}$ inch
Feed roller .	$\frac{7}{16}$ „ × $\frac{7}{16}$ „	$1\frac{1}{4}$ „ × 12 „	$\frac{3}{8}$ „
1st stripper .	$\frac{1}{2}$ „ × $\frac{1}{2}$ „	$1\frac{1}{4}$ „ × 13 „	$\frac{1}{4}$ „
1st worker .	$\frac{7}{16}$ „ × $\frac{7}{16}$ „	$1\frac{1}{2}$ „ × 13 „	$\frac{3}{8}$ „
2nd stripper .	$\frac{1}{2}$ „ × $\frac{1}{2}$ „	$1\frac{1}{4}$ „ × 13 „	$\frac{1}{4}$ „
2nd worker .	$\frac{7}{16}$ „ × $\frac{7}{16}$ „	$1\frac{1}{2}$ „ × 13 „	$\frac{3}{8}$ „
Doffer . .	$\frac{3}{8}$ „ × $\frac{3}{8}$ „	$1\frac{1}{8}$ „ × 14 „	$\frac{5}{16}$ „

Jute breakers of this sort are sometimes provided with two doffers instead of only one. For some classes of work, such as sacking wefts, for instance, an up striker breaker card is preferred by spinners. In this make of card the feed is below the level of the centre of the cylinder, while the workers and strippers are upon the top of the card instead of being below it, as in the down striker card. Figure 22 shows a finisher card for jute, as made by Messrs. Fairbairn Macpherson, Leeds. It is fed with sliver furnished by the breaker card shown in Figure 21. These slivers may either be wound in rolls or laps or fed from cans. They pass to a pair of porcupine feed rollers or shell feed, the fibre being then carried round by the cylinder as before, and carded by a series of pairs of workers and strippers, before being deposited upon the doffer, from which it is stripped by rollers and condensed into a sliver.

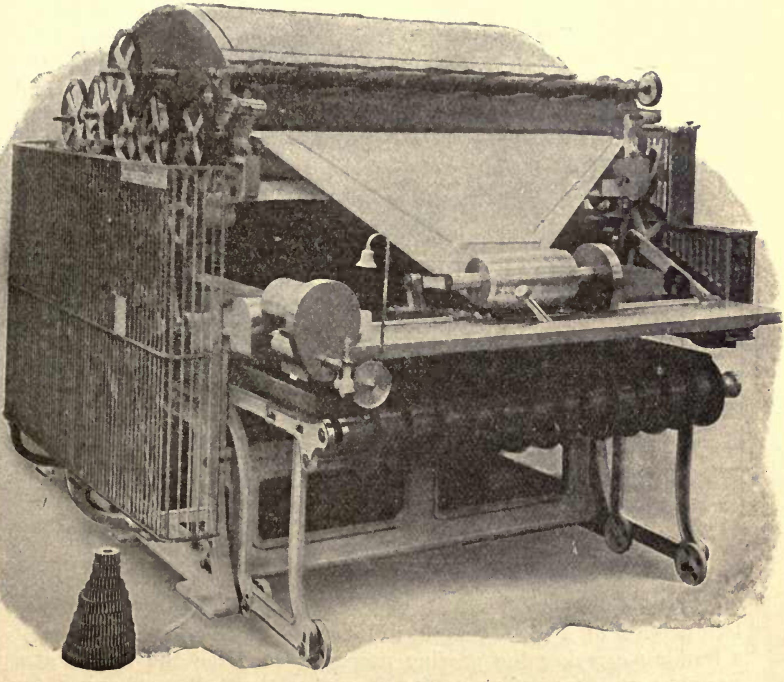


Fig. 22.—Finisher card.

Suitable speeds, settings, and covering for a card of this description are the following:

Draft	14.
Speed of cylinder	185 revolutions.

Speed of	Nos. 1 and 2 strippers,	145 revolutions per minute.
,,	Nos. 3 and 4 ,,	175 ,, ,,
,,	Nos. 1, 2, 3, and 4 workers	$8\frac{1}{2}$,, ,,
Diameter of	strippers . .	12 and 10 inches.
,,	workers . .	8 inches.
,,	doffer . .	15 ,,
,,	drawing-off roller .	4 ,,

The feed roller may be $\frac{3}{16}$ inch from the shell, and the shell $\frac{1}{4}$ inch from the cylinder. The feed roller may be distant from the cylinder, 16 B.W.G.; first worker, 14 B.W.G.; second, third, and fourth workers, 16 B.W.G.; strippers, 16 B.W.G.; and doffer, 14 B.W.G. The distance between workers and strippers should be equal to 16 B.W.G.; and between the doffer and drawing off roller, 10 B.W.G.

Specification of Clothing.

	Pitch of Pins.	No. of Wire.	Total Length.	Length out.
	Inch.	B.W.G.	Inch.	Inch.
Cylinder	$\frac{7}{16} \times \frac{7}{16}$	15	$\frac{7}{8}$	$\frac{9}{32}$
Feed roller	$\frac{3}{8} \times \frac{3}{8}$	14	$1\frac{1}{8}$	$\frac{3}{8}$
1st and 2nd strippers .	$\frac{7}{16} \times \frac{7}{16}$	14	$1\frac{1}{8}$	$\frac{7}{32}$
3rd and 4th ,, . .	$\frac{3}{8} \times \frac{3}{8}$	15	$1\frac{1}{8}$	$\frac{7}{32}$
1st and 2nd workers . .	$\frac{3}{8} \times \frac{3}{8}$	14	$1\frac{1}{2}$	$\frac{5}{16}$
3rd and 4th ,, . .	$\frac{5}{16} \times \frac{5}{16}$	15	$1\frac{1}{2}$	$\frac{5}{16}$
Doffer	$\frac{5}{16} \times \frac{1}{4}$	16	1	$\frac{9}{32}$

The sliver lap machine required to form the breaker sliver into laps or rolls of a given length, to feed the finisher card, consists of a framing carrying the gearing necessary to drive the bobbin at a variable speed according to its diameter, the bell machanism for determining the length of sliver in the lap and a calender roller for compressing the lap. The bobbin or tube upon which the lap is formed is driven through intermediate gearing by a friction disc, about 28 inches in diameter, driving a bowl sliding upon a vertical shaft. Upon the upper extremity of the vertical shaft is keyed a bevel pinion of say sixteen teeth driving a bevel wheel of sixty teeth working upon a stud. Compounded with this latter wheel is a spur pinion of twelve teeth gearing into the bobbin wheel of eighty-four teeth. As the bobbin increases in diameter the calender roller is forced upwards, carrying with it the rack and sliding friction bowl, which is thus brought nearer to the centre of the friction disc, and is thus driven slower and slower as the lap increases in diameter, the surface speed of the latter remaining constant, however, the while.

Figure 23 shows a breaker finisher card, as made by Messrs.

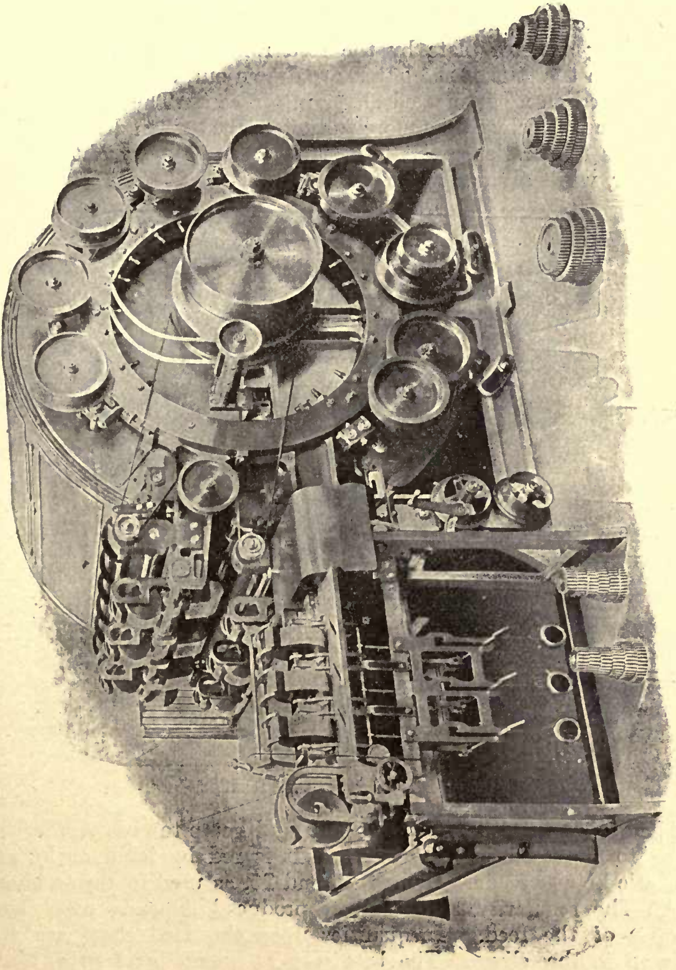


Fig. 23.—Tow finisher card.

Fairbairn Macpherson, Leeds. with two doffers, $8\frac{1}{2}$ pairs of rollers, and drawing head, designed to break up and card in one operation jute, flax, and coarse tow, etc. This is a full circle down striker card with porcupine or shell feed. The doffers are stripped by quickly vibrating knives, and the fleece drawn off each in three sections through trumpet-mouthed conductors by drawing off rollers. The three slivers from the top doffer pass down at the back of the drawing-off rollers of the lower doffer, and unite with the three slivers produced by the latter. The three combined slivers are then drawn along a sliver plate by the feed roller of a drawing head, pass through the gills of the latter, are drawn out, doubled together, and delivered in a compressed sliver into a can. The duty of the drawing-head, which will be more fully described when dealing with drawing, is to parallelise the fibres and reduce the weight of the card sliver, while giving it more strength.

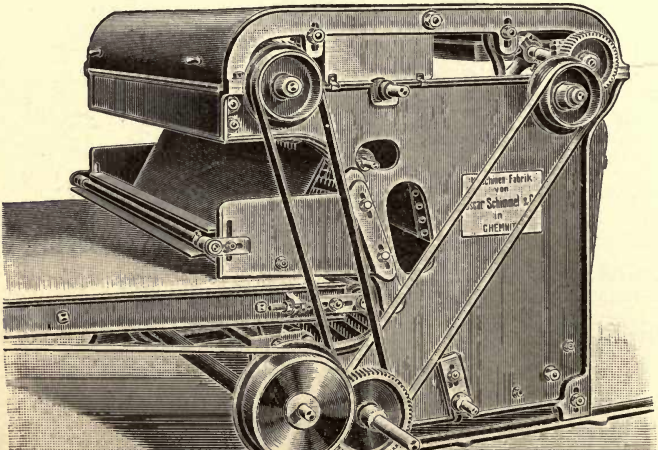


FIG. 24.—Hopper card feed.

The ordinary finisher card for flax and hemp tows is similar in design to the card just described. It is fed by hand or by an automatic hopper feeder, Figures 24 and 25, as used in the woollen trade. The regularity of the sliver produced depends upon the evenness of the feed. Inequalities upon the feed sheet are reproduced in the sliver. The best way to obtain level sliver is to spread handfuls of equal weight evenly over equal areas of feed sheet. To produce this result the carders are provided with a beam and scale to weigh the laps of tow, while the feed sheets are divided out into areas, say 2 feet by 3 feet, over which the operative is required to spread the lap evenly. Automatic feeders with beam and scale, and periodically opening bucket, do not as a rule produce regular sliver, although their great defect is minimised by causing the bucket to deposit its lap diagonally across the feed sheet. Long fibre and unequal charging of the hopper likewise tend to interfere with the proper weighing of the laps.

The cotton trade system of feeding cards by means of laps has recently been adopted in one section of the flax-spinning trade. The tow is formed into a sheet, which is in turn rolled into a lap in a machine called a "lapper." This machine is hand-fed, the material being heavily spread upon a feed sheet, and delivered to a shell-feed roller, from whence it is struck by a rapidly revolving beater, and deposited upon a travelling lattice, which carries it forward to a set of rollers, by which it is compressed into a firm sheet and lapped upon a lap rod or roller until the lap attains a diameter of about 18 inches. The lap is then doffed and conveyed to the card, upon the feed sheet of which it is placed side by side with another similar lap, both unrolling themselves with the forward motion of the feed-sheet, the material thus passing in a continuous sheet to the feed rollers.

Following will be found details as to suitable speeds, settings and coverings for two double doffer 6 feet by 5 feet finisher cards, the first suitable for forming flax and hemp tow into sliver for coarse numbers, and the second suitable for treating the finest and most expensive tows for fine numbers.

COVERING FOR COARSE FINISHER CARD. LAP 7 OZ., ON 600 SQ. INCHES. DRAFT, 14.

	Pitch of Pins.	No. of Wire.	Length out.	Diameter of Roller, Unclothed.
	Per inch.	B.W.G.	Inch.	Inches.
Cylinder	3½	16	¼	60
Feed rollers	2 × 5	13	½	2¾
Feed stripper	2 × 5	13	⅜	10
1st ,,	3 × 5	14	5/16	10
2nd ,,	3 × 5	14	5/16	10
3rd ,,	3 × 6	15	5/16	10
4th ,,	3 × 6	15	5/16	10
5th ,,	3 × 7	16	5/16	10
1st worker	2 × 4	13	⅜	8
2nd ,,	2 × 5	13	⅜	8
3rd ,,	3 × 4	14	⅜	8
4th ,,	3 × 6	15	⅜	8
5th ,,	3 × 6	15	⅜	8
Top doffer	3 × 7	16	⅜	14
Bottom doffer	3 × 8	17	⅜	14

The space between the cylinder and the top feed roller should be equal to 15 B.W.G.; bottom feed, 9 B.W.G.; feed stripper, 13 B.W.G; first stripper, 14 B.W.G.; second, third, and fourth strippers, 15 B.W.G.; fifth stripper, 16 B.W.G.; first worker, 11 B.W.G.; second, third, and fourth workers, 12 B.W.G.; fifth worker, 13 B.W.G.; top doffer, 15 B.W.G.; bottom doffer, 16 B.W.G. The bottom feed roller should be 14 B.W.G. distant from its stripper; the first worker, 15 B.W.G. from its stripper; and the remaining workers, 16 B.W.G. from their respective strippers.

COVERING FOR FINE FINISHER CARD, FED WITH 2-OZ. LAPS ON 600 SQ. INCHES.

	Pins per Inch.	No. of Wire.	Length out.	Diameter of Roller.
	Per Inch.	B.W.G.	Inch.	Inches.
Cylinder	7	19	⅛	60
Feed rollers	3 × 6	15	⅜	2¼
Feed stripper	3 × 6	16	¼	5½
1st ,,	3 × 7	16	3/16	5½
2nd and 3rd stripper	3 × 8	17	3/16	5½
4th stripper	3 × 9	18	3/16	5½
5th ,,	4 × 9	19	3/16	5½
6th ,,	4 × 10	19	3/16	5½
7th ,,	5 × 9	20	3/16	5½
8th ,,	5 × 10	21	3/16	5½
9th ,,	5 × 12	22	3/16	5½
1st worker	3 × 5	15	3/16	4½
2nd ,,	3 × 6	16	3/16	4½
3rd and 4th worker	3 × 7	16	3/16	4½
5th worker	3 × 8	17	3/16	4½
6th ,,	4 × 7	18	3/16	4½
7th ,,	4 × 8	19	3/16	4½
8th ,,	5 × 9	20	3/16	4½
9th ,,	5 × 10	21	3/16	4½
Top doffer	5 × 10	21	3/16	14
Bottom doffer	5 × 12	22	3/16	14

The top feed roller should be distant from the cylinder a distance equal to 18 B.W.G.; bottom feed roller, 12 B.W.G.; feed and first strippers, 18 B.W.G.; other strippers, 19 and 20 B.W.G.; first worker, 14 B.W.G.; second and third workers, 15 B.W.G.; fourth and fifth workers, 16 B.W.G.; sixth and seventh workers, 17 B.W.G.; eighth and ninth workers, 18 B.W.G.; top doffer, 20 B.W.G.; bottom doffer, 22 B.W.G. The feed stripper may be 20 B.W.G. distant from the bottom feed roller, and the remaining strippers, 21 B.W.G. from their respective workers.

The cylinder is usually run at a surface speed of about 3000 feet per minute, the strippers at 570 feet, and the workers at 15 feet. These speeds will give good results with Baltic tows. When working nappy tows, it is often advisable to run the strippers comparatively fast, as they throw off impurities in proportion to their speed. Slow workers give more work to the material, while they produce more work. A large cylinder pinion, causing the workers, feeds, and doffers to turn quickly, runs the material quickly through the card, and puts it into sliver without much waste or cleaning.

As regards the quantity of work which can be got off cards of various descriptions, it is usual in the jute trade to pass about 7000 lbs. per day of ten hours over a jute breaker, while one jute breaker supplies two finishers. The same figures may be taken to apply to breaker and finisher cards for hemp tow rope yarns. The weight put through flax tow cards per day of ten hours varies from 250 to 500 lb. according to the weight of the sliver and the numbers to be spun. The weight of a 500 yards can of sliver suitable to be prepared for 35's to 60's lea yarn should be alone 7½ lbs., 15 lbs. for 20's lea, and 30 lbs. for 10's lea.

As makers of card clothing, Messrs. Henry Taylor & Sons Ld. of Belfast have studied the subject for years, and have been largely instrumental in bringing forward the adoption of a shorter pin. A short pin has the advantage over a long pin, in that the fibres being carded are kept upon the surface, and do not sink into the spaces between the pin-point and the wood to the same extent as with a long pin. Neither can impurities accumulate in these spaces, all "shive" and woodly matter being compelled to fall into the card pit. The increased stiffness of a short pin furthermore diminishes the danger of "turned pins," and enables the rollers of the card to be more closely set to the cylinder, giving better carding.

Figure 25 shows a single doffer card of German make specially constructed to work short fibre. As it will be noticed, it is provided with endless bands or travelling aprons to carry forward the weak slivers from the drawing-off rollers to the drawing head.

The calculations connected with the card are those which concern the speed of workers, cylinder, and strippers, and the so-called draft of the card, or the ratio between the speeds of feed and delivery. The speed of the card cylinder may be found from that of the line shaft by multiplying the speed of the latter by the diameter of the drum which it carries, and dividing by the diameter of the pulley upon the card cylinder axle. Thus, suppose that the line shaft makes 150 revolutions per minute, and has upon it a drum 30 inches in diameter driving a pulley 24 inches in diameter upon the axle of the card cylinder, the speed of the

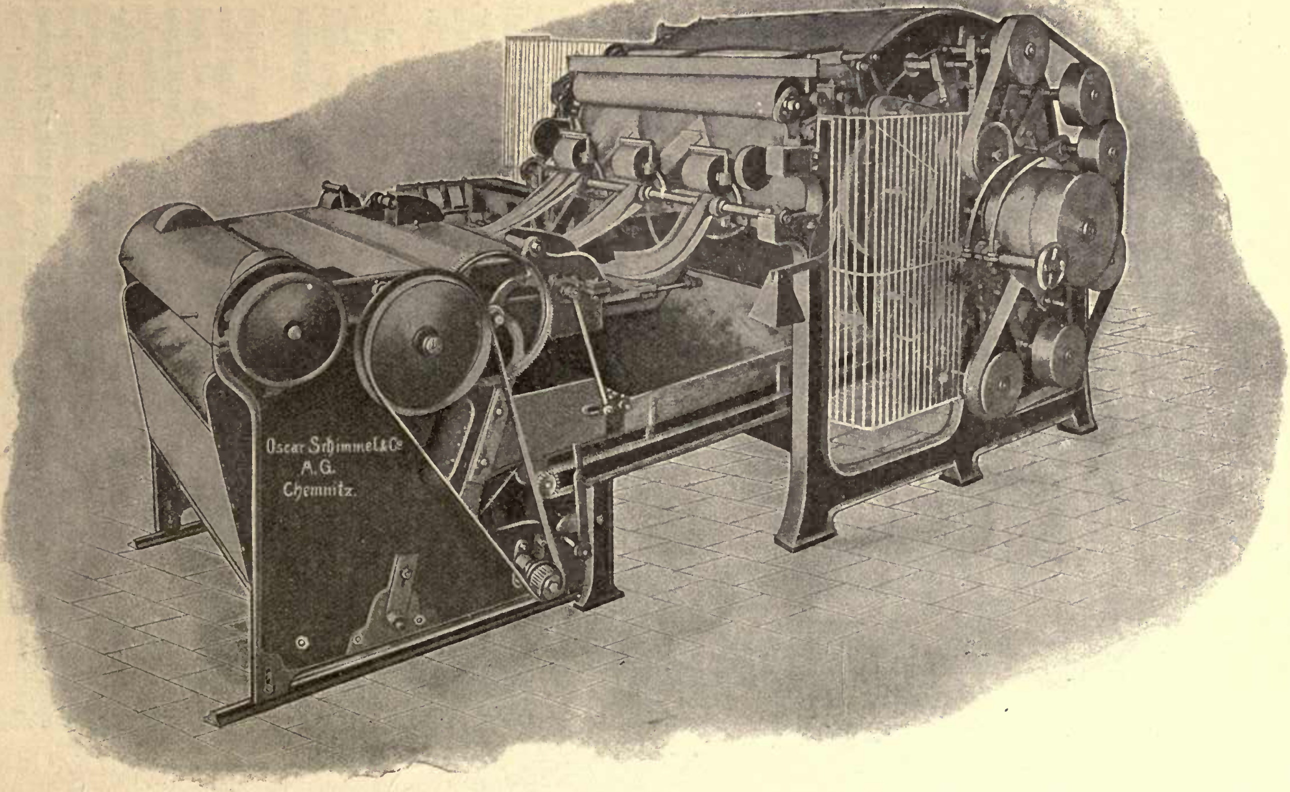

Oscar Schimmel & Co.
A.G.
Chemnitz.

FIG. 25.—Special short fibre card with hopper feed.

latter will then be $\frac{150 \times 30}{24} = 187{\cdot}5$ revolutions per minute. If the diameter of the card cylinder be 61¼ inches over the points of the pins, the surface speed of the latter will be $\frac{187{\cdot}5 \times 61{\cdot}25 \times 3{\cdot}1416}{12} =$ 3006 feet per minute.

The strippers are driven by a belt from another pulley, often called the "fancy pulley," keyed upon the cylinder axle. If this latter be 18 inches in diameter and the pulleys upon the stripper axles 12 inches in diameter, the speed of the strippers will be $\frac{187{\cdot}5 \times 18}{12} = 281$ revolutions per minute. Their surface speed may be found in exactly the same way as was that of the card cylinder. The workers are driven by gearing from the cylinder pinion keyed upon the opposite extremity of the cylinder axle from that which carries the pulleys. Their speed may be calculated as follows: Suppose the cylinder pinion to have 36 teeth, first stud wheel 130 teeth, first stud pinion 35 teeth, second stud wheel 136 teeth, worker change pinion 50 teeth, and worker wheels 72 teeth, the speed of the latter will be $\frac{187{\cdot}5 \times 36 \times 35 \times 50}{130 \times 136 \times 72} = 9{\cdot}2$ revolutions per minute.

Both the feeds and doffers are driven from the cylinder pinion, so that it will be seen that the use of a large cylinder pinion causes the material to be run quicker through the card, resulting in less carding, the speed of the card cylinder remaining the same. In a similar manner a small cylinder pinion produces better carding.

The gearing between the feed and delivery rollers of the card comprises the feed roller wheel of say 75 teeth, doffer pinion of 35 teeth, doffer wheel 135 teeth, and delivery roller pinions of 25 teeth. The delivery rollers therefore make $\frac{75 \times 135}{35 \times 25} = 11{\cdot}6$ revolutions for one of the feed roller. The diameter of the feed roller being 3½ inches and that of the delivery roller 4 inches, their relative surface speeds are as 1 : 14·3 nearly—14·3 being the so-called theoretical draft of the card proper.

Having devoted considerable space to the question of sliver formation by means of the card, we will next deal with the formation of sliver from long parallel fibres by means of a spreader or spread board.

Figures 26, 27, and 28 give views of three sorts of spreaders, the two latter differing merely in details. Figure 26 is what is known as a combined hackler and spreader, constructed on Good's principle, intended to turn the long and undressed stricks of Manila, Sisal, New Zealand, Russian, and Indian hemps into sliver, giving

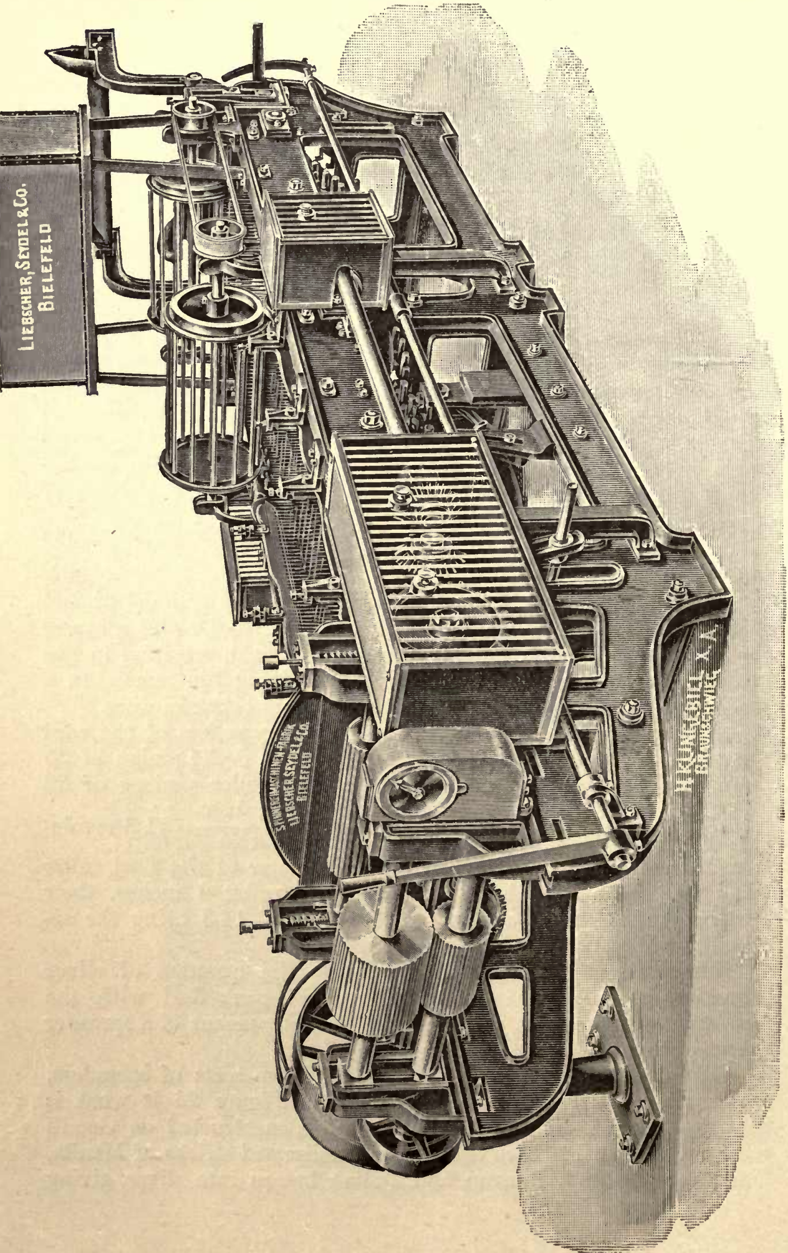

LIEBSCHER, SEYDEL & Co.
BIELEFELD
SPINNEREIMASCHINEN-FABRIK
LIEBSCHER SEYDEL & Co.
BIELEFELD

Fig. 26.—Combined hackler and spreader, breaker, or dressing machine for Manila, New Zealand, Russian, and Indian hemps.

the fibre a slight opening and straightening at the same time. The stricks of fibre are laid endwise upon a feed sheet in the rear of the machine, and not shown in the figure, spread flat as far as possible, and caused to overlap each other, forming one continuous sliver, which is drawn into the machine by the feed rollers. It may be seen, upon close examination, that the machine has two chain sheets of gill bars, the first, into the teeth of which the fibre is pressed by a lantern roller as it leaves the feed rollers, travels at a slightly greater surface speed than that of the feed rollers, which are fluted and pressed together by means of springs. The second sheet of gill bars has a surface speed 5 to 11 times greater than that of the first sheet, so that, while the long fibre is held by the feed rollers and the teeth of the first sheet, it is combed or hackled, and the fibres straightened and parallelised by the teeth of the second or hackling sheet. A second lantern roller, shown in the figure, keeps the fibre well down in the pins of the hackling sheet, so that it cannot rise and escape being thoroughly opened. Carried forward by the hackling sheet, the fibre is then caught by heavily weighted and fluted drawing rollers, which have a greater surface speed than the hackling sheet, so that the fibre is consequently drawn through the teeth of the latter and still further parallelised. A tapered conductor between the drawing and delivery rollers condenses the web of fibre into a wide sliver, which passes into a large can or box, or is coiled by hand upon the floor.

The elevated reservoir seen above the feed rollers contains heated oil, which is allowed to drop continuously and evenly over the fibre as it enters the machine. Hard fibre, such as Manila and New Zealand hemp, becomes much more pliable and works better through the gills if it is slightly lubricated. Cheap mineral oil of fair body is what is generally used. A very good automatic oiling arrangement consists in a plain oil roller, the width of the gill sheet, partly submerged in a trough of oil, which should be kept filled up to as nearly as possible the same level. The oil roller is turned by a rope and pulley from another pulley connected by gearing with the feed roller, and carries round with it a thin film of oil, which is scraped off by an edge pressed against the surface of the roller, and runs down an inclined and grooved plane, dropping evenly upon the fibre in the slow sheet. The feed of oil is thus regularly distributed, and stops and starts with the machine. The chief particulars of a combined hackler and spreader of this sort, suitable for forming sliver to be prepared for binder twine or rope yarn, are as follows: Pitch of gill bars, 4½ inches; width of gill (one row of teeth), 23 inches; 28 teeth in the row; teeth project 5 inches from the bar; speed of the slow sheet, 16 to 32 feet per minute; speed of the quick sheet in feet per minute, 175; suitable drafts, 10 to 20; rate of delivery, 200 feet per minute.

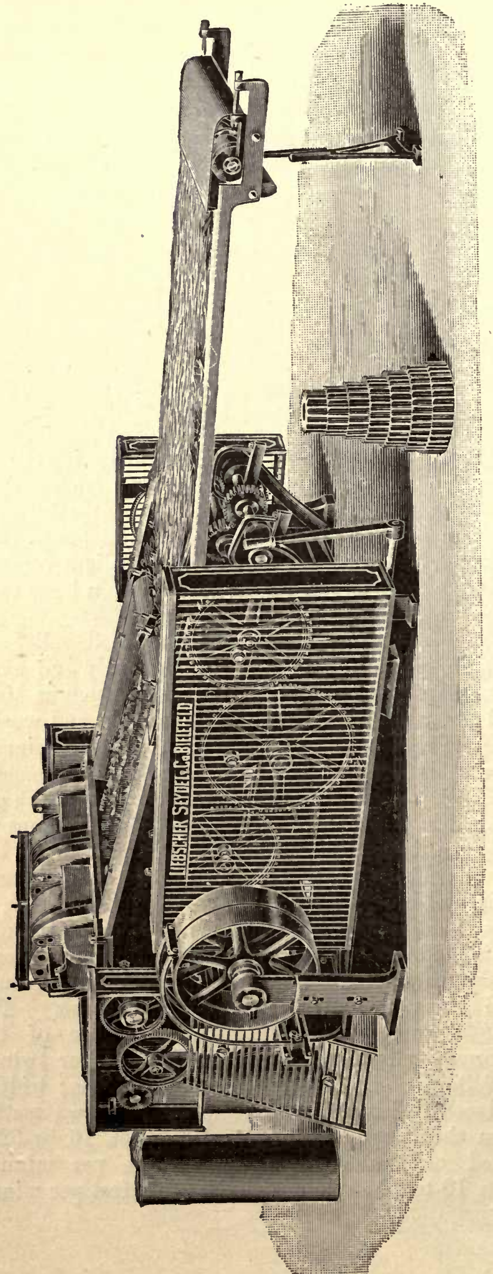

LIEBSCHER SEYDEL & Co. BIELEFELD

FIG. 27.—Spreader for long hemp, jute, etc.

The spreader shown in Figure 27 is of the screw gill type. It is a heavy, long-reach machine suitable for the formation of slivers from long hemp of medium fineness. It has two rows of gills per delivery, and two deliveries or four rows of gills in all. The spreaders spread the stricks of fibre lengthwise upon the four endless leather bands upon the feed table, the ends overlapping each other so that the sliver may be continuous and as regular as possible. The sheet leathers deliver the fibre to the feed rollers, after passing through which it is "pinned" by the gills as the fallers rise close up to the "nip" of the feed rollers.

The fallers, as depicted in Figure 29, are thin but deep bars, extending parallel with the feed rollers and resting at the ends upon top and bottom slides, the ends themselves being formed to work in the square threads of revolving screws, by means of which those upon the top slide are moved forward from the feed rollers, and those upon the bottom slide in the opposite direction. The bottom screws are coarser, since they are only employed to conduct the fallers back again to the feed rollers, where they are raised by a tappet into the top screw and on to the top slide, when they conduct the fibre forward to the boss or drawing roller, and are then knocked down by another tappet into the bottom screw and on to the bottom slide, there to repeat the motion. Guides are provided at each end of the slides to regulate the rise and fall of the bars front and back. The back end of the top slide is shaped to work in a groove in the faller end, to assist in keeping the latter in position. The guard or guide at the front works in the same groove with the same object. Wear and tear of the fallers and slides, entailed by the fall of the former, is minimised by the use of levers, actuated by the screws, or by an eccentric shaft, which receive the faller as it leaves the top slide and deposits it upon the lower. The slides of the spread board are usually inclined from back to front, to give the necessary height for a can at the front and a convenient height of table at the back. The fallers are of wrought iron with steel ends, the brass stocks of the gills being riveted on by rivets passing right through the faller. The surface speed of the top fallers is from 2 to 5 per cent. greater than that of the feed rollers, for the purpose of keeping the sliver tight and facilitating through and through pinning. Nevertheless with coarse material it is often found necessary to place an iron rod between the nip of the feed rollers and the rising point of the fallers, to insure the proper pinning of the fibre.

The drawing rollers, with a surface speed fifteen to thirty times that of the feed rollers and fallers, draw the fibre through the gills, hackle and parallelise it. The comparatively light slivers issuing from the drawing rollers pass through diagonal slots in a doubling plate and are doubled together, two into one, in this particular case, and pass through a conductor to the delivery rollers, which deposit the sliver in a can. For heavy work the drawing roller is usually "scored," to give it increased gripping power. The large pressing rollers are either of wood or leather, the latter when placed on edge forming a very good roller for very coarse work. For large wooden rollers, there is nothing to equal mahogany, or a sort of sabica called

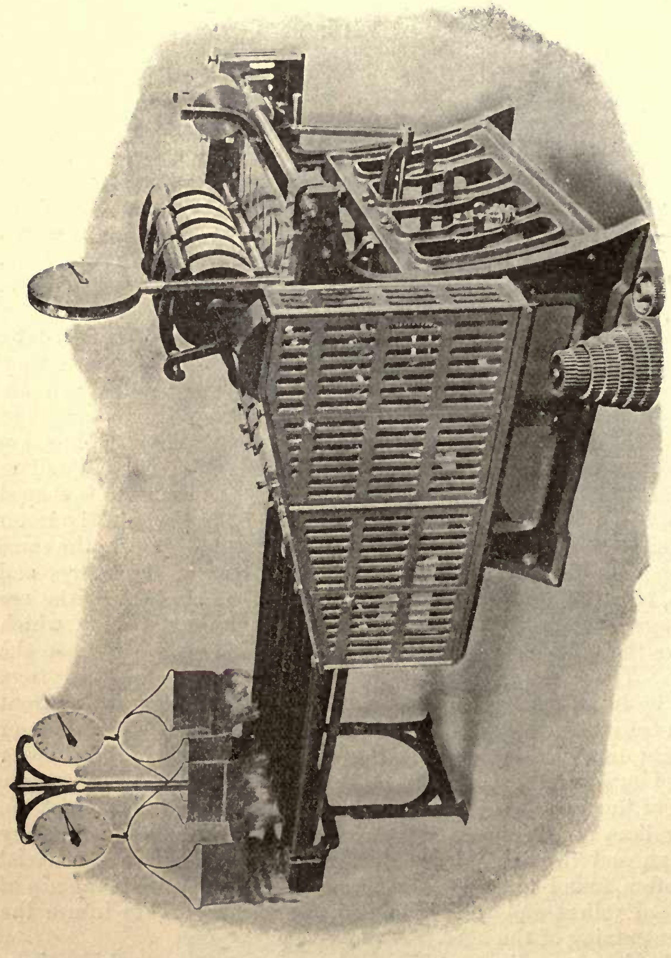


Fig. 28.—Flax spreader.

"watered wood," although the first cost is very high. Pressure is applied to the axles of the pressing rollers by means of hangers, compound levers, and weights. The conductors behind the feed and delivery rollers are in two pieces, and fixed at the required distance apart by means of screws. In this class of machine the front roller conductors are usually in one piece, and attached by set screws and steady pins to a bar running behind the roller. The front portion of the conductor is circled to half surround the boss roller, the toe projecting right into the nip of the rollers. The top face of the conductor is hollowed out to correspond with the curve of the largest pressing roller to be worked. The maximum diameter of pressing roller which can be used depends upon the height of the U's or supports which receive the ends of the axle upon which each pair of rollers is rigidly fixed. Brass or cast-iron washers should be used, to prevent the ends of the revolving axle from wearing the U's. The point of contact of the pressing roller with the boss should be slightly in advance of the centre, and the angle of the slides in the U's such that the line of pressure passes through the centres of both rollers.

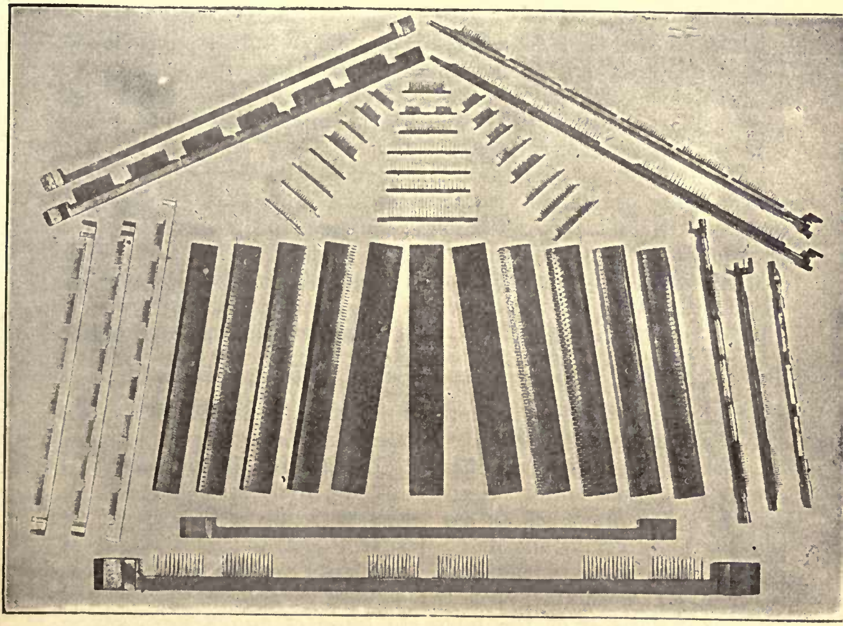


FIG. 29.—Fallers, gills, push bars, and card staves.

The way to calculate the pressure exerted upon the rollers by the levers and weight is as follows: Suppose that compound levers be employed, one with a weight of 20 lbs. attached to a point 36 inches from its fulcrum, and compounded with another by means of a link pivoted at a point 3 inches from the fulcrum of the first and 24 inches from the fulcrum of the second, the "spring-wire" which unites the hanger to the lever being attached at a point 2 inches from the fulcrum of the latter, the pressure upon the bosses, as usually calculated, and neglecting the weight of the levers themselves and the angle of the "spring-wire," is then $\frac{20 \times 36 \times 24}{3 \times 2} = 2880$ lbs.

Rubbers are used to prevent loose fibres from lapping round any of the revolving rollers between which they pass. In heavy machinery of this sort they are generally of the "dead" type, *i.e.* a block of wood lined with felt pressed against the roller by means of a weighted lever or springs.

The draft of the spread-board is produced by the greater surface speed of the drawing roller as compared with that of the feed roller. It is calculated as follows: Suppose the feed-roller wheel to have 60 teeth, stud pinion 32 teeth, stud wheel 120 teeth, back shaft pinion 30 teeth, draft change wheel 80 teeth, and boss roller wheel 40 teeth; the diameter of the boss or drawing roller is 4 inches, and that of the feed roller 3 inches; the surface speed of delivery is therefore $\frac{60 \times 120 \times 80 \times 4}{32 \times 30 \times 40 \times 3} = 20$ times as great as that of the feed, consequently the draft of the spreader is 20. Figure 28 shows a flax-spreader with six leathers and one delivery as made by Messrs. Fairbairn Macpherson, Leeds. It differs merely in details from that already described. The dials seen at the back and front of the machine are there to regulate the weight of the sliver by compelling the spreader to put a given weight of material into a given length, the regularity with which she does so, however, depending upon her application and diligence. The dials over the rear of the table are those of two Salter's spring balances, graduated up to say 20 lbs. The dial seen at the front of the board is graduated in a similar manner to those of the balances, but the hand is actuated by gearing from the delivery roller. If 20 lbs. of fibre is put in each of the scales when the hand of the geared dial points to 20, all three dials will be alike. The board being started, the spreader must endeavour to keep them alike by spreading the fibre evenly, taking it from the scale and reducing the weight indicated by the dial as fast as the geared hand moves round backwards from 20 to 0. The 40 lbs. of fibre may thus be formed into any length of sliver as the weight of the rove or yarn may require, by changing a pinion which governs the speed of the geared dial hand, the delivery remaining constant.

The clock system of spreading is by no means general. Many mills adopt the "set" system of regulating the weight of the rove or yarn. It will be fully explained in our next chapter. It is now merely necessary to say that the spread-board is provided with a bell motion, which rings every time a certain length, 500 yards for instance, is delivered into the can. The production of cans of sliver of given weight is left to the skill of the spreader, who with constant practice can hit off the weight very correctly. The arrangement of the bell motion may be as follows: A single threaded worm on the end of the delivery roller drives a worm wheel of 37 teeth, upon the pap of which is another worm, driving a bell wheel of 39 teeth. For one revolution of this bell wheel, then, the delivery roller makes $39 \times 37 = 1443$ revolutions. If its diameter be 4 inches and its circumference consequently $4 \times 3{\cdot}1416 = 12{\cdot}5664$ inches, $\frac{1443 \times 12{\cdot}5664}{36} = 540$ yards nearly, will be delivered for each revolution of the bell wheel.

Here are the particulars of several spreaders suitable for coarse, medium, and fine work.

Particulars of a spreader for forming long hemp of medium fineness into sliver to be prepared and spun into rope yarn, etc.: Rows of gills, 4; deliveries, 2; length of reach, 48 inches; pitch of screw, 1¾ inches; breadth of conductor, 7 inches; breadth of gill, 8 inches; pins per inch in gill, 2.

Next, for preparing jute long line to be spun into from 12 to 8 lb. yarn: Rows of gills, 4; length of reach, 40 inches; breadth of gill, 7 inches; breadth of conductor, 6 inches; length of pin in gill, 2½ inches; pins per inch (2 rows), 3; pitch of screw, 1 inch.

For preparing flax, jute, and hemp long line for from 5's to 10's lea yarn: Rows of gills, 4; deliveries, 1; length of reach, 40 inches; breadth of gill, 6½ inches; breadth of conductor, 5½ inches; length of pins in gill, 2½ inches; pins per inch (2 rows), 4; pitch of screw, ⅞ inch.

For forming flax, hemp, and jute long line into sliver to be prepared for from 10's to 16's lea yarn: Rows of gills, 4; length of reach, 38 inches; breadth of gill, 5 inches; breadth of conductor, 4 inches; length of pin, 2¼ inches; pins per inch (2 rows), 6; pitch of screw, ¾ inch.

For preparing flax and hemp long line for from 18's to 25's lea yarn: Rows of gills, 4; length of reach, 38 inches; breadth of gill, 4 inches; breadth of conductor, 3 inches; length of pin, 2 inches; pins per inch (2 rows), 8; pitch of screw, ¾ inch.

For forming flax long line into sliver for from 30's to 50's lea yarn: Rows of gills, 6; length of reach, 36 inches; pitch of screw, ½ inch; breadth of conductor, 2¾ inches; breadth of gill, 3½ inches; length of pin, 1⅞ inches; pins per inch in gill, 10.

For preparing flax long line for from 50's to 80's lea yarn: Rows of gills, 8; length of reach, 30 inches; pitch of screw, $\frac{1}{2}$ inch; breadth of conductor, $2\frac{1}{2}$ inches; breadth of gill, $3\frac{1}{4}$ inches; length of pin, $1\frac{1}{2}$ inches; pins per inch in gill, 15.

For forming flax long line into yarn from 80's to 120's lea: Rows of gills, 6; length of reach, 28 inches; pitch of screw, $\frac{3}{8}$ inch; breadth of conductor, $1\frac{1}{4}$ inches; breadth of gill, $2\frac{1}{4}$ inches; length of pin, $1\frac{1}{8}$ inches; pins per inch, 20.

For preparing flax line into yarn from 120's to 250's lea: Rows of gills, 6; length of reach, 20 inches; pitch of screw, $\frac{3}{8}$ inch; breadth of conductor, $\frac{7}{8}$ inch; breadth of gill, $1\frac{1}{2}$ inches; pins per inch, 36; length of pin, $1\frac{1}{16}$ inch.

Although spread-boards of this description are still in use, a system known as the "heavy spreader" system has of late years made much headway owing to the saving in labour which its use entails. The system consists in spreading the pieces whole upon the leathers of a coarse spread-board, and afterwards reducing the heavy sliver thus obtained to its proper grist by drafting and doubling upon a doubling frame. Only about one-third the usual number of spreaders are required to carry out this system, so that the cost of labour is considerably reduced, while it is claimed that better work is obtained through the spreading of the hackler's pieces whole, without the usual sub-division and consequent tossing of the fibre.

Here are particulars of a coarse spreader to carry out this system in preparing for yarns of 40's to 120's leas per lb.: Rows of gills, 4; length of reach, 36 inches; width of gill, 8 inches; width of conductors, $6\frac{1}{2}$ inches; pins per inch, 12; length of pin, 2 inches; pitch of screw, $\frac{3}{4}$ inch; length of bell, 500 yards.

Good work may be produced when the sliver weighs about 22 lbs. per 500 yards.

The production of a sliver uniform in weight and grist from yard to yard depends entirely upon the method of spreading. The degree of uniformity is inversely as the size of the pieces, and directly as the amount by which these pieces overlap each other. The smaller the pieces, the more closely together must they be spread to produce a sliver of given weight, and the leveller that sliver will be. Thin places, if not actual gaps in the sliver, will always be present if the draft upon the board be too long or if the pieces be not sufficiently closely spread. Short fibre requires a short draft, while longer fibre will stand a longer one. Suppose we observe a board upon which 16-inch cut line is being spread. Being cut line, the fibres composing the piece are of more uniform length than uncut fibre, and for this reason, and for the purpose of demonstration, we may consider the pieces as single fibres. The spreader overlaps the pieces, leaving, say, 2 inches from point to point of each. The pieces composing this hand-formed sliver are presented to the drawing rollers in the same relative position as spread. Suppose that the point of one piece is just caught in the nip of the drawing rollers—the draft being 20, while the succeeding piece is moving forward the 2 inches which it has to travel before being caught by the rollers, the preceding piece has been drawn forward twenty times that distance, thus forming a gap in the sliver. Had the fibre been longer or the draft shorter, the second piece would have been caught before the first had entirely disappeared, and a continuous and more uniform sliver would have been produced. This shows, on an exaggerated scale, what really takes place in practice. Even in cut line, unless it be sheared through, the fibres are not really of the same length, consequently they are each caught in the nip at a different instant and drawn forward to correspondingly advanced positions, thus forming an elongated and consequently attenuated sliver.

CHAPTER IV

LINE AND TOW PREPARING

A **sliver** having been formed, whether from long fibre or "long line," or from short fibre or tow, the next process consists in repeatedly doubling together a number of these slivers in order to increase their evenness or regularity, drawing them out the while in order to reduce their bulk or grist preparatory to spinning them into yarn. This drawing out and doubling is done upon drawing frames, which differ slightly in details but are the same in principle. The different sorts of drawing frames are link or chain drawings, slide or push-bar drawings, circular and rotary drawings, and screw gill drawings. The four former are used almost exclusively for hemp and jute, and the last for all three fibres, but principally for flax. The screw gill box arrangement is undoubtedly the most perfect mechanically, and will give better results as regards levelness in the yarn, owing to the fallers rising and falling quite close to the feed and drawing rollers, and in a perpendicular position, giving direct penetration to the gills. The advantages of the link, circular, rotary, and slide drawings are the greater speeds at which they may be run; consequently they reduce the cost of production and give sufficiently good results when dealing with a cheap material such as jute. With an expensive fibre, such as flax, being prepared for fine yarns, it is not worth while reducing the cost of production in this way, the object being to produce as perfect a yarn as possible. Two hundred drops of the faller per minute may be considered a maximum speed for the ordinary screw gill arrangement. Higher speeds than this result in excessive wear and tear upon the ends of the slides and cams, and frequent stoppages owing to stuck fallers. Slower speeds are to be recommended, both on account of the quality of the work turned off and on account of the longer life of the machinery.

The recent invention of a patent disc cam or wyper, combined with a front steel spring, has made it possible to attain a much higher faller or bar speed in screw gill boxes. No back spring is necessary when the disc cam is used, the face of the disc keeping the bar in position during its rise on to the top slide. The disc cam is made of one piece of steel and fixed on to the body of the bottom screw. The advantage of the patent front spring is that it is more sensitive than the old spring, and guides the bar, at the drop, more easily into the bottom screw, thus saving wear and tear. The author has seen a frame fitted with this arrangement make over 300 drops of the faller per minute and work quite smoothly.

In the jute trade 350 drops of the gill bar per minute is considered a fair speed for a push-bar drawing. At this speed a two-headed drawing will take sliver produced by a finisher card producing 35 cwts. per day of 10 hours. The working of the screw gill arrangement has been previously described in connection with the spreader.

The gill bars of the circular drawing still in use in the jute trade work as follows: Between the drawing and retaining rollers there is a barrel with deep gun-metal flanges or ends, in which a number of slots are cut in an almost radial direction. Into these slots the ends of the gill bars pass freely, projecting on the other side into a cam-shaped groove, which, while the barrel revolves, determines and directs their movements as they are carried round. The shape of the groove is so arranged that the gills rise fairly perpendicularly and close to the feed rollers, and approach fairly close to the nip of the drawing rollers.

In the push-bar arrangement the bars are raised and lowered in the teeth of wheels, of about 17 teeth, keyed upon two parallel shafts. The rear gill-bar wheels raise the bar and push it on to a horizontal slide, along which it is impelled by the bar behind until it slides into the teeth of the front gill-bar wheels and is lowered on to the bottom slide. The opposite ends of alternate bars have crank-shaped lugs or pieces attached to them, which, while the round of the bar is in the teeth of the gill-bar wheels, are guided in an outside groove, which controls and renders perpendicular the ascent and descent of the gills. In Gamble's patent push-bar arrangement, in order that the gill bars may be controlled into the required angle during their ascent and descent, the ends of the bars are made flat or oval, and are more or less twisted. Special guides act progressively along the twisted surface, and coming in contact with different portions of it turn the bar into the required position, and keep it there while the rise and fall takes place.

The rotary drawing is now in very limited use, and that in only a small portion of the jute trade. The gills, resembling the porcupine feed roller of a card, are fixed upon a shaft placed close up to the drawing roller. Sometimes the rotary gill is double, a second porcupine roller being placed over and parallel to the first, and the sliver drawn through the intersection of the two.

In the link or chain drawing, as the name implies, the gill bars are linked together and kept in motion by means of a pair of sprocket wheels back and front, around which the bars form an endless sheet. The bars are guided and kept rigidly in position by means of blocks on their ends, the arms of which engage with either side of the top slide.

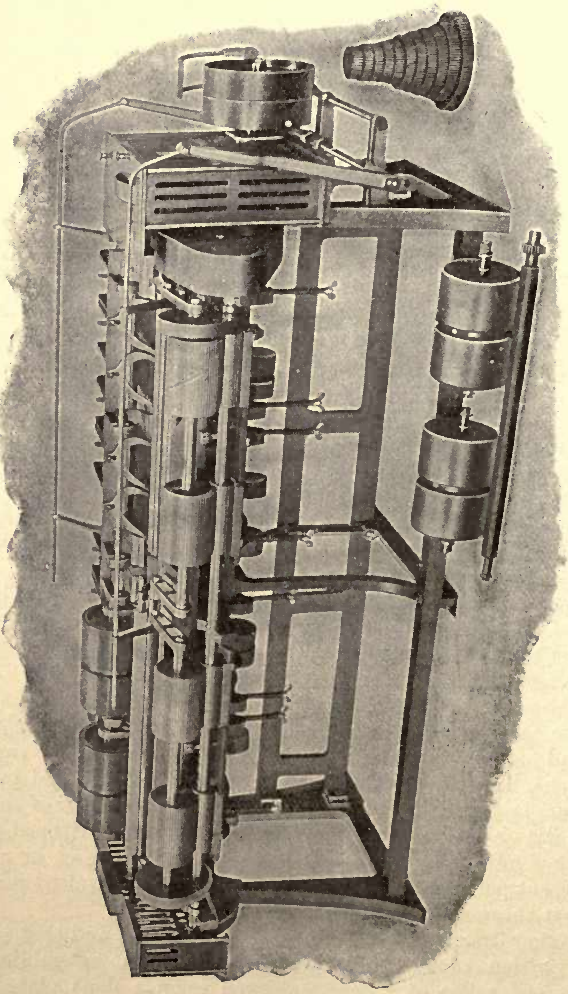


FIG. 30.—Drawing frame for jute.

In the "Ring" push-bar drawing frame recently put upon the market by Messrs. Douglas Fraser & Sons of Arbroath, the bars are compelled to follow a semicircular path by the shape of the grooves in which their ends are introduced. They are kept in motion by internally toothed "rings" or wheels, with which they engage while following their semicircular path, being pushed along the horizontal slide by those behind.

In spiral drawing frames, as a means of avoiding crushed gills and broken fallers through a faller jamming or through a "choke," the fallers are often driven by a small brass pin inserted in corresponding holes in the boss of the draft wheel and in the fixed collar, upon the back shaft, against which the draft wheel is tightened. When a jam or a "choke" occurs, this brass "pitch pin" is sheared through, and the frame "goes out of gear," that is to say, the fallers cease to move. Sometimes a double back shaft is employed, and a "pitch pin" inserted for every head, so that when a faller sticks, only the head where the accident occurs is thrown out of gear. A similar arrangement is employed in push-bar drawings. A No. 8 B.W.G. brass pin is sufficient to drive a two-headed first drawing for jute, while for a spiral second drawing, with double back shafts, pins of No. 10 B.W.G. will be found sufficient.

Figure 30 shows a second or finishing spiral drawing for jute, with two heads and two deliveries per head, as made by Messrs. Fairbairn Macpherson, Leeds. Such a drawing is usually deemed sufficient to supply a 56-spindle roving with 10 × 5-inch bobbin, but [it is better to have three heads of second drawings and to run slower. In this drawing the pressings are leather covered, and the delivery and calender rollers scored and geared. In jute machinery the pressing and drawing rollers are occasionally metal on metal, both being fluted, but leather-covered pressings, either fluted to work upon a fluted drawing roller, or plain to work upon a scored roller, are to be preferred. The drafting arrangements of a drawing frame are very similar to those of the spread-board described in our last chapter. Cans of sliver are put up at the back, one and sometimes two for each row of gills. The ends of sliver are passed through the back conductors, and feed or retaining rollers to the gills, which convey them forward to the drawing rollers, which attenuate them by reason of the relatively greater surface speed. The drawn slivers are then doubled two or more together over the doubling plate, and delivered through a conductor and calender or delivery rollings into a can which will go to feed the next machine.

Figure 31 gives a rear view of a finer make of drawing frame than that depicted in the previous figure, and shows some details, such as a cam shaft and hand wheel for raising the levers and taking the pressure off the pressings during a stoppage, the back shaft for driving the screws and fallers, and the sliver pulleys and backs for raising the slivers from the cans and passing them to the feed rollers.

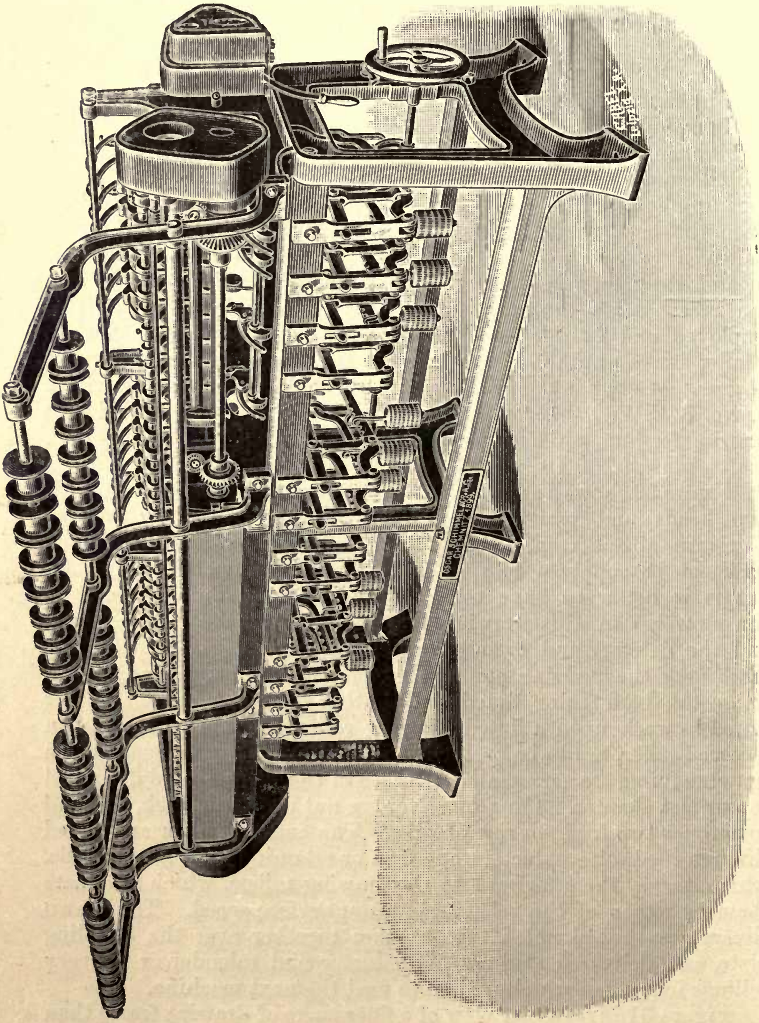

OSCAR SCHIMMEL & Co. A.G.
CHEMNITZ 1899.

Fig. 31.—Rear view of drawing frame for flax, hemp, jute, or tow.

Figure 32 gives a section through a tow drawing-frame, and shows the screws and how they are driven.

In flax mills where the heavy spreading system has been adopted, most of the old ordinary spreaders have been provided with backs and employed as doubling frames, to reduce the sliver to a grist suitable for the gills of the first drawing frame.

In jute preparing, two drawings with 8 to 16 doublings are usually deemed sufficient. For hemp and flax tows, three drawings with at least 96 doubling should be provided. For ordinary flax and hemp yarns, three drawings with about 384 doublings will be found advisable; while for fine and superior yarns, four drawings in addition to the doubler before mentioned, giving a total of from 18,432 to 50,000 doublings, will be found to give good results. The total doublings correspond with the product of the doublings upon the separate frames.

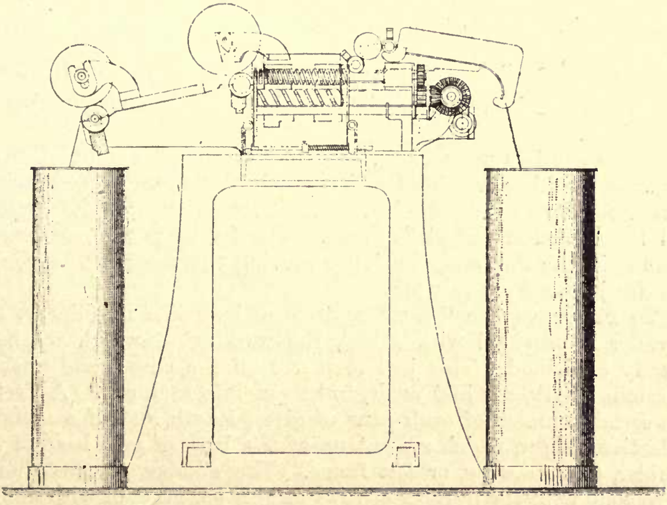


Fig. 32.

As regards the length of drafts, the usual practice in jute spinning is to give the first circular or push-bar drawing a draft of about 3·5, the second spiral drawing a draft of 8, and the roving frame a draft of 9, making a total draft of 252. For the time being we will consider the roving frame as a drawing frame, as it really is. Its twisting and winding mechanism will be treated of in another chapter. In a three-drawing tow system comprising first drawing or bell frame, second and third drawings and roving, drafts of 8 upon each frame will give good results, making a total draft of 4096. For long line, drafts of 12 all over will give satisfaction, so that for a three drawing line system the total drafts will be 20,736, and for a four drawing system with a doubler, draft 15, 3,732,480.

The weight of the slivers in preparation must be based upon the weight of the yarn to be produced, taken in conjunction with the spinning draft. For instance, in preparing Manila to be spun upon the automatic gill spinner into binder twine, 200 yards or 600 feet per lb., with an average draft of four upon the automatic, the sliver must weigh $\frac{200}{4} = 50$ yards per lb. when leaving the finishing drawing.

In the jute trade the weight of yarn and rove is denoted in lbs. per spindle of 14,400 yards, so that to spin 8-lbs. yarn with a spinning draft of 7, the rove will weigh $8 \times 7 = 56$ lbs. per spindle, or 257 yards per lb. In the fine spinning trade, the weight of the yarn being denoted in leas per lb., and the weight of the rove in yards per oz., the weight of rove required to spin 120's lea with a draft of 10 upon the spinning frame will be $\frac{120 \times 19}{10} = 228$ yards per oz. It will be explained later on how the constant number 19 is obtained.

There are two ways of arriving at the correct weight of sliver from the finishing drawing for gill spinning, or at the correct weight of rove for dry or wet spinning. One is termed the "Sett" system, and the other the "Clock" system. The former is the one usually adopted in the fine end, the latter serving the purpose sufficiently well for jute and coarse work.

To carry out the "Sett" system on long line machinery, the spreader is provided with a bell, the working of which we have already explained. This bell measures off the sliver, and enables a certain length, say 500 yards, to be put into each can. A "sett" is a certain number of such cans of given length and of a suitable collective weight, which are put up at the back of each head of the doubler, first drawing, or sett frame. The number of cans should correspond with the number of rows of gills per head, or with double that number, according to whether single or double slivers are being worked. Since all the cans in the sett are doubled into one upon this head, the weight of the sett may be considered to be the weight of say 500 yards of sliver. The question as to the weight of sett then resolves itself into the question as to what weight of sliver per 500 yards will, when drafted and doubled to the desired extent, produce rove of the weight desired. It is understood, of course, that no doubling takes place on the roving frame. The number of yards per oz. of rove divided by the draft of the roving frame gives the weight in yards per oz. of the sliver which feeds the roving frame, or otherwise of that which is delivered from the finishing drawing. The weight of this sliver in yards per oz., divided by the draft of the finishing drawing, and multiplied by the doublings upon the same drawing, gives the weight of the sliver feeding the finishing drawing, and so on. If, then, we multiply the weight of rove in yards per oz. by all the doublings, with the exception of those on the sett frame, or, in other words, the number of cans in the sett, and divide by all the drafts, including that of the sett frame, we get the number of yards per oz., or fraction of a yard per oz., of sliver equivalent to the collective weight of the slivers in the sett. This fraction multiplied by 16 gives the yards per lb. We know that the length of the slivers is 500 yards, so that if we divide the length of the bell by the yards per lb., we get the weight of sett required. As an example, take for instance the four drawing systems of which we spoke, with drafts of 12 all over, and a draft of 15 upon the doubling frame, at the back of which the setts are put up, the doublings being 12 upon the first drawing, 8 upon the second, 8 upon the third, and 4 upon the fourth, or finishing drawing; the weight of rove is to be 228 yards per oz., so the required weight of sett will be

$$500 \div \frac{228 \times 12 \times 8 \times 8 \times 4 \times 16}{15 \times 12 \times 12 \times 12 \times 12 \times 12} = \frac{500 \times 15 \times 12 \times 12 \times 12 \times 12 \times 12}{228 \times 12 \times 8 \times 8 \times 4 \times 16}$$
$$= 166 \text{ lbs.}$$

If the material is clean, as it is nearly sure to be for this weight of rove, and if there be not undue licking up upon the rollers, 5 per cent. or 8 lbs. may be deducted from this theoretical weight to counterbalance the effects of "bulking," leaving the weight of sett at 158 lbs. If an old 6-leather spreader be used as a doubler, there may conveniently be 12 cans in the sett, so that the average weight of each can from the spread-board will be $\frac{158}{12} = 13$ lbs. $2\frac{1}{2}$ oz., a weight rather light for the 6-inch conductor of the ordinary heavy spreader, unless both deliveries be used, in which case the effective doublings will be reduced by one-half. For this reason, then, the author prefers for fine numbers the use of a 6-leather board with 3-inch conductors, although the cost of production is thereby slightly increased. The use of such a board need not entail the subdivision by the spreaders of the hacklers' pieces, if they are of the size they should be for perfect hackling for fine and superior numbers.

Before going into the calculation as to the weight of a "dollop" for the breaker card to produce rove of so many lbs. per spangle over a system of jute preparing, we will show how the length of the clock may be calculated. Upon the end of the feed roller is a treble-threaded worm working into a stud worm wheel of 42 teeth. Compounded with this latter is a pinion of 36 teeth, which actuates another of a like number of teeth upon the arbour of the clock. One revolution of the feed roller, then, produces a movement of the clock equal to $\frac{3 \times 36}{42 \times 36} = \frac{1}{14}$th of a revolution, so that the feed roller must make 14 revolutions for each round of the clock. If the diameter of the feed roller be $10\frac{1}{2}$ inches, giving an effective circumference of 33 inches, 14 revolutions correspond to a length of $\frac{33 \times 14}{36} = 13$ yards, nearly.

Suppose that it is required to produce rove 56 lbs. per spangle, or 257 yards per lb., the drafts and doublings being as follows: Breaker draft, 13; finisher draft, 13; first drawing (push bar) draft, 3·5; second drawing (spiral) draft, 7·5; roving draft, 8·5, ten cans of sliver feed the finisher card, four ends are doubled into one on the first drawing, and two into one on the second drawing. Starting with 257 yards per lb. of rove, then, and working backwards, we find that the weight upon the feed-sheet of the breaker card must be $\frac{257 \times 2 \times 4 \times 10}{8{\cdot}5 \times 7{\cdot}5 \times 3{\cdot}5 \times 13 \times 13} = {\cdot}54$ yards per lb. The weight of 13 yards will therefore be $\frac{13}{{\cdot}54} = 24$ lbs. = the weight of the "dollop," no allowance being made for waste or bulking of the sliver. In practice, about 1 per cent. may be added to the weight of the dollop to bring out the rove the right weight.

When the clock system is applied to the spread-board in line preparing, the weight of material, corresponding to the jute trade dollop, remains constant. It is the length of the clock which is changed to give different weights of rove as required. This is done by changing one of the pinions which connects the delivery roller to the clock dial, the hands of the clock being caused to travel faster or slower, according as it is desired to produce heavier or lighter rove.

When the combing machine is used in tow preparing, it is introduced with the object of removing those short fibres and naps which cannot well be parallelised, the presence of which label it as a tow yarn, and reduce its value. It is generally used either for coarse fibre, such as Flemish scutching tow or codilla, or for rather fine and nappy tows. In the former case it removes the short fibres, leaving the long ones straight and parallel, and in the latter case it effects the removal of the naps, enabling the remaining fibres to be spun up much finer, and into a sightly yarn. In any case it is necessary first to prepare a level sliver by doubling the card sliver over a drawing frame or doubler, the cans from which may be put up at the back of the combing machine.

The best combing machine is that which gives a sliver of parallel fibres with the minimum of noil. Two good machines are the Slumberger and the Delette. Giving 80 strokes per minute, these machines should pass from 130 lbs. to 180 lbs. of sliver per day of ten hours, with from 27 to 43 per cent. of noil according to the class of tow being worked, the former figure referring to

St. Petersburg tow, and the latter to nappy Courtrai tow. Figure 33 gives a rough idea as to the form of the machine.

As will be seen from the figure, the cans, usually to the number of twelve, are placed behind the machine and the slivers drawn up over conductors A, which pass them in side by side to the feed roller B. Thence they pass to a feeding and retaining arrangement C, consisting of intersecting gills, then through and between the cushion plate and nipper to the comb circle D, which together with the top comb extracts the noil. The combed fibre is drawn off and formed into a sliver by the detaching roller E and drawing off segments K working in combination. The roller E is surrounded by a leather apron, which serves to carry the fibre quickly forward, leaving it sufficiently slack to be drawn away, notwithstanding the intermittent motion of the machine, by a condensing and delivery roller M revolving constantly. These rollers deliver the compressed sliver into a can as shown. More minutely described, the action of the machine is as follows: Issuing from the retaining arrangement C, feed rollers deliver the slivers between the nipper knife and the cushion plate, which hold it firmly while one of the comb segments D combs out the end. When the comb segment has gone by, the nipper knife, which is actuated by levers and a cam, is raised from the cushion plate, the single row top comb comes down and penetrates the protruding fibres, and the detaching rollers are brought down into the path of the fluted segments K of the comb cylinder. The fibres, which are being slowly and intermittently let down through the feed rollers, will have been

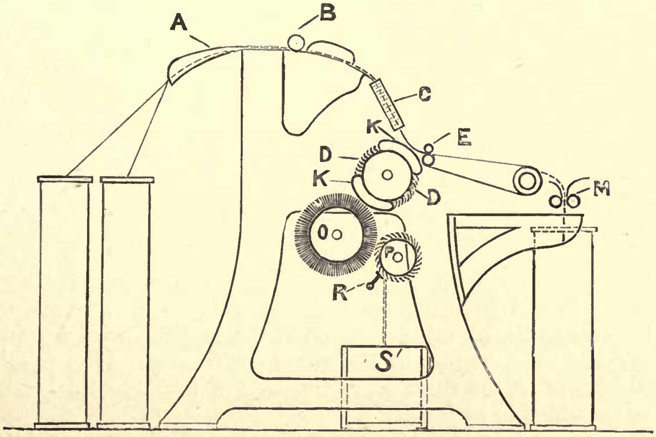


FIG. 33.

subjected to several strokes of the comb cylinder before they project sufficiently far to be caught between the drawing-off roller and the fluted segment. When they are caught, their tail ends are drawn through the top comb, which prevents any shorter and not fully combed fibres from being drawn after them, and they themselves pass between the rollers and form the foundation of the sliver. When the fluted segment follows the comb round the next time, there are some fresh fibres ready to be added to those already drawn through, which for the purpose of being spliced, so to speak, with them, are brought back half the distance they were previously advanced. This is effected by a cam, which turns the detaching rollers E one-third of a revolution backward and two-thirds of a revolution forwards. This cycle of operations being repeated, a continuous sliver is formed of long fibres, which have been combed repeatedly through their entire length by the revolving comb segments DD. The latter are cleared of short fibre or noil by the circular brush O, which deposits the noil upon a toothed doffer P, from which it is removed by a vibrating knife R and drops into the box S. On account of possible variations in the percentage of noil, the sett should not be made up until the sliver has been passed over the combing machine. If the latter be provided with a bell, the sett may conveniently be made up for the following drawing frame.

In connection with the sett weight it was stated that an allowance should be made for bulking of the sliver. Bulking is the increase in the effective diameter of the feed rollers of a drawing frame due to the passage of the sliver over them. It is equal to the thickness of the sliver or to the sum of half the thickness of the sliver added to each side.

A compound system is a system composed of drawing frames of sufficient length, number of heads, and deliveries to follow more than one roving frame. Compound systems usually follow two roving frames, but the author has worked one, compounded up to and including the third drawing, which followed three roving frames, or 336 roving spindles in all. The advantage of a compound system lies in the saving in floor space, due to the absence of the passages which would be required between independent frames, and also in the saving in wages effected through being able to give the drawers more heads to mind without a proportionate increase in pay. The system has everything to recommend it, especially if the systems are similar and kept upon the same weight of rove. It has its limitations and disadvantages, however, if the various sections are not similar as regards fineness of gill, and are intended to produce rove of different weights. For instance, the pitch of screws must be the same for all the heads of the same frame, whether the gills be coarse or fine. The speeds, also, of the various sections of the same frame must of necessity be the same, hence confusion when preparing for different weights of rove; for if the roving making the finer rove be not speeded up, the fine system will produce too much sliver, or else the coarse system will not keep its roving running full time.

The independent head system, combined with automatic stop motion, recently put upon the market by a continental firm of machinists, seems to be a solution of this problem, for any number of heads may be stopped for a few hours when not required without running through the slivers. The saving in the number of heads of drawings required is claimed to be in the ratio of 7 : 12; for when, for instance, a roller requires to be changed, it is not necessary to stop the whole frame as under the old system, but merely the head affected, each head being in itself a separate gill box with independent boss or drawing roller, delivery rollers, etc. The stop motion automatically brings the head to a standstill when a sliver breaks or runs out, and that before the end has disappeared through the back conductors. It acts in the following manner: The slivers, before passing to the feed rollers, pass over spoon or butterfly conductors balanced upon a knife edge in such a way that, while the weight of the sliver is sufficient to keep the loaded tail ends of the conductor up and out of the path of a reciprocating bar, yet as soon as the tension is relaxed through the breaking of an end, the tail end of the spoon lever falls in between a projection upon the clutch bar and a corresponding projection upon the above-mentioned reciprocating bar, and the clutch which drives the head is thrown out of gear. When the sliver has been pieced up again and the spoon depressed, the clutch may be put into gear again by the starting lever, and the head put in motion again.

The small drawing head sometimes applied to the card with the object of parallelising the fibres and producing a lighter but stronger sliver, is nothing but a small one-headed circular or push-bar drawing such as we have already described, with usually 3 rows of gills and a draft of from 2 to 3.

The draft calculation for a circular-drawing head is made as follows: Suppose that the feed-roller wheel has 44 teeth and gears into a stud pinion of 16 teeth, compounded with a stud wheel of 28 teeth, which in turn gears with a back shaft pinion of 22 teeth. The other end of the back shaft carries the draft change wheel, which we will suppose has 25 teeth, and drives, through intermediates, the drawing roller wheel of 40 teeth. The diameter of the feed roller is $1\frac{3}{4}$ inches and that of the boss roller 2 inches, so that their relative surface speed or the draft of the head is

$$\frac{44 \times 28 \times 25 \times 2}{16 \times 22 \times 40 \times 1{\cdot}75} = 2{\cdot}5.$$

The draft gearing of a patent slide or push-bar drawing may be as follows: Feed roller wheel, 32 teeth; stud wheel, 40 teeth; stud pinion, 23 teeth; faller bar shaft pinion, 39 teeth; faller shaft wheels, 50 teeth; short shaft pinion, 34 teeth; short shaft wheel, 73 teeth; stud pinion, 20 teeth; stud wheel, 56 teeth; draft change pinion, 56 teeth; effective diameter of the drawing roller, 3 inches; and diameter of feed roller, 1⅞ inches, giving a draft of

$$\frac{32 \times 23 \times 50 \times 73 \times 56 \times 3}{40 \times 39 \times 34 \times 20 \times 56 \times 1\frac{7}{8}} = 4.$$

We now give particulars of a series of machines suitable for drawing and doubling various classes of sliver for various purposes. Among these machines we include the roving frame, when such is used, considering it merely as a drawing frame. We do not include spreaders or other sliver formers, details of which we have already given.

Firstly, a system to be used in conjunction with a Good's spreader and hackler to prepare Manila, Sisal, or New Zealand hemp for automatic gill spinning into binder twine or reaper yarn, rope yarn, or white Manila for trawl twine:

	Chain Gill Finishers.		Screw Gills.		
	1st.	2nd.	Bell Frame.	Sett Frame.	3rd Drawing.
Rows of gills per delivery .	1	1	4	6	6
Deliveries per frame . .	1	1	4	6	6
Width of gill . . .	22½ in.	19½ in.	7½ in.	4¾ in.	4 in.
Pitch of gill bars or screws	3¾ ,,	3¾ ,,	1½ ,,	1¼ ,,	1 ,,
Pins in row of gill . .	36	39	13	14	15
Length of pin out of bar .	4 in.	3½ in.	2¾ in.	2½ in.	2½ in.
Suitable drafts . . .	10–20	10–20	10	10	10
Speed of quick sheet in feet per minute . . .	175	175	...	...	...
Speed of slow sheet in feet per minute . . .	16–32	16–32	...	...	...
Rate of delivery in feet per minute	200	200	...	...	...

Next, to prepare carded jute for weft 20 lbs. per spangle:

	Push Bar, 1st Drawing	Spiral, 2nd Drawing.	Rotary, Roving.
Heads per frame	2	3	7
Slivers per head.	4	4	8
Deliveries per head	1	2	8
Doublings.	4	2	1
Drafts	3–7	5–10	5
Width of gill	7 in.	6 in.	2⅛ in.
Rows of pins in gill	2	2	...
Pins per inch	2½	5	6
Over all length of pin and B.W.G.	No. 14, 1⅜ in.	No. 16, 1¼ in.	No. 16, 1 in.

A system for preparing jute long line for warp 12 to 8 lbs. per spangle:

	Spiral Drawings.			Spiral Roving.
	1st.	2nd.	3rd.	
Heads per frame	2	3	3	7
Rows of gills per head	4	6	6	8
Deliveries per head.	1	1	2	8
Doublings	8	6	3	1
Length of reach	36 in.	32 in.	28 in.	24 in.
Breadth of gill	5 ,,	4 ,,	3 ,,	2 ,,
Breadth of conductor	4 ,,	3 ,,	2 ,,	¾ ,,
Overall length of pin	2 ,,	1¾ ,,	1½ ,,	1¼ ,,
Pins per inch (two rows)	4	5	6	7
Pitch of screw	⅞ in.	¾ in.	⅝ in.	½ in.

For preparing for spinning 5's to 9's lea flax and hemp yarns, or 5 to 9 lbs. jute line warp:

	Spiral Drawings.			Spiral Roving.
	1st.	2nd.	3rd.	
Heads per frame	2	3	4	7
Rows of gills per herd	4	6	8	10
Deliveries per head	1	1	2	10
Doublings	8	6	4	1
Length of reach	36 in.	32 in.	28 in.	24 in.
Breadth of gill	4½ ,,	3½ ,,	2¾ ,,	2 ,,
Breadth of conductor	3½ ,,	2½ ,,	1¾ ,,	¾ ,,
Over all length of pin	2 ,,	1¾ ,,	1½ ,,	1¼ ,,
Pins per inch (two rows)	5	6	7	8
Pitch of screw	¾ in.	⅝ in.	½ in.	½ in.

A 3-drawing system for preparing flax, hemp, and jute long line for spinning from 8's to 12's lea, or from 4 to 6 lbs. yarn:

	Spiral Drawings.			Spiral Roving.
	1st.	2nd.	3rd.	
Heads per frame	2	3	4	7
Rows of gills per head	4	6	8	10
Deliveries per head	1	1	2	10
Doublings	8	6	4	1
Length of reach	36 in.	32 in.	28 in.	24 in.
Breadth of gill	4 ,,	3 ,,	2½ ,,	2 ,,
Breadth of conductor	3 ,,	2 ,,	1¾ ,,	¾ ,,
Over all length of pin	2 ,,	1¾ ,,	1½ ,,	1¼ ,,
Pins per inch (two rows)	7	8	9	10
Pitch of screw	¾ in.	⅝ in.	½ in.	½ in.

Next, for preparing flax and hemp tow sliver for spinning 12's to 16's lea:

	Spiral Drawings.				Spiral Roving.
	Bell Frame.	Sett Frame.	3rd.	4th.	
Heads per frame	2	2	3	4	8
Rows of gills per head	6	6	6	8	10
Deliveries per head	1	1	1	2	10
Doublings	6	6	6	4	1
Length of reach	12 in.	11 in.	10 in.	9 in.	8 in.
Breadth of conductor	$2\frac{1}{4}$,,	$2\frac{1}{16}$,,	$1\frac{7}{8}$,,	$1\frac{3}{4}$,,	$\frac{1}{2}$,,
Breadth of gill	3 ,,	3 ,,	$2\frac{3}{4}$,,	$2\frac{1}{2}$,,	2 ,,
Over all length of pin	$1\frac{1}{4}$,,	$1\frac{1}{8}$,,	1 ,,	1 ,,	1 ,,
Pins per inch (two rows)	8	10	12	14	16
Pitch of screw	$\frac{5}{8}$ in.	$\frac{9}{16}$ in.	$\frac{1}{2}$ in.	$\frac{7}{16}$ in.	$\frac{3}{8}$ in.

For spinning flax, hemp, and jute long line into yarn from 10's to 16's lea:

	Spiral Drawings.			Spiral Roving.
	1st.	2nd.	3rd.	
Heads per frame	2	3	4	8
Rows of gills per head	4	6	8	10
Deliveries per head	1	1	2	10
Doublings	8	6	4	1
Length of reach	36 in.	32 in.	28 in.	24 in.
Breadth of conductor	$2\frac{1}{2}$,,	2 ,,	$1\frac{1}{2}$,,	$\frac{1}{2}$,,
Breadth of gill	$3\frac{1}{2}$,,	$2\frac{1}{2}$,,	$2\frac{1}{8}$,,	$1\frac{3}{4}$,,
Over all length of pin	$1\frac{3}{4}$,,	$1\frac{1}{2}$,,	$1\frac{1}{4}$,,	$1\frac{1}{8}$,,
Pins per inch (two rows)	8	9	10	12
Pitch of screw	$\frac{11}{16}$ in.	$\frac{5}{8}$ in.	$\frac{9}{16}$ in.	$\frac{1}{2}$ in.

A 3-drawing system for spinning flax and hemp long line into yarn weighing 14's to 18's leas per lb.:

	Spiral Drawings.			Spiral Roving.
	1st.	2nd.	3rd.	
Heads per frame .	2	3	4	8
Rows of gills per head . . .	4	6	8	10
Deliveries per head .	1	1	2	10
Doublings . .	8	6	4	1
Length of reach .	36 in.	32 in.	28 in.	24 in.
Breadth of conductor	$2\frac{1}{4}$,,	$1\frac{7}{8}$,,	$1\frac{1}{2}$,,	$\frac{1}{2}$,,
Breadth of gill .	$3\frac{1}{4}$,,	$2\frac{1}{4}$,,	2 ,,	$1\frac{3}{4}$,,
Over all length of pin	$1\frac{5}{8}$,,	$1\frac{3}{8}$,,	$1\frac{1}{4}$,,	$1\frac{1}{8}$,,
Pins per inch (two rows) . . .	9	10	12	14
Pitch of screw .	$\frac{11}{16}$ in.	$\frac{5}{8}$ in.	$\frac{9}{16}$ in.	$\frac{1}{2}$ in.

Next, for preparing flax and long line sliver for spinning 18's to 22's leas:

	Spiral Drawings.			Spiral Roving.
	1st.	2nd.	3rd.	
Heads per frame .	2	3	4	8
Rows of gills per head . . .	6	8	8	10
Deliveries per head .	1	1	2	10
Doublings . .	12	8	4	1
Length of reach .	36 in.	32 in.	28 in.	24 in.
Breadth of conductor	$2\frac{1}{8}$,,	$1\frac{3}{4}$,,	$1\frac{3}{8}$,,	$\frac{1}{2}$,,
Breadth of gill .	3 ,,	$2\frac{1}{2}$,,	2 ,,	$1\frac{3}{4}$,,
Over all length of pin	$1\frac{5}{8}$,,	$1\frac{3}{8}$,,	$1\frac{1}{4}$,,	$1\frac{1}{8}$,,
Pins per inch (two rows) . . .	10	12	14	16
Pitch of screw .	$\frac{11}{16}$ in.	$\frac{5}{8}$ in.	$\frac{9}{16}$ in.	$\frac{1}{2}$ in.

For spinning flax long line into 20's to 30's lea yarn :

	Spiral Drawings.			Spiral Roving.
	1st.	2nd.	3rd.	
Heads of frame	2	3	4	8
Rows of gills per head	6	8	8	10
Deliveries per head	1	1	2	10
Doublings	12	8	4	1
Length of reach	30 in.	28 in.	26 in.	24 in.
Breadth of conductor	2 ,,	$1\frac{5}{8}$,,	$1\frac{1}{4}$,,	$\frac{7}{16}$,,
Breadth of gill	$2\frac{3}{4}$,,	$2\frac{1}{4}$,,	$1\frac{7}{8}$,,	$1\frac{1}{2}$,,
Over all length of pin	$1\frac{3}{8}$,,	$1\frac{1}{4}$,,	$1\frac{1}{8}$,,	1 ,,
Pins per inch (two rows)	12	14	16	18
Pitch of screw	$\frac{5}{8}$ in.	$\frac{1}{2}$ in.	$\frac{7}{16}$ in.	$\frac{3}{8}$ in.

A 4-drawing system for preparing flax tow sliver for spinning into yarn 16's to 25's leas per lb. :

	Spiral Drawings.				Spiral Roving.
	Bell Frame.	Sett Frame.	3rd.	4th.	
Heads per frame	2	2	3	4	7
Rows of gills per head	6	6	6	8	10
Deliveries per head	1	1	1	2	10
Doublings	6	6	6	4	1
Length of reach	12 in.	11 in.	10 in.	9 in.	8 in.
Breadth of conductor	$2\frac{1}{8}$,,	2 ,,	$1\frac{7}{8}$,,	$1\frac{3}{4}$,,	$\frac{1}{2}$,,
Breadth of gill	3 ,,	$2\frac{3}{4}$,,	$2\frac{1}{2}$,,	$2\frac{1}{4}$,,	$1\frac{1}{2}$,,
Over all length of pins	$1\frac{1}{8}$,,	1 ,,	$\frac{7}{8}$,,	$\frac{7}{8}$,,	$\frac{3}{4}$,,
Pins per inch (two rows)	10	12	14	16	18
Pitch of screw	$\frac{1}{2}$ in.	$\frac{1}{2}$ in.	$\frac{7}{16}$ in.	$\frac{7}{16}$ in	$\frac{3}{8}$ in.

Another 4-drawing system for preparing tow sliver for spinning into yarn 30's to 50's leas per lb. :

	Spiral Drawings.				Spiral Roving.
	Bell Frame.	Sett Frame.	3rd.	4th.	
Heads per frame . .	3	3	4	5	11
Rows of gills per head.	6	8	8	8	10
Deliveries per head .	1	2	2	4	10
Doublings . . .	6	4	4	4	1
Length of reach . .	11 in.	10 in.	9 in.	9 in.	8 in.
Breadth of conductor .	$1\frac{3}{4}$,,	$1\frac{5}{8}$,,	$1\frac{3}{8}$,,	$\frac{7}{8}$,,	$\frac{3}{8}$,,
Breadth of gill . .	$2\frac{1}{2}$,,	$2\frac{3}{8}$,,	$2\frac{1}{8}$,,	$1\frac{1}{2}$,,	$1\frac{1}{8}$,,
Over all length of pins.	$1\frac{1}{8}$,,	1 ,,	$\frac{7}{8}$,,	$\frac{13}{16}$,,	$\frac{11}{16}$,,
Pins per inch (two rows)	16	18	20	24	28
Pitch of screw . .	$\frac{3}{8}$ in.	$\frac{3}{8}$ in.	$\frac{3}{8}$ in.	$\frac{11}{32}$ in.	$\frac{5}{16}$ in.

For spinning flax long line into 30's to 50's lea yarn :

	Spiral Drawings.				Spiral Roving.
	1st.	2nd.	3rd.	4th.	
Heads per frame . .	3	4	5	6	14
Rows per head . .	6	8	8	8	8
Deliveries per head .	1	1	1	2	8
Doublings . . .	12	8	8	4	1
Length of reach . .	24 in.	22 in.	20 in.	18 in.	16 in.
Breadth of conductor .	$2\frac{1}{8}$,,	$1\frac{7}{8}$,,	$1\frac{1}{8}$,,	1 ,,	$\frac{3}{8}$,,
Breadth of gills . .	3 ,,	$2\frac{3}{8}$,,	$1\frac{7}{8}$,,	$1\frac{1}{2}$,,	$1\frac{1}{4}$,,
Over all length of pins.	$1\frac{1}{8}$,,	1 ,,	$\frac{7}{8}$,,	$\frac{13}{16}$,,	$\frac{3}{4}$,,
Pins per inch (two rows)	16	18	22	26	30
Pitch of screw . .	$\frac{3}{8}$ in.	$\frac{11}{32}$ in.	$\frac{11}{32}$ in.	$\frac{11}{32}$ in.	$\frac{5}{16}$ in.

A 5-drawing system for preparing "heavy spread" flax sliver for spinning into yarn 60's to 80's leas per lb.:

	Spiral Drawings.					Spiral Roving.
	Doubler.	1st.	2nd.	3rd.	4th.	
Heads per frame . .	1	3	4	5	6	14
Rows of gills per head .	6	8	8	8	8	8
Deliveries per head .	1	1	1	1	2	8
Doublings . . .	12	16	8	8	4	1
Length of reach . .	30 in.	24 in.	22 in.	20 in.	18 in.	16 in.
Breadth of conductor .	2½ ,,	1½ ,,	1¼ ,,	1 ,,	11/16 ,,	¼ ,,
Breadth of gills . .	3 ,,	2¼ ,,	1¾ ,,	1½ ,,	1¼ ,,	⅞ ,,
Over all length of pins .	1⅜ ,,	1 ,,	⅞ ,,	¾ ,,	11/16 ,,	⅝ ,,
Pins per inch (two rows)	14	18	22	26	30	34
Pitch of screw . .	¾ in.	5/16 in.	9/32 in.	9/32 in.	9/32 in.	¼ in.

Another 5-drawing system for preparing "heavy spread" flax sliver for spinning into yarn 80's to 120's leas per lb.:

	Spiral Drawings.					Spiral Roving.
	Doubler.	1st.	2nd.	3rd.	4th.	
Heads per frame . .	1	3	4	5	6	14
Rows of gills per head .	6	8	8	8	8	8
Deliveries per head .	1	1	1	1	2	8
Doublings . . .	12	16	8	8	4	1
Length of reach . .	28 in.	24 in.	22 in.	20 in.	18 in.	16 in.
Breadth of conductor .	2 ,,	1¼ ,,	⅞ ,,	11/16 ,,	½ ,,	3/16 ,,
Breadth of gill . .	2⅜ ,,	1¾ ,,	1½ ,,	1⅜ ,,	1⅛ ,,	⅞ ,,
Over all length of pins .	1¼ ,,	1 ,,	⅞ ,,	¾ ,,	⅝ ,,	⅝ ,,
Pins per inch (two rows)	16	20	26	30	36	40
Pitch of screw . .	⅝ in.	5/16 in.	9/32 in.	9/32 in.	9/3 in.	¼ in.

For preparing flax long line to spin from 120's to 250's lea yarn:

	Spiral Drawings.					Spiral Roving.
	1st.	2nd.	3rd.	4th.	5th.	
Heads per frame . .	2	3	4	5	6	14
Rows of gills per head .	8	8	8	8	8	8
Deliveries per head .	1	1	1	1	2	8
Doublings . . .	16	16	8	8	4	1
Length of reach . .	26 in.	24 in.	22 in.	20 in.	18 in.	16 in.
Breadth of conductor .	$1\frac{1}{4}$,,	1 ,,	$\frac{3}{4}$,,	$\frac{9}{16}$,,	$\frac{3}{8}$,,	$\frac{1}{8}$,,
Breadth of gills . .	2 ,,	$1\frac{1}{2}$,,	$1\frac{1}{8}$,,	$\frac{7}{8}$,,	$\frac{3}{4}$,,	$\frac{1}{2}$,,
Over all length of pins .	$1\frac{1}{16}$,,	$\frac{15}{16}$,,	$\frac{13}{16}$,,	$\frac{11}{16}$,,	$\frac{9}{16}$,,	$\frac{1}{2}$,,
Pins per inch (two rows)	32	36	40	45	50	60
Pitch of screw . .	$\frac{3}{8}$ in.	$\frac{5}{16}$ in.	$\frac{9}{32}$ in.	$\frac{9}{32}$ in.	$\frac{1}{4}$ in.	$\frac{3}{16}$ in.

The proper proportioning of the gills to suit the work being done on the frames is of great importance. If the gills are too narrow they will be overloaded. It is a very important point to see that the gills are not overloaded, that is, that the sliver is well down through the gill pins. The points of the gill pins should always be seen if the sliver is to be level at the front of the drawing. No matter how well the material has been carded or hackled, if the gills of the drawings are overloaded, irregular and lumpy rove will result, through the fibre being "gulped" by the drawing rollers. The gills should be about 1 inch wider than the front conductor, and the back conductor set so that it is about $\frac{1}{4}$ of an inch narrower than the gill, or the same width as the front conductor of the previous frame, so that the sliver may be flat and well spread in the gill, which it should nearly fill as regards width. The best results as regards perfect drawing will be obtained when the sliver is rather light in the gill.

The weight of the slivers upon the doubling plate is another important point, for if the slivers be too light there will be a troublesome tendency to licking up, while if they be too heavy it shows in all probability that the gill is overloaded, and that the pressing roller is getting too much to do, and consequently drawing imperfectly. A good axiom will be found to be that the separate slivers upon the sliver plate should weigh 32 yards per oz. per inch in breadth. If the following method of proportioning the conductors and gills be carried out, the results will be found to correspond with the best practice. First determine the heaviest rove combined with the longest drafts it is proposed to work over the system. The yards per oz. of rove, divided by the draft of the roving frame and multiplied by the rows of gills per delivery on the fourth drawing, gives the yards per oz. of sliver on the doubling plate of the fourth drawing. If the slivers are single in the gills of the fourth drawing, the yards per oz. of sliver on the doubling plate of the third drawing may be found as before. If, as is sometimes the case, the slivers are doubled in the gills of the fourth drawing, the yards per oz. of sliver on the doubling plate of the third drawing will be twice the yards per oz. on the plate of the fourth drawing, multiplied by the rows per delivery on the third drawing and divided by the draft of the fourth drawing. Proceeding backwards in this way, the weight of the sliver on all the doubling plates may be calculated, and the proper width of the front conductors arrived at on the basis of 32 yards per oz. per inch. The gills should be about $\frac{1}{4}$ of an inch wider than the front conductor of the preceding frame.

The number of wire or size of pin to be used, in order to obtain a sufficiently strong gill, must be directly as the pins per inch, and inversely as the length of the pin, for a closely set gill of fine pins may be as firm and strong as a coarser gill of stronger wire. A long-pinned gill is not so firm as one of shorter pins; hence, if the pins be very long, they should be of heavy wire.

The finer the screw, the shorter the nip, and the more level the sliver obtained, as, when the faller does not approach close enough to the drawing roller, the material is apt to be gulped, or drawn away quickly when the bar falls, and thus produce thicks and thins in the sliver. The pitch of screw can scarcely be made less than $\frac{3}{16}$ inch, to give a strong enough screw thread and a sufficiently rigid faller bar.

The following tables of gills, screws, and faller bars correspond with modern practice:

Breadth of gill in inches . . .	5	4	$3\frac{3}{4}$	$3\frac{1}{2}$	$3\frac{1}{4}$	3
Pitch of screw . .	$\frac{3}{4}$ in.	$\frac{11}{16}$ in.	$\frac{5}{8}$ in.	$\frac{9}{16}$ in.	$\frac{1}{2}$ in.	$\frac{1}{2}$ in.
Rows per head . .	6	6	6	6	6	6
Pins per inch in gill	6–9	7–10	8–13	8–14	9–15	9–16
No. of wire, B.W.G.	13–16	14–17	14–18	14–19	15–20	15–21

Breadth of gill in inches	$2\frac{3}{4}$	$2\frac{1}{2}$	$2\frac{1}{4}$	2	$1\frac{3}{4}$
Pitch of screw . .	$\frac{7}{16}$ in.	$\frac{3}{8}$ in.	$\frac{3}{8}$ in.	$\frac{3}{8}$ in.	$\frac{3}{8}$ in.
Rows per head . .	6	8	8	8	8
Pins per inch in gill .	10–18	12–23	14–24	14-27	14–28
No. of wire, B.W.G. .	15–22	16–23	18–24	18–24	18–25

Breadth of gill in inches	$1\frac{1}{2}$	$1\frac{1}{4}$	1	$\frac{3}{4}$	$\frac{1}{2}$
Pitch of screw . .	$\frac{3}{8}$ in.	$\frac{3}{8}$ in.	$\frac{5}{16}$ in.	$\frac{1}{6}$ in.	$\frac{3}{16}$ in.
Rows per head . .	8	8	8	8	8
Pins per inch in gill .	16–30	18–35	20–42	36–42	44–60
No. of wire, B.W.G. .	21–25	22–26	24–27	27–28	28–30

"Licking up," or the adhesion of light slivers to the wooden pressing or drawing rollers, is a frequent source of trouble in the preparing room. It is most troublesome when the air is dry, as it often is in cold and frosty weather, or when easterly winds prevail, as they often do in the month of March. The cause may be looked for in the electricity generated by the friction of the fibres as they are rapidly drawn through the gills. "Licking up" does not take place when the atmosphere is moist, since the frictional electricity referred to is absorbed. There is, however, a gummy matter which is deposited upon the wooden rollers by the passing fibre. It must be removed from time to time by washing the rollers with linseed oil, or with a wash made up after the following recipe, which acts as a solvent for the gum and, being volatile, dries up quickly: Two parts of petroleum, one part of raw linseed oil, and one part of turpentine.

Preparing rooms may be ventilated in a similar manner as described in connection with the hackling shop, *i.e.* by the plenum system. The underground suction ducts may be utilised to produce, in addition to a general ventilation of the room, a localised ventilation of those places where the larger part of the dust is produced, *i.e.* below the fallers and behind the drawing rollers, by connecting these localities to the duct by means of zinc pipes furnished with trumpet-mouthed collectors. The humidification of the air blown into the room and distributed by the overhead ducts may be effected by the use of a sort of openwork drum or cylinder covered with jute sacking, and turning in a water trough. This cylinder should be placed in the suction duct in such a way that the air is forced to pass through it before entering the fan, and thus absorb moisture from its wet covering. If the room requires to be warmed at the same time, the water may be heated in the trough, or steam may be blown off in the duct. If dry heat is required, the first suction duct may be closed and another used, into which the air may be drawn through the pipes of an aero-condenser, through pipes placed in a flue or through a steam coil or heater.

If ordinary exhaust fans placed in the windows or walls are used to evacuate the dust generated, the local humidification of the room may be effected by means of the Drosophore humidifier, Figure 34, in which a jet of water under pressure, impinging upon a nickle pin, forms a cone of spray which is carried into the room by the air current which it itself produces.

The ventilation of a carding room is also thoroughly accomplished by the use of underground ducts. All the openings in the envelope of the card which can be closed up should be closed up; so that, the underground duct being joined up with the underneath part of the card, the air is drawn through all the small openings which cannot be closed up around the feed rollers, strippers, workers, and

CALIFORNIA

doffers, and the rising of the dust into the air of the room prevented. The speed of the air current in the duct should not exceed 180 feet per minute, so that the fibres may not be caused to fall from the heavily loaded cylinder or workers. The underground duct is sometimes placed under the tables of a row of cards, and is of sufficient height and width to permit of men entering to bale up the card waste, an extremely unhealthy occupation. The author advises rather the use of a system in which the duct is of smaller section and provided with a travelling lattice, which receives the waste either directly as it falls from the card cylinder, or through the intermedium of a secondary lattice. The main lattice automatically removes and bales the heavy waste, while the fine dust is drawn along the duct by the suction of a fan. In either case the section of the duct should diminish in proportion to its distance from the fan, so that the air current may be sufficiently strong at the end to prevent the issue of dust. The dust drawn in and expelled by fans may be caused to settle by a water spray produced by pulverisers fed by water under pressure and placed in the roof of the discharge duct, or else by the use of a large settling chamber, in which the speed of the air is reduced to such an extent that the dust settles of its own accord, while the air escapes by an opening high up in a distant part of the chamber. An apparatus called a "cyclone separator" may likewise be employed to bring about the settling of the waste and heavy dust. In this case the fan blows the air full of dust and short fibres into the upper part of the apparatus, where the heavier particles are caused to take a spiral downward path, and are at length thrown out of an opening at the bottom, while the air issues at the top.

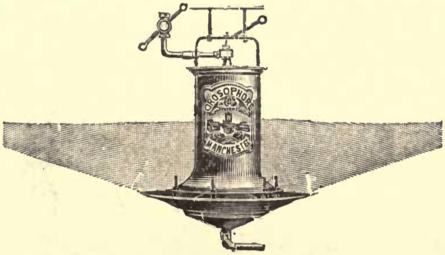


Fig. 34.—Drosophore humidifier.

The usual arrangement of the preparing machinery in a jute mill is to have all the breaker cards in one long line behind another parallel line of finisher cards. The first drawings extend in another line parellel to the others, and behind a line of second drawings, thus forming four long parallel lines of machines. The rovings are set at right angles to these lines, each opposite to the second drawing which supplies it with cans.

In a tow-preparing room a neat arrangement is to have the roving frames in a line end to end and parallel with the line shaft.

Behind each and parallel with them are the second and third drawings end to end. Behind the third drawing is the card which supplies the sliver, and behind the second drawing is the bell frame. When the systems are compounded, however, or when the independent head system is adopted, the long sets of first, second, and third drawings may be placed in parallel lines and the rovings set at right angles, each opposite the section which supplies it. In line preparing, the same arrangement may be adopted if the systems are compounded or if the heads be independent. With short simple drawings, the three or four frames may be placed in pairs behind the roving which they supply.

CHAPTER V

GILL SPINNING

GILL spinning is practised either for very heavy yarns, such as rope yarns, reaper yarn, 48–60 lbs. jute weft, or for superior flax and hemp yarns, up to 20's lea, where great strength and levelness is required, such as for shoe threads, etc.

There are two main types of gill-spinning machines, that in which the drafting is done by rollers, which may be called the roving-frame type, and that in which the drafting is done by the pull of the yarn itself passing round the haul pulleys and being wound at a constant speed. The latter type of machine usually goes by the name of automatic spinner, or simply automatic.

Figure 36 is an example of the former type, being a gill-spinning frame for spinning long hemp into rope yarns. It is a 5-headed frame of 40 spindles (tape driven), 10 × 5-inch bobbins, and 42-inch reach. The bobbins rest upon and engage with the pin in a friction carrier, which is braked by a friction brake in the form of two pieces of wood, hinged and tightened together by a thumbscrew. Thus the flyers drag the bobbins round and wind the yarn tightly upon them. The drafting arrangements, consisting of feed rollers, screw gills, and drawing rollers, are similar to those of the drawing or roving frame, the machine being fed with cans from the finishing drawing of a suitable system of preparing. The tops of the spindles are steadied by a cap plate and may be run up to 1000 revolutions per minute. The twist calculation may be made as follows: Suppose that the drawing roller wheel has 80 teeth, twist pinion 60 teeth, crown wheel 85 teeth, and cylinder pinion 30 teeth, that the tin cylinder is 15 inches in diameter, and the wharve on the spindle 3 inches, and that the drawing roller is likewise 3 inches in diameter, or 9·4 inches in circumference, the spindles then make $\frac{80 \times 85 \times 15}{60 \times 30 \times 3}$ = nearly 19 revolutions for each revolution of the drawing roller, or $\frac{19 \times 12}{9 \cdot 4} = 24 \cdot 2$ turns per foot, the correct twist for No. 40's rope yarn. The number of turns per foot twist required for rope yarns equals the product of 3·75 and the square root of the number of the yarn. For 25's spun yarn, for instance, the correct twist will be $\sqrt{25} \times 3 \cdot 75 = 5 \times 3 \cdot 75 = 18 \cdot 75$ turns. The number of rope yarn indicates the number of threads of that yarn which will be required to make one of the three strands which will form a rope 3 inches in circumference. No. 20, for instance, indicates that three strands of 20 threads each, or 60 threads in all, make a rope 3 inches in circumference. The weight of 100 yards of No. 20 rope yarn may be calculated as follows: The weight of 100 yards of white rope, 3 inches in circumference, averages about 84 lbs. The contraction by twist being about 25 per cent., each of the single yarns composing the rope must have a length

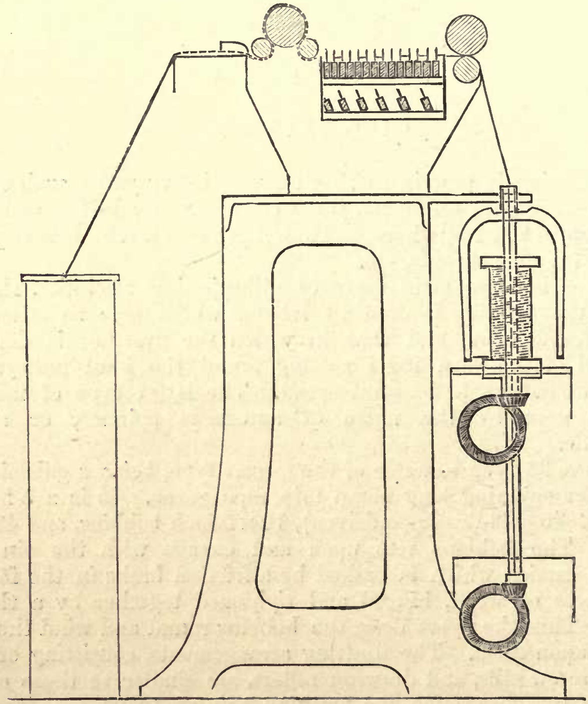


FIG. 35.

of 125 yards, or the total length of the 60 strands will be 7500. Since this length weighs 84 lbs. or 1344 oz., 100 yards weigh

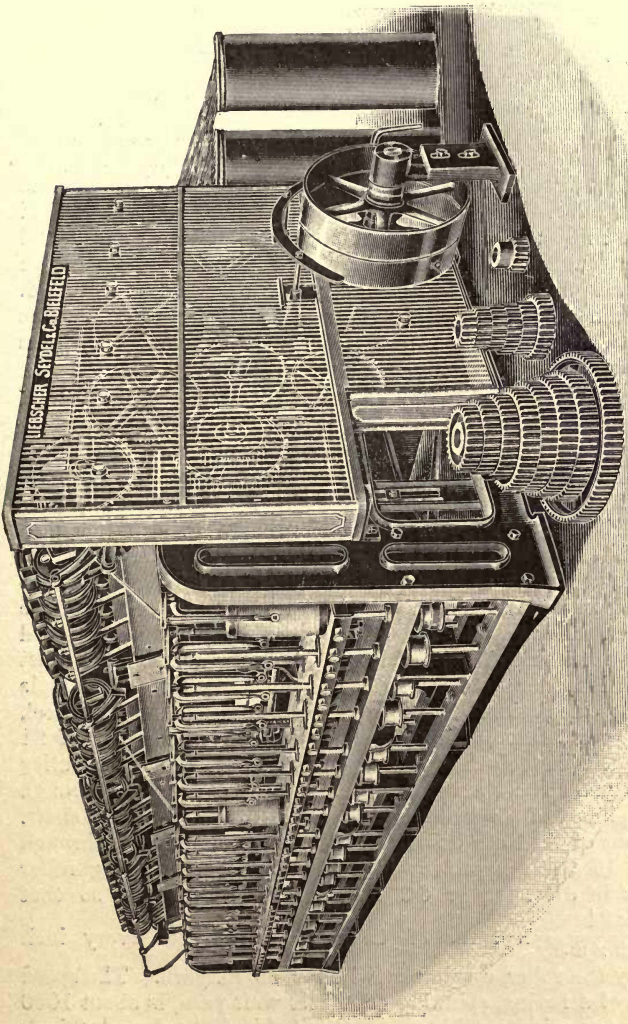

LIEBSCHER SEYDEL & Co. BIELEFELD

FIG. 36.—Gill-spinning machines for spinning rope yarns from long hemp.

nearly 18 oz. Similarly, No. 40 weighs 9 oz.; No. 30, 12 oz.; and No. 18, 20 oz., per 100 yards.

The Continental or Metric System of numbering rope yarns is based upon the number of times a thousand metres is contained in a kilogramme of yarn. Thus

No. 1 yarn = 1000 metres per kilogramme.
No. 2 „ = 2000 „ „
No. 3 „ = 3000 „ „
and so on.

A kilogramme = 2·2 lbs.; a metre = 39·37 inches.

In changing from one yarn No. to another, the twist pinion may be changed in the inverse proportion to the square roots of the yarn numbers. For instance, we found that a 60-twist pinion gave the correct twist to No. 40, what pinion will give No. 25's its correct twist? $\sqrt{25} : \sqrt{40} :: 60 : 78$ Ans. A simpler way, nearly correct and suitable for rough calculation, is done as follows: Find a pinion in the inverse proportion to the numbers, thus 25 : 40 : : 60 : 96. Find the mean between the old pinion of 60 teeth and the new one of 96 teeth, or add the two together and divide by 2, thus $\frac{60+96}{2} = \frac{156}{2} = 78$, the pinion required to give No. 25 yarn its proper twist.

The spinning roving frame used in the jute trade for heavy wefts is similarly constructed to the machine shown in Figure 36, except that the reach is much shorter and that the bobbin is positively driven by gearing, as in the ordinary roving frame, at a speed regulated so that the flyer shall wind the yarn upon the bobbin without undue strain. The bobbin winding motion is that of the roving frame, and will be explained under that heading in the next chapter. The spindles are also driven by gearing at a speed about three times that of the main shaft of the frame. As the twist arrangement is rather different in consequence, we give an example of the twist calculation. Suppose that the drawing roller wheel, of 90 teeth, gears through intermediates with a twist pinion of 21 teeth upon the end of the frame shaft; upon the other or pulley end of the main shaft a speed wheel of 44 teeth drives, through carriers, a pinion of 22 teeth upon the end of the spindle shaft. Bevel pinions of 24 teeth upon the shaft drive the spindles through pinions of 16 teeth keyed upon their feet. The drawing roller is 2 inches in diameter, or 6·3 inches in circumference, so that $\frac{90 \times 44 \times 24}{21 \times 22 \times 16 \times 6{\cdot}3} = 2$ turns of twist are given for every inch delivered by the roller, a suitable twist for 48 lb. yarn. The speed of spindles of a roving, spinning 48–60 lb. weft yarn, is about 1050 revolutions per minute with a bobbin of 4-inch head and 8-inch traverse.

A very much finer spinning roving frame of similar construction is sometimes used to spin up to 18's lea yarn for shoe threads upon a 6 × 3-inch bobbin, when it is desired to obtain a very long length of yarn free from knots.

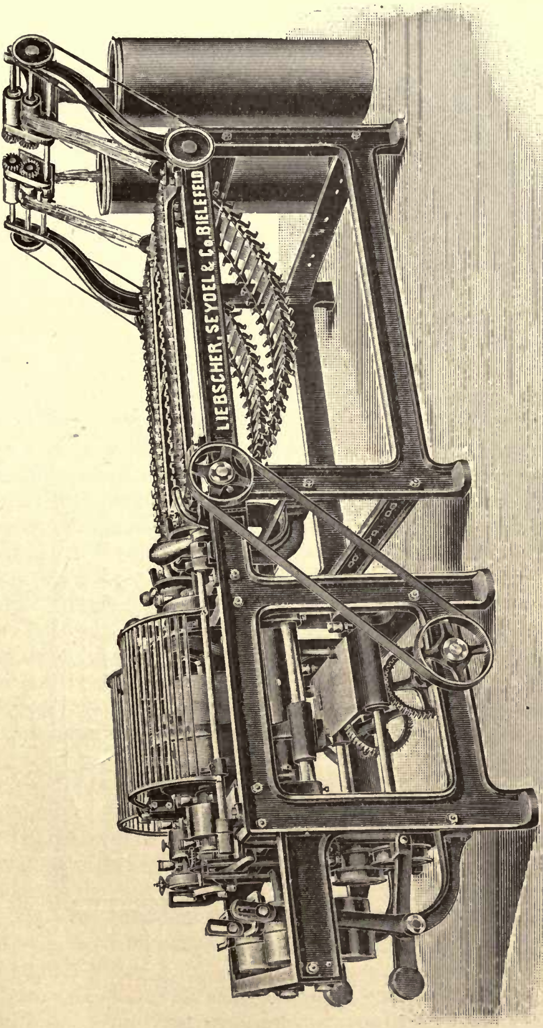


Fig. 37.—Automatic gill spinner for rope yarns, binder twine, etc.

In the ordinary gill spinning frame the bobbins are supported upon ordinary builder plates and dragged by drag bands as in the wet and dry spinning frame. These drag bands are attached at the back of the builder, touch the base of the bobbin, and pass over a nicked builder strip, the tension being maintained by a drag-weight attached to the free end of the band. The drag upon the bobbins is increased by shifting the bands farther along upon the nicked

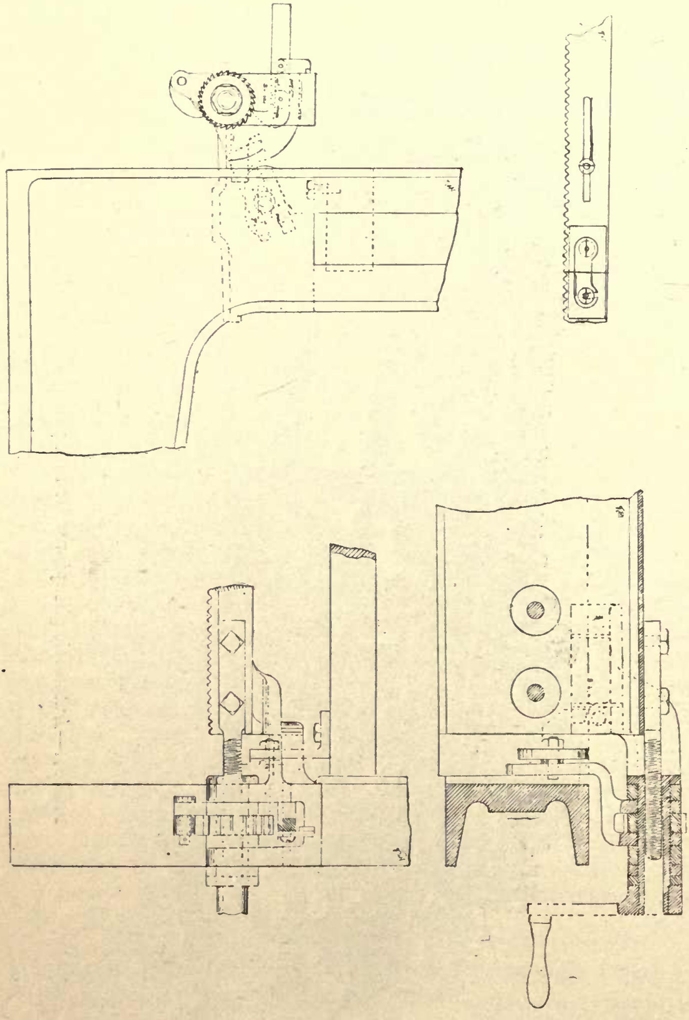


Fig. 38.—Carter's automatic bobbin-dragging motion.

front builder strip, and in this way causing them to embrace a larger part of the base of the bobbin. This "tempering" of the drags requires some skill, and must be done regularly and uniformly as the bobbin fills and becomes heavier, and as the pull of the thread becomes more effective through acting upon the end of an increasing radial line. When the bobbins are to be doffed, the drag bands must be set back out of contact with the bobbin bases, and replaced in light contact with them when the frame is again started.

In Figure 38 we give a view of an automatic bobbin dragging device applicable to gill, dry and wet spinning frames alike. In this motion it will be seen that the upward movement of the builder is utilised to move round, by means of a ratchet and pawl, an internally threaded sleeve, which forms a nut working upon a screw attached to the front builder strip. This front nicked builder strip is made movable, while the screwed sleeve turns in a bracket attached to the builder, which bracket keeps it in position, so that in turning automatically it draws the nicked builder strip from right to left. As the builder falls, the pawl slips over as many teeth in the ratchet wheel as it will move forward upon the return journey, the ratchet being kept from turning the while by the lower catch shown. The pawl may be caused to move forward more or less teeth each time, by shifting backwards or forwards the stud which is carried in a slotted bracket attached to the neck rail, and which works in an open-ended slot in the swinging arm which actuates the pawl. Thus for every two layers of yarn which are put upon the bobbin the drag is slightly increased, so that the tension of the end remains regular from start to finish of the doff without any attention on the part of the spinner. The result is that there is no ballooning of the ends, that the yarn is built harder upon the bobbin, which consequently contains more yarn, and that the yarn is rounder and stronger, since the fibres lie closer together in consequence of having been twisted together under tension. The handle shown is provided to turn back the screwed sleeve, and in so doing carry back the nicked strip and put the drag bands out of contact with the bobbins for doffing. The handle is also used to wind the nicked strip forward again, and bring the bands into contact with the bobbins before starting the frame with a fresh set of bobbins. A damping roller, turning in a trough of water, is sometimes placed in contact with the yarn between the drawing roller and the head of the flyer. Its object is to lay any outstanding fibres, and give a smoother and more sightly yarn.

Figure 37 shows an automatic gill spinner for rope yarns, binder twine, etc. This class of machine was first introduced in America by John Good, a name well known in the rope trade. As seen in the illustration, cans of sliver from the finishing drawing frame are placed behind the machine, and the sliver drawn up and passed through a trumpet mouth which prevents the passage of knots and entanglements, then through a pair of feed rollers which are geared and given the same surface speed as the gill sheet, by means of a band and pulleys, as shown. The sliver passes through another trumpet mouth before being pinned by the gills, which are placed on bars, and form an endless sheet, working in the same manner as in the chain or link drawing. From the gills the fibres are drawn through a condenser apparatus, consisting of a trumpet mouth with a grooved cam-shaped nipping plug centred in its throat, the two together being intended to automatically contract and enlarge the size of the opening according to the size of the yarn, and at the same time to maintain a nip upon the passing fibres. Leaving the condenser, the fibres pass between the cheeks of a stop motion lever, which falls to one side when the sliver breaks or runs out, and brings the spindle and sheet to a standstill, and then through the twist tube to the haul pulleys, turning upon studs set in the disc of the flyer. The twist tube is a tube driven at a speed of about 1400 revolutions per minute by means of a belt and a pulley keyed upon the tube. Upon the end of the tube, which is inside the flyer, is a small pinion which drives the haul pulleys. The haul pulleys have each three grooves, around which the yarn is wound before passing over guide pulleys, upon the flyer arms, to the bobbin. The degree of twist put into the yarn depends upon the speed of the twist tube in relation to that of the flyer. The haul pulley drive is a sort of epicyclic gear. If the twist tube were stationary, the flyer would carry the haul pulleys round the stationary pinion upon the twist tube and give them a motion in the same direction as it itself turns. When, however, the twist tube is run in the same direction as the flyer, it tends to drive the haul pulleys in the opposite direction. The speed given by the flyer is the greater, consequently the haul pulleys turn in the same direction as the flyer at a speed equal to the difference between the two contrary motions given to them by their two drivers. It is the amount of this difference which may be regulated by the speed of the twist tube, which gives the draft and affects both draft and twist. It is thus essential, in this type of machine, in order that the size and twist of the yarn may be regular, that the twist belt is kept tight and cannot slip, and that the flyer revolves at a constant speed. The draft and twist are both changed by altering the speed of the twist tube. The draft alone is changed by increasing or diminishing the rate of feed by changing the lower of the two sheet pulleys in the inverse proportion to the draft required.

The condenser is mounted upon an upright lever centred at the bottom and held in its normal position by the pull of the yarn and by a spring. This lever is also connected with a mechanism for changing the speed of the feed sheet. When it is in its normal position with a yarn of the average diameter passing through the condenser, the gill sheet has its normal speed. When the upright arm is pulled forward by a thick portion of the sliver trying to get through the condenser, the gill sheet momentarily stops or slows down, while the thick part is drawn out and the yarn levelled, when the condenser recedes again and the gill sheet resumes its normal speed. When a thin portion of the sliver reaches the condenser, it tends to pass through the contracted opening more readily, and the tension upon the upright arm is relaxed, permitting the spring to draw the lever backwards, when the gill sheet is driven quicker, delivering an increased supply of the material to the condenser and producing uniformity in the yarn.

The flyer is composed of two discs about 12 inches in diameter and 26 inches apart, joined by two stay rods, and turning upon hollow gudgeons working in bearings at either end. As the flyer is heavy, and turns at a speed of over 1600 revolutions per minute, it should have a band around it to prevent it flying to pieces at high speed, and be protected by a grating as shown, or by a circular iron cover with a sliding door in the top to give access to the hands of the spinner when doffing the bobbin or piecing an end. The bobbin is usually about 8 × 10 inches, with a barrel 2 inches in diameter and 1 inch bore. It turns upon a stationary spindle which passes through the flyer, and which is withdrawn to doff the bobbin. The end of the bobbin has in it a small hole, protected by a metal ring, in which engages a pin projecting from the disc of a long sleeve, both sleeve and bobbin being carried round upon the stationary spindle by the pull of the yarn as the flyer revolves, and both having a reciprocating motion given to them by a screw block and a traverse screw. There is a pulley upon the long sleeve, around which pulley is a belt termed the friction belt. Its function is to control the speed of the bobbin and sleeve, and prevent them overrunning when the machine stops, and also to overcome the inertia of the bobbin when the machine starts, and prevent the yarn from breaking under an undue strain. As may be seen from the illustration, the automatic spinner has two spindles running independently side by side. The yarn must be wound around the haul pulleys in the direction of rotation of the flyer, otherwise the machine will not work at all. Either right or left hand twist may be put in as required. The machine is well adapted for spinning from Nos. 18 to 40's rope yarn from hard fibre, and for producing the four standard sizes of binder twine, *i.e.* 500, 550, 600, and 650 feet per lb. from Manila and New Zealand hemps.

Owing to the recent imposition of preferential duties, the greater part of the Manila hemp crop now goes to America, the United States being the largest users of hard fibre in the world. There are many large rope works, one of the principal being the M'Cormick binder twine mill in Chicago, which has a capacity of 90 tons of binder twine per day.

For lighter yarns from hard fibre, say for 1 lea yarn from white Manila, suitable for twisting into trawl twine, a machine somewhat similar in principle but different in construction is required. It is known as Lawson inclined gill-spinning machine, and has usually six spindles side by side, and is adapted for an 8 × 4-inch bobbin. The cans of sliver from the finishing drawing frame are put up at the back as before, and the sliver passed to the feed rollers. As it issues from these latter, the sliver is pinned by gills, fixed upon faller bars in the usual way. The bars or fallers are moved forward by screws upon the screw gill principle. The fibre is drawn from the gills through a condenser and twist tube by means of haul pulleys in a similar manner as in the automatic spinner. Gearing, however, takes the place of belts in the flyer and twist tube drive, and in dragging the bobbin, and has the advantage that, being a positive drive, the weight and twist of the yarn cannot be affected by slipping belts, as in some makes of automatic spinners. Unlike the automatic, the condensing trumpet mouth has no draft-controlling power. It merely serves to retain and draw out lumps, and to preserve such a grip upon the fibres as will prevent them from being gulped. The theory of the drafting, twisting, and winding is similar to that of the automatic spinner. The particulars of this machine are: Length of reach, 80 inches; breadth of gill, $1\frac{1}{2}$ inches; pins per inch in gill (1 row) 8; over all length of pin, 1 inch; pitch of screw, $1\frac{5}{16}$th inch.

CHAPTER VI

THE FLAX, HEMP, AND JUTE ROVING FRAME

THE roving frame is one of the most important and interesting machines in the spinning mill. It is important because badly made rove can never make good yarn. It is interesting on account of its winding and differential gear, which is a most ingenious and beautiful piece of mechanism.

Of the drafting arrangements of the roving frame we have nothing more to do, they being practically the same as in the drawing frame. The gills are of the screw, link, slide, ring, circular, or rotary types. When the sliver reaches this frame it has been attenuated to such an extent that if it is to be drawn out still further before spinning it must be given a slight twist to strengthen it, and must be wound upon a bobbin.

Figure 39 gives a general view of a coarse roving frame as made by Messrs. Fairbairn Macpherson & Co. of Leeds. It will be seen that this frame has 64 spindles ranged in two rows. The tendency of the times is to increase the length of the frames, and consequently the number of spindles. The author has worked frames of 112 spindles with a 7 × 3½-inch bobbin, which is probably the maximum length made so far. The speed of the spindles has likewise increased. Twenty years ago 500 revolutions per minute was considered a good speed, but they are now sometimes run up to double that speed. The spindles are of steel, 2 to 3 feet long and ½ to ¾ inch in diameter. The spindle "foot" rests in a brass step set in the step rail. The spindles are supported in a vertical position by brass collars fixed in the builder. These collars, which should be of a good length, form a sleeve or socket upon which the wharves or bobbin carriers may run without wearing the spindles. In coarse frames the spindle tops are usually steadied by cap plates, seen in Figures 39 and 40. The tops of the spindles are fitted to receive the flyers, which are of wrought iron or steel. The flyer is attached to the spindle top by means of a small round button fixed inside the socket of the flyer, and engaging in a spirally cut groove in the spindle top. The revolving spindle keeps the button

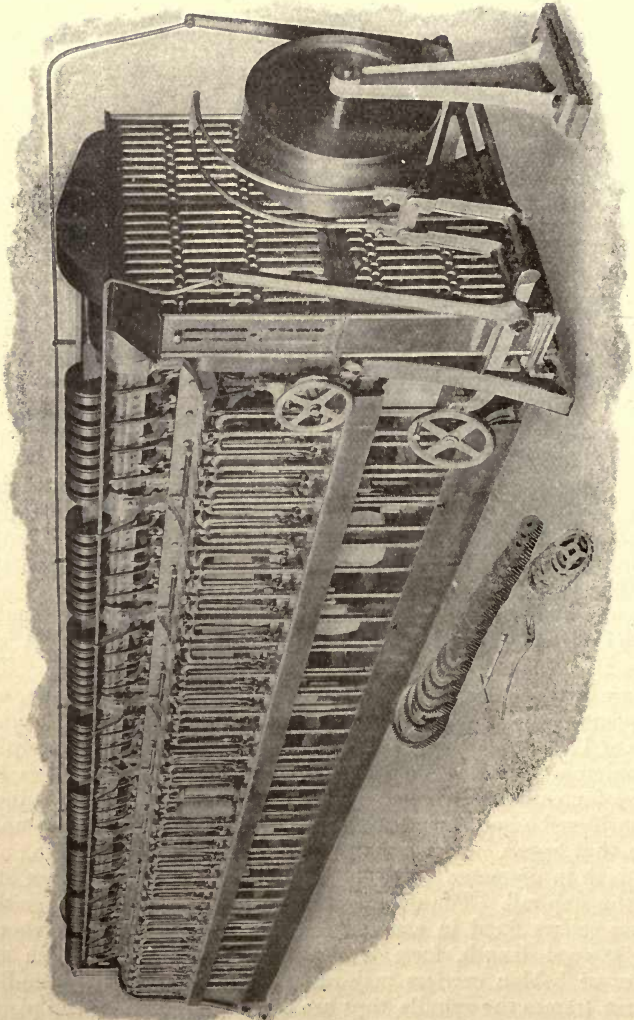


FIG. 39.—Coarse roving frame.

pressed against the end of the groove, which prevents the flyer flying off when at work, but does not hinder its speedy removal for doffing. The neck and leg of the flyer are hollow, the latter being split to facilitate threading. The rove or twisted sliver, after leaving the drawing roller, enters the neck or throat of the flyer, passes to the leg through one of the two lateral holes, and is thence led to the flyer eye, which is of the ordinary curl pattern, on to the bobbin. The rove should be passed almost completely round the neck before leading it through the leg of the flyer, as the rove is thereby rendered smoother and the tension and strain localised in the twisted portion of the sliver.

The speed of the spindles may be thus calculated. Suppose that the line shaft makes 180 revolutions per minute, and has upon it a drum 36 inches in diameter driving the frame through a pulley 18 inches in diameter; the speed wheel has 76 teeth, spindle shaft wheel 48 teeth, spindle shaft bevel 26 teeth, stud bevel 36 teeth, stud wheel 40 teeth, and spindle pinions 20 teeth. The speed of the spindles will then be $\frac{180 \times 36 \times 76 \times 26 \times 40}{18 \times 48 \times 36 \times 20} = 823$ revolutions per minute. The number of doffs or shifts taken off per day depends upon the weight of the rove and the speed of the spindles, varying from 2 doffs of $7 \times 3\frac{1}{2}$-inch bobbins roving 250 yards rove to 30 doffs on a jute roving, rove 70 lbs. per spindle.

As it is very important that the preparing room should produce as much rove as possible, it is a very good plan to check the production of the roving frames by means of clocks or counters actuated by a worm upon the end of the drawing roller.

The differential motion and bobbin-winding mechanism of the roving frame is for the purpose of giving the bobbin a positive motion, so that a comparatively weak rove may be built upon the bobbin in a regular manner without strain.

In flax, hemp, and jute spinning the rove is laid upon the bobbin by the flyer, which travels quicker than or leads the bobbin. Since the rate of delivery is constant, the bobbin must run quicker when full than when empty, its diameter being greater. This change in the speed of the bobbin is effected by means of a differential motion, which gradually increases the speed of the socket wheel which drives the bobbins. There are two sorts of differential motions employed in modern machinery: the older, on Houldworth's principle, seen in Figure 41, being employed by the majority of makers; the other, the invention of my friend Mr. Shaw, being taken from the cotton roving frames made by Messrs. Brooks & Doxey. The first arrangement, as shown to the left of Figure 41, consists in a large spur wheel of say 105 teeth, having two bevel wheels working upon studs set at right angles to its axes, and placed between the latter and the rim of the wheel. The large spur wheel, or crown wheel as it is sometimes called, revolves loosely upon the frame shaft, carrying round with it the wheels which it contains. Upon either side of it, and upon the frame shaft, are two bevel wheels of equal diameter and pitch to those in the differential wheel. One of these, that to the left, is fast upon the shaft; the other, to the right, is loose and compounded with the socket wheel before referred to, which drives the bobbins through the link gearing shown. Study the motion carefully, and you will see that if the crown wheel be held at rest, the bevel wheels which it contains will merely serve as carriers to transmit the motion unchanged, except as regards direction, to the socket wheel. The socket wheel, then, always travels in an opposite direction to the frame shaft when at work. If the frame shaft be at rest, and we turn the crown wheel by hand in the same direction as it usually turns in flax rovings, *i.e.* in the opposite direction to the frame shaft, we will find that, since the two bevels upon the shaft are the same size, the loose one and socket wheel will make two revolutions for each made by the crown wheel, and in the same direction, one revolution being due to the motion imparted to the intermediate bevel by being carried round the fixed bevel, and the other to the crown wheel carrying round the

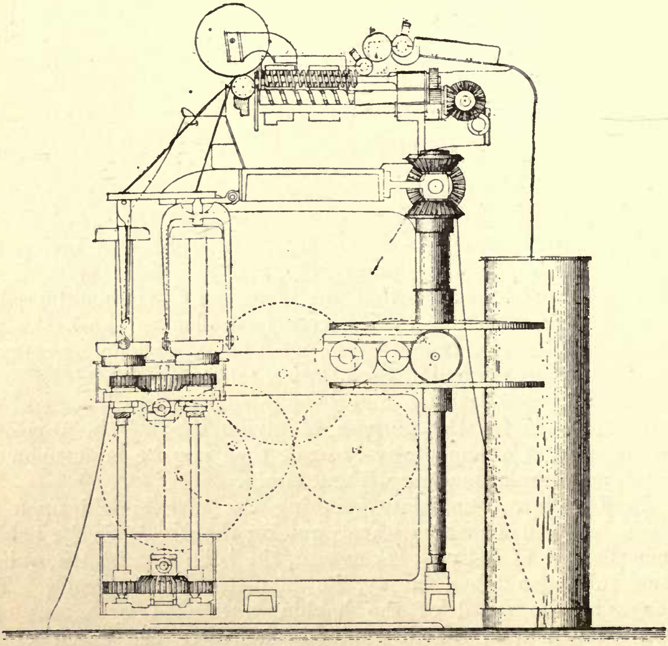


FIG. 40.

loose bevel with it in consequence of the reaction of its teeth upon those of the intermediate bevel. The motion of the socket wheel is then, when at work, the resultant of two velocities in opposite directions—one imparted to it by the frame shaft, and the other by the crown wheel. The former is equal to that of the frame shaft, but in an opposite direction; the latter is equal to twice that of the crown wheel, and in a direction opposite to the former. In other words, if the velocity of the frame shaft be called x and the velocity of the crown wheel y, the resultant velocity of the socket wheel is $x-2y$. The bobbin, then, is driven faster or slower by changing the speed of the crown wheel or its equivalent by means of one of the arrangements which we will presently describe. In the Brooks, Doxey, and Shaw differential motion, the crown wheel is replaced by a circular metal box, compounded with a spur wheel, through which it is driven from cones. Inside the box, near its periphery and between and at right angles to its sides, two studs are fixed which carry double pinions revolving freely upon them. One of each pair, those nearer the geared end of the box, are driven by a spur wheel fast upon the frame shaft. The two other pinions gear with a spur wheel compounded with the usual socket wheel, which runs loose upon the frame shaft and drives the bobbins. If the box was fixed, the socket wheel would be driven at a certain speed by the wheel upon the frame shaft, through the carriers fixed in the box. When the box is turned

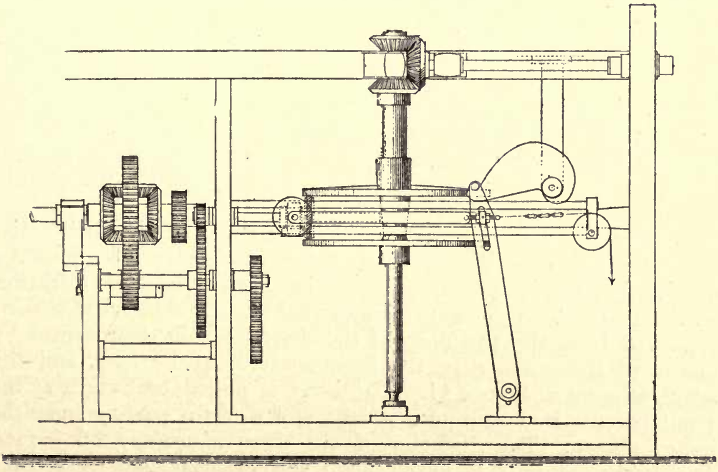


Fig. 41.

in the same direction as the frame shaft, the carrier pinions move round the driver in the same direction as that in which it turns, and its driving power is diminished by every additional revolution of the box; consequently the quicker the box turns, the slower the socket wheel and bobbins turn. Hence with these two arrangements the crown wheel or box is driven *quickly* in order that the bobbins may move *slowly* at the start of the doff, and *diminishes* in speed as the bobbins fill, in order that the bobbins may *increase* in speed.

It must be clearly understood that it is not the crown wheel nor its driver which drives the bobbins quicker or slower. The socket wheel driven from the frame shaft is the driver of the bobbins, the use of the differential motion being merely to govern or vary its speed slightly.

There are several ways of driving the differential wheel or box at a variable speed. Nearly every maker has his own method. Messrs. Fairbairn Macpherson & Co. employ the disc and scroll arrangement shown in the Figures 40 and 41; Messrs. Combe & Barbour and Messrs. Douglas Fraser & Co. employ the expansion pulley; while Messrs. Lawson, Messrs. Mackie, and Messrs. Walker employ a pair of cones.

Under the disc and scroll system the speed of the differential wheel depends upon the position of the friction bowl between the discs which give it motion. The friction bowl slides upon a feather on the shaft which drives the differential wheel. The friction bowl is moved from the periphery of the discs towards their centre by means of the guide rods, the lever centered at its base, and the scroll, all seen in Figure 41. The lever is pulled backwards as the scroll permits by means of a weight and a chain passing over the pulley shown. The diameter of the discs is usually 20 inches. The lower one only is keyed upon the vertical shaft or spindle which rests in the footstep shown, and which receives its motion through mitre gearing from the twist wheel. The upper disc is fixed upon a long sleeve, which turns upon the vertical spindle and is driven in an opposite direction to the lower disc by means of the mitre wheel upon its upper end as shown.

The expansion pulley used by Messrs. Combe & Barbour is made in two halves. One half is fixed upon its shaft, while the other is free to move inwards and intersect the other, as it is constrained to do so by being gradually raised and at the same time pressed against a triangular slide. In Messrs. Combe & Barbour's frame, the raising of the expansion pulley compensates exactly for its increase in diameter, and keeps the driving band, which passes round a grooved pulley upon the drawing roller, at a constant tension. The expansion pulley is raised by means of a quadrant which supports one end. The angle plate which controls the intersection of the two sides of the pulley is generally made with a bevel of one inch per inch perpendicular. The angle of the sides of the pulley is generally such that, for every inch the pulley is pushed in, its diameter is increased by $1\frac{1}{4}$ inches. As in the other forms of mechanism, each shift is effected, when the builder has reached the extremity of its travel at either end, by the escapement of a ratchet wheel, the catch retaining which is released by the motion of the builder. The speed of the bobbin and builder is thus regulated for the succeeding layer of rove.

The cones used by Messrs. Lawson and others to control the motion of the differential wheel and drive the builder, are usually about 36 inches in length, and vary in diameter from 3 to 6 inches. Their axles are placed parallel, the smaller end of one cone being opposite to the big end of the other. A belt passes round the two and communicates motion from the driving cone to the driver, the speed of the latter, and consequently that of the crown wheel and builder, depending upon the position of the belt upon the cones. In a properly constructed pair of cones the slope from the small to the large end is not a straight line, in one being slightly rounded and in the other correspondingly hollowed. This curve is what is known as hyperbolic, and is the only one with which the speed of one being constant, the speed of the other and consequently that of the crown wheel and the lag of the bobbin may be diminished by a given shift of the belt, by amounts proportionate to the increasing diameter of the bobbin barrel. It will be noticed that the change in speed of the bobbins is much more rapid when they are comparatively empty than when full, as then the constant increase bears a greater ratio to the diameter of the barrel than when the bobbin is larger. The diameter of a properly shaped cone at any point may be found by multiplying the length of the cone in inches by the greater diameter, and dividing by the length of the cone in inches, plus the distance of the given point from the large end of the cone. Thus the diameter of a cone $36 \times 6 \times 3$ inches, at a point 12 inches from its large end, is $\frac{36 \times 6}{36+12} = \frac{216}{48} = 4\frac{1}{2}$ inches. The diameter of the complementary cone at a similar distance from the small end is $(6+3 \text{ inches}) - 4{\cdot}5 \text{ inches} = 4\frac{1}{2}$ inches. Thus the mean diameter of cone is situated at a point 12 inches from its big end, and the mean diameter of the other cone at a distance of 12 inches from its small end. The cone belt is shifted upon the cones by means of a fork attached to a rack, actuated by the escapement of the index or ratchet wheel.

On account of the slope of the cones, it will be found that the cone belt does not bear evenly upon the faces of the two cones, but that it is the opposite edges of the belt which bear upon the upper and lower cones respectively, and which consequently do the driving. For this reason one of the cones should be deplaced a distance equal to the width of the belt, so that the complementary diameters, instead of being in the same vertical plane, are where they will be acted upon by the opposite edges of the belt as it runs in practice. It is with this object that in the frames of some makers the cones, while being seemingly between the same perpendiculars, have upon the small end of the lower cone a parallel part of length equal to the width of the belt, the true curve only commencing at that point.

The cones, expansion pulley, or disc and scroll mechanism, drives the builder rack shaft through a quick-change motion of varying form. Its object is to change as rapidly as possible the direction of motion of the builder when it reaches the end of its travel. It is actuated by the builder itself pressing upon levers, which at the correct moment cause instantaneously in Combe's frame the throwing out of gear of one pinion and the engagement of another turning in the opposite direction, these two pinions alternately driving the builder rack shaft in opposite directions. In Lawson's frame a small pinion on the end of the crown driving shaft drives another shaft through a wheel keyed upon its end. The other extremity of this latter shaft has a small lateral movement controlled by a spring "rat-trap" motion, actuated by the upward and downward motion of the builder. The small lateral movement which it imparts to the shaft is sufficient to put the wheel upon its end alternately into gear with one or other of two spur pinions upon either side of it. These two pinions are compounded with stud wheels, which are themselves in gear, so that their direction of rotation depends upon which pinion is in gear with the driver. From either of the strike motion wheels, motion in one direction or the other is conveyed through a changeable builder pinion and other intermediates to the builder rack shaft running the whole length of the frame behind and below the builder. This shaft has pinions keyed upon it at frequent intervals. These pinions engage with vertical racks attached to the builder, which is thus given a reciprocating vertical motion, being guided by vertical slides and balanced by weights supported by chains passing over pulleys.

In Mackie's frame the builder motion is somewhat similar to the strike motion, however, being composed of two bevel face wheels with a double bevel wheel between them, and caused to slide, upon a feather upon its shaft, into gear with one or other of the two face wheels.

We believe that Fairbairn still uses the old mangle wheel upon the end of his rack shaft. The mangle wheel referred to consists of a face plate from which strong round pins project and almost encircle it. The driving pinion is upon the end of a shaft which has a little freedom in its bearings. It gears with the pins in the mangle wheel, and when it arrives at the end of the row is constrained by a guide to pass round to the other side, and consequently drives the mangle wheel and rack shaft in the opposite direction.

The index or ratchet wheel which controls the shift of the cone belt, the shift of the friction bowl, or the rise of the expansion pulley, is turned by the action of a weight and chain. It is allowed to escape by half a tooth at each rise and fall of the builder by the raising of the pawl, which holds it, by the action of the builder itself. Care must be taken that the pawls themselves and the rods which raise them are properly set, so that they do slip half a tooth every time, and that at the right moment, *i.e.* exactly when the builder reaches the end of its travel. If this point be not properly watched, "floating" and tightening will result, and imperfect rove will be produced. The escapement of the index wheel affects the differential motion and brings about a change in the speed of the bobbins. If the wheel be too coarse, *i.e.* has too few teeth, the speed of the bobbins wlll increase too rapidly, and soft built rove will result. If, on the other hand, the index be too fine, the speed of the bobbins will increase too gradually, and the rove will be too hard built and strained. Theoretically, the number of teeth in the index wheel should be inversely proportional to the diameter of the rove, although the latter is flattened somewhat as it is laid upon the bobbin. The calculation necessary to find the requisite index pinion for rove of given weight or diameter is of too complicated a nature for practical men. For this reason it is not given here, but may be found in another work by the same author. A like remark applies to the calculation to find the correct builder pinion which gives the builder the speed necessary to build the spirals of rove side by side upon the barrel of the bobbin. This speed, of course, varies or diminishes as the bobbin fills, or has a greater winding diameter, being governed by the variable speed of the lower cone, expansion pulley, or bowl, as the case may be.

For practical purposes, it is sufficient, in starting a new frame, for instance, to arrive at the correct index and builder pinions by trial or by comparison with a similar frame already running. A piece of paper may be laid upon the barrel of the bobbin or between two layers of rove, by means of which it may easily be seen if the spirals of rove are laid closely together, as they should be if the correct builder pinion be used. The tension of the rove and the hardness of the build of the bobbin show if the index wheel is too coarse or too fine. When changing from one weight of rove to another, the new index and builder pinions may be correctly found by calculation, the old one being to the new in the same ratio as is the square root of the yards per oz. of old rove to the square root of the yards per oz. of the new. If, for instance, a 26 index pinion builds 75 yard rove correctly, a 30 pinion will be required to build rove 100 yards per oz.: thus $\sqrt{75} : \sqrt{100} : 26 : 30$. It is simpler, and almost as accurate to work by proportion. Then add the old index to the result, and halve the total thus obtained. For $75 : 100 : 26 : 35$ and $\frac{35+26}{2} = 30$ nearly. The builder pinion may be found in a similar manner, but care must be taken to see whether, in the make of frame under observation, this pinion is a driver or a driven. If it be a driver, then it must be smaller for finer rove; but if a driven, then must it be larger in order that the builder may be driven slower.

Twist is another important matter in connection with the rove. It is the habit of some spinners to twist their rove rather hard in order to avoid trouble in the spinning room through rove breaking in defective troughs, or in consequence of defective skewers or creels. This is not the way to produce perfect yarn. If the material has been properly prepared over up-to-date machinery, there should be no thin places in the rove to be strengthened by additional twist. The proper degree of twist to give is that which is just sufficient to carry the rove through the trough or from the bobbin to the feed roller. It may be gauged by allowing the bobbin to rest upon the palm of the left hand and pulling off a length of rove. If it breaks off short it is a sure sign that the rove is not sufficiently twisted; while if when about three feet has been pulled off it requires a pull to break it, it is an indication that the rove is too hard twisted, and that there is a danger of it "running" through the feed rollers of the spinning frame, and producing "shired" and slubby yarn. Of course short fibre or tow will require more twist in the rove, to give it the necessary strength, than will long line. The author has found that, on the average, one turn per inch twist is sufficient for 240 yard rove made out of Irish or Flemish long line flax. The twist required is *directly* proportional to the square root of the number of yards per oz. of rove. In Combe's, Lawson's, and Fairbairn's roving frames the number of teeth in the twist pinion is inversely proportional to the twist it produces; hence, in changing from one weight of rove to another, the new twist pinion may be found by squaring the number of teeth in the old twist pinion, multiplying by the number of yards per oz. in the old rove, dividing by the number of yards per oz. in the new rove, and extracting the square root of the result. Thus, if a 48 twist pinion is required for rove 200 yards per oz., what pinion will be required for rove 175 yards per oz. more, or $\sqrt{\frac{48^2 \times 200}{175}} = \sqrt{\frac{2304 \times 200}{175}} = \sqrt{2633} = 51$ nearly. Or again, as in the shortered index pinion calculation, work by proportion, add the old twist pinion to the result, and halve the sum of the two, thus 175 : 200 : 48 : 55, and $\frac{48+55}{2}=51$ nearly.

In Mackie's and in Walker's new roving frames, the twist pinion, instead of being a driver, is a driven pinion, hence a small twist pinion gives less twist instead of more, as in the frames of the other makers. In dealing with these frames, the answer to the same question would therefore be 200 : 175 : 48 : 42, and $\frac{48+42}{2}=45$, the twist pinion required.

A rove stock of say 10 bobbins per spinning spindle should be kept and stored in a cool and dry place near the preparing room. The rove may be carted to the spinning-room as required in a rove cart or carried in baskets. Needless to say, it must be very carefully handled and not tossed or ravelled. Fine and light-coloured rove may be carefully packed and closed up in boxes at the roving frame and thus delivered to the spinning-room, so that all unnecessary handling may be avoided and light excluded. Light-coloured rove will undoubtedly change colour if exposed to sunlight, so that it is advisable that the store should be in semi-darkness. The oldest rove should always be taken first, so that if a change of colour should occur, the change may gradually appear in the yarn, and not as "stripes," which buyers, of course, object to.

CHAPTER VII

DRY AND HALF-DRY SPINNING

FIGURES 42, 43, and 45 give general views of dry-spinning frames for flax, hemp, jute, and tow. The frame shown in Figure 43, made by Messrs. Fairbairn Macpherson & Co., Leeds, may also be used for half-dry spinning, for, if closely observed, it will be seen to be provided with a brass damping roller running parallel to and just behind and above the thread plate. The working of the frame will be more clearly understood if Figures 44 and 46 be studied.

The bobbins of rove made upon the roving frame as described in our last chapter, are placed upon the pins in the creel, seen in all the above-mentioned figures. The ends are brought down through the feed or retaining rollers, as clearly seen in Figure 46, and then pass over the rove plate or breast beam and through the tin rove conductors to the drawing rollers, which draft it or draw it out to the required size. The end, which is now receiving twist, passes next through the thread plate eye E, Figure 44, to the flyer or traveller, and is then wound upon the bobbin or cop. The fish-tailed flyer used upon the dry spinning frame is most clearly seen in Figure 48. The ends of the flyer legs are flattened and pierced by an open eye. In order to minimise ballooning, and keep the end in the flyer eye, the thread is lapped round the flyer leg in the manner seen in Figure 46. In the flyer frame the bobbin is loose upon the spindle, and is pulled round by the thread and flyer which leads and wraps the thread upon the bobbin, which is dragged or retarded in its motion by a drag band, as described upon page 90. The automatic bobbin dragging motion described and illustrated in Figure 38 may be advantageously used upon the flyer dry spinning frame, being applied in the same way as upon the gill spinning frame for fine yarns.

Upon the ring frame, Figure 45, the principles of twisting and winding are different. The builder D in Figure 44 is replaced by a copping plate, which is given a short traverse quick up-and-down motion as well as a very slow upward motion. It is cut out around the spindles for specially constructed steel rings, upon which the

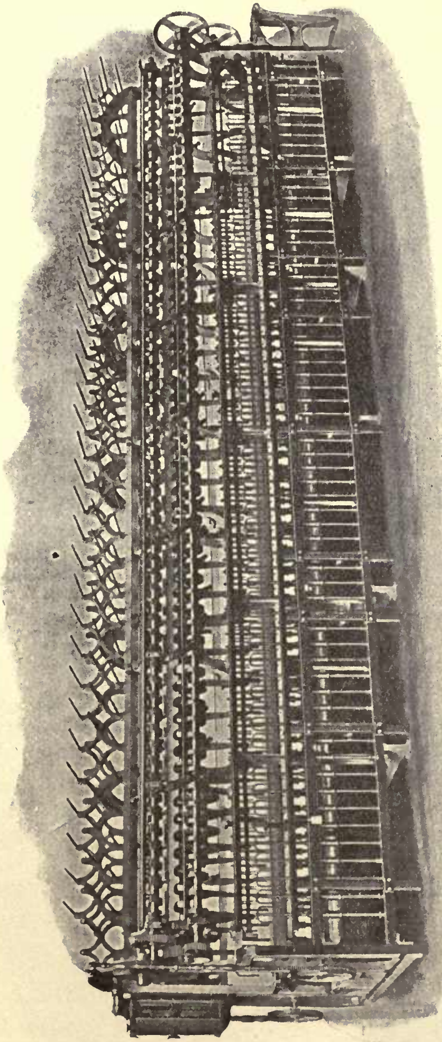


FIG. 42.—Dry spinning frame.

carriers or travellers run. The end passes from the drawing roller through the thread plate eye to the traveller, through which it passes to be wound upon a paper tube or ring bobbin fixed upon the spindle. It is the revolution of the spindle and bobbin which drags

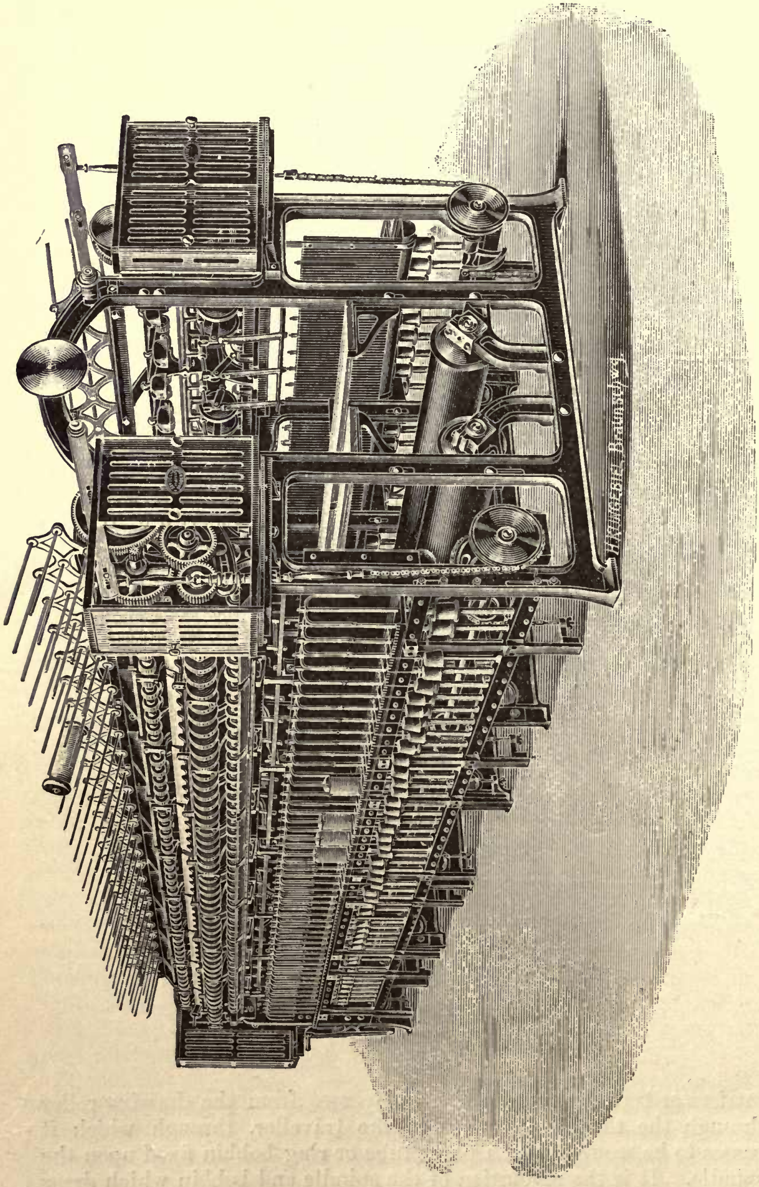


Fig. 43.—Dry spinning frame.

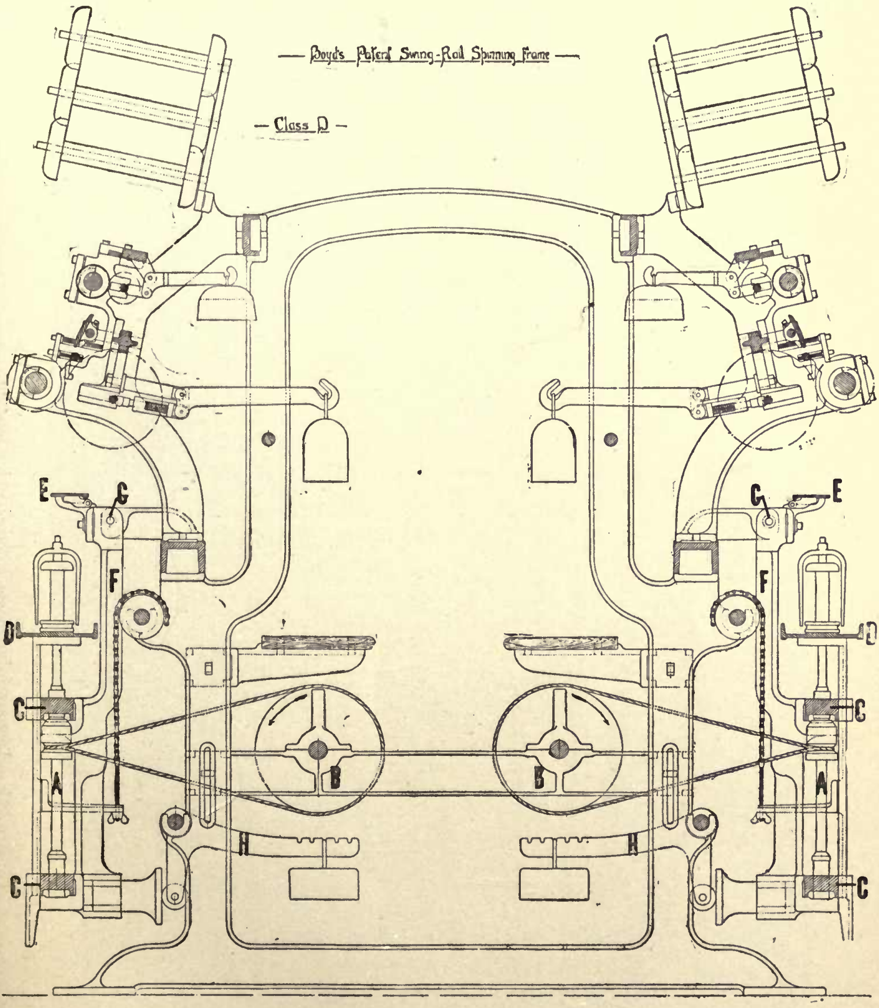

Boyd's Patent Swing-Rail Spinning Frame
Class D
E
G
G
E
F
F
D
D
C
C
B
B
A
A
H
H
C
C

Fig. 44.—Section through swing-rail dry spinning frame.

the traveller round its ring and puts in the twist. The degree of twist which is put into the yarn depends upon the rate of delivery

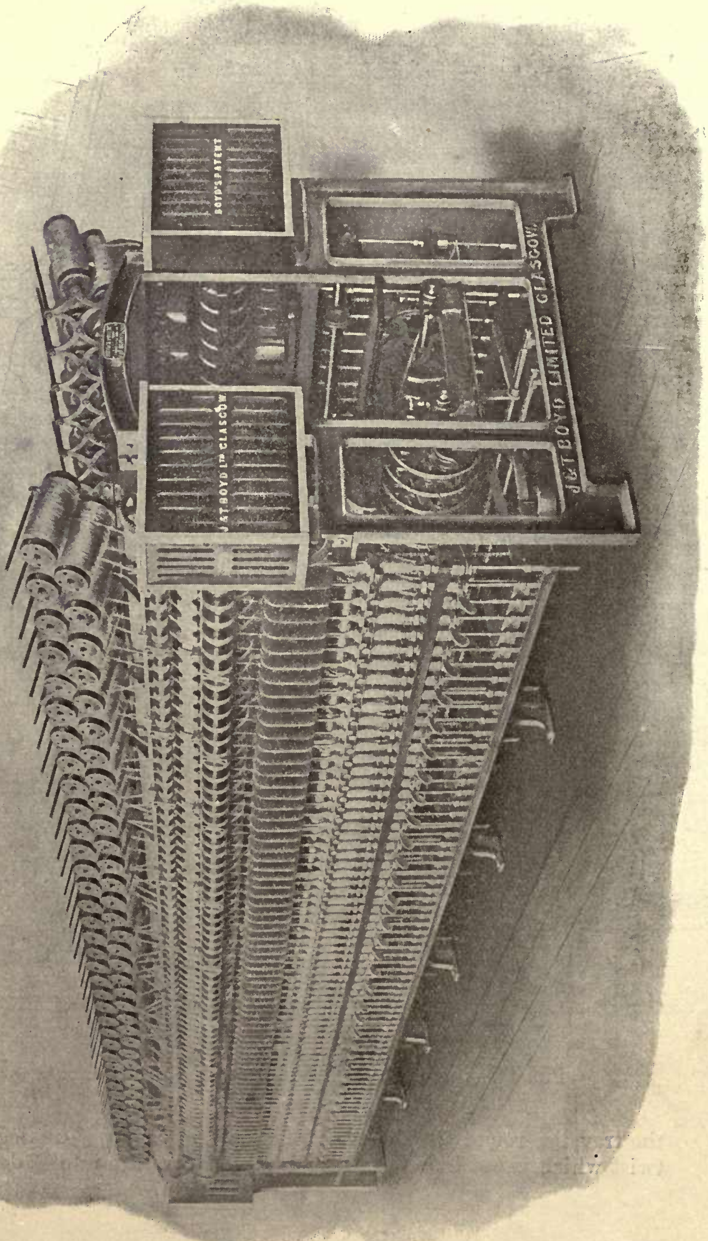

BOYD'S PATENT
J & T BOYD Ltd GLASGOW
J & T BOYD LIMITED GLASGOW

Fig. 45.—Dry spinning frame upon the ring system.

and the speed of the spindle. It is effected to some extent by the effective winding diameter of the cop, for the traveller runs slower than the spindle by an amount required to wind up the yarn as it is delivered and twisted. In practice, however, the variable lag of the traveller may be neglected, both as regards the twist calculation and as regards any variation in the twist, which never amounts to more than 5 or 6 per cent.

Spinning and winding into cop form lends itself very conveniently to winding off endwise and without strain, as in the warping machine. Ring spindles may be run much quicker than flyer spindles, since they are not top-heavy, and may be constructed on the Rabbeth principle. The friction of the traveller upon the ring is the chief difficulty experienced in ring spinning. The presence of dirt and water has led to the abandonment of the ring system in wet spinning. The rings should be regularly oiled, and care must be taken that the diameter of the ring does not bear too high a ratio to the smallest diameter of the tube, and that the weight of the traveller is suitable for the yarn being spun. When the yarn, in passing from the traveller to the cop, becomes the tangent of a comparatively small circle, and when the tension on the yarn at this point is split up into its component factors, *i.e.* a force pulling towards the centre of the ring, and another pulling the traveller round the ring, it will be found that the latter force is comparatively small; hence it is that with the ordinary traveller, spinning on to the bare spindle is extremely difficult, and that when spinning on to a tube or ring bobbin, the end generally breaks when it is being wound on to a small diameter. If any difficulty is experienced in this way, the pin form of traveller, which reduces the effective distance from the spindle, will be found to be an improvement.

The frames shown in Figures 44 and 45 are of special construction. The spindles A are each driven by a separate band from the tin cylinders B. Instead of the neck rails C, the step rails C, and thread plate E being fixed to the gables and carriages, they are carried upon swinging supports F, fulcrumed upon strong studs G set in the gables. In this way they can swing towards or away from the tin cylinders, so as to keep a uniform tension upon the spindle bands. Weighted levers H are used to give the required tension to the cords. Irregularities of tension occasioned by the dryness or humidity of the atmosphere are thus avoided, and a Monday morning's start may be made without the usual additional load upon the engine. The ordinary flyer spindle turns in a gun-metal collar and footstep set in the neck and step rails respectively, being held down by the bearing of the collar against a shoulder at the junction of the spindle neck and butt.

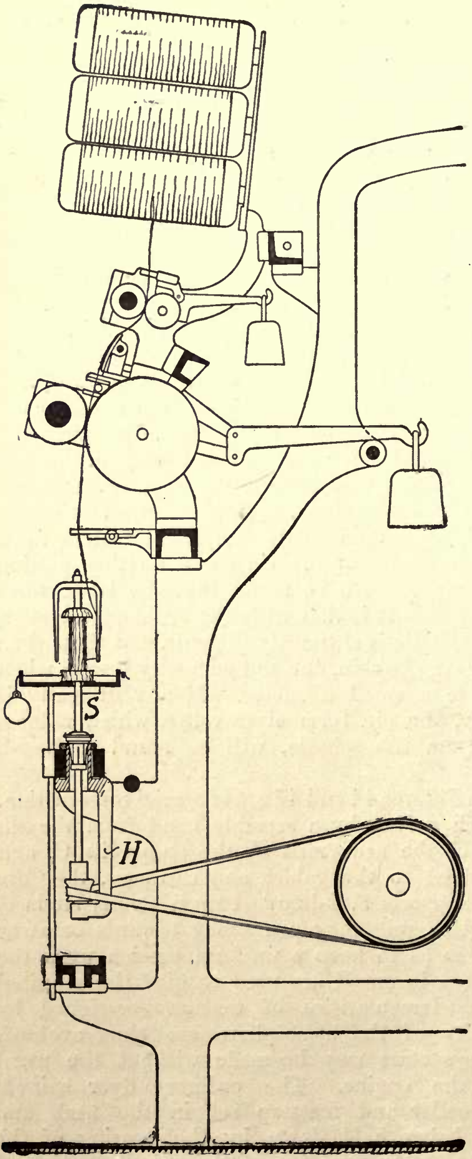


FIG. 46.—Section through part of dry spinning frame, showing the Bergmann spindle.

Figures 46, 47, 48, and 49 show a patent flexible flyer spindle of German design and construction. It will be seen that each spindle S is supported by a separate step bracket H attached to the neck rail. The wharve V is fixed upon and over the spindle foot, which turns in the footstep U. The collar is held in the neck rail B by means of springs *e*, which render the spindle flexible. It is covered by a cover *d*, which keeps out dirt from a washer of absorbent material which holds the oil. It will be seen from Fig. 49 that the spindle may be lifted out for oiling the step. The wharve being upon the spindle foot gives a steady drive without vibration.

The drawing and retaining rollers of the dry spinning frame are of steel. The top or feed roller is fluted, while the bottom or drawing roller is merely scored to give it gripping power. The pressing rollers are placed *behind* the long rollers, and are pressed against them by means of a lever and weight, as clearly seen in Figures 44 and 46. The top pressing rollers are of steel, and fluted to correspond with the feed roller. The bottom pressing rollers are of wood, usually sycamore, and turned down to a narrow face, which is embraced by the wings of the tin conductors which hang loose upon their bar. The pressure upon each pair of top bosses is about 40 lbs., and upon the bottom or drawing rollers, from 60 to 80 lbs. The rove guide above the feed rollers should have a short traverse given to it, by means of a worm and cam or heart, so that the roller may not become grooved through the constant passage of the rove in one place. Since the bottom pressing rollers are fixed in position, the drawing roller should be given a short traverse to reduce wear in one place. This may be conveniently done in a similar manner as in the drawing and roving frame.

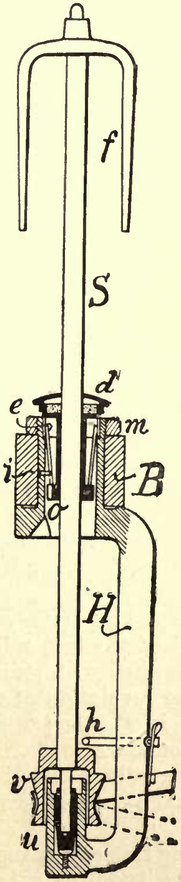


Fig. 47.—Section through Bergmann spindle.

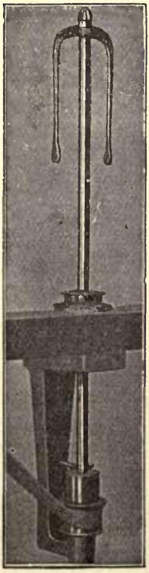


Fig. 48.—Bergmann spindle.

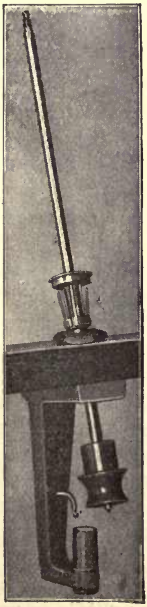


Fig. 49.—Bergmann spindle.

The proper adjustment of the rove or breast-plate, and with it the conductors, is a most important point in dry spinning. Most modern frames are provided with an arrangement, by means of which one movement causes the rove plates across the whole length of the frame to be moved at one time, and which saves a great deal of time in setting the plates. The bringing forward or putting backward of the rove plate and conductor in a spinning frame has the effect either of opening out the twist of the rove or of keeping it in for a certain length of time while the rove is passing between the top and bottom rollers.

In spinning a light size of yarn, say 8-lb. jute for instance, the twist must be kept in the rove between the rollers by keeping it forward by the plate, as if the twist be allowed to run out too quickly the ends will break too much and the yarn be "*shirey.*" In spinning from 12 to 14-lb. jute yarn the rove plate should be brought forward, so that the rove may touch the plate across its entire breadth. The conductor rod must then be put back, so that the rove, while passing through the conductor, will only touch the back of its lower half. For heavier yarn, the plate must be brought still farther forward, and the conductor rod put farther back.

In jute-spinning mills the speed of the spindles of the dry spinning frame range from about 2500 revolutions per minute for 24-lb. weft upon a 5-inch frame to 3300 revolutions per minute upon a 3¾-inch frame spinning 8-lb. warp. The spindles should be driven by tapes from 1¾ to 2¼ inches in width, according to the pitch of the frame. The overall length of the usual frame is about 27 feet, giving from 114 to 154 spindles for the double frame.

The bobbin traverse arrangement of the dry spinning frame consists of a heart, driven by a pinion upon the end of the feed roller. Levers rest upon the hearts or cams, and are connected with pulleys upon the builder shafts by means of chains. The revolution of the heart wheel produces an up-and-down motion in the levers and through the builder shaft to the poker rods and builder.

As in the preparing room, the wooden pressing rollers should be gone over day by day, and the defective ones taken out and turned up in the lathe.

As regards the production of the dry spinning frame, 4 spangles per spindle per week of 7-lb. hessian warp may be taken as a basis of fair turn off.

The reach of the dry spinning frame varies from 9 inches for jute and tow to 24 inches for long line flax and hemp.

The average twist required by flax, hemp, and jute yarns may be taken to be the product of 2 and the square root of the number of leas of 300 yards contained in 1 lb. Thus the number of turns per inch required for 25's lea yarn equals $2 \times \sqrt{25} = 2 \times 5 = 10$ turns. For jute yarns numbered upon the Scotch basis, it may be taken that 3-lb. yarn requires 8 turns per inch twist. The number of turns per inch required by any other number may then be obtained by multiplying the turns per inch for 3-lb. yarn by the square root of 3 and dividing by the square root of the number of the yarn to be twisted. Thus the twist required for yarn weighing 8 lbs. per spindle at the rate of 8 turns per inch for 3-lb. yarn is $\frac{8 \times \sqrt{3}}{\sqrt{8}} = \sqrt{\frac{64 \times 3}{8}} = \sqrt{24} = 4{\cdot}9$ turns per inch.

The reason that the square root of the number is introduced into the calculation is that the twist should vary inversely as the diameter of the thread, and that the diameter of the thread varies inversely as the square root of the number of leas per lb., or directly as the square root of the lb. per spindle. To obtain the degree of twist required upon the spinning frame, the correct twist pinion must be put on, so that the drawing rollers may run at such a speed that they deliver 1 inch of sliver while the spindles make the required number of revolutions. Thus, if the drawing roller wheel have 120 teeth, twist pinion 40 teeth, crown or double intermediate wheel 90 teeth, cylinder pinion 28 teeth, diameter of tin cylinder 10 inches, and diameter of wharve $1\frac{3}{4}$ inches, the spindles will make $\frac{120 \times 90 \times 10}{40 \times 28 \times 1\frac{3}{4}} = 55$ revolutions while the drawing roller turns once. If the drawing roller is 4 inches in diameter, or 12·5 inches in circumference, the spindles will turn $\frac{55}{12{\cdot}5} = 4{\cdot}4$ times while the roller delivers 1 inch of sliver, and will put in 4·4 turns per inch twist. The correct twist pinion for any number of turns per inch twist may be found by determining a constant number, which when divided by the turns per inch twist, gives the required pinion, or which, when divided by any pinion, gives the turns per inch twist which will be produced. The twist constant for the frame, with particulars as above, is $\frac{120 \times 90 \times 10}{28 \times 1\frac{3}{4} \times 12{\cdot}5} = 176$.

In practice the twist pinion may be conveniently changed as follows: Suppose that a 40-twist pinion is giving the correct twist to 6-lea yarn, and it be required to change to 4-lea yarn with a similar twist, the pinion required must be a larger one, so that the delivery roller may run faster. It may be larger in proportion to the square roots of the numbers. It will therefore have $\frac{40 \times \sqrt{6}}{\sqrt{4}} = \sqrt{20^2 \times 6} = \sqrt{2400} = 49$ teeth, or $\frac{\frac{40 \times 6}{4} + 40}{2} = 50$ roughly.

Under the Scotch system, the number of teeth in the twist pinion will be in *direct* proportion to the square root of the yarn numbers.

The draft of the dry spinning frame is, as in other spinning machinery, the ratio between the rates of feed and delivery. The gearing between the feed and drawing rollers may be as follows: Feed roller wheel 110 teeth, stud pinion 44 teeth, stud wheel 90 teeth, drawing roller or draft change pinion 45 teeth; the draft produced, if the diameter of the drawing-roller be 4 inches and that of the feed roller $2\frac{1}{2}$ inches, will be $\frac{110 \times 90 \times 4}{44 \times 45 \times 2\frac{1}{2}} = 8$. As in the twist calculation, a constant number $\frac{110 \times 90 \times 4}{44 \times 2\frac{1}{2}} = 360$ may be formed, which when divided by the draft gives the draft pinion required, or *vice versâ.*

The draft required to spin any yarn is of course the ratio in weights of unit lengths of yarn and rove. Thus the draft required to spin 8-lb. yarn from 56-lb. rove is $\frac{56}{8} = 7$. The calculation required to find the draft required to spin a given lea yarn from rove weighing so many yards per ounce is more complicated, as the data must first be reduced to the same denomination, *i.e.* yards per oz. There are roughly $\frac{300}{16} = 19$ yards per oz. in 1-lea yarn, and $16 \times 19 = 304$ yards per oz. in 16-lea yarn, for instance. The rule to find the draft, then, in such a case is to multiply the lea to be spun by 19 and divide by the yards per oz. of rove. Thus the draft required to spin 16's lea yarn from rove weighing 32 yards per oz., will be $\frac{16 \times 19}{32} = 9{\cdot}5$.

When the bobbins are full of yarn, the flyers are removed and the bobbins doffed and replaced by empty ones. The full bobbins are put into boxes or baskets and removed either to the cop winding, warp-winding, or reeling departments.

CHAPTER VIII

WET SPINNING OF FLAX, HEMP, AND TOW

THE so-called fibre of the flax and hemp plants is composed of short or ultimate fibres, from 1½ to 2 inches in length, joined together by gummy matter or pectose.

In dry spinning the long compound fibres are spun into a comparatively coarse yarn, which, however, is very strong, on account of the length of the fibre.

It has been found impossible to produce the finer counts of yarn, say over 20's lea, upon the dry system, so that many hemp yarns and almost all flax yarns are spun upon the wet system.

In the wet spinning of flax and hemp the fibre is macerated by a passage through a trough of hot water, the gummy matter or pectose being softened, permitting of the separation of the ultimate fibres between the drawing and retaining rollers set comparatively closely together, say 1¾ to 4 inches centre to centre.

Figure 50 gives a general view of a wet spinning frame as made by Messrs. Fairbairn Macpherson & Co., Leeds, and Figure 51 represents a somewhat similar frame made by a German firm.

In both figures the creel, in which the bobbins of rove are placed upon skewers, is clearly seen. The water trough lies below and behind the top or feed rollers. It is covered with wooden lids to keep in the steam. The rove passes from the bobbins, over the rove guides, between the back of the trough and lid, under another guide in the bottom of the trough, which keeps it submerged, and then passes to the feed-rollers over the lip of the trough and the rove shifter. Its course may then be followed by reference to Figure 52, through the top or feed rollers *a* to the bottom or drawing rollers *b*, in which passage it is drafted to the desired degree, then through the thread plate eye *c* to the flyer eye *d*, being twisted and wound upon the bobbin *e* as described in the last chapter. The water trough is heated by live steam, which is usually brought down a pipe in the centre of the frame and distributed by perforated branch pipes which extend along the bottom of the trough below the line of rove and nearly up to each end.

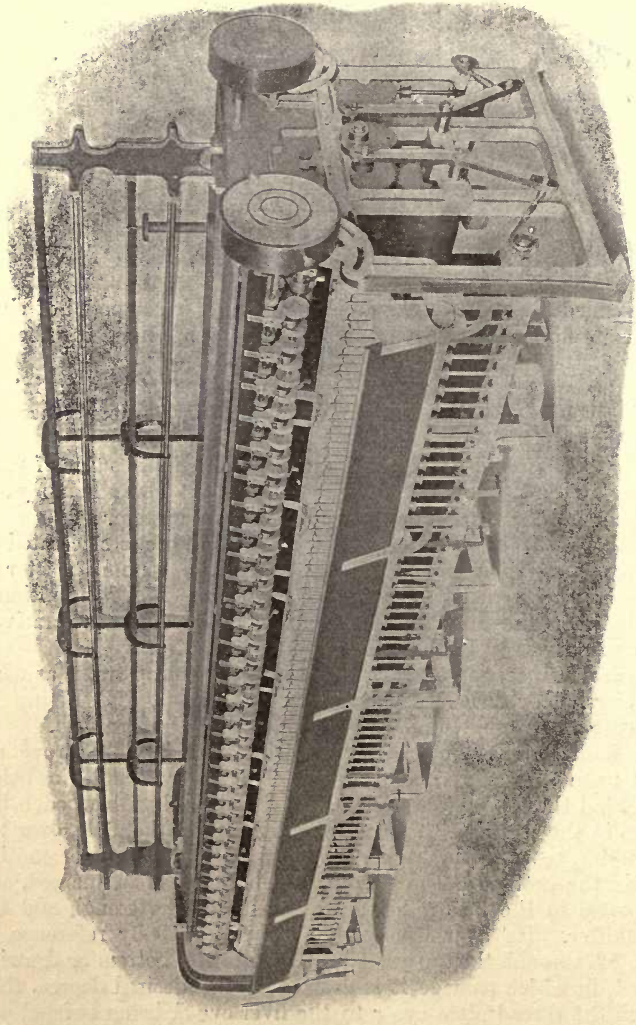
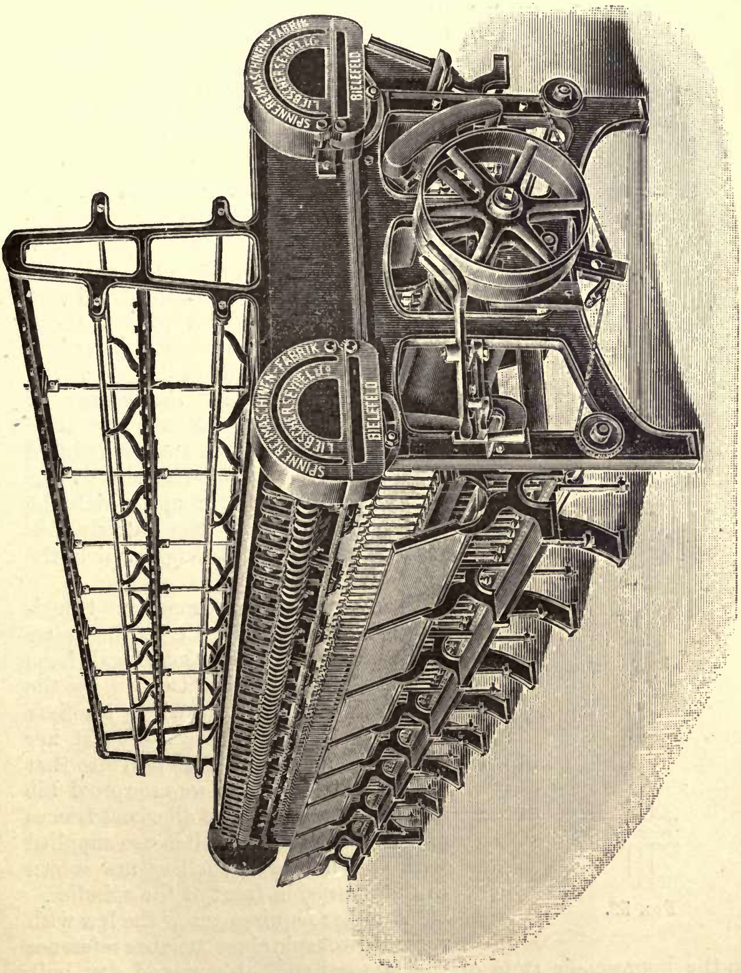


FIG. 50.—Hot water spinning frame.

A new way of heating the water troughs is to connect the two ends of the trough by a U tube or pipe passing underneath. One bend of the U is formed by a T-piece, permitting of the joining up of the steam pipe. The steam, when turned on, circulates the water round and round and heats it, additional water being added when required from a supply pipe connected with the steam pipe


SPINNEREIMASCHINEN-FABRIK LIEBSCHER SEYDEL & Co
BIELEFELD
SPINNEREIMASCHINEN-FABRIK LIEBSCHER SEYDEL & Co
BIELEFELD

just below the steam valve. This method of heating the water has the advantage of dissolving and preventing the formation of gum upon the top of the water. With certain classes of flax this gum often gives much trouble at the morning start, especially on Monday mornings, if not removed by hand. While with many sorts of dew-retted fibre the water may be kept almost cold, yet hard fibre and coarse numbers require nearly 200° F. of heat. Water at this temperature gives off much aqueous vapour, in addition to the steam which may escape by ebullition from the distribution pipes in the trough. The escape of this vapour into the atmosphere makes the air of the spinning-room very damp, and is most injurious to the health of the work-people. Its escape may be prevented to a great extent by the application, to the underside of the trough lids, of two ribs, one at the front and one at the back, which project down into the water in the trough, reduce the surface exposed to the air, and thus greatly minimise the escape of steam. The water surface exposed to the outside air may be further reduced by the suppression of the slit at the back of the trough through which the rove passes, and by the introduction of porcelain tubes through which the rove enters the trough.

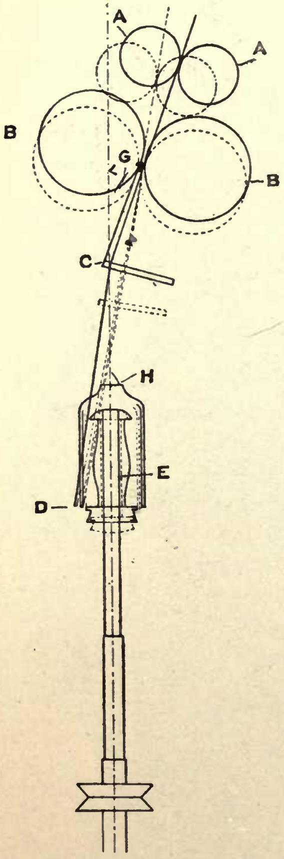


FIG. 52.

The rove issuing from the trough carries much water with it, the water being thrown off by centrifugal force as the thread is being twisted by the flyer. This water is thrown by the flyer upon the spinner as she stands at her work. The law therefore provides that she be provided with a waterproof bib and apron, and also that all coarse frames of more than $2\frac{3}{4}$-inch pitch are supplied with splash boards, such as are shown in the figures, in front of the spindles.

Another requirement of the law with regard to wet spinning rooms has reference to the hygroscopic state of the atmosphere. A wet and dry bulb thermometer, such as is shown in Figure 53, and supplied by the Sturtevant Engineering Co., London, must be hung up in the room. As it will be seen from the figure, this instrument consists of two ordinary thermometers side by side. The bulb of one is enveloped

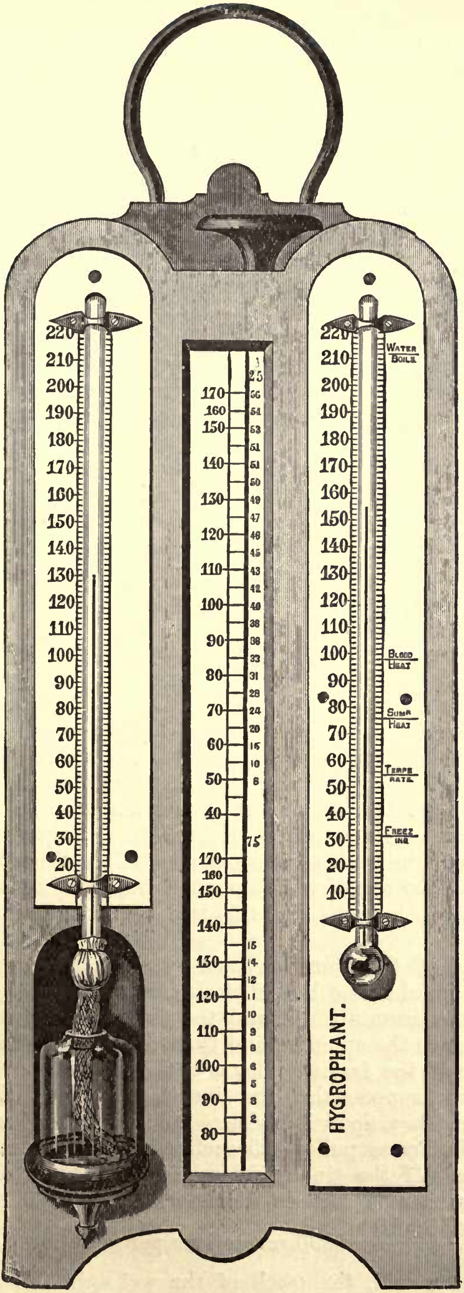

WATER BOILS
BLOOD HEAT
SUMR HEAT
TEMPERATE
FREEZING
HYGROPHANT.

FIG. 53.—Hygrometer.

in muslin and connected by a wick with a small reservoir of water. If the reservoir be dry the two thermometers will indicate the same temperature. The reservoir must be kept supplied with water, when, unless the air be fully saturated with moisture, evaporation from the wet bulb will cause that thermometer to indicate a lower temperature than the dry one. The law requires that in the wet spinning room the wet and dry bulb thermometers should show a difference of at least two degrees at the ordinary spinning-room temperature.

In the cold water system of spinning, which is practised to a very limited extent, the rove is wound upon rove bobbins with perforated barrels and steeped in water for some time prior to spinning. Then, upon the spinning frame, the bobbins, instead of being put in the creel, as in hot water spinning, are placed vertically upon upright pegs in a specially deep spinning frame trough, kept full of water. They revolve quite freely upon these pegs, since the buoyance of the water supports them and reduces friction. This method of spinning gives satisfactory results with some classes of flax, such as the dew-retted varieties, which are often devoid of any great strength, and has as an advantage the saving in the cost of steam for heating the troughs, and the cooler, dryer, and more healthy atmosphere of the room.

The "turn-off" or production of a spinning spindle in a given time is limited by the quality of the material, the degree of twist put in, and the speed of the spindle. Six thousand revolutions per minute is a fairly quick speed even for fine spindles. Twenty cuts or leas per spindle per day of ten hours is a fair turn off for 40's lea line. If doffers are quick and clever, and if there are a sufficient number of them, the maximum production will be obtained by spinning rather coarse numbers on finer frames than what was the usual custom of the trade some years ago. The author has obtained a high turn off by spinning 60's upon a frame of 2-inch pitch and 40's upon a $2\frac{1}{8}$-inch frame, and this is a common practice upon the Continent.

The speed of the spindles is easily calculated by multiplying together the speed of the line shaft in revolutions per minute, the diameter of the drum upon it, and the diameter of the tin cylinder which commands the spindles, and then dividing by the product of the diameter of the frame pulley and the diameter of the spindle wharve. Thus, suppose that the line shaft makes 200 revolutions per minute and has upon it a drum 36 inches in diameter, which commands the frame pulley, 15 inches in diameter, upon the tin cylinder axle. If the tin cylinder be 10 inches in diameter and the spindle wharve 1 inch in diameter, the speed of the spindles will be $\frac{200 \times 36 \times 10}{15 \times 1} = 4800$ revolutions per minute.

As we have said, the reach of the wet spinning frame varies from 1¾ inches to 4 inches, being the distance from centre to centre of the feed and drawing rollers, or, what is the same thing, half the sum of their diameters plus the space between them. A 1¾-inch reach is often suitable for 120's lea upon a 1¾-inch frame, while a coarse hemp tow yarn may require as long a reach as 4 inches upon a 3-inch frame. The reach is raised or lowered by means of brass screws in the stands, which raise or lower the blocks carrying the top roller bushes upon a slide in the stands, which are attached to the roller beam as seen in Figure 54. The roller beam may be brought forward bodily, or the angle of the rollers changed in order to alter the lines of the frame as shown in Figure 52, and augment or decrease the bearing upon the thread plate eye *c*. The following table gives suitable settings for frames of various pitches :—

Pitch of Frame.	Bottom of Spindle Screw *h* to Nip *g*.	Distance back *g* from Line of Spindle.	Angle of Beam.	Angle of Rollers.	Distance from Spindle Screw *h* to Thread Plate *c*.
Inches.	Inches.	Inches.	Deg.	Deg.	Inches.
4	9¾	1¼	17	19	3¾
3½	8¾	1⅛	17	19	3½
3	7¾	1	16	18	2⅞
2¾	7¼	⅞	16	18	2⅝
2½	6¾	13/16	15	17	2⅜
2¼	6¼	¾	15	17	2⅛
2	5¾	⅝	15	17	2
1¾	5¼	½	15	17	2

The distance from the spindle screw *h* to the thread plate *c* must be sufficient to allow the builders to be lifted off, and also to give room for the spinner's hand in stopping the spindle. The effect of raising the thread plate is to put an increased bearing or tension upon the yarn, which is sometimes an advantage in spinning warp numbers. It has also the effect of enabling the thread to clear the head of the bobbin when the builder is at the top of its travel. It is most important that the thread plate eye should be vertically over the spindle top.

The bobbins are wound and dragged as in the dry spinning frame, the weight of the drags varying from a few ounces, upon a 1¾-inch frame spinning a fine number, up to two pounds upon a 3-inch frame spinning a coarse warp number. In wet spinning the tension of the yarn between the bobbin and the delivery roller should be all that it can stand, as if the bobbin be well dragged the fibres will be drawn closer, and a smoother, rounder, and stronger yarn be produced. This is specially important in the spinning of double rove and warp numbers, in order that all weak spots or single may be broken, and that they may not pass on to the bobbin.

The up-and-down motion of the builder of the wet spinning frame is usually produced by means of a "quadrant," as in Figure 51. Other arrangements exist, however, such as that employed by Messrs. Fairbairn Macpherson, and seen in Figure 50. This latter arrangement will be seen to consist of a heart wheel acting against runners upon studs set in the extremities of lever arms, the ends of the other arms being connected with the builder rod irons by means of chains. What is known as a "quadrant" is a long and short armed lever, fulcrumed upon a stud is the gable end. The short arm of the lever is connected by chains with the builder shaft as before. The long arm has upon its extremity a toothed sector of a circle, the teeth being in the form of brass pins, with which the

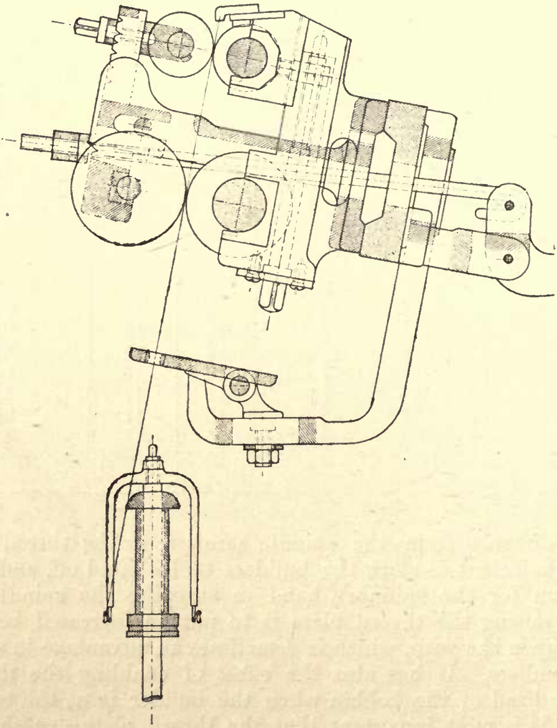


FIG. 54.—Section through rollers and stand.

small quadrant pinion, upon the end of the quadrant shaft, engages and gives an oscillating motion to the lever arm, the same being transformed into the up-and-down motion of the builder. When the quadrant pinion pushes the quadrant over until the last pin engages with the pinion, the latter is guided round and caused to act upon the other side of the teeth, producing motion in the opposite direction.

As in other spinning and twisting machinery, the twist put in depends upon the relative speed of the spindles and that of delivery of material to be twisted. The degree of twist is changed by increasing or decreasing the speed of the delivery or drawing roller. Upon the wet spinning frame this is done by changing the twist pinion upon the pap of the crown wheel. This pinion being a driver, must be increased in size to deliver a greater length in a given time, so that less twist may be put in, and *vice versâ*. The following example, taken from actual practice, will show the method of calculation. Boss roller wheel, 120 teeth; twist pinion, 34 teeth; crown wheel, 120 teeth; cylinder pinion, 28 teeth; diameter of tin cylinder, 10 inches; diameter of wharve on spindle, 1 inch; and circumference of boss or delivery roller, 7·4 inches. The number of turns per inch twist being put in is then $\frac{120 \times 120 \times 10}{34 \times 28 \times 1 \times 7{\cdot}4} = 20{\cdot}4$ turns per inch.

By leaving the twist pinion out of this calculation, a twist constant number 693 is found, which when divided by the twist per inch required, gives the correct twist pinion to produce that twist. The usual turns per inch twist given to wefts is the product of 1·75 and the square root of the number; to warps and tows, the product of 2 and the square root of the number; to thread yarns from $2\frac{1}{4}$ to 3 times the square root of the number. The effective circumference of a fluted roller is more than that of a plain roller of the same diameter, for the material being drawn is pressed into the flutes. When the flutes are new, a good approximation to the effective circumference of the roller may be obtained by multiplying the diameter by 3·4 for 20 flutes per inch, by 3·35 for 26 flutes per inch, by 3·3 for 36 flutes per inch, and by 3·25 for anything finer. The reason that thread yarns are twisted so hard is, that when being twisted into a thread they are twisted in the opposite direction to that in which they were spun, and thus loose some twist which would diminish their strength had not extra twist been previously given to counteract this loss. Most yarns are given left-hand twist and threads right-hand twist; but when, as occasionally occurs, the thread is required with left-hand twist, the twist of the single yarn must be reversed, requiring the turning of the spindles in the reverse direction and the right-hand threading of the spindle tops.

The draft of the wet spinning frame is the ratio between the surface speeds of the feed and delivery rollers. It is calculated in the following manner, the particulars being taken from actual practice: Top roller wheel, 100 teeth; draft pinion, 50; stud wheel, 90; bottom roller pinion, 30 teeth; diameter of boss roller, $2\frac{1}{4}$ inches; and the diameter of the top roller, $1\frac{5}{16}$ inch. The draft is then $\frac{100 \times 90 \times 2\frac{1}{4}}{50 \times 30 \times 1\frac{5}{16}} = 10{\cdot}3$ nearly.

A constant number may be formed by leaving the draft pinion out of the calculation, thus $\frac{100 \times 90 \times 2\frac{1}{4}}{30 \times 1\frac{5}{16}} = 514$, which when divided by the required draft, say 12·8, gives $\frac{574}{12{\cdot}8} = 40$ as the draft pinion required, or which when divided by the draft pinion upon the frame gives the draft produced.

The spindles of the wet spinning frame are driven either by tapes or cords, which must be kept tight, or slack-twisted yarn will result. When tapes are used the wharve must be of barrel shape, the tapes being cut to length and sewn or fastened with a patent fastener. A tension pulley must always be used, with a tape drive to take up stretch in the tape.

When bands are used, as they always are on fine frames, the spindle wharve has either an angular groove or is of the capstan type, around which the band passes twice, giving it additional driving power. One band is occasionally made to drive two or more spindles, but this practice is not to be recommended, unless it is rendered compulsory, as when the column falls in the frame. The correct band-tyer's knot is the flat intersecting loop knot, which if properly made will not slip, and is so small that it passes without difficulty between the wharves and poker-rods of even the finest frames. There are two sorts of banding used. The one which is to be preferred is made up of three strands, each containing 3, 4, 5, or 6 threads of $2\frac{1}{2}$ lea cotton yarn of long staple. This make of banding is softer and has more driving power than that made up of more numerous, finer, and harder twisted yarns.

In a general way, as much oil is used in the spinning room as in all the other departments of the mill combined. The spindles are great oil users, as they run at a great speed and consume a great deal of power if they are not kept supplied with oil. The constant and efficient lubrication of the spindle neck is most difficult, as, being a vertical bearing, the oil has a tendency to pass downwards and out of the bearing. There is usually an oil cup upon the upper end of the brass neck collar, and a nick in the inside edge which surrounds the spindle, through which the oil slowly passes to the neck. With this arrangement the oiling of the necks twice a day is sufficient if the frame is in good order and the spindles a good fit in the necks. If the necks and collars are much worn, the oil passes away as fast as supplied, and efficient lubrication under these conditions is out of the question.

The efficient lubrication of the spindle necks is a question which has long occupied the attention of practical men. The most perfect arrangement with which the author is acquainted consists in the hollowing out and utilisation of the neck rail as an oil reservoir, from which the oil passes to the spindle necks through nicks in the collars. When it passes down between the neck and the collar it is thrown off the spindle by a projecting tongue and received in a dish which surrounds the spindle. Each dish is connected to a return oil pipe, through which the oil passes to a pump, which raises it again into the neck rail to be again utilised. The oil is thus circulated round and round, and has only to be drawn off occasionally to be filtered and mixed with some fresh oil.

Sperm oil is really the best lubricating oil for spinning room use. Its excessive price, however, has led to the use of cheaper oils, such as lard, mineral, rape-seed oil, etc., either as substitutes or as mixtures.

Once a week will suffice to oil the spindle steps. The open necks of the drawing roller, which runs at a comparatively high speed, must be oiled every day with the aid of a brush and a grease of considerable consistency. Owing to their construction the lubrication of these necks is seldom good. An ingenious device is used by a continental spinner for the more perfect lubrication of the roller necks. It consists in a brass cover attached to the brass bush, and containing a small oil reservoir, into which dips a little runner which bears against the surface of the roller neck, and which is thus caused to revolve and carry with it the oil necessary to keep up the proper lubrication of that neck.

Great care must be taken that the oil or grease which is used upon the roller necks, rove guide, eccentric or other parts, does not spread or fall upon the brass bosses of the roller. Inattention to this point results in the production of those black threads in the yarn which the weaver and bleacher so bitterly complain of, and which often show up red in white cloth.

The use of propeller fans is generally necessary to remove hot damp air from the spinning room and to cause it to be replaced by dryer and cooler air. These fans are usually set in the window frames or in the walls, and driven by a belt and guide pulleys from a line or counter shaft.

Localised ventilation, or the drawing off of the steam as it issues from the back of the troughs by means of suction pipes, has been tried with some success. The windows, which may be opened in fine weather, should be constructed so that the upper half is hinged on its lower edge. They consequently open inwards in such a way that the air as it enters is thrown upwards and does not blow directly upon the frames. Cold currents of dry air entering in this way do much harm in the spinning, causing breakages of the thread, especially in fine work. If the steam pipes which supply steam for heating the troughs are not of large section and do not radiate much heat, it is sometimes necessary to provide a winged radiating pipe to raise the temperature of the room after a stoppage and in cold weather, lest the dew point should be so low that the room becomes full of a mist or fog of steam.

CHAPTER IX

THE YARN DEPARTMENT

When the yarn has been spun, whether upon cop or bobbin, it must be reeled, either to put it into marketable form, or in order that it may be dried, bleached, or dyed. Fine flax yarns for handloom weavers are occasionally spun wet in cop form upon a specially arranged spinning frame, and wound upon patent paper tubes, upon which they can be dried and sold for direct weaving, but as a general rule wet spun flax yarns are reeled. Another exception is sometimes made when a wet spinning mill is combined with a weaving factory. Then wet warp yarn may be wound directly from the spinning frame bobbin on to the tin warper's spools, which are afterwards dried in a stove or hot room. The author has also occasionally had fine wefts dried upon the spinning bobbin, and then wound in cop form upon paper tubes for use in the shuttle. Dry spun yarn need only be reeled if it is required to bleach or dye it. Jute yarns are nearly always copped for weft and cheese-wound for warp, direct from the spinning bobbin.

Figures 55, 56, and 57 show the form of the reel used for flax or hemp yarns. A is the shifter upon which the bobbins are placed upon brass sockets which turn freely on pins. The reels are usually made double, there being from 20 to 50 bobbins per side. Even for fine numbers a 50-bobbin reel is rather long, as the swift must be either too heavy or too limber. The swift B is collapsible, so that the hanks may be removed. It is held in shape by tapes which are attached to the inside of the rails. One rail x is capable of being moved towards the centre when it is required to slacken the yarn in order to allow the swift to collapse. The shifter has a very slow traverse of from 2 to 5 inches, so that the threads may be wound side by side into cuts and hanks. With the long or 90-inch reel, a cut has 120 threads, and 12 cuts make one hank. There is a bell arrangement which rings when each cut is complete. The reeler then puts in her leasing, which keeps each cut separate. When twelve cuts have been reeled, the thread is tied into a knot with the leasing and both cut off. To remove the yarn from the reel the swift must be collapsed, as we have said, and the hanks drawn to one end and placed in a half-moon doffing arrangement, which permits of their removal without raising the axle of the swift from its bearings and without risk of oiling the yarn. The swift is

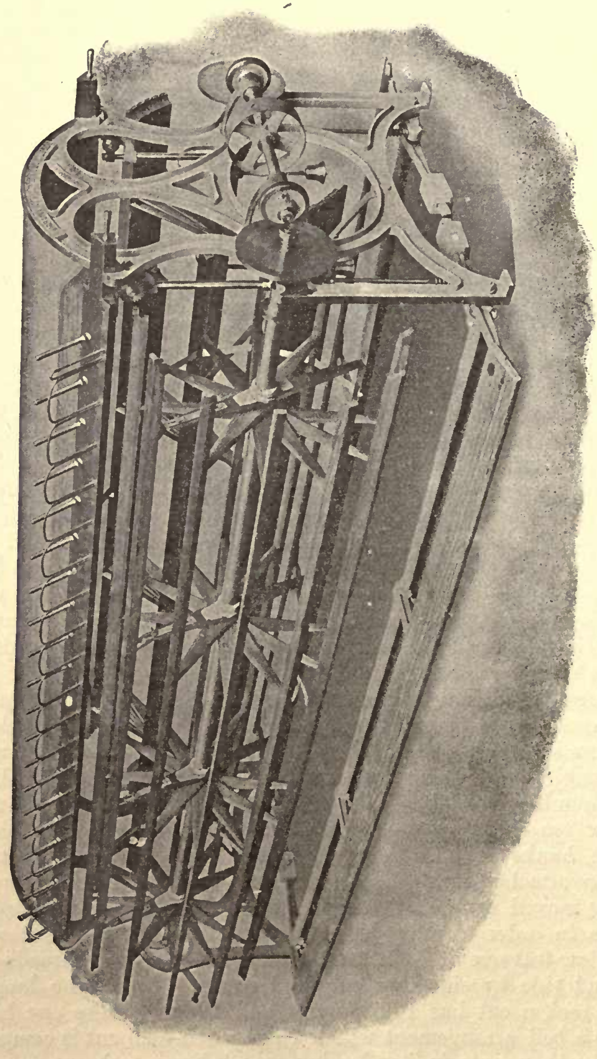


Fig. 55.—Power reel.

then opened out again, the shifter moved back to its starting position, the threads tied to a rail and a new set of hanks commenced. When the first cut or lea is complete the ends which are attached to a rail must be cut, and each lapped and looped round the cut to which it belongs. When a bobbin runs out it must be replaced by another, and the ends joined by a weaver's knot. Coarse yarns are sometimes taken off in 6-cut hanks, and one or two hanks may be chain-leased or knotted at the 3rd or 6th cut, to provide bands to tie up the bunches.

Yarn is short reeled when it is wound upon a 54-inch swift, with only 100 threads per cut. Twelve cuts of short-reeled yarn thus contain but half the length of 12 cuts of long-reeled yarn.

Upon a reel arranged for cross reeling the shifter is given a quick backward and forward motion, usually making the journey twice for each revolution of the swift, so that the threads are crossed twice, forming two diamonds. The advantage of cross-reeled yarn is that the threads being crossed the end is more easily found if it breaks in the winding. The shifter of the reel should be as low down as possible, and quite near to the point where the yarn touches the periphery of the swift. The shorter the distance *a*, *b*, Figure 57, the less the strain upon the end and the more easily may weak and fine yarn be reeled. The angle of the shifter should be such that the axis of the bobbin is at right angles to the yarn being drawn off it when that yarn comes from the middle point of the bobbin barrel.

Figure 56 is a sectional stop motion reel of German construction.

The usual faults in reeling are bad knots, loose ends, crossed threads, and oily yarn. The correct knot to use is, as we have said, the weaver's knot, or intersecting loop knot, and an expert reeler can tie this knot as quickly as another can tie an inferior knot, such as the overthumb or granny's knot; nevertheless it is often difficult to get reelers to tie the proper knot.

Loose ends, properly speaking, are ends which, when a thread breaks or a bobbin runs out, the reeler fails to find and join up, contenting herself with passing the end of the fresh bobbin under the yarn upon a rail and proceeding with her work. They must not be confounded with cuttings which the reeler lets fall upon her swift, instead of throwing them upon the floor. The presence of these cuttings in the yarn is rightly objected to by weavers, as they are apt to cause breakages in the hank-winding department.

Crossed threads are caused by the reeler inserting her leasing in the wrong place or knotting up a wrong end. They may easily be detected by opening out a hank upon the horn and seeing that the cuts are only connected together by the one running thread.

Oily yarn is produced by a too copious supply of oil to the pins of the shifter, or by carelessness in taking the yarn over the end journal of the swift when doffing. The shifter is apt to become saturated with oil, which may ooze out and drop upon the yarn upon the swift in hot weather. Too much care cannot be taken in this respect, as oil invariably shows up in the bleaching.

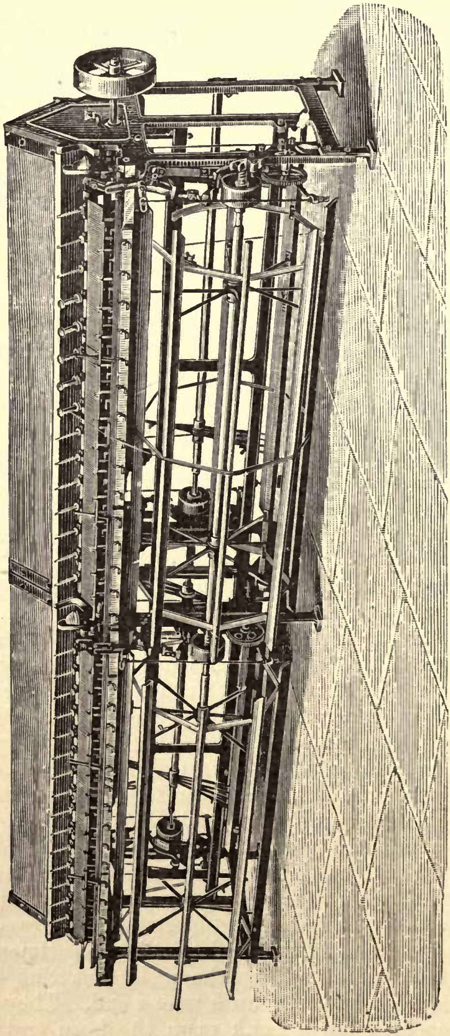


Fig. 56.—Sectional stop motion reel.

If all the threads are tight upon the swift, it is much easier to find a broken end. A good reeler, therefore, holds the end which she has knotted in place until it becomes tight, while a bad reeler lets it fall and produces a long thread. Long threads are also produced by turning the swift backwards in order to knot an end. Such a practice should be avoided, as long threads are generally broken in the bundling shop and produce loose ends.

When an end breaks or a bobbin runs empty, the reeler is supposed to stop the swift by pressing her knee against it. She seldom does, however, being paid by piecework. Several turns are thus lost. In order to make up for this loss in count, it is usual to give the bell wheel from 2 to 6 additional teeth, or from 122 to 126 for long reel, and from 102 to 106 for short reel. In addition to this, reelers, if they are afraid of being fined for short count, often put some additional threads into the last cut and turn back the bell wheel to its proper position before commencing a new set of hanks.

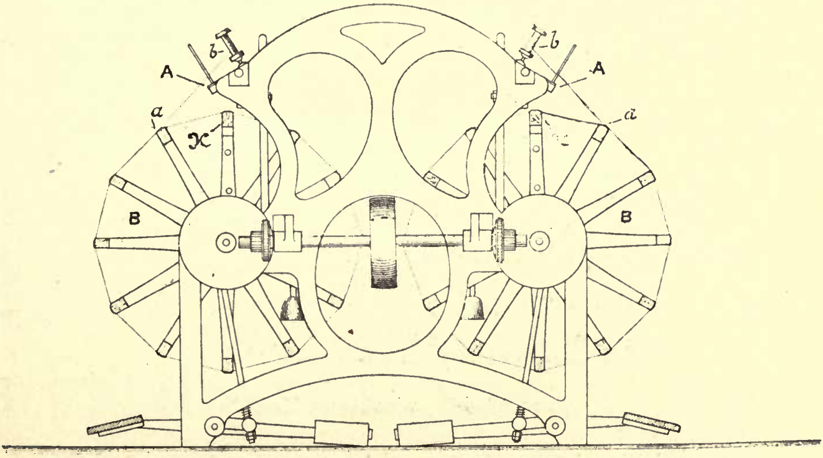


Fig. 57.—Section through power reel for 90-inch hanks.

The bell wheel is a gunmetal wheel fixed upon the lower end of a vertical spindle, and actuated by a worm upon the end of the swift axle. Upon the upper end of the bell wheel spindle is a wyper, for ringing the bell, which is hung upon a strip of spring steel; also a worm, which engages with a stud worm pinion, compounded with a spur pinion, which moves the shifter through its engagement with a rack.

Practically all reels are now power driven, although they may also be turned by hand if desired. The swifts are usually turned by means of a friction plate sliding upon a feather upon the end of the swift axle, and pressed, by means of a foot-board and levers, against a leather friction pulley fixed upon a short counter shaft, working in bracket bearings attached to the gable end, and turned by a pulley and a belt from the line shaft. The leather friction bowl may be shifted to positions more or less remote from the centre of the friction plate, and a suitable speed thus given to the swift. The drive is sometimes simplified and belts dispensed with by placing the line shaft upon wall brackets at the same level as the axles of the swifts, by taking away the short counter shafts and pressing the friction plates directly against split friction bowls tightened upon the line shaft. This latter shaft must be well boxed in, however, between the reels, lest an accident should occur through the reeler's clothing or apron being caught by the shaft.

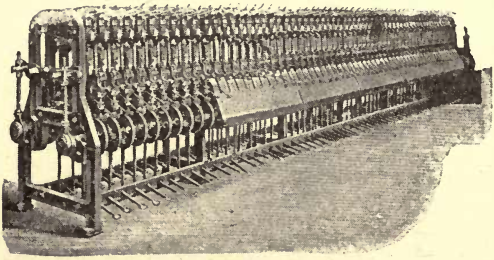


Fig. 58.—Cop-winding machine.

Cop winding is the winding of dry weft yarn into such a form that it may be put into the shuttle to fill or weft the cloth. The requirements are that the yarn may be drawn from the shuttle without strain, which would cause breakages of the weft and bad selvedges. This is accomplished by winding the yarn in such a way that it may be drawn off endwise either from the centre or nose of the cop which is firmly held in the shuttle. Coarse yarns are generally copped upon the bare spindle of a copping machine, such as Figure 58, and in weaving, the end drawn from the inside of the cop. Fine flax yarns, on the other hand, are wound upon paper tubes and the end drawn off endwise from the nose of the cop. On account of the slippery nature of flax, hemp, and jute fibre, as compared with cotton and wool, the yarn must be wound under great tension and pressure, so that a hard and firm cop may be produced.

In the cop-winding machine the spindles may be either vertical or inclined almost into a horizontal position. The principle of winding is almost the same as upon a self-acting mule. The thread guide has a short slow upward or forward motion, and a quicker downward or backward motion to put on the binding thread which gives solidity to the cop. The nose of the cop is given its conical form and its uniform diameter preserved by means of a conical split cap, which is either movable, and pressed on to the cop as it is formed upon a vertical spindle, or fixed and pressed into by the cop upon an inverted vertical or horizontal spindle, which is pressed forward or downwards by a lever or by gravity. The cop when completed is removed by raising the cop in one machine, and by pushing back or lifting the spindle in another. The spindles are usually driven by friction, so that they may be easily stopped for tying an end. Figure 58 shows a cop-winding machine suitable for coarse yarns, and made by Messrs. Urquhart, Lindsay & Co., Dundee. Boyd's horizontal spindle machine, which the author has used with success in winding fine linen yarns upon paper tubes, has an ingenious arrangement, by means of which the spindles automatically stop when the cop has been made the desired length.

The winding of wet warp yarn on to tin warper's bobbins for stove drying and warping, is generally done upon an upright spindle machine, the warper's bobbins being placed upon the spindles and driven by friction against a revolving disc upon which they rest. The thread guide has a regular up-and-down traverse equal in length to the barrel of the spool.

Jute warps are usually wound from the cop or bobbin into the form of cheeses upon cross-drum winding frames such as Hill & Brown's patent. These cheeses are formed upon a paper tube about 5 inches long, which lies upon a surface drum, the yarn being crossed and built by a quick reciprocating thread guide, or else by a helical cut in the face of the drum itself. Winding machines of the latter type are known as split-drum winders. The quick traverse motion producing a rapid crossing of the thread, gives the cheese firmness and solidity, so that the ends do not ravel. These cheeses may be worked in the creel of the warping machine just as warper's spools usually are.

Ordinary wooden warper's spools are usually wound upon a surface drum winder with a slow thread guide traverse. The bobbins are driven by friction, against the surface of the drum upon which they lie. An automatic motion is often provided to raise the spool out of contact with the drum, and stop winding when the spool becomes full. A stop motion, consisting of a leather tongue which passes between the spool and the drum, stops the revolution of the spool when an end breaks or runs out.

Dry spun hemp yarns and patent flax yarns for shoemakers' or saddlers' use, may be balled direct from the spinning bobbin upon a balling machine such as is shown in Figure 59, which is an automatic 12-spindle baller as made by Messrs. Wm. Ayrton & Co., Manchester. When the yarn has previously had to be reeled for bleaching, dying, or both, it may be previously hank wound into cheeses, or upon conical bobbins shown in the figure. In balling machines of this sort, the yarn is wound upon a very slowly revolving spindle or mandril by a quick-running flyer, the desired form being given to the ball by the variable inclination of this mandril to the axis of the laying-on flyer. In a machine such as illustrated all the movements for forming the ball are automatic, and produced by a specially shaped cam. The machine, furthermore, stops automatically when the ball has attained the desired weight, one and two ounce balls being the usual size for this class of work.

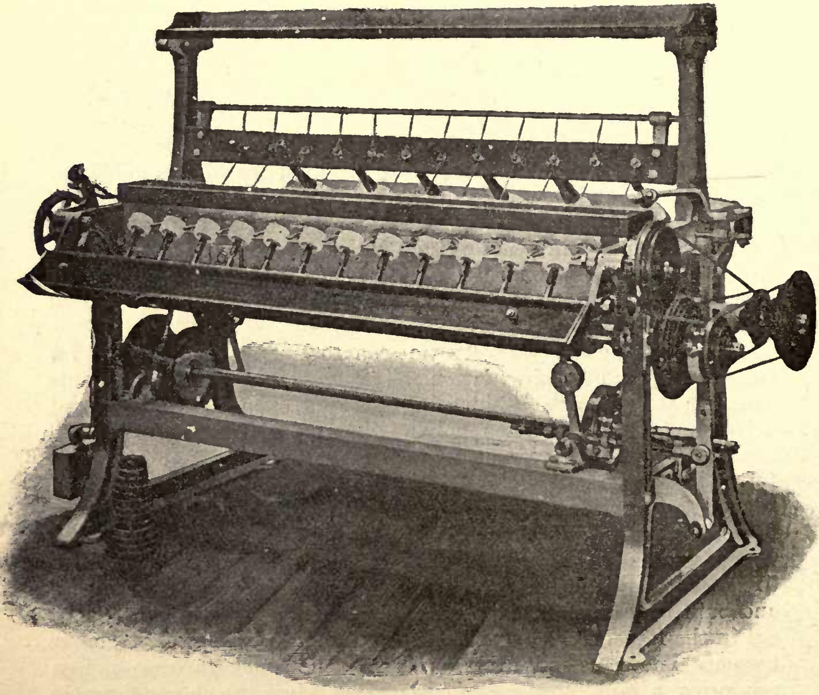


Fig. 59.—12-spindle baller for shoe and saddlers' hemps.

Figure 60 is a 2-spindle machine for balling binder twine or reaper yarn. The movements of this machine are likewise automatic. An automatic tension-regulating device is also added to keep the winding tension constant, whether the automatic bobbin is full or nearly empty. Figures 61 and 62 show an ingenious German device for detecting and removing slubs and lumps when winding yarn from one bobbin to another. The yarn passes in the direction of the arrows from A to B between an adjustable plate C and a chisel-pointed tumbler D. When a lump passes, it raises the tumbler D, allowing the other tumbler E to overbalance, and the end F to come into contact with a projection upon the friction-driven spindle, and thus causing a stoppage until the lump has been cut out and the ends knotted. Wet spun yarn is generally dried in a loft, often placed above the boilers, so that advantage may be taken of the heat arising therefrom. The hanks should be spread out to their full extent or width upon wooden poles which are supported at each end. A second pole

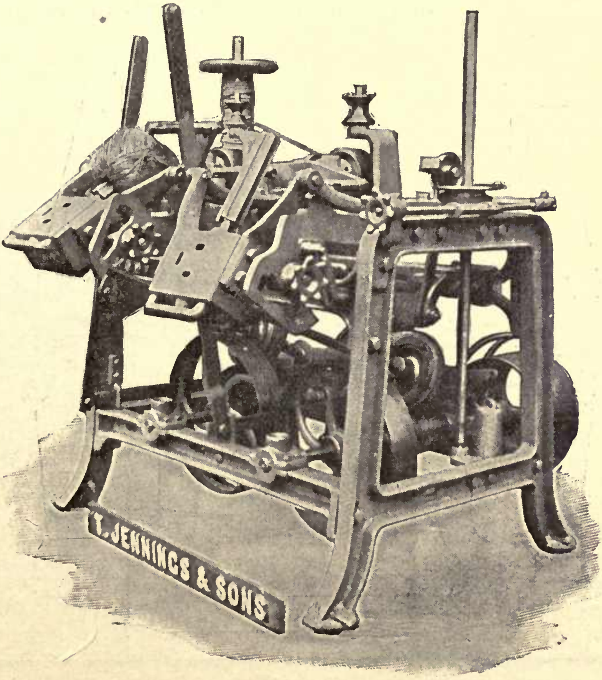


FIG. 60.—Binder twine balling machine.

hangs by its own weight in the hanks, to keep them from twisting while drying. The poles are usually from 8 to 12 feet long, and will hold from one to two 25-hank reels according to their length and the weight of the yarn. The hanks of yarn should be as evenly spread upon the drying poles as they were upon the swift of the reel, and carefully rolled round when half dry, so that that portion of the hank which is in contact with the poles may be changed and allowed to dry. The poles themselves must be perfectly smooth and straight. Smooth, so that the threads may not catch upon knots and splinters, and straight so that all the threads may be kept under the same tension without freedom to twist together. Attention to this point is particularly necessary in drying fine wefts, which, unless every care be taken, may be found difficult to wind from the hank. Expense should be no object where excellence is aimed at, so that the poles may be of the best seasoned canarywood. It is the usual custom to heat the drying loft at night by means of steam pipes, and to change the yarn during the day, the hot damp air being allowed to escape through specially constructed chimneys in the roof. Quick drying in this way con-

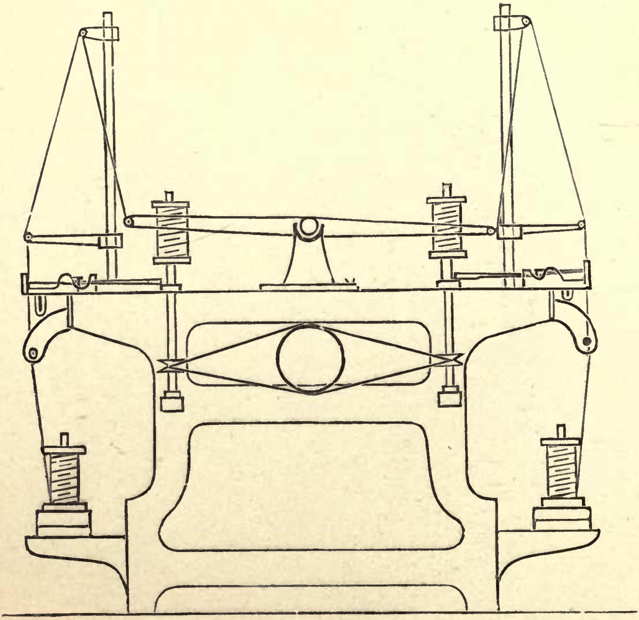


FIG. 61.

tracts the hanks, twists the threads, and renders the yarn hasky and unsightly. It is much better to dry the yarn by a current of dry and slightly heated air supplied by a fan and passed through the loft. Hot air may be drawn from around the boiler flues or supplied by the fan of an aero-condenser. Yarn, air dried under tension, is worth at least 3d. per bundle more than yarn which has been quickly dried by a great heat, being smoother, more silky, and supple.

Air-dried yarn may be straightway bundled, as it contains that percentage of moisture which it will hold under atmospheric conditions.

Steam-dried yarn, on the other hand, must be "brought to" or conditioned before bundling. Bone-dry yarn will hold and requires 8 per cent. of moisture to put it into good weaving condition. This moisture will be most perfectly taken up in a cooling shed, in which the yarn is spread upon poles as in the drying loft. The cooling shed is open to the outside air, which, if very hot and dry, may be moistened by a humidifier, such as the Drosophore, Figure 34.

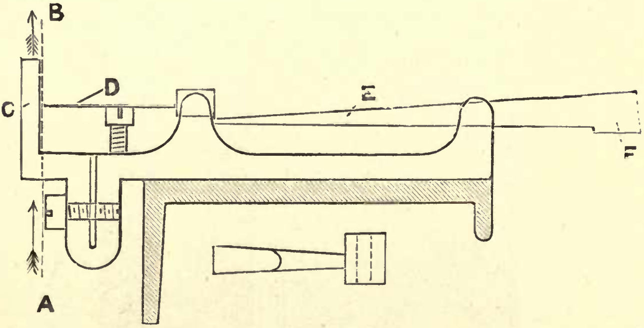


Fig. 62.

Flax, hemp, and jute yarns in the hank are usually either bundled or bunched for storing, or for delivery to the weaver, bleacher, or dyer. The difference between a bundle and a bunch is that a bundle is formed upon a bundling stool and is the full length of the hank, *i.e.* about 40 inches; while a bunch is formed in a bundling press, such as is shown in Figure 63, in which the hanks are doubled, forming a bunch about 20 inches in length for long-reeled yarn, and about 12 inches in length for short-reeled yarn.

The bundling stool is a heavy wooden stool about 45 inches in length. Sides are formed by wooden pegs about 14 inches long, between which the "heads" of yarn are built. A "head" is a certain number of hanks, often six, which are separated from the reel of yarn and twisted together by hand upon the "horn." These "heads," often to the number of sixteen, are laid side by side between the sides of the stool, say in four rows of four heads each, and then tied round by four bands, each a twisted hank, at equal distances. A 100-hank bundle is thus composed. The word "bundle" as thus used is not to be confounded with the word bundle as applied in the English yarn table, where it signifies a

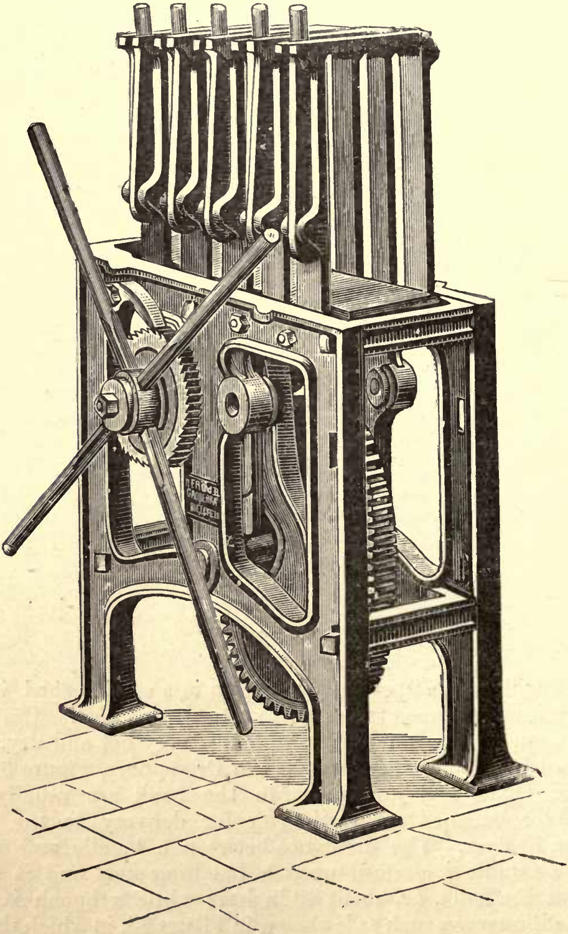


Fig. 63.—Yarn bundling press.

length of 60,000 yards or 16⅔ hanks. A press bunch is formed in a somewhat similar manner, save that in the formation of heads the hanks are not so much twisted together, one turn only being given before they are doubled in two, given a half-turn, and placed in the press. Four hank, half-hank, or quarter-hank bands are first placed between the bars of the press to tie it with when complete. When the desired number of heads have been built in, the top straps are put down, the hand wheel, seen in the illustration, turned to the right, and the bottom of the press slowly raised by means of a pinion and cam wheel. A great pressure is thus applied, the gearing being prevented from running backwards by means of the pawl and ratchet wheel seen in the illustration. When the bunch has been tied, the pawl is raised and the gearing allowed to run slowly backwards to the starting point. The hinged straps are then lifted and the finished bunch taken out. While coarse yarns, comprising jute and all dry spun yarns, are usually bundled upon the stool, finer yarns, usually wet spun, are press bunched, as although the labour costs more, the yarn has a nicer appearance and travels better. The following tables give the usual make-up of bundled and bunched yarns:

LONG STOOL BUNDLES.

Leas.	Hanks in Bundle.	Heads in Bundle.	Hanks in Head.	Number of Bands.	Hanks in Bands.
6's to 12's	25	16	1½	4	¼
14's to 25's	50	16	3	4	½

PRESS BUNCHES.

Leas.	Hanks in Bunch.	Heads in Bunch.	Hanks in Head.	Number of Bands.	Hanks in Bands.
up to 20's	25	16	1½	4	¼
20's to 30's	50	16	3	4	½
35's to 45's	100	24	4	4	1
50's to 70's	100	16	6	4	1
75's to 160's	200	24	8	4	2
160's to 140's lea, short reel .	200	40	5	4	cord
160's upwards, short reel .	200	25	8	4	cord

Coarse yarn may be exported in bundles or bunches by the usual routes without much risk of damage. Fine, light coloured, and bleached yarn, however, must be baled, preferably in a hydraulic press, covered with hessian or other coarse baling material, and bound by wire, hoop-iron, or cords.

The weight of the bunches should be tested separately, and the gross weight of the bale checked by reference to the following tables, in which the weights of the various numbers in different quantities are given:

Leas per lb.	Lbs. per Scotch Spindle.	Lbs. per English Bundle.		Lbs. per Belgian Paquet.		Lbs. per French Paquet.		Belgian Paquet.	French Paquet.	Dorset Number.
		lbs.	oz.	lbs.	oz.	lbs.	oz.	kilogs.	kilogs.	lbs.
4	12	50	0	150	0	300	0	68·00	136	18
6	8	33	4	99	12	199	8	45·32	90	12
8	6	25	0	75	0	150	0	34·00	68	9
10	...	20	0	60	0	120	0	27·20	54 or 55	...
12	4	16	10	49	14	99	12	22·66	45	6
14	...	14	4	42	12	85	8	19·43	40 or 38·50	...
16	3	12	8	37	8	75	0	17·00	34	4½
18	...	11	1½	33	4½	66	9	15·11	30 or 31	...
20	...	10	0	30	0	60	0	13·60	28	...
22	...	9	1	27	3	54	6	12·36	25	...
25	...	8	0	24	0	48	0	10·88	22	...
28	...	7	2	21	6	42	12	9·71	20	...
30	...	6	10½	19	15½	39	15	9·06	18	...
32	...	6	4	18	12	37	8	8·50	17	2¼
35	...	5	11¼	17	1¾	34	3½	7·77	16	...
38	...	5	4	15	12	31	8	7·15	15	...
40	...	5	0	15	0	30	0	6·80	14	...
42	...	4	12	14	4	28	8	6·48	13	...
45	...	4	7	13	5	26	10	6·04	12	...
48	1	4	2½	12	7½	24	15	5·66	11·50	1½
50	...	4	0	12	0	24	0	5·44	11	...
52	...	3	13½	11	8½	23	1	5·23	10·50	...
55	...	3	10	10	14	21	12	4·95	10	...
60	...	3	5¼	9	15¾	19	15½	4·53	9	...
65	...	3	1	9	3	18	6	4·20	8·05	...
70	...	2	13½	8	8½	17	1	3·88	8	...
80	...	2	8	7	8	15	0	3·40	7	...
90	...	2	3½	6	10½	13	5	3·02	6	...
100	...	2	0	6	0	12	0	2·72	5·50	...
110	...	1	13	5	7	10	14	2·48	5	...
120	...	1	10½	4	15½	9	15	2·27	4·50	...
130	...	1	8½	4	9½	9	3	2·10	4·25	...
140	...	1	6¾	4	4¼	8	8½	1·94	4	...
150	...	1	5¼	3	15¾	7	15½	1·81	3·60	...
160	...	1	4	3	12	7	8	1·70	3·50	...
180	...	1	1¾	3	5¼	6	10½	1·51	3	...
200	...	1	0	3	0	6	0	1·36	2·70	...

The English yarn table, which is almost universally accepted among wet spinners at home and on the Continent, is as follows, the yarn number being equal to the number of cuts per lb. :

Yards.	Threads.	Cuts or Leas.	Hanks.	Bundles.
2½	1	0	0	0
300	120	1	0	0
3,600	1,440	12	1	0
60,000	24,000	200	16⅔	1

The yarn table as used in the Scotch dry spun trade is as follows, the yarn number being the weight in lbs. of one spindle or spangle :

Yards.	Threads.	Cuts.	Heers.	Hanks.	Hesps.	Spindle.
2½	1	0	0	0	0	0
300	120	1	0	0	0	0
600	240	2	1	0	0	0
3,600	1440	12	6	1	0	0
7,200	2880	24	12	2	1	0
14,400	5760	48	24	4	2	1

A Belgian paquet is equal to 3 English bundles, and a French paquet to 6 English bundles.

The Austrian yarn table as used in the Trautenau district is as follows, the yarn number being equal to the number of hanks required to weigh 10 lbs. :

Threads.	Cuts.	Hanks.	Pieces.	Bundles.	Schock.
60	1	0	0	0	0
1,200	20	1	0	0	0
4,800	80	4	1	0	0
24,000	400	20	5	1	0
288,000	4,800	240	60	12	1

The metric system usually used in numbering French rope yarns, shoe and saddlers' hemps, etc., is arranged as follows:

No. 1 = 1000 metres = 1000 grammes = 1 kilogramme.
No. 2 = 2000 ,, = 1000 ,, = 1 ,,
No. 3 = 3000 ,, = 1000 ,, = 1 ,,

and so on. (The metric number multiplied by 10 and divided by 6 gives the English number in leas per lb.)

The Dorset and Somerset system of yarn numbering is based upon the weight in lbs. of a "dozen" containing 21,600 yards, or 12 half-hanks.

The size of binder twine or reaper yarn is indicated by the number of feet per lb. There are four standard sizes, viz. 500, 550, 600, and 650 feet per lb. The size or number of rope yarn indicates the number of threads of that yarn which will be required to make one of the three strands which will form a rope 3 inches in circumference. No. 30, for instance, indicates that three strands of 30 threads each, or 90 threads in all, make a rope 3 inches in circumference. The sizes usually met with range from 12's to 40's.

The import duty upon linen yarns entering France is at the rate of one franc per kilogramme. This duty is of course prohibitive for coarse yarns, except perhaps upon a small quantity of very superior thread warps. It does not fall so heavy upon fine yarns, amounting to only sixpence per bundle upon 150's lea, for instance. Hence a considerable quantity of fine wefts are shipped from Belfast to Lille, Cambrai, and other linen trade centres.

CHAPTER X

THE MANUFACTURE OF THREADS, TWINES, AND CORDS

Yarns destined for the manufacture of threads, twines, and cords, and which have been reeled into hanks for export or for bleaching or dyeing, must be hank-wound on to bobbins or into cheeses before they can be employed upon the twisting frame.

The hank-winding frame required is a drum or split-drum winder, similar to those described in the last chapter, but provided with as many "swifts" or "flies" as there are drums. A "fly" is a light wooden framework which extends and carries the hank. It turns upon a central axis which rests upon supports at either side, and should revolve quite freely as the yarn is pulled from it. A small drag or brake hangs from its centre, so that it may not overrun itself when an end breaks, and so that an even tension may be kept upon the end. Great care must be taken to place the hank straight and evenly upon the fly, otherwise great difficulty will be experienced in winding fine and weak yarn. The first end is easily found, being tied in the leasing, if the reeler has done her work properly.

Both ring and flyer frames are used for thread and twine twisting. Upon the ordinary frame, such as is shown in Figure 64, the bobbins of yarn are placed upon the pins in the creel as shown, and the ends brought down through a guide under the glass rod in the water trough, over the edge of the latter, round the under side of a brass roller, and then between the two rollers *a* and *b*, and over the top of the latter to the thread-plate, through the eye of which it passes to the flyer eye, passing once round the leg of the flyer on the way, and being at length wrapped upon the bobbin, which is dragged as in the spinning frame. Splash-boards are provided, and the spindles driven as already described. If the thread is to be dry twisted, the trough may be run dry or the ends passed directly to the roller over the edge of the trough. The smoothness and strength of the thread produced depends to a great extent upon equal tension and length of the threads. If an end runs slack it will ride or float on the surface of the thread, and, being longer than the others, will not bear its share of any strain put upon the thread. Attention to this point is of great importance in the production of threads for sole sewing upon the Blake, M'Kay, or Goodyear machine, a smooth thread being required for this purpose. In order that all the threads may have the same surface speed, they should not be allowed to cross in passing through the rollers, but should be kept perfectly parallel by means of a reed. A conical die, the bore of which is a tight fit for the thread, placed in the thread-plate eye, will give the thread a polish and a smooth, round appearance as it is twisted and drawn through it. The extra tension put upon the thread by this arrangement necessitates, however, the use of geared spindles and block-dragged bobbins.

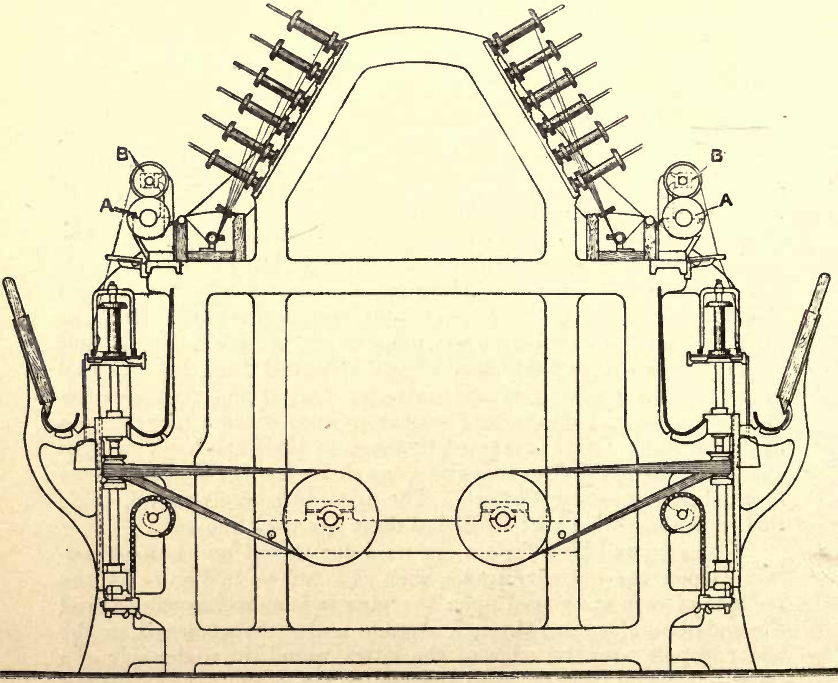


Fig. 64.—Wet twisting frame.

A thread suitable for a Goodyear lock-stitch sole-sewing machine may be composed of say six ends of 18's lea yarn twisted together by a number of turns, equivalent, approximately, to the product of $2\frac{1}{2}$ to 3 and the square root of the finished weight of the thread, in this case 3 lea. The yarns for such a thread should be composed of the best thread flax, so that the finished thread may sustain a weight of about 36 lbs. without breaking. Other threads which may be twisted upon a frame such as illustrated, are 3 and 4 cord linen machine threads from 10's to 80's lea for saddlers' machine sewing, and 14's and 16's 2-cord for bookbinders' thread, as well as 3-cord fishing lines, and 2, 3, 4, 5, and 6 cord hemp shop twines from 1 to 16's lea yarn, with twists varying from 64 to 440 turns per foot.

When an exceptionally hard make of twine is required, and one which will not untwist when cut, the yarns must be given some extra twist, usually called "forehard," at the moment when they are twisted together. Manila "trawl twine" is a twine of this sort. It is usually made upon a machine somewhat similar to Figure 65. The bobbins of yarn from the spinning machine are placed upon the horizontal spindles in the left-hand section of the machine. They are connected with carriers, through which tension is applied by means of friction drags, or are dragged by means of spring pressers, which bear against the surface of the yarn upon the bobbin. A stop motion, consisting of a wire with a heavy tailpiece, should be provided for each end as it passes through the forming top. The wires are centred upon a stud, and the heavy tailpieces are kept supported by the pressure of the end upon the wire arm of the lever. The falling of the tailpiece, when an end breaks, causes the stoppage of one side of the machine. The yarn is given "forehard" as it passes to the cabling flyer by the revolution of the smaller flyers which surround the bobbins in the left-hand section of the machine. Trawl twine is made from three threads of white Manila, each weighing about 320 yards per lb., the grist when combined being about 100 yards per lb.

Figure 66 shows a single horizontal laying machine suitable for the manufacture of rather heavier goods, such as box and sash cords, clothes-lines, etc.

When a thread or cord is made up of three strands, each containing two or more yarns, and when the strands have been twisted before being brought together or laid, that thread or cord is said to have been cabled. Cabling gives the cord or thread a very hard surface, and enables it to resist wear, as in the sewing machine. The commonest make of cabled twine is "whip cord," which is usually 6-cord 6's, 8's, or 10's lea hemp yarn, composed of three strands of 2-fold yarn forehardened and twisted together in the opposite direction with 215, 248, or 277 turns of twist per foot respectively.

In laying twines and strands for cabling, the twist must always be put in in the opposite direction to that in which the yarns were spun. When strands are being laid into a cable thread or cord,

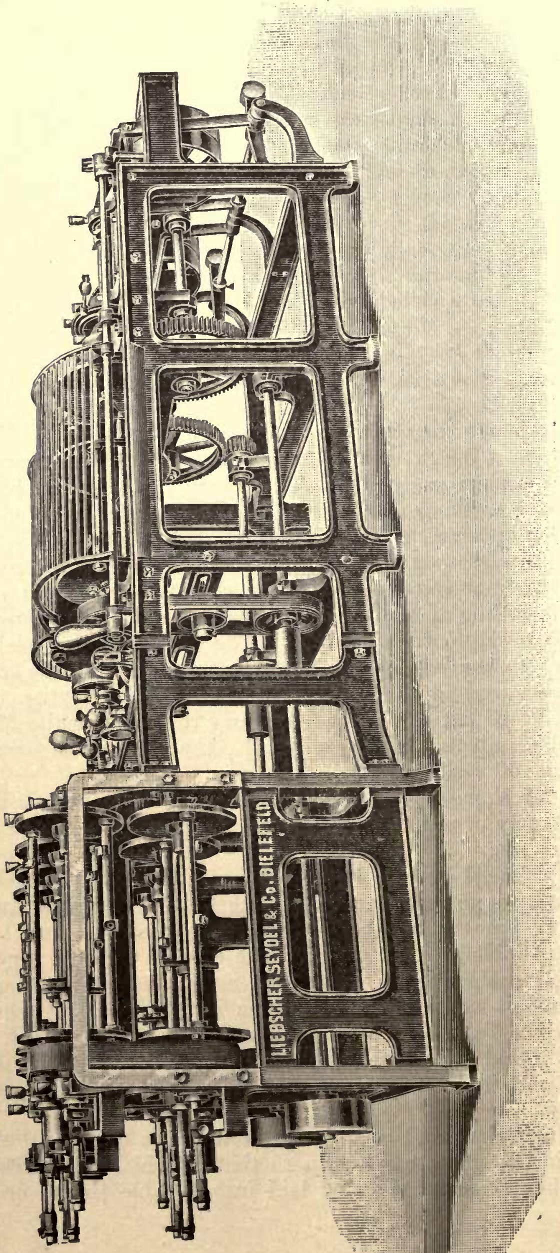

LIEBSCHER SEYDEL & Co. BIELEFELD

FIG. 65.—2-spindle twine machine.

they must again be twisted together in the opposite direction to that in which the strands were formed, or in the same direction as that in which the yarn was spun. This is the fundamental principle of thread, cord, and rope making.

Although the author has made small quantities of fancy linen threads for upholstery purposes, flax, hemp, and jute yarns are too stiff and heavy, and do not lend themselves to this class of work. The method of twisting is nevertheless interesting. There are several makes of fancy twisting frames, their essential organs consisting of three or more lines of rollers to which variable speeds and intermittent motions may be given, also of reciprocating bars and oscillating rods for bead forming.

Loop thread is made up of two ground threads around which a coarse thread of much greater length is twisted. The two ground threads pass between the back rollers, through guides, and then between the faster front rollers. Two parallel grooves are cut in the front pressing roller, and through these the ground threads pass, and are therefore not held nor pulled by the roller. The fancy or loop thread passes first through a thread guide and then directly to the front roller, where it is gripped between the two grooves. The ground threads unite with the fancy thread as soon as they emerge from the front roller and form a loop effect. This loop is developed by twisting a fourth thread around the three in the opposite direction. The finished loop thread consists of at least four single threads, and if it be untwisted it will appear as if made with a 2-ply ground thread which had been previously twisted, but this is not the case. The ground and fancy threads are twisted with from 8 to 13 turns per inch. The fancy thread is from 2 to 3 times as long as the ground threads. This increased length is given by running the front rollers, which supply the fancy thread, from 2 to 3 times as fast as the back rollers. A better loop is obtained when the thread passes perpendicularly and not diagonally from the front roller to the spindles. The grooves in the roller should be of V shape.

The majority of fancy yarns are produced by running two threads together at unequal speeds and then twisting them together. Most novelty yarns are made with a ground thread and a fancy thread. The ground thread is usually 2-ply and the fancy thread heavier. A third thread, called a binder, is often used, and twisted around them to hold the fancy thread in position.

Bead yarn is produced by delivering a thread at a uniform speed by one pair of rollers, while another thread is delivered intermittently, forming the ground thread around which the longer thread laps in the form of beads, while the ground thread is held by the rollers. Another way of making bead yarn consists in delivering the two threads constantly at a different speed. Bars or levers,

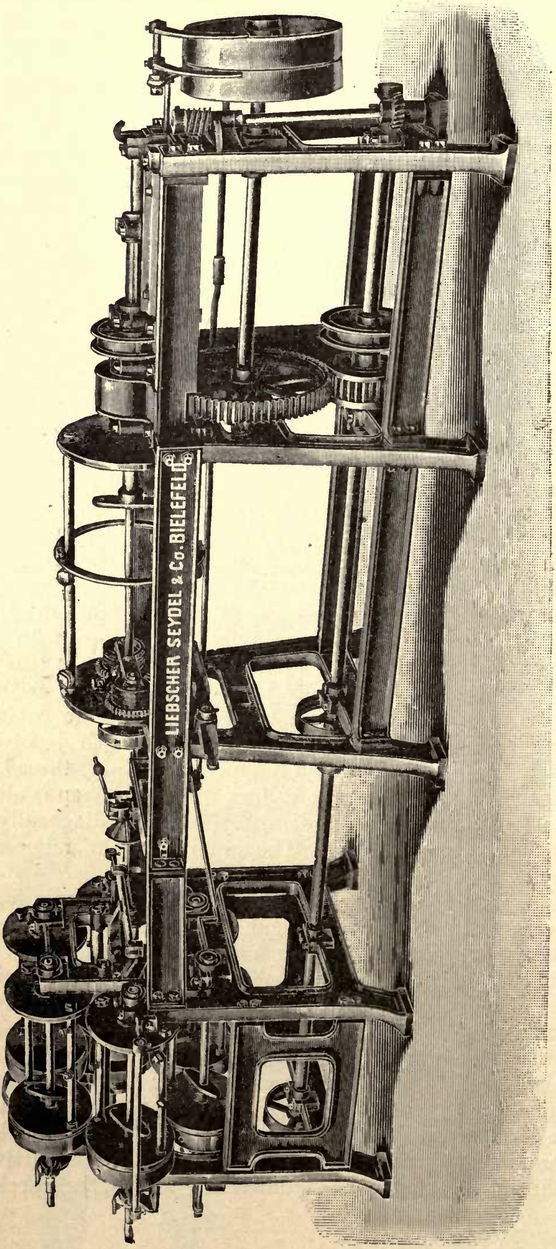

LIEBSCHER SEYDEL & Co. BIELEFELD

FIG. 66.—1-spindle cord machine.

which are raised and lowered, are employed to take up the slack and deliver it quickly to the short or ground thread. The downward speed of the bars is the same as that of the ground thread, so that the long thread is lapped around the shorter at one spot and the bead formed. Beads or slubs of different lengths are produced by using two bars or levers. When the first method is employed, the alternate stopping of the ground thread is done by means of cut gears, teeth being cut away from the driving wheel and the intermittent motion of the driver thus produced.

Twines are sometimes tarred in order that they may better resist humidity, while shoe threads are occasionally waxed ready for use upon the sole-sewing or welting machine. Tarring and waxing are done in a similar manner, *i.e.* in winding the cords or threads from bobbin to bobbin through a trough of heated Norwegian tar or molten cobbler's wax, the excess of tar or wax being squeezed out by rollers and the threads wiped by a passage between felt pads. The threads may be dried and polished upon a machine similar in principle to that shown in Figure 67, in which, on their passage from bobbin to bobbin, they are first subjected to the action of a brushing cylinder, and then polished by contact with several polishing cylinders, being dried at the same time by the heat which rises from a steam radiating pipe underneath the machine, as well as by the fanning action of the quickly revolving cylinders.

Shop twines, clothes lines, and other cheap goods are usually washed, carded, sized, and polished, to give them a more sightly appearance. All these operations are accomplished in winding the cords from bobbin to bobbin. The twine washing and carding machine has usually two washing troughs and six carding rollers. The carding rollers are covered with coarse wire cards or with coir fibre, which removes much shove and inequalities from rough twines. In the polishing machine the twine first passes through a washing trough and a pair of squeezing rollers, then over a rubbing roller and into a size trough, then through squeezing rollers to the tin or copper drying cylinder, around which it passes before coming in contact with three polishing rollers. In the machine used for heavier twines there are often two size troughs and two drying cylinders.

For fine work the use of steam-heated drying cylinders are objectionable, because there is always a danger of the threads being scorched and tendered if the machine be stopped without first running through the threads. For yarns and threads, the use of a polishing machine such as is shown in Figures 67 and 68 is to be preferred, since its drying action is due to the current of dry or hot air produced by the fanning action of its quickly revolving organs.

In this machine, which is made by Messrs. Wm. Ayrton & Co., Manchester, and suitable for as many as 50 ends, the thread leaves the

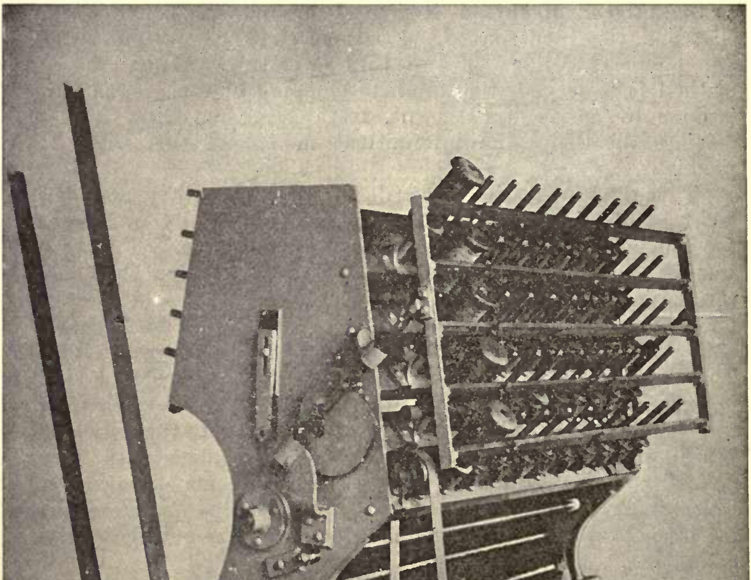


FIG. 67.—Bobbin-to-bobbin thread polishing machine.

twisting frame bobbins A, follows the dotted line through the size trough B, round and between the squeezing and delivery rollers C, past the brushing cylinder D, behind the adjustable guide roller

J, touches the first polishing cylinder F before passing round the reciprocating top thread guide roller E, and again touching the polishing roller F and the following three polishing rollers, against which it is pressed by the adjustable guide rollers J, before passing round the taking-off rollers G, and being wound upon the bobbins I.

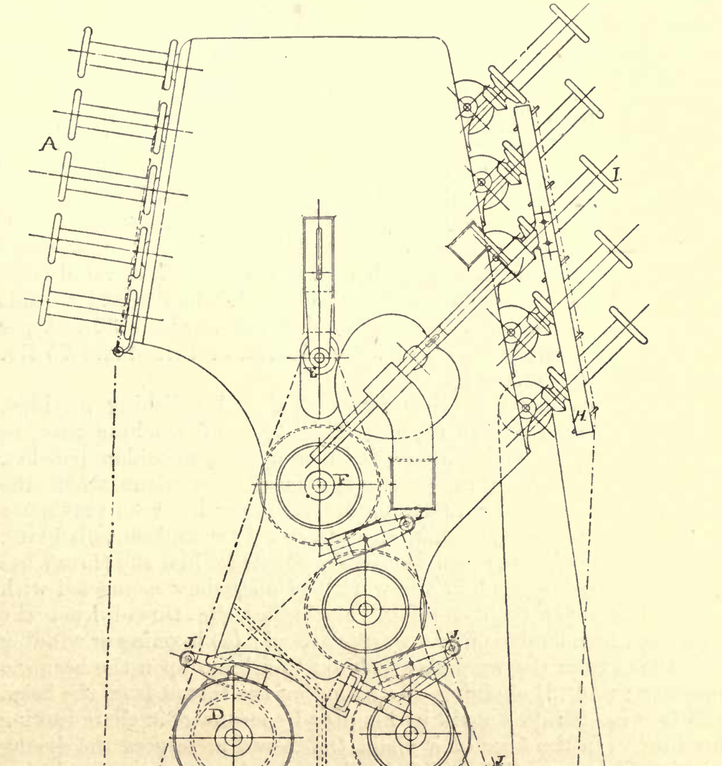


Fig. 68.—Bobbin-to-bobbin thread polishing machine.

H are the lifting rails with a guide for each thread, and K is the gilled steam pipe which heats the air underneath the machine and increases its drying capacity. The tension upon the ends is controlled by the drawing-off rollers, which are geared to and run slightly faster than the size or delivery rollers. On fine work, each end passes in direct line from the winding-off bobbin to the winding-on bobbin. On heavy counts of thread and twine, each end passes in direct line to the last brass thread-guide roller, and then passes back once or twice to the third last brass roller, which is grooved to keep each coil thus made, separate. In this manner the material receives extra friction from the third and fourth polishing cylinders. The five polishing cylinders are covered with brushes and hardwood beaters. The thread-guide rails are actuated by a heart lifting motion at each end. A waxing trough and brass roller may be substituted for the size trough when waxed threads are required. The average speed of delivery is about 30 feet per minute, giving a production of about 40 lbs. of thread and 75 lbs. of twine per day of ten hours.

Figure 69 shows another form of thread polishing machine, intended to give a soft finish. This type of machine may be worked either as a bobbin-to-bobbin or a beam-to-bobbin polisher. The bobbin-to-bobbin system is the most convenient when the thread to be polished is in its natural colour or has been previously dyed or bleached in the hank, and afterwards wound on to bobbins. The beam-to-bobbin system is usually adopted when the thread has been dyed or bleached in the warp, the operations connected with which being (1) spool-winding or winding the thread from the twisting-frame bobbin on to a warper's spool; (2) beaming or winding the thread from the warper's spools on to a beam upon the beaming machine; and (3) chaining or unwinding the thread from the beam and forming it into a chain by hand or by means of a chain-linking machine. In the form of a chain the thread undergoes the dyeing or bleaching operations, and is then dried upon a warp-drying machine, being finally stretched and wound upon a beam again by means of a chain beaming or "holding back" machine. The beam-to-bobbin system is specially advantageous in dealing with large quantities of thread. General uniformity of colour and economy of labour are obtained by the warp dyeing and bleaching process. Long lengths of thread pass through uninterruptedly, thereby reducing piecing up and the frequency of knots to a minimum.

The proper polishing of thread requires much skill and experience. It is well known that to polish a boot, too much or too little moisture and friction may be applied. A shade either way may alter the effect entirely. So it is with thread, which, according to its thickness and the lustre desired, must be treated with careful

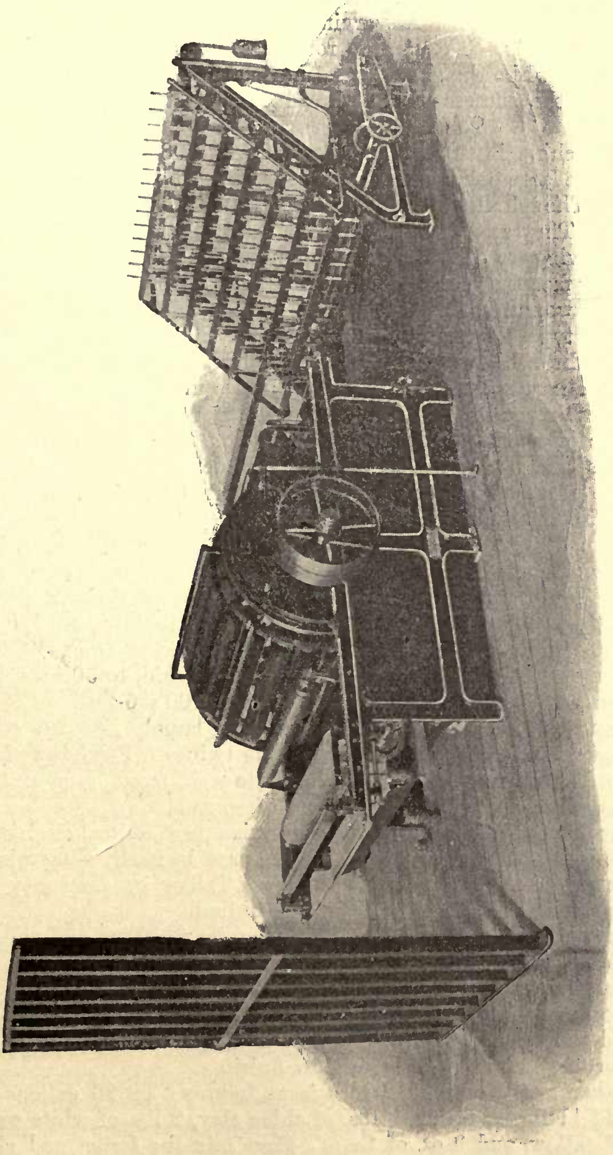


FIG. 69.—Soft finish thread polishing machine.

LIBRARY
OF THE

attention to four points: Correct sizing, exact tension, and exact brushing and drying. A varying treatment will produce unsatisfactory results. The natural roundness of the thread must also be preserved, while the smoothness and softness of polish are often essential to the success of the thread when tested by the sewing machine.

The machine illustrated in Figure 69 is a 98-spindle machine, with but one large polishing cylinder covered with best soft horse-hair brushes. The spindles of the winding-off frame are upon the Rabbeth principle. They are band driven; one band, tightened by a tension pulley, serving to drive seven spindles. The lifting motion is actuated by means of a mangle and quadrant, and produces well-built and evenly wound bobbins.

Similar types of machines are made for 200, 300, or 360 ends, and carry three balanced polishing cylinders, covered with brushes and special hardwood beaters. The threads are pressed upon the brushing cylinders by adjustable grooved brass thread guide rollers, which are given a slow reciprocating motion to carry the threads backwards and forwards across the cylinders. The burnishing rollers are of metal, and the drying accelerated by means of steam pipes. The small brushing cylinders of a three-cylinder machine make from 600 to 800 revolutions per minute, while the larger cylinder of a single cylinder machine makes but 350 revolutions per minute. The power required to drive machines of this sort varies from 2½ h.-p. for a 98-spindle single-cylinder machine, to 5 h.-p. for a 360-spindle machine. The production varies from 50 lbs. per day upon a 98-spindle machine upon 80's 3-cord, to 300 lbs. per day upon a 360-spindle machine polishing 100's 6-cord. Potato flour, farina, soft soap, and china clay enter largely into the composition of sizes for finishing and polishing twines. For fine twines and threads requiring a gloss finish, white wax, borax, gum arabic, glycerine, olive oil soap, and starch are often used.

For common twines of common Russian tow, animal size made from the horns and hoofs of cattle can be used by itself, being mixed with water to the desired consistency. Tallow or soap may be added to obtain the soft or hard finish required.

A very good recipe for size or dressing for finishing and polishing twines is to boil in a tub, iron cistern, or steam-jacketed pan, 28 gallons of water to which 24 lbs. of farina and 1½ lb. of tallow or soft soap are added. Common glycerine may be used in place of soap and tallow, and 2 lbs. of white wax and 2 oz. of borax be added for fine twines requiring a gloss finish.

Another recipe for fine twines is as follows: To 26 gallons of water add 11 lbs. of farina, 9 lbs. of china clay, 2 lbs. of white wax, 1½ lb. of tallow, and 9 oz. of soap. First mix the farina and clay in cold water and then boil with steam, the steam pipe passing to the bottom of the cistern and there blowing off. Stir and mix well, lest the china clay settle to the bottom. When all is properly dissolved, drain through a fine sieve before using. Common flour or Irish moss may be used in place of farina. Gum Tragasol may also be used for dressing and polishing twines. It is first digested with boiling water, and then more water added until the size is of the desired consistency.

A recipe for lustering threads and fine twines reads as follows: 9 lbs. of potato starch, 1 to 1½ lb. of Marseilles or olive soap, 2 to 2½ lbs. of paraffin wax, and 2 oz. of borax. The paraffin wax and soap should be cut into small pieces, melted together, stirred for ten minutes, and then mixed with a little boiling water. The starch should be mixed with a little cold water, and added to 20 gallons of water and well boiled. The paraffin wax and borax are then added, and the whole boiled for ten minutes more. If a very high polish is wanted, more starch may be added.

Sometimes linen threads require to be softened. This is done in the hank upon a machine known as an iron-man, or by the aid of a small beetling engine. In the case of the iron-man or hank-twisting machine, the hanks are placed upon a pair of hooks, which first twist the hanks tight in one direction and then antomatically reverse the motion and twist them in the other direction, repeating the operation until the desired degree of softness is obtained. The lower hook rail lifts as the hank shortens or contracts by twist, and in this way actuates the reversing gear, consisting of the usual arrangement of two loose and one fast pulley, with an open and a crossed belt. The top hooks are turned by bevel gear. In the beetling engine, the hanks to be softened are hung upon a beam which slowly turns, carrying the hanks with it. Every portion of the hank thus receives the same amount of work or beetling from the stampers which fall upon it.

Bookbinders', tailors', carpet, and jacquard threads are usually skeined, generally upon the short 54-inch reel. The skeins, from ½ oz. to 8 oz. in weight, are tied up separately, doubled, knotted, and done up in neat parcels weighing 1 lb. upwards.

"Gilling" twine for fishing-nets, whip cords, and all sorts of shop twines are balled either upon a hand machine or upon a semi-automatic machine such as is shown in Figure 70. This machine is a 6-spindle machine suitable for making balls up to 6 inches by 4½ inches. The adjustable cam for shaping the balls is seen at the left-hand side of the machine, and the gearing for the automatic stop motion, to the right.

Balls of various shapes, such as shown in Figure 71, may be produced upon this machine. In balling, it is customary to wind the interior of the ball with an open mesh, and then to alter to a close mesh just as the last few layers are going on. In the machine

Figure 70 this change is automatically brought about at the proper moment. The size and shape of the hole in the ball is determined by a cap which fits upon the winding spindle. The caps are detachable, and may be changed according to requirements. When it is required to produce balls of light weight with large external appearance, expanding and collapsible spindle caps must be used. These caps are expanded during the process of winding, and collapse to allow the balls to be withdrawn when completed—that is to say, when the ends have been severed by an ingenious arrangement of hooks and knives worked by a hand lever.

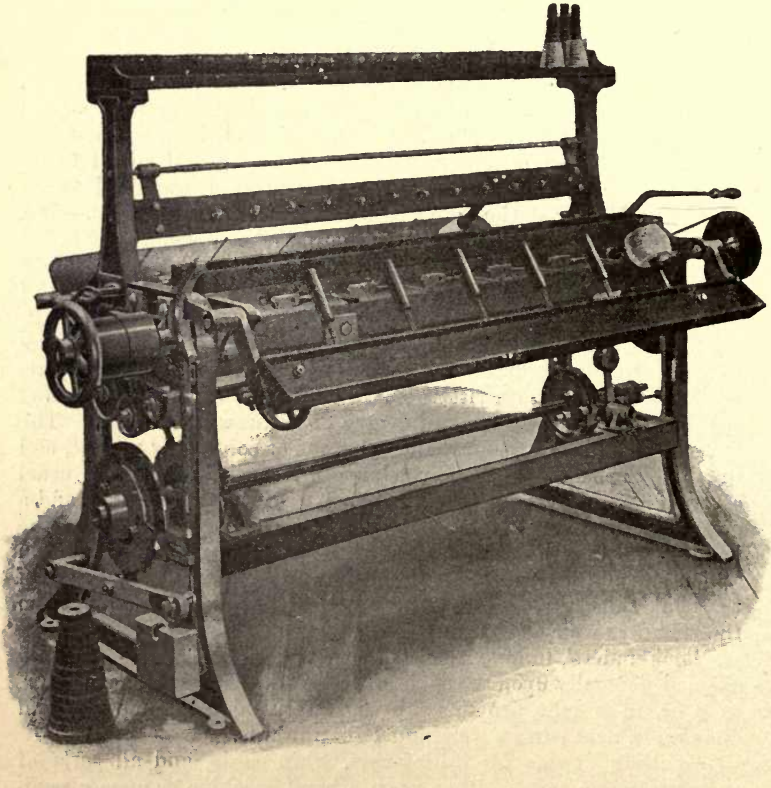


FIG. 70.—6-spindle twine baller.

As in cop-winding, the use of large conical bobbins is to be recommended, in order that the ends may unwind smoothly and quickly during the balling process. It is impossible to produce good results with a jerky and varying delivery of the twine. The balls shown in Figure 71 are wound upon the patent "lock mesh" principle. Owing to the plaiting action of the motion, the threads are locked together where the crossings occur, and the ball can be freely handled without losing its shape or becoming unravelled. The squares formed by the crossings in this mode of winding enhance the attractiveness of the material considerably.

Several makes of linen thread, intended for use upon leather sewing machines, are now made up in what the trade calls "cops," but which are in reality cross-wound cheeses built upon short paper tubes. The winding machines best adapted for this sort of work are of the Leeson's Patent type, embracing the Universal and International winding machines and the Morse machine. In the smaller makes of these machines, which are suitable for winding threads into "cops" about 2¼ inches long, the thread-guide traverse is worked by a cam. Each head stops automatically at any given size of cheese or when the end breaks or runs out. When the cheese reaches a certain diameter, the speed of the thread traverse bears such a relation to the angular velocity of the roll that the laps of thread lie closely and regularly, forming regular crossings somewhat similar to those seen in the balls in Figure 71.

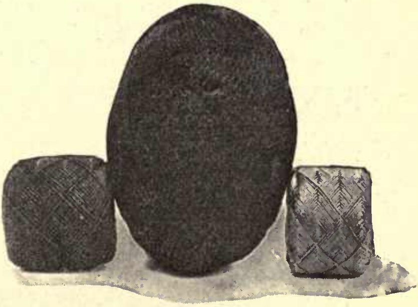


Fig. 71.—"Lock-mesh" winding.

Cords, such as clothes-lines, etc., are sometimes randed upon a machine called a randing machine. This machine comprises a framework carrying a driving shaft and gearing for driving two hooks, upon and between which the cord to be randed is lapped when at rest; also a leading screw to act as a guide in winding the end round the rand when the requisite number of laps have been put upon the hooks. The speed of the leading screw is changeable, so that the end may be closely wound, no matter what may be the thickness of the twine.

Linen sewing threads, when they are not wound into "cops" upon a machine of the Leeson type, are generally wound upon wooden spools or reels containing from 50 to 500 yards.

Modern spooling machines are quite automatic in their action.

The empty spools are supplied from a hopper, and automatically carried forward and taken up by the spindles, from which the fully wound bobbins are automatically doffed, after the ends have been cut and inserted in a nick which is cut in the spool flange at the same moment.

Figure 72 gives a general view of the latest and most improved machine of its kind, the "Baines" spooler as constructed by Messrs. Wm. Ayrton & Co., Manchester. Figure 73 is a front elevation of the same machine, showing the hopper and endless band mechanism, by means of which the empty spools are automatically supplied to the spindles and the full spools removed and deposited in a receptacle. 9D is the adjustable hopper in which a pile of empty bobbins is normally held by a spring lever 9E, until the latter is released by a tripper lever 9M operated by a rocking shaft 9U, which carries pawl levers for moving the band longitudinally. The frame carrying the

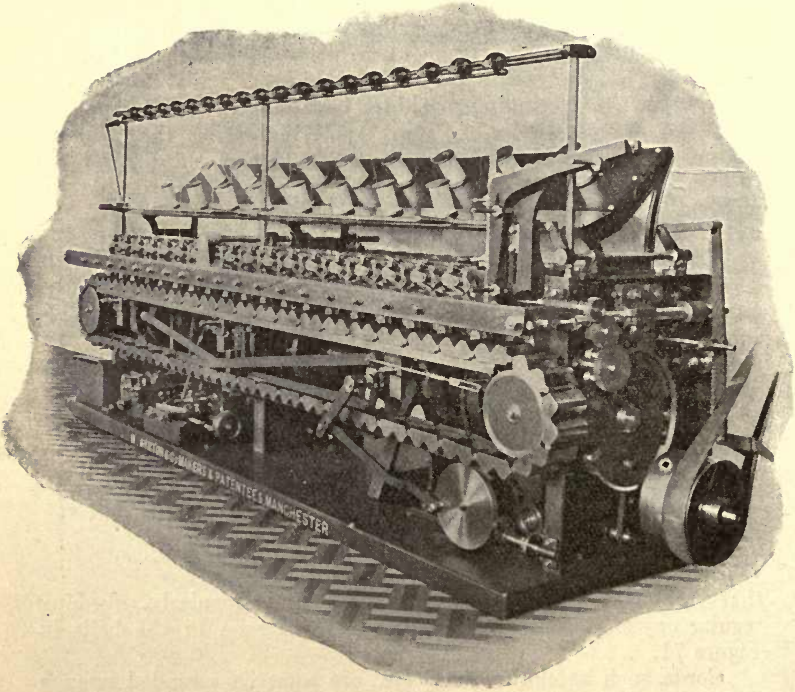


FIG. 72.—"Baines" automatic spooling machine of 18 spindles.

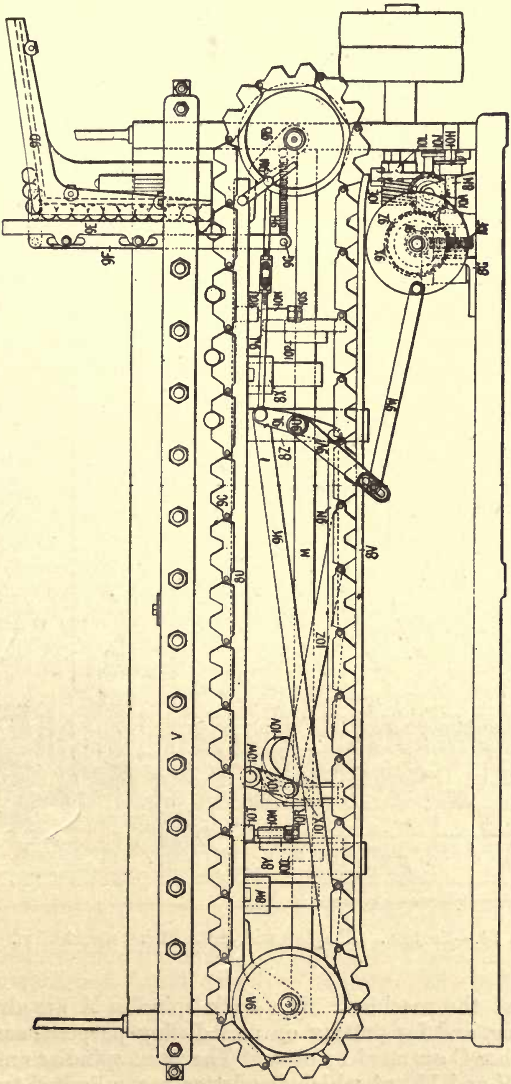

9D
9E
9F
9C
9A
9K
9M
9N
9L
8X
8Z
8U
8V
M
V
10Z
10V
10W
10T
10M
10X
8Y
8W

FIG. 73.—Baines' spooler, front elevation, hopper and endless band mechanism.

endless band is raised to the level of the spindles, and receives the full bobbins as they are pushed from the spindles. It is then lowered, and when it has reached its lowest position a cam on the cam shaft operates a lever and pawl, whereby the band is moved forward a distance equal to half the pitch of the spindles, so as to bring the empty bobbins in the notched band opposite the spindles for restarting. The band is then once more raised for the application of the empty bobbins to the spindles.

In Figure 74 A and B are the spindles between which the spools are held. These spindles or centres are arranged at right angles to the length of the machine. The back spindles A are driven by helical gearing, and for putting on and doffing purposes are carried by a sliding bar C operated by cams. The front spindles are carried by the bars V and 1L, of which the latter has a limited transverse movement with respect to the bar V. When applying empty spools to the spindles, the spools are brought into the desired position between the spindles, which advance towards one another so as to

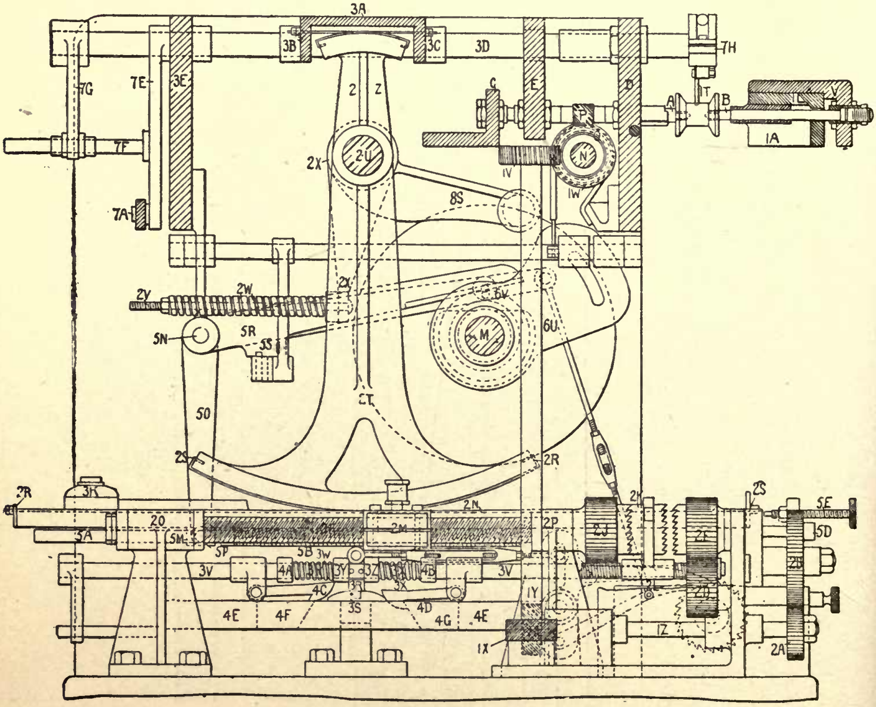

3A
3B
3C
3D
7H
7G
7E
3E
2
Z
C
E
D
A
IT
B
V
1A
7F
2X
2U
IV
N
IW
8S
7A
2X
6V
2Y
2W
5N
5R
5S
M
6U
50
CT
2S
2R
2R
3K
2N
2K
2S
5E
20
5M
2M
2P
2J
2F
5D
3A
5P
5B
3W
3V
4A
3Y
3Z
3X
4B
3V
2B
4C
3R
IY
2L
2D
4E
4F
3S
4D
4G
4E
1Z
1X
2A

FIG. 74.—Section. Shaping and guide lifting mechanism.

grip the spools between them. When doffing, the back spindles A are first withdrawn, leaving the spools supported only on the spindles B. The bar V is then moved backwards, the first effect of which is to carry with it also the doffing bar 1L, until the latter is blocked by stops, when further movement of the bar V causes the bobbins to be removed from the spindles by the bar 1L. The thread-guide shaft 3D, together with the thread guide 1T, which it carries, is given a reciprocating motion by means of a combination of quadrants 2Z and 2T, the latter being oscillated by means of the bar 2N, which is given a reciprocating motion through the split nut 2M on a traverse screw, which is alternately driven in opposite directions through spur gearing and a clutch 2K. The variable length of traverse required by the inclined sides of the spool flanges is determined by inclined plates. The guide rods 3D are gradually rotated during the winding operation so as to lift the thread guides as the bobbins fill. At the end of the winding operation the guides are lifted above the spools by reason of the bar 7A being given a sudden longitudinal movement by means of a cam, lever, and chain. The bobbins are nicked and the threads drawn into the nicks by semicircular and barbed knives. The threads are then severed by a set of knives and the spools doffed, as already described. The ends are held by hooks and springs opposite to the back spindles where they are nipped and held by the empty spools until the bobbin is started, when they are severed by cutters. An 18-spindle machine, as illustrated, will produce 100 gross of 200 yard spools per day of ten hours.

The prices of flax, hemp, and jute yarns, cords, and threads are considerably higher to-day than they have been for years. The fine end of the trade is in a very healthy state, and flax weft spinners are very prosperous. The following prices will give some idea as to the value of the various sorts of flax threads.

Flax machine thread, 6-cord cabled, from 2s. 6d. to 20s. per lb. according to colour and fineness.

Flax machine thread, 3-cord upon 500-yard reels or cops, Nos. 10's to 130's, from 12s. to 5s. per dozen reels or cops.

Flax machine thread, 3-cord upon cops, 10's to 80's, 2s. to 7s. per lb.

Waxed machine threads, 6's to 25's, 3 to 8 cord, 3s. per lb.

Flax machined thread, 6-cord, extra waxed, 25's to 100's on 3 oz. reels, from 2s. to 4s. per lb.

Brown hemp yarn for saddlers' and shoemakers' use, 5's to 17's lea, 10s. 6d. to 16s. per dozen lbs.

Patent flax yarn, grey, white, or coloured, 8's to 18's lea, for saddlers' and shoemakers' use, 16s. to 23s. per dozen lbs.

4 to 12 ply flax thread for sole sewing, 10's to 18's lea, 16s. to 28s. per dozen lbs.

Hemp netting twine, tanned, 4's to 8's lea, 3-cord, 1s. to 1s. 6d. per lb.

Flax netting twine, 10's to 20's lea, 3-cord, 1s. 9d. to 2s. 4d. per lb.

Polished fine hemp twines, 3's to 20's lea, 2 to 6 cord, in balls, 11d. to 2s. per lb.

2 and 3 ply hemp seaming twine, 8½d. per lb.

2 and 3 ply hemp shop twines, 6½ to 8½d. per lb.

CHAPTER XI

ROPE MAKING

Ropes or hawsers are usually composed of three strands, each containing from 36 to 120 ends per inch in diameter. It will be remembered that as a basis of the usual system of rope yarn numbering, the number of the yarn corresponds with the number of threads required to form a strand, which when laid with two others will form a rope 3 inches in circumference. The first operation in rope making, then, is to bring together into strands the requisite number of ends of yarn to form a rope of the required dimensions. The number of ends required depends, of course, upon the No. or coarseness of the yarn employed, and is also proportional to the square of the circumference or diameter of the rope to be made. The number of threads per strand for a 3-strand rope of any diameter may be found by squaring the circumference of the rope, multiplying by the number of the yarn which is to be used, and dividing the product thus obtained by 9 or 3^2.

In a similar manner, the number of threads per strand for a 4-strand rope of any diameter may be found by dividing the product of the square of the rope's circumference and the number of the yarn by 13·5.

Or again, if the size of a rope be measured by its diameter, the diameter being proportional to the circumference, the number of threads per strand for a 3-strand rope of any diameter may be found by dividing the product of the square of the rope's diameter and the number of the yarn by ·81 or $\cdot 9^2$, ·9 being the diameter of a rope 3 inches in circumference. The number of threads per strand for a 4-strand rope of any diameter may be found by squaring the diameter of the rope, multiplying by the number of the yarn which is to be used, and dividing the product thus obtained by 1·2. Thus the number of threads of 20's rope yarn required to form a strand for a 3-strand rope, 2 inches in diameter, will be $\frac{2^2 \times 20}{\cdot 81} = 99$ nearly; while for a 4-strand rope of the same diameter it will be only $\frac{2^2 \times 20}{1 \cdot 2} = 67$ nearly.

The correct number of ends of yarn required to form the strands having thus been found, the first operation in rope making is the twisting or forming of these ends into a strand.

Before going any farther, it must be explained that there are two ways of making ropes: the first, or old-fashioned method employed in rope walks; and the second, by the use of "house" machines in a modern rope works. In the first case, the yarn has been spun by hand in the walk or bought from a machine spinner in the form of a chain, haul, or warp of given length, and containing a given number of ends. These threads of rope yarn are stretched down the length of the walk, the correct number picked out, separated from the others, and attached to the "nibs" or twisting hooks of a "Jack twister," such as is shown in Figure 75. The other end of the strand is attached to a drag, which keeps it under constant tension, while giving way before the contraction due to twist. The

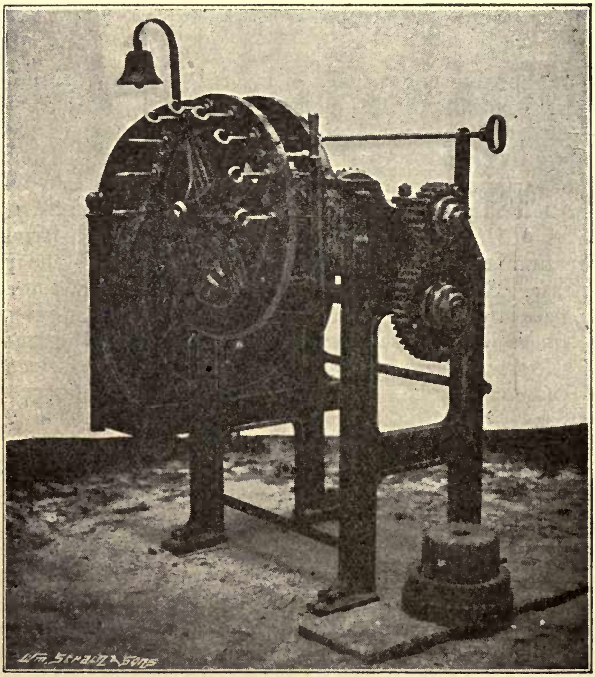


FIG. 75.—Jack twister.

number of turns per foot twist required in a strand may be found by dividing the No. of the rope yarn used by the number of threads per strand, extracting the square root of this result and multiplying by 3·75. Thus the number of turns per foot twist required for a strand containing 40 threads of No. 20's rope yarn, will be $\sqrt{\frac{20}{40}} \times 3{\cdot}75 =$ nearly 2·7. This twist must be put in in the opposite direction to that in which the yarn was spun.

In the best-equipped rope walks the rope yarns are wound from the haul, upon large bobbins placed upon the spindles of a yarn-winding machine. These bobbins when wound are then placed in a "bank," the ends drawn through a register plate, and then through a taper tube, the smaller inside diameter of which is exactly the diameter of the strand to be made. The diameter of strands may be calculated upon the basis of $\frac{1}{2}$ inch for the strand of a 3-strand rope 3 inches in circumference. The end of the strand is then attached to the hook of a forming machine or traveller, which runs on rails from one end of the walk to the other. It is made to recede from the bobbin bank and register plate by means of a ground rope, which, made fast at the ends of the walk, is coiled round a drum which in turning causes the machine to travel along the walk. The ground rope drum and twisting hooks are turned by means of an endless rope, called the "fly rope," which takes a turn round the "whelp" wheel, and, passing round pulleys at the top and bottom of the walk, acts as a driving rope, being driven by an engine. The traveller thus recedes, drawing the yarn from the bobbins and twisting the ends together into a strand. The turns per foot given to the strand depends upon the relative speed of the hooks and the backward motion of the traveller. It is regulated as desired by means of a change pinion in the line of gearing which lies between the ground rope drum and the twisting hooks.

Stranding in a modern rope works is usually done upon a house machine such as is shown in Figure 76. This machine, which occupies comparatively little space, draws the ends from the bobbins set in the bank through the register plate and compressing block or conical tube, twists and winds it upon a bobbin in a somewhat similar manner to the automatic spinner. The machine used for making strands of larger diameter is of rather different construction, but works upon the same principle. The winding-on bobbin is set in a revolving frame with its axis at right angles to the line of the advancing strand, the strand being correctly wound upon it by means of a guide, which is made to move from end to end of the bobbin by means of a block working upon a right and left handed screw. The strand is drawn forward at a regular speed by means of two drawing pulleys, around which it is lapped, and from whence it is delivered to the winding-on bobbin. The speed of this latter is regulated by means of a friction clutch, according to its effective diameter.

In the manufacture of tarred ropes the yarns are passed in the haul through a tarring machine consisting of a tar tank about 12 feet long, 18 inches wide, and 30 inches deep, and the necessary hauling mechanism. Norwegian tar, heated to 220° Fahr. by means of copper steam coils, is usually employed, and enables the cordage to resist the weather. The yarn will take up about 25 per cent. of its weight in tar. While leaving the tank the yarn is pressed by a nipping arrangement, which squeezes out the surplus tar, and is then allowed to remain for a few hours, so that the tar may sink in and dry before being wound upon bobbins in the winding machine.

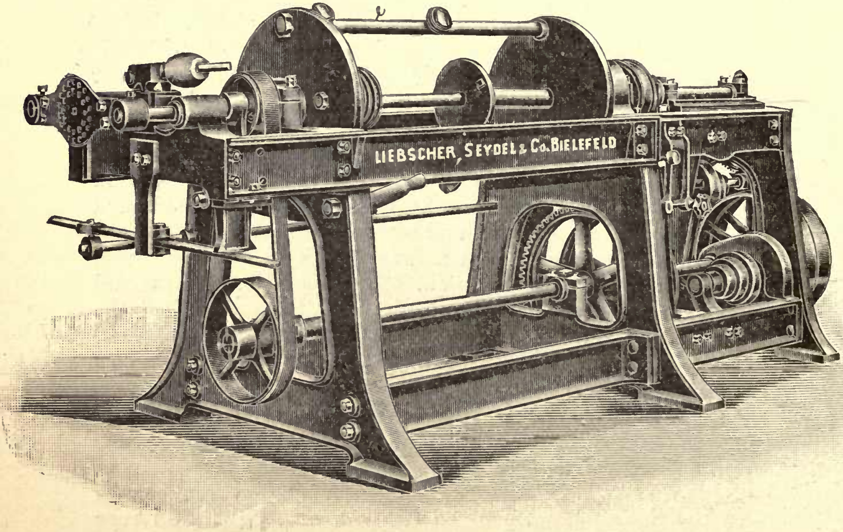


Fig. 76.—Stranding or register machine.

In stranding tarred yarn, and in closing the strands into a rope, the compressor tubes are set in a steam chest heated by gas to a temperature sufficient to soften the tar and produce a smooth and close lying strand.

In the rope walk the strands are closed into a rope by means of two machines, a "foreturn" machine and a "traveller." The strands which are to be closed together are each attached to one of the hooks of the "foreturn" machine, which is fixed at the end of the walk. The other ends of the strands are united together and attached to the central hook or forelock of the traveller, the strands being supported and kept off the ground and separate by means of posts, crossbars, and pegs. The forehard machine puts extra twist into the strands, while the traveller twists them together in the opposite direction. A taper piece of wood, with three longitudinal grooves to carry the strands, is supported upon a top-cart and inserted between the strands close to the traveller, small end foremost. The top is held by a piece of rope attached to the handle or top-stick, which passes through it, and coiled round the rope already twisted. It acts as a drag, and only allows the top to be forced backwards very regularly and slowly, causing the strands to be laid close

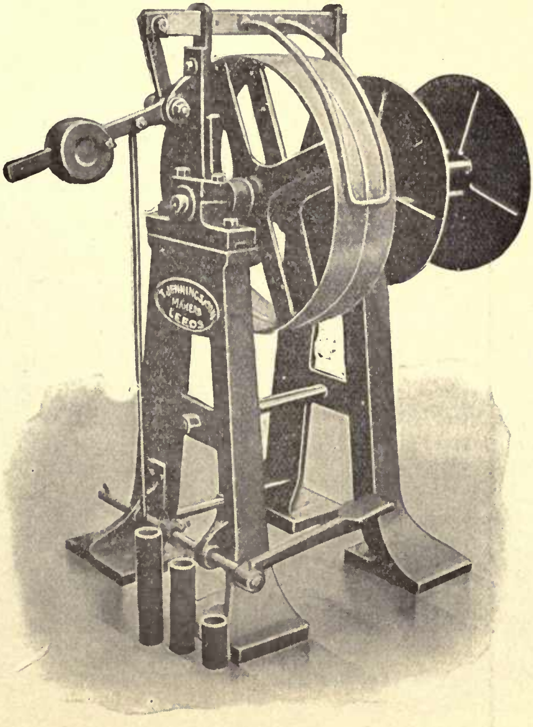


Fig. 77.

together. The contraction by twist in closing the strands amounts to about 30 per cent. of the length of the strands. As the rope shortens, the traveller is drawn up the walk, its motion being retarded and the rope kept under tension by means of a brake, or by means of weights placed upon the framing of the machine.

In the machine rope works the strands from the register or stranding machine are put into a laying or closing machine, which in one operation puts additional twist into the strands, closes the strands into a rope, which it draws through the machine by means of draw-drums, and automatically winds upon a bobbin. A horizontal laying or closing machine of this sort is similar in principle to the trawl twine layer shown in Figure 65, but is much heavier. Three or four spools of strand, for 3 or 4 strand rope respectively, are placed in the revolving spool frames and the ends drawn through

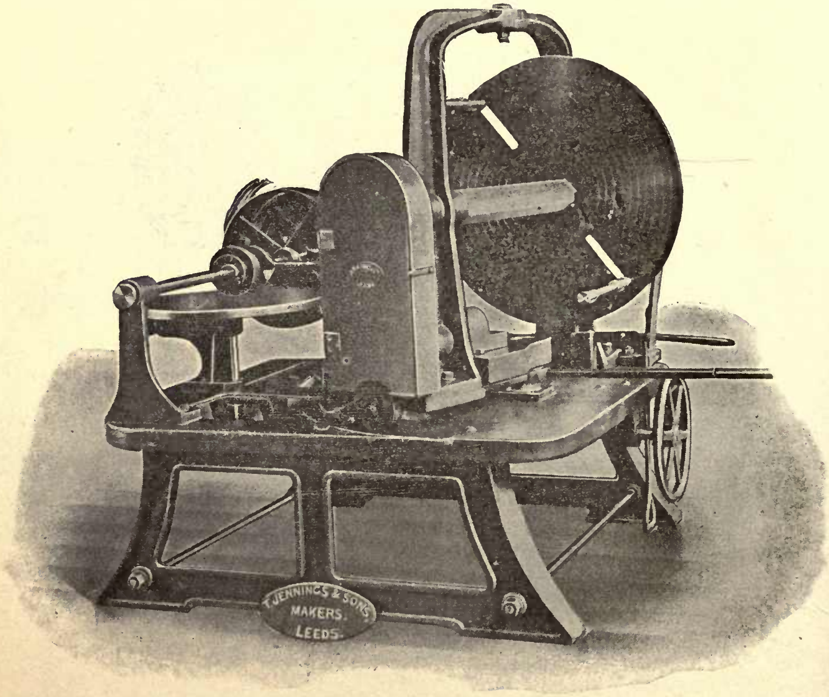


FIG. 78.

the hollow bearings, and then together through a compressor to the draw-drums, which revolve with the rope drum frame and twist the strands into a rope, which is delivered through the hollow bearings and automatically wound upon a drum. Friction brakes applied to the flanges of the strand spools ensure a regular tension upon the strands. In some machines of this sort a draw-off gear is fitted to the strand bobbin flyers to ensure perfect equality in the lengths of the strands.

In closing the strands into a rope, they are twisted together in the reverse direction to that in which they were stranded. The spool frames are turned in the opposite direction to the rope reel frame, and at such a speed that not only is the original twist of the strands maintained, but a slight additional twist or forehard is given to make the strands lie well together.

For the larger sizes of ropes, vertical closing machines are usually employed, as it is easier to get the large strand bobbins into them. The number of turns per foot twist required to close strands into a firm rope is inversely proportioned to the diameter or circumference of the rope. It may conveniently be calculated on the basis of eight turns per foot for a rope 2 inches in diameter.

Compound rope machines are now much used. These machines combine the stranding of the yarn with the closing of the strands into rope. The bobbins full of yarn are placed in sets upon skewers in wrought-iron flyers, which revolve upon their own axes in order to make the strands. At the same time the three or four flyers revolve round a common centre, in order to close the strands into a rope, which is drawn through and wound up as in the ordinary closing machine.

Vertical machines are more convenient for a large number of threads. Compound vertical machines are constructed to deal with as many as 160 ends, turning them into four strands of 40 threads each, which it lays into a 4-strand rope.

A cable is formed by twisting together three ordinary 3-strand ropes, the twist being of course put in in the opposite direction to that in which the ropes were twisted.

European hemp makes the strongest ropes, those produced from the best Russian hemp having a breaking strain of about 1700 lbs. per square inch of section. The average breaking strain of Manila rope is about 1400 lbs. per square inch.

Tarring the yarn lessens the strength of a rope.

The size of cordage is sometimes indicated by the weight in lbs. of 200 fathoms, or by the length in feet of 1 lb. A Manila rope, $1\frac{3}{4}$ inches in circumference and $\frac{9}{16}$ inch in diameter, may weigh 130 lbs. per 200 fathoms, and measure 9 feet per lb.

The following table gives the number of yarns per strand, and the weight of 200 fathoms of various sizes of rope:

Circumference of Rope in Inches.	Ends of Yarn per Strand.						Weight per 200 Fathoms.	Feet per lb.
	12's.	18's.	20's.	25's.	30's.	40's.		
							lbs.	
¾	...	...	...	...	...	...	25	48
1	...	...	...	...	...	4	44	27
1¼	...	...	...	4	5	7	69	17
1½	..	...	5	6	7	10	94	13
1¾	...	6	7	9	10	14	131	9
2	5	8	9	11	13	18	175	7
2¼	7	10	11	14	17	22	219	5½
2½	8	12	14	17	21	28	269	4½
2¾	10	15	17	21	25	34	325	3¾
3	12	18	20	25	30	40	394	3
3½	16	24	27	34	...	...	525	2¼
4	21	32	35	...	...	...	687	1¾
4½	27	40	...	...	...	...	872	1⅓
5	33	...	...	...	...	...	1075	1⅛
5½	40	...	...	...	...	...	1300	12/13

The weight in lbs. of 200 fathoms or 400 yards of any other sized rope may be found by squaring the circumference of the rope and multiplying by 44. The weights of ropes are to one another as the squares of their diameters.

The number of threads per strand for a 3-strand cable, which consists of three 3-strand ropes laid together, may be found by squaring the diameter of the cable, multiplying by the number of the yarn, and dividing by 3¼. For a 4-strand cable proceed in the same way, but use the number 4⅓ instead of 3¼.

The length of each thread required to make the strands of a 3-strand hawser laid rope may be calculated by multiplying the length of rope required by 1·5. For a 4-strand hawser, multiply the length of the rope by 1·6.

To find the length of each thread of rope yarn required to make a *cable*, multiply the length of the cable to be produced by 1·7 for a 3-strand cable, and by 1·75 for a 4-strand cable.

In 4-strand ropes and cables the strands in being laid together leave the centre of the rope or cable hollow. This hollow centre is, however, usually filled in by a thread of tow yarn, which is run in while the strands are being closed together.

The length of core or heart yarn required is from 1¼ times the length of the rope for a 4-strand hawser to 1⅕ times the length of the cable for a 4-strand cable.

The length of each thread of yarn required for bolt rope is $1\frac{2}{5}$ths the length of the rope to be made.

The diameter of each strand of a 3-strand rope is half that of the rope itself. The diameter of each strand of a 4-strand rope is but $\frac{2}{5}$ths of that of the rope itself.

The diameter of the "lessom" or primary strand of a 3-strand cable is $\frac{1}{4}$th of that of the cable itself, and of a 4-strand cable, $\frac{2}{9}$ths of that of the cable.

The length of rope required to make a 3-strand cable will be found to be about $\frac{1}{9}$th more than the length of the cable to be made. To make a 4-strand cable, the ropes which form that cable will be $\frac{1}{4}$ longer than the cable to be made.

The tubes employed in forming the strands of a rope should be a tight fit for the strand, so as to give it smoothness. Their smallest inside diameter should therefore be less than the diameter of the strand, as found above.

It will thus be seen that the contraction by twist when laying and closing strands into 3-strand rope amounts to about 33 per cent. In laying and closing strands into 4-strand rope the contraction by twist amounts to about $37\frac{1}{2}$ per cent. on the length of the yarn.

Stretching decreases the diameter of a cable inversely as the square root of the relative lengths before and after stretching. For instance, if a 2-inch rope, 100 feet long, be stretched until it is 144 feet long, it will come to be only 1·7 inches in diameter.

Ropes are generally made up for the market in coils or balls. Large-sized ropes must be coiled upon a rope reel such as is shown in Figure 77. Ropes of small diameter are balled upon a machine of similar construction to that shown in Figure 78, the principle of its working being similar to that of the balling machines already described.

CHAPTER XII

THE MECHANICAL DEPARTMENT

Steam is the usual motive power employed in mills and rope works. When water power is available, however, it is generally utilised either alone or in conjunction with steam power. When a water fall of from 3 feet and upwards exists or can be created, it should be utilised as a source of power, as each horse-power taken from the load of the engine means a reduction of the coal bill. It is also convenient, in the case of a break down, for instance, or upon a holiday, to have an auxiliary motor to drive the mechanic shop.

Water wheels of the old type are altogether out of date. They are too cumbersome, too heavy, and too slow in their movements. The most perfect are inefficient, and a well-constructed turbine is without question the best means of using water power under ordinary circumstances. Whether the fall be high or low, a turbine gives a very much greater percentage of power from any quantity of water than do under-shot or breast wheels of the best construction, for a good turbine will give back in work from 75 to 83 per cent. of the energy applied to it.

Turbines may be divided into two classes, viz. those in which there is, and those in which there is not, a pressure in the clearance space between the guide blades and the wheel. The former are called "Pressure" or "Re-action" turbines; and the latter, turbines of "Free Deviation" or "Impulse" turbines. Generally speaking, for falls from 100 feet to 200 feet, a double or twin turbine of the "Pressure" class, with horizontal shaft, is to be recommended. For low falls of from 3 to 15 feet, a single pressure turbine with vertical shaft is advisable; while for falls above 100 feet, impulse turbines with horizontal shaft will give good results.

As a good example of the pressure or re-action turbine, we illustrate the double Vortex turbine as made by Messrs. Gilbert Gilkes & Co. Ld. of Kendal. The principle of this turbine, and the way in which the water is applied to it, will be easily understood by reference to Figures 79 to 83.

Figure 79 shows the internal arrangement of the Vortex. The water enters the outside casing at the top—or in any other position that may be convenient—and passing thence is directed by four (or more) guide blades on to the outer circumference of the revolving wheel, which is driven round at a velocity depending on the height of the fall. The water having expended its energy in giving motion to the wheel, is discharged through the two central openings, half the amount being carried away by each suction pipe. The guide blades, it will be noticed, are movable, and turn about on a pivot placed near their inner ends. The method in which these guides are simultaneously regulated will be seen by reference to Figure 80, which is an outside view of the same turbine. The Vortex turbine runs very steadily and regularly in consequence of the action of the

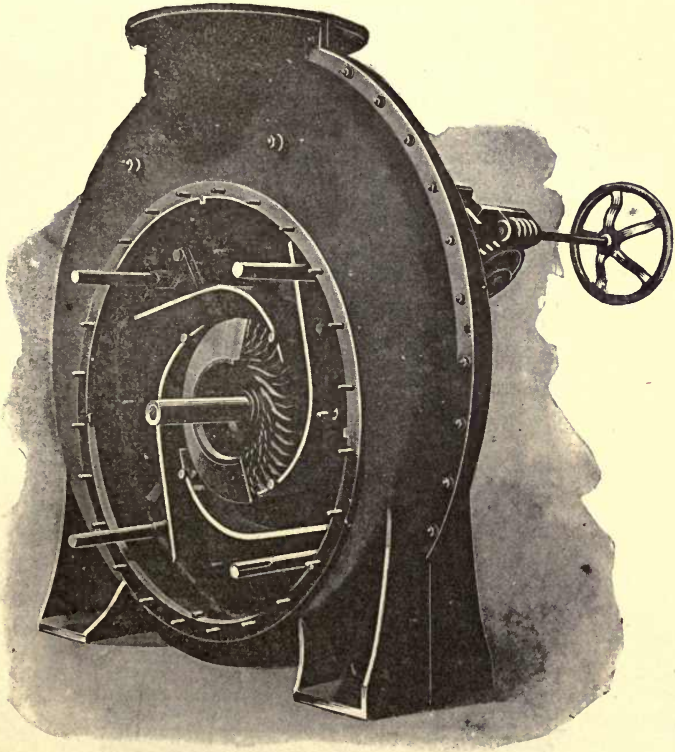


FIG. 79.—Internal arrangement of the Vortex turbine.

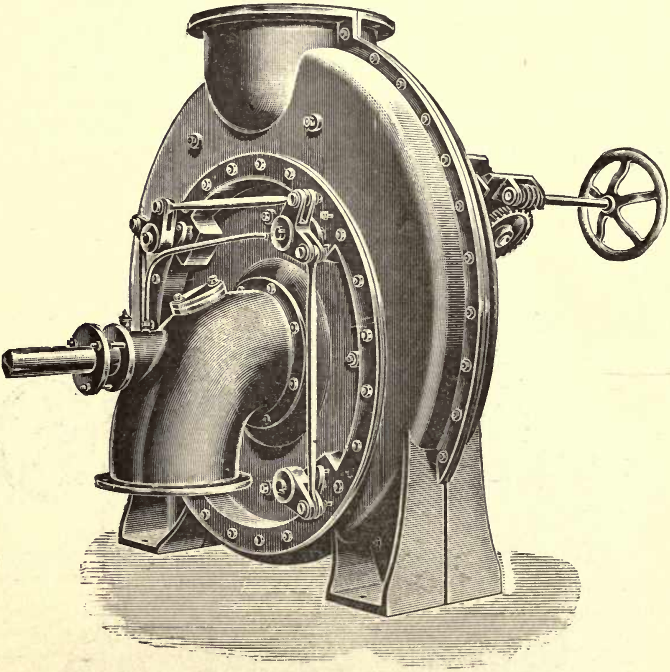


FIG. 80.

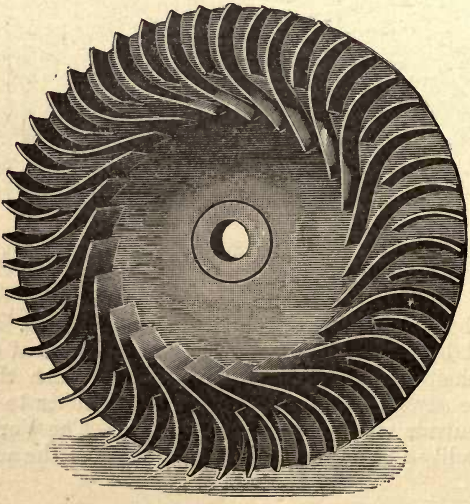


FIG. 81.—Vortex wheel and vanes.

centrifugal force of the water, which, on any increase in the velocity of the revolving wheel, increases, and so checks the supply entering from the guide passages; and on any diminution of the velocity of the wheel, diminishes and admits water more freely; thus counteracting in degree the irregularities of speed arising from variations in the load.

Figure 81 is taken from a photograph of a Vortex wheel, with the cover removed to illustrate the form of the vanes. Some of these do not extend to the central orifice, the object in so making them is that they may not too much fill up the contracted part of the passages, and thus impede the flow of the water. The vanes are of steel, and fixed on each side of a steel plate, which has a boss in the centre to secure it upon the shaft. There are two outer discs or covers in which circular openings are left, through which the

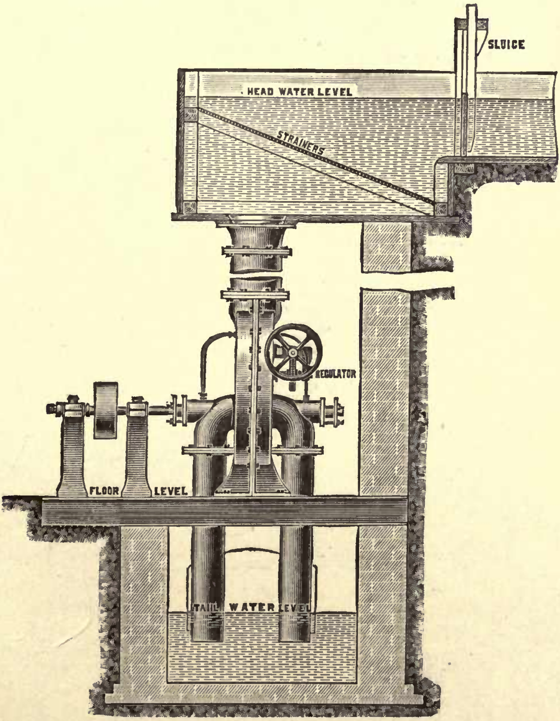


Fig. 82.—Arrangement of a water turbine.

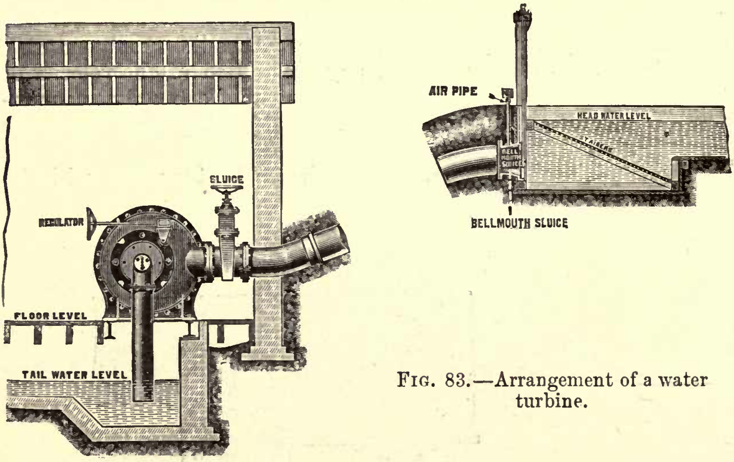

AIR PIPE
HEAD WATER LEVEL
STRAINERS
BELL MOUTH SLUICE
BELLMOUTH SLUICE
SLUICE
REGULATOR
FLOOR LEVEL
TAIL WATER LEVEL

Fig. 83.—Arrangement of a water turbine.

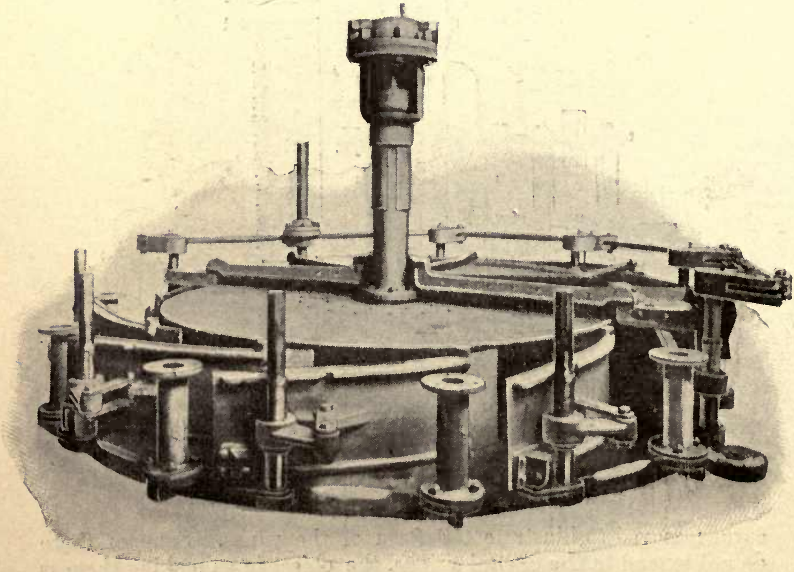


Fig. 84.

water passes after it has done its work, one-half of the water being discharged on each side of the wheel.

Figures 82 and 83 show how the turbine may be applied, and

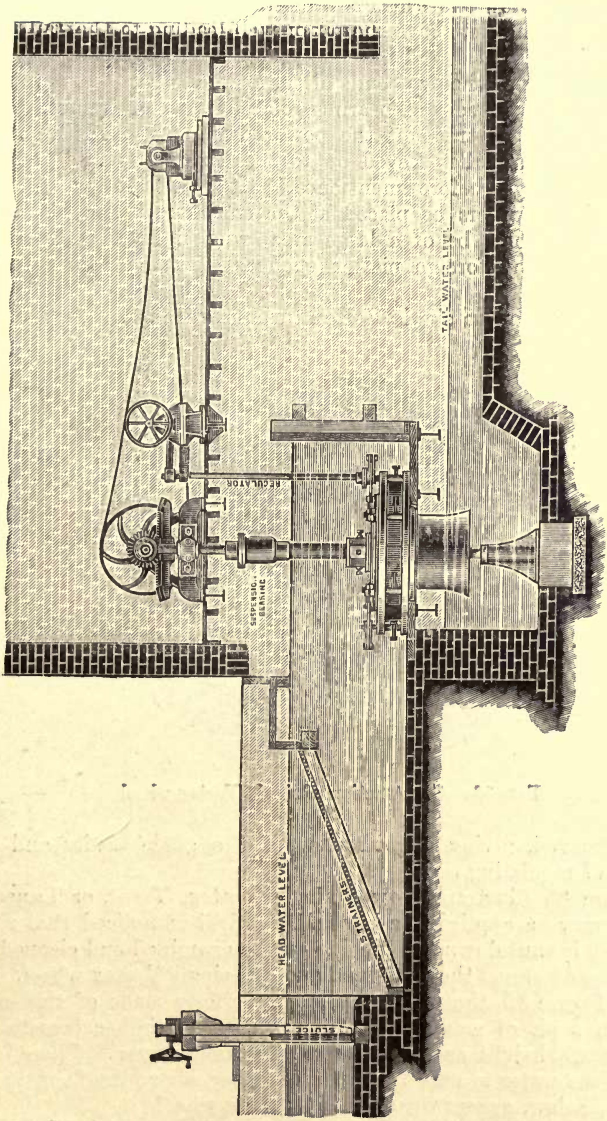

TAIL WATER LEVEL
REGULATOR
SUSPENSION BEARING
HEAD WATER LEVEL
STRAINERS
SLUICE

FIG. 85.

practically explain themselves. The water, on leaving the wheel, passes through two pipes into the tail race, and by suction in these pipes, the fall below the wheel is utilised. The turbine stands upon the floor of the house, above the pit or well leading to the tail race. The shaft is horizontal, and passes through two stuffing boxes placed one on each side of the two bends of the suction pipes. It is further supported by two pedestal bearings placed upon A frames. It is generally possible to transmit the power directly upwards by means of a belt from a pulley keyed on to the turbine spindle between the two bearings before mentioned. It is absolutely essential that suitable strainers be placed at the entrance to the pipes, and that these strainers be of a large area, with holes of such a size as to prevent any foreign matter (such as sticks and stones) from entering.

Figure 84 shows a single Vortex turbine wheel, with part of the cover removed, giving a good view of the guide blades and the method of regulating them.

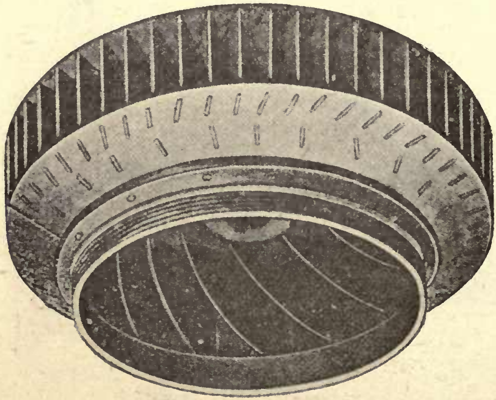


Fig. 86.—Construction of single Vortex wheel.

Figure 85 illustrates how a single Vortex, Trent, or Lunedale turbine may be applied to a low fall. It will be noticed that when the sluice is shut down the turbine can be examined and cleaned.

Figure 86 shows the construction of the single Vortex wheel. As seen in Figure 85, the wheel is placed on a floor made of timber or metal, in a pit of masonry or brickwork. The timber breasting is of the same height as the sides of the water-course. There is no way for the water to pass from the chamber, above the floor, to the tail race, below, except through the turbine wheel.

An installation of the Lunedale turbine is illustrated in Figure 87. This turbine is of the mixed Radial and axial flow type. The water is directed on the outside of the wheel by fixed guide-blades.

A ring sluice, between the guide chamber and the wheel, which is raised or lowered by the gearing shown in the illustration, is used for regulating the quantity of water.

The power which may be derived from a fall of water depends upon the number of cubic feet of water utilised per minute, the head, height of fall, or difference in level of head water and tail water, together with the efficiency of the water engine used. The efficiency of the turbines which have just been illustrated may be taken at 75 per cent. The weight of a cubic foot of water is 62·5 lbs. A horse-power is equivalent to 33,000 foot pounds, *i.e.* 33,000 lbs. falling through a distance of 1 foot, 330 lbs. through 100 feet, etc.

Thus a Vortex turbine passing 1765 cubic feet of water per minute in a 40-foot fall can develop $\frac{1765 \times 62{\cdot}5 \times 40 \times 75}{33{,}000 \times 100} = 100$ H.P., and will make 220 revolutions per minute. A single Vortex turbine on a low fall of only 6 feet, and passing 11,766 cubic feet of water per minute, will likewise develop $\frac{11{,}766 \times 62{\cdot}5 \times 6 \times 75}{33{,}000 \times 100}$ $= 100$ H.P., and make 26 revolutions per minute.

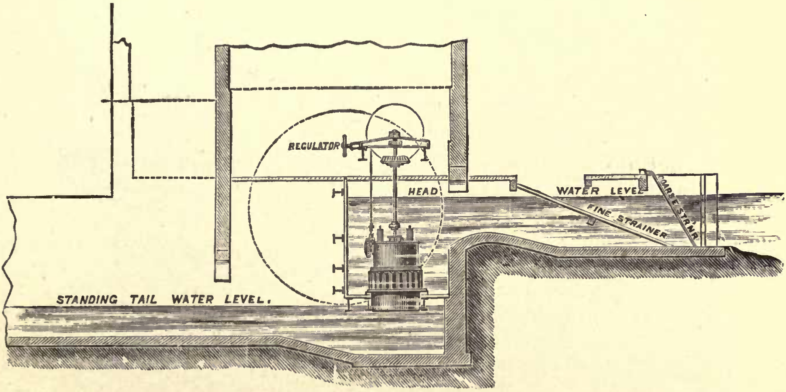


Fig. 87.—An installation of the Lunedale turbine.

A Trent turbine with a 44-inch wheel will pass 3530 cubic feet of water per minute upon a 20-foot fall and develop $\frac{3530 \times 62{\cdot}5 \times 20 \times 75}{33{,}000 \times 100} = 100$ H.P., while making 124 revolutions per minute.

In a similar manner a Lunedale turbine with a 36-inch wheel will develop 100 H.P. on a fall of 16 feet when passing 4433 cubic feet of water and turning at a speed of 129 revolutions per minute.

Falling water is the cheapest motive power. In years gone by mills were built in those localities where such power was available, generally in the country. As the steam engine became more perfect and economical, mills and factories became located in the towns, where labour was more plentiful and where there were greater facilities for the transport of goods and raw material. Nowadays, with the advent of electric transport of force, there is no reason why the natural force of our waterfalls should not be yoked, and the power developed transmitted in the form of electric energy to far distant cities. This is already being done in America, and might with advantage be attempted in this country.

The quantity of water, in cubic feet per minute, flowing down a stream may be approximately ascertained in the following manner. Choose a part of the stream where the section is fairly regular. Mark off a convenient distance, say 30 yards, along the bank. Then throw a float into the centre of the stream and note how long it takes to traverse the distance set off. Repeat the experiment several times in order to obtain a good average. The speed thus obtained is that of the surface at the centre of the stream where the water moves faster than elsewhere. How much faster it moves there depends upon the nature of the channel. If it be a rough mountain stream, 36 per cent. must be deducted from the speed obtained in the centre of the channel. If it be a brick channel, take off 17 per cent.; and if a wooden trough with smooth sides, 15 per cent. The average depth and width of the stream must next be

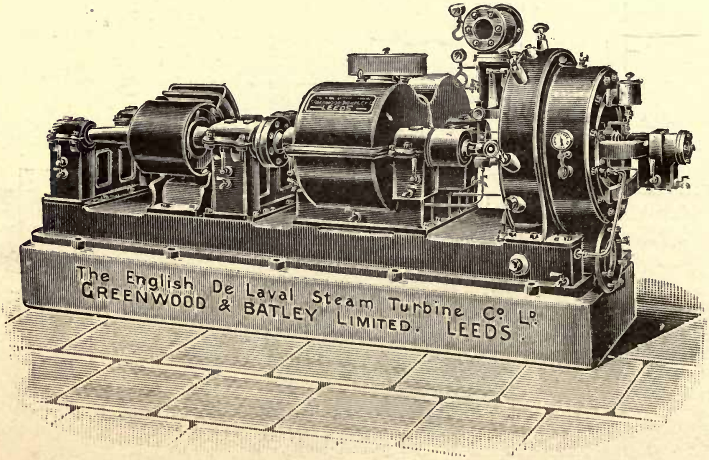

LEEDS
The English De Laval Steam Turbine Co. Ld.
GREENWOOD & BATLEY LIMITED. LEEDS.

FIG. 88.

ascertained by careful measurements, and the area of the section calculated in square feet. The product of the section of the stream in square feet and the velocity of the stream in feet per minute will give the number of cubic feet of water available per minute as a source of power. Suppose that the average depth of the stream be 6 inches, or ·5 feet, while its width is 30 feet and average velocity 100 feet per minute—$\cdot 5 \times 30 \times 100 = 1500$ cubic feet of water per minute are available for developing power with the aid of a fall and suitable turbine.

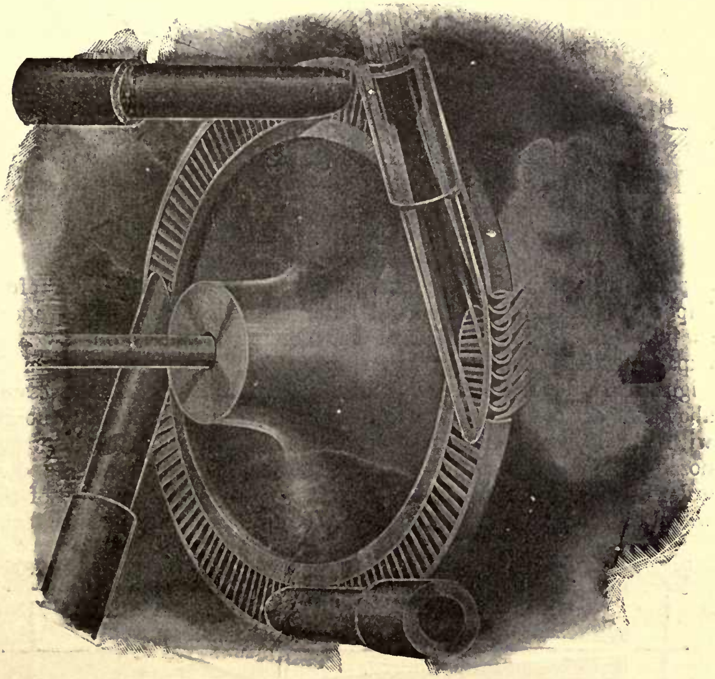


FIG. 89.

Analogous to the water turbine is the steam turbine, which has already been adopted in more than one spinning mill. The author has had considerable experience of the De Laval steam turbine in the driving of a flax spinning mill. This turbine, as made by Messrs. Greenwood & Batley of Leeds, is constructed upon the "Impulse" principle. Figure 88 gives a general view of the machine in question, and Figures 89, 90, and 91 illustrate the internal organs.

As seen in Figure 89 the steam is blown from stationary nozzles against the vanes of a revolving wheel. The steam passes through the vanes, delivering most of its energy to the wheel, and is afterwards exhausted into an ejector condenser. The working of the machine depends upon the kinetic energy of the steam. It is therefore important that the steam should enter the wheel at as high a speed as possible. A high speed of the driving steam is obtained by expanding the admission steam in conical nozzles, as shown in Figures 90 and 91. Steam expanded in a nozzle from 280 lbs. pressure above the atmosphere down to 28 inches vacuum, leaves the nozzle with a velocity of 4229 feet per second. The angle between the nozzles and the plane of rotation of the wheel is 20 degrees, and in order to obtain the maximum efficiency the peripheral speed of the wheel or vanes should be 47 per cent. of the velocity of the steam.

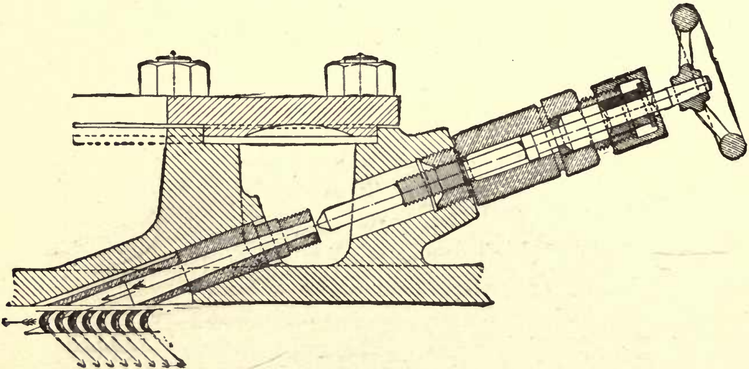


Fig. 90.

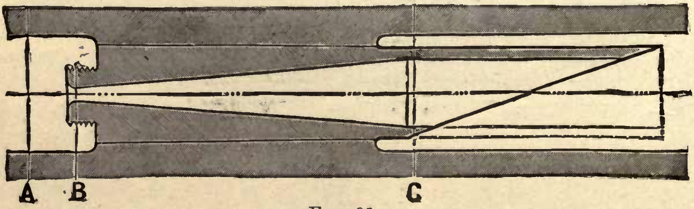


Fig. 91.

The nozzles are placed very close up to the vanes of the wheel, there being a clearance of only $\frac{1}{16}$ inch. The wheel is made as a solid disc, on the circumference of which the vanes are dovetailed in. The wheel is mounted upon a flexible shaft, the bearings upon each side of the wheel being at some distance from it, so that the wheel may swing a little in its plane of rotation. The diameter of this flexible shaft is, on account of the high speed, very small, the shaft of a 300 H.P. turbine being only $1\frac{5}{16}$ inches in diameter. The normal speed of the turbine wheel is too high for the direct driving of spinning machinery, and must therefore be reduced by means of gearing. This gearing is made upon the double helical system. The driving pinion upon the end of the flexible shaft is made of hard steel, and the teeth of the driven wheels of rather softer material. These driven wheels are mounted upon short shafts which carry the belt or rope pulleys. The bearings of the slow speed shafts are lubricated by rings, and those of the flexible shaft by sight feed lubricators. The turbines have a series of nozzles, which are arranged at intervals in a ring, close to the wheel, and receive the steam from a steam chest in the turbine case. Each nozzle is provided with a shutting-off valve, as seen in Figure 90, so that it may be closed or opened at any time. Before the steam enters the steam chest and passes to the nozzles, it is regulated by the governor-valve, which is in turn controlled by the centrifugal governor of the machine, shown in Figure 92. The governor-valve is a balanced, double-seated valve, connected with a link motion to the centrifugal governor, which is mounted horizontally on the end of the gear wheel shaft.

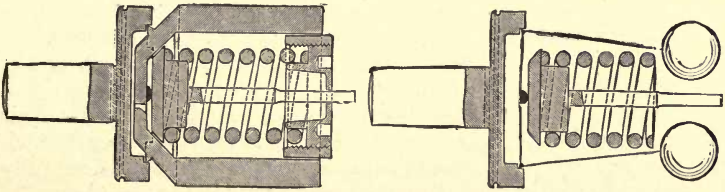


FIG. 92.—The centrifugal governor of the turbine.

Figure 92 shows the form of the centrifugal governor used. The De Laval steam turbine will work with any steam pressure between 50 and 200 lbs. per square inch, and either with or without vacuum. The shape of the nozzles, however, must be arranged to suit the admission pressure and the pressure in the exhaust. It is convenient to have a certain number of nozzles for running with condensation and others for use when the steam is exhausted into the atmosphere. When the turbine is running light some of the nozzles may be closed, and others opened as the load increases or the vacuum or steam-pressure falls.

A cheap and simple condensing arrangement for use with the steam turbine is arranged on the "Ejector" system, with which no air pump is required. To work it, a head of water at least

20 feet above the floor of the engine-room must be provided. A centrifugal pump is thus often required to raise the water into a suitable reservoir, from which it descends, and passing through a jet arrangement, is broken up as it meets the steam from the exhaust and condenses it. The condensing water falls downwards into a tank in which the tail pipe is submerged, and a vacuum is thus formed, which materially increases the efficiency of the machine.

A form of condenser which is used in at least one flax-spinning mill is the aero-condenser. In this condenser the exhaust steam passes into a series of pipes around which cold air is circulated and drawn by a powerful fan. The steam in the pipes is thus condensed and a vacuum produced, while the heated air is utilised for drying and ventilating. Any sort of condenser may, however, be used with steam turbines such as those of the Jet and Surface types, which may in some cases be best suited to local conditions.

The steam turbine must be kept thoroughly lubricated by a constant supply of a rather light mineral oil. Vegetable and animal oils must upon no account be used, as they are oxidised and carbonised by the heat. Upon the De Laval turbine an oil tank placed above the machine supplies oil to all the bearings. A good vacuum depends to some extent upon the lubrication of the white metal bush which forms the bearing upon the geared end of the wheel spindle, for if the clearance space be not filled with oil, air will be drawn in and the vacuum spoiled. The oil which runs through the bearings collects in reservoirs placed underneath, and if carefully filtered and of good quality may be used again more than once.

The form of boiler most suitable for a wet spinning mill is one having a considerable steam reservoir. The Lancashire, Cornish, and French type of boiler have a good steam space, especially if provided with domes, and are to be recommended where a supply of steam is required at night for drying, etc.

In dry spinning mills, jute mills, and rope works, a water-tube boiler, such as the Babcock & Wilcox or the Belleville boiler, may be used, as steam may be got up very quickly. If the boiler feed water be very hard, a water-softening plant, upon Clarke's principle, should be adopted. In the best modern plants of this sort the doses of lime water and soda are automatically measured and regulated, and the degree of hardness, as indicated by the standard soap solution, reduced to a minimum.

If a steam engine be preferred to a steam turbine to furnish the motive power, it should be of the compound or triple-expansion condensing type. Both the horizontal and vertical inverted cylinder engine give good results. If the horizontal type be adopted, the tail-end of the low-pressure cylinder piston rod should pass through a stuffing box and gland in the cylinder end, thus supporting the weight of the heavy piston and preventing the cylinder from wearing oval. Piston valves of the Sultzer type are taking the place of the Corliss valve in many instances.

There are four ways of transmitting the power developed by the engine, steam or water turbine, that is to say, in the form of an electric current or by means of belts, ropes, or gearing. Electrical transmission of power is convenient, but not very economical for short distances and for constant driving. It is the only practical method, however, of transmitting force over long distances, say from a big waterfall to a mill in a neighbouring town. When it is adopted, the power generated by the motor is turned into electric energy by means of a dynamo coupled either directly to the engine or turbine, or driven from it by means of ropes or belts. The electric current generated may be conveyed to any distance through copper wires. The larger the section of the conducting wire, the purer the copper, and the higher the voltage or pressure of the current, the less loss there is by friction through the conductor. The main outward flow and return wires are connected up, through a rheostat or resistance frame, with one main electric motor or with a series of smaller motors, which put the shafting or individual machines in motion. Electric motors are in reality dynamos, the bobbins of which, when correctly connected up and put in the circuit, commence to revolve. The motors may be directly coupled up with the shafting or with the machines to be driven, thus dispensing entirely or in part with belts, ropes, or gearing.

Gearing, as a means of transmitting power from the flywheel of the engine to the second motion shaft, and from thence to the line shafting, has almost entirely disappeared, on account of the noise and vibration, and the liability to accidents and breakdowns owing to the sudden breaking of teeth in the said gearing.

Power is now generally transmitted from the engine to the shafting of the mill by means of ropes of either cotton or Manila, or by means of belts of leather or of woven cotton or hair. Leather belts are now built up to transmit any power, and belts 6 feet in breadth and of great length are constantly in use at the present day. The average breaking strain per square inch of ordinary leather belting is 5000 lbs. and the percentage of stretch 25. The power which a belt will transmit depends upon several factors, *i.e.* (1) the width of the belt, (2) its thickness, (3) diameter and construction of the smallest pulley (bare metal or wood), and (4) the velocity of the belt in feet per minute. A single leather belt 1 inch wide should not slip upon an 18-inch C.I. pulley when transmitting 1 H.P. at a velocity of 2400 feet per minute, nor upon a 24-inch C.I. or WI. pulley at a speed of 1600 feet per minute, nor upon a 36-inch pulley at a speed of 1066 feet per minute, and at the usual tension. The power which a belt will transmit without slipping, then, depends upon the area which is in contact with the pulley and upon the speed of the belt. If the pulleys are so large that there is no danger of slippage, the force which the belt will transmit depends upon its sectional area and its speed. Force is usually measured in horse-power. One horse-power = 33,000 foot lbs., or the moving of 33,000 lbs. through 1 foot per minute, or 33 lbs. through 1000 feet per minute. The greater the speed of the belt, then, the smaller the strain upon it in transmitting a given force. The strain upon the belt is that due to the force transmitted plus the tension necessary to make the belt adhere to the pulley. The pull necessary to put a small machine in motion may be determined by the aid of a spring balance and a cord attached to and passing round the pulley. This pull in lbs., multiplied by the velocity of the belt in feet per minute, and divided by 33,000, gives the horse-power required to drive the machine.

In belt driving, the force transmitted depends upon the difference in tension between the two sides of the belt and upon its surface speed. If T = the working tension upon the tight side of the belt in lbs., t = the tension of the slack side in lbs., and V = the velocity of the belt in feet per minute, then the force transmitted $= \frac{V\,(T - t)}{33{,}000 \times 2}$. The usual working tension of a single belt is about 110 lbs. per inch in width, and the tension when at rest about 20 lbs. per inch in width. Hence at a velocity of 3500 feet per minute a single leather belt 1 inch wide will transmit $\frac{3500\,(110 - 20)}{33{,}000 \times 2} = 4{\cdot}77$ H.P., if the smallest pulley be of sufficient diameter to give the necessary gripping surface. Upon this basis the width W of single leather belting required to transmit any given number of H.P. at any given speed, may be determined from the equation $W = \frac{3500 \times \text{H.P.}}{4{\cdot}77\ V}$.

If a main driving or countershaft belt be found to be of insufficient width to transmit the required force, its driving power may be almost doubled by "compounding" or placing another belt of equal width on the top of it. Each belt takes its own drive from the engine to the shaft or from one shaft to the other, and increases the driving power by nearly 100 per cent. Upon a single flywheel you can put say six driving belts, and let each driving belt drive a different shaft, with practically the same result as if you had a flywheel of six times the width.

Personally, the author prefers the use of ropes to belts for main driving. Although, if carefully looked after and repaired in time, a belt seldom breaks down, yet, should such a breakdown occur, it involves a stoppage of at least one department for probably an hour at least. Ropes, besides requiring less width of face on the pulleys to transmit a given power, should never break without warning, any more than should a belt, and, working with others upon the same drive, may be cut down individually when they begin to unravel, and replaced after a stoppage, the work meanwhile being carried on with the remaining ropes. Every rope race should be fitted with electric alarm signals placed close to the running ropes, and rung by the passing of a hanging and untwisted strand.

Driving ropes are now made either of Manila, aloe fibre, or of cotton. Cotton ropes bend more easily round the pulleys, in the grooves of which they have a better grip than ropes of hard fibre. The sides of these grooves are usually inclined to each other at an angle of about 45 degrees, so that the rope may wedge itself and its driving power be thereby increased. There is a difference of opinion among driving rope makers themselves, and amongst rope users, as to whether the rope should turn upon its axis or not. The author's experience is that a Manila rope should, and that a cotton rope should not, turn in its groove while working.

At a speed of 4500 feet per minute, which is a good average velocity when transmitting power from the flywheel of an engine, a good 3-strand cotton driving rope $1\frac{3}{4}$ inch in diameter, will transmit 45 H.P., if the diameter of the smallest pulley be not less than 30 times the diameter of the rope. Other diameters of ropes will transmit forces proportional to the squares of their diameters. The force which may be transmitted is also directly proportional to the velocity of the rope in feet per minute, but should never exceed 4800 feet per minute. The rope is made endless by means of a splice, the length of which should not be less than 72 times the diameter of the rope in length, and very carefully made, so that the correct diameter of the rope is preserved.

As regards the diameter of the shafting required to transmit a given power, it may be taken that a line shaft 3 inches in diameter will transmit 45 H.P. when running at 150 revolutions per minute. The power transmitted by shafting varies directly as its velocity and as the cube of its diameter. When shafting is merely used to transmit power, the distance, apart of the bearings, may be obtained from the formula $L = 5\sqrt[3]{d^2}$, where $L =$ the length in feet between the supports and d the diameter of the shaft in inches. If the shaft carries pulleys, the formula $L = 4{\cdot}8\sqrt[3]{d^2}$ should be used.

Lighting by electricity is now almost universal in modern mills, although recent improvements in gas lighting, such as pressure gas and anti-vibration mantles for incandescent gas light, may bring gas into favour again.

Electric arc-lamps produce the cheapest light, as they consume less current per candle-power than do glow or incandescent lamps. They may be advantageously used in machine hackling rooms, preparing rooms, or shed rope works where a good general light is required. When a more concentrated and localised light is needed, as upon the rollers, thread plate, and bobbins of a spinning frame, incandescent lamps are to be preferred, as they may be hung, say three in the alley, at a height of about 4 feet from the ground, so as to throw their light exactly where it is required. One of the great objections to the arc light is the deep shadows which it throws. The inverted arc light does away with this objection, as the light is thrown upwards by a reflector placed underneath, and is diffused and radiated from a white ceiling.

Dynamos and motors are now usually constructed with two or more electro-magnets giving four or more poles and sets of brushes. The larger the number of segments in the collector or commutator, and the larger its diameter, the better. It should be of bronze, with a good deal of copper in its composition. Most modern dynamos and motors have now carbon brushes, which are both durable and easy on the collector. The pressure or voltage of the current produced depends upon the speed of the dynamos. The quantity of current or ampères which it will furnish without heating depends upon its construction and the diameter of wire with which it is wound. In inverse fashion, the speed of a receiver or motor depends upon the voltage of the current with which it is supplied and the power which it can supply, upon the ampères of current which it receives and can utilise without heating. The product of the volts and ampères are watts, and 746 watts = 1 electrical H.P.

The most economical glow lamps are those of least resistance, which, however, have usually the shortest life. Lamps, however, are so cheap now that a long life is not of the same importance in a lamp as it used to be.

Passing now to the question of fans for ventilation, for induced and force draught, and for drying. Fans may be divided into three classes, *i.e.* radical flow, mixed flow, and axial flow, or screw and propeller fans. In radical flow fans, the air passes through the wheel in a plane perpendicular to the axis of the fan. In mixed flow fans, the inflow is axial, and the direction is gradually changed in the wheel to a radical one. In screw and propeller fans, the direction of flow is axial.

The simplest form of fan is the propeller type, to which belong all fans on the Blackman model. It is a very good fan to use in buildings where a large volume of air is required at a very low pressure. The efficiency of this type of fan is greatest with free discharge, and falls off rapidly if a discharge pipe of any length is used. Hence this type of fan is not the one to use to force or draw air through ducts or suction pipes.

The Rateau fan, which is almost unknown in this country, is the best example of the mixed flow type.

All centrifugal fans belong to the radical flow type, the best known being the Sirocco, the Farcot, the Sturtevant, and other American blowing fans. These fans give excellent results when used to force air through ducts for ventilating, or in drawing air through flues, as when, upon the induced draught system, they are used to replace or supplement a stack or chimney, or to draw away the dust and waste from underneath a series of cards. It must be noted, however, that the Sirocco fan must be modified as to the number and pitch of its blades, before it will efficiently pass short waste fibre.

Lubrication of machinery is the application of oil or grease between two surfaces which rub together, with the object of diminishing friction and wear and tear. The lubricant should form a cushion or film between the surfaces and keep them out of contact. If the surfaces are pressed together with considerable force, the lubricant must be sufficiently viscous or thick to remain between them, since a light oil would be squeezed out. A constant and copious flow of light oil will, however, lubricate even the heaviest bearings and diminish the driving power required by a heavier oil. The use of greases, solidified oils, etc., although apparently economical, and actually so as far as the oil bill is concerned, are in reality most uneconomical, since they necessitate the burning of more coal to produce the power lost in friction, not perhaps between the bearing surfaces, but in the lubricant itself.

A constant and copious flow of light oil is then the cheapest means of lubricating, since the oil may be filtered and used over and over again with a small addition of fresh oil. On page 127 we explained how spindle necks may be constantly supplied with oil, also how the roller journals may be continuously lubricated. Modern bearings or pedestals for shafting are now made in such a way that the brass is supported over a reservoir of oil, which is carried up on to the bearing by chains or rings which lie upon it, surround it and the brass, and dip into the oil in the reservoir, and by their revolution carry up the oil; or, the brass bearing, supported over an oil reservoir, may be divided into two, and the space between the two halves occupied by a collar fast upon the shaft, and dipping under the surface of the oil in the reservoir. In revolving, the collar carries with it a quantity of oil, which is scraped off by a scraper fixed in the pedestal cap, and dispersed on both sides over the bearing. The oil should be periodically drained from the reservoir of such bearings and replaced by fresh oil; the dirty oil, after being filtered, may be used over again by admixture in small proportions with fresh oil.

By ingenious arrangements, all the revolving and reciprocating parts of the steam engine may be lubricated from sight feed lubricators and a constant supply of oil assured. The cylinder oil may be forced in small quantities into the cylinder at each stroke of the engine, or injected into the steam pipe by a small pump actuated by a connecting rod from any reciprocating part. It is preferable that the cylinder oil should be forced into the steam pipe, as it is thus broken up and intimately mixed with the steam, which carries it into the cylinder and spreads it over the cylinder sides, piston rod, etc. Cylinder oil should be of pure mineral origin, since animal and vegetable oils carbonise at comparatively low temperatures. The best cylinder oil should not volatilise even under the high temperature of superheated steam.

Mineral oil or oleonaphthe, which is the cheapest lubricant and quite suitable for even the heaviest bearings if copiously and constantly supplied, is produced by distillation by heat or under the vacuum process from the crude mineral oils of Russia and America. In the distilling process the light volatile products used as lighting oils first pass off, after which, by a more perfect vacuum or at a higher temperature, the lubricating mineral oils are collected, leaving as a residue those heavy oils which are serviceable for the lubrication of steam cylinders. Russian oils have a blue shade in them, while American oils are possessed of a corresponding green shade.

Every flax, hemp, and jute spinning mill and rope works should have a well-equipped mechanic shop, in order that all repairs may be done upon the premises. A small steam or gas engine should be at hand to drive the shafting when the mill engine is stopped. The tools which will be found most necessary comprise a vertical drilling machine, a shaping machine with quick return motion, a sliding and screw-cutting lath with 40-inch centre, chucks, face-plate, etc., and with a 20-foot bed for turning up roving frame rollers, etc. It is also advisable to have a smaller lathe, say 10-inch centre and 8-foot bed, for smaller work, a wheel-cutting machine, and a fluting machine for the brass-spinning frame rollers.

The repairs required to be done may be divided up into those to the engine and gearing, and those to the small machinery. Those to the engine comprise the replacement of any part which becomes unduly worn, such as the studs of the link or cut-off motion and of the speed governor; the tightening up and eventual renewel of the cross head and crank pin brasses, so that there may never be a "knock" in the engine; the periodical examination and replacement of the piston rings.

Boilers may be run for three months without cleaning if purified and softened feed water be used. When stopping for cleaning, the water should be allowed to stand for a few days when possible, so that it may cool down before being run off, as in this way any mud left in the boiler will settle in the form of soft sludge, and be carried off by the water instead of hardening upon the plates in a hard scale. If any scale be found upon the plates it must be chipped off by the blows of a hammer, for, being a non-conductor, its presence brings about a great waste in coal, and is a positive danger, as it is a frequent cause of sinking of the furnace crowns, and even of explosions. At the time of cleaning, all the fittings should be carefully looked to. All cocks and valves should be ground in their seats, the joints should be renewed, and the high and low water indicators and whistles examined. When the repairs and cleaning have been accomplished, and the boiler refilled with water, the temperature should be raised very gradually, so that the boiler may not be strained by undue forcing.

A staff of hackle setters should be employed to keep all the hackles and gills in good order, and to make new ones when the old are worn out. The number of men required depends upon the size and coarseness of the place. Coarse hackles and gills last longer, and are more easily repaired than are fine ones. The cards should be regularly gone over every week-end, and the pins straightened and replaced when necessary. At least one wood-turner will be required, to turn and slide preparing-room and dry-spinning frame rollers.

In wet spinning mills at least one fluter must be employed, to keep up and flute the spinning frame rollers. One or two mechanics should devote themselves to the preparing room, and two more to the spinning room. The work of the former lies chiefly in keeping up the tappets, slides, and faller ends of the screw gill frames. The work is constant if the fallers are run quickly, as they now often are.

The spinning-room mechanics' work consists in keeping the frames properly lined up and the spindles running without vibration. In a 10,000 spindle mill one frame should be always under repair, as profitable spinning depends largely upon turn-off, and frames in bad order cannot be driven up to a good speed without making excessive waste. When the roller bushes wear, the roller is pushed backwards, increasing the bearing upon the thread plate and the strain upon the yarn, as will be seen by reference to Figure 52. The thread plate eyes cut in time, and must be rimmed out and eventually replaced. Vibration and dancing of the spindle, due to wear in the neck, collar, foot, and footstep, cause breakages of the yarn, and consequent waste. When the collars wear, they must be replaced or rimmed out, and employed for another set of spindles with heavier necks. When collars are replaced, the new ones should be a tight fit for the spindle necks, and should be rimmed out when in place in the neck rail. The same remark applies to the footsteps, which should be rimmed out to the correct diameter and depth, when in place with a long rimer, which should be passed through the collar in order to insure that the spindle is perfectly vertical. If the depth of the footstep be not correct, the spindle will either have too much play room and bounce, or else it will be held too tightly between the step rail and the collar which bears against the neck-collar.

The tin cylinder should be taken out whenever repairs are undertaken, and its seats or bearings lined up, since they, especially the centre bearings, are very apt to wear through lack of oil, it being difficult to get at them for oiling purposes. Even when oil tubes are provided, projecting through the creel board, they are apt to get displaced, and to empty their oil upon the floor.

The spindle tops should be regularly oiled to minimise wear. New flyers should be ordered from the makers of the spindles, so that there may be no difference whatever between the threading of spindle and flyer. Undue wear of the spindle tops may generally be traced to this cause, if the spindle tops are properly tempered and not too soft.

If the drawing roller is made of good close-grained and compressed brass of uniform texture, it should run for seven years without refluting, especially if warp numbers be kept upon the newer frames.

CHAPTER XIII

MILL CONSTRUCTION

Almost all modern jute mills and rope works are built upon the shed principle, with very often no partition between the departments, the object being to minimise labour, and to permit of the raw material coming in at one end, passing through, and going out as a finished product at the other end. The disadvantages of the shed system are—(1) the excessive ground space taken up (an important item if the ground is valuable or ground rent high), and (2) the difficulty in keeping sheds cool in summer and of heating them in winter, to which may be added difficulties due to roof condensation, especially if artificial humidification is employed. Unequal degrees of temperature and humidity affect the spinning of fine flax yarns to such an extent, that flax wet spinning mills are nearly always built in a three or four storied block: the ground floor being usually occupied by the carding and tow preparing rooms, the first floor by the line preparing room, the second and third floors by spinning rooms, and the top floor by the reeling room. The drying loft is usually over the boilers, and the hackling department and tow stores in a different building.

The engine-house should project from the main building at one end, so as to give depth to the rope race, and a more satisfactory drive if the sag of the ropes is upon the upper side, as it should be.

Shed roofs are made upon the saw-tooth principle, running north and south, the steep or glazed side facing the east, so as to catch the first rays of morning light.

The best roof for a fire-proof building of several storeys is flat, with a parapet forming a reservoir. The bottom of the reservoir may be of armoured concrete, or of I-girders held together by tie-rods and filled in with concrete. If any depth of water is to be stored upon the roof, this reservoir must be cemented inside; but if it is merely intended to hold a few inches of rain-water, a covering of asphalted and sanded paper over the concrete will be sufficient.

A fire-proof building of this sort must be very solidly constructed, both on account of the weight of the roof and by reason of the weight of flax-spinning machinery. The foundations must be sunk until a good firm bottom is found, the usual depth being about 8 feet. The width of the foundation at the bottom may be 5 feet, and 27 inches at the ground level. The piers between the windows may have a section of 23 square feet, or be 6 feet 4 inches × 3 feet 8 inches. The width of the bays should be 9 feet for wet spinning. Modern mills are being built wider than formerly, to accommodate longer frames, and may be from 57 feet to 70 feet wide, to suit two rows of 23 feet to 30 feet frames, and leave a 6-foot passage down the middle. The columns must be set out of the centre line, so that the passage be not obstructed. In a mill 57 feet wide, the girders may be 28 feet long on one side and 32 feet upon the other, resting at one end upon the columns, and at the other end upon stones, 18 inches × 18 inches × 6 inches, set in the piers. Girders of I-section, with web 23 inches in depth, and flanges 10 inches wide, should be used for the first floor. Girders 23 inches × 8 inches will do for the second floor, and so on in proportion. The cast-iron columns which support the first floor may be 9 inches in diameter, and should rest upon blocks of stone, 2 feet cube, placed upon a brick foundation 2 feet high, resting in turn upon a bed of concrete 12 inches thick. A piece of sheet lead should be placed between the round plate forming the column base and the stone. The length of the columns should be from 12 to 13 feet, giving a like height from beam to floor. The width of the piers and the thickness of the wall may diminish in proportion to the height above the ground, but should never be less than $\frac{1}{20}$th of the height above them, so that windows 5 feet 4 inches wide may be available to give good light between the spinning frames. The height of the windows is usually about 10 feet. In cold countries the windows should be double, with a space between the two, in order that the rooms may maintain their temperature.

Bricks and mortar of good quality must be employed in the construction of the walls, which should be capable of carrying a load of at least 10 tons per square foot of section. A good mortar may consist of $\frac{1}{3}$ Portland cement and $\frac{2}{3}$ sand. The concrete for insertion between the girders may be composed of $\frac{1}{3}$ broken brick, $\frac{1}{3}$ coarse cinders, and $\frac{1}{3}$ cement.

If the induced draft system be not adopted for the boilers, a chimney must be provided of sufficient height and section to produce the necessary draft for the battery of boilers. A chimney 170 feet high, 12 feet inside diameter at the base and 9 feet inside diameter at the top, will be found to give sufficient draught for a battery of boilers supplying engines of 1000 H.P. Such a chimney should be built upon a bed of concrete 30 feet square and 3 feet thick, with I-beams $6\frac{1}{2}$ inches by $2\frac{1}{2}$ inches section embedded in the centre at 3 foot pitch, and bolted together with tie-rods. The outside diameter of this chimney at the base may be 18 feet.

The author prefers a round chimney, as better resisting the weather. He likes the German principle of using specially constructed bricks, which when placed together, with an allowance made for a close joint of mortar, form the peripheries of circles whose diameters correspond with those found in every section of the chimney. The exterior batter should be about 4 per cent., or $\frac{1}{2}$ inch per foot. The main flue leading to such a chimney may be semicircular in section, and have a radius of 4 feet 8 inches, or a section of 34 square feet.

During cold weather the workrooms of the mill are usually heated by steam pipes. The older system of heating with low-pressure steam is being abandoned in favour of high-pressure steam, which is more economical, in that all the water of condensation may be returned to the boiler. In the low-pressure system, reducing valves and steam traps are usually required, and often give trouble, while the heating power of the pipe varies with its distance from the boiler.

In a high-pressure heating installation a circuit is made, and all water may be run into the boiler again through a return valve, if there be a fall all the way and a difference in level of not less than 4 feet. If the drying cylinders of thread and twine polishing machines be connected up in this way, a considerable saving will be effected. Heating, when required, may be combined with the plenum system of ventilation by passing the incoming air through a series of coiled steam pipes, through an aerocondenser, or through pipes traversing the boiler flues.

The floors of the mill may be tiled with cream-coloured tiles or cemented. Asphalte floors are not to be advocated, since heavy machinery is liable to sink into it, especially in hot weather, necessitating frequent lining up if the frame is to be run with the minimum power.

The wet spinning room floor should be waterproof, and sloped in such a way that the water may run off. The feet of the frames should rest upon a flat row of tiles, but the space under the frames should be raised or barrelled, as should also be the passes, so that the water may run off. The latter must not be too much barrelled, or the hands will slip and fall; but the space underneath the frames should be well raised, so that bobbins, etc., may not lodge there. The junction of the rows of tiles upon which the feet of the frames rest, and the slope of the spinner's pass, form a small channel, which carries off the water to either side of the room into the main channel along the wall, this main channel emptying itself into down pipes, into which any waste is prevented from entering by means of grates.

Since a fall of at least $\frac{1}{2}$ inch per yard is required from the centre line of the room to the wall at either side, and since the frames must be "packed" up quite level, hardwood blocks of oak or pitch-pine of varying thicknesses are placed under the feet of the frame.

The following details as to the floor space occupied by various machines will be useful in deciding upon the dimensions of a new mill. The width of a mill containing a spinning room should be based upon the length of the frames to be used, and placed in two parallel lines, the frames lying at right angles to the central passage, about 6 feet wide.

A jute softener occupies floor space equal to	28 ft. × 5 ft.
A jute opener ,, ,, ,,	9 ft. × 6 ft.
A breaker card ,, ,, ,,	14 ft. 6 in. × 9 ft.
A jute finisher card ,, ,, ,,	10 ft. × 8 ft.
The usual 2-headed 1st drawing for jute	7 ft. × 6 ft. 6 in.
The usual 2-headed 2nd ,, ,,	9 ft. × 6 ft.
A jute roving frame (56 spindles)	23 ft. × 4 ft.
Dry spinning frame (144 spindles, 4-in. pitch)	27 ft. × 7 ft.
Jute cop winder (108 spindles)	20 ft. × 5 ft.
Jute warp winder	23 ft. × 5 ft.
Double jute reel	13 ft. × 5 ft.
Warping mills, 10 to 12 feet diameter.	
A tow drawing frame, 6 heads, 6 rows, 2½-in. gill, occupies	18 ft. × 5 ft.
A tow drawing frame, 7 ,, 8 ,, 2⅜ ,, ,,	25 ft. × 5 ft.
A tow drawing frame, 8 ,, 8 ,, 2⅛ ,, ,,	26 ft. × 5 ft.
A tow drawing frame, 9 ,, 8 ,, 1½ ,, ,,	25 ft. × 5 ft.
A tow roving frame, 12 heads, 10 rows, 1⅛-in. gill, 8 × 4 bobbin, occupies 40 ft. × 5 ft.	
Flax hackling machines, 18 tools, 10-in. holders, occupy	18 ft. × 6 ft.
Flax wet spinning frame, 2-in. pitch, 300 spindles, occupies 27 ft. 6 in. × 6 ft. 6 in.	
Flax wet spinning frame, 2½-in. pitch, 300 spindles, occupies 30 ft. 6 in. × 6 ft. 6 in.	
Good's combined hackler and spreader for Manila, occupies	24 ft. × 7 ft.
,, ,, ,, drawing ,, ,,	21 ft. × 8 ft.
,, automatic spinner occupies	13 ft. 6 in. × 3 ft. 6 in.
24-thread, 3-strand rope making machine (horizontal) occupies 14 ft. 6 in. × 5 ft.	
6-thread, 3-strand rope making machine (horizontal) occupies 11 ft. 6 in. × 3 ft. 6 in.	
6-ply cord laying machine occupies	13 ft. × 3 ft. 6 in.
A 4-ply cord laying machine occupies	10 ft. × 3 ft. 6 in.
A horizontal strand former, ¼-in. machine occupies	9 ft. × 3 ft.
A 2-spindle horizontal layer, ¼-in. machine, occupies	15 ft. × 10 ft.
A 45's thread horizontal rope machine ,,	22 ft. × 6 ft.
A 160's thread vertical rope machine ,,	18 ft. × 15 ft.
A 12-spindle Baines' automatic spooling machine occupies	9 ft. × 4 ft.
An 18-spindle ,, ,, ,,	12 ft. × 4 ft.
A 12-spindle semi-automatic balling machine occupies	7 ft. × 4 ft.
A 50-end bobbin polishing machine for threads ,,	4 ft. × 4 ft.

A coarse flax mill requires about 50 hands per 1000 spindles. The cost of the actual labour varies from 9d. to 11d. per bundle of yarn produced. To arrive at the actual cost of producing a bundle of yarn, about 6d. must be added to the cost of labour, to cover rent and taxes, mill furnishings, coal, insurance, salaries, interest and discount, commissions, etc.

The profits on spinning vary from zero to £2 per spindle per annum, according to the management, the condition of the plant, and the state of the trade.

The cost of equipping a medium flax spinning mill with machinery may be roughly taken at £3 per spindle.

INDEX

Abaca, 1.
Agave fibre, 2.
Aloe fibre, 2.
American hemp, 9.
Angle of beam, 123.
  ,, of rollers, 123.
Arrangement of preparing machinery, 83, 84.
Artificial humidification, 82.
Atmosphere of spinning room, 122.
Austrian schock, 143.
  ,, yarn table, 143.
Automatic bobbin dragging motion, 90.
  ,, card feeder, 44.
  ,, spinner, 89.
  ,, stop reel, 132.
  ,, ,, motions in preparing, 71.

Baines' spooler, 161.
Balling, 158, 159.
  ,, binder twine, 137.
  ,, shoemakers' hemp, 137.
Band-tyer's knot, 126.
Base marks of Russian flax, 10.
Batching jute, 16, 17.
Belgian paquet, 143.
  ,, scutching system, 8.
Bell motion for spreader, 57.
  ,, ,, for reel, 133.
Belt driving, 188.
Bergmann spindle, 112, 113.
Binder twine, 93.
Black threads, 127.
Blake thread, 146.
Bobbin winding, 97.
Bookbinders' thread, 157.
Bow-string hemp, 2.
Braidwater lapper, 45.
Breaker finisher card, 43.
Breaking strain of ropes, 171.
Brooks and Doxey's differential motion, 97.
Brush and doffer hackling machine, 29.
Builder motion, 102.
  ,, pinion, 103.
Bulking, 67–70.
Bunching yarn, 139–141.
Bundling press, 140.

Cable laid ropes, 171.
Cabled thread, 147.
Cabling, 147, 171.
Cannabis sativa, 1.
Capstan wharves, 126.
Card clothing, 37, 42, 45, 46.
  ,, setting, 40.
  ,, staves, 55.
Carding, 38.
Carpet thread, 157.
Carter's automatic bobbin dragging motion, 90, 91.
Catch bar and dogs, 27.
Centrifugal fans, 190.
Chain drawing frame, 61, 62.
Changers, 28.
Changing index and builder's pinions, 103, 104.
  ,, twist, 88.
Channel, 26.
Cheese winding, 135.
Choke, 63.
Circular gill drawing frame, 61.
Classification of Manila fibre, 9.
Cleaning Manila hemp, 9.
  ,, New Zealand hemp, 8.
  ,, pita, 9.
Clock system, 57, 67, 68.
Closing strands, 171.
Cold water spinning, 122.

Combined hackler and spreader, 50.
Combing machine, 69.
Comparative flax, hemp, and tow prices, 12, 13.
Compound leverage, 55, 56.
  ,, rope machines, 171.
  ,, systems, 70.
Condenser, 92.
Conductors, 55.
Cones, 101.
Contraction by twist, 86.
Co-operative retting, 5.
Cop winding, 134, 135.
"Cops," 134, 135, 159.
  ,, wet spun on paper tubes, 129.
Cost of equipping a mill, 199.
  ,, of roughing, 21.
  ,, of production, 199.
Cotton's end comb, 33.
Courtrai botte and sack, 11.
Cross reeled yarn, 131.
Crossed threads, 131.
Crown wheel, 97.
Cultivation of flax, hemp, jute, agave, New Zealand hemp, and sisal, 2, 3.
Cyclone separator, 47.
Cylinder of card, 83.

Daisee jute, 12.
Damping roller, 106.
Dead rubbers, 56.
Delette comb, 68.
Demi-sec spinning, 106.
Devil card, 38.
Dew retting, 4.
Diameter of shafting, 189.
Differential motion, 97, 98, 99.
Dimensions of machines, 198.
Disc cam, 61.
  ,, and scroll, 100.
Doffers, 38.
Dollop, 68.
Dossche's brush and doffer machine, 29.
Dorset numbers, 144.
Double back shafts, 63.
Doublers, 58, 65.
Doubling, 60.
Draft, constant number, 116.
  ,, of card, 49.
  ,, of push bar drawing, 72.
  ,, of spread board, 56.
  ,, of wet spinning frames, 125, 126.
Drafting, 60.
Dragging bobbins, 90, 91.
Drawing head for card, 71.
Drieband flaxes, 11.
Drive for reels, 134.
Driving ropes, 187, 189.
Drosophore humidifier, 83.
Drum winding, 135.
Dry spinning, 106–114.
  ,, ,, frame, 106, 107, 114.
  ,, twisting, 145.
Drying loft, 138.
Duplex hackling machine, 26.
Dust removal, 35, 36, 82.
Dutch stuiver, 11.
Dynamo, 190.

Electric light, 189.
English yarn table, 143.
Erskine's ender, 33.
Eves' antifriction washers and nuts, 24.
Expansion pulley, 100.

Faller tappets, 53.
Fallers, 53.
Fancy threads, 151.
Fans, 190.
Faults in reeling, 131.
Feed roller and shell feed, 38.
Fibre extraction, 6.
  ,, extractor, 9.
  ,, store, 16.
Filler, 24.
Finisher card, 43.
Fireproof mills, 195, 196.
Fish-tailed flyer, 106.
Flax and hemp breaking, 6.
  ,, cultivation in America, 4.
  ,, cutter, 19.
  ,, exports, 14, 15.
  ,, hackling machine, 23.
  ,, hemp, and jute dust, 35.
  ,, line store, 34, 35.
  ,, New Zealand, 2.
  ,, numbers, 34.
  ,, roughing, 21.
  ,, spinning centres, 13.
Flemish crown, 11.
  ,, stone, 12.
  ,, stuiver, 12.
Floor space, 198.
Floors, 197.
Fluting, 193.
Flyer twisting frame, 146.
French hemps, 10.
  ,, import duty on foreign yarns, 144.
  ,, paquet, 143.
Friesland flax, 11.

Gas lighting, 189.
Gill spinning, 85.
,, ,, frame, 89.
,, stocks, 55.
Gilling twine, 157.
Good's combined hackler and spreader, 49, 51.
Goodyear thread, 146.
Gradation of hackles, 30.
Grassing, 6.
Grouping of machine hackles, 31, 32.

Hackle-setters, 193.
Hackler and spreader for Manila, 50.
Hackling, 16.
,, shop ventilation, 35, 36.
Half-wet spinning, 106.
Hand-dresser's tools, 21.
,, dressing, 21.
,, scutching, 7.
Hands required, 198.
Hank drying, 138, 139.
,, winding frame, 145.
Harvesting flax, 4.
Hattersley flyer, 95, 96.
Haul pulleys, 92.
Hauls, 166, 168.
Hawser laid rope, 165.
Head of hackling machine, 26.
Heating, 197.
,, water trough, 117, 118.
Heavy spreading system, 58.
Hemp exports, 15.
,, in the Philippines, 1, 2.
,, plant, 1.
,, softening, 18.
,, spinning centres, 13.
Henequin, 2.
Hoff's flaxes, 10, 11.
Holder, 23.
Hopper feeder, 44.
Horner's hackling machine, 23.
,, stripping rod machine, 23.
Horse-power, 188.
Huglo's ventilating system, 35, 36.
Humidity in the preparing room, 83.
,, of the spinning room, 120, 122.
Hygrometer, 120, 122.

Import duties, 14.
Independent head system, 71.
Index wheel, 103.
Induced draught for boilers, 196.
Intersection, 31.
Iron-man, 157.
Italian hemp, 9.

Jacquard thread, 157.
John Good, 91.
Jute, 2.
,, breaker card, 38.
,, cuttings, 12.
,, drawing frame, 63.
,, exports, 15.
,, finisher card, 41.
,, opener, 17.
,, preparing, 65.
,, rejections, 12.
,, snipper, 19.
,, softener, 17.
,, spinning centres, 13.

Knifing hemp, 19.

Lantern roller, 51.
Lap-feeding, 45.
Lap-machine, 45.
Lawson's trawl twine yarn spinner, 94.
Laying machine, 170.
,, top, 169.
Leasing, 129.
Leeson's universal winder, 135.
Legrand's retteries, 5.
Length of bell, 57.
,, of gill pins, 81.
,, of rope splices, 189.
Level spreading, 58.
Licking-up, 82.
Lift motion, 26, 27.
Lifts of head per minute, 28.
Line preparing, 60.
Linen sewing threads, 147.
Lines of spinning frame, 120, 123.
Link-drawing frame, 61.
Linum usitatissimum, 1.
Lock-mesh balling, 159.
Long and short reel, 129, 130.
Longs, 21.
Loose-ends, 131.
Loppens and Deschwarte's retting system, 5.
Lubrication, 191.
Lupis, 9.
Lustering threads, 156, 157.

Machine end comb, 32, 33.
,, hackles, 27.
,, tows, 35.
M'Kay thread, 146.
Mangos, C. D., 12.
Manila dressing machine, 50.
,, hemp, 1.
,, ,, prices, 12, 13.
,, trawl twine layer, 148.

Manufacture of fancy threads, 149.
,, of M'Kay and Blake threads, 146.
,, of trawl twine, 147.
Maraingunge jute, 12.
Mauritius hemp, 2.
Mechanic shop, 192.
Metric rope yarn numbers, 88.
,, system of yarn numbering, 143.
Mill chimney, 196, 197.
,, construction, 195, 197.
Motchenetz flax, 11.
Motors, 190.
Murta, 2.

Nap extractor, 33.
New Zealand flax, 2.
,, ,, hemp, 2.
Nipping the end, 34.

Oiling apparatus for Manila, 51.
,, spindle tops, 194.
Oils, 192.
Oily yarn, 131.

P. C. Hemp, 9.
Particulars of gills and screws, 81.
,, of preparing machinery, 72–80.
Percentage of noil, 68.
Pernau and district flax, 11.
Phormium tenax, 2.
Piecing out, 20.
Pita, 2.
Pitch of screws, 81.
,, of spinning frame, 123.
,, pin, 63.
Plenum method of ventilation, 35.
Polishing threads and twines, 151, 154.
Porcupine card feed, 41.
Power of rope, 187, 189.
,, reels, 134.
,, transmission, 187.
Preparing flax and hemp tows, 65.
,, room pressing rollers, 54, 55.
Press bunches, 141.
Preventing escape of steam, 120.
Prices of cords, lines, and twines, 163, 164.
Production of comb, 68.
Profits on spinning, 199.
Projection, 123.
Propeller fans, 190.
Push-bar drawing, 61.
,, bars, 55.

Quilot, 9.

Randing machine, 159.
Ratchet wheel, 103.
Rat-trap motion, 102.
Reach of wet spinning frame, 117.
,, screws, 123.
Reaper yarn, 93.
Reel, 130.
Reeling, 129–134.
,, faults, 131.
Refluting boss rollers, 194.
Rest of head, 26.
Retteries, Legrand, 5.
Retting flax and hemp, 4.
Ring push-bar drawing frame, 63.
,, spinning, 106, 107.
Rope construction, 165.
,, making in the States, 93, 94.
,, race, 195.
,, yarn numbers, 86, 87.
Rotary drawing, 61.
Rotation of crops, 3.
Rougher's hackle, 21.
Rove stock, 105.
Roving frame, 95.
Rubbers, 56.
Rules for rope-makers, 165, 173.
Russian berkowitz, 11.
,, flaxes, 10.
,, hemp, 9.
,, rouble, 11.

Sansivera, 2.
Scotch spindle or spangle and yarn numbers, 66.
,, yarn table, 143.
Screw-gill drawing, 61.
Scutching, 7.
Semi-automatic balling machine, 157.
Separating the jute fibre, 8.
Sett system, 66.
,, weight, 67.
Setting of cards, 46.
,, the intersection of hackling machines, 31.
Shafting, 189.
Shift in machine hackling, 32.
Shifting motion, 27.
Short card pin, 47.
,, count, 133.
,, fibre card, 47.
,, reel, 131.
Shorts, 21.
Sisal hemp, 2.
Size of binder twine, 144.
,, of cordage, 171.
,, of pieces, 20.
,, of rope yarns, 144.

Size for twines, 156, 157.
Slanetz flax, 11.
Slide drawing, 61.
Sliver conductors, 55.
  ,, formation, 38.
  ,, lap machine, 42.
Slub detector, 137, 138.
Slumberger comb, 68.
Softening threads, 157.
Somerset numbers, 144.
Sorter's switch, 21, 22.
  ,, ten, 21.
Sorting flax, 33, 34.
Sowing flax, 3.
Spangle, 66.
Specifications of hackling machines, 30.
Speed of fallers, 60, 61.
  ,, of machinery, 32.
  ,, of roving spindles, 95, 97.
  ,, of spinning spindles, 122.
  ,, of the organs of the card, 42, 49.
Spindle, 66.
  ,, oiling, 127.
Spinning double rove, 124.
  ,, frame banding, 126.
  ,, ,, oiling, 127.
  ,, ,, repairs, 193.
  ,, ,, quadrant, 124.
  ,, roving frame, 88.
  ,, spindles, 13.
Spiral drawing frame, 63.
Splash board, 120.
Spool drying, 129.
Spooling sewing threads, 159, 163.
Spread-board, 53.
Spreader, 52.
  ,, particulars, 57.
Spreading, 58.
St. Petersburg hemp, 9.
Stands of spinning frame, 123, 124.
Steam boiler, 192.
  ,, engine, 186.
  ,, power, 182–187.
  ,, turbine, 182–185.
Stell's disc cam, 61.
Stop motion reel, 132.
Stove drying, 129.
Strand formation, 167.
Strike motion, 102.
Striped yarn, 105.
Stripper cocks, 28.
Strippers, 38.
Stripping rod machine, 28.
Sunn hemp, 10.
Swing-rail spinning frame, 111.
Switch, 22.

Tailors' thread, 151.
Tarred ropes, 168.
  ,, twines, 151.
Tarring ropes, 168.
Teeth in bell-wheel, 133.
Theory of regular spreading, 58.
  ,, of retting, 5.
Threads per strand, 172.
Tipple box and press, 29.
To find spinning twist pinion, 115.
Total drafts and doublings, 65.
Tow combing, 68, 70.
  ,, lap machine, 45.
  ,, preparing, 60.
Trawl twine, 94.
  ,, ,, layer, 150.
Turbines, 174–187.
Turn off, 122.
Twine carding, 151.
Twist for rope yarns, 86.
  ,, in rove, 104.
  ,, of yarns, 115, 125.
Twisting, 145.

Up striker and down striker cards, 41.
Use of tin or dummy card rollers, 40.

Value of flax, 14.
Ventilation of carding rooms, 82.
  ,, of hackling shops, 35, 36.
  ,, of preparing room, 82.
  ,, of wet spinning room, 172.
Vertical closing machine, 171.
  ,, rope machine, 171.

Walloon flax, 12.
Warp winding, 135.
Water power, 174, 181.
  ,, retting, 5.
  ,, turbine, 174, 181.
Waterproof aprons, 120.
Weight of drags, 123.
  ,, of ropes, 172.
  ,, of rove, 66.
  ,, of slivers, 80.
  ,, of yarn, 142.
Wet spinning frame, 119.
  ,, twisting, 145.
  ,, and dry bulb thermometer, 120, 122.
Whipcord, 147.
Width of bays, 196.
  ,, of gills, 80, 81.

Wire gauge for gill pins, 81.
Workers, 38.
Wrack flaxes, 11.

Yarn bunching, 139, 14.
,, bundling, 139.
,, ,, stool, 139.
Yarn cooling, 139.
,, drying, 138.
,, poles, 138.
,, tables, 143.
Yield of flax, 9.
,, of flax fibre per acre, 14.
,, of jute fibre per acre, 8.

2 B

LIBRARY
OF THE
UNIVERSITY
OF
CALIFORNIA

Printed by Morrison & Gibb Limited, *Edinburgh.*

RETURN TO the circulation desk of any
University of California Library
or to the
NORTHERN REGIONAL LIBRARY FACILITY
Bldg. 400, Richmond Field Station
University of California
Richmond, CA 94804-4698

ALL BOOKS MAY BE RECALLED AFTER 7 DAYS

- 2-month loans may be renewed by calling (510) 642-6753
- 1-year loans may be recharged by bringing books to NRLF
- Renewals and recharges may be made 4 days prior to due date.

DUE AS STAMPED BELOW

APR 1 1 1997

12,000 (11/95)

TS
1705
C3

193639

THE UNIVERSITY OF CALIFORNIA LIBRARY